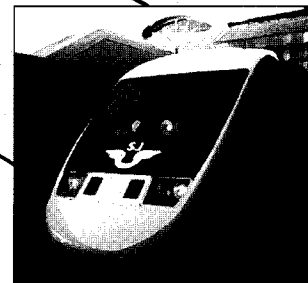


Constructed Civil Infrastructure Systems R&D: A European Perspective

CERF Report #94-5010



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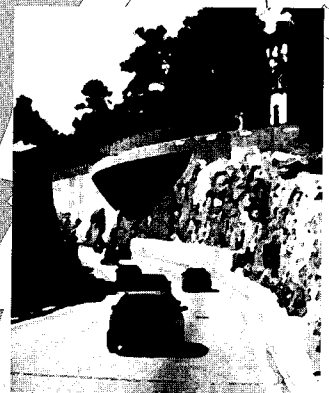
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Abstract

This report, *Constructed Civil Infrastructure Systems R&D: A European Perspective*, presents findings from the Civil Engineering Research Foundation's (CERF) 1993 international task force trip to western Europe. The report examines constructed civil infrastructure systems (CCIS) and their research and development (R&D) activities in the United Kingdom, Sweden, the Netherlands, Germany, France, and Italy. Findings from each country are presented, including state-of-the-art CCIS technology; R&D trends; processes and strategies for implementing innovation; and recommendations for improving CCIS in the U.S. The impact of the European Community (EC) on CCIS is also discussed.

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Foreword

This report documents the major findings gathered during a one-week task force trip to western Europe during June of 1993. The task force trip was organized by the Civil Engineering Research Foundation (CERF) in coordination with the National Science Foundation (NSF), which co-funded the study with CERF. Additional funding was provided by the Federal Highway Administration, the U.S. Army Corps of Engineers, and the U.S. Air Force.

During the trip to Europe that is documented in this report, a team of 28 leaders from the construction industry, government, and academia visited six countries, observed a variety of laboratories and construction sites, and met with many private and public sector representatives to gain an understanding of constructed civil infrastructure systems R&D in western Europe.

These visits yielded considerable information. However, the trip's short duration inevitably restricted the depth of the team's exploration. This report is the team's "best effort," rather than a complete in-depth survey and analysis. In some cases, the findings may raise more questions than they answer. The recommendations represent the collective effort of the entire task force and do not reflect the thoughts of any one particular member or sponsoring organization.

The report is intended to provide a baseline for further study. For example, while one of the objectives of the trip was to identify state-of-the-art technologies being used in each country visited, a thorough examination of these technologies is beyond the scope of this report. Rather, exciting new technologies are identified for possible investigation by future researchers.

This current effort draws on the results of two task force trips to Japan in 1991. CERF's Japan International Task Force looked at methods for transferring construction research results into practice. NSF's Japanese Technology Evaluation Center (JTEC) led a trip that examined the latest construction technologies in that country.

Although this report is published by CERF, and has partial sponsorship from NSF, it does not reflect the format and depth of material typically found in other NSF reports, due to the time limitations and extended breadth of this study.

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 STINFO Program Manager

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Acknowledgements

This report reflects the efforts of many construction industry experts, on both sides of the Atlantic Ocean. In addition to the time and expertise contributed by the 28-person task force team members themselves, the Civil Engineering Research Foundation (CERF) is also deeply grateful for the help provided by our gracious European coordinators and hosts. We would like to thank especially those key persons in each country who coordinated meetings and made contacts on our behalf: Paul Alba, CNISF, France; Giulio Ballio, Polytechnic Institute of Milan, Italy; J.N. Bennett, The Institution of Civil Engineers, United Kingdom; Raymond Best, Buchart-Horn GmbH, Germany; Eric Boiteux, SETRA, France; Jan Jerstrom, Bygg & Bo Media AB, Sweden; Tony Knowles, Translink Joint Venture, United Kingdom; Inger-Siv Mattson, Swedish Council for Building Research, Sweden; Luigi Natale, University of Pavia, Italy; and Govert Sweere, Strategic Highway Research Program, the Netherlands. We would also like to thank the members of the European governments, private organizations, and universities who took the time to meet with us and host our visits to their facilities. We appreciate their willingness to assist us in our attempt to further the civil engineering profession.

The trip was co-sponsored by CERF and the National Science Foundation (NSF), with additional funding support from the Federal Highway Administration (FHWA), the U.S. Army Corps of Engineers, and the U.S. Air Force. The National Science Foundation asked the World Technology Evaluation Center (WTEC) at Loyola College in Baltimore, Maryland, to assist CERF in supporting the technology assessment component of the study. WTEC also assisted CERF in the early dissemination of trip results by organizing a follow-up workshop/symposium in the United States in September 1993.

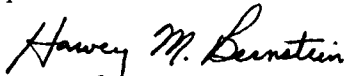
Principal authors of the country summaries include Dr. Richard Tucker, Director of the Construction Industry Institute, University of Texas at Austin; Dr. Andrew Lemer, Principal, Matrix Group, Inc.; Dr. Richard Wright, Director, Building and Fire Research Laboratory, National Institute of Standards and Technology; and Dr. Michael Gaus, Professor, Department of Civil Engineering, State University of New York at Buffalo.

Additionally, I wish to personally thank Dr. Andrew Lemer for integrating observations from all of the countries into the main report body and assisting with final editing of the entire document. Thanks also go to Paul Knapp, CERF Communications Coordinator, and Dr. Neil Hawkins, Head of Civil Engineering Department, University of Illinois, who worked closely with me in organizing and editing this report. Finally, the trip could not have been such a success without Elizabeth Delo, CERF Industry Program Administrator, who worked long hours to schedule all of the trip logistics with our counterparts in Europe, in addition to organizing the CERF Forum in Brussels; and, Melody Spigel, who assisted in creating the itinerary books and sending documents overseas.

Publication of this report was made possible, in part, through contributions by members of CERF's New Century Partnership:

- Charles Pankow Builders
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On behalf of the civil engineering profession, I would like to reiterate my thanks to the entire 28-person task force for their efforts in making this report possible. Not only did they work very hard during the very hectic and intense one-week program, they also helped assemble, document, and analyze an enormous amount of information to provide a better understanding of western European CCIS for the global civil engineering profession and industry.



Harvey M. Bernstein, President
Civil Engineering Research Foundation
and CERF International Task Force Chairman and Coordinator

Table of Contents

Chapter 1

INTRODUCTION AND SUMMARY	1
Trip Overview	1
Summary Observations	4
Structure of the Report	10

Chapter 2

EUROPE'S CCIS TECHNOLOGY	11
Europe Versus European Nations	12
State-of-the-Art Technology Observations	15
Significant CCIS Technology Trends	20

Chapter 3

R&D AND INNOVATION	21
European CCIS Research and Development	21
R&D Drivers and Innovation Trends	22
The Role of EC Programs	25

Chapter 4

LESSONS FROM EUROPEAN EXPERIENCE	27
Competitive Outlook	27
Opportunities for Collaboration	29
Adaptations to U.S. Practices	30

APPENDICES

Introduction to the Appendices

Appendix A

UNITED KINGDOM	A-1
-----------------------------	------------

Appendix B

SWEDEN	B-1
---------------------	------------

Appendix C

THE NETHERLANDS	C-1
------------------------------	------------

Appendix D

GERMANY	D-1
----------------------	------------

Appendix E

FRANCE	E-1
---------------------	------------

Appendix F

ITALY	F-1
--------------------	------------

Appendix G

TASK FORCE TEAM MEMBER & TRIP LOGISTICAL INFORMATION	G-1
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Chapter 1

INTRODUCTION AND SUMMARY

In aggregate, the nations of western Europe rank within the top ten world markets for capital investment in buildings, water supply, highways, waste treatment, and other constructed civil infrastructure systems (CCIS). The size of this market in 1991 exceeded \$500 billion. In comparison, the United States spends about \$250 billion annually to construct and maintain its CCIS systems.

Steps made in 1993 toward economic and political unification of the European Community (EC) are transforming western Europe from a disparate collection of independent countries into a single market for goods and services. The former EC, now referred to as the European Union (EU), is growing as well, as other European countries seek entry to the larger market and perhaps to the union itself.

This recently-unified European market offers substantial business opportunities for U.S. infrastructure design, construction, and manufacturing firms. Public works construction in Europe has experienced a sustained growth of about five percent annually during the past decade. The emerging economies in the former Soviet Bloc countries of eastern Europe further expand the opportunities.

However, the new economic force represented by the EC poses threats to U.S. CCIS business as well. Building on a larger base of nearby opportunity, some European firms will become even stronger competitors in the global marketplace, as well as on their own continent. Over the past decade, western European governments and CCIS industry have shown strength in the development, assimilation, and dissemination of technological innovation in CCIS design and construction, thereby enhancing their competitive position in the global CCIS market.

***The new European
Community market offers
substantial business
opportunities for U.S.
infrastructure design,
construction, and
manufacturing firms.***

TRIP OVERVIEW

Seeking to learn more about the status of European CCIS technology and industry, the Civil Engineering Research Foundation (CERF) and the National Science Foundation (NSF) sponsored an eight-day reconnaissance trip to western Europe. NSF asked the World Technology Evaluation Center (WTEC) at Loyola College to assist CERF in supporting the technology assessment component of the study.

In June 1993, a task force of 28 leaders from CCIS-related industry, government, and academic organizations in the U.S. and Canada visited six European countries—the United Kingdom, Sweden, Germany, the Netherlands, France and Italy. Observations from each of these countries are documented in Appendices A through F, respectively. The body of the main report summarizes overall lessons learned from the trip; the appendices provide details specific to each country.

While the six countries visited are richly diverse in terms of strengths, capabilities, and practices, and do not adequately represent the whole of Europe, for ease of presentation the report often treats these countries as “Europe.” With the exception of Sweden, the countries visited are members of the EC, which became the EU subsequent to the task force visit. (This report uses “EC” throughout, since at the time of the task force’s visit, that was the proper

Table 1-1a**Participating European Organizations***Team A—United Kingdom and Sweden*

Organization*	Identifier	Type
UNITED KINGDOM		
British Board of Agrément	BBA	government agency
Building Research Establishment	BRE	government research
Building Services Research and Information Association	BSRIA	private research
Channel Tunnel		construction site
Construction Industry Research & Information Association	CIRIA	information services
Department of Environment	DoE	government agency
Department of Transport	DoT	government agency
Imperial College of Science, Technology & Medicine	IC	university
Institution of Civil Engineers	ICE	professional society
Institution of Structural Engineers	ISE	professional society
John Laing Construction		private contractor
Ove Arup & Partners	OAP	private consultant
Science and Engineering Research Council	SERC	government research
Taywood Engineering Limited	TEL	private consultant
Transport Research Laboratory	TRL	government agency
Thames Water Offices		private company
University College, London	UCL	university
Water Research center	WRc	private company
SWEDEN		
NCC BYGG AB		private contractor
Royal Institute of Technology	BFR	university
Royal Swedish Academy of Engineering Sciences	IVA	private science institute
Skanska Teknik		private consultant
Swedish Council For Building Research		government research
Swedish Geotechnical Institute	SIG	government agency
Swedish National Rail Administration	Banverket	government agency
Swedish National Road Administration	Vagverket	government agency
Swedish Road and Traffic Research Institute	VTI	government research agency

Table 1-1b**Participating European Organizations***Team B—The Netherlands and Germany*

Organization*	Identifier	Type
THE NETHERLANDS		
Ballast Nedam Beton En Waterbouw, Airport Project		private contractor, construction site
Delft Geotechnics		private research
Delft University of Technology		university
DHV Amersfoort	DHV	private consultant
Hollandsche Beton Groep, Storm Surge Control Project		private contractor, construction site
The Netherlands Organization for Applied Research	TNO	government research
Royal Institution of Engineers in the Netherlands	KIVI	professional society
Stichting Bouwresearch	SBR	joint public/private research
Screg Routes		private contractor, French subsidiary
GERMANY		
Aachen University of Technology		university
Bilfinger & Berger		private contractor
Deutsche Forschungsgemeinschaft	DFG	government research
Federal Ministry for Research & Technology	BMFT	government agency
German Highway Center	BAST	government agency
Information Center for Planning & Construction	IRB	private research
Philipp Holzmann AG		private contractor
Strabag Bau AG		private contractor
Technische Hochschule Darmstadt		university
University of Karlsruhe		university
Verein Deutscher Ingenieure	VDI-Bau	professional society

* English translation for organization name provided, where available.

designation.) Sweden participates in the European Free Trade Union, and some observers predict that this organization and the EC countries will ultimately join in a single European confederation. There is little agreement regarding how quickly and how effectively this alliance will occur.

The trip was planned with a number of specific objectives:

- To observe state-of-the-art CCIS technology and research trends in Europe;
- To assess trends in European CCIS industry, such as privatization and organizational consolidation, that are likely to influence the state-of-the-art of CCIS and U.S. international competitiveness;
- To observe mechanisms used to introduce research results into practice, such as innovative contract delivery systems and code modification processes;
- To assess the potential impact of emerging EC institutions and programs on European CCIS technology development; and,
- To explore opportunities for facilitating working relationships between U.S. and European CCIS research communities.

Because of the trip's short duration, there was not enough time to focus on all CCIS areas in every country equally. Other reconnaissance trips to Europe (e.g., FHWA's International Technology Scanning Program) have investigated specific CCIS issues, such as transportation, in detail.

THE TEAMS AND THEIR VISITS

The task force was divided into six teams, with each team visiting two countries. The structure of the task force is shown in Appendix G-1, and biographical sketches of task force members appear in Appendix G-2. The teams met with their counterparts from government agencies and research laboratories, universities, professional societies, private research laboratories, and private construction and design firms. Participating European organizations, defined as those visited or referred to during the trip, are listed in Tables 1-1a, 1-1b, and 1-1c, and described in more detail in Appendix G-3. Each country was visited by two teams. At times those teams had separate agendas, and at other times they converged; itineraries of the task force teams are contained in Appendix G-4.

Table 1-1c
Participating European Organizations
Team C—France and Italy

Organization*	Identifier	Type
FRANCE		
Bouygues		private contractor
Center for Buildings and Public Works Research	CEBTP	private R&D and testing
Central Laboratory for Roads and Bridges	LCPC	government research
Channel Tunnel		construction site
Dumez		private contractor
École Nationale des Ponts et Chaussées	ENPC	university
National Council of French Engineers and Scientists	CNISF	professional society
Screg Routes		private contractor, Bouygues subsidiary
Road & Highway Engineering Department	SETRA	government research
ITALY		
American Society of Civil Engineers Italy International Group	ASCE-IIG	professional society
Central Institute For Building Industrialization & Technology	ICITE	government research
Coliseum rehabilitation		construction site
Consiglio Superiore Dei Lavori Pubblici	CSLP	government agency
European Laboratory for Structural Assessment	ELSA	EC joint research center
Institute for Safety Technology		government research
Istituto Sperimentale Modelli e Strutture	ISMES	private research
Italian Association of Contractors	ANCE	professional society
National Research Council	CNR	government research
Polytechnic Institute of Milan		university
Timber Research Institute		private research

* English translation for organization name provided, where available.

Task force members comparing their experiences found that certain patterns were observable in the European approach to CCIS technology state of the art, development trends, and applications.

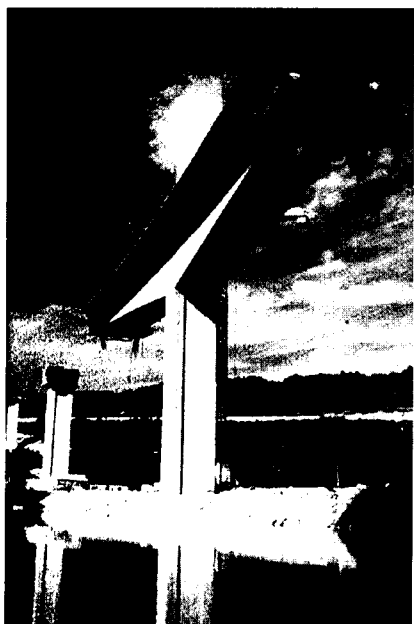
The task force teams had 78 meetings altogether, in the course of visits to:

- 7 government funding agencies
- 9 government mission agencies
- 15 professional groups
- 11 technical universities
- 12 government research laboratories
- 5 private research organizations
- 2 design firms
- 13 contractors
- 2 project sites

Although these visits provide a substantial basis for judgement, the group's observations have inevitable limitations. The trip was short, as were meetings with individual groups. Each task force member experienced directly only some of these meetings. Because the European Community is in its infancy, it is continually changing. As mentioned above, one nation visited, Sweden, is not a member of the EC, and some EC member nations were not visited.

Some members of the task force arrived in Europe prior to commencement of the formal program of reconnaissance and toured portions of the Channel Tunnel construction site (see box, pages 23–24). This group also met with engineering and construction staff on the project. This visit to the Channel Tunnel was the task force's only formal tour of a major construction site, although some teams during the course of their visits were able to observe other construction sites and operational CCIS facilities.

Following their visits to the six European countries, task force members convened in Brussels, Belgium, to assess their initial findings. Following a day of meetings among task force members to review their experiences, there was a half-day forum with task force members and representatives of the countries visited and the European Community. The forum provided an opportunity for task force members to confirm their understanding of what they had seen in their visits, to test their initial conclusions with their European colleagues, and to explore further the role of EC organizations and programs in CCIS technology development. The forum's agenda and attendees are listed in Appendix G-5 and G-6, respectively.



Many French bridges use state-of-the-art technologies developed under government-sponsored "National Projects."

SUMMARY OBSERVATIONS

Task force members comparing their experiences found that certain patterns were observable in the European approach to CCIS technology state of the art, development trends, and applications. EC programs fostering innovation and development of a true common market are already having significant impact on CCIS practices in Europe, and that impact seems likely to grow. Task force members concluded that their observations offer lessons, both for how U.S. industry and government may improve domestic practice and for what U.S. industry will face in an increasingly global market for CCIS technology.

STATE-OF-THE-ART TECHNOLOGY

Task force members observed a wide variety of cutting-edge CCIS technologies and state-of-the-art processes in Europe, as described in Chapter 2. Examples were found in each of the countries visited: Germany's hazardous materials containment methods, and fiber optic structural strain gauging; Italy's methods for repair and rehabilitation of masonry structures, and dam performance

modeling; the United Kingdom's innovative pre-casting techniques and high-performance concrete used in the Channel Tunnel; Sweden's construction site management and performance contracting procedures; France's asphalt surface dressing technologies and very high-strength concrete; and marine construction and probabilistic methods applications in the Netherlands.

The task force undertook to use its observations to assess the relative level of technology development in Europe and the United States. In Chapter 2, relative judgements are made within seven specific areas, with reference to a number of specific aspects of technology in each area. Team members who had visited Japan previously judged that both U.S. and European practices in several areas lag this third major force in the market (Table 1-2). The task force concluded that U.S. CCIS technology trails Europe in only a few key areas, most notably with regard to energy conservation in buildings and marine and tunnel construction.

Table 1-2

World CCIS Technology Leadership

U.S. Leads	Europe Leads	Japan Leads
High-performance concrete	High-performance asphalt	High-performance steel
Waste/wastewater treatment	High-speed rail/Mag-lev	Automated equipment
CAD/CAE	Tunneling	Field computer use
Solid/hazardous waste disposal	Real-time site positioning systems	High-speed pavement assessment
Environment	Restoration	Safety
GPS/GIS	Marine construction	Intelligent buildings
Integrated databases	Energy conservation	Building systems

R&D AND INTRODUCING NEW TECHNOLOGY

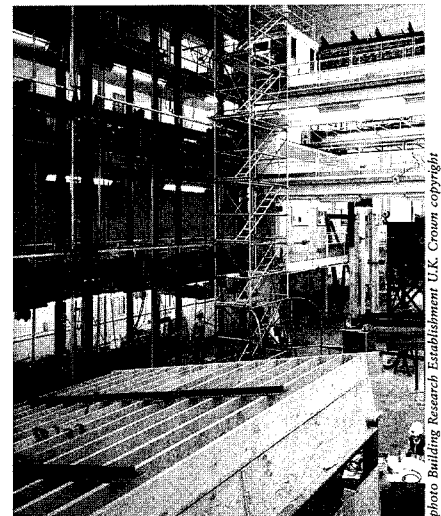
As described in Chapter 3, the task force found industry conditions in the European countries visited more conducive and open to CCIS technological innovation, as compared to the United States. Research and development (R&D) activities are supported by governments as a contribution to national interests. Private and public sectors work together for common purposes of increasing export potential and improving domestic productivity. In almost all countries visited, the national government, and often the provincial governments as well, take a leadership role in offering incentives to industry to work as a team with universities or government to pursue technological advancement. In this sense, task force members felt that Europe surpasses the United States.

The task force could not conduct a comprehensive analysis, but gained the impression that U.S. funding levels for CCIS R&D are lower than in Europe, in comparison to population or levels of CCIS investment. Total U.S. CCIS R&D resources, however, may still be greater than the European aggregate spending; consequently, task force members sought other explanations for the seemingly more robust European outlook for innovation. They concluded that institutional factors are crucial.

While there were distinctive differences among the countries visited, as documented in Appendices A through F, industry representatives throughout Europe seemed generally to lack the overriding concern for liability issues that pervade U.S. CCIS practice. In Europe, new technology resulting from R&D has a better chance of being tried in practice, which in turn increases the likelihood of continued spending on CCIS R&D. The generally cooperative relationship found between government and industry further encourages testing of new technology in practice and positive payback from R&D investment.

R&D DRIVERS AND INNOVATION TRENDS

As detailed in the Appendices, the task force found that several key factors seem to be driving CCIS R&D in the European countries visited, and are thereby



The U.K.'s BRE Structures Laboratory does testing work for organizations from other EC member countries.

photo Building Research Establishment U.K. Crown copyright

influencing the trends of likely innovation. Growing environmental awareness of the population, relatively high long-term energy prices that encourage conservation, a widespread economic slowdown that has cut government tax revenues and private spending, and political turmoil associated with eastern Europe and the formation of the EC are among the factors having pervasive influence on Europe's CCIS technology. "Privatization" of government CCIS enterprises, such as rail services and government research and testing laboratories, is a trend that has favor in several countries.

The task force team found that the "vision" for CCIS R&D is coming from the private sector in most of the countries visited. For example, the STEP program, a major multinational cooperative effort aimed at developing automatic exchange of product information between diverse computer systems, is being carried out under the auspices of the EC. Major construction contractors in several countries are leading the effort and setting its agenda. This leading role reflects the typically larger R&D departments that European contractors maintain, in comparison to their American industry counterparts.

As a governmental body, the EC is funding several R&D programs aimed at or encompassing CCIS technology. The BRITE/EURAM program seeks to develop new materials and design methodologies. The THERMIE and JOULE programs target energy efficiency and alternative energy sources. These programs provide incentives for industry to collaborate across national borders, and with government agencies and academia.

National R&D programs are designed to encourage partnerships as well. Sweden's construction unions and contractors requested that government collect a small payroll tax to be used for R&D support. The fund collects about US\$6 million a year, for which researchers in companies submit research proposals. In Germany and the Netherlands, government research funding is channelled through "research societies" or "collective foundations" that then oversee actual research efforts at university, government, and private labs.

The French government has established an "innovation charter" program to protect new technologies long enough for the developer to recoup its R&D investments. Innovative products, processes, or equipment that are not specifically covered by standards or technical appraisal certificates are granted a charter that provides exclusive rights to the new proprietary technologies for several years. Innovation charters also allow contractors to team with government research institutes when the contractor does not possess the technical expertise or equipment to develop the innovation itself.

EUROPE VERSUS EUROPEAN NATIONS

Task force members agreed that two decades or more may be required before a truly integrated market in CCIS technology in Europe will emerge. However, notwithstanding the factors encouraging integration of the CCIS industries in Europe, innovation could become more difficult as the EC becomes better established. As a unified collection of states, the EC will more closely resemble the United States, but it is more densely populated and has more extreme cultural variations. Nationalism may retard the adoption of new CCIS-related EC directives. Added bureaucratic steps and longer time needed to gain official approval of new technology may eventually discourage innovation. Smaller countries within the EC, unaccustomed to such delays, could judge innovation no longer worth the effort.



Photo courtesy Commission of the European Communities

A multipurpose composite pavement system developed under the EC's BRITE/EURAM program for new materials R&D.

LESSONS FROM EUROPEAN EXPERIENCE

While recognizing that their experience on this trip was limited, task force members concluded that their European observations offer lessons for U.S. CCIS practices, as detailed in Chapter 4. These lessons underlie a series of seven recommendations to U.S. industry and government to strengthen U.S. ability to undertake and profit from CCIS R&D, and thereby to enhance U.S. productivity and competitiveness in international markets.

Change Contract Delivery Systems

Experience in Europe demonstrates that substantial benefits can be gained if government and industry join forces through the use of contract delivery systems that foster CCIS technological innovation. European design-build and “best-bid” procurements, for example, while not appropriate for all applications, would represent a shift from the largely adversarial relationships—among designers, construction contractors, and their government agency clients—frequently fostered by predominant current U.S. practices. Task force members observed that these contract delivery systems encourage equitable sharing of construction risks among owners and contractors, control liability, and thereby encourage adoption of promising new technology.

Government agencies at federal, state, and local levels are the principal purchasers of CCIS design and construction services, and so are in the best position to foster adoption of such “innovation-friendly” contracting formats. *U.S. CCIS-related agencies such as the Department of Transportation, the U.S. Army Corps of Engineers, the Environmental Protection Agency, the General Services Administration, the Department of Housing and Urban Development, and the Department of Energy should establish programs to demonstrate “innovation-friendly” contracting procedures in their own projects and projects developed by their state and local government program-fund recipients.* Careful assessment of results should be an integral part of these demonstrations, so that successes and failures, and their causes, can be shared widely within the CCIS industry.

Adopt Performance Specifications

Despite more than two decades of discussion, usage of performance specifications in U.S. CCIS construction is limited. Task force members observed in Europe that the performance-based approach to CCIS development is not only more advanced, but is apparently yielding benefits to all parties to these developments. *U.S. CCIS agencies should demonstrate use of performance specifications by adapting European examples and encouraging their application in this country.* Government agencies should work with private sector groups to establish risk-sharing programs to underwrite sureties, warranties, and guaranties for these performance specifications. These programs could be integrated with those designed to demonstrate “innovation-friendly” procurement practices.

Update Industry Practitioners

CCIS technologies are evolving rapidly, on a global basis, threatening to make traditional U.S. crafts and construction labor practices obsolete. Task force members observed that labor and professional groups in several countries visited

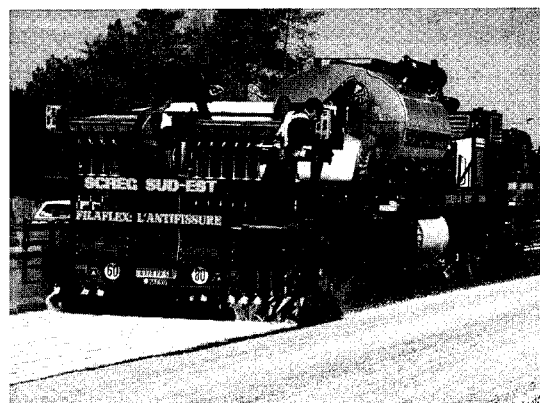


photo courtesy Société Internationale Routière

The Filaflex system developed by Screg Routes combines a network of interwoven threads with a bitumen binder film to ensure road impermeability and prevent crack propagation.

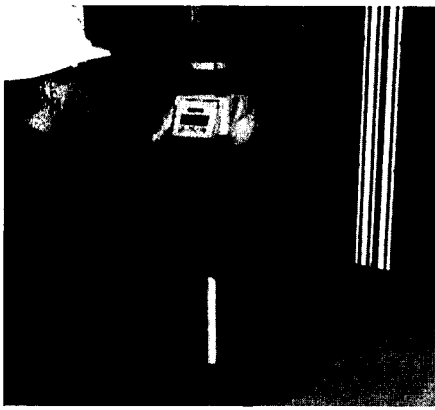


photo courtesy ICD-Bouw

This laser site-positioning system developed in the Netherlands automates traditionally labor-intensive surveying and site layout work.

are actively involved in education and training to upgrade the industry's ability to adopt and apply new CCIS technology. Members agreed that the U.S. cannot afford to find itself lagging in this area. While changes in university curricula and early professional career-training programs are warranted, training for crafts and skilled labor (i.e. "blue collar" workers who actually construct CCIS facilities) seemed to task force members relatively weak in the U.S., compared with European practices. *U.S. management and professional groups should work with labor to enhance labor education and training programs.*

In addition to advancing applications of CCIS technologies, more attention should also be directed toward adapting technologies from other industries, such as manufacturing, where lessons about overseas competition and adaptation of foreign practices have already brought about important changes. Government, particularly at the federal level, has an important supportive role to play in developing such technology transfer programs, but the initiative should come from the private sector to assure broad support.

Encourage Federal Sponsorship of Prototype Projects

Task force members took special note of broad multinational participation in European technology development projects and the early benefits that these projects seem to be achieving. *As a principal funder and major customer for CCIS development, the U.S. government should undertake prototype projects designed to foster innovation.* The Department of Transportation's demonstration grants program (for urban mass transportation projects, for example) and similar past activities at other agencies may be useful U.S. models, supplementing those of European programs, for new CCIS demonstrations. These prototypes should involve local or state agencies, along with federal sponsors and private sector partners, such as construction contractors and materials suppliers.

Increase U.S. Participation in International Standards

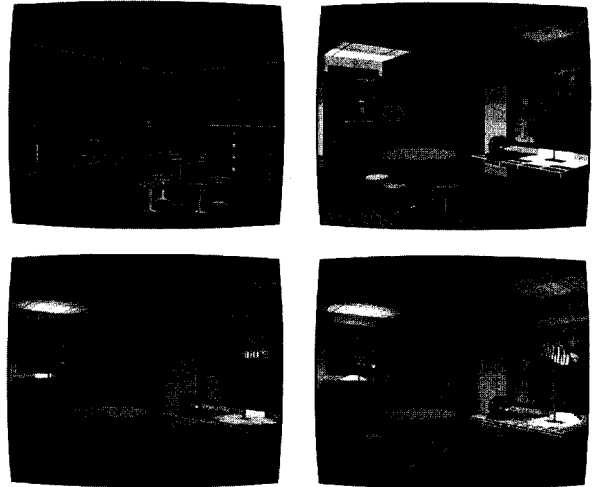
Task force members observed that the European countries are moving quickly toward common standards for CCIS designs, equipment, and materials. While variations among regions will remain, reflecting geographical differences (e.g., climate and soils), Europe in future years is likely to present a much more uniform market with much less variation in its CCIS codes and standards. Because much of the world market relies on European models for their own standards and practices, the impact of increasing European uniformity will be felt well beyond the EC countries. If U.S. industry wishes to compete globally, it will become more important that U.S. firms be able to meet these emerging standards. Yet, task force members found that opportunities to participate in standards development have not been actively pursued by U.S. firms or agencies. *The U.S. government and private industry should develop a more active and influential stance by formally participating in international standardization activities.*

Increase U.S. Participation in International R&D

Throughout their trip, task force members observed the growing significance of cooperative international CCIS research and development in Europe. Private companies found that their participation supported their own internal technology development and strengthened their competitive position. Government agencies and professional groups found their access to the best technology expanded. Task force members agreed that *efforts should be made to increase U.S. participation*

in international CCIS research and development programs as a means to strengthen areas of relative technological weakness.

To encourage such participation, CERF will conduct an international symposium in February 1996 in Washington, D.C., entitled *Engineering and Construction for Sustainable Development in the 21st Century: An International Research Symposium and Technology Showcase*. One of the main goals of this event is to develop an internationally acknowledged agenda for the civil engineering-related R&D needed by the world's construction industry. This symposium will bring together researchers and users of research results from many countries to share their visions of the future and to mobilize the resources necessary to pursue advancements in CCIS technology.



Improve Dialogue between Industry, Academia, and Government

In Europe task force members observed strong joint actions by the private sector, academia, and government to enhance CCIS technology and the industries that use that technology. The strength of these joint actions is reflected in new processes and products being applied in the countries visited and in the high export potential that CCIS represents for several countries. In the U.S., the construction industry accounts for eight percent of the nation's economy as measured by gross domestic product (GDP), making it the second largest industry in the U.S. Nevertheless, both the producer and buyer sides of this industry are very fragmented, weakening the industry's abilities to mobilize research resources and to assume the risks of demonstrating promising new technologies. In Europe, government programs at national and EC levels are demonstrating that such fragmentation can be overcome. For example, the French government assists French companies such as Bouygues, so that one-third of those companies' work is abroad, representing an equivalent amount of "exports."

Task force members agreed that more leadership is needed in the U.S., and recommend that it should come from the federal level. *Therefore, national representation and leadership for the industry should be established at the White House level to improve the dialogue between industry, academia, and government concerning matters relating to CCIS R&D.*

Because the Clinton administration views the construction industry as a key sector in its program to increase America's economic prosperity, enhance U.S. global competitiveness, and ensure the general well-being of Americans through infrastructure renewal, working with the design and construction industry is central to the administration's strategy. In support of this strategy, the administration established a subcommittee on Construction and Building within the Committee on Civilian Industrial Technology of the cabinet-level National Science and Technology Council (NSTC).

The NSTC's Construction and Building subcommittee is responsible for developing specific research goals for the construction sector. If these goals can be attained, the construction sector will be propelled from its current "low-tech/low-productivity" image into a technology-focused contributor to America's future

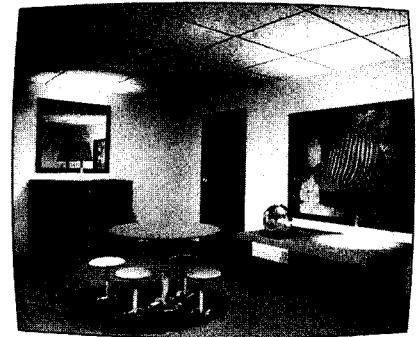


photo courtesy Ove Arup & Partners

Computer-based rendering of building interior created by a "Lighting Visualization" program developed under the EC's European Strategic Program for Research in Information Technology (ESPRIT).

prosperity. In developing these goals, the subcommittee utilized the Civil Engineering Research Foundation (CERF), the research affiliate of the American Society of Civil Engineers, in order to establish a dialogue with industry concerning CCIS R&D.

As the subcommittee's primary contact within the construction industry, CERF is coordinating industry and academia input to ensure that these goals materialize into a defined, attainable path for the construction sector to follow to fulfill its promising potential in the 21st century. CERF will continue this dialogue with the subcommittee on Construction and Building in order to promote cooperative research projects involving industry, academia, and government as a means to achieve the construction industry goals established by the NSTC.

Generally speaking, European experience illustrates the advantages to be gained through cooperation among government and private sector participants in CCIS technology development, and how obstacles to CCIS innovation may be substantially reduced.

STRUCTURE OF THE REPORT

This report describes the task force members' observations and their interpretation of lessons these observations offer for U.S. CCIS practice. From their experience, task force members developed recommendations for actions U.S. industry and government might take to enhance the productivity of U.S. CCIS research and the rate at which CCIS innovation occurs in this country.

Chapter 2 presents the task force's assessment of CCIS technology in the countries visited, and how that technology compares with U.S. practice. The task force found that the state of the art of U.S. CCIS technology, in most technical areas considered, compares favorably with Europe. However, active research programs and a societal setting more conducive to technological innovation are supporting rapid introduction of new technology and could give European firms distinct competitive advantages in the future.

Chapter 3 reviews the task force's observations of CCIS research and development activities in Europe, and the innovations being introduced. Task force members found that several factors common to the six countries visited are driving the level and direction of these activities, including the drive toward privatization of formerly government-owned CCIS industries and research facilities. European unification and EC-sponsored multinational research programs are also driving CCIS research and innovation.

From their experiences, task force members extracted lessons for U.S. policy and practice. These lessons are presented in more detail in Chapter 4. Generally speaking, European experience illustrates the advantages to be gained through cooperation among government, academic, and private sector participants in CCIS technology development, and how obstacles to CCIS innovation may be substantially reduced. Actions to capture these advantages in U.S. practice can yield benefits for domestic CCIS performance and for the competitive position of U.S. products and services in the increasingly global CCIS marketplace.

Appendices A through F present separate summary reports for each of the six countries visited. These reports document the team members' observations of R&D trends in each country, state-of-the-art CCIS technologies, and processes and strategies for implementing innovation. The exact structure of Appendices A through F is described in the *Introduction to the Appendices* located before Appendix A. Appendix G contains additional information about the task force team and the logistics of the trip.

Chapter 2

EUROPE'S CCIS TECHNOLOGY

The task force teams visited a variety of government funding agencies and mission agencies, professional groups, technical universities, research laboratories, private research organizations, design firms, contractors, and project sites—78 meetings in total. This is a substantial basis for judgement, but has inevitable limitations. The trip was short, as were meetings with individual groups. Each task force member experienced directly only some of these meetings. Also, the European Community itself is young and still evolving. One nation visited, Sweden, is not a member of the EC, and some EC members were not visited.

Historically there have been differences in CCIS practices in Europe and the United States. The U.S. occupies a much larger land area than western Europe, requiring maintenance of many more miles of road, pipe, rail, and cable to provide high levels of service. The U.S. is blessed with relatively abundant natural resources, making it seldom necessary to ship heavy materials, such as stone aggregate for road base and concrete construction, long distances. In contrast, the Netherlands imports about half of the 20 million tons of gravel that it uses annually. Climate and topography tend to remain consistent within the smaller European countries, facilitating faster adoption of national standards and designs; however, because these conditions vary between countries, “harmonization” of standards among all EC members promises to be difficult.

At the same time, culture and language have accentuated historic differences among European nations. Italy's abundance of historic old buildings creates a large market for specialized maintenance and preservation technologies, and archeological sites are more frequently encountered in the European cities than in the United States.

The advent of the EC promises much change, although the change may be slow to develop. On one hand, a united Europe will encompass a diversity of geography and culture similar to or exceeding that of the United States. Regional CCIS sub-markets are likely to be maintained, although their boundaries may no longer be so strongly influenced by national frontiers. On the other hand, the rationale underlying the creation of the EC (i.e., lowering trade barriers the continent will stimulate productivity) seems already to be proving true in the CCIS industries. If the EC concept is fulfilled, there will be more uniformity in codes, specifications, licensing, and bidding for public works among the EC nations than now exists among the various levels of government in the U.S., Canada, and Mexico.

Despite the limitations of their experience, task force members stated that patterns were observable in the European approach to CCIS technology state of the art, development trends, and applications. EC programs fostering innovation and development of a true common market are already having significant impact on CCIS practices in Europe, and that impact seems likely to grow. Although several of the European companies visited have extensive subsidiaries in the U.S., few U.S. companies are currently operating in Europe. Task force members concluded that their observations offer lessons, both for how U.S. industry and government can improve domestic practice and for what U.S. industry will face in an increasingly global market for CCIS technology.

If the EC concept is fulfilled, there will be more uniformity in codes, specifications, licensing, and bidding for public works among the EC nations than now exists among the various levels of government in the U.S., Canada, and Mexico.

EUROPE VERSUS EUROPEAN NATIONS

The European Community (EC) was formed by multilateral agreement to establish a common market among twelve nations of western Europe. Motivated by a desire to achieve economic efficiencies and market power comparable to that of the United States and Japan, EC agreements are eliminating intra-community trade barriers and setting the stage for adoption of a standard monetary system. The aim of many planners is a truly unified Europe, economically if not politically, although task force members encountered scant usage of the term "European Union" (EU) among their European colleagues.

A substantial policy-oriented bureaucracy is developing to serve the EC as a single entity, based in Brussels. This bureaucracy is able to establish community-wide policy and programs influencing CCIS, through a combination of extension and specification of higher level agreements. EC "directives," in particular, are issued by the EC but then implemented and enforced through legislation in the individual member countries.

The EC has identified civil infrastructure systems as a high priority means to improve social conditions in Europe. Transportation networks, water distribution, communication and energy systems are all target areas for investment. The EC seeks a uniformly sound infrastructure to "level the economic playing field" and redress or prevent imbalances in opportunity that the evolving internal market conditions may create. CCIS technology consequently is viewed as an important policy area.

Task force teams encountered particular evidence of EC policy and program initiatives in four major areas, as described below: harmonization of building codes and standards, implementation of innovative contract delivery methods, privatization of CCIS services, and incentives for multinational R&D collaboration.

HARMONIZATION OF BUILDING CODES AND STANDARDS

"Harmonization" is the term used for efforts to transform a multitude of national standards now used in construction and manufacturing into a single, coordinated regulatory framework. The Construction Products Directive is intended to assure that national building codes and product standards do not inhibit international competition and trade within the EC. In the European Council for Standardization (CEN), the primary forum for harmonization discussion, only representatives from the EC and the European Free Trade Association (EFTA) are allowed to vote on adoption of harmonized standards. Participants in the process have set a goal of devising a European Standard by 1995 or 1996. Developers seeking a Europe-wide market for new technologies or products not covered by these standards may apply for a European Technical Approval, as described in Chapter 3. Slow and often difficult progress on harmonization make achieving the 1996 goal unlikely, but task force members concluded that the process of inter-country comparisons will winnow out the best from each country's system to create a broadly acceptable set of standards. Task force members foresee that such a regulatory instrument is likely to gain wide acceptance outside the EC.

IMPLEMENTATION OF INNOVATIVE CONTRACT DELIVERY METHODS

The EC Directive on Public Tender requires that major public works projects be advertised and open to EC-wide competitive bid. While only a small fraction of the CCIS construction market involves cross-border trade, task force members



Photo courtesy: Stralag, AG

The EC supports CCIS improvements, such as for clean drinking water, an important issue throughout Europe.

observed that such projects as the Channel Tunnel and the high-speed rail network are serving as significant multinational opportunities for technological innovation. New contract delivery methods are being perfected to assure performance and distribute financial risks and rewards equitably. Performance-based specifications, in particular, are being demonstrated in several countries, with construction contractors retaining responsibility for operating performance of the facility over a period of years. Task force teams also observed growing acceptance of "best bid" systems, which encourage owners and constructors to explore the trade-offs between cost and performance above minimum specified standards, and thereby facilitate application of new technologies.

PRIVATIZATION OF CCIS SERVICES

Initiatives in several countries and the EC as a whole are encouraging privatization of formerly government-operated CCIS services. National railroads are being expected to operate profitable enterprises, and government research and testing laboratories are being spun off or sold. The task force teams observed that such changes are causing some apprehension within the CCIS professional communities, because of the potential loss of technical research capabilities. However, team members also found cases where the strong emphasis on the market potential of new CCIS technologies is driving innovation.

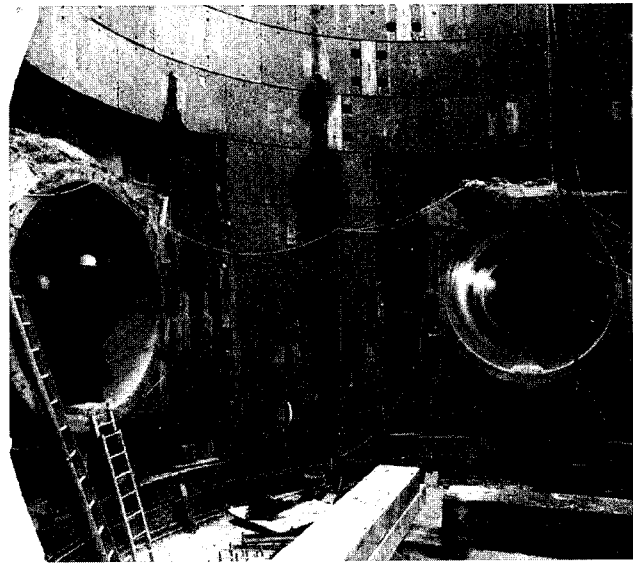


Photo courtesy Thames Water Utilities Ltd.

The tunnel for the London Water Ring Main, a major privatized CCIS project, will be wide enough to drive a car through.

INCENTIVES FOR MULTINATIONAL R&D COLLABORATION

Several cooperative EC research and development initiatives have been started, in which half of project costs are paid from EC funds, with the balance provided by project participants. The participants' share of costs may come from national government budget allocations or private company contributions. The initiatives typically require that multinational industry-government consortia compete for participation. Such programs as BRITE/EURAM (for development of advanced materials), THERMIE (for new energy technologies), and ESPRIT (for information technology) now include CCIS participants (see Table 3-1). Task force teams observed widespread enthusiasm for these programs, which participants are finding valuable as a means for leveraging their own research spending. However, team members also encountered concern that CCIS access to these initiatives (which are open to a range of industries) is suffering because of perceptions that the technology content of CCIS is low compared to other industries. Team members learned that a multinational group of construction firms has formed, seeking to influence the EC bureaucracy to place greater emphasis on CCIS technologies.

Institutional changes accompanying these initiatives are having important consequences for CCIS technology, as discussed below and in Chapter 3. While task force members observed differences among CCIS participants in the countries visited and their attitudes toward the significance and impact of EC policymakers and policies, evidence of some EC impact was pervasive in all countries visited, even Sweden, which is not yet an EC member.

The influence of European unification notwithstanding, task force members concluded that innovation could become more difficult as the EC becomes better established because the effects of cultural variation and lingering nationalism may

become more influential in retarding community-wide adoption of CCIS-related EC directives. Added bureaucratic steps and longer time needed to gain official approval of new technology may in the end discourage innovation. Entrepreneurs in smaller countries within the EC, unaccustomed to such delays, could judge innovation no longer worth the effort. Task force members agreed that it may be two decades or more before a truly integrated market in CCIS technology will emerge in Europe.

Table 2-1

Task Force Observations of State-of-the-Art CCIS Technologies

TECHNOLOGY OBSERVED		U.K.	Sweden	Netherlands	Germany	France	Italy
High-Performance Materials	High-strength concrete	●	●		●	●	
	Paving materials		●	●	●	●	
Automation & Robotics	Pavement evaluation machinery	●	●			●	
Computer-Aided Construction	Computer software applications	●	●	●	●	●	
	Probabilistic modeling			●			
	Information systems development	●					●
Construction Methods	Sewer pipe repair/lining	●		●	●		
	Construction methods		●	●	●	●	
	Manufacturing				●		●
	Corrosion rehabilitation			●			
	Special tunneling	●	●	●		●	
	Road building	●	●			●	
	Repair masonry structures	●					●
	Marine construction			●			
Structural Systems	Composite concrete/steel systems			●			
	Forming systems				●		
	Glass fiber reinforcing systems	●			●		
	Railway track systems		●		●		
Environment	Storm water retention				●		
	Waste containment systems				●		
	Dredging			●			
	Geotechnical	●	●	●		●	
	Storm surge control			●			
	Materials re-use	●	●	●	●		
	Environmental impact/green tech.	●	●		●	●	
Instrumentation & Measurement	Fiber optic instrumentation	●	●	●	●		
	Performance standards	●	●	●		●	
	Traffic/weather evaluation systems		●				
	Quality control						●
Total Number of Observations Noted		14	14	15	14	10	4

STATE-OF-THE-ART TECHNOLOGY OBSERVATIONS

Task force members assessed the state of the art in CCIS technologies in Europe, primarily in comparison to U.S. practices. Task force members who had traveled previously to Japan made comparisons to their observations in that country as well [CERF, 1991, and Tucker et al., 1991]. Those comparisons had inevitable impact on task force discussions, but are addressed only tangentially in this report.

Table 2-1 (opposite page) summarizes the task force observations of CCIS technologies that team members judged to be innovative. The seven major technology categories were determined by team members' observations, rather than any other studies or decisions made prior to the reconnaissance trip, and are discussed in depth in the sections below. The six teams' observations were developed from several sources: (1) the presentations, discussions, and site visits made in each country; (2) individual team members' questioning and review of documents (e.g., government program descriptions and policy papers, company brochures, and reports), that extended beyond the topics initially raised by host institutions; (3) background work by team members in preparation for the visits; and (4) insights gained from observations of facilities and construction during the teams' travel. For example, the teams visiting the United Kingdom were surprised that major highways and commuter rail lines were physically damaged by unseasonably hot summer temperatures that seemed not unusual for U.S. visitors.

Although the countries visited offered diverse pictures of CCIS practices, in meetings after the trip team members reached a consensus on some overall relative comparisons of the state of the art of major CCIS technology areas in the countries visited versus current practice in the United States, as illustrated in Table 2-2. While examples of cutting-edge CCIS technologies and state-of-the-art processes were found in each of the countries, the members' impressions of the overall CCIS state of the art varied from country to country. For example, teams visiting the Netherlands and Sweden were impressed with the generally high levels of technology application, despite these nations' smaller market size. The special needs posed by the constant threat of flooding and severe climate are credited with driving CCIS innovation in those countries, respectively.

Institutional variations were observed as well. In France, CCIS R&D seems oriented primarily toward

Table 2-2

Task Force Assessment of Relative Status of Selected CCIS Technology Areas

TECHNOLOGY AREA		RELATIVE STATUS
High-Performance Materials	Portland cement concrete	<i>U.S. slightly ahead</i>
	Asphalt	<i>Europe slightly ahead</i>
	Steel	<i>U.S. & Europe about equal</i>
	Composites	<i>Europe ahead</i>
Automation & Robotics		<i>U.S. & Europe about equal</i>
Computer-Aided Construction	Field computer use	<i>U.S. very advanced</i>
	Integrated databases	<i>U.S. ahead</i>
	CAD/CAE	<i>U.S. very advanced</i>
	Global positioning systems	<i>U.S. ahead</i>
	Geographical information systems	<i>U.S. ahead</i>
	Project management information systems	<i>U.S. very advanced</i>
Construction Methods	Underground construction	<i>Europe ahead</i>
	Tunneling	<i>Europe very advanced</i>
	Marine construction	<i>Europe very advanced</i>
	Construction site safety	<i>U.S. ahead</i>
Structural Systems	Steel systems	<i>U.S. slightly ahead</i>
	Concrete systems	<i>U.S. ahead</i>
	Mixed systems	<i>U.S. slightly ahead</i>
	Vibration damping	<i>U.S. slightly ahead</i>
	Retrofit (concrete)	<i>Europe ahead</i>
	Building systems	<i>U.S. ahead</i>
	Retrofit (steel)	<i>U.S. ahead</i>
Environment	Solid/hazardous waste disposal	<i>U.S. ahead</i>
	Recyclability	<i>U.S. & Europe about equal</i>
	Water/wastewater treatment	<i>U.S. ahead</i>
	Energy conservation	<i>Europe ahead</i>
	Site remediation	<i>U.S. & Europe about equal</i>
Instrumentation & Measurement	Fiber-optic sensing	<i>Europe ahead</i>
	High-speed pavement measurement	<i>Europe slightly ahead</i>
	Real-time site positioning	<i>Europe slightly ahead</i>
	Intelligent buildings	<i>U.S. ahead</i>

the short-term introduction of innovations in construction, and various mechanisms have been established to promote introduction of new technology. Pressed by growing public awareness, British CCIS practice is actively developing "green" technologies, including energy-efficient and "healthy" buildings and use of wastes as construction materials. Representatives from Italy presented the task force teams with a multitude of differing independent views of technological development. These institutional variations were especially apparent in the team's observations of research and development processes in the six countries, but also have consequence in relation to CCIS state of the art.

In almost all countries, major projects are providing important opportunities to apply and advance state-of-the-art CCIS technologies. The Channel Tunnel and London Ring Water Main in Britain, France's Normandy Bridge, and the Stockholm Ring Road in Sweden are among the most prominent cases the task force encountered.

HIGH-PERFORMANCE MATERIALS

By U.S. standards, "higher performance" construction materials can be said to have entered the European marketplace. However, interest is focused primarily on concrete and asphalt. While there is research on steel and composite materials, team members did not observe applications of notably innovative technologies.

Applications of high-strength concrete, chemical-resistant concrete, and high-precision concrete construction were apparent in several countries. Research in Britain, France, Germany, and Sweden on the durability of high-alumina cement in buildings, nonmetallic fiber reinforcements for concrete, and rheology of fresh concrete, for example, is yielding promising new products and construction aids. Team members noted that French designers routinely use high-strength concretes, with compressive strengths of 60 to 100 MPa (approximately 8 to 14 ksi), in bridges and buildings.

Research results on reactive powder concretes indicate that compressive strengths exceeding 800 MPa (100 ksi) may soon be in use. At Bouygues in France, the company's research on high-performance concrete (HPC) is yielding materials with a strength of 800 MPa. Ductility of these HPC concretes is a concern, but methods for "growing" fibers in the cement matrix show promising results. If successful, some of the problems with fiber-reinforced concrete, such as the balling of fibers in mixing, can be overcome. It was indicated that the new material can provide energy absorption of 40,000 Joules/m³, compared to energy absorption of 100 Joules/m³ for plain concrete. The new material is very dense, with a 37 Å porosity. Company officials feel that they may be able to achieve a level of 20 Å maximum pore size. This low level of porosity, and the resulting low level of permeability, should greatly increase the durability of these concretes and greatly reduce the risk of reinforcing steel corrosion in high-chloride environments.

Also in France, the team observed a high-performance surface dressing for asphalt pavements. Called Novachip, the product was developed by Screg-Routes, a subsidiary of Bouygues, and requires special equipment for its placement. High-performance asphalt is the focus of interest in Germany, as well, where hot-mixed rubberized asphalt and reclaimed-asphalt pavements are being used in the rehabilitation of the former East Germany's roads.

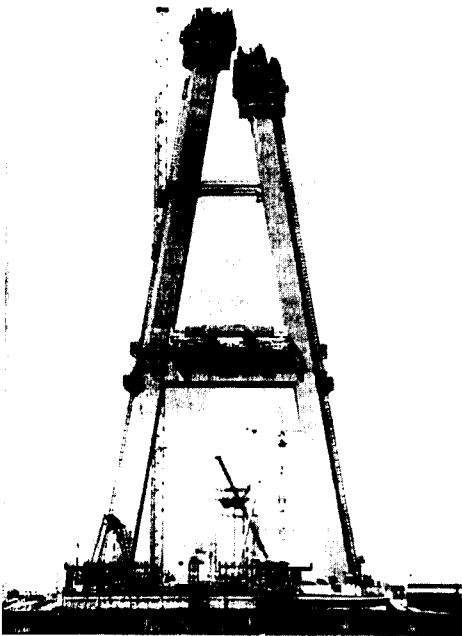


Photo courtesy: Civil Engineering magazine

The Normandy Bridge's record-setting 856-meter main span is called "longitudinally composite" because of its steel and concrete design; pictured above is construction of one of two "inverted Y" supports for the main span.

Materials recycling is an important factor in Dutch construction, where some 60 percent of asphalt rubble and 75 percent of other construction and demolition waste is reused. The trend is not yet significant in other countries visited, although forthcoming EC codes may soon motivate broader interest in innovative reuse and disposal options. Research in Sweden and Britain is producing pavers and blocks utilizing fly ash, alone and with Portland cement, that may prove commercially viable.

AUTOMATION AND ROBOTICS

Team members familiar with Japanese CCIS technology were particularly surprised by the lack of European innovation and limited research on robotics and automated construction equipment. A recently-developed automated paver was encountered in Germany that can work on steep slopes and curves at speeds up to two meters/minute. The Swedish National Highway Administration has developed automatic highway surface profiling and pavement stiffness measurement devices that can do nondestructive pavement-condition assessment at a rate of 200 km per day. The task force team also saw automated tunneling techniques developed in the Channel Tunnel and London Ring Water Main projects.

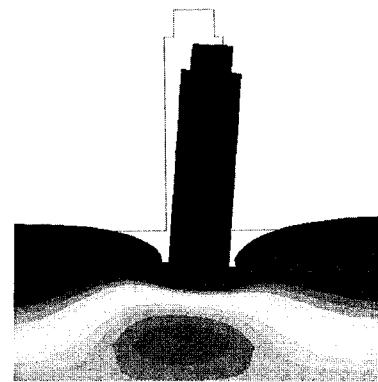
Otherwise, little activity in this area was observed. Labor market conditions in the countries visited varied, ranging from no shortages to significant unemployment. These conditions have seemingly discouraged interest in automation and robotics, despite the substantial construction equipment export market that Italy and other European countries seek to maintain.

COMPUTER-AIDED CCIS AND INFORMATION SYSTEMS

Computer applications in design, manufacturing and construction, and data management are widespread in the countries visited, but team members found that their levels of integration, among applications and from one stage in CCIS development to another, are generally low, compared to U.S. practice. Advanced computer-based technologies such as global positioning systems (GPS), geographical information systems (GIS), and integrated project information systems (IPIS) were encountered in several countries. In France, all building regulations have been placed on compact disc (CD-ROM) and made commercially available at modest cost.

The task force team noted several automated real-time monitoring systems for site construction and system performance. In the Netherlands, systems are available for automated monitoring of soil pore pressures, surface loading, toe movements, and other variables influencing slope stability and soft soil settlements that may influence conditions for roadwork. The North Western Europe (NWE) socio-economic traffic modeling system, also created in the Netherlands, maintains census and road data in conjunction with a graphical information system.

GIS and GPS are being actively used on CCIS construction sites, for such diverse tasks as placement of steel frame elements in large structures, in-field plat and structure location control in residential developments, and leveling of large concrete slabs. Mathematical modeling of structural performance is highly developed and advancing as a result of research. State-of-the art applications of finite element methods and other computer-based modeling procedures were observed in Germany (analysis of groundwater movement), France (analysis of driven piles), Italy (dam design and safety management), and the Netherlands (the internationally recognized DIANA system). The Netherlands also is advancing the



Geotechnical applications of the DIANA finite element analysis software package can be used to analyze the effects of earthquakes, settlement, and changes in the groundwater level.

photo courtesy TNO Building and Construction Research

state of the art in probabilistic methods applications. British research on nonlinear and chaotic dynamic behavior of structures is yielding results that may advance the state of the art in frame analysis. Related studies of traffic systems show potential for new highway traffic control systems.

Studies of life cycle benefits and costs, including values of quality and costs of failures, are developing information needed to design for life cycle performance. This information is critical to the success of performance-based guarantees, such as the seven-year warranty offered by a Swedish contractor.

CONSTRUCTION METHODS

Building construction methods observed in the six countries visited included no particularly noteworthy technologies or cases of innovation. Representatives from several countries spoke of efforts to develop construction as a manufacturing process, but team members observed little practical consequence of such efforts, although Swedish manufactured housing is exported. Task force members were told that Swedish construction companies and the Swedish government are also working to develop improved site safety management methods.

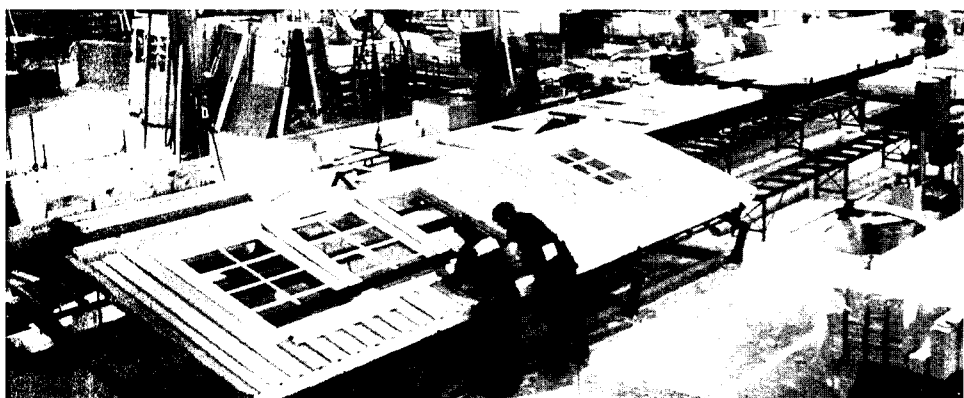
Considering that task force members were told that over 50 percent of the construction activity in Italy deals with existing and often historic structures, there was surprisingly little research activity on innovative building construction

or maintenance technology observed, although evidence was given of advanced methods for repair of masonry structures.

For larger CCIS facilities (e.g., highways, water supply, waste management) geographic factors are shaping technology applications. Sweden, with its extensive hard-rock foundations, is reputed to lead in techniques for tunneling and underground construction, although the task force did not directly observe this technology. Automated

tunneling techniques developed in the Channel Tunnel and London Ring Water Main projects may find other applications in extensions of London's underground transit lines. As might be expected, Dutch marine construction is at the forefront of technology applications. Emphasis on road repair and maintaining high levels of pavement service have motivated the Swedish National Road Administration to support studies of fast-setting concrete for highway repair, but no significant results were observed. In no case did task force members observe indications of major innovation.

European developments in high-speed rail transportation have attracted worldwide attention, and task force teams observed progress in France, Germany, and Sweden. France's TGV (for Très Grande Vitesse, very high speed) system is being expanded and will soon provide high-speed service to all major areas of the country. Work nearing completion on the Channel Tunnel project will establish a direct rail link between England and the continent. Sweden is upgrading route alignments and roadbeds on major routes to be linked with the European high-speed system. These various projects are providing opportunities for development



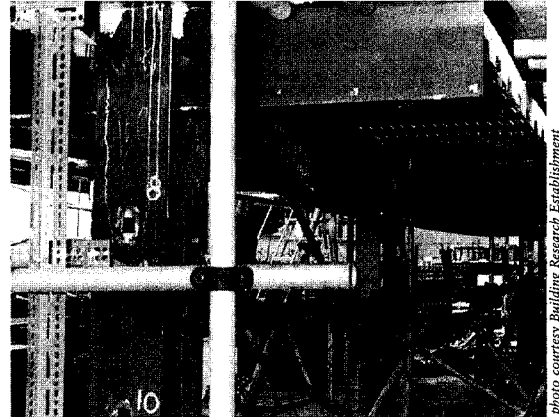
The Swedish Factory-Crafted House System uses the "systems approach" to manufacturing high-quality housing. All components are designed and packed to minimize site labor and chances for error.

of precision concrete precasting and prestressing techniques, for example for tunnel liners and rail ties.

STRUCTURAL SYSTEMS, BUILDINGS, AND HABITATION SYSTEMS

Task force members observed little of note regarding European applications of advanced technology in building systems, although ongoing research seems close to yielding useful results in some areas. British research on nonlinear and chaotic dynamic behavior of structures, for example, may advance the state of the art in frame analysis for buckling.

High energy prices and an abundance of older buildings have encouraged past development of technology for energy efficiency and indoor environmental quality. That technology, now widely used, gives these European countries leadership in this area. Swedish district facilities, for example, recover waste heat from power generation and industrial processes for use in residences, and researchers are exploring ground storage of thermal energy as a means to reduce total energy use further.



Tests to determine the behavior of beam-to-column connections in a steel and concrete composite sub-frame.

Photo courtesy Building Research Establishment

GEOTECHNICAL AND ENVIRONMENTAL SYSTEMS

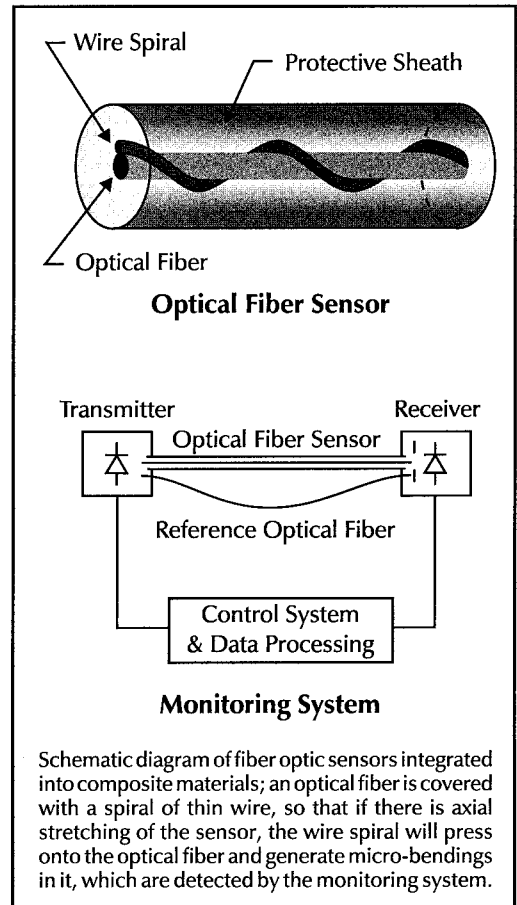
Trenchless, “no dig,” and microtunneling technologies for water and sewer network inspection, repair, and replacement were encountered in several countries. Team members judged British, French, and German applications to be state of the art, although no major innovations were cited. Widespread existence of aging combined sanitary and stormwater sewer systems in the countries visited poses problems of repair and retrofit to meet new environmental standards, but no major innovations have yet emerged from active research programs.

In contrast, team members judged hazardous materials containment methods being used in Germany, and site remediation of industrially-contaminated soils in Britain, to be at the forefront of available technology. Swedish district-heating and other energy management technologies, in addition to waste management and reduction technologies, were judged to be particularly innovative, as well.

INSTRUMENTATION AND MEASUREMENT

As has already been noted, team members observed European developments of highway pavement condition monitoring equipment representing the latest applications of available technology. Advanced systems for monitoring soils and slope stability, as well as systems for monitoring CCIS service conditions (e.g., conditions of highway traffic), were also observed. Team members noted particularly the system of sensors being established in Paris to enable continuous monitoring of water system service conditions.

Team members were told of project applications of fiber-optic sensing technology that appear to be advancing the state of the art in structural strain gauging (diagram, right). German firms are developing this application for use in concrete prestressing and in-situ monitoring of deformations in bridge members. Basic research underlying the



Schematic diagram of fiber optic sensors integrated into composite materials; an optical fiber is covered with a spiral of thin wire, so that if there is axial stretching of the sensor, the wire spiral will press onto the optical fiber and generate micro-bendings in it, which are detected by the monitoring system.

innovation was conducted at universities and then applied on a Dusseldorf bridge. Team members were informed of similar applications of this German technology in Britain.

SIGNIFICANT CCIS TECHNOLOGY TRENDS

Taken as a whole, the task force observations comprise a broad view of Europe's CCIS technology. The team's failure to observe a particular technology does not necessarily mean the technology in a particular country is lagging. However, the observation of what individual team members felt to be state-of-the-art technologies correlate with task force conclusions that some countries, the Netherlands in particular, lead others in putting new technology into practice. These conclusions shaped the team members' assessments of lessons that European experience offers to U.S. CCIS agencies and industries, as discussed in Chapter 4.

The task force undertook to use its observations to assess the relative level of technology development in Europe and the United States and relative developmental trends in the two markets. Table 2-2 (page 15) summarizes the team members' judgements. The task force concluded that U.S. CCIS technology, taken as a whole, trails Europe in only a few key areas, most notably with regard to energy conservation in buildings and marine and tunnel construction.

Significant trends of new technology development may emerge from current research and development programs, particularly those with substantial national government or EC backing. In the United Kingdom, LINK is a government scheme which supports collaborative research between industry and academia (see page A-14). The LINK program on facility maintenance and refurbishment, for example, has more than 50 industrial participants working with 14 science partners on ten first-phase projects. Other examples include: enhanced engineering materials; transport infrastructure and operations; structural composites; ventilation, air-conditioning and refrigeration; and construction maintenance and refurbishment. The total cost for this one LINK program, including government and industry contributions, is estimated at US\$10 million from 1988-95.

Task force members observed that the move toward European unification, rising standards of living, and growing environmental awareness are likely to continue serving as incentives for substantial public investment in CCIS facilities and research. Large projects, which have served as test beds for new CCIS technology, will continue to be a force for innovation. Extension of the Jubilee Line of London's underground, peripheral highways with extensive tunneled segments in Stockholm and London, and major bridges linking the Scandinavian countries are among the projects task force members found to be in early stages of development.

Team members agreed that a pattern of substantial investment in Europe's CCIS is likely to support technological advancement. Continuing European CCIS research and development efforts could enable this advancement to be based largely on European technology. This new technology could then become an important source of competitive strength for European firms in global CCIS markets.

Chapter 3

R&D AND INNOVATION

The task force set out to observe CCIS research and development efforts in Europe, and found that such efforts are being actively pursued in all six countries visited. National governments and private industry are involved in these efforts, often working closely together to advance CCIS technology. In addition to national programs, substantial multinational programs are being pursued under EC sponsorship.

There were distinctive differences among the countries visited, but the task force found similar forces to be driving research and development efforts throughout the EC. Industry representatives throughout Europe generally seemed to lack the overriding concern for liability issues that pervades U.S. CCIS practice, with a result that new technology produced by research is more likely to be tried in practice. This, in turn, increases the likelihood of CCIS research spending paying off with useful innovations actually being used in the field.

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EUROPEAN CCIS RESEARCH AND DEVELOPMENT

Constrained by time and resources, the task force could not conduct a comprehensive analysis of CCIS R&D spending or its results for Europe or the EC as a whole, but gained the impression that European CCIS research funding levels exceed those of the United States, relative to population or levels of CCIS investment. However, because the U.S. economy and population exceed those of the European nations considered, total U.S. CCIS research resources may still be greater than the European aggregate spending.

Nevertheless, task force members agreed that continuing European research and development efforts could become an important source of new CCIS technology, adding to the competitive strength of European firms competing in global CCIS markets. To many task force members, industry conditions in the European countries visited seemed generally more conducive and open to CCIS technological innovation than the United States. Research and development activities are more actively supported by European governments because they are seen as a contributor to national interests. Private and public sectors work together for common purposes of increasing export potential and improving domestic productivity.

National R&D programs in many cases seemed to be designed specifically to encourage partnerships. Sweden's construction unions and contractors requested that the government collect a small payroll tax to be used for R&D support. The fund collects about US\$6 million a year, for which researchers in companies submit research proposals. Similarly, Belgium has a "construction R&D tax." In Germany and the Netherlands, government research funding is channelled through "research societies" or "collective foundations" that then oversee actual research efforts at university, government, and private laboratories.

The French government has established an "innovation charter" program to protect new technologies long enough for a developer to recoup its R&D

investment. Innovative products, processes, or equipment that are not specifically covered by standards or technical appraisal certificates are granted a charter that provides exclusive rights to the new proprietary technologies for several years. Innovation charters allow contractors to team with government research institutes when the contractor does not possess the technical expertise or equipment to develop the innovation itself.

R&D DRIVERS AND INNOVATION TRENDS

“Best bid” procurement allows contractors to submit alternatives to the specified design. Alternative proposals need not have the lowest initial cost, but may permit the recovery of added construction costs through savings in future facility operating and maintenance costs.

The task force found several key factors that seem to be driving CCIS R&D in Europe. These “R&D drivers” are thereby influencing innovation trends, although the strength of these factors’ influence varies substantially among the countries visited. Sweden and the Netherlands, for example, exhibit relatively high degrees of coordination and common direction among members of the research community, suggesting that such factors are driving CCIS research efforts at the national level. At the other extreme, variety in direction and focus among researchers in Italy and France suggest that the influence of specific R&D drivers is more dependent on individual companies or other research institutions in these countries. In general, however, task force members observed the following factors at work in driving European CCIS research activities: European unification, contract delivery methods, privatization, competition, and geography and history.

EUROPEAN UNIFICATION

While the task force found that applying the term “unification” may be as yet premature with respect to Europe’s CCIS technology, the political forces leading toward unification are having a definite impact on research. Implementation of EC standards and codes is forcing changes in industry practices in all countries visited. In turn, firms and national governments are undertaking research to find efficient ways to make these changes. Examples observed range from accommodating heavier highway vehicle loads to meeting more stringent environmental standards.

CONTRACT DELIVERY METHODS

Task force members found that interest in construction contracting based on “best bid” procurement and performance specifications is encouraging CCIS research. Both methods rely on participants’ ability to characterize the trade-offs among current construction costs, future operating and maintenance costs, and long-term system performance, and then to make financial commitments extending beyond the construction and commissioning period. These contracting procedures effectively encourage innovative proposals from the construction contractors, and increase the need for reliable performance measurement and prediction methods.

“Best bid” procurement allows contractors to submit alternatives to the specified design. Alternative proposals need not have the lowest initial cost, but may permit the recovery of added construction costs through savings in future facility operating and maintenance costs. Life cycle characteristics such as operation and maintenance procedures, materials durability, safety, and operating performance are considered when comparing proposals. Contractors reported that only a small portion (about 15 percent) of their work now is based on the best overall bid, but anticipated increased use of this procurement method.

Performance specifications are prepared by the facility owner, and call for guaranteed or warranted work by the contractor. This procedure motivates the contractor to ensure the facility will satisfy requirements not only during the final construction inspections, but also for the specified performance period of several years. For example, task force members in Sweden found that highway projects are being constructed with major contractors committed to deliver seven years of adequate ride and load carrying capacity. The long-term commitment required to assure performance reportedly precludes smaller or less financially stable firms from bidding on large public projects because they are unable to secure warranty insurance.

PRIVATIZATION

Task force members found that the trend toward removing key infrastructure services from direct government control and putting them in private hands is providing greater incentives for innovation, and seems in turn to be fostering CCIS research. While many of the privatization schemes observed are in their early stages, making solid assertions about this relationship difficult, European representatives at several research institutions now slated for full or partial privatization reported active efforts among their colleagues to develop both new marketable services and an effective approach to customer service.

COMPETITION

Task force members observed that large construction contractors in the countries visited are looking to expanded markets within Europe and globally. Recognizing that their labor costs may not be the lowest, these contractors are seeking to establish product quality, safety, and controllable life cycle costs as bases for distinguishing themselves from their competition. Technological innovation is an essential element of this strategy.

GEOGRAPHY AND HISTORY

Despite trends toward common standards and markets in Europe, geography and history remain powerful influences on CCIS research activity. For example, in the Netherlands, the proximity of the sea and potential flooding dominate and drive research on marine construction, storm surge control, dredging, and underwater construction.

Sweden, separated by water from direct access to the EC markets, places emphasis on efficient transportation, especially the ability to operate at higher speeds or reduce by other means (e.g., bridges and tunnels) its effective distance from much of Europe. In addition, harsh climate drives research on ways to reduce frost heave in highways, low temperature pavement cracking, and energy efficiency. An especially cold winter in 1964 damaged some two-thirds of France's roads, motivating several decades of research on ways to maintain pavements and monitor their condition.

In Germany, unification remains a crucial issue. Research on inspection and repair technologies seeks ways to deal more effectively with the need to upgrade the inadequate infrastructure of the former East Germany. Italy's large stock of historic structures creates a need for effective rehabilitation and repair methods, and its often rugged, mountainous terrain drives research on construction methods to cope with such conditions.

CHANNEL TUNNEL PROVIDES TEST BED FOR INNOVATION

Before the official start of the task force trip, team members were given an opportunity to see the Channel Tunnel, which was still under construction at the time. This side trip gave task force team members a chance to see and ask questions about the tunnel construction methods and the state-of-the-art CCIS technologies used.



Task force members tour Channel Tunnel construction site and work in progress.

Transmanche-Link (TML) is the contractor responsible for designing, constructing, and commissioning what is generally known as the "Channel Tunnel," but which is, in fact, a project encompassing far more than just a tunnel under the English Channel. As such, TML is acting on behalf of its client, Eurotunnel, which is a totally separate entity. Eurotunnel will own and operate the Fixed Link once it is completed. The project is being funded entirely through private sources, without any government money.

TML is a consortium of ten major construction companies—five British and five French. When first formed in 1986, TML had a staff of six; at peak, that figure rose to more than 14,500,

with daily expenditures averaging more than US\$3 million.

While TML exists in a liaison capacity to coordinate the project, two separate companies were formed to carry out the work on their respective sides of the Channel. GIE Transmanche Construction is based in Calais on the French side of the tunnel; Translink Joint Venture is headquartered in Shakespeare on the British side.

State-of-the-art CCIS Technology Observed

The three tunnels in the Fixed Link were driven by full-face tunnel boring machines. These machines were highly automated, laser-guided devices that drilled out the ground ahead, ejected the spoil to waiting muck wagons, and subsequently erected the precast concrete segments that make up the tunnel lining. Behind the cutter heads and erection equipment there were backup trains several hundred meters long. These trains carried the precast segments, a conveyor system, equipment for placing grout and laying flooring and rails, and other services such as electrical power packs, ventilation and dust removal systems, compressors, offices, canteen, toilets, and workshop facilities.

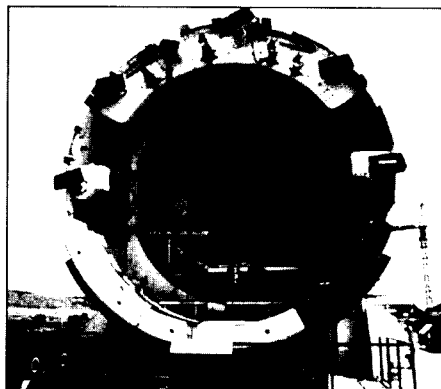
The three tunnels in the Fixed Link are lined, for the most part, with reinforced concrete rings, each made up of a number of two-foot thick precast segments. In order to guarantee both the quality and supply of these segments, TML created its own manufacturing facilities. While this activity centered in France and the U.K., many other EC members participated in the effort. For example, the molds for these precast tunnel segments were made in Italy, as shown on page F-12.

In France, tunnel segments were cast at a facility adjacent to the great access shaft at Sangatte. Lack of space precluded a similarly convenient location in the U.K. In fact, the segments destined for Shakespeare Cliff were made in a plant on the Isle of Grain. They had to be ferried to the site by TML's own fleet of railway wagons, a circuitous journey of about 100 miles.

The different ground conditions through which the French and British teams

tunneled required the use of different types of concrete rings. On the U.K. side, segments abut each other; the service tunnels have six segments, while the running tunnels have eight. These segments were expanded and wedged into place with a "key." The rings in all of the French tunnels have six segments, which were bolted together. Each segment was also fitted with a gasket to make sure that the rings were totally watertight.

On both sides of the Channel, cages roughly the shape of the finished segment were made with reinforcing bar. Because the French tunnels all used six segments,



Special tunnel boring machines were developed especially for the Channel Tunnel construction.

Sangatte only had to make a total of 24 types of segments, compared with 70 different types at Grain. The cages were placed in molds which were filled with concrete and then passed through a steam curing tunnel. The consistency of design on the French side permitted the use of a state-of-the-art automated line to shape the steel reinforcing cages; this system processed enough steel to build three Eiffel Towers. On the other hand, because of the many different types of tunnel segments in the U.K., much of the steel work was done manually.

Setting new standards for the precast industry, both Sangatte and the Isle of Grain borrowed from other industries to test the accuracy of their products. Working within tolerances of 0.1 mm in certain cases, the British used a measuring device driven by software originally developed to check turbine blades in jet engines. The French equivalent was originally used by automobile manufacturers for equally high-precision industrial quality control.

Because of close attention to accuracy, the rejection rate at the Isle of Grain was only 2:1,000, compared with an industry norm of over 7:1,000.

The rings lining the tunnels were not only precision made, they were also made to last. The concrete is the strongest ever produced in the world. Ninety days after leaving the curing tunnels, the segments possessed a crushing strength of 70 to 100 MPa. To put that into perspective, the pressure vessel in a nuclear power station is around 50 MPa, the average concrete high-rise building is 30 MPa, while the concrete foundation of an average home is around 20 MPa.

Moving Innovation into Practice

Besides the tunneling and concrete, there were many problems which called for the latest technical solutions:

1. **A new Austrian tunneling method was used**—a fast, flexible, and cost-effective system allowed cathedral-like TBM erection chambers in the Shakespeare Cliff marshaling area to be completed in just 30 days.
2. **Highly complex stabilization work** had to be done to prevent surrounding hills at the U.K. terminal from slipping downward.
3. **Draining the terminal** called for some original solutions on the French side—five elevated water tanks with a surface area of 100,000 square meters were constructed, in addition to 10 kilometers of canals.
4. **The control and communication system** incorporates the very latest ideas in automatic train protection and is, by definition, "fail-safe"; this system includes the largest real-time data systems ever assembled outside the world of space research.

Overall, the task force team found the Channel Tunnel construction an extraordinary effort, given its magnitude and the international collaboration required—especially considering that it was completely developed using private funds. The project struck them as truly unique, not only as an engineering feat, but also in terms of logistics, safety, and public relations.

THE ROLE OF EC PROGRAMS

In addition to the forces acting to encourage and direct CCIS research within each country visited, the EC itself has established research programs that are driving multinational CCIS research efforts. Most of these EC research programs are not directed specifically at CCIS technology, but several are available to those public and private researchers who wish to team together to pursue this area of work. As was noted in Chapter 2, researchers in several of the countries visited have done so successfully. Table 3-1 summarizes several EC research programs that task force members learned were supporting CCIS research and development activities.

The task force team found, in general, that the "vision" for CCIS R&D in these EC programs is coming primarily from the private sector, rather than government, and funding is likely to follow a similar course as government resources become more constrained. Nevertheless, task force members estimated that three-quarters of all European CCIS research is being performed for the public sector, and the EC accounts for an important share of this work. Public monies allocated to the EC are made available to multinational groups that are then able to leverage their other resources with this new "foreign" infusion of support. Task force members observed that private firms view these EC resources as a valuable way to gain added funding for research that they view as likely to enhance their competitive positions.

One example of a major multinational cooperative effort is the STEP program, which is aimed at developing means for automatic exchange of construction industry product information between diverse computer systems. Large construction contractors in several countries are leading the effort and setting its agenda. The task force concluded that a primary reason these contractors can participate so extensively in this type of program is because they have larger R&D departments than their American industry counterparts.

Table 3-1

EC Research Programs Supporting CCIS in Countries Visited

Program Name	Focus	Construction-Related Activities
BRITE/EURAM	Advanced Materials	Design methodologies and quality assurance; advanced concrete, corrosion-resistance, concrete repair, and pavements
THERMIE	Energy Technologies	Improvements in building energy efficiency, environmental technologies, and renewable energy sources
STEP	Information Systems	Developing means for exchange of construction industry product information between diverse computer systems
ESPRIT	Information Technologies	Computer-integrated manufacturing applied to the construction site; intelligent buildings; computer-integrated design and construction
EUREKA	European Competitiveness	Market-oriented R&D aimed at enhancing competitiveness of Europe's construction industry

Chapter 4

LESSONS FROM EUROPEAN EXPERIENCE

While recognizing that their experience on this trip was limited, task force members concluded that their European observations offer lessons for U.S. CCIS practices. As summarized in Table 4-1, these lessons underlie a series of seven recommendations for actions that task force members agreed U.S. industry and government should take to strengthen U.S. ability to profit from CCIS R&D, and thereby enhance our productivity and competitiveness in international markets.

Experience in Europe demonstrates that substantial benefits can be gained if government and industry join forces through use of contract delivery systems that foster CCIS technological innovation.

COMPETITIVE OUTLOOK

It seemed likely to task force members that the active research efforts and increasing market size faced by organizations in the six countries visited will lead to even greater rates of CCIS innovation. While the overall levels of CCIS technology in the countries visited generally does not now exceed U.S. practice, team members agreed that European innovation could in coming years pose threats to U.S. market potential. This threat seems greatest with respect to concrete technology (i.e., both cement and concrete construction methods) and contracting based on life-cycle performance guarantees.

Table 4-1
Task Force Observations and Resulting Recommendations

Task Force Observation	Recommendation	Specific Action Proposed
European use of "best-bid" and design-build type contracts	Change U.S. contract delivery systems	U.S. CCIS-related agencies should establish program to demonstrate "innovation-friendly" contracting procedures in their own projects and projects developed by their state and local government program-fund recipients.
Swedish highways built with a seven-year warranty provide a more cost-effective CCIS investment	Adopt performance specifications	U.S. CCIS-related agencies should demonstrate use of performance specifications by adapting European examples and encouraging their application in this country.
Swedish/Dutch trade labor unions work closely with research and demonstration projects, so they are prepared to use new technologies when introduced	Update industry practitioners	U.S. management and professional groups should work with labor to enhance labor education and training programs.
Participants reap early benefits from cooperative CCIS R&D projects	Encourage federal sponsorship of prototype projects	As a principal funder and major customer for CCIS development, the U.S. government should undertake demonstration projects designed to foster innovation.
European countries moving quickly toward common standards for CCIS designs, equipment, and materials	Increase U.S. participation in international standards	U.S. government and private industry should develop a more active and influential stance by formally participating in international standardization activities.
Growing significance of international CCIS R&D in Europe; increased exposure to best technology	Increase U.S. participation in international R&D	Efforts should be made to strengthen U.S. R&D programs in areas of relative weakness by increasing U.S. participation in international CCIS research.
Strong European joint private/public R&D programs developing new processes and materials that meet current needs and have potentially high export value	Establish national leadership to improve dialogue between industry, academia, and government	CERF should facilitate dialogue between the design and construction industry, academia, and the federal government, specifically with the White House Office of Science and Technology Policy and the National Science and Technology Council.

While many task force members agreed that greater CCIS research effort by the U.S. is warranted, they recognized that obstacles to implementing innovation resulting from research must be reduced before U.S. companies or government agencies can be expected to substantially increase their levels of R&D spending. For example, task force members' observations that liability and related litigation are much less significant as deterrents to CCIS innovation in Europe highlight the role of these factors as obstacles to realizing research payoffs in the United States.

Experience in Europe demonstrates that substantial benefits can be gained if government and industry join forces through use of contract delivery systems that foster CCIS technological innovation. European design-build and "best-bid" procurement, for example, while not appropriate for all applications, would represent a shift from the largely adversarial relationships—among designers, construction contractors, and their government agency clients—frequently fostered by predominant current U.S. practices. Task force members observed that these contract delivery systems seem to share construction risks among owners and contractors equitably, control liability, and thereby encourage adoption of promising new technologies.

In the United States, government agencies at federal, state, and local levels are the principal purchasers of CCIS design and construction services, so they are in the best position to foster adoption of such "innovation-friendly" contracting formats. *Task force members recommend that U.S. CCIS-related agencies such as the Department of Transportation, the U.S. Army Corps of Engineers, the Environmental Protection Agency, the General Services Administration, the Department of Housing and Urban Development, and the Department of Energy should establish programs to demonstrate "innovation-friendly" contracting procedures in their own projects, as well as projects developed by their state and local government program-fund recipients.* Paramount focus on the R&D aspects of the project and careful assessment of results should be integral parts of these demonstrations, so that successes and failures, and their causes, can be shared widely within the CCIS industry.



photo courtesy: Ministère de l'Équipement

This advanced tunnel boring machine was developed as a potential export under a French "National Project."

CCIS technologies are evolving rapidly, on a global basis, threatening to make traditional crafts and construction labor practices obsolete. Task force members observed that labor and professional groups in several of the countries visited are actively involved in education and training to upgrade the industry's ability to adopt and apply new CCIS technology. Members agreed that the U.S. cannot afford to find itself lagging in this area. While changes in university curricula and early professional career-training programs are warranted, training for crafts and skilled labor ("blue collar" workers who actually construct CCIS facilities) seemed to task force members a more crucial difference between U.S. and European practice. *Task force members recommend that U.S. management and professional groups work with labor to enhance labor education and training programs.*

In addition to advancing applications of new CCIS technologies, more attention should also be directed toward adapting technologies from other industries, such as manufacturing, where lessons about overseas competition and adaptation of foreign practices have already brought about important changes. Government, particularly at the federal level, has an important supportive role to play in developing such technology transfer programs, but the initiative should come from the private sector to assure broad support.

Task force members took special note of broad multinational participation in European technology development projects and the early benefits that these projects seem to be achieving. While care is needed to avoid major projects that serve limited purposes or have primarily a political justification, the value of such projects as a force for advancing CCIS technology should not be discounted. *Task force members recommend that the U.S. government, as a principal funder and major customer for CCIS development, should undertake prototype projects designed to foster innovation.* The Department of Transportation's demonstration grants program (for urban mass transportation projects, for example) and similar activities at other agencies may be useful U.S. models, supplementing those of European programs, for new CCIS prototypes. These prototypes should involve local or state agencies, along with federal sponsors and private sector partners, such as construction contractors and suppliers.

Throughout their trip, task force members observed the growing significance of international CCIS research and development in Europe.

OPPORTUNITIES FOR COLLABORATION

Throughout their trip, task force members observed the growing significance of international CCIS research and development in Europe. Private companies found that their participation in these programs supported their own internal technology development and strengthened their competitive position. Government agencies and professional groups found their access to best technology expanded. Task force members agreed that there are substantial opportunities for U.S. productive collaboration in this international activity. *Task force members recommend that efforts should be made to strengthen U.S. R&D programs in areas of relative weakness by increasing U.S. participation in international CCIS research.*

CERF has sought to encourage such participation in the past, for example through the task force visit to Japan [CERF, 1991] and research needs forums. To continue these efforts, in 1996 CERF will conduct an international symposium, entitled *Engineering and Construction for Sustainable Development in the 21st Century: An International Research Symposium and Technology Showcase*, to develop an internationally acknowledged agenda for the civil engineering-related R&D needed by the world's construction industry. This symposium will be held in Washington, D.C., and will bring together researchers and users of research results from many countries to share their visions of the future and to mobilize the resources necessary to pursue advancement of CCIS technology.

However, more immediate action can and should be taken. Task force members observed that the European countries are moving quickly toward common standards for CCIS designs, equipment and materials. While geographical variations among regions will remain, Europe in future years is likely to present a much more uniform market with much less variation in its CCIS codes and standards. Because much of the world market relies on European models for their own standards and practices, the impact of increasing European uniformity will be felt well beyond the EC countries.

If U.S. industry wishes to compete globally, U.S. firms must be able to meet these emerging standards. Yet, task force members found that opportunities to participate in standards development have not been actively pursued by U.S. firms or agencies. *Task force members recommend that the U.S. government and private industry should develop a more active and influential stance by formally participating in international standardization activities.* This collaboration in

setting international standards will help to assure that U.S. products and processes have equal chance of competing in the emerging global CCIS technology market, without bearing an undue burden of conforming to others' standards.

ADAPTATIONS TO U.S. PRACTICES

Task force members observed in Europe that the performance-based approach to CCIS development is not only more advanced, but is apparently yielding benefits to all parties involved.

Despite more than two decades of discussion, usage of performance specifications in U.S. CCIS construction is limited. Task force members observed in Europe that the performance-based approach to CCIS development is not only more advanced, but is apparently yielding benefits to all parties involved. Perfecting a performance-based approach will give firms products that are likely to have great appeal in both U.S. and global markets. Despite some U.S. experience in this area (e.g., roof warranties), task force members agreed that U.S. firms are hampered in their own efforts to develop such products by lack of institutional support and financial mechanisms for equitably distributing risk.

To provide domestic market incentives for performance-based CCIS development, *task force members recommend that U.S. CCIS-related agencies should demonstrate use of performance specifications by adapting European examples and encouraging their application in this country.* Government agencies should work with private sector groups to establish risk-sharing programs to underwrite sureties, warranties, and guaranties for these performance demonstrations. These programs could be integrated with those designed to demonstrate "innovation-friendly" procurement practices.

Task force members observed in Europe strong joint actions by the private sector, academia, and government to enhance CCIS technology and the industries that use that technology. The strength of these joint actions is reflected in new processes and products being applied in the countries visited and in the high export potential that CCIS represents for several countries. A similar partnership between industry, academia, and government in the U.S. is necessary to develop strategic research at universities relevant to industry needs, transfer technology effectively from research laboratories to industrial applications, and prepare students with proper industrial perspectives during their graduate training.

In the United States, the construction industry accounts for eight percent of the nation's economy (as measured by gross domestic product, or GDP), making it the second largest industry in the U.S. Nevertheless, both the producer and buyer sides of this industry are very fragmented, weakening the industry's abilities to mobilize research resources and to assume the risks of demonstrating promising new technologies. In Europe, government programs at national and EC levels are demonstrating that such fragmentation can be overcome, yielding benefits to producers and consumers alike.

Task force members agreed that national leadership is needed in the United States. This leadership should come from the federal level, although the private sector, academia, and state and local government must also be partners in CCIS improvement. *Therefore, national representation and leadership for the industry should be established at the White House level to improve the dialogue between industry, academia, and government concerning matters relating to CCIS R&D.*

Because the Clinton administration views the construction industry as a key sector in its program to increase America's economic prosperity, enhance U.S. global competitiveness, and ensure the general well-being of Americans through

infrastructure renewal, working with the design and construction industry is central to the administration's strategy. In support of this strategy, the administration established a subcommittee on Construction and Building within the Committee on Civilian Industrial Technology of the cabinet-level National Science and Technology Council (NSTC).

Based on research priorities expressed by the construction industry in a meeting coordinated by CERF, the following goals were defined by the subcommittee on Construction and Building for focus of R&D in the construction and building area in FY 1996 federal initiatives:

- 50% reduction in delivery time
- 50% reduction in operation and maintenance costs
- 50% more durability and flexibility
- 30% increase in comfort and productivity
- 50% less waste and pollution
- 50% fewer occupant-related illnesses and accidents
- 50% reduction in construction-related accidents

If these goals can be attained, the construction sector will be propelled from its current "low-tech/low-productivity" image into a technology-focused contributor to America's future prosperity. In developing these goals, the subcommittee utilized the Civil Engineering Research Foundation (CERF), the research affiliate of the American Society of Civil Engineers, in order to establish a dialogue with industry concerning CCIS R&D.

As a focal point for the subcommittee's contacts with the construction industry, CERF is coordinating industry and academia input to ensure that these goals materialize into a defined, attainable path for the construction sector to follow to fulfill its promising potential in the 21st century. CERF will continue this dialogue with the subcommittee on Construction and Building to promote cooperative research projects involving industry, academia, and government as a means to achieve the construction industry goals established by the NSTC.

In conclusion, many task force members found remarkable differences between European and U.S. CCIS practice that seem to result from the more cooperative and less adversarial relationship among private and public sectors, and among companies, labor, and public agencies in the countries visited. The degree of cooperation varied among countries, reinforcing the task force's conclusion that enhancing cooperation among participants in U.S. CCIS may be the most important lesson that can be adapted from their European visit.

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- Civil Engineering Research Foundation, 1991. *Transferring Research into Practice: Lessons from Japan's Construction Industry*. #91-N5005. Washington, D.C. 50pp.
- Tucker, Richard L., et al. 1991. *Construction Technologies in Japan*. National Science Foundation, Japanese Technology Evaluation Center. Baltimore, Md. PB91-100057. 242pp.

APPENDICES

Introduction to the Appendices

Appendix A

UNITED KINGDOM **A-1**

Appendix B

SWEDEN **B-1**

Appendix C

THE NETHERLANDS **C-1**

Appendix D

GERMANY **D-1**

Appendix E

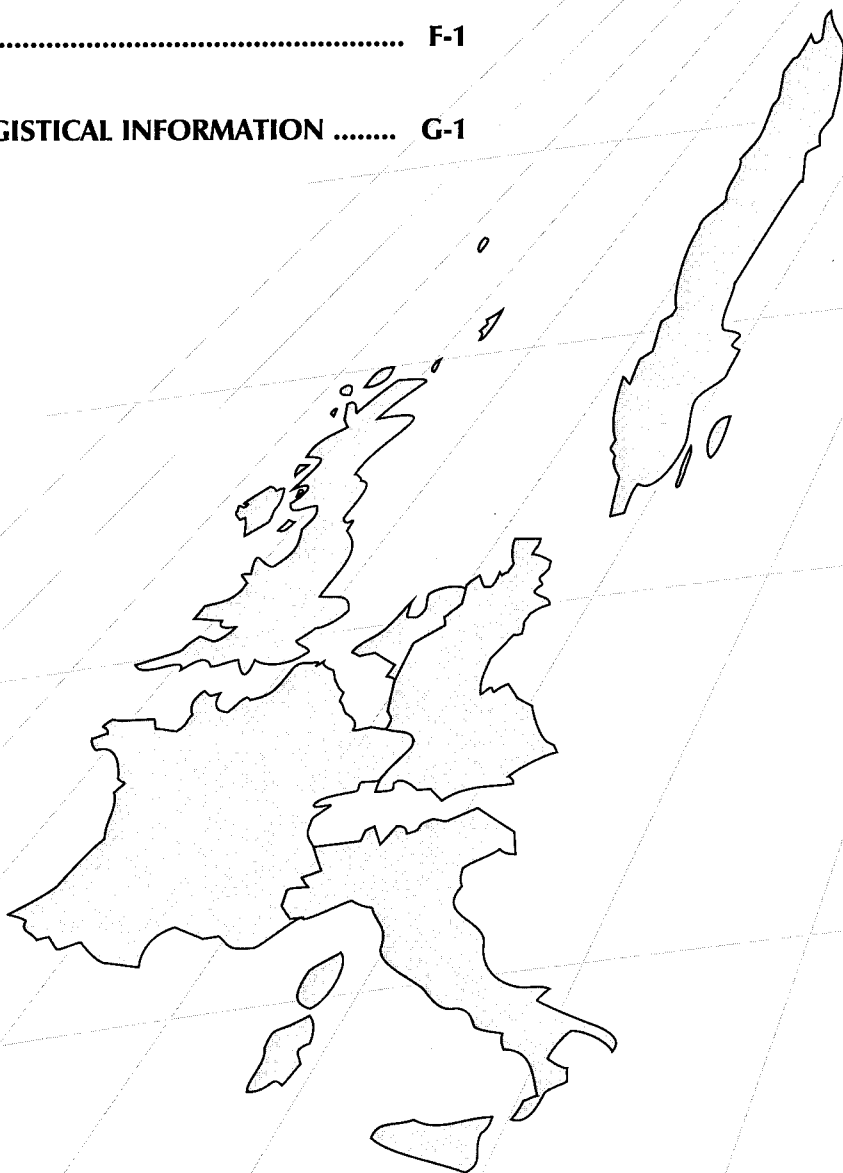
FRANCE **E-1**

Appendix F

ITALY **F-1**

Appendix G

TASK FORCE TEAM MEMBER & TRIP LOGISTICAL INFORMATION **G-1**



INTRODUCTION TO THE APPENDICES

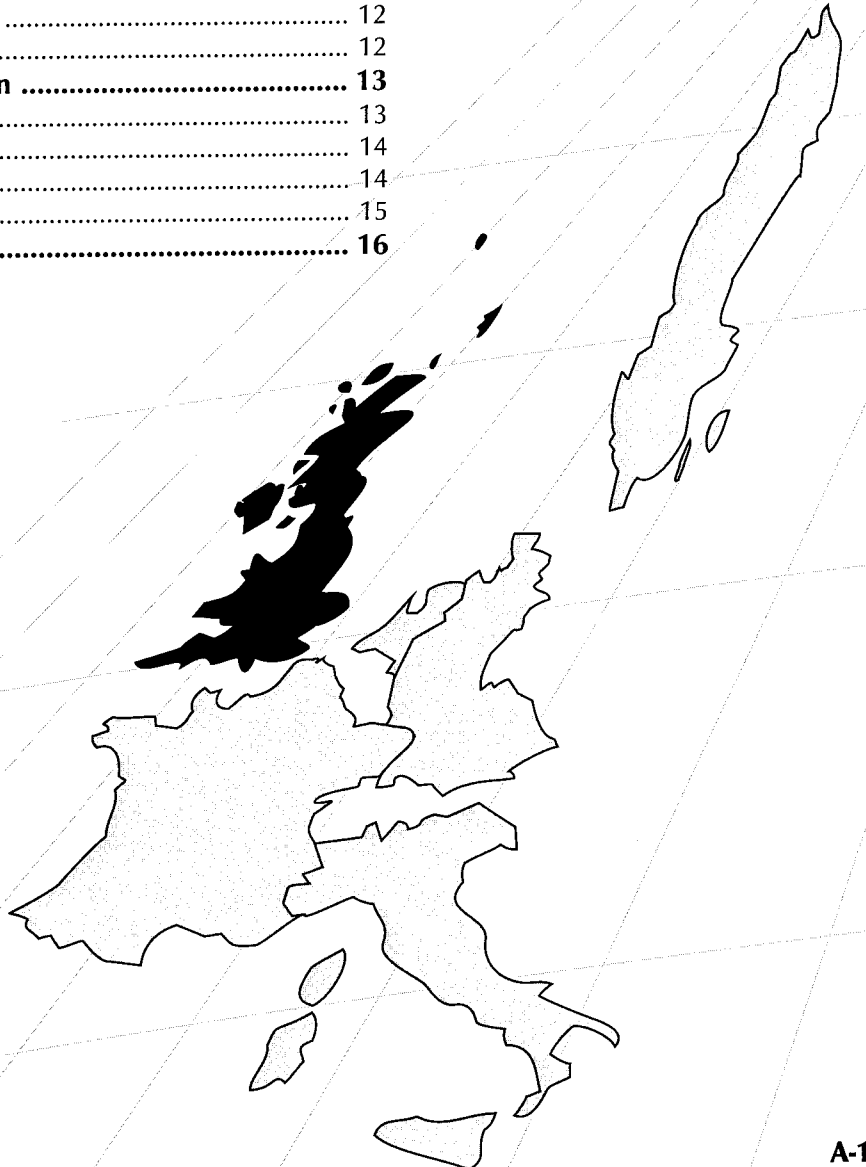
Appendices A through F present separate summary reports for each of the six countries visited. The order in which the countries appear reflects the structure of the task force team. The appendices document team members' observations in each country of R&D trends, state-of-the-art CCIS technologies, and processes and strategies for implementing innovation. Appendix G contains additional information about the task force team and the logistics of the trip.

Appendices A through F are organized in a manner similar to each other, as follows. Section 1 provides summary observations for the specific country. Section 2 explains the historical, economic, regulatory, cultural, legal, and competitive environment perceived by task force members as influencing CCIS practices and technology transfer. Section 3 provides the task members' assessment of the state of the art of CCIS technologies in that country and R&D trends, focusing in turn on R&D drivers and technologies related to each major CCIS area such as materials, automation, building systems, etc. Section 4 examines the processes and strategies observed for technology transfer in each country, focusing in turn on the role of government, industry, and academia. Finally, Section 5 outlines the way in which the country is seen as responding to the challenges posed by the institution of the European Community.

Appendix A

UNITED KINGDOM

1. Summary	3
2. Context for CCIS Technology	3
2.1 Historical Perspective	3
2.2 Economic, Regulatory, and Cultural Environments	4
2.3 Legal and Competitive Environments	5
2.4 R&D and Technology Innovation Policies	6
2.5 Private Sector Technology Partnerships	7
3. CCIS R&D and Technology Trends	7
3.1 R&D Drivers and Activities	8
3.2 Construction Materials	9
3.3 Computer-Aided Design, Automation, and Information Systems	9
3.4 Building and Construction Systems	10
3.5 Highway and Rail Systems	11
3.6 Environmental and Geotechnical Systems	12
3.7 Water and Sewage Systems	12
4. Strategies for Innovation Implementation	13
4.1 Role of Government	13
4.2 Role of Industry	14
4.3 Role of Academia	14
4.4 Financial Incentives	15
5. Response to European Community	16



Appendix A

UNITED KINGDOM

1. SUMMARY

The United Kingdom is the first western European country to encourage privatization of infrastructure services. Therefore, it is already prepared for the most radical changes likely to result from European unification. However, its environmental standards fall short of some EC directives and will need upgrading. For instance, shipping solid wastes to other countries, which is its current practice, will be severely restricted.

Overall, CCIS technologies are competitive with the rest of Europe. Contractors are increasingly using integrated project information systems, geographical information systems, and CAD systems in everyday operations. The Channel Tunnel project has resulted in some excellent boring and water sealing technologies. Fiber optic strain sensing techniques developed in Germany are being used to monitor the performance of real projects.

The mix of government agencies, private organizations, and academic institutions visited are listed in Table A-1.

2. CONTEXT FOR CCIS TECHNOLOGY

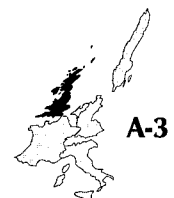
2.1 HISTORICAL PERSPECTIVE

The United Kingdom (U.K.) is a nation composed of England, Scotland, Wales, and Northern Ireland. Fifty-eight million people occupy a country about the size of Oregon (242,000 km²). This island nation has a rugged coastline that land-borne traffic now pierces via the Channel Tunnel. The weather is moderate and extreme temperatures are rare. Low hills generally dominate the landscape.

With a 1992 gross domestic product (GDP) of US\$1,042 billion [DoE, 1992], the U.K. is a leading member of the European Community (EC). Reflecting a long and noble history as the birthplace of the Industrial Revolution and a global source of CCIS innovation, the U.K.'s strong engineering community seeks to maintain leadership in CCIS technologies. The U.K.'s Institution of Civil Engineers (ICE) founded in 1818, has 80,000 members in 140 countries, and the Institution of Structural Engineers (ISE), founded in 1908, has more than 20,000 members. The government's Building Research Establishment (BRE) was founded in 1921 as the world's first national building research laboratory. It was an early and influential proponent of performance

TABLE A-1
Participating Organizations—United Kingdom

Organization	Identifier	Type
British Board of Agrément	BBA	government agency
Building Research Establishment	BRE	government research
Building Services Research and Information Association	BSRIA	private research
Channel Tunnel		construction site
Construction Industry Research & Information Association	CIRIA	information services
Department of Environment	DoE	government agency
Department of Transport	DoT	government agency
Imperial College of Science, Technology & Medicine	IC	university
Institution of Civil Engineers	ICE	professional society
Institution of Structural Engineers	ISE	professional society
John Laing Construction		private contractor
Ove Arup & Partners	OAP	private consultant
Science and Engineering Research Council	SERC	government research
Taywood Engineering Limited	TEL	private consultant
Transport Research Laboratory	TRL	government agency
Thames Water Offices		private company
University College, London	UCL	university
Water Research center	WRc	private company



standards that addressed users' needs directly rather than through prescriptive statements for physical properties of construction materials and systems. British professional and trade organizations and governmental institutions remain strong forces in international CCIS R&D.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

The United Kingdom has made the most of its limited resources and land. As the first industrialized country in the world, it continues to maintain a leadership position in many technology areas. Historically, the U.K. used its technological advantage to colonize underdeveloped foreign lands; it now uses this technological prowess to compete in international markets.

The U.K. economy is growing slowly, with 1 percent growth forecast for 1993, following a 1990–1992 recession. The recession had strongly negative effects in construction firms' R&D, which fell from 0.09 percent of output in 1989 to 0.05 percent in 1990 [DoE, 1992]. As in the U.S., most private sector CCIS R&D is funded by materials and equipment suppliers, and neither designers nor contractors feel they have adequate resources to fund R&D aimed at overall improvements in CCIS performance or design and construction practices.

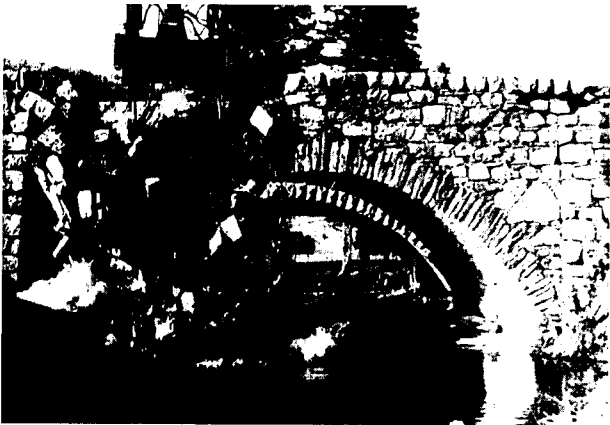


photo courtesy Transport Research Laboratory

By testing aging, redundant bridges to failure, the Transport Research Laboratory can determine whether other structures of similar nature can be allowed to continue in service.

Much of the U.K.'s infrastructure is nearing the end of its design life, needing replacement or refurbishment, and many large cities are becoming overly congested. Consequently the U.K. is looking below ground to relieve the pressure on current transportation systems and facilities. An underground loop around London is being studied and might be financed through private sources. Also ongoing are some of the world's most challenging, and largely privately financed, CCIS construction and renovation projects: the Channel Tunnel, the Canary Wharf urban development, the London Ring Water Main, extensions of the London Underground (subway), and North Sea oil and gas drilling and production platforms. These projects provide many opportunities and strong incentives for continuing innovation.

Funding for CCIS R&D is provided by three government departments. The Department of the Environment currently provides annual funding of US\$144 million for environmental, construction, housing, and other research areas. The Department of Transport provides annual funding of US\$57 million, with the principal emphasis on inland surface transport. The Department of Trade and Industry funds demonstration projects to assist technology transfer. An interesting point to note is that the Department of Environment regulates the construction industry, while also being responsible for protecting consumers. Some see this as a conflict of interest, but most feel that it effectively balances Department's interests.

The Science and Engineering Research Council (SERC) distributes funding for research at universities and cost sharing with industry. Annual funding is US\$28.5 million for construction, US\$10.5 million for environment, and US\$9 million for marine technology.

In addition to professional organizations such as the Institution of Civil Engineering (ICE) and the Institution of Structural Engineers (ISE), several industry and trade groups are active. The Construction Industry Research and Information Association (CIRIA), founded in 1960, provides best practice

guidance to civil engineers that is authoritative, convenient to use, and relevant to their needs. Its members include contractors, materials suppliers, governmental organizations, educational establishments, professional institutions, and trade associations. The Construction Industry Council provides a unified forum and voice for numerous professional organizations concerned with construction. The Construction Industry Environmental Forum, organized by CIRIA, BRE, and the Building Services Research and Information Association (BSRIA), helps the construction industry understand environmental issues, best current practice, and factors which may necessitate new design and working practices. The Standing Committee on Structural Safety, established by ICE and ISE, maintains a continuing review of building and civil engineering matters affecting the safety of structures.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

Over the past 50 years, the U.K. has swung from a market economy to a planned economy and back again as the ruling government party has changed. The current strong trend toward privatization of public sector activities has now progressed from what were previously national industries (e.g., airlines and telecommunications) to civil infrastructure facilities and related services. Operations of selected government agencies are planned to follow this trend.

Thames Water, formerly a government authority providing water to 7 million people and sewer services to 13 million people in the London area, was privatized in 1989. The Water Research Centre (WRC), with a staff of 700 and offices in six countries, formerly was a national laboratory.

BRE and the Transport Research Laboratory (TRL), while still parts of government departments in 1993, are both anticipating similar spin-offs as private operations. Such agencies receive limited government support during the transition, but are expected to become fully self-supporting within a few years. However, the government departments of which these newly-privatized organizations formerly were a part remain substantial customers for their services, and in some cases reportedly dominate the organizations' attentions at the expense of clients from private industry.

British government policy recognizes CCIS as an important element of the economy and encourages collaborative R&D among industry, research institutes, and universities, with the aim of moving technology quickly and reliably into the marketplace. A 1992 DoE report classified research as *basic* (seeking knowledge for its own sake); *strategic* (fundamental, but purposeful); *applied* (problem solving); and *experimental development* (product development). The government's policy concerning public support of research is contained in a recently-issued white paper [HMSO, 1993]. However, this policy emphasizes that construction, which accounts directly for between 6 and 8 percent of GDP and together with the related supply industries for more than 12 percent, has national strategic importance. Construction output is accorded special importance to the efficiency of the nation's economy as a whole, since it represents over half the nation's fixed capital. The white paper notes that low labor productivity results in construction cost increases, and a lack of R&D in new construction technologies leads to poor

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The superstructure of the second bridge at Runnymede, designed by Ove Arup & Partners, consists of four balanced frames of prestressed concrete that were cast as half frames on the bank and then slid into their final positions.

photo courtesy Ove Arup & Partners



performance in use. Both effects are cited as having adverse consequences for the nation's economy and international competitiveness, and so justify the strategic importance allocated to CCIS R&D.

The construction industry is still controlled primarily by the architects, but a multi-discipline approach to design is fast emerging. The contracting corps consist of many small firms and a few large companies. Only the largest companies are exploring international markets.

Litigation and liability considerations are more of an obstacle on British construction jobs than the rest of western Europe. Contractors are cautious about introducing innovations and high-risk technologies. Still, litigation problems are small compared to those in the U.S. For instance, team members visiting the Channel Tunnel construction site were not requested to sign release of liabilities as would be required by many U.S. construction sites.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

Presently, only 40 percent of construction related R&D money originates from the government and this percentage is shrinking. Figures A-1 and A-2 display the relative current contributions of British academia, government, and industry to CCIS R&D. The distribution of funding in the first chart will shift more towards industry as more government departments are privatized.

FIGURE A-1
CCIS R&D Funding—United Kingdom

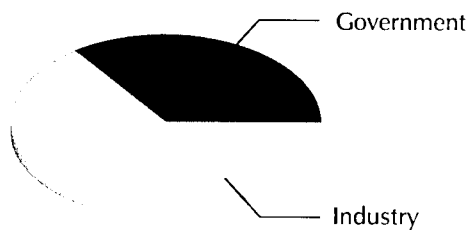
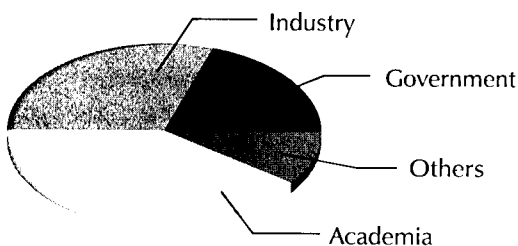


FIGURE A-2
CCIS R&D Performers—United Kingdom



Government funding moves through the Science and Engineering Research Council (SERC), which sees construction as a manufacturing process and a major element of Innovative Manufacturing. SERC supports research at field sites to obtain knowledge unavailable from laboratory or simulation studies. SERC also funds major research facilities, which are open to U.K. users from research organizations or industry. These facilities include a six degree of freedom, 15-ton shaking table for seismic studies; a movable anaerobic digestion facility; a geotechnical experimentation site; a wave generator and coastal engineering model; and a flood flow modeling facility.

As a major element of its fourth Corporate Plan, SERC is developing an initiative on innovative manufacturing that will be industry-led and responsive to the challenges of managing interfaces, integrating manufacturing with design and processing, and promoting information technology [Science and Engineering Research Council, 1993]. The initiative is intended to identify opportunities for the 21st century and establish a strong strategic research platform. Funding for that Corporate Plan is expected to exceed US\$25 million annually. [As of April 1, 1994, SERC no longer exists; the Engineering and Physical Sciences Research Council (EPSRC) assumes many areas of SERC responsibility, including environmental and civil engineering.]

The Construction Industry Research and Information Association (CIRIA) provides US\$4 million funding for research annually. The Construction Industry Environmental Forum, which includes CIRIA, BSRIA, and BRE, provides matching funds for government research funding. However, the Cement and Concrete Association has severely downsized its research funding and limited its services to providing information. The Concrete Research and Innovation Center at Imperial College has been organized to fill the gap left by this change.

Large contractors support internal CCIS research. Laing, a major contractor, supports information technologies and technical research at an annual level of US\$480,000 in small, near-market projects. Thames Water funds US\$11 million of research annually; that amount is about 0.7 percent of sales.

Limited R&D support comes from professional organizations. The ICE raises from its members US\$160,000 annually for research initiation grants, each of about US\$8,000 in magnitude, and publishes a newsletter "Research Focus" to inform practitioners of research results. The ISE provides abstracts of research results specially formatted to meet the needs of practicing engineers. The Construction Industry Council raises annually US\$400,000 for research policy studies. For example, its recent report *Crossing Boundaries* [CIC, 1993] calls for major changes in education—more demand-driven for engineering and more systematic for architecture.

These organizations are considering advocating a levy on construction payrolls, in the range of 0.8 percent to 1.5 percent, to fund industry research. The government is only likely to support such a levy if it has the backing of parties affected.

***The task force team found
that U.K. manufacturing
and construction
enterprises are
enthusiastic participants in
collaborative efforts.***

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

The task force team found that U.K. manufacturing and construction enterprises are enthusiastic participants in collaborative efforts. Examples include the collaboration of five U.K. and five French contractors in advancing construction technology for the Channel Tunnel Project, and the joint support of Thames Water, equipment manufacturers, and a tunneling contractor for the development of advanced tunneling machines for the London Ring Water Main. In addition, British firms are taking advantage of EC research initiatives, which they are using to leverage their own limited investments.

Academia plays a strong role in these collaborations to advance and implement new CCIS technologies. Academic researchers work closely with practitioners, helping prepare for the actual implementation of new technologies in the field.

SERC's Teaching Company Scheme provides half the salary and academic support costs for recent university engineering graduates or scientists to work for industry on implementing advanced technologies, while in many instances simultaneously gaining advanced degrees. For all industries, about 400 of these partnerships are active at a time. British industry and professional organizations generally provide substantial and sustained political and intellectual support for research in industry, universities, and government laboratories. Strong public demand for improved infrastructure and environmental quality, desire to reclaim land contaminated in earlier industrial development, and perceived needs to meet international competition, within the EC and worldwide, are apparent forces driving CCIS R&D. British government and industry are working to adopt high performance standards for CCIS, incorporating principles of Total Quality Management and ISO 9000 quality procedures.

3. CCIS R&D AND TECHNOLOGY TRENDS

Few new cutting-edge technologies were encountered in the U.K. However, the overall level of new technology applications is high. Computer-aided design is actively used, and integrated information systems make project data readily available in design, construction, and facilities operation and maintenance



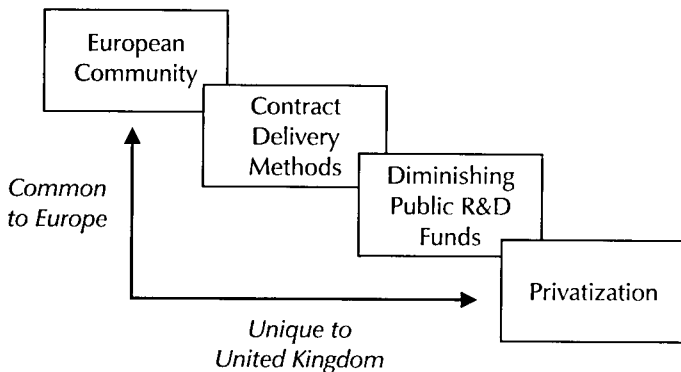
activities. Geographical information systems, geographical positioning systems, and site positioning systems have all been introduced into practice and are currently being used. Advanced tunneling procedures and high-performance concrete have been used both in the Channel Tunnel and the London Ring Water Main. The U.K. is also active in developing “green” technologies, including energy efficient and “healthy” buildings and use of solid wastes as construction materials.

As to be expected, some CCIS in the U.K. are configured for the type of conditions normally encountered in that nation, and may not be directly applicable to prevailing conditions elsewhere in Europe or the world. For example, during the task force team’s visit, unusually warm weather kept daytime temperatures in the mid-80 degree Fahrenheit range. Two major highways and at least one heavily-used commuter rail line were disrupted by heat-induced pavement buckling and track warpage.

3.1 R&D DRIVERS AND ACTIVITIES

In the U.K., construction is experiencing many of the same impacts as in other western European countries. Figure A-3 shows that impending EC unification, new contract delivery methods, and (to a lesser extent) shrinking public R&D funds are significant factors affecting R&D activities in many of the European countries visited. The same figure shows that privatization is an R&D driver producing some effects as yet unique to the U.K. While privatization is a trend in many nations, nowhere has it progressed more than in the U.K.

FIGURE A-3
CCIS R&D Drivers—United Kingdom



European Community

The EC standards and codes will continue to dictate where the U.K. concentrates its R&D efforts for the immediate future. Currently, the environment and transportation activities need the greatest support to meet EC requirements. In particular, innovative methods will be needed for solid waste disposal to meet EC directive procedures.

Contract Delivery Methods

The EC is promoting performance-based specifications, and British contractors are leading the response. Contractors want the freedom to innovate as a means to increase productivity and compete with international companies.

Diminishing Public R&D Funds

The percentage of construction R&D funds provided by government is decreasing as private industry is encouraged by EC directives to sponsor its own R&D. It is anticipated that funding for applied and strategic studies will benefit, probably at the expense of basic research. Life cycle costing of CCIS facilities is being integrated into project design, and this will stimulate more efficient operation and maintenance.

Privatization

As discussed previously, infrastructure services in the U.K. are increasingly being removed from direct government control and placed into private hands. Thames Water and Eurotunnel are both private, for-profit organizations. It was observed that several traditionally public organizations, now converted over to private enterprises, were catching the entrepreneurial spirit and may soon become international competitors.

3.2 CONSTRUCTION MATERIALS

Construction materials research, particularly in the Building Research Establishment and university laboratories, is addressing the durability of high alumina cement concretes in buildings, fiber reinforcements for concrete, and rheology of fresh concrete to aid placement. By U.S. standards, high-performance construction materials have already entered the U.K. marketplace [DoE, 1993].

The Channel Tunnel and the London Ring Water Main Tunnel have both utilized durable 150-year service life concrete. Concrete mixes with 90-day compressive strengths of 70–100 MPa were used in the Channel Tunnel. Pipe relining technologies, such as polymer linings, are being implemented for renovating water and sewer pipes. However, team members were not told of any technique, short of digging out, for making connections to renovated pipe.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

British contractors are incorporating advanced project information systems into their construction practices. There is substantial and growing use of global positioning systems (GPS) and geographical information systems (GIS), as well as integrated project information systems (IPIS).

As in the United States, a variety of private and public databases exist in the U.K. on CCIS technologies, and provide an important source of critically assessed information. The National Building Specification Services Ltd. and the Royal Institute of British Architects Services Ltd. are also working to develop a Specifications Manager and an Annotation Manager which link computer-aided design (CAD) drawings with specification documents, encompassing fully the texts of British Standards manuals held on CD-ROM; this system is similar to one being supported in the U.S. by the National Institute of Building Sciences.

U.K. designers, contractors, and manufacturers are supportive of government policies promoting performance standards. For example, performance standards are used in Scottish highway procurements. The British Board of Agrément (BBA) is the national authority providing the mechanism for evaluating innovations for compliance with performance standards. The European Community recognizes the BBA as the U.K. authority for Technical Approvals.

Design and construction processes, such as computer integrated construction, are receiving increasing attention in the Department of the Environment's research program. Studies of life cycle benefits and costs, including values of quality and costs of failures, are developing information needed for life cycle design.

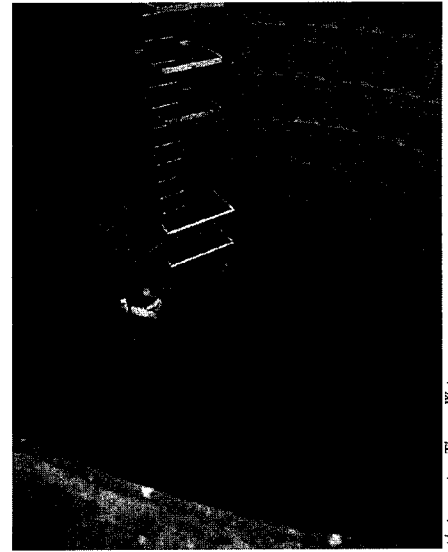


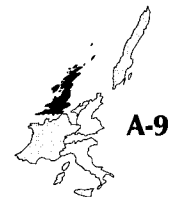
photo courtesy Thames Water

The London Water Ring Main is a privatized CCIS project due to be completed in 1996.



photo courtesy Que Amp & Partners

Demonstration project testing viability of a solar curing shed in concrete block manufacture.



As mentioned above, advanced computer-based technologies such as GPS, GIS, and IPIS are in use in the U.K. Such systems have been applied to placement of steel frame elements in large structures. Logistics management techniques developed for the Channel Tunnel project have also been employed successfully in the London Ring Main and other projects.

Several contractors are implementing the fiber optics sensing technologies from Germany into real projects. Innovative precasting techniques were utilized on the Channel Tunnel to meet strict tolerances ($\pm 0.1\text{mm}$).

Some innovative equipment was observed in the laboratories of the Laing Technology Group. A Hall Effect strain measuring device was being used for soil studies, and the use of automatic data logging had substantially increased the efficiency of their laboratory work.

Remedial technologies for contaminated land are important research topics in the U.K. because of its population density and long history of urban development and industrialization. Photogrammetric techniques are being developed for documenting details for historical renovation projects and for decontamination projects. CERF team members were told of large area reclamations controlled with great accuracy via these photogrammetric techniques.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

The British approach construction as a manufacturing process. While team members did not visit any major construction sites other than the Channel Tunnel, their general impression from presentations and discussions was that the levels of technology in the U.S. and the U.K. were comparable.

Nonlinear and chaotic structural dynamics are being studied at University College, London, with applications anticipated for control of vehicles. Optical fiber strain measurement techniques for monitoring bridges are under development by Laing.

Advanced finite element modeling (FEM) techniques have been developed by Imperial College and applied to control damage to London structures as a result of tunneling. Imperial College has also developed rational damage classification measures for foundation settlements.

The building construction and systems industry is participating in the LINK initiative (Section. 4.1), with a major program on construction maintenance and refurbishment. Over 50 industrial participants are working with 14 science partners on 10 projects in the program's first phase. The total program cost, including government and industry contributions, is estimated at US\$10 million from 1988-95, and has as its main objective the development of commercially valuable technologies. Topics being studied include:

- Whole life cost of buildings and building services
- Concrete durability
- Design guides for structural and non-structural building elements
- Services to improve the environment in existing buildings
- Optimization of initial and maintenance expenditures
- Techniques for improving and extending the life of existing building
- Design, management, and training needs for cost-effective maintenance

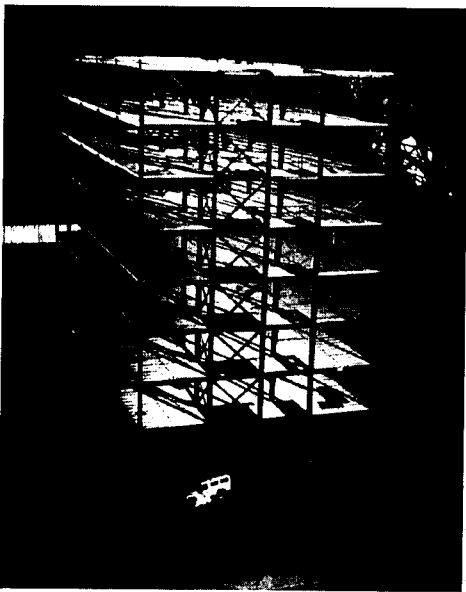


Photo: Building Research Establishment UK. Crown copyright

The eight-story, steel-framed experimental building nearing completion in BRE's Cardington Large Building Test Facility.

The Construction Industry Council has requested studies of the performance of buildings as systems. The Building Research Establishment established in March 1993 a full-scale building test facility to support such investigations (photo, opposite page). The Cardington Large Building Test Facility has a 70m by 50m by 1.25m strong floor that can take full-scale experimental structures up to 40m high. It provides unique experimental facilities for assessing or calibrating design methods, and for testing or demonstrating new ideas, materials, and construction methods. Initially, an eight-story steel frame with composite metal deck floors satisfying Eurocode requirements will be studied for static, dynamic, fire, and explosion loading.

3.5 HIGHWAY AND RAIL SYSTEMS

Underground transportation technologies are being developed to relieve congestion in urban areas. Rapid repair methods have been developed to streamline the monumental task of maintaining roads.

Much attention is being given to improving both automotive and public transportation. For example, Imperial College is leading a feasibility study, with participation by industry, of underground urban roads. Home employment and telecommunications were mentioned as alternatives to people transportation, but, as in the U.S., such alternatives do not yet appear to affect transportation demands significantly.

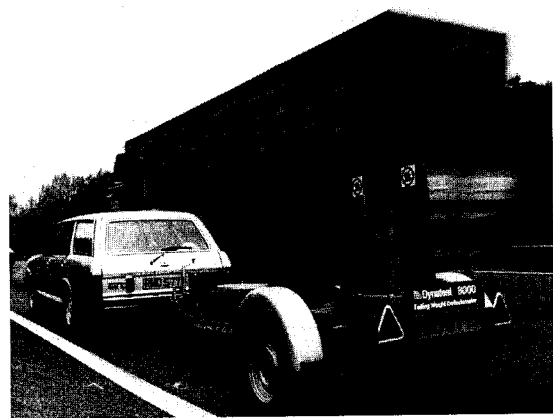
A number of technological advances were implemented for the Channel Tunnel. Well-controlled factory fabrication yielded concrete tunnel lining segments meeting very stringent tolerances (0.1mm). Each segment was permanently identified by a serial number to allow tracing for any performance problems. Major studies were conducted of the safety and capacity of tunnel ventilation systems, and novel, automated inter-model transfer systems combining rail and highway traffic were implemented at Tunnel ends.

Savings are being achieved by utilizing highway management information systems with a common database. The HERMIS Management System combines inventory inquiries, routine maintenance management, general maintenance budgets, pavement management, graphics, and network studies.

The Department of Transport (DoT) is the principal authority for tunnel roads and highways. DoT conducts research in its own laboratories, and sponsors research in other laboratories. This research is related to: 1) policies for highways, road safety, public transport, marine and aviation safety; 2) its statutory duties related to standards and safety; and 3) purchasing decisions. About half of DoT's R&D deals with highways.

DoT spends about \$45 million annually on highway research. Projects include:

- Trials of safety engineering measures
- Road pricing
- Parking strategies for congested urban areas
- Composite plastic materials for bridges
- Reuse of materials, principally in sub-bases



TRL's advanced condition survey equipment can perform all types of pavement assessment, from analysis of skid resistance to detailed investigations of structural problems in bituminous and concrete pavements.

photo courtesy Transport Research Laboratory



- Noise barriers and quiet pavements
- Long-life pavements
- Rapid curing concrete for repairs
- Geotextiles
- Slope stability
- Upgrading bridge structures
- Contracting process—design/build to bring construction considerations into design
- Education and other measures to improve the safety of young and inexperienced drivers
- Safety features in vehicle design

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

The Channel Tunnel was the test bed for many improvements in boring technologies. Advanced rock tunneling machines were developed for the Channel Tunnel and London Water Ring Main. Thames Water reported that the Canadian manufacturer and the U.K. contractor of the boring machines for the London Ring Water Main developed and implemented those machines in less than one year.

High-performance clay pipes are being tested as an alternative to PVC and iron. The “no dig” and microtunneling technologies used on water network repair/replacement are advanced. The combined sewers are state of the art.

Recycling requirements have not yet been mandated in the U.K. Currently, solid wastes are simply shipped to other countries. However, forthcoming EC codes will make it necessary to devise innovative reuse and disposal procedures. The only recycling observed was the use of waste materials, such as fly ash, in concrete.

3.7 WATER AND SEWAGE SYSTEMS

In the U.K. a primary emphasis is on improving centralized systems for water supply and sewage treatment. While the Water Research Centre and Thames Water showed awareness of concepts for on-site water supply and waste disposal, they gave no indication that they were exploring such concepts. Combined waste water and storm water sewers are customary in the U.K., and there are no strong efforts to eliminate such combined sewers. Fortunately, torrential rains that overload the sewage system are relatively uncommon in the U.K..

Discussions with the Thames Water and the Water Research Centre indicated that major research interests include:

- Impact of absolute standards on water quality and treatment practices
- Advanced membrane technologies to avoid side effects of chemical water treatment
- Process engineering, point of use treatment and new biological treatments for water and waste water
- Water quality measurements
- Odor reduction from sewage treatment
- Toxicology of water treatment

Water Research Centre applications of Total Quality Management (TQM) were cited as the motivation behind the development of a statistical approach to operations and diagnoses of water and sewage systems.

Additionally, “no dig” microtunneling technologies for water and sewer piping are being applied in the U.K., and sewers are being used as conduits for information utilities, such as optical fibers.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

4.1 ROLE OF GOVERNMENT

As described previously, British government classifies research in four categories: *basic*, *strategic*, *applied*, and *experimental development*. British strategies for CCIS innovation include efforts in all four areas, as well as in moving research results beyond these four stages into practice.

The government white paper referred to earlier [HMSO, 1993] was aimed at resolving “the widely perceived contrast between our excellence in science and technology and our relative weakness in exploiting them to economic advantage.” The paper stated several general principles for shaping government support of industrially-oriented R&D:

- The government accepts its role as the main funder of basic research. However, there is a limit to the amount affordable. Research Councils are to support research in appropriate places only—universities, research institutes, and private laboratories. That policy is expected to reduce funding for basic research and benefit strategic and applied research.
- Collaborative research between universities or research institutes and industry is encouraged by providing cost-sharing for research with industry.
- The Science and Engineering Research Council (SERC), which was reconstituted in April 1994 as the Engineering and Physical Sciences Research Council (EPSRC), supports construction-related research.
- The 1972 Rothschild policy is reaffirmed. This policy calls for government laboratories to be supported by paying customers. The private sector Construction Industry Council, however, has cautioned that this policy has led government laboratories to focus their programs on the needs of paying government agencies and neglect the needs of private sector customers, such as architects, engineers, and contractors, that cannot pay for laboratory programs.
- A “Forward Look” (planning) aimed at realizing the potential of technologies resulting from government-supported research.
- The Department of Trade and Industry is to establish “one-stop shops” for delivery of R&D and technology services, particularly to smaller firms. These are similar to the Manufacturing Technology Centers currently promoted by the U.S. Department of Commerce.

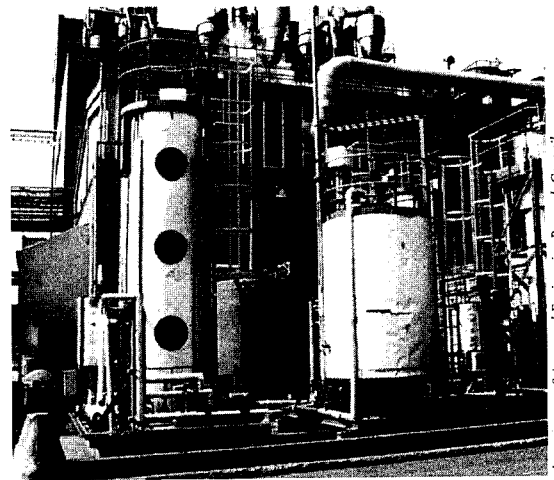
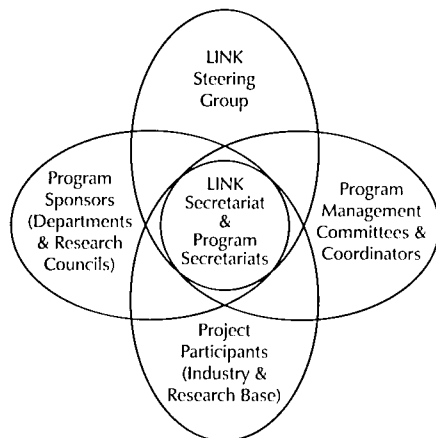


photo courtesy Science and Engineering Research Council

This pilot-scale anaerobic waste treatment plant was developed by five universities and an industrial partner, with funding from SERC, for on-site biological treatment of polluted effluent by industry.

FIGURE A-4
The LINK Partnership



The task force members concluded that the U.K. government's efforts on CCIS research were focused mainly on strategic research. The LINK initiative (Figure A-4) is an ongoing government program supporting collaborative research between industry and academia to enable and accelerate commercial exploitation of science and technology. From its start in 1988 through the end of 1991, thirty programs with a value in excess of \$420 million had been announced. LINK Programs related to CCIS have received funding totaling \$115 million thus far. The LINK program on facility maintenance and refurbishment, for example, has more than 50 industrial participants working with 14 science partners on ten first-phase projects targeting the following:

- Advancing building services
- Concrete durability
- Design guides for structural and non-structural building elements
- Design and operation of services to improve the environment in existing buildings
- Optimization of initial and maintenance expenditures
- Techniques for improving and extending the life of existing buildings
- Design, management, and training needs for cost-effective maintenance and refurbishment

The total cost for this one LINK program, including government and industry contributions, is estimated at US\$10 million from 1988-95.

U.K. construction contract delivery systems were not extensively discussed. Members were told that design/build and build/operate/transfer procurements are finding favor as means to integrate the design and construction team, focus their attention on downstream performance, and reduce the duration of construction.

4.2 ROLE OF INDUSTRY

Industrial organizations are valuable transferrers of technology. Memberships in the various CCIS-related professional societies, such as the Institutions of Civil and Structural Engineers, far outstrip memberships in the American Society of Civil Engineers (ASCE) in the U.S. on a per capita basis, and have a worldwide orientation. These societies serve to unite the many voices of civil engineers and focus research resources.

Private companies in the U.K. seek to exploit technologies for their own commercial advantage. They are careful to screen and prioritize research for profitability and risks. The industry uses technological advancements as a basis, other than price, on which to compete. This attitude has resulted in industry promoting performance standards and specifications in CCIS contracts. Further, private companies supply full-time personnel to lead R&D projects at universities. With such industry involvement, applied research is strong in the U.K..

4.3 ROLE OF ACADEMIA

British academicians subscribe to a teaching philosophy similar to Americans. Scientific principles and systematic problem-solving techniques are taught at the expense of professional practices.

University research funding originates from two public sources: the Higher Education Funding Council for England (HEFCE) and SERC. The former supplies general support according to a ranking system based on past research excellence and activity. The latter extends funds to individual researchers and projects.

Academic researchers are at present the primary agents for basic research. The HEFCE is revising how it distributes funds for research to seek enhanced effectiveness. University departments are being ranked in classes 1 through 5 to indicate competence in research, and funding is adjusted accordingly. Class 1 receives no funding. These research funds are particularly prized because they support investigator-initiated research.

The Civil Engineering Department at the University College of London noted that the U.K. is turning away well-qualified citizens from Ph.D. programs for lack of funding support. This contrasts with the shortage of U.S. citizens interested in postgraduate CCIS engineering education and research.

While academic commitment to basic research and teaching of fundamental principles remains strong, team members meeting with civil engineering departments at University College London and Imperial College found strong commitments to close working relations in research with industry. "Needs-driven" engineering education has been found effective in giving undergraduates motivation and a context for learning. In contrast, graduate education is moving toward a program of formal courses, rather than needs-driven self-study and consultations with tutors. Changes may arise in departmental boundaries, for instance, as civil and mechanical engineering build on their common interests in solid mechanics and structures.

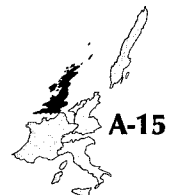
Academia assists in technology transfer to industry through cooperative R&D. LINK projects and SERC's Teaching Company scheme support strong collaborations between industry and academia. Representatives from both industry and academia told the team that technology transfer from university research to practice is effective for CCIS technologies because of long-term cooperative relations and mutual direct involvement in research. The actual construction site is an important laboratory for academic CCIS research in the U.K. However, British researchers noted that technology transfer from academia is less effective for the building segment than the civil engineering segments, primarily because the building industry is less interested in technology and less knowledgeable.

4.4 FINANCIAL INCENTIVES

A central tenet of the U.K. government's economic and technology strategy has been privatization of government industries and agency functions. Privatization is seen as a means to make the U.K.'s R&D establishment more responsive to the marketplace and industry's needs. This strategy appears to be working.

For example, since its privatization, the Water Research Center (WRc) has become an internationally-competitive, high-technology consulting organization and private laboratory. However, university researchers noted that WRc no longer is able to undertake fundamental studies and is less helpful in responding to general scientific and technical requests for information. Architects and engineers in consulting and construction practice also noted that the Building Research Establishment (BRE), slated for privatization, will need to become more responsive

***The actual construction site
is an important laboratory
for academic CCIS
research in the U.K.***



Privatization, uses of performance standards, conformity assessment practices for acceptance of innovations, and research collaborations of government, industry and academia are examples of EC models used in U.K. practice.

to the needs of private industry. Practitioners and researchers expressed concern that BRE's privatization may yield an increase in high-technology engineering services that are already available from laboratories of major construction firms. This could result in reductions in forward-thinking fundamental and strategic research, and in services to small and medium-sized consulting and construction firms that cannot pay for applied research services.

For industry-based CCIS R&D, there was an almost exclusive emphasis on problem solving and immediate application of new findings to practice. Examples presented to the team included technology to increase the durability of oil platform structures in the North Sea, analysis methods that reduce design uncertainty and steel requirements for foundation retaining walls, and applications of advanced bridge design methods to building frame analysis. The exceptions to this problem-solving emphasis were cases in which firms found it advantageous to draw on cooperative EC-funded strategic research initiatives.

5. RESPONSE TO EUROPEAN COMMUNITY

The U.K. CCIS community appears to support the European Single Market. However, firms seem to believe that competitors from other EC countries will find it difficult to enter the U.K. market.

British CCIS leaders are active in European standardization, and U.K. policies are implementing EC directives. Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations of government, industry, and academia are all examples of EC models currently used in the U.K.

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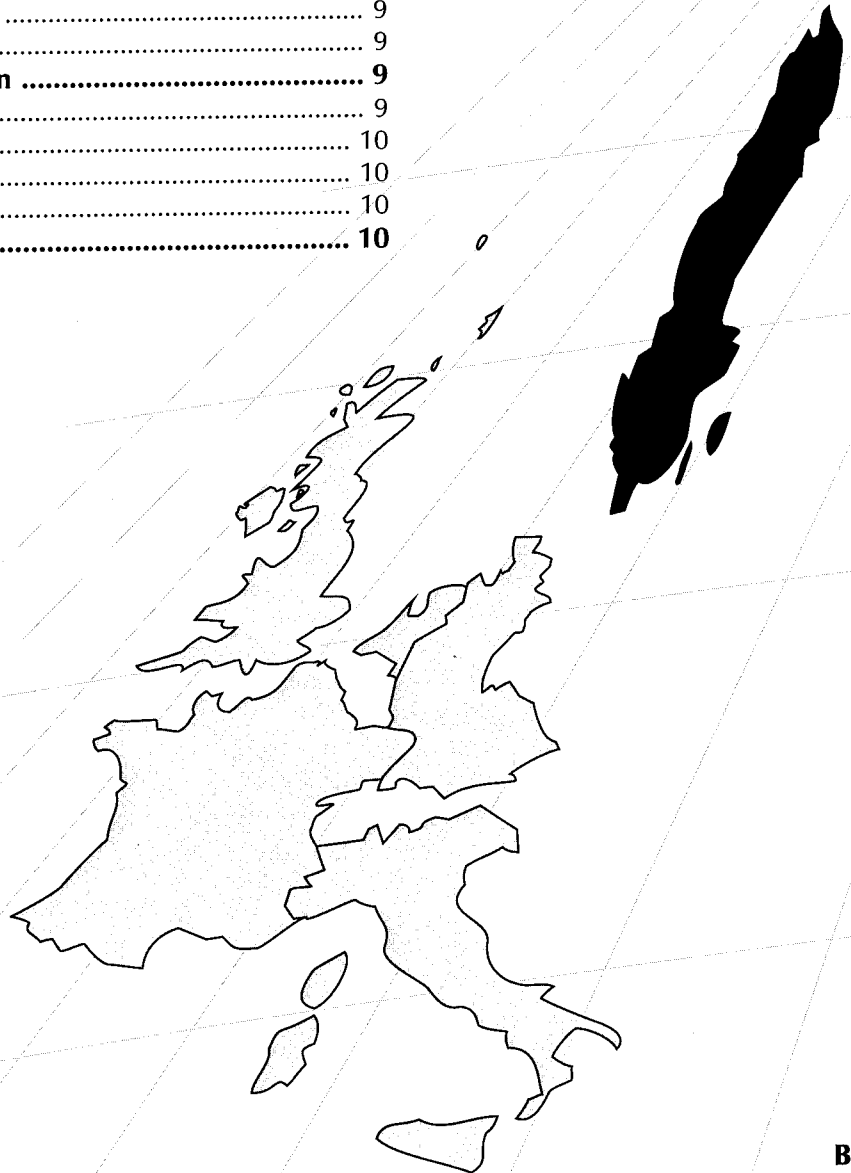
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Appendix B

SWEDEN

1. Summary	3
2. Context for CCIS Technology	3
2.1 Historical Perspective	3
2.2 Economic, Regulatory, and Cultural Environments	3
2.3 Legal and Competitive Environments	4
2.4 R&D and Technology Innovation Policies	5
2.5 Private Sector Technology Partnerships	5
3. CCIS R&D and Technology Trends	5
3.1 R&D Drivers and Activities	6
3.2 Construction Materials	7
3.3 Computer-Aided Design, Automation, and Information Systems	7
3.4 Building and Construction Systems	8
3.5 Highway and Rail Systems	8
3.6 Environmental and Geotechnical Systems	9
3.7 Water and Sewage Systems	9
4. Strategies for Innovation Implementation	9
4.1 Role of Government	9
4.2 Role of Industry	10
4.3 Role of Academia	10
4.4 Financial Incentives	10
5. Response to European Community	10



Appendix B

SWEDEN

1. SUMMARY

Sweden seeks to expand its firms' CCIS markets in Europe and, while not yet a member of the EC, participates in the EC's CCIS forums and anticipates entry to the group. Infrastructure that can enhance trade opportunities with western Europe has high priority for investment and new technology development. This priority is reflected in a variety of current activities aimed at improving Swedish rail and highway networks, ranging from large-scale transportation network investments to enhancement of materials performance. The closely-allied public and private sectors invest heavily in environmental technologies, such as to address problems evident in the acid-rain damage to the nation's forests. Strong environmental values also foster opportunities for enhancing resource utilization efficiency and waste reduction.

Task force teams visiting Sweden were based in the nation's capital, Stockholm, but teams also visited CCIS facilities in other cities. Table B-1 lists participating government agencies, private organizations, and academic institutions in Sweden.

Infrastructure that can enhance trade opportunities with western Europe has high priority for investment and new technology development, as reflected in current activities aimed at improving Swedish rail and highway networks.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 HISTORICAL PERSPECTIVE

The 8.6 million inhabitants of Sweden occupy an area of about 411,000 km², similar in size to the state of California, with settlement concentrated primarily in a few urban centers. Much of the nation experiences a sub-Arctic climate, although the southern part of the country is more moderate, with conditions comparable to those encountered in Minnesota. Climate, terrain that becomes rough in the country's western portions, and physical separation from the mainland of Europe are decisive factors shaping Sweden's CCIS investment and technology interests.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

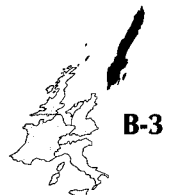
Sweden is an industrialized nation with a relatively high standard of living. An historically strong commitment to social welfare is reflected in an extensive social services system and government spending that has accounted for as much as half of the nation's gross national product (GNP). Changes in government and an extended period of economic recession underlie a current policy emphasis on private-sector development.

TABLE B-1

Participating Organizations—Sweden

Organization*	Identifier	Type
NCC BYGG AB		private contractor
Royal Institute of Technology	BFR	university
Royal Swedish Academy of Engineering Sciences	IVA	private science institute
Skanska Teknik		private consultant
Swedish Council For Building Research		government research
Swedish Geotechnical Institute	SGI	government agency
Swedish National Rail Administration	Banverket	government agency
Swedish National Road Administration	Vagverket	government agency
Swedish Road and Traffic Research Institute	VTI	government research agency

* English translation of organization name provided, where available.



Along with other Scandinavian countries in the European Free Trade Association (EFTA), Sweden aggressively pursues selected export markets as a means of maintaining national income with a small domestic market. Sweden's long-standing international reputation for high technical specialization, advanced design and management methods, and high quality product, combined with the opportunities of a single European market and demands for reconstruction of eastern Europe, are expected to provide strong international markets for Sweden's construction industry. The government expresses keen interest in the European Community (EC) and has applied for membership.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

In 1990, Sweden's total construction volume amounted to US\$30 billion and the industry employed some 600,000 people. Recessionary declines are expected to have reduced total volume by 25 percent by 1993 and employment by some 100,000 jobs. Residential and commercial construction demand have declined and construction firms report that funds are not readily available to support construction of planned CCIS projects. The larger contractors have turned to Asia and South America to support themselves. The domestic industry is, on the whole, made up of predominantly small companies.

Nevertheless, construction is viewed as an important sector of the nation's economy, and CCIS is viewed as an export market, as well as supporting all economic activity. The Swedish Building and Energy Export Agency has a budget of US\$60 million and supports 175 people abroad to market construction products and services. Swedish firms offer manufactured housing in the United States, and have established at least one manufacturing facility in this country (in Oregon).

Investments are being made to serve Sweden's own needs as well. The most substantial of these investments are the US\$2 billion Stockholm Ring Road project "Ringen," the US\$1 billion annual investment in upgrading the Swedish railroads, and a grand connecting bridge between Sweden, Denmark, and the European mainland. To avoid shortages in the CCIS work force, efforts are underway by the Swedish National Highway Administration to promote education of engineers and to recruit women into the field.

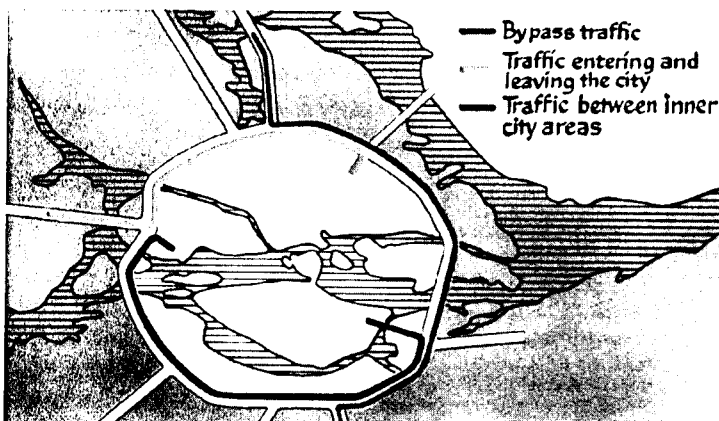
Following the trend in other Swedish public sector enterprise, CCIS and related research services are being spun off through privatization. The Swedish National Rail Administration has been reorganized as a quasi-governmental enterprise responsible for the capital system, while a separate enterprise provides transport services. Both activities are slated for full privatization. The functions of the Swedish Institute for Building Research, formerly a governmental operation, have been assigned to the Royal Institute of Technology and Uppsala University. Privatization is foreseen for the Swedish Road and Traffic Research Institute (VTI).

Labor is an active participant in privatization activities as well as a strong proponent of R&D as a means for enhancing export competitiveness. The Development Fund of the Swedish Construction Industry, created in part at labor's request, is supported by a three-cent-per-



artwork courtesy Stockholmstads AB

The Stockholm Ring Road, "Ringen," is intended to improve the environment and increase accessibility within the Stockholm region. Above: more than half of the Ringen will consist of underground tunnels, such as the one depicted in this model. Below: the road's three major subsections.



hour levy on construction employment payrolls that yields US\$6 million annually for research. Figure B-1 shows the relative distribution of research funding from this Development Fund to materials producers, constructors, universities, and private consultants.

Professional organizations such as the Royal Swedish Academy of Engineering Sciences and the Swedish Society of Civil and Structural Engineers, as well as major private organizations such as engineering constructors Skanska and NCC, seem actively involved in the government's CCIS policy decisions.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

The Swedish government supplies 37 percent of the nation's total R&D spending. Much of this spending goes to the universities, research councils, and sectorial agencies.

The government directly funds construction-related research through the Swedish Council for Building Research (BFR), within the Ministry of Industry and Commerce, at an annual rate of US\$35 million. Local governments, industry, and research institutes also contribute to the BFR budget. Figure B-2 shows the relative distribution of BFR R&D funds to various research performers.

BFR is reported to be formulating an infrastructure research strategy. Research priorities include infrastructure, information technologies, materials durability and advanced performance, buildings and infrastructure management, "healthy" building design and operations, and new energy sources and efficiency.

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

The Swedish National Board for Industrial and Technical Development (NUTEK) provides matching funding for industry research. NUTEK has an annual budget of US\$700 million, distributed among academia (51 percent), research institutes (25 percent), and industry (24 percent), to fund technical research and development, materials research, energy research, and bio-engineering research.

Construction company researchers may apply for grants from the Development Fund of the Swedish Construction Industry. Studies supported by this fund have included use of heated concrete for cold weather placement, measurement of quality failure costs, and development of methods for reducing construction project duration. Task force members were told that Swedish contractors' R&D spending averages 1.6 percent of annual revenue, and that Skanska, the nation's second largest construction firm, is increasing research spending despite company-wide financial losses. Swedish firms are reported also to assign staff to work directly on R&D within universities or government laboratories.

3. CCIS R&D AND TECHNOLOGY TRENDS

The task force team observed several factors that appear to be driving Swedish CCIS R&D and new technology applications. The already advanced level of technology application in Swedish CCIS practice seems likely to continue

FIGURE B-1
Performers of Swedish Industry Development Fund-sponsored R&D

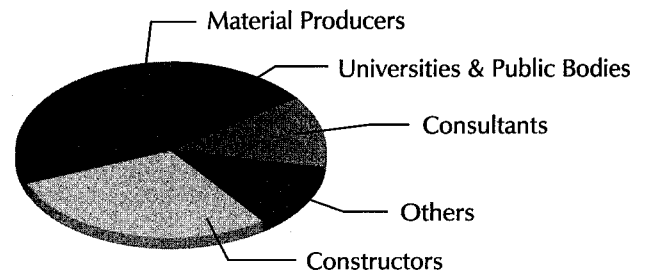
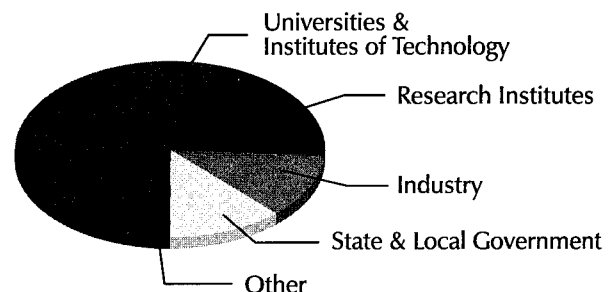


FIGURE B-2
Recipients of BFR R&D Funding

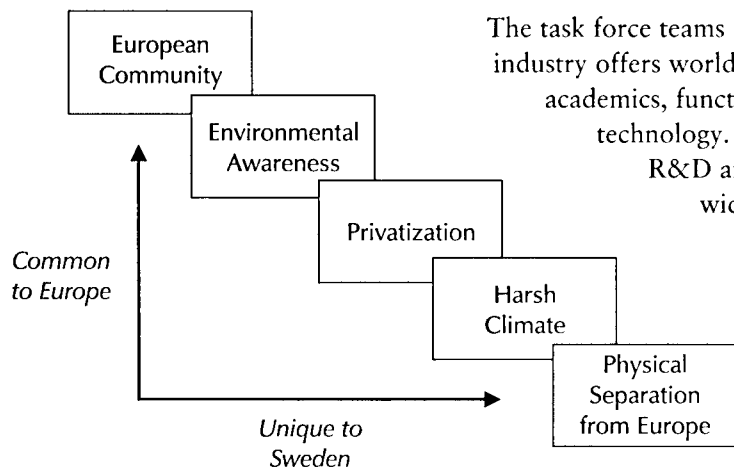


advancing, due in part to a willingness of CCIS owners and providers to test promising new technology in field applications. While liability is a concern in Sweden, the concern and related litigation appear to present few barriers to innovation. Task force team members observed an attitude of cooperative assumption of risk among owners, designers, constructors and manufacturers, backed by insurance and warranty programs to protect firms willing to undertake well-founded innovation.

FIGURE B-3

CCIS R&D Drivers—Sweden

3.1 R&D DRIVERS AND ACTIVITIES



The task force teams found that despite the nation’s modest size, the Swedish CCIS industry offers world class technology, management capability, professionals and academics, functioning at or close to the leading edge in many areas of CCIS technology. As illustrated in Figure B-3, aggressive programs to foster R&D and applications of new technology are being driven by widespread concern for environmental quality, the shift towards privatization of CCIS institutions, the nation’s remote location and harsh climate, and the progress of EC formation and European unification. The task force teams found major efforts under way to improve railway systems, road durability and maintenance, energy efficiency of buildings and urban districts, and other aspects of Sweden’s CCIS.

European Community

The major firms in Sweden’s CCIS industry seek access to the EC market. These firms and government agencies are undertaking to influence and meet EC standards, and to participate in the EC’s multinational R&D programs.

Environmental Awareness

Environmental concerns are, for the most part, integrated into a new facility’s overall design, but the search continues for “green” technologies such as low-waste construction and operations, and recycling. Cleaning up and building on contaminated land is receiving more attention as well. These environmental technologies are finding ready international markets.

Alternative sources for power generation is another area receiving substantial attention. Sweden’s nuclear power plants are to be phased out within the coming two decades, and must be replaced 20 years by other technology viewed as environmentally more benign.

Privatization

Swedish CCIS activities are being privatized to meet EC recommendations and to improve their effectiveness. The Swedish Institute for Building Research was privatized, purportedly to improve its relationship with industry, and the Swedish Road and Traffic Research Institute (VTI) is also preparing for open market operations. The Stockholm Ring Road project, a major undertaking involving substantial tunnelling and likely new ventilation, signage, and guidance technology, is to be financed and operated through private sources. Increasing use of performance specifications and warranted work in public sector projects will effectively shift management responsibility to private contractors.

Harsh Climate

The harsh climate affecting most of the nation influences Swedish CCIS and R&D priorities. Current related efforts include research on higher performance materials, ways to minimize frost heave and low temperature cracking in highway pavements, and improved energy efficiency at all stages of the facility life cycle.

Physical Separation from Europe

Sweden seeks to enhance its transport efficiency by reducing the time and cost of transporting goods across the 1,800-kilometer overland distance that separates it from the other European countries. Railways are being upgraded to accommodate higher-speed operations, and pavements are being monitored to maintain driving quality. R&D studies are being conducted to support these efforts, and the proposed bridge linking Sweden to Denmark and the European mainland is likely to be a significant test bed for new technology.

Sweden seeks to enhance its transport efficiency by reducing the time and cost of transporting goods across the 1,800-kilometer overland distance that separates it from the other European countries.

3.2 CONSTRUCTION MATERIALS

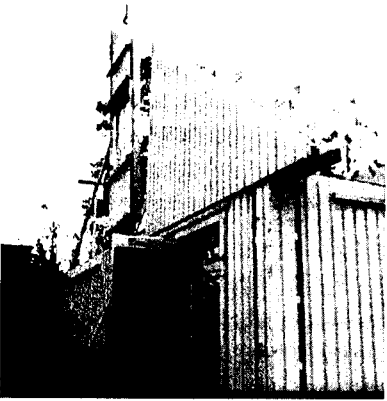
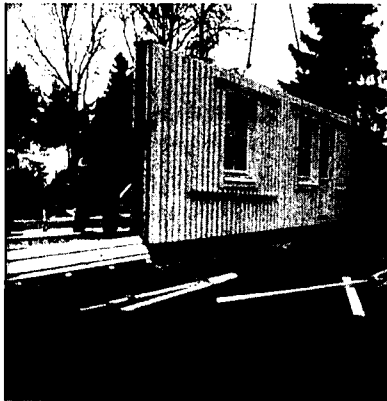
A very large fraction of road mileage in Sweden is paved with asphalt concrete, reportedly because researchers have concluded asphalt is less susceptible to frost heave than Portland cement concrete pavements. Asphalt mix designs further enhance the material's generally desirable characteristics. Stone-mastic asphalt pavements are being constructed for their high durability, and research is also being done on noise attenuation and wearing characteristics of porous-surface pavements. A six-year, US\$10 million program on high-performance concrete is being sponsored by the Swedish Cement and Concrete Institute, NUTEK, SIB, and Skanska, with 18 projects focusing on microstructure and physical properties, mix rheology and placement techniques, fiber reinforcement, and fly ash utilization. Fifty-five percent of funding comes from industry, and 45 percent from government. Use of hot concrete for cold weather placement and curing, and uses of fly ash and bottom ash wastes in concrete, are other areas of research receiving substantial attention.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

Computer-aided design is widely used, and integrated project information systems make project information readily available to participants in design, construction and facilities operation and maintenance. The Swedish National Road Administration has developed and implemented a user-friendly, computer-aided highway design system that appears to have wide acceptance. The task force teams were told that geographical information systems (GIS), geographical positioning systems (GPS), and automatic site positioning technologies have also been introduced into practice and applied on actual construction projects. For example, a GPS method for site layout has been developed, enabling automatic location of points in the field from the electronic project database (e.g., for positioning individual dwellings in a residential development), and is being used to level large concrete floor slabs. Technology also has been developed to locate electrical cables ahead of an excavator.

A US\$1.4 million per year R&D program in information technology in building and property management is supported by the Swedish Council for Building Research (SCBR), the Swedish National Board for Industrial and Technical Development (NUTEK), and the Development Fund of the Swedish Construction





Photos courtesy SWERC/Secodis/ Council for Building Research

Less than fourteen hours after starting with a bare foundation, a crew of four (above) completed the shell and partitions of a 1,400 square foot house and made it weathertight (right).

Industry (SBUF). Topics include simulation of buildings and building services, neutral building product model, interface standards for facility management, knowledge-based systems for professional and nonprofessional users (including elderly apartment dwellers). This program is contributing to STEP, an EC program aimed at developing standards for automated exchange of construction industry product information. Professional interactions are maintained with Stanford University's Center for Integrated Facilities Engineering.

Additional research funded by SBUF considers life cycle benefits and costs including values of quality and costs of failures. Skanska, and probably other major construction firms, has work underway to develop knowledge-based systems to support decisions in CCIS and to improve integrated project information systems. The Swedish Work Environment Fund, the Working Life Fund, SCBR and SBUF have studied "Tight Construction Schedules," addressing methods for calculating optimal construction time, a model for assessing the influence of variables on the construction process, and a dynamic model for construction.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

While Sweden is noted as a leader in building technology and asserts leadership in prefabricated housing, task team members observed little of special note in the Stockholm area, either in high-rise or lower-density dwelling construction.

The Swedish Council for Building Research has long funded building systems and construction studies. In recent years much emphasis has been given to energy efficiency and environmental quality. Swedish healthy-building studies include collaborations of medical and building researchers to provide world leadership in indoor environmental quality. District heating studies provide technical bases for efficient central heating, and central heating plants have been developed using waste heat from power generation and industrial processes.

3.5 HIGHWAY AND RAIL SYSTEMS

The planned Stockholm Ring Road, "Ringen," project provides stimulus for substantial highway systems research. A driving simulator based on air pilot training equipment is used to support geometric and driver information system design. Studies are being made of tunnel safety and ventilation systems, and a "smart card" toll collection system is under development. The Swedish National Road Administration is supporting studies of fast-setting concrete for highway repair, social science research on transportation and urban development and a multimodal transportation system analysis method that includes consideration of home employment and telecommunications as alternatives to transportation.



High-speed surface profiling and pavement stiffness measurement equipment (with abilities to cover 200 km per day) has been developed and used by Swedish

Highways (RST), and ground penetration radar is being investigated. A pavement conditioning monitoring system (for wet or icy pavements and for traffic conditions) is being implemented by the Swedish Highway Administration. The Swedish Highway Administration provides pavement management instruction (in English) for officials of third world countries.

The Swedish railway system has placed in service advanced "tilt" vehicles that maintain passenger comfort at higher operating speeds on existing roadbed. Maintaining catenary contact, controlling track-bed vibration and external noise, and addressing passenger complaints of motion-sickness are among the problems continuing to be researched. Continuous-welded rail and prestressed concrete ties are conventional for Swedish railroads, and an extensive program of railroad upgrading and new development has been undertaken. Swedish Rail uses ISO 9000 for its quality assurance programs.

The Swedish National Rail Authority uses automated equipment for rail and tie replacement. The system appears to be state of the art in a field long employing specialized, mechanized equipment. Research is being conducted, focusing on such topics as rail fatigue, geographical positioning systems for support of construction, operation and maintenance, an information system for right of way facilities, soil properties, routing of oversize or overweight loads and developing a code of practice for railroad bridges.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

Swedish underground construction methods are very advanced, particularly for hard, competent rock. Similarly, environmental protection and remediation practices were judged by team members to be some of the best in the world. Experimentation with ground-storage and extraction of heat is one of the R&D areas that task force team members felt may further advance these practices.

The Swedish lead also in practices for minimizing construction waste and recycling materials.

3.7 WATER AND SEWAGE SYSTEMS

While the task force teams made no significant direct observations, secondary sources available to team members indicate that emphasis continues to be placed on improving centralized systems. The Swedish Council for Building Research reported that environmental quality and waste minimization are major research priorities, with such study topics as on-site water supply and waste treatment facilities, and "supertubes" that serve as conduits for multiple utilities (e.g., water, sewage, gas, electricity, telecommunications).

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

Sweden seemingly relies on a close and active collaboration of all members of the CCIS industry to foster productive R&D activity and innovation. The relatively small size of the country's population and the industry's leadership may strengthen this collaboration's effectiveness.

4.1 ROLE OF GOVERNMENT

Government programs such as NUTEK and the research supported by government agencies provides financial incentives to industry for innovation. NUTEK's



projects, however, appear to emphasize generic technologies and do not provide intellectual property rights to participating industries. Much research is privately supported for improving competitiveness in the marketplace, largely because the use of performance specifications encourages innovation.

4.2 ROLE OF INDUSTRY

Contractors are reported to reinvest an estimated 1.6 percent of turnover into R&D, and the construction industry requested government imposition of a payroll tax of \$0.03/labor-hour, paid into a Development Fund (SBUF) used to support R&D. In addition to this levied Development Fund, industry's R&D also receives additional government support through the Swedish Board for Industrial and Technical Development (NUTEK), which provides matching resources for industry-initiated research on high-priority projects in such areas as materials, energy, and bioenergy. New technology developed with NUTEK support is non-proprietary.

4.3 ROLE OF ACADEMIA

Academic researchers maintain close relationships to practitioners, consider requirements for implementation of research-based new technology, and help prepare practitioners for the implementation. Swedish academic researchers told task force team members that their research is transferred effectively to practice through long-standing professional relationships with practitioners and standards organizations.

Leading Swedish universities have been active in CCIS research and the transfer of research results to practice, but changes occurring in academia make the future less certain to be a continuation of past practices. The Swedish Royal Institute of Technology is condensing eleven faculties to five (in some cases going from one full professor per faculty to several). Architecture, civil engineering and surveying are being combined. The formerly governmental Swedish Building Research Institute at Gavle is being transferred to the Swedish Royal Institute of Technology and to Uppsala University. The two universities' activities at the Gavle site will include teaching and research.

Other technical universities involved with construction R&D are Lulea, University of Gothenburg (Chalmers), and Lund. The majority of their funds come from the government, with only a small percentage coming from industry.

4.4 FINANCIAL INCENTIVES

Private researchers submit proposals for grants from the \$US 6 million collected annually by the SBUF. Companies can use this research money to improve their technology, enabling them to use of superior, more cost-effective solutions that conform with set performance specifications.

5. RESPONSE TO EUROPEAN COMMUNITY

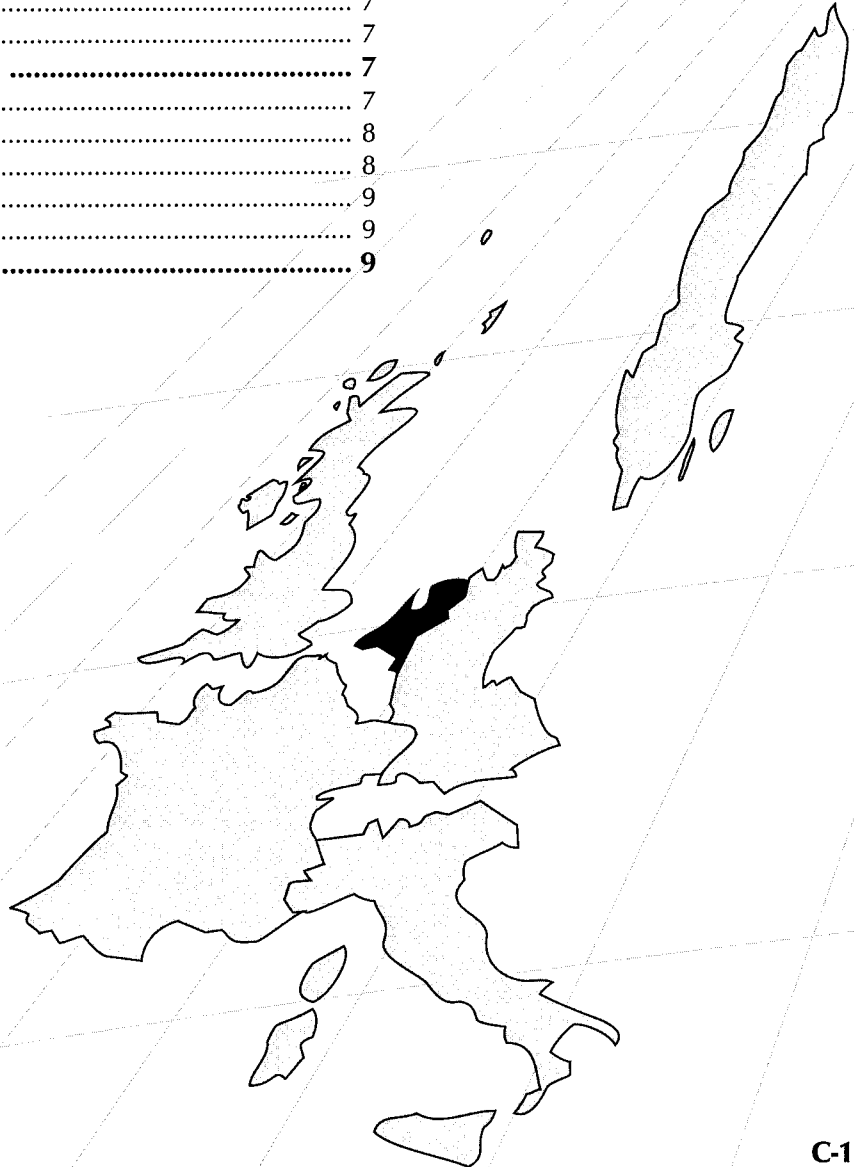
While not yet a member of the EC, Sweden does appear to support the European Single Market concept. Swedish CCIS leaders are active in European standardization and Swedish policies are implementing European Community directives. Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations between government, industry, and academia are examples of EC models in Swedish practice.

Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations between government, industry, and academia are examples of EC models in Swedish practice.

Appendix C

THE NETHERLANDS

1. Summary	3
2. Context for CCIS Technology	3
2.1 Historical Perspective	3
2.2 Economic, Regulatory, and Cultural Environments	4
2.3 Legal and Competitive Environments	4
2.4 R&D and Technology Innovation Policies	4
2.5 Private Sector Technology Partnerships	5
3. CCIS R&D and Technology Trends	5
3.1 R&D Drivers and Activities	5
3.2 Construction Materials	6
3.3 Computer-Aided Design, Automation, and Information Systems	6
3.4 Building and Construction Systems	7
3.5 Highway and Rail Systems	7
3.6 Environmental and Geotechnical Systems	7
3.7 Water and Sewage Systems	7
4. Strategies for Innovation Implementation	7
4.1 Role of Government	7
4.2 Role of Industry	8
4.3 Role of Academia	8
4.4 Financial Incentives	9
4.5 Liability Considerations	9
5. Response to European Community	9



Appendix C

THE NETHERLANDS

1. SUMMARY

The Netherlands' physical characteristics have a great impact on CCIS. Its small size results in several advantages. The dense population means a more compact infrastructure network, and national directives more easily communicated and enacted across the entire country. Its close relations with the sea have also steered construction's direction. Marine-related work such as tunneling, dredging, and storm surge control have all been developed to state-of-the-art technologies.

The Dutch capabilities are enhanced by their efficient R&D framework. Government clearly leads in promoting integrated and coordinated efforts among academia, government, and industry. Now that the EC has highlighted Western Europe's need for improved transportation and environmental systems, the Netherlands can be expected to develop some of the first significant advancements.

Participating organizations from the Netherlands are listed in Table C-1. These agencies were concerned primarily with geotechnical, hydraulics, and materials issues. Little information was gathered on building systems.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 HISTORICAL PERSPECTIVE

The Netherlands is a small country situated among the three major European economic powers: Germany, France, and the United Kingdom. The nation is divided into 12 provinces and approximately 700 municipalities. Fifteen million people live in a densely populated area of 42,000 km². Most of the land lies close to, if not below, sea level. This physical characteristic of the Netherlands has historically been a dominant factor in the development of CCIS technologies.

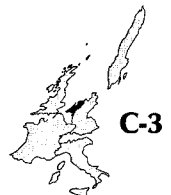
Other physical characteristics also have had great impact on CCIS. The country's small size results in a more compact infrastructure network, controllable by the national government. Its close relationship to the sea has also steered construction's direction. Marine-related work such as tunneling, dredging, and storm surge control have all been developed into state-of-the-art technologies.

TABLE C-1

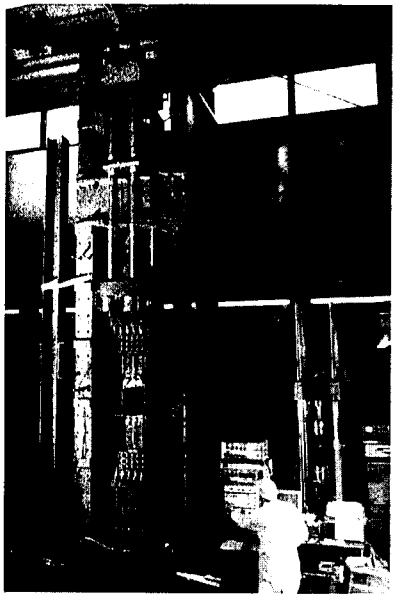
Participating Organizations—The Netherlands

Organization*	Identifier	Type
Ballast Nedam Beton En Waterbouw, Airport Project		private contractor, construction site
Delft Geotechnics		private research
Delft University of Technology		university
DHV Amersfoort	DHV	private consultant
Hollandsche Beton Groep, Storm Surge Control Project		private contractor, construction site
The Netherlands Organization for Applied Research	TNO	government research
Royal Institution of Engineers in the Netherlands	KIVI	professional society
Stichting Bouwresearch	SBR	joint public/private research
Screg Routes		private contractor, French subsidiary

* English translation for organization name provided, where available.



2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS



TNO has a 1,000 metric ton tensile/compression rig designed to test extremely large components.

photo courtesy TNO Building and Construction Research

The Dutch are enthusiastic about civil engineering, perhaps since their country is predominantly a man-built, “created,” environment of reclaimed land. Additionally, the Netherlands controls some of the largest natural gas deposits in Europe. As a result, dredging, hydraulics, geotechnics, and marine construction are necessarily strong points. Understandably, Dutch per capita expenditures on CCIS R&D are greater than those of the U.S. and most of Europe.

Being surrounded by three economic giants has forced the Dutch to specialize their efforts to remain competitive. Plus, limited natural resources have forced the Dutch to sustain their economy mainly through processing imported raw materials. Nevertheless, the private sector economy is relatively stable and produces an annual GNP of US\$225 billion.

Similar to much of Europe and the U.S., the Netherlands’ infrastructure is nearing the end of its design life. This rebuilding of national systems will drive many domestic policies. However, at the same time, public funds are diminishing. Private industry will be asked to carry more of the infrastructure load by contributing to national R&D and financing large civil projects.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

The Dutch have one of the only performance-based building codes in the world.

Liability related to CCIS projects is not a prominent concern for Dutch contractors. Most problems are settled at the site. Risks are more evenly shared by the owner and the contractor than in the United States.

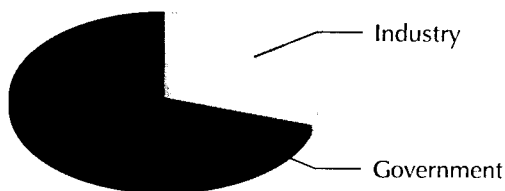
Several companies visited have American subsidiaries that do a significant amount of work in the U.S. and have access to the latest U.S. technologies.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

The Netherlands’ construction industry is more dependent on government involvement than most European nations. The government is clearly the leader in setting research directions and promoting integrated and coordinated efforts between academia, government, and industry. As illustrated in Figure C-1, the government provides the vast majority of CCIS R&D funding.

FIGURE C-1

CCIS R&D Funding—The Netherlands



The Dutch capabilities are enhanced by their efficient R&D framework. One unique aspect of their system includes the role of research coordinators, or “brokers.” These coordinators are four institutes: the Center for Research and Contract Standardization in Civil and Traffic Engineering (CROW), the Center for Civil Engineering Research and Codes (CUR), SBR Building Research, and the Institution for the Study and Promotion of Research in the Field of Building Services (ISSO). These institutes receive funds from the government and industry and redirect them to the proper research

performers. However, the R&D coordinators only broker 10 percent of the total accounted for monies.

The Dutch system actively involves the three principal R&D players: academia, government, and industry. The degree of coordination and integration is so high that the program could well be described as “Netherlands Incorporated.” To better illustrate the national program, the framework for construction R&D is

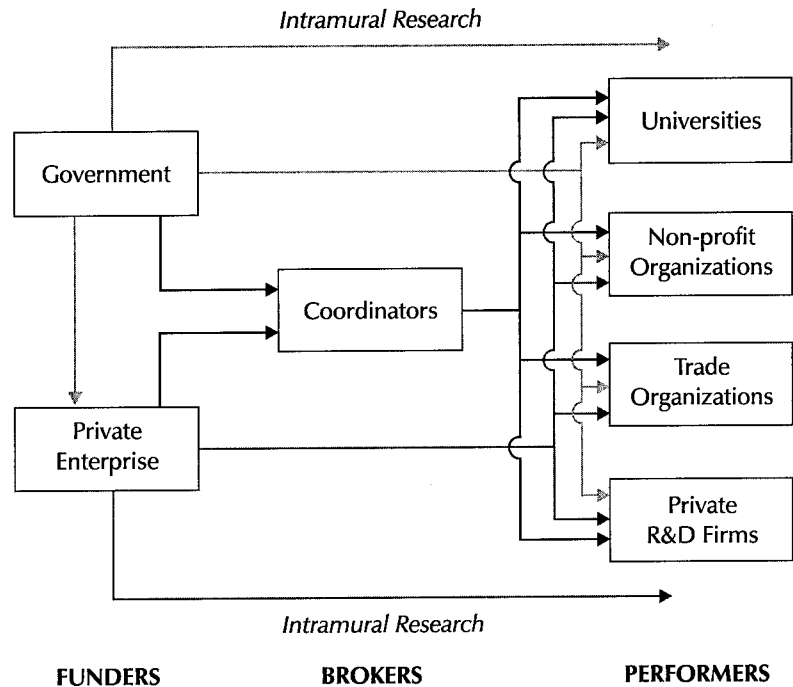
diagrammed in Figure C-2. Even though only 10 percent of R&D funds are routed through the coordinators, their actual involvement is substantially more because of their donated services.

The CCIS R&D process in the Netherlands is a "market pull" system, with economic demands driving much of the research work. Probably, it is more economically driven than the U.S., mainly because the Dutch researchers have close ties with industry and because their overall process is more integrated among industry, government, and academia than most European countries and the U.S.

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

The major research performers in the Netherlands are actively pursuing technology as a competitive industry. The Netherlands Organization for Applied Research (TNO) is completely independent and supports practical industry concerns in the defense, health, environmental, and construction arenas. Innovations developed at TNO, in conjunction with private partnerships, remain proprietary. Likewise, Delft Geotechnics receives 90 percent of its funding by submitting bids for research or testing work.

FIGURE C-2
Dutch CCIS R&D Infrastructure



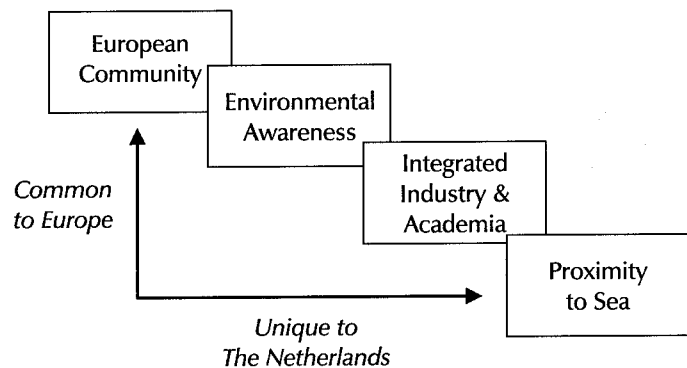
3. CCIS R&D AND TECHNOLOGY TRENDS

The physical characteristics of the Netherlands are probably the dominant drivers of CCIS technologies. An ever-receding shoreline can certainly motivate those living nearby to seek fast and effective solutions. Other factors, such as the impending EC and close industry involvement, also pull technology forward.

3.1 R&D DRIVERS AND ACTIVITIES

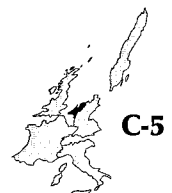
Figure C-3 shows that of the four most prevalent R&D drivers in the Netherlands, "Proximity to the Sea" and "Integrated Industry and Academia" are unique to this country, while the remaining two drivers are more common to the other countries visited. The descriptions that follow briefly describe each of these four primary R&D drivers.

FIGURE C-3
Dutch CCIS R&D Drivers



European Community

The new, tougher standards for road transportation and water/wastewater quality will especially impact the Dutch. EC unifications standards will require that pavement conditions be improved. Combined water systems must be rehabilitated and existing water treatment plants upgraded or rebuilt.



Environmental Awareness

Green technologies are national directives. Recycling and alternative disposal methods are being stressed. Obviously, the Dutch have only a limited amount of buildable space, so they do not want to use more than necessary for solid waste landfills. Upcoming EC regulations will make it difficult to export wastes to other countries. Similarly, the Dutch must also clean contaminated land. Finally, new construction technologies must consider their possible effects on the environment.

Integrated Industry and Academia

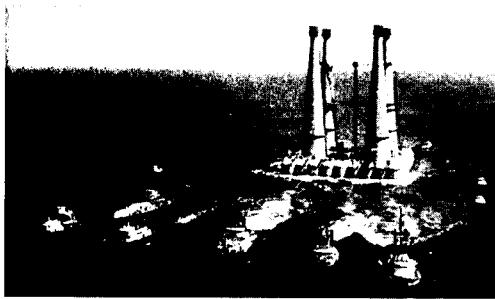


photo courtesy Delft Geotechnics

The Netherlands produces many off-shore structures in connection with oil and gas exploitation.

Construction research tends to be driven by the economic or market demands of industry. The desirability of the quick impact of applied research is preferred over that of uncertain, long term basic research. Close industry and academic ties are the origin of this trend. Several factors contribute to this mutually beneficial relationship. First, most university professors are required to spend considerable time working in industry. Business contacts and networks developed through those activities translate into closer industry and academia ties when the professors return to teaching. Second, polytechnic students must work for one year as a requirement of their curriculum. This practical experience may indeed steer their research interests toward solving the problems they witnessed while in industry.

Proximity To Sea

The topography necessitates state-of-the-art marine construction, storm surge control, dredging, and tunneling. The Dutch advancements in underwater tunneling have also resulted in associated subdiscipline technology advances in low porosity concrete and water tight jointing. These factors have led to the establishment of excellent geotechnical and hydraulic institutes in the Netherlands. The dredging industry has recently been in a downturn, but Dutch technology is still the best in the world.

3.2 CONSTRUCTION MATERIALS

The recycling of materials is important in Dutch construction R&D. In fact, 60 percent of all asphalt rubble and 75 percent of all construction and demolition waste is re-used. High-performance concrete and porous asphalt are other strong areas of research.

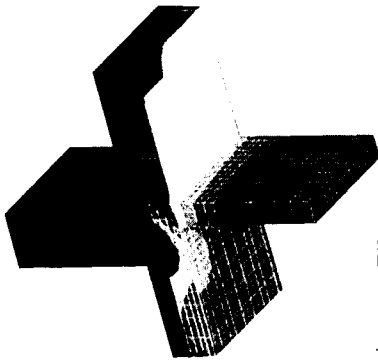


photo courtesy TNO

The DIANA finite analysis software can be used for many engineering applications, from structural engineering to environmental problems; a temperature flow analysis is pictured.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

Several promising computer modeling software programs have been developed and are operational in the Netherlands. One example is the general purpose finite element analysis system called DIANA. This system specifically caters to civil engineering applications and is internationally known.

Automated real-time monitoring devices for site construction are being developed and implemented. One system, WASPAN, monitors changing slope stability with reference to several variables (pore pressures, added top weight, toe changes, etc.). Another system, ZAKBAK, monitors soft soil settlements and predicts future conditions for roadwork.

DHV maintains a North Western Europe socio-economic traffic modeling system in conjunction with a graphical information system. This may be the only database in the world that integrates these unique features.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

Task force members had little opportunity to discuss Dutch building technology. However, it was observed that the Netherlands has one of the few performance-based building codes in the world.

3.5 HIGHWAY AND RAIL SYSTEMS

Underground transportation techniques are state-of-the-art. The NWE integrated traffic system may be one of a kind. Considerable resources are also being invested in developing durable, low noise and environmentally-safe pavements. For example, the task force noted some of the most elaborate noise barriers they had seen anywhere, made up of a long noise wall with a cantilevered extension over the outside shoulder and part of the outside lane. Located in a relatively rural area, the barrier protected some scattered buildings and *wildlife* native to the area.

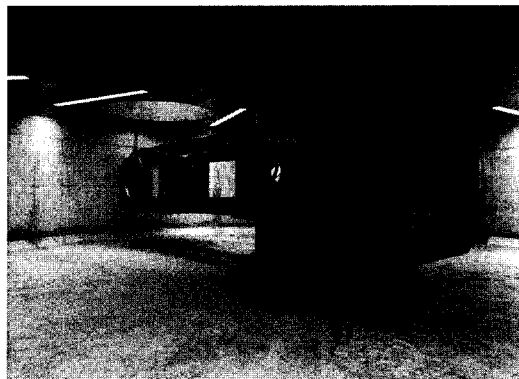


photo courtesy Delft Geotechnics

The Delft centrifuge is used for geotechnical analysis, such as testing the impact of large structures on surrounding soil.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

Dredging, marine construction, and tunneling operations are all state of the art, and soil sampling equipment and modeling devices are cutting edge. As an example, the Delft centrifuge has a capacity of two cubic meters, which makes it among the largest centrifuges in the world.

The Dutch's storm surge control barrier gates are an impressive engineering feat and their marine construction methods are the world's best. Further Dutch trenchless technology for pipeline inspection and repair is improving as the combined sewers are upgraded for EC standards.

Environmental impacts are also being incorporated into facility design. Alternative waste disposal and recycling are also active fields of research.

3.7 WATER AND SEWAGE SYSTEMS

The poor state of Dutch water disposal systems has forced them to refocus R&D efforts in that field. First, most Dutch disposal systems are combined sewers. As a result, considerable R&D effort is being placed on improving pipeline repair methods. Second, the existing 500 waste water treatment plants are substandard. Policy makers are examining how best to upgrade the current plants rather than build new ones.

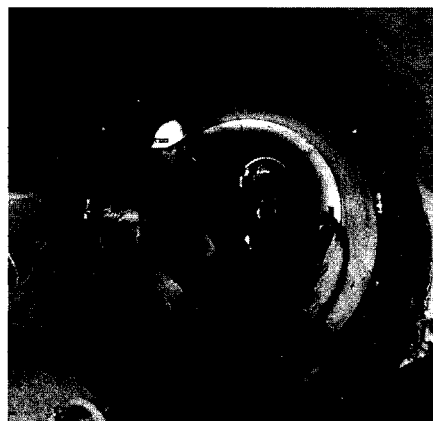


photo courtesy Hollandische Beton Groep nv

Construction of a 725-meter sewer using a proprietary horizontal drilling method.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

4.1 ROLE OF GOVERNMENT

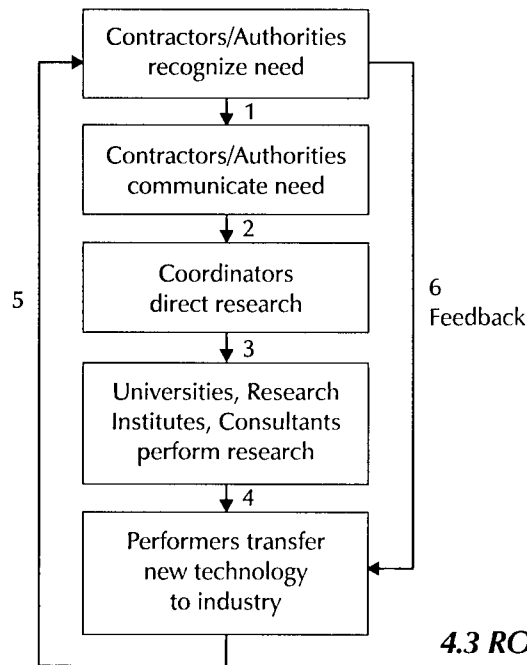
As diagrammed in Figure C-2, the Dutch system for construction R&D actively involves three main players—government, industry, and academia—plus, to a lesser extent, non-profit groups and trade organizations.



The targeting of research was observed to be a growing trend in the Netherlands. Examples of recent R&D activities include: construction and demolition waste recycling, asphalt rubble utilization, and porous asphalt applications.

The government's strategy has been to replace gradually the traditional budget mechanism of handing out money for interesting subjects proposed by academia or industry; instead, market mechanisms are now being used, so that industry must be willing to pay for research results. The newer system is shifting studies to short-term basic research that possesses real economic promise. Best-bid contract awarding and performance specifications are also being used by government to promote acceptance of new products and processes.

FIGURE C-4
Dutch CCIS R&D Process



4.2 ROLE OF INDUSTRY

The Dutch construction industry's R&D involves six basic steps, as illustrated in Figure C-4. Initially, market needs are identified by government authorities or contractors, who request that appropriate studies be made through one of the research coordinating institutes. Then, these coordinators pass those needs to the universities, research institutes, and consultants. Finally, the researchers return the technology to industry and receive feedback.

Industry imposes a voluntary levy on itself to collectively fund R&D. This program, called the Social Foundation for Education and Development, pools money from a tax on hourly labor wages and uses it mainly for worker training, but also for R&D.

4.3 ROLE OF ACADEMIA

There are two types of post-secondary schools for aspiring engineers—the universities and the higher vocational education, or polytechnics. Students receive the equivalent of a master's degree after four years of study at universities. Dutch secondary schools provide one more year of education than American high schools and cover much of the liberal arts and basic science courses normally taught during the first two years at American colleges. Graduating engineers from the universities receive the “doctoral” degree and are granted the title *ingenieur*, abbreviated “*ir.*”

The polytechnic programs are geared towards developing practical knowledge or skills for specific jobs. These schools maintain close ties with companies that hire their graduates. Polytechnics also require four years of studies, but the ultimate degree is more akin to the bachelor's degree in the U.S.A. Polytechnic graduates can use the abbreviation “*ing.*” with their names.

The studies done at the university are mainly geared toward applied research. This can be traced back to the ten years of practical, industrial experience that most professors are required to complete before returning to teach. University R&D is traditionally financed through the Ministry of Education. Task force members estimate that 90% of the cost of Dutch Universities and Polytechnics is provided by the government. The remaining funds come from contract research with industry, and there is growing pressure for this private money to increase.

4.4 FINANCIAL INCENTIVES

The Social Foundation for Education and Development distributes money from wage taxes for worker training and limited R&D. In addition, the government assists some private studies.

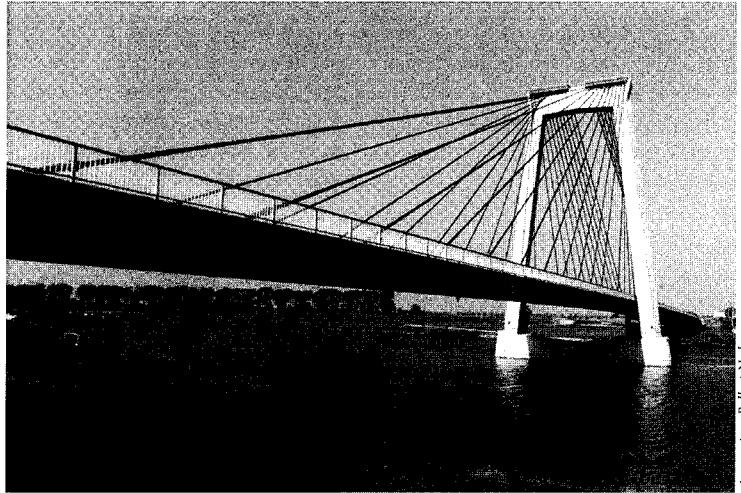
4.5 LIABILITY CONSIDERATIONS

Liability related to CCIS projects is not a prominent concern for Dutch contractors. Most problems are settled at the site. Risks are more evenly shared by the owner and the contractor than in the United States.

5. RESPONSE TO EUROPEAN COMMUNITY

The new, tougher standards for transportation and environment will especially impact the Dutch. Their crumbling infrastructure needs significant refurbishing. Pavements will need to be improved, combined water systems must be rehabilitated, existing water treatment plants must be upgraded, and contaminated land must be restored. As a result, new construction technologies must consider their effects on the environment.

Now that the EC has highlighted Western Europe's need for improved transportation and environmental systems, expect the Netherlands to develop some of the first advancements. Their national system is well suited to such rapid development of applied technologies. Conversely, the Netherlands may find innovation a more difficult task once EC approvals become necessary. The red tape and delays associated with getting the Community's "stamp of approval" may significantly discourage new technology. Plus, the smaller Dutch companies may have a more difficult time taking advantage of the EC's multinational venturing incentives.

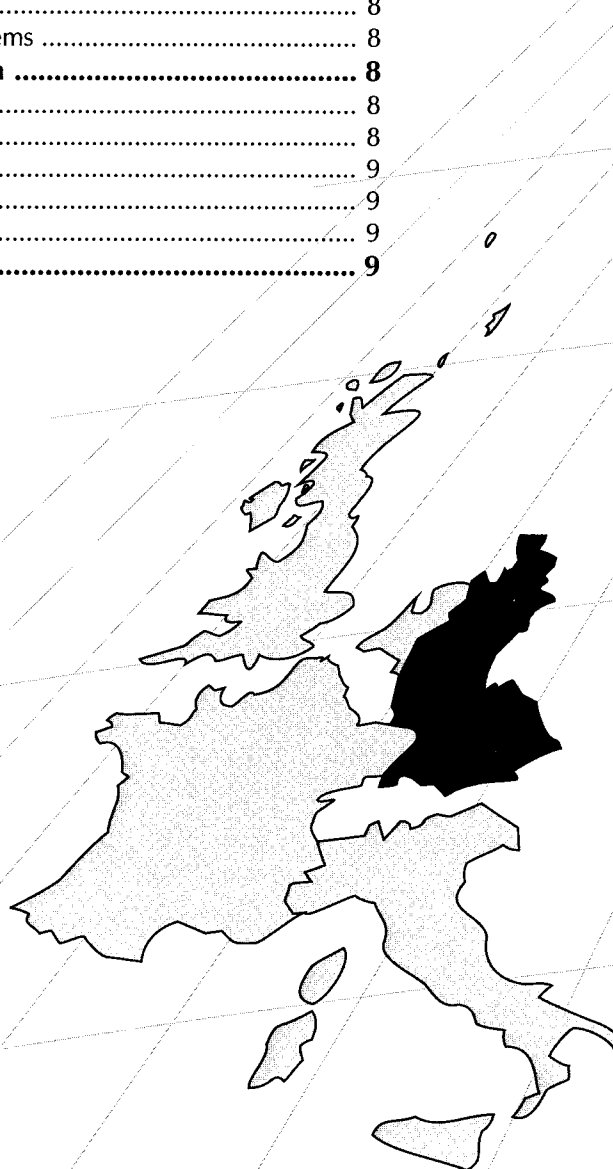


The contractor Spanstaal was awarded a 1991 Dutch Concrete Association prize for its contribution to the construction of this cable-stayed bridge over the Bergsche Maas near Heusden.

Appendix D

GERMANY

1. Summary	3
2. Context for CCIS Technology	3
2.1 Historical Perspective	3
2.2 Economic, Regulatory, and Cultural Environments	4
2.3 Legal and Competitive Environments	4
2.4 R&D and Technology Innovation Policies	4
2.5 Private Sector Technology Partnerships	5
3. CCIS R&D and Technology Trends	5
3.1 R&D Drivers and Activities	5
3.2 Construction Materials	7
3.3 Computer-aided Design, Automation, and Information Systems	7
3.4 Building and Construction Systems	7
3.5 Highway and Rail Systems	7
3.6 Environmental and Geotechnical Systems	8
3.7 Water and Sewage Construction and Systems	8
4. Strategies for Innovation Implementation	8
4.1 Role of Government	8
4.2 Role of Industry	8
4.3 Role of Academia	9
4.4 Financial Incentives	9
4.5 Liability Considerations	9
5. Response to European Community	9



Appendix D

GERMANY

1. SUMMARY

The unification of former West and East Germany is a primary factor shaping CCIS development activities. Decades of under-investment and environmental neglect in the East, combined with aging of the West's postwar networks pose major problems for the newly-unified nation. While government has taken a strong leadership role in past CCIS technology development, the scale of this challenge may require greater industrial involvement, and government's coordinating skills may be challenged. In addition, the government seeks to maintain and enhance Germany's central position in the EC.

Germany's transportation network requires much rehabilitation, similar to the U.S. situation. They are looking to develop durable pavement materials and effective pavement/bridge management systems to maintain them. In the environmental area, currently 90 percent of their sewers are combined. Policy makers prefer to upgrade the existing systems instead of constructing new treatment and disposal networks. Nevertheless, one of the hosts estimated 1,500–2,000 more treatment plants are needed, primarily in eastern Germany.

The infrastructure of German construction research and development appears more integrated than in the U.S. The large industrial firms perceive the importance of technology in the market today and are willing to invest. The government is the recognized leader for R&D, but their coordinating skills will be challenged by the East German condition.

Task-force teams based their activities in Frankfurt and Bonn, traveling from there to sites within the surrounding regions. Table D-1 lists participating organizations in Germany.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 HISTORICAL PERSPECTIVE

Centrally located between the advanced, industrialized economies of western Europe and the emerging Eastern Bloc nations, Germany stands poised to provide vital goods and services for development of the latter's economies, an innate advantage over their western competitors. Common language and culture provide a basis for unification of the post-cold war German state, but nearly five decades of physical and ideological division will not be easily overcome.

TABLE D-1
Participating Organizations—Germany

Organization*	Identifier	Type
Aachen University of Technology		university
Bilfinger & Berger		private contractor
Deutsche Forschungsgemeinschaft	DFG	government research
Federal Ministry for Research & Technology	BMFT	government agency
German Highway Center	BASt	government agency
Information Center for Planning & Construction	IRB	private research
Philipp Holzmann AG		private contractor
Strabag Bau AG		private contractor
Technische Hochschule Darmstadt		university
University of Karlsruhe		university
Verein Deutscher Ingenieure	VDI-Bau	professional society

* English translation for organization name provided, where available.



The nation's climate and topography are for the most part gentle, with sometimes cold winters nationally, and mountainous areas in Bavaria in the south. With only a short coastline in the north, most of Germany's 350,000 km² are landlocked. The capacity of the Rhein river is somewhat limited and navigation is interrupted in dry years due to low water. However, the Rhein-Main-Donau Canal system was recently completed and connects central Germany (Frankfurt) with the Black Sea.

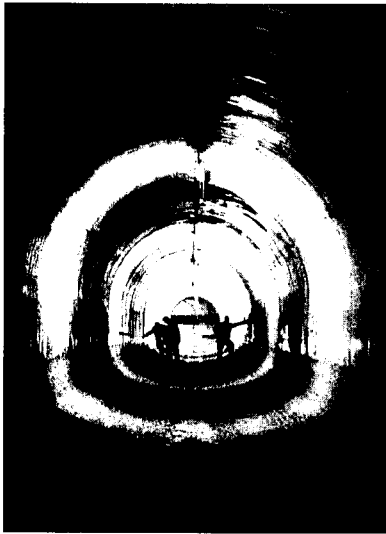


photo courtesy: Michael Benschke

Combined sewers in the former East Germany require extensive upgrading.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

The combined German population, the largest in Europe at 77 million people, is distributed among a number of medium-sized cities. The estimated gross national product (GNP) of US\$1,500 billion is also the continent's largest. Unlike most nations of western Europe, Germany's population is distributed among a number of medium-sized cities, rather than concentrated in one preeminent metropolitan center. Physically connecting the distributed economy presents additional challenges for Germany's infrastructure.

Although currently burdened with bringing the former East Germany up to western standards, Germany's fellow-members of the EC have expressed concern that a unified Germany may again dominate the European union, economically and politically.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

Legal and business climates for CCIS in Germany are relatively mild as well. Limitations are placed on the amount of liability a contractor can incur, and law declares that a builder cannot go bankrupt on a single project. Disputes seldom lead to litigation.

The larger German contractors reportedly are focusing their efforts on the substantial reconstruction work in eastern Germany. These projects, awarded mostly to domestic builders, should provide an effective test bed for rehabilitation and restoration technologies well suited to many applications in other former Eastern Bloc countries.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

Germany's policy-level approach to R&D is relatively centralized, with the BMFT, a government ministry, ultimately responsible for all science and technology research in Germany. The Deutsche Forschungsgemeinschaft (DFG) and Landers (states) dispense government funds as well, providing both general support allocated to a university or similar institute that filters down to the actual researchers, and specific grants rewarding excellent research.

The DFG grants US\$900 million annually (only a portion is construction-related) to mostly unsolicited university research proposals. Sixty percent of such unsolicited requests receive funding in Germany, while only 20 percent of such proposals are accepted in the U.S. The DFG also specifies Priority Programs to focus academic research efforts. In addition, each state has the power and funds to direct customized R&D activities.

Figure D-1 shows the relative contributions to CCIS R&D by German industry and government. Figure D-2 shows the relative breakdown of work by organizations that actually perform CCIS R&D.

FIGURE D-1

CCIS R&D Funding—Germany

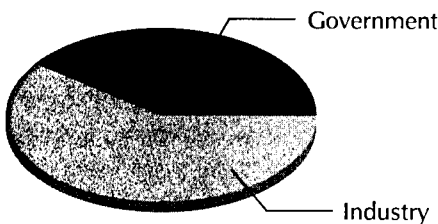
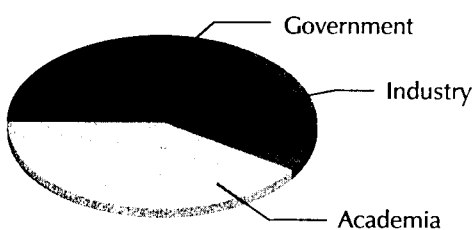


FIGURE D-2

CCIS R&D Performers—Germany

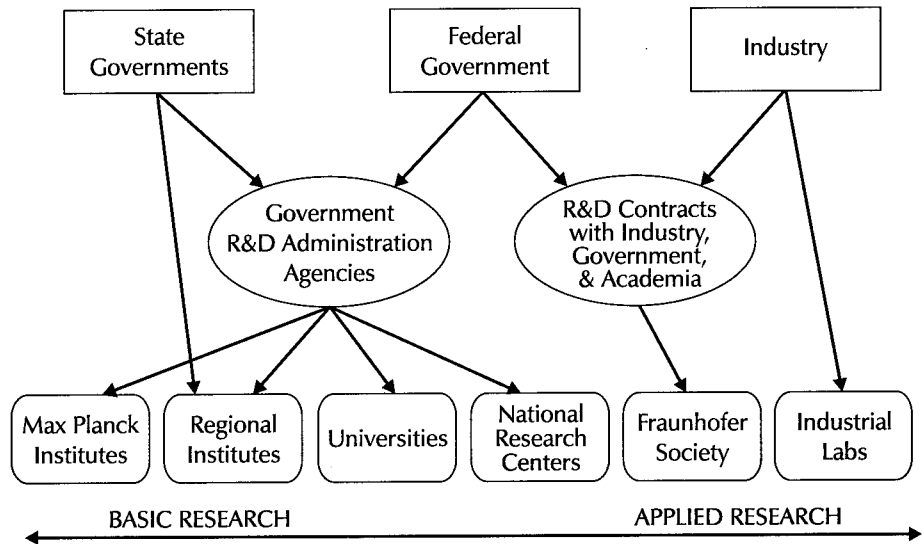


2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

As illustrated in Figure D-3, industry R&D funds are spent largely internally, although there are R&D institutions (other than universities) that serve the industry as a whole. ARCONIS, for example, is a consultancy service funded through the government and private sponsorship. The Information Center for Planning & Construction (IRB) maintains three national construction databases: a summary of current building research projects, a regional database for construction work, and an international data base on civil engineering.

The Fraunhofer Society, primarily a training and education organization, is closely allied with industry, and conducts US\$650 million worth of research annually in many practical fields. Funding through contract work originates equally from government, industry, and academia. Work at the Fraunhofer Society tends to emphasize applied rather than basic research. The latter is the primary emphasis of the Max Planck Institute, which is the home to the most Nobel Prize winners in Germany. The Institute has minimal involvement in CCIS-related research.

FIGURE D-3
German CCIS R&D Infrastructure



3. CCIS R&D AND TECHNOLOGY TRENDS

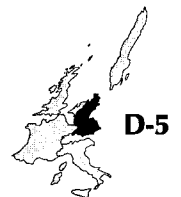
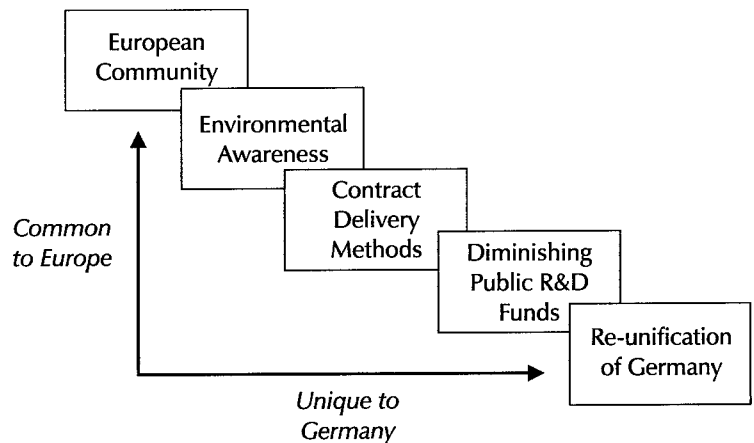
Task force members observed several state-of-the-art CCIS technologies in practice in Germany. For example, trenchless sewer inspection and retrofit technologies in Germany are very well developed. Railroad and high-speed rail systems are being upgraded with sophisticated signal and control systems, and magnetic levitation (MagLev) technology is being studied with government funding.

Work on composites and concrete seems to be yielding good results. One contractor is developing an innovative sensing and prestressing technology for concrete, an in-situ system using glass fiber reinforcing and fiber optics to monitor real time deformations in bridge members. Enhancing asphalt performance is another area of active R&D, including investigations of hot-mixed rubberized asphalt and reclaimed asphalt pavements.

3.1 R&D DRIVERS AND ACTIVITIES

As illustrated in Figure D-4, German CCIS research and innovation are subject to the same growth of environmental awareness and concern for the EC's influence as counterpart institutions in other European countries. R&D drivers unique to

FIGURE D-4
CCIS R&D Drivers—Germany



Germany are related to German re-unification; these include diminishing public funds and the poor state of the infrastructure in eastern Germany, which is inadequate to meet the demands of EC standards.

European Community

Most European countries recognize and use (or model theirs after) German standards, such as DIN (Deutsche Industrie Normen) and VDE. For example, Italy, Austria, Greece, and Turkey all base their standards on the German norms. Germany has begun to prepare for EC standards by enacting tough environmental laws and regulations, some deemed so strong that some contractors consider their growing expertise to be an exportable technology.

Environmental Awareness

Environmental technologies are important to the German infrastructure. Methods for dealing with solid waste problems, mechanical treatment of contaminated soils, and effective capillary barriers for landfills are areas in which interest is particularly high. Severe industrial pollution in eastern Germany underlies forecast needs for developing 1,500 to 2,000 water treatment plants and 50 new solid waste landfills. Environmental construction and restoration activities are anticipated to grow at rates of 30 percent or more annually.

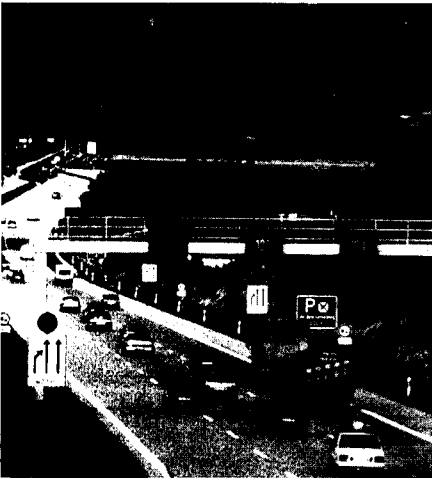


photo courtesy IAW

There is a major emphasis on cost-effectively bringing roads in the former East Germany up to the high standards of other German roads.

Contract Delivery Methods

Task-force members found that best-bid contract awards and performance specifications are spurring German CCIS R&D and new technology. While most project construction procurements still stress low initial price, owners are beginning to shift to a more thorough analysis of bid proposals, considering safety, life cycle costs, and quality among factors for selection. In addition, contractors' liability is limited by law, and disputes are typically settled efficiently through negotiation or arbitration. These contracting procedures effectively encourage innovative proposals from the builders.

Diminishing Public Funds

The government has, in the past, supplied some 40 percent of CCIS construction funding, but this is on the decline and German industry will be asked to shoulder more of the burden of rebuilding. The funds that are available will be devoted to reunification efforts. The move to more industry R&D should shift the balance towards applied or strategic research. In the past, German design standards did not consider engineering economics. The German roads performed well, but the standardized designs tended to be in many cases over-engineered. A need to improve efficiency is driving demand for new tools for road and bridge management.

Re-Unification Of Germany

The infrastructure of eastern Germany is in bad shape. Road transportation networks must be upgraded in the East to conform with EC standards. Special attention must be focused on the east-west corridors, while the north-south network is acceptable. Water and sewage delivery systems need much rehabilitation. Therefore, inspection and repair technologies will be paramount.

3.2 CONSTRUCTION MATERIALS

While the German structural steel industry is experiencing bad times, composites and concrete are gaining interest. Research is being actively pursued to improve concrete's strength, ductility, and corrosion resistance. One contractor is developing an innovative sensing and prestressing technology for concrete. The in-situ system uses glass fiber reinforcing and fiber optics to monitor real-time deformations in bridge members. The basic research was conducted at the universities and then applied by a builder on a bridge in Dusseldorf.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

Software applications are being used in all forms of civil engineering works. Especially impressive were geotechnical and environmental modeling capabilities. Task force team members also observed some advanced work with automated design tools. Aachen University is working to combine finite element ground water modeling from GIS data. An Automated Design Change, CAD (DICAD) system has promising capabilities for better integrating design and construction. In general, separate computer aided design and information systems are being used in Germany, but integration is seemingly uncommon.

Pavement management systems are just being introduced into practice. An automated paver was recently developed that paves steep slopes and curves at speeds of as much as 2 meters/minute, but automated equipment and robotics are receiving relatively little attention. Germany does not presently have substantial labor shortages, nor did task-force team members encounter substantial concern for increased productivity in CCIS-related activities.

As mentioned above, IRB maintains three national construction databases: a summary of current building research projects, a regional database for construction work, and an international database on civil engineering.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

Composite concrete and steel structures is an active area, along with hybrid structural systems. The task force team spent little time discussing other German building technologies.

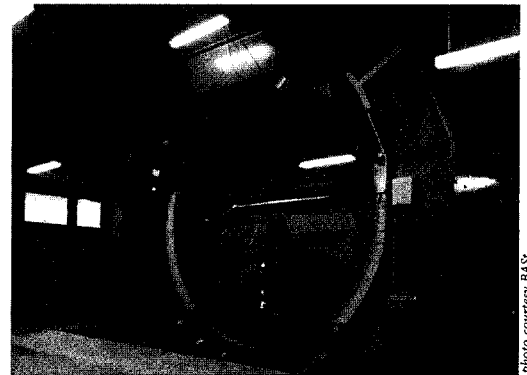
3.5 HIGHWAY AND RAIL SYSTEMS

As mentioned above, in the past, German standards did not consider engineering economics. German roads perform well, but their standardized design tends to over-engineer. For instance, all pavements must be designed and constructed to resist frost heave. Such roads prove costly to construct, and it is unclear if these initial expenditures are recouped later. The new trend towards life-cycle costing may force the Germans to reevaluate their pavement systems. Task force members noted concern by German engineers that in the course of rebuilding the East German highway systems, they may have to accept less than a "full" design. Rather, because of economic constraints, they might have to use five to seven year maintenance "fixes," which under normal circumstances would be highly unacceptable.



Recycling the Berlin Wall into high-grade road building materials.

Photo courtesy Straub Bau-AG

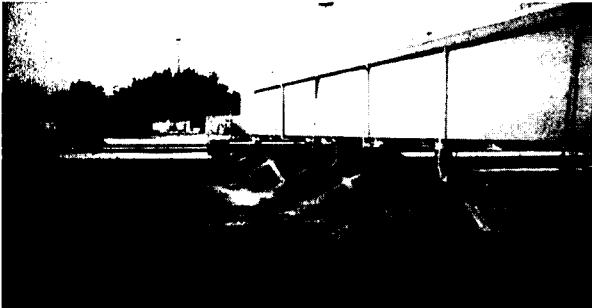


The German Highway Center (BAST) uses this facility to test the interaction between wheels and pavement surfaces.

Photo courtesy BAST

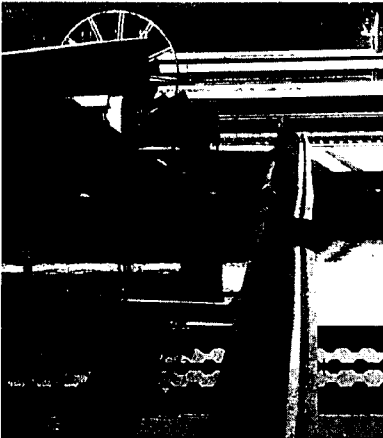


High-performance asphalt is receiving a great deal of attention, since enhancing pavement performance is deemed important as the huge task of rehabilitating east Germany's roads begins. Examples include hot-mixed rubberized asphalt and reclaimed asphalt pavements. The need to improve inadequate east-west traffic corridors in Germany is driving the implementation of several CCIS technologies, such as pavement management systems to better maintain the highway network.



Photos courtesy: Straube Bau-AG

State-of-the-art water collection, purification, and distribution systems in western Germany (above) provide a stark contrast to the antiquated systems in eastern Germany badly needing replacement (below).



Railroad and high-speed rail systems are being upgraded to sophisticated systems. High-speed rail and MagLev systems are being upgraded to relieve much of the load from highways. These MagLev studies are being subsidized by the government because they may be an exportable technology in the future.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

Solid waste disposal problems, mechanical treatment of contaminated soils, and effective capillary barriers for landfills are all environmental areas in which interest is particularly high in Germany.

3.7 WATER AND SEWAGE CONSTRUCTION AND SYSTEMS

German trenchless sewer inspection and retrofit technologies are state of the art. This will continue to be a hot topic as Germany's inadequate combined sewer system is repaired. Surprisingly though, no major research centers are concentrating on this issue; instead, five or six universities are administering programs in this area.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

4.1 ROLE OF GOVERNMENT

As illustrated in Figure D-3, public research funding and management is decentralized. The government invests 850 million DM annually in construction-related R&D, which is distributed through the BMFT, DFG, and Landers (states). These organizations provide two types of support: 1) general support allocated to institutes and universities that filters down to the actual research performers, and 2) specific funds that directly reward promising research.

4.2 ROLE OF INDUSTRY

The German construction industry participates in research and development by contributing to the universities and Fraunhofer Society. Yet, only the largest equipment manufacturers and contractors allocate significant funds to outside institutes. In this sense, it mirrors the role of the construction industry in the United States; however, unlike the U.S., most of the larger private firms also maintain their own in-house labs. Several companies visited have American subsidiaries that do a significant amount of work in the U.S. and have access to the latest U.S. technologies.

Estimates of total industry investment range from one-half to two percent of construction turnover. Accurate industry contributions are difficult to estimate since much research and development is undocumented. Also, marketing and proposal preparation costs are included in German R&D totals, so "real" research money is somewhat less.

4.3 ROLE OF ACADEMIA

As already noted, much of the German basic or strategic CCIS R&D is conducted in universities or other noncommercial institutions. Much of the research work is done by postgraduate students, doctoral candidates who spend a maximum four to five years in graduate studies and then must enter industry, with or without a completed degree. Since all those who return to academia as professors have spent some time in industry, teaching and research tend to be closely linked with technology applications.

Universities receive most of their R&D funds from consulting work, service to industry, industry contributions, state and federal governments, and personal sources. Professors are encouraged to do consulting work and their schools cover overhead associated with this work. As a whole, German academia appears to coordinate research with the construction industry better than the U.S.

Since all those who return to academia as professors have spent some time in industry, teaching and research tend to be closely linked with technology applications.

4.4 FINANCIAL INCENTIVES

German industry is committed to R&D in order to remain competitive. New technologies allow them to compete in international markets more successfully. Government does aid industry in some target areas such as MagLev transportation, but otherwise the government does not contribute as much to R&D as in France and the Netherlands.

4.5 LIABILITY CONSIDERATIONS

Liability is not the insurmountable inhibitor that it is in the U.S. Instead, disputes are settled efficiently through negotiation or arbitration. Since contractors by law cannot go bankrupt on a project, the legal environment certainly facilitates innovation by limiting the possible financial losses. For example, a fiber optic monitoring system was constructed into a composite fiber-reinforced bridge in Dusseldorf using performance specifications at no liability to the contractor. Furthermore, contractors can correct design errors and are routinely paid for such alterations. Also, under special circumstances, the government will share the risks of new innovations.

5. RESPONSE TO EUROPEAN COMMUNITY

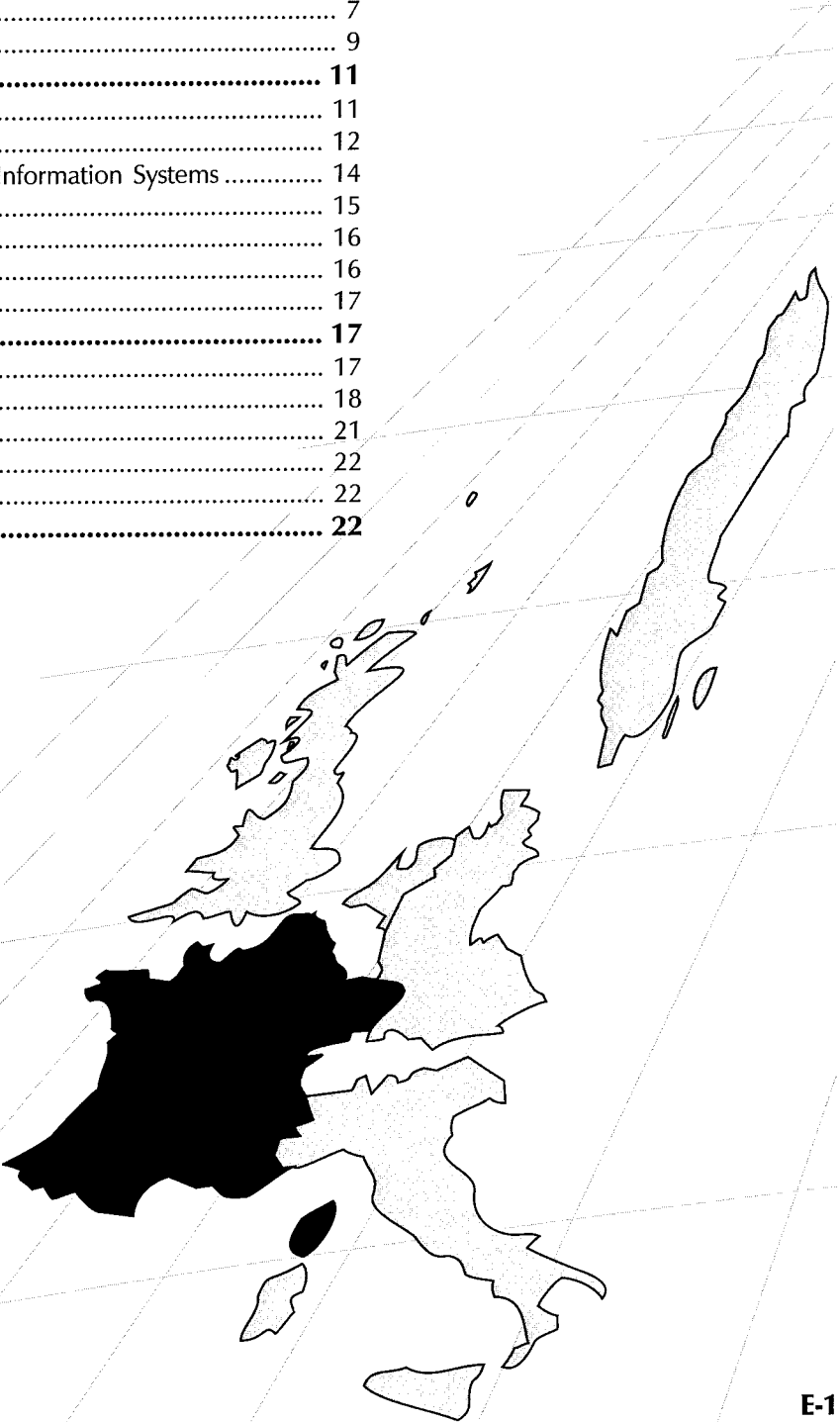
All aspects of civil constructed infrastructure systems will be affected by the EC, as well as reunification with the former East Germany. The EC's common infrastructure standards will significantly impact areas where eastern Germany falls short: roads, water systems, and waste disposal systems. Germany has already begun to prepare for the EC standards by enacting their own tough regulations. The German standards are generally considered higher than in most EC countries. These are deemed so strong in fact, that many contractors consider their growing expertise as an exportable technology.



Appendix E

FRANCE

- 1. Summary 3
- 2. Context for CCIS Technology 3
 - 2.1 Historical Perspective 3
 - 2.2 Economic, Regulatory, and Cultural Environments 5
 - 2.3 Legal and Competitive Environments 6
 - 2.4 R&D and Technology Innovation Policies 7
 - 2.5 Private Sector Technology Partnerships 9
- 3. CCIS R&D and Technology Trends 11
 - 3.1 R&D Drivers and Activities 11
 - 3.2 Construction Materials 12
 - 3.3 Computer-aided Design, Automation, and Information Systems 14
 - 3.4 Building and Construction Systems 15
 - 3.5 Highway and Rail Systems 16
 - 3.6 Environmental and Geotechnical Systems 16
 - 3.7 Water and Sewage Systems 17
- 4. Strategies for Innovation Implementation 17
 - 4.1 Role of Government 17
 - 4.2 Role of Industry 18
 - 4.3 Role of Academia 21
 - 4.4 Financial Incentives 22
 - 4.5 Liability Considerations 22
- 5. Response to European Community 22



Appendix E

FRANCE

1. SUMMARY

France's infrastructure industry is more technically oriented than those in most European countries. The national government provides active leadership through funding rewards and mechanisms encouraging technology transfer. In public works contracts, the French government uses warranties, performance specifications, and best bids to encourage alternative designs from contractors. And, just as valuably, French contractors do not fear the liabilities associated with innovations since the government shares in the risks. As a result of these factors, major French contractors have acquired the expertise to compete successfully for international projects.

Because arrangements for the task force's visit were handled by the French national road authority, SETRA, the primary focus was on roads and paving materials and there was less discussion of building, water, geotechnical, or environmental concerns. The participating organizations in France are listed in Table E-1.

In public works contracts, the French government uses warranties, performance specifications, and best bids to encourage alternative designs from contractors.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 HISTORICAL PERSPECTIVE

France is located centrally within the European Economic Community and the major European countries. This position affords it a strategic location linking Spain, Italy, Germany, and the United Kingdom. The country is subdivided into 22 administrative regions and 94 counties. Despite being the Western European nation with the largest area at 547,000 km², it is still much smaller than the United States and only about four-fifths the area of Texas. Relative to the U.S., this size difference simplifies the development and implementation of nationwide systems. However, its population at over 55 million is more than three times that of Texas.

The general climate is moderate, with temperature ranges similar to the U.S. mid-Atlantic states. The Mediterranean coast, or Côte d'Azur, is warmer and experiences hotter summers and milder winters. The rugged terrain of the Pyrenees and the Alps dominates the southern and eastern sections respectively, and the Massif Central is a mountainous plateau in the center. Gentle river valleys and rolling hills cover more than half the country in the north and west.

TABLE E-1
Participating Organizations—France

Organization*	Identifier	Type
Bouygues		private contractor
Center for Buildings and Public Works Research	CEBTP	private R&D and testing
Central Laboratory for Roads and Bridges	LCPC	government research
Channel Tunnel		construction site
Dumez		private contractor
École Nationale des Ponts et Chaussées	ENPC	university
National Council of French Engineers and Scientists	CNISF	professional society
Screg Routes	Screg	private contractor, Bouygues subsidiary
Road & Highway Engineering Department	SETRA	government research

* English translation of organization name provided, where available



Civil and construction engineering in France have a long and distinguished record of achievements. Typical are the great contributors Coulomb and Eiffel. Coulomb, educated in mid-18th century at École Nationale des Ponts et Chaussées (ENPC), became a military engineer. He was posted for nine years to Martinique where his observations of quarry operations led to the Coulomb theory of earth pressure. Similarly, there are few individuals in developed countries who are not familiar with the Eiffel Tower even though they may not be familiar with the many other achievements of this 19th century French civil engineer. Many other impressive civil engineering works have been designed and constructed by French engineers both within France and in other countries. Thus, France has an outstanding civil engineering tradition which has continued to this day.

This tradition was reflected in the early formation of engineering associations in France. France has had many engineering specialty associations with the count at one time totaling 724 organizations. Among the progression of major organizations there have been:

- Société des Ingénieurs Civils de France (**ICF**) formed in 1860
- La Fédération des Associations et Sociétés Françaises d'Ingénieurs Diplômés (**FASFID**)
- Association for Alumni of Grand École–1929
- Le Conseil National des Ingénieurs Français (**CNIF**)–1957, an organization of public works engineers
- La Société des Ingénieurs et Scientifiques de France (**ISF**)–1978, a broadening of ICF to include scientists
- Le Conseil National des Ingénieurs et des Scientifiques de France (**CNISF**), a confederation of CNIF, FASFID, and ISF

Work to assemble all those organizations into CNISF started in 1978 and involved the presidents of 40 French engineering societies. At that time, there were more than 300 associations with 150,000 members. Many of those associations did not have sufficient members to provide a critical mass for presenting views on educational, social, and economic problems. By joining to form the CNISF, the engineering profession in France was better able to present policy views, establish engineering criteria, and take positions regarding social and educational problems. Within CNISF the 22 administrative regions of France are represented. Each region has a local association. The CNISF also has members from outside the country, and at present there are currently 300 British members. It is felt that by banding together, a more effective organization has been formed which provides greater visibility for engineering.

Because of its small size relative to the U.S., its tradition of centralized government, and its relatively uniform climate, engineering and construction issues are more coherent than in the U.S., allowing many problems to be dealt with effectively at a national level, rather than a regional level. Further, there is close cooperation between government and the construction industry.

Another factor promoting a great degree of coherence in civil engineering in France is that the Grand École grants more than 80 percent of the civil engineering degrees in the country. The Alumni Organization of the Grand École is very strong. The result is that many civil engineers know each other and are familiar with civil engineering activities in progress around the country.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

The French economy was in recession when the task force visited. The GNP in 1990 was about US\$940 billion, of which construction represented eleven percent. For the past decade a significant fraction of the nation's resources has been devoted to defense and, because France lacks natural energy sources, to atomic energy research. The peace dividend may free up defense funds.

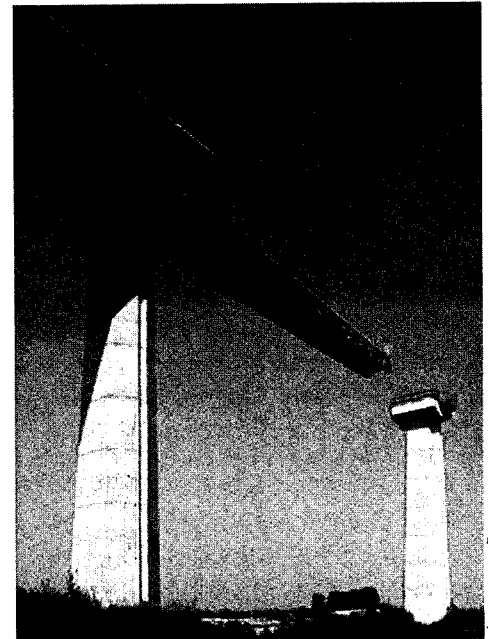
At 11 percent, construction activity in France is a higher fraction of the GNP than in the U.S., where it is 8.6 percent. In addition, French firms have been successful in competing for construction work and in selling construction equipment and materials in many other parts of the world. Since construction is recognized as an important economic activity for France, financing for its activities is furnished both from government sources and from the private sector. Thus, construction is a significant economic activity, a source of employment in France, and a major export for France.

The cultural environment in France encourages significant CCIS projects. Recent examples are the successful introduction of the TGV high speed rail system; the development of a nuclear power industry which supplies a significant fraction of the nation's electric power and reduces the need to import oil or fossil fuels; the construction of many notable bridges; and many innovations in utilizing new sensor technologies and control systems methodologies to improve the quality and efficiency of water supply systems, such as the water supply system for Paris.

A significant factor in the operation of the French construction industry, possibly arising from this culture, is a much greater use of performance rather than prescriptive procedures and the use of a bidding process in which engineers and contractors can submit alternate designs for projects. This situation differs from the U.S. situation and encourages companies to establish research and development departments to develop and support innovations in design and construction that may give them a competitive edge. The effectiveness of these procedures is most apparent for large projects and public works activities.

There are five major construction companies in France that can undertake very large projects and have the capability to provide the financing, design, construction, and guarantees for such construction. General construction activity is divided up among a large number of smaller companies that may also engage in design-build activities. However, these smaller companies are more dependent upon government research laboratories for new developments, or may use the services of private research and development laboratories such as the Centre Expérimental de Recherche et D'Études du Bâtiment et des Travaux Publics (CEBTP) for development of innovations and for quality assurance.

As a result of the greater concentration on performance, the French construction industry is not as heavily regulated as in the U.S. Another reason for reduction of regulation is that most construction in France is warranted. For most civil engineering work, including housing, the legal warranty is ten years. Warranties of up to 50 years for large public works projects and nine to fourteen years for road pavements are technical aims only, and do not have legal value. For smaller projects and smaller contractors, the insurance industry plays an important role, both in providing backing for contractors who must warranty their work and in setting rates for systems and components which have or have not been subject to a



Construction of a bridge along the TGV North using a movable modular deck forming system.

review and approval process. Owners provide additional fees to cover these warranties and seem quite willing to do so. A house or apartment is typically warranted for ten years and national performance needs are established for most construction components and processes.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

The makeup of the French construction industry parallels that in the U.S., with many small, and several large, contractors. However, France is more top heavy than the U.S., with seven of Europe's largest 26 contractors. Several French companies visited have American subsidiaries that do a significant amount of work in the U.S. and have access to the latest U.S. technologies.

The construction industry is esteemed at the national government level and is prominently represented in several ministries. The government recognizes construction's importance to the national economy and strives to keep it active. For example, the national government has funded many large, high-profile projects such as the Pompidou Center, le Musée d'Orsay, and La Cité de la Villette. However, even with this support, the domestic market alone is not sufficient to maintain the entire French construction industry. As a result, domestic work is highly competitive and the government encourages the bigger firms to compete in international markets. In that competition they have been very successful, with one-third of the construction industry's earnings coming from exports.

Construction jobs in France are generally awarded on a competitive basis. For larger projects, government regulations require that the bidding process or submission of design-build proposals be open to foreign competition. Although most construction contracts are still awarded on the basis of lowest bid, there is a strong movement toward what is called the best bid rather than simply the lowest bid. The best bid can involve a number of factors other than price and can consider the quality of the technical proposal, time required for construction, track record of the company submitting the bid, and other factors.

On public projects, bids to supply products must typically include a product description, method of use, price, information from laboratory studies and experimentation, and data from completed projects.

In the highway directorate, SETRA, evaluations of proposals for new processes are performed in three stages: (1) small test sections; (2) an experimental demonstration using a job site; and (3) a technical demonstration using an actual job site. The cost of the evaluations for these three stages is provided by the government. The final technical evaluation is an economic demonstration job site where the innovative process is placed in competition with standard materials.

The use of this process has not led to large amounts of litigation as is often the case in the U.S. where awards are often challenged. The best bid process may involve prequalification of bidders for a particular project.

A non-litigious legal environment prevails in French construction. The relaxed attitude brought about by warranties allows builders to innovate without the fear of unlimited liability. Risks are shared jointly by the owner and contractor and



Photo courtesy, Ministry for Public Works, Transport and Tourism

The French government recognizes the impact roads and other infrastructure projects have on the economy, and supports the implementation of state-of-the-art technology on such projects.

when disputes do arise, arbitration is the normal course of action. Various professional construction societies have established an effective arbitration structure to settle disagreements before litigation is used. Also, if the performance of a new technology is the subject of disagreement, the technical review boards approving the innovation are held responsible.

Environmental impacts related to civil engineering activities are not as important as in the U.S. The CERF team observed that there were not many environmental regulations for construction except for roads where an environmental impact statement was required. There seemed to be an awareness in France of a need to give more emphasis to this area and to include environmental protection in the list of future priorities for innovation.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

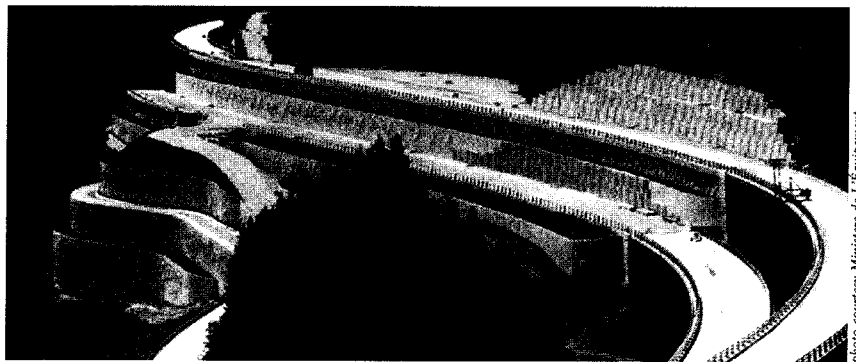
There is considerable R&D cooperation between the public and private sectors in France. A strong example of this cooperation is seen in road design and construction. Many major contractors have their own technical departments and laboratories for the development of construction innovations and for quality control. Government laboratories have specialized equipment for testing and results are made available to construction companies. This leads to greater cooperation between government and industry.

Private industry may also make arrangements to use government facilities. Industry pays for the use of the facilities and may also send researchers, who are educating themselves, to a government facility to learn procedures or to participate in research or approval programs. Intellectual property rights become similar to those in the U.S. when public funds have been used in the program.

It is not necessary for contractors to have their own research laboratory or technical team, but it helps to assure that new procedures and products receive quick approval.

The driving force for innovations is sometimes technical and sometimes economic. The innovation could be a better quality product at the same price or the same quality product at a better price. Engineering research needs are developed and managed by private organizations such as the Association Française pour la Normalisation (AFNOR) or by government institutions.

CNISF plays a consulting role on major national research programs, as well as in establishing national technical guidelines and standards. The Civil Engineering Committee sponsors conferences on civil engineering research needs and on the technical, economic, and environmental aspects of development. Standards in France are developed and managed by private organizations under the auspices of the Ministry for Industry. Those standards are guidelines only, but have been made compulsory by law for all national and local public contracts; if desired, they can also be made compulsory



New CCIS technologies such as this interlocking terracing system can be evaluated under an "Innovation Charter" developed by the French Highway Administration. Approved proprietary technologies are protected from use by other contractors for a period of time specified by the charter.

Photo courtesy Ministère de L'Équipement

for private work. There are national codes in many areas; however, for some activities, such as tunneling, there are no national regulations, and an appropriate committee provide codes, standards, and guidelines.

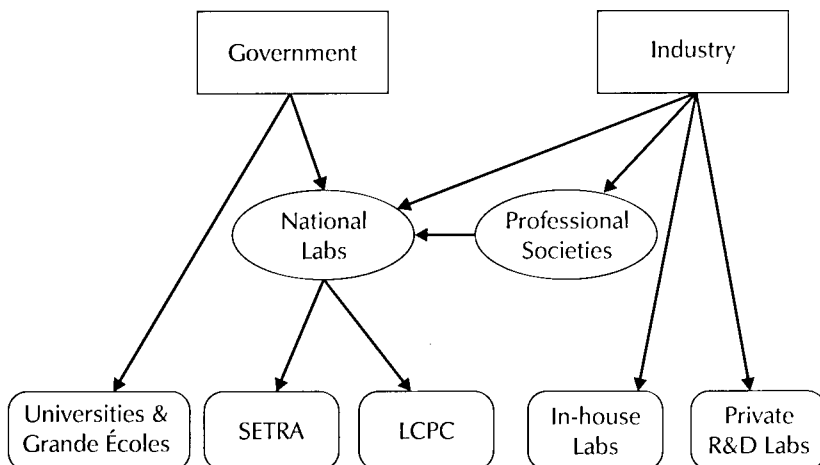
One major problem in this field is adapting French specifications to EC standards. Therefore, a strong effort is being made to separate technical aspects, which will be dealt with in standards, and contractual aspects dealt with in codes. The new ISO 9000 standards present problems for CNISF which must decide which groups should provide the interface and what the mixture between areas should be.

Several ministries oversee CCIS research and development in France. Among these ministries are the Ministry of Equipment, Housing and Transport (which includes the Directorate for Roads, of which SETRA, the Road and Highway Engineering Department and LCPC, the Central Public Works Research Laboratory are part); the Directorate for Housing (CSTB, RILEM, and IABSE); the Ministry for Research and Technology; the Ministry for Industry; and the Ministry for Education.

Each ministry undergoes an annual budget preparation using a bottom-up procedure. Program plans include individual organizational programs and special national schemes. Programs for civil engineering include Construction and Architecture, Urban Problems, and Transport. One special civil engineering research project is GRECO, a geotechnical program covering basic and applied research with a funding level of about US\$3-4 million. That research funding is shared among government laboratories, government-owned companies, and private firms. National projects fall under an organization known as IREX, the Institute for Experimental Research in Civil Engineering.

Each agency identifies subjects for innovation. The subjects are identified by committees within the agency or directorate and several are selected as priorities for the directorate. For example, in the highway directorate, the priorities for 1992 were technologies for reducing corrosion, use of local materials, technologies for tack coatings, and technologies for reducing rutting. The 1993 priorities include easing traffic during construction, environmental protection, and recycling of waste materials. The monies for research are supplemented by monies for implementation of that innovation in practice.

FIGURE E-1
French CCIS R&D Process



An important problem which France has addressed is how to speed the acceptance of new innovations in civil engineering practice. These innovations can be new materials or products, construction systems, design approaches, equipment or any other aspects of CCIS. The French government has developed a system in which reference committees are established to evaluate innovations and recommend ways to implement those new technologies. An innovation that has been subjected to a reference committee evaluation and approval provides assurance to anyone proposing the use of the innovation and promotes use of the new innovation. These reference committees receive offers from local governments to apply the innovation in practice with help of money from

the committee. The local government receives publicity for its activities and assurance of quality work. Through this procedure, the acceptance time for an innovative technology is greatly reduced.

The government is heavily involved in construction R&D. It is the main supporter of research at universities and also administers the well-funded National Laboratories, which do basic, strategic, and applied research. Over 20 professional societies related to civil engineering also help the industry. A schematic of the French construction R&D process is presented in Figure E-1.

The accompanying charts display relative efforts in construction R&D in France. Figure E-2 compares the CCIS R&D investment levels of government and industry, and Figure E-3 shows the relative amount of research work performed by academia, government, and industry. Construction research is a poor relation to overall research in France. While the government invests large amounts of money in its main laboratories (CSTB and LCPC), still only about 0.11 percent of the French industry's total turnover is invested in research.

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

Large firms in France maintain their competitive position by investing in innovation and through the formation of joint partnerships. Through innovation they are able to win projects through the "best bid" process. An example of a private sector firm is the Dumez company, which is a division of the large utility company Lyonnaise des Eaux. Dumez has constructed many large projects, including over 300 to 400 structures. Some notable projects were the TGV South in 1989, the TGV Atlantic in 1991, and the TGV North, which is currently under construction.

Dumez maintains research laboratories to support its design and construction activities. One of its largest activities is numerical mathematical modeling. All analyses are performed in-house. Dumez interacts closely with organizations such as SETRA and collects information on ongoing research from published sources. Although the internal research activity might seem substantial, most of the effort is to support proposed or ongoing projects, and the amount of company money going into research is less than one percent of its gross turnover. Dumez does not perform much basic research.

There are not many firms in France that are able to take on large jobs. However, France has seven of the major contractors in Europe [the number in parenthesis is the company's ranking within Europe relative to turnover in 1989]: Bouygues (1), SGE (4), Dumez (8), SAE (9), Spie Batignoles (10), GTM (15), and Fogerolle (26). Each firm has its areas of expertise. Large jobs in France (over a certain monetary level) must be open to bids from all over Europe. However, as their rankings show, French firms compete successfully all over Europe.

For the Normandy Bridge, which for a while will be the longest cable-stayed bridge in the world, Dumez proposed the winning design, which was different in concept to the "official" design prepared by SETRA (the highway agency). As explained, previous bidders are not obligated to use the official concept. The Dumez design was carried out in-house using linear elastic finite element analysis. The innovation was a combined use of concrete and steel for the deck. The actual construction is a joint venture with Bouygues and Campenon Bernard furnishing concrete work with

FIGURE E-2
CCIS R&D funding—France

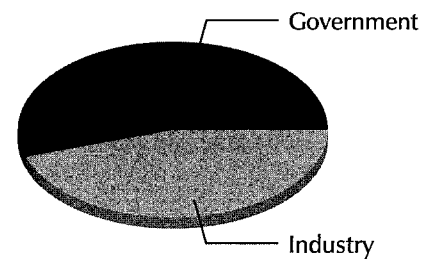
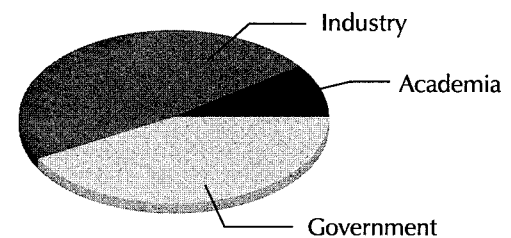


FIGURE E-3
CCIS R&D performers—France



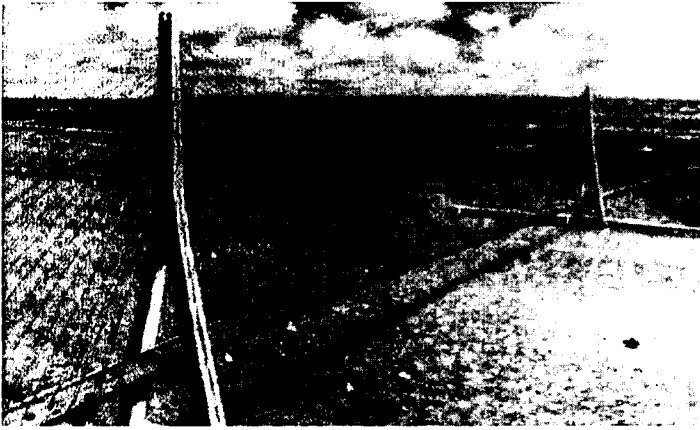


photo courtesy N.F.R.A. and Civil Engineering magazine

Artist's rendering of completed Normandy Bridge, which will be the longest cable-stayed bridge in the world when completed in late 1994.

Freyssinet as a subcontractor, and metal fabrication furnished by Monberg & Thorsen, a Danish firm. About two-thirds of the cost of the construction is being performed by French firms.

Smaller construction firms make use of private research and development laboratories. For example, CEBTP (Center for Buildings and Public Works Research) was created in 1933 and currently has seven regional centers. CEBTP operates as a private company both in France and overseas, and provides services to contractors and government agencies. The scope of CEBTP activities is wide, covering research, development, engineering tests, inspection, and design engineering services. Research accounts for only 25 percent of its activities. Thus, in an American context, CEBTP would be a combination of

organizations such as CTL (Construction Technology Laboratories), Wiss Janey, Elstner & Assoc., various private testing companies (e.g. Pittsburgh Testing), and a few other organizations which exist but are not integrated in the U.S.

Within CEBTP the departments cover testing procedures, materials, geomechanics, structures, roads, security and control, acoustics, and inspection. It appears that the organization can respond to any area in which it sees a need and can develop funding. Clearly, the French construction industry is willing to utilize the critical mass provided by CEBTP to provide research, development, inspection, and other services for which it would be difficult to maintain in-house laboratories.

CEBTP has well-equipped laboratories with adequate space, which have been constructed to meet contractors' needs. One area receiving increasing emphasis involves non-destructive measurement and assessment procedures for pavements. CEBTP has been developing several assessment approaches using techniques such as impact wave propagation.

The current flagship of CEBTP's evaluation equipment is the MT15 Curviameter test vehicle. This vehicle can make "real time" measurements of pavement profiles and surface temperatures. The profile is measured with a moving chain that is synchronized to run along the road without slipping. The chain is located on the side of a specially-designed truck that can apply double wheel loads of 80 to 130 KN. The chain also contains a series of geophones that can dynamically measure, to a high level of accuracy, their elevation. The geophones are arranged along the chain so that an elevation measurement can be obtained before, at, and behind the applied load. This procedure provides the deflection profile of the pavement under the applied wheel loading. The data is recorded using an on-board computer and a variety of analyses can be carried out using the data. The test vehicle can be operated at speeds up to 40 mph and can measure 40 to 80 miles of road each day. Calibration of the sensors on the vehicle can be carried out in the field and is not a time-consuming operation. The cost of the test vehicle is around US\$1 million and three or four are in service in Europe.

Other CEBTP laboratories concentrate on inspection and evaluation procedures. They can design and manufacture special test equipment. A test procedure for evaluating piles, and in particular, cast-in-place piles, was observed to be well-developed and in general use. Equipment involving remote collection of data was being developed and seemed innovative. However, an ultrasonic test unit which

CEBTP was building appeared to be very much in the development phase compared to commercial units now on the market in several countries at a reasonable price.

Other large private research institutes providing services to industry are CERIB (Center for Studies and Research in Manufactured Concrete Products), CETIAB (Technical Center for HVAC manufacturers), and CTICM (Technical Center for Steelwork Construction).

3. CCIS R&D AND TECHNOLOGY TRENDS

The primary emphasis of CCIS R&D in France is oriented toward the short-term introduction of new technologies and innovations in construction. The various mechanisms which the French have established to promote introduction of new technology innovations are very successful and have resulted in reducing the time-span for introduction of new innovations to a fraction of the norm in the U.S. A relatively smaller emphasis is given to basic research in CCIS, as much of the basic research information is freely available from countries such as the U.S. However, the government is also recognizing the limitations of that approach and assisting with the construction of research facilities for the Grand École.

3.1 R&D DRIVERS AND ACTIVITIES

France has its own unique set of driving factors acting on the construction industry. As in Figure E-4, the EC and contract delivery methods are influencing many European countries, but other drivers such as government directives and the devastating winter of 1964 are more unique to French construction R&D than to Europe in general. The descriptions that follow briefly describe each of these primary R&D drivers.

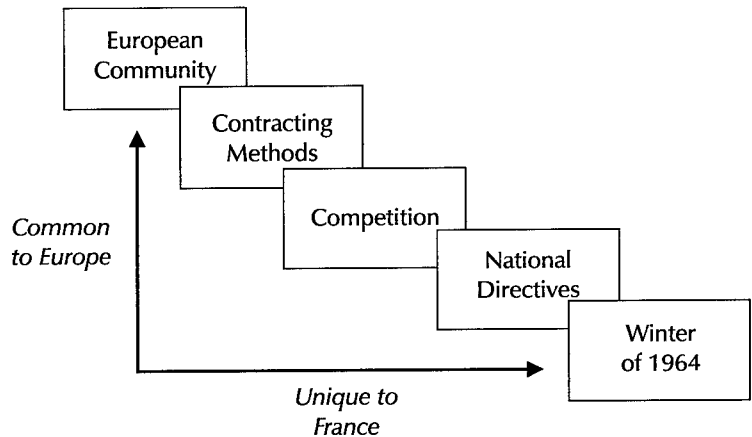
European Community

The Ministry of Equipment, Housing, and Transport allocates special funding to contractors on EC-sponsored projects. New common standards will soon be enacted which will impact the French systems. For instance, maximum permissible axle and vehicle loads will vary from current national regulations. For the European road system the maximum axle and vehicle loads will be 12.7 metric tons and 48.4 metric tons, respectively, while the corresponding French loads are 14.3 metric tons and 38.5 metric tons, respectively. Also, solid and hazardous waste levels must eventually meet EC standards. Surprisingly though, these latter areas are not driving current research to the degree that might be expected, due to a lack of agreement on EC standards in several critical areas.

Contracting Methods

Best bid and performance specifications probably do more to encourage R&D than any other single item. Best bidding allows contractors to submit alternatives that may not have the lowest initial cost, but recover the difference in future facility costs. Life cycle characteristics such as operation and maintenance, durability, construction safety, and performance are considered when comparing proposals. One contractor estimated that only fifteen percent of its contracts were

FIGURE E-4
CCIS R&D Drivers—France



Product quality, safety, and life cycle costs are avenues other than price on which French contractors compete. This high-technology approach makes French contractors effective outside their domestic market.

based on the best overall bid, but anticipated more of this type. Performance specifications result in guaranteed or warranted work by the contractor. This procedure motivates the contractor to ensure the facility will satisfy requirements not only during the final construction inspections, but more importantly, several years later. This procedure effectively screens smaller or less stable firms from bidding on large public projects because they are unable to secure the necessary warranty insurance.

Competition

The construction market is so competitive within France that the large contractors have expanded into international markets. To compete on a much broader scale, where their labor wages may not be the lowest, contractors must find other ways to enhance their proposals. Product quality, safety, and life cycle costs are avenues other than price on which French contractors compete. This high-technology approach makes French contractors effective outside their domestic market.

Domestic competition drives contractors to innovate to the same degree. To get on the pre-qualified bid list, contractors must show the technical expertise to handle complex projects properly. Without adequate technical skills and a proactive approach to technology implementation, contractors can be shut out from bidding.

National Directives

National directives and large publicly-sponsored "National Projects" drive much construction R&D. For example, the national highway directorate identifies, as described in Section 2.4, R&D priorities for each year. Even while upcoming EC directives favor a shift from public to private financing of large projects, France activity continues to remain publicly-oriented. Three-quarters of all CCIS work is performed for the public sector and most large, high-profile projects are funded by the government.

Winter Of 1964

The winter of 1964 did much to change France's management of its roads and highways. Two-thirds of the roads were damaged during the extreme weather of that year. As a consequence, highway administrators today have an orientation toward repairing pavements before distress appears. This has spurred considerable R&D activity in pavement monitoring systems, repair methods, and durable materials.

3.2 CONSTRUCTION MATERIALS

French contractors are recognized as major innovators in the area of construction materials, particularly for pavements. Typical advances are a high-performance surface dressing called Novachip developed by Screg Routes, a subsidiary of the Bouygues Group, for surface dressing of asphalt pavements, and a high-performance reactive powder concrete with compressive strengths of 800 MPa (100 ksi), developed again by the Bouygues Group. Growing fibers in the concrete mix was another technology that Bouygues said it had developed. Other contractor research groups actively involved in construction materials research are GTM-Entrepose in steel welding and tunneling, Saint Gobain in glass, and Lafarge Coppee in cements.

Construction materials are considered to be an area of vital concern and both government and private organizations are conducting research activities. Primary emphasis in the agencies visited was on cementitious and composite materials, materials for road construction, and better understanding soils as a construction material.

One example of private investment in materials research is the work carried out by Bouygues on high-performance cements and concretes. Cement and concrete research has been conducted at Bouygues since the 1980s. As a result of its concentration on high-performance cements and concretes, Bouygues is routinely using 60 to 100 MPa concrete in bridges and buildings. Concretes with strengths of 300 MPa have also been produced using densified systems containing homogeneously arranged ultra-fine particles. These concretes have been used for non-structural applications such as flooring and storage barrels for nuclear waste. Current research has developed high-performance concrete (HPC) with strengths of up to 800 MPa (about 112,000 psi) using reactive powders.

Because of the great concern about the ductility of HPC concretes, Bouygues has also researched increasing the ductility by growing fibers in the cement matrix. It has found reactive powder concretes that have, with the addition of steel fibers, energy absorptions of 40,000 Joules/m³ and flexural strengths of 100 MPa. By contrast, ordinary concrete only absorbs 100 Joules/m³ and has flexural strengths of 4 MPa. The material is very dense with a 37 Å porosity. Bouygues feels that it may be able to reach a level of 20 Å maximum pore size. This low level of porosity, and resulting low level of permeability, should greatly increase the durability of these concretes and greatly reduce the risk of reinforcing steel corrosion in high-chloride environments.

Plans are to promote industrial production of new materials. The French are a participant in the EC's BRITE project for which the EC provides 50 percent funding. The Danish and Spanish want to produce materials on-site on an industrial scale. Plans are to start with a 250 MPa material first. The HPC material is made from crushed silica sand, silica fume and no other aggregate. The resulting material is called "powder concrete." A water-cement ratio of 0.35 to 0.47 is used with the ratio computed on (cement + silica fume). The material has very good abrasion resistance.

The use of HPC requires considerably more attention to design to obtain the proper benefits and performance of the material. Its use also requires much better training of designers and constructors to assure proper tolerances, quality control, placement, and post-placement treatment. An early HPC form of this material was used for the defense arch. In this case the material was pumped 400 meters. A reduced size aggregate was used, along with the lowest possible water/cement ratio and both compression and thermal curing.

Curing under pressure and the use of high temperatures are important for obtaining the maximum benefits from the properties of HPC concrete. The following figures were given:

	<u>20 °C</u>	<u>40 °C</u>	<u>250 °C</u>
with pressure	260 MPa	400 MPa	800 MPa
without pressure	200 MPa	250 MPa	Not Available

Experiments have shown that this material can be used for small and medium-sized prefabricated elements and for panels to resist projectiles. The steel fiber

The use of high-performance concrete requires considerably more attention to design to obtain the proper benefits and performance of the material. Its use also requires much better training of designers and constructors to assure proper tolerances, quality control, placement, and post-placement treatment.



used in this mix was a 3mm long stainless steel microfiber. The following figures were given for the composite concrete with self-growing fibers:

	<u>20 °C</u>	<u>40 °C</u>	<u>250 °C</u>
with pressure	50 MPa	70 MPa	100 MPa
without pressure	25 MPa	30 MPa	40 MPa

Again, this product is currently being considered for prefabricated concrete elements.

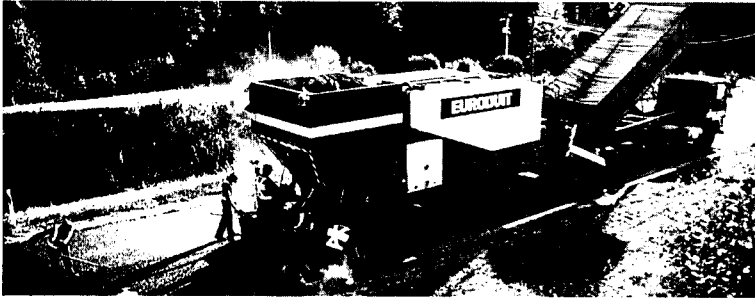
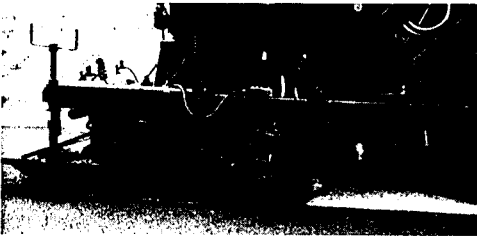


Photo courtesy of Screg-Route Internationale Routiere

Novachip is a layer of hot pre-coated chippings for waterproofing pavement. Above: Chips are spread and laid in one pass on a thick layer of modified binder. Below: Simultaneous spreading of binder and chippings ensure cohesion and excellent bonding to the road.



Another innovation developed by Screg-Routes is Novachip, a process for surface coating of roads. This process, which involved both the development of the material properties and the application equipment, is finding considerable acceptance in Europe. The French innovators explained they had difficulty introducing Novachip in the U.S. in 1992, when they sent one machine to the U.S. for demonstrations. Those demonstrations, in three different southern states, were a technical success, but Screg was not able to develop any orders for the machine and its process. All they achieved was requests for more demonstration projects in three

northern states. Screg attributed its difficulties to the absence of something similar to the Innovation Charters that exist in France, as well as the fragmented nature of highway activities in the U.S.

Another high-priority area is the recycling or reuse of construction materials. One goal is to eventually achieve a 90 percent recycling rate in areas such as road construction.

No research or development activity related to steel construction was observed, although there are many examples of innovative steel construction by French companies reported in the technical literature. GTM-Entrepose was not visited, but is active in that area.

One National Project for 1992 is to develop a French system of roller-compacted concrete. Another is a study to increase the use of sand concretes, particularly for rehabilitation of the infrastructure.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

The French are active in computer-aided design/computer-aided engineering (CAD/CAE). National building regulations are being maintained and updated on CD-ROM, and France's numerical modeling of driven piles is state of the art.

Information is viewed as an important resource for the construction community. Government policy is to make a strong effort to assure that information is readily available and accessible. All of the French building regulations have been placed on a CD-ROM that can be purchased by anyone; the cost is less than US\$3,000 for the original disk and about US\$600 for updates. Similar activities are underway to make information, codes, and regulations in other areas readily available at very modest cost.

Industrialized techniques and product engineering are two of seven thematic lines of action chosen for civil engineering research by the Ministry of Equipment, Housing, and Transport (MELTM) in 1993. For instance, a National Project called ITELOS developed tele-surveillance methods to continually monitor major structures such as dams, tunnels, bridges, and power plants. Bouygues uses an interactive system with a graphical interface that allows a close, step-by-step, monitoring of construction.

The development and evaluation of construction equipment is considered to be a vital activity of some government directorates. For example, under the Directorate for Roads, a part of MELTM, a laboratory is maintained for the study and development of highway-related equipment. The team observed work underway focused on assessing state-of-the-art equipment with both laboratory and field studies. Problems of safety were of particular concern.

No work on applications of robotics to road construction or on the possible application of manufacturing research to construction problems were observed. However, CSTB's Sophia-Antipolis Laboratory is active in research on the mobility and operation of on-site robots, with the purpose of developing enabling technologies for future robotic devices. Current high unemployment in construction does not encourage research in robotics because such automation could put additional people out of work.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

The building sector of civil engineering is represented on the technical level by CSTIB. That organization is more than 45 years old and is funded by the state and through its own commercial activities. Three specific areas of concern were discussed with CSTIB: (a) *Why do innovations occur in the building sector?*, (b) *The nature of innovation*, and (c) *Procedures for fostering innovation and implementing innovations*. CSTIB positions on these issues are as follows:

(a) *Why do innovations occur in the building sector?*

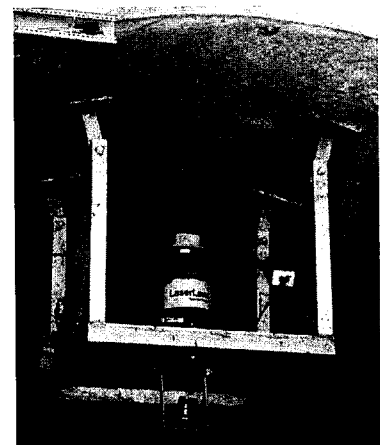
One driving force comes from regulations. An example was the development of new energy regulations in 1974, in 1983, and again in 1988. These regulations led to many innovations in products and design. Examples of innovations in response to these regulations include higher efficiency appliances and heating systems, and improved performance of thermal envelopes on buildings.

Another driving force are the wishes, demands, or behavior of occupants of buildings. Many innovations are stimulated by the desires of building occupants.

Manufacturers also create innovations to protect or extend markets. They must modify products, produce cheaper products, provide better performance, and develop entirely new products.

(b) *The nature of innovation*

Developments in the building sector relate mainly to materials and performance of materials, including items such as window frames, slabs, protection of the environment, use of substitute materials, communication, use of computers to replace people in design or manufacturing processes, and computer-aided design and drawing.



ITELOS, a French tele-surveillance system, provides constant monitoring of construction site conditions.

The development and evaluation of construction equipment is considered to be a vital activity of some government directorates.

(c) Procedures for fostering and implementing innovation

A number of activities are used to develop a climate which encourages innovations and their implementation. One is a strong effort to make information readily available to the entire community. An example of this is placing all French building regulations on CD-ROM. The general policy is to make information available at a minimum cost.

3.5 HIGHWAY AND RAIL SYSTEMS

Construction and transportation systems infrastructure is receiving much attention as extensive rehabilitation efforts swing into gear. Highway and airfield pavements, bridges, tunnels, subsurface investigation, and monitoring and measuring devices are all areas of emphasis. For example, the "MT 15

Curviameter" pavement profiler developed by CEBTP can give accurate pavement surface profiles at highway speeds.

The policy in France is that there should not be any potholes in its roads. That policy evolved from France's experience in the "Winter of 1964." In keeping with this policy, careful attention is paid to initial construction and an aggressive program of nondestructive assessment is used to maintain the roads. It appeared that the goals they set are being realized.



photo, courtesy Ministère de l'Équipement

The Channel Tunnel utilizes tunneling technology developed under a French "National Project."

French developments in high-speed rail transportation have attracted worldwide attention. The TGV system is being expanded and will soon provide high-speed service to all major areas of France. Work is nearing completion on the Channel Tunnel to provide a rail link between France and England. The Channel Tunnel was a major engineering project and represents a significant engineering achievement for both the French and British civil engineering communities (see box, pages 23–24).

At Screg-Routes, the main reasons to innovate were stated to be the development of better or more economical solutions than traditional solutions, and to improve the firm's image in society's eyes. Innovation is also necessary in France to enter a market where a firm has not been before. Innovation also motivates employees and improves profits by allowing the firm more flexibility to negotiate prices. It was emphasized that innovation also takes time and requires promotion. For Novachip, for example, it took five years from concept until a Technical Assessment was granted for general application in 1992. Screg-Routes also emphasized that government cooperation in innovation is essential for support of research, assisting in implementation, and sharing liability risks.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

There was only limited discussion of French geotechnical systems. Among the 1992 National Projects is a US\$4 million budget for a five-year research project on soil nailing that includes full-scale tests on walls loaded to failure, centrifuge tests, pull-out tests, and monitoring tests of instrumental structures.

Another National Project involves the development of pressurized shield techniques for tunneling in soft ground and aquifers. A number of sites throughout France were used for these studies between 1985 and 1990. The budget was US\$5.5 million. Included were studies of shield steering techniques and control of surface settlements.

Environmental and urban engineering are important R&D activities. Work is being conducted on safety, natural risks and disasters, water and noise pollution, vibration, and solid waste.

3.7 WATER AND SEWAGE SYSTEMS

The team visit did not include exposure to water and sewage system design and construction activities in France. However, team members are aware that the French have done a great deal of work in these areas. The problem is particularly acute in many French cities, such as Paris, where many components of the water and sewage systems are 100 to 150 years old. The assessment and repair of systems containing a mix of components of vastly differing ages present a real challenge. Innovative repair techniques, such as the insertion of various types of liners, are in use and are being improved upon.

In Paris, water distribution has been approached as a "system." Sensors have been installed to provide real-time information to help control of the system. The French are advanced users of microtunneling techniques for construction of new facilities and for upgrading existing facilities.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

4.1 ROLE OF GOVERNMENT

There are a number of strategies which the French government is using to encourage research and innovation in the construction industry. One motivation behind these strategies is a cooperative government/business relationship, based on national objectives to sell French technology worldwide.

On a central government level, basic and strategic research is performed by Conseil Nationale de la Recherche (CNRS) and its various laboratories. CNRS is an arm of the Ministry of Research and Technology, and therefore has little to do with construction. CNRS receives about 30 percent of France's budget for fundamental research, which totals about 2.5 percent of GNP. The Atomic Energy Agency receives about 20 percent of that same budget.

Under the CNRS, however, a number of priority areas have been established for which a broad-scale effort is felt to be needed. One example in civil engineering is the GRECO program. GRECO is supported by the Ministries of Research and Technology, Equipment and Transportation, and Education. This large program is concerned with development of new materials related to concrete soils and rocks, and problems of developing new numerical modeling for those materials. At the present time there are about 300 researchers participating in the project. Subjects include geocomposites, interactions, discontinuities, dynamics, and validation of computer code. The budget for the program is around US\$6.5 million per year. There is participation from a number of universities and government laboratories.

Screg-Routes also emphasized that government cooperation in innovation is essential for support of research, assisting in implementation, and taking liability risks.



The team observed a number of conditions conducive to the implement of new technologies in France, including:

- Activities of the technical societies or associations
- Government policies that encourage innovation for practical application
- Use of processes such as Innovation Charters to speed the acceptance and introduction of innovations
- An apparent willingness of both the government and private owners to share in risks associated with innovations through the issuance of technical assessments and information notes
- A low level of litigation in the construction industry associated with the introduction of innovations.

Within this atmosphere, individual companies are willing to propose new designs and to provide the warranties which are expected with these designs in France.

For industry innovation activities related to special themes such as defined in National Projects, the MELTM provides 50–70 percent of financing for exploratory and feasibility studies, 70–90 percent for project promotion operations, 15–20 percent for research, and 30–50 percent for application and dissemination actions.

Clearly, the bidding and contracting procedures now used for some projects in France provide a much more friendly climate for introduction of innovation than is the case in the U.S. Furthermore, based on their success, these procedures are receiving wider use in France.

4.2 ROLE OF INDUSTRY

The system of encouraging a design-build approach and the expectation of warranties or guarantees on construction provide incentives for industry to experiment with and invest in innovation. In addition, the system is set up to reward innovation without undue risk for the innovators. As a result, most larger construction firms maintain some type of research, development, and quality assurance operations. As mentioned above, this activity not only provides opportunities to introduce new products, but also maintains the image of the company.

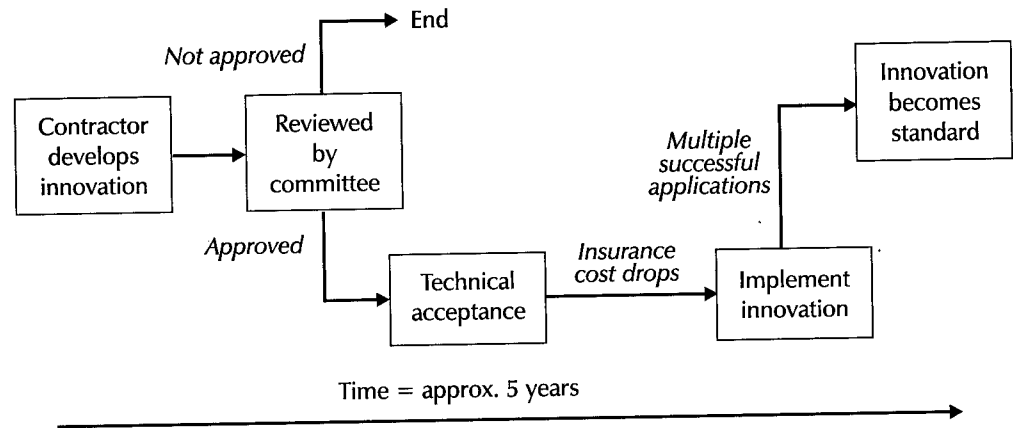
Innovation by the construction industry is encouraged in France through a system of risk sharing. This involves a willingness on the part of owners to pay additional fees to cover insurance and other costs associated with new innovations, as well as an effort on the part of the government to protect the developers of innovations so they can reap the benefits of their efforts.

On the other hand, most of the innovation and development is short-term in nature and is oriented either toward the development of designs the industry is trying to sell or to the execution of a particular project.

French construction contractors and manufacturers perform more R&D than most of their European counterparts. Two government-directed mechanisms facilitate industry commitment to innovation: “Technical Assessments” and “Innovation Charters.” To a lesser extent, “Information Notes” (i.e., formal, documented means for incorporating constructability ideas into national codes and standards) also support innovation.

Technical Assessments (Figure E-5) are used to encourage advancements in both the building construction and transportation sectors. By having the new technology (material, process, or equipment) approved by an independent committee of experts, much red tape can be avoided. This "stamp of approval" shortens the turnaround time for new technologies. Technical Assessments for buildings are issued by CSTB and for transportation by SETRA.

FIGURE E-5
Building Technical Assessment Process



For buildings, a Bureau of Control provides inspection on-site, in addition to inspection of drawings, proposed construction methods, etc. The cost of these procedures is covered by a fee assessed on the building owner and is in addition to architectural and engineering fees. An appraisal is required for each project even if the construction system and materials are the same as have previously been in use. This provides a revenue source to evaluate new products, systems, and construction methods. This control system has been in use in France since 1986.

Insurance companies play a major role in the acceptance of innovations. Insurance fees are less if proper inspection and appraisal procedures have been followed. As many projects involve a design-build procedure with a warranty, the ability to obtain insurance coverage is vital both for the builder and the owner. Insurance fees for products and processes on which Technical Assessments have been made are *half* those for products and processes on which those appraisals have not been made.

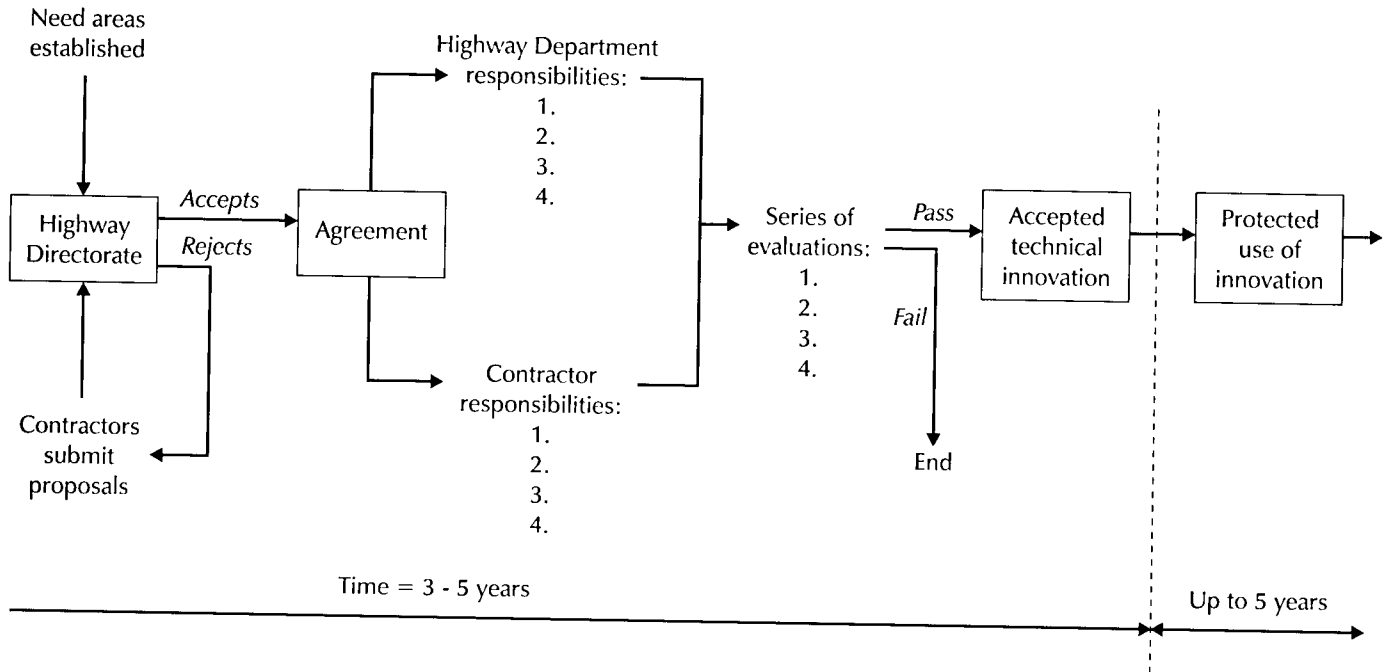
Upon proper review and acceptance of an advancement, insurance costs to warranty a project are lowered. The government also grants proprietary rights to the developing company for a limited time (usually three to five years) to allow the recouping of initial investments and to encourage further innovations. These sole source contracts can in turn be used as a bargaining tool to negotiate contracts with owners instead of going through the formal bidding process.

In the transportation sector, technical assessments are used to obtain endorsement by the government through issuance of the assessment by SETRA and to overcome the resistance of some county engineers to the use of the product or process.

Another interesting feature of the French system is the use of an Innovation Charter. An Innovation Charter works as depicted in Figure E-6. Innovation Charters were initiated in 1991 and are unique to the MELTM, having started with SETRA. These charters allow contractors to team with government research institutes when the contractor does not possess the technical expertise or equipment to develop the innovation itself. This agreement spells out responsibilities of the private firm and the public agency. In 1992, fifteen of the 35 proposals made to MELTM were accepted for evaluation.

FIGURE E-6

Innovation Charter Process



The Innovation Charter can be applied to products, processes, or equipment that are not covered by existing standards or that do not have a Technical Appraisal certificate. The use of the Innovation Charter allows the bureaucracy to be bypassed, encouraging private sector investment in developing innovations. Under the Innovation Charter, a company can propose its findings for an innovation for approval. Overall, these charters allow the government to move toward a performance basis for construction using the best bid—not the lowest bid—and to encourage innovation.

The Innovation Charter describes conditions for acceptance of full-scale innovations, such as a road-subgrade system, which does not fit current codes or standards. Innovations may receive approval on the basis of an already used and successful approach. References and documentation for six to eight installations are used to show that an innovation meets needs and satisfies requirements. In other cases, the manufacturer or appropriate group may submit data, test results, and other information that could be used for the evaluation of an innovation. The approval time for an innovation submitted for a commission evaluation is about two years. Approvals are issued by a commission which is set up by an appropriate government department such as the MELTM or the Ministry of Industry, etc., or through the technical associations. Each commission is chaired by a civil servant, but members of the commission may come from many different organizations.

Approval work for building-related items is done by CSTIB, which establishes committees to respond to approval requests for specific building areas. At the present time, there are about seventeen committees that are active in the building area. A problem exists for an entrepreneur who does not have funds for a Technical Assessment. There are no specific provisions for these cases except that the price of assessments of innovations are kept low and actual costs are not charged for the use of government facilities. There is a flat fee of about

US\$15,000 for one approval. In general, this system does not result in liability for the parties involved. However, CSTIB could be liable in extreme cases when an approved innovation fails. However, if an examination shows that the provisions for manufacture or use are not followed, then CSTIB would not be liable.

Some examples of innovations which have been recently approved by CSTIB are:

- Colored plastics for window units (four processes for coloring have been approved)
- Glazing (thermopane-type systems)
- Structural glazing

A list of approvals which have been made is published in CSTIB bulletins. In principle, the approval procedure has been adopted at the European level for the EC.

4.3 ROLE OF ACADEMIA

Academia does not play a strong role in research and development in France. The Grand École and universities have been mainly teaching institutions, and in many cases the faculty members primarily have part-time appointments.

From Figure E-3, it is apparent that university research is not a significant contributor to CCIS research in France. The French government is seeking to alleviate this shortcoming by sponsoring focused basic research programs at universities. For example, the École Nationale des Ponts et Chaussées (ENPC) from 1947 to 1980 was entirely a teaching institution and did no research; however, in the 1980s it established new facilities outside of Paris with considerable research capabilities. Similarly, the École Polytechnic has also established research facilities on its new campus outside of Paris. Its research arm was originally LCPC, which in 1947 was made a separate entity with an applied research agenda. Doctoral students accepted for studies at an academic institution are free to pursue their studies at any facility of that institution or a government or industry laboratory. Doctoral graduates, domestic and foreign, have no difficulty finding employment, and government support for those students rose 67 percent between 1990 and 1993. That rate of increase was greater than any other rate of increase for state support in the same three-year period.

Anyone graduating from high school can go to a university; this leads to overcrowded and underfunded universities. Few students entering a university graduate, so only about 10 percent of French civil engineers are university graduates. The majority (70 percent) are Grand Écoles graduates, with the remainder comprised of National Institute graduates. Grand Écoles are difficult to enter and only accept 10 percent of applicants; however, nearly all who matriculate graduate.

ENPC is a very old school which graduates the majority of civil engineers in France. The school presently consists of three major divisions: the Department of Education, the Department for Continuing Studies, and the Department of Research. The institution graduates about 150 undergraduate equivalents per year and about 80 students in specialized post-graduate studies.

ENPC has a heavy reliance on persons outside the institution for teaching. Most of the teaching is done by outside staff. In the academic section of the school, only



In some cases EC procedures have adopted French approaches, such as the use of the Innovation Charter.

department chairmen are full-time and they often do not teach. A professor is in charge of a discipline area and is selected by the Board of the institution. The professor, in turn, selects his assistants. A professor appointment is for a maximum of eighteen years, of which the first three years are a trial period and the remaining are up to three appointments of five years each. After eighteen years, the professor must step down or move to another area. Currently there are 305 teachers, of which 29 are professors, 200 are occasional lecturers, and the remainder are assistants. All of these participate on a part-time basis. However, the ENPC's research centers do have some full-time staff. Research center support comes 60 percent from the university budget and 40 percent from outside contracts.

Degrees are offered in Construction of Buildings, Industrial Engineering, Economics and Management, Civil Engineering Construction, Materials Science, Mathematics, and Information Networks. The academic program is organized in departments which include Civil Engineering and Construction, Mechanical Engineering, Industrial Engineering, Transportation and Environment, Economics and Social Science, and Material Science.

Only about 10 percent of the students at the ENPC are women. It also appears that there is no professional engineering license in France.

The Continuing Education Program of ENPC is quite extensive. It provides 200 short seminars for off-the-job training, which involve about 5,000 participants each year. ENPC also offers programs outside of France.

4.4 FINANCIAL INCENTIVES

As discussed in Section 4.1., there are many financial incentives related to the introduction of construction innovations in France. One of these is the competitive environment in which the introduction of innovations may also be related to the procurement of new projects. This is particularly true when a performance approach and contracting procedures can encourage design-build approaches.

4.5 LIABILITY CONSIDERATIONS

As has been previously discussed, there is relatively little litigation associated with construction projects in France. Liability problems are greatly reduced due to the risk sharing procedures that are used for managing innovation programs and the clearer responsibility for liability which exists in a performance specification and design-build approach to projects.

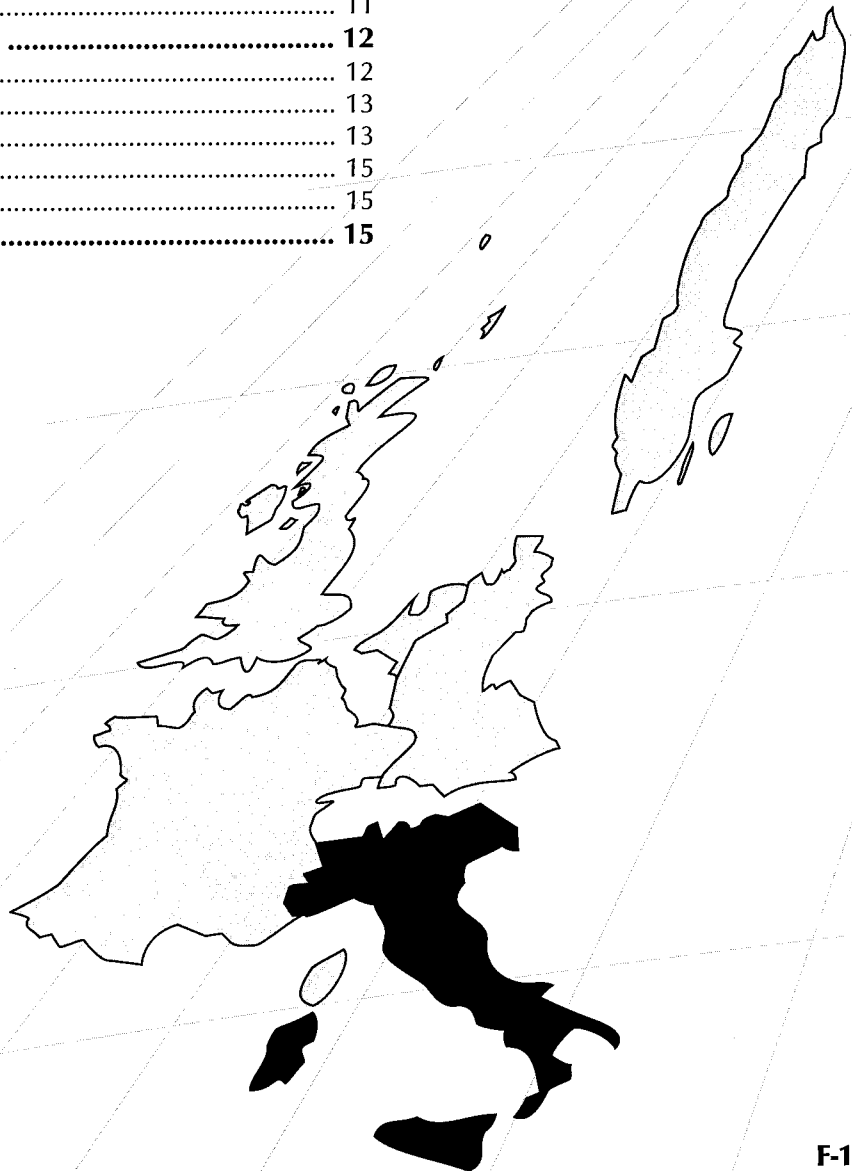
5. RESPONSE TO EUROPEAN COMMUNITY

The EC does not appear to be causing any major disruption or changes in the construction industry in France. In some cases EC procedures have adopted French approaches, such as the use of the Innovation Charter. The one area in which EC agreement has not yet been fully developed is in environmental issues, and clearly that lack of agreement was affecting R&D in environmental issues in France.

Appendix F

ITALY

1. Summary	3
2. Context for CCIS Technology	3
2.1 Historical Perspective	3
2.2 Economic, Regulatory, and Cultural Environments	4
2.3 Legal and Competitive Environments	4
2.4 R&D and Technology Innovation Policies	5
2.5 Private Sector Technology Partnerships	6
3. CCIS R&D and Technology Trends	7
3.1 R&D Drivers and Activities	8
3.2 Construction Materials	8
3.3 Computer-aided Design, Automation, and Information Systems	9
3.4 Building Construction and Systems	10
3.5 Highway and Rail Systems	11
3.6 Environmental and Geotechnical Systems	11
4. Strategies for Innovation Implementation	12
4.1 Role of Government	12
4.2 Role of Industry	13
4.3 Role of Academia	13
4.4 Financial Incentives	15
4.5 Liability Considerations	15
5. Response to European Community	15



Appendix F

ITALY

1. SUMMARY

Italy's construction industry is far more fragmented than that of other European countries. Neither the central government nor industry seems prepared to take the lead in CCIS. Industry and academia do not coordinate research. Perhaps the root cause for this disunion stems from cultural conditions. Most constructors are taught the trade by their family predecessors and do not hold doctorate degrees. Likewise, academia is not encouraged to cultivate ties with industry leaders.

Specialty contractors in Italy are usually small and highly skilled. In order to undertake larger projects, the industry develops partnerships. Informal partnering between specialty contractors helps communicate best methods and constructability ideas.

Contractors believe that international competition resulting from EC agreements will not significantly impact their public works projects. They are confident their skills are superior and that the Italian government will continue to grant them contracts over foreign bidders. This belief may prove true, because much of the work in Italy involves repairs of historical town centers and few companies outside of Italy have the knowledge necessary to properly repair such monuments.

The data used in this section is based on the observations made while touring numerous Italian construction agencies. Most were public institutions or professional societies. Little time was available to observe the implementation of technologies at construction sites. The organizations visited during the trip to Italy are listed in Table F-1.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 HISTORICAL PERSPECTIVE

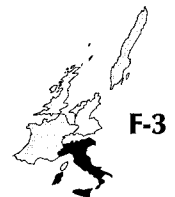
Italy is a mountainous country susceptible to earthquakes, and as a large peninsula it has an extensive coastline. Italy measures 300,000 km² in area and has 50 million inhabitants. A warm Mediterranean climate prevails over much of its area. Only the extreme north can be cold. Its location in the eastern part of the EC and historic ties result in it also having close economic ties to a different group of trade partners than the remainder of the EC.

In Italy there have been significant construction projects for several thousand years. Major roads and aqueducts were constructed in Roman times and parts of these facilities still survive and are in use today. Numerous historical buildings and other

TABLE F-1
Participating Organizations—Italy

Organization*	Identifier	Type of Facility
American Society of Civil Engineers Italy International Group	ASCE-IIG	professional society
Central Institute For Building Industrialization & Technology	ICITE	government research
Coliseum rehabilitation		construction site
Consiglio Superiore Dei Lavori Pubblici	CSLP	government agency
European Laboratory for Structural Assessment	ELSA	EC joint research center
Institute for Safety Technology		government research
Istituto Sperimentale Modelli e Strutture	ISMES	private research
Italian Association of Contractors	ANCE	professional society
National Research Council	CNR	government research
Polytechnic Institute of Milan		university
Timber Research Institute		private research

* English translation of organization name provided, where available.



facilities date from centuries ago. There are more historic structures in Italy than in any other country in the world. Additionally, many notable civil engineering structures have been constructed recently, ranging from innovative dam designs to modern transportation systems. Thus, the construction industry in Italy has wide experience, ranging from maintenance and preservation of historic structures to the most modern construction.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

Although the Italian construction market is the fifth largest in the world, the industry has few large companies that compete directly with the industry leaders of France, Germany, and the U.K. Italian construction is characterized by many family-owned companies that willingly affiliate in joint ventures either within Italy or abroad to compete for large projects. There is also a very active construction equipment industry that provides support to the general construction industry and sells large amounts of specialized equipment abroad.

Eighty percent of Europe's historical monuments and buildings are in Italy. Maintaining and restoring these relics make up much of Italy's construction activity. Italian authorities can designate any structure older than 50 years as historic and prevent demolition.

Although Italy is faced with some very major environmental problems, such as those of Venice, very little mention was made by officials of construction projects related to such problems. While this may have been due to the small number of organizations visited, the general impression was that environmental issues were not nearly as important a factor in construction in Italy as they are in the U.S.

The construction industry is heavily regulated, not only by law but also by the weight of the bureaucracy and inflexibility of codes and standards. Structural requirements are dictated by the engineers and must be followed by the contractor. There is more flexibility with building insulation and fireproofing regulations, but in general contractors do not have much incentive to innovate except to maintain market share.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

During the time of the task force's visit, the Italian government, and particularly its Ministry of Public Works, was in turmoil since major bribery had recently been proven in the awarding of public works contracts. Understandably, government officials, such as the Consiglio Superiore Dei Lavori Pubblici (CSLP), were hesitant to discuss procedures for awarding public works contracts. Clearly those scandals may have some long-term impacts on the Italian construction industry.

The CSLP advises the Ministry of Public Works on the awarding of construction contracts in a reactive mode, but is pro-active with regard to codes and standard technical specifications for contracting. Through the latter the CSLP can control whether any innovation goes forward and they can request background information they deem necessary. These codes and standards are developed at the national level and have the force of law.

Liability is more of a problem in Italy than in the other five nations visited. Construction disputes often result in litigation and there is no culture of settling such disputes by arbitration. Italy has a major problem with contractors bidding a job too low and then walking away and leaving the job uncompleted after it

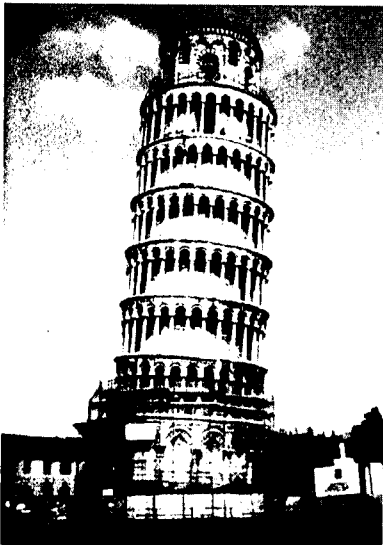


Photo courtesy ISMEA, S.p.A.

A truck-mounted static penetrometer (lower right) provides geotechnical site investigation at the Tower of Pisa.

reaches a certain stage of development. Legal actions take so long they are seldom effective in such cases.

There is strong competition among medium-sized contractors and consortia of small specialty firms for jobs. That competition and the culture result in private firms investing little in R&D.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

None of the Italian construction-related ministries appears to have any well-defined innovation policy. The private sector appears to be more receptive to experimenting with innovation than government agencies. Most Italian contractors do not support R&D unless they can solicit outside support. Some partnerships are being formed to carry on EC projects. An example of such a project is on the use of aramid or non-conventional reinforcing for prestressed concrete elements. The motivation for this research is international competition from Japan and other countries. In recent years the National Research Council (CNR) has attempted to foster joint academia and industry research programs; however, those efforts have been largely unsuccessful.

Industry-wide integrated research efforts are rare in Italy. The government and industry work together on a selective basis, as does the government and academia. However, industry and academia are effectively discouraged from communicating by government funding and university administrative practices. The research programs of industry and academia are generally small and independent. Research is predominantly funded by the government or by manufacturers of equipment and components, not by contractors. Figures F-1 and F-2 display the relative current contributions of Italian academia, government, and industry to CCIS R&D. University faculty members must decide if they wish to be part-time or full-time faculty members. If full-time, they are expected to do research, receive a standard amount of support from the government for that research and do not indulge in consulting. If part-time, they receive two-thirds of their full-time salary from the government and usually establish their own consulting practices to provide the remainder. They do not receive government support for academic research. Most civil engineering faculty hold part-time university appointments.

None of the major R&D players in Italy had adequate leadership to effectively focus construction industry research. Academia performs studies according to individual interests, and except for CNR programs, that research is uncoordinated. For competitive reasons, industry prefers to develop methods privately and avoids collaborating with the universities. The government has a laissez-faire attitude, providing neither aid nor incentive for CCIS R&D. As illustrated in Figure F-3, because of a lack of national leadership, the Italian "system" for CCIS R&D is effectively two separate systems.

FIGURE F-1
CCIS R&D Funders—Italy

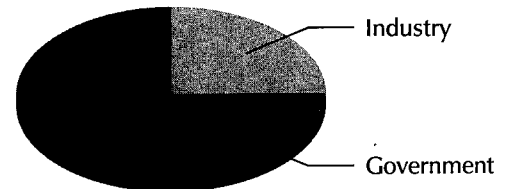


FIGURE F-2
CCIS R&D Performers—Italy

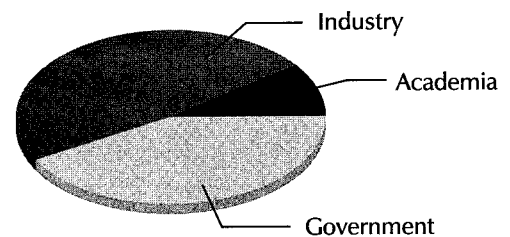
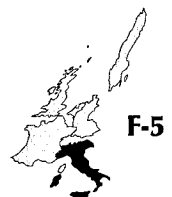
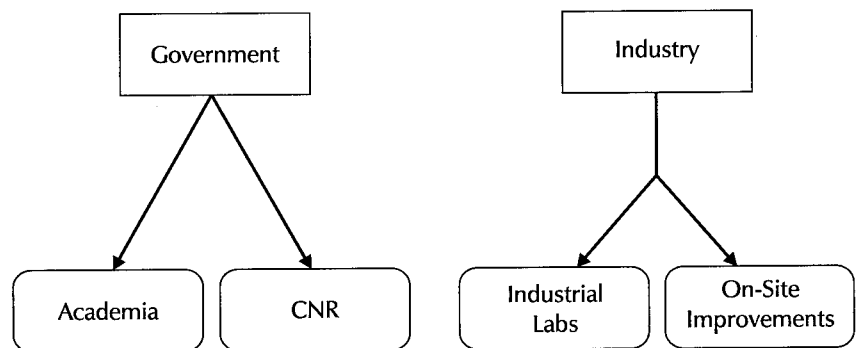


FIGURE F-3
CCIS R&D Infrastructure—Italy



There is one program the CNR initiated, the Building Goals-Oriented Research Program, that is ostensibly attempting to unite the research efforts of government, academia, and industry. This five-year program encourages coordinated work in three fields:

1. Process and procedures
2. Design innovation
3. Quality and technical innovation.

These three fields are the primary concerns of builders, design professionals, and materials and equipment suppliers, respectively. Unfortunately, industry participation in that program has been negligible. Between its initiation in 1989 and 1993, this program developed primarily into a government/academia effort.

It was observed that codes and standards were largely formulated by the academic community and by government officials with relatively little involvement of designers, constructors, or industry. Italian codes and standards have the weight of law and are rigidly enforced with little opportunity for innovation. The situation is further complicated by the lack of any effective innovation approval mechanism. The net result is a negative incentive for innovation unless threatened by foreign competition or unless short-term economic gain is apparent. The formation of the EC is having some impact, since the EC utilizes innovation charters and similar mechanisms to encourage innovation.

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

Italy has one noted research organization providing significant support to selected sectors of the construction industry. ISMES, S.p.A. (Istituto Sperimentale Modelli e Strutture) was originally established to provide construction research services to the private hydroelectric industry. Since then, the electric power industry has become nationalized, but ISMES operates as a private laboratory. Presently about 70 percent of its funding comes from electric power companies, 20 percent from contractors, and the balance from a variety of sources. The laboratory specializes in structural and geotechnical mechanics. To some extent the interest of the laboratory reflects the needs of the nuclear power industry of a decade ago. Interest in those needs has subsided in Italy, as it has in most other countries.

The ISMES laboratory is headquartered at Bergamo, Italy. The company has a working capital of US\$20 million, does about US\$80 million worth of business each year, and has about 550 employees. The lab is involved in applied research and development, engineering software, environmental protection and land use, land management, geotechnical engineering and site investigation, dams, power generation installations, structural and civil engineering works, historical buildings and monuments, measuring and monitoring systems, industrial and mechanical engineering, and scientific-technical education and training.

To carry on its activities the company is organized into departments, design centers and an engineering and coordination structure, as follows:

Departments

- Geophysics
- Surveying and testing of structures and plants
- Mathematical modeling
- Testing of materials



Seismic vulnerability test using the ISMES main shaking table on a 1:2 scale model of a brick masonry building.

- Instrumentation and monitoring systems
- Environmental protection and land management

Design Centers

- Civil and industrial engineering
- Geotechnical engineering and environmental studies

Engineering Coordination Structure

- Coordinators of multi-disciplinary services
- Project management
- Quality assurance system

Clearly, the company now covers a larger segment of the construction industry than when it was first established.

ISMES laboratories are impressive, with good equipment and a competent staff. The facilities for large structural testing include shaking tables for earthquake studies and a geotechnical centrifuge. There are, at present, enough projects to utilize the shaking table only about 30 percent of the time. The centrifuge is booked most of the time. There is also a large software activity which has developed programs such as FIESTA. While those programs are competent, they are not up to the state of technology in the U.S. However, ISMES does provide a very useful service in supplying computer programs which are tailored for specific applications, such as monitoring and control.

In the geotechnical area, ISMES has developed a series of cone penetrometers and down hole measuring devices which are in wide use.

ISMES views certification and project management as areas of activity that will grow in importance in the future. Most of their activities are of an applied nature in support of specific construction projects. They have little basic research activity.

Overall, ISMES is a very advanced and capable research establishment with many excellent programs. Thus Italian contractors are willing to utilize ISMES to conduct research and development programs which they are not able to undertake themselves although the primary users of ISMES' services are still designers and constructors of major projects such as dams and power stations.

Except for ISMES, little was observed in the way of private sector partnerships for CCIS R&D.

3. CCIS R&D AND TECHNOLOGY TRENDS

R&D trends in Italy appear to progress along a series of seemingly unrelated paths. The university system strongly influences the subjects studied and the conduct of research. This research path is primarily supported by the government and the coupling to industry and applications is loose and vague. The situation is very much like the situation in the U.S. except that there is not as much emphasis on basic research as in the U.S. The Italian construction industry does not interact significantly with academia nor conduct much research, except when it must develop information in support of a project or maintain a competitive position—such as when threatened by foreign competitors. Government laboratories conduct some research, but most research is oriented toward product certifications or in support of specific projects. Some examples of innovative research in the private sector were observed with respect to specialized construction equipment development, which constitutes a significant foreign market for Italy.

The Italian construction industry does not interact significantly with academia nor conduct much research, except when it must develop information in support of a project or maintain a competitive position—such as when threatened by foreign competitors.

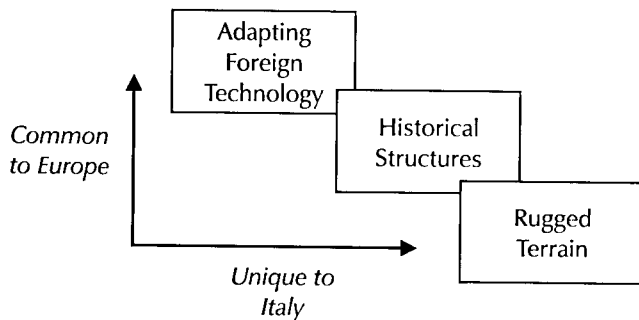


Little activity was observed in the areas of robotics applied to construction, or in bringing new manufacturing technologies into construction. No examples were observed of research related to environmental impacts or problems of construction, although consideration of such impacts is mandated for major projects.

3.1 R&D DRIVERS AND ACTIVITIES

Italy's construction industry is so fragmented that national drivers are difficult to identify. However, as shown in Figure F-4 the country's terrain, its wealth of historical structures, and the need to adapt foreign technology to Italian conditions appear to be the most significant drivers, all of which are somewhat unique to Italy. Unlike the other countries visited, EC unification is not predicted to have a major impact on Italian R&D activities. Contractors believe that owners will respect the Italian builders' expertise and will continue to grant them contracts in preference to competitors from other countries. A second general trend is the adaptation of other countries' construction technology to the Italian market. In particular, that practice has led to refinements in the precision of construction equipment or alternate ways of working. The only true driver is the need to maintain Italy's numerous historical monuments and structures. Repairing these sensitive relics forces contractors to develop and test best practices.

FIGURE F-4
CCIS R&D Drivers—Italy



Rugged Terrain

The challenge posed by mountainous terrain has resulted in contractors and equipment suppliers developing particularly effective techniques for constructing their infrastructure. Road, bridge, dam, and tunneling contractors are well versed at solving problems associated with this challenging topography.

Historical Structures

Sixty percent of Italy's construction resources are spent restoring and rehabilitating historical structures. While it would seem that such a large market would substantially drive R&D efforts, this is not the case. Very little research in the purest sense is spent on refining methods for evaluating structures. Rehabilitation procedures appeared to be very dependent on the best methods developed by highly skilled specialty contractors.

Adapting Foreign Technology

Italian builders have historically borrowed new technology from other countries and adapted it to their own market. The majority of contractors in Italy are small operations with neither the private nor the public support to conduct research and development on their own. Therefore, customizing foreign advancements is the only feasible alternative.

3.2 CONSTRUCTION MATERIALS

High-performance concrete and the development of aramid or non-conventional reinforcement for prestressed concrete elements were the main construction materials R&D activity discussed.



Full-scale dynamic characterization tests on structural parts of the Augustus Forum, Rome.

photo courtesy ISMEX, S.p.A.

Construction materials research is conducted at a number of locations in Italy. There are active research programs underway at universities with the major emphasis on masonry research, which is a very common construction material in Italy, and on concrete and steel. Most of this research appeared to be state of the art. The task force team observed particular concern for earthquake effects, a major consideration in Italy. The research on non-conventional reinforcing materials for ordinary or prestressed concrete is being performed with foreign partners and under EC sponsorship.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

In 1989 (CNR) started a series of Strategic Projects grouped under several major theme areas:

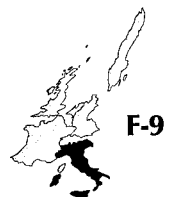
- Information technologies
- Environment and territory
- Advanced technologies
- Infrastructure and services
- Cultural themes

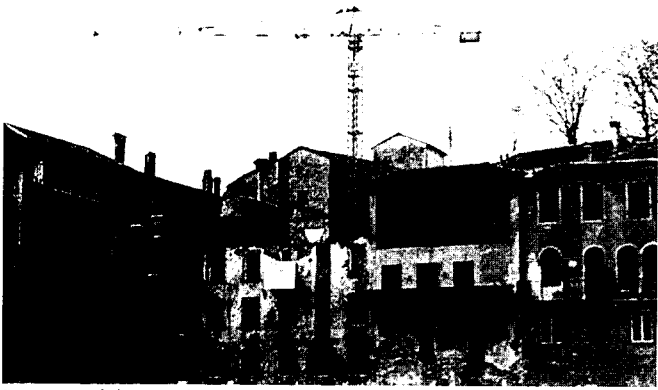
Within the information technologies theme area is a Building Goals-Oriented Research Program divided into three major programs concerning: *process and procedures*, *design innovation*, and *quality and technological innovation*. Within those programs much of the emphasis is on developing CAD, automation, and information systems aimed at enabling the Italian building industry to compete effectively in the EC.

Process and procedures aims at redefining (in terms of models and easily accessible computerized tools) the entire building process from contracting through management and financing. Thus, this element involves the primary concerns of the builder contractor. *Design innovation* aims at achieving advances in both design procedures, particularly in the area of information processing using CAD systems, and in the design content, particularly related to the functional, spatial, and technological model of certain advanced classes of buildings, such as intelligent buildings. Thus, this element concerns primarily the design professional. *Quality and technical innovation* aims at introducing building product and equipment innovations with appropriate quality control and operational effectiveness. Thus, this element concerns primarily product and process suppliers. The research in the Building Goals-Oriented Research Program is being conducted over five years at a cost of US\$82 million. Finally, there is a fourth area, called the "experiment," where the technologies developed will be used for building and testing a full-scale complex that includes a biomedical research institute, a scientific documentation center, and a building research institute.

Apart from this CNR activity, ISMES has developed state-of-the-art programs for mathematical modeling of dams and actively cooperates with the U.S. Army Corps of Engineers and Bureau of Reclamation in using this expertise in the U.S.

***The task force team
observed particular
concern for earthquake
effects, a major
consideration in Italy.***





Because of the need to work in close proximity to historic structures, Italian manufacturers produce a wide variety of specialized cranes.

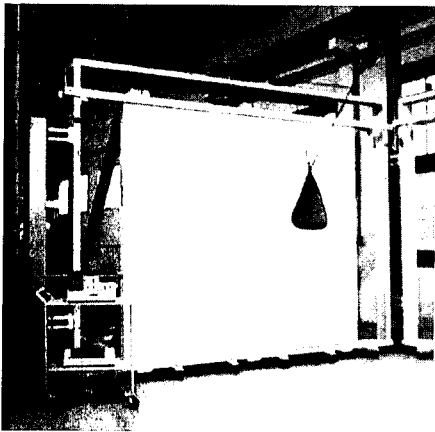
While architects and professional engineers are highly regarded in Italy, professional engineering societies did not exist until recently and there is little culture of cooperation between firms in bringing a product to market. Thus, there are few mechanisms for making available information on technological advances except by advertising. Universities utilize publications and workshops, like the U.S., but there is little communication between universities and industry.

Sale of specialty construction equipment abroad has been a major activity for Italian companies. Those companies carry on research in support of their product development. There did not, however, seem to be much activity in the area of robotics and automation applied to construction.

3.4 BUILDING CONSTRUCTION AND SYSTEMS

Most of the specialty building trades in Italy can be considered highly skilled. Especially fine work is accomplished in ceramics and tiles, masonry repair, waterproofing, carpeting, and concrete finishing. No specific law has to be satisfied to put a new material on the market and most businesses are small, so virtually none perform research.

The Central Institute for Building Industrialization and Technology (ICITE) is a government research institute that gives technical approvals for building products for the entire EC. It has a state-of-the-art large-scale structural materials testing facility. ICITE is one of 60 research institutes that operate under the National Research Council (CNR) funding from the national government. Its total budget is about US\$5.3 million and of this 80 percent comes from the national government and 20 percent comes from fees charged for testing and certification work. The institute has a staff of 70 people.



ICITE's experimental setup for the characterization of impacts on building components, up to real scale.

ICITE certifies nontraditional building materials and has been active in developing common European guidelines. There is participation by industry in establishing standards, but there is not much participation by architects and engineers because they appear unable to afford the time. However, public procurement is starting to be required or specified on a performance basis, and this action will result in more participation by architects and engineers. As Italian companies sell large amounts of materials and systems outside of the country, it is important that they conform to EC and the new ISO 9000 standards.

Research by ICITE is always based on products. There has been some interaction with universities; however, the universities are increasingly being forced into more teaching and theoretical research.

Technology transfer is considered to be a very important part of ICITE's programs, and it has had many discussions regarding the best way to achieve that transfer. However, such transfer is easier for ICITE than other organizations because it concentrates on *applied* research.

Over half of the construction activity in Italy concerns existing buildings. Thus, it might be expected that there would be a significant research program related to existing structures. While task force members were told that the primary research on existing buildings was for retrofit of historic structures, little activity was observed supporting this. Further, no mention was made of plans for future coordinated activities in that area. Literature furnished by ISMES showed pictures

of their evaluation of historical structures, but no mention of this was made during the team's visit to ISMES.

The government is interested in encouraging the recycling of old materials but there was no evidence of the research on recycling in the organizations visited. The areas of assessment, repair, retrofit, and recycling would seem to be important, but are not receiving adequate research attention in Italy.

A tour of ICITE laboratories showed that they were well equipped for the functions they perform. Most work involved certification and testing and there was some original work in the area of solar energy. The institute has sufficient insurance to cover the standards and certification work it oversees.

The Timber Research Institute was established in 1968 and then split into two institutes in 1981. One branch located in Florence is concerned with wood technology and products, and forestry operations excluding pulp and paper—these are the concerns of the second Institute. The Florence center has a staff of 22 persons, concerned mainly with wood structural elements, chip boards, plywood, connections, doors and windows, and similar products. They are also initiating work on gluelam beams and composite timber structures. Fire performance is a major concern, and they have test facilities for wood fire research. They are particularly concerned that Italian door and window products meet European standards, as this is a competitive market in which Italian firms have been successful. The Florence branch carries on about half of the wood preservative research of the country, and also has a responsibility for research related to furniture. Of particular concern are finishes and the various panels which are used in furniture. There is some outside support of research activities. However, funds from the outside support go to the central government and only 40 to 50 percent are returned to the institute. The policy on services to be provided by the Institute to industry is not clear, and there is confusion regarding how far the institute should go in providing these services. The institute views European standards as a mixed benefit.

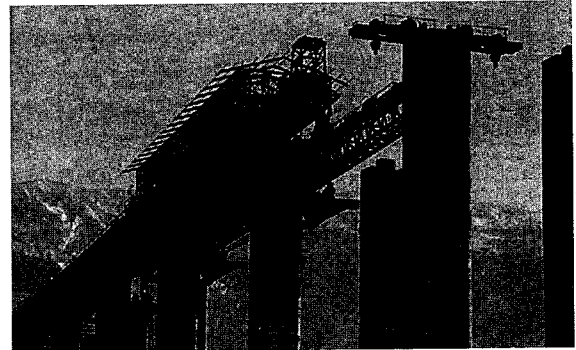


photo courtesy UConMESA

To meet the demands of a rugged terrain, Italian contractors frequently adapt the latest construction techniques from other countries, such as this self-launching decking system.

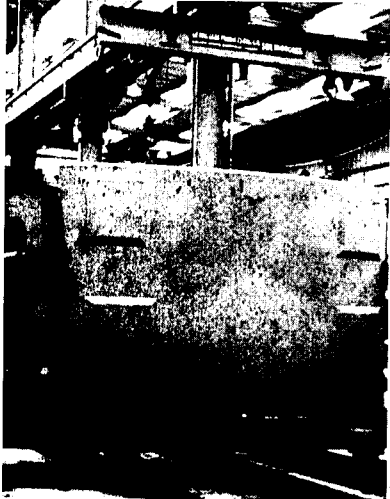
3.5 HIGHWAY AND RAIL SYSTEMS

The team received little information concerning transportation systems and their construction. As with all European countries there was considerable evidence of construction related to primary roads and public transportation systems. With respect to research, it did not appear development of innovations or mechanisms to accelerate the adoption of new innovations were much different for roads than for other areas of construction in Italy.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

The task force team had little discussion of environmental or geotechnical systems. For major construction projects, master plans must be approved by the Ministry of Environment before being submitted to the Ministry of Public Works (CSLP) for design and construction approval. A representative from one of the largest construction companies (Lodigiani, S.P.A.) described the company's difficulties in gaining acceptance of a railway ballast replacement system that could save significant money, especially for tunnels. The system is being used on a trial basis for about 100 meters on a National Rail Line and is being evaluated by ISMES. In this project, as in several other process improvements developed by the company, it





An Italian-made mold for production of precast tunnel segments for the Channel Tunnel.

has had to pay all development testing and validation costs. The government has not provided any help. For Italian transportation systems, if a firm can demonstrate improved performance by changing the project design, it may be able to get into a market that it could not have entered by the low-bid system. The authority controlling toll highways uses this provision frequently to introduce new products. However, it still requires testing of such a product, even if it has had a Technical Assessment by France's LCPC.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

It was observed that there were no well-defined policies in Italy to encourage construction innovation, particularly in the private sector, or to transfer new innovations into practice. Italy was observed to have one of the lowest levels of R&D activities in the six European countries visited.

4.1 ROLE OF GOVERNMENT

The Italian government is trying hard to establish an improved climate for innovation in the construction industry. However, efforts to involve the private sector in supporting R&D have been unsuccessful and most of the funding for R&D in construction is provided by the government.

The directions of construction industry R&D activities are determined primarily by three agencies: universities, CNR, and Istituto Mobiliare Italiano (IMI). Both universities and CNR receive their support through the Ministry of University, Science and Technology (MURST). IMI receives its support through an interministerial committee, CIPE. It is responsible for providing assistance in the form of loans or grants to industry for developing applied research through industrial projects implementing or experimenting with prototypes. Ministries involved in IMI include Public Works, Interior, Industry and Environmental as well as MURST.

Starting in 1983, CNR initiated a series of national projects, aimed at improving construction technology, and involving university researchers as well as researchers from government and industry. The aim was to place the construction industry at the same technological level as the microelectronics and chemical industries. In 1989 CNR replaced those projects with the Building Goals-Oriented Research Programs described in Section 3.3. The three intelligent buildings to be constructed as part of that project will serve as a test bench for the project as a whole. Of the total government monies allocated to this project, 10 percent was to go to research institutes of CNR, 12 percent to universities, and 78 percent to industry. Initially industry was to provide matching monies, but because of the cultural background in Italy, little industry support has materialized and most of the funding for the program is provided by the government.

Raising the level of construction technology is a national goal and receives attention at all the highest levels of government. This situation is quite different than in the U.S., where construction activities are fragmented among government agencies and do not receive centralized attention at the highest levels of government. Until 1993 public works jobs were awarded to the bidder with the bid closest to the average after elimination of the lowest bid. In 1993, procedures were altered to require acceptance of the lowest possible bid. EC Laws will accelerate acceptance of new contracting procedures that include best bid and

design-build provisions. However, in there has been some investigation of the legality of the design-build system, so use of design-build-maintain systems may be necessary.

Although one arm of the government is giving considerable attention to initiating construction-related research programs, other arms appear to be giving little attention to the problem of implementing new technologies. There is no "innovation charter" mechanism, such as exists in France, and the rigidity of codes and standards presents a formidable obstacle to potential innovators.

4.2 ROLE OF INDUSTRY

Many firms seek to license proprietary technology in order to obtain a competitive edge. A substantial portion of this technology comes from abroad.

Some individual firms engage in pilot demonstration projects to foster innovation. While the small size of most firms does not permit an in-house research establishment, many firms are willing to utilize government laboratories and private companies such as ISMES to obtain approvals for innovations.

4.3 ROLE OF ACADEMIA

There are a large number of engineering or technical universities in Italy and the number is growing. One of the leading schools is the Polytechnic Institute of Milan. That University is organized in two divisions: architecture and engineering. The current enrollment is about 10,000 in architecture and 15,000 in engineering.

The Polytechnic Institute of Milan started at the beginning of the century with architecture and engineering. Various engineering departments evolved, such as civil, mechanical, and aeronautical engineering. Currently the civil engineering department has 30 professors, seventeen associate Professors, and seventeen researchers (assistant professors). The faculty size is therefore comparable in size to that of the civil engineering departments at major U.S. universities.

As mentioned above, basic funding for university research comes from MURST. Those funds are given directly to each professor with very few strings attached. There is little obligation to carry out any research with those funds. As a result, some professors do as much research as possible, and some do little.

A larger source of funds comes from the CNR, an organization somewhat similar to the National Research Council of Canada. The CNR has an elaborate committee structure which decides on the distribution of funds. Committee members are elected to their positions. Professors present requests for support to the committees. CNR has established a set of national priorities and funding requests tend to focus on these areas. About 60 percent of the funds available are allocated toward national goals. Linking with other universities is encouraged. The research funds provided by the government have remained constant for several years, but appear to have a possibility of shrinking. The government is also encouraging partnering between university and industry for research, which up to now has been largely lacking. A comparison was made regarding the level of government research



photo courtesy ISMES, S.p.A.

Structural monitoring of the Brunelleschi dome of Santa Maria del Fiore, Florence, using system developed by ISMES.

funding going to the Polytechnic with the situation in other countries. For example, the University of Aachen (a similar institution in Germany) has about 60 percent public funding and 40 percent private funding. At the present time, Milan Polytech has about 95 percent public funding.

Currently, universities interact with practice primarily through codes. Most code writers in Europe are professors because consultants feel they cannot afford to donate the time required for such activity. Consequently, while Italian codes have the status of law, those codes also frequently lack input from the groups who are responsible for implementing them.

In the Structural Engineering Program at the Polytechnic Institute of Milan, approximately 30 percent of the funds come from private sources. At present the US\$1 million they receive are roughly divided among 30 percent for staff, 30 percent for the testing costs, and the remainder for equipment. There are 35 technicians in the laboratories paid for by the government.

Specialized numerical analyses for changing codes and for the CNR-Civil Protection Ministry are among the ongoing research performed at the Polytechnic Institute of Milan. Under the Civil Defense program there is a national group for defense against earthquakes. This group involves both geologists and structural engineers. One large activity is a program on earthquake effects on masonry structures, where a number of full-scale tests are being carried out. Another area involves structural engineering and earthquake zoning. These programs are funded at a level of about US\$2 million per year.

There are other technical universities in Naples, Rome, and Turin, which are about the same size as the program at Milan. Students must choose between a diploma (three years) or a university degree. Students can also earn a doctoral degree that involves three additional years of study beyond the five-year degree "laurea." Previously, most student academic support funds came from the government, and as a result tuition was very low. Now those funds are shrinking and tuition costs are rising.

There is also significant research activity in the Hydraulics Program. This program is equipped with flumes and water tunnels. A wind tunnel is shared with the Aeronautical Department. Research activities cover numerical modeling, turbulent flow, dynamic fluid forces, etc. Some of the problems students have been working on include water hammer in new materials (a highly nonlinear problem), regulation devices for stilling basins, pollution migration, computer studies of turbulence, hydraulic modeling, flow in porous media, sediment transport, and flood waves.

Some of the support for these programs comes from government agencies' strategic cooperative projects and from private companies. At the present time about 15–20 percent of funding comes from private sources.

The Milan Polytech makes a strong effort to achieve technology transfer of its research results. Methods used include publications, conferences and seminars, continuing education, and private contracts to present courses.

4.4 FINANCIAL INCENTIVES

Financial incentives for implementing innovation are mainly competition and the impact of the EC. As there are no established mechanisms to assure innovators that they can reap the rewards which might come from innovation, there is not much incentive to carry on innovations except to maintain a competitive position for a company. There are some tax breaks for energy conservative investment, but for little else.

4.5 LIABILITY CONSIDERATIONS

There are no special provisions to protect a firm if an innovation proves unsuccessful. In fact there are a number of disincentives. The innovator must pay for all product testing and a potential liability problem exists if an innovation does not work out. Thus, the major liability is placed on the innovator, and other parties are not willing to share in that risk.

5. RESPONSE TO EUROPEAN COMMUNITY

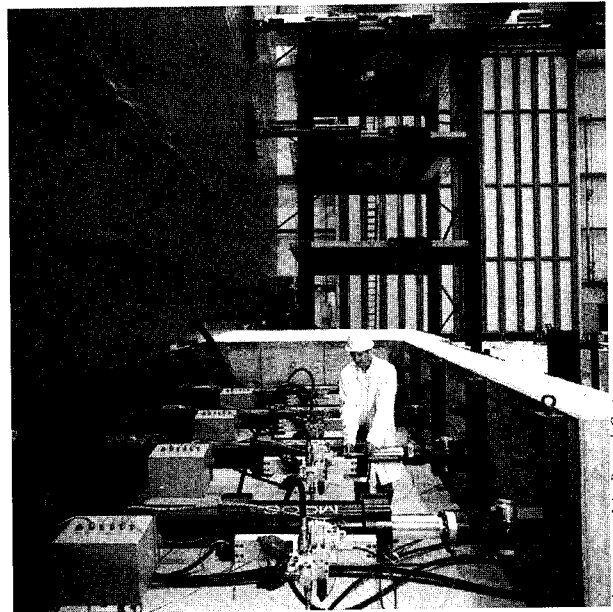
The formation of the EC is affecting the Italian construction industry in several ways. The government initiated the Building Goals-Oriented Research Program to ensure that the country could compete effectively in the EC market by taking a pro-active stance. This research program aims to assure that Italian-made building components will satisfy any new standards, and Italian-produced components can continue to supply markets in Europe. The larger construction companies are also participating in EC research projects such as BRITE, where 50 percent of the funding must be provided by private industry. Projects in which these companies are involved include joint ventures on maintenance of old walls, machinery for tunneling, and corrosion resistance of anchors.

There is also a major EC research facility located in Italy. The Joint Research Center of the Commission of the European Communities is supported by European Community funding and covers biology, chemistry, physics and most other scientific fields. In all, there are about 2,000 people working at the Joint Research Center (JRC). Security at the Center is a major concern.

Among the facilities at the JRC's Safety Technology Institute (STI) is the the European Laboratory for Structural Assessment (ELSA). ELSA represents 30 European Structural Mechanics laboratories and operates under a Human Capital and Mobility Program. This program is intended to allow smaller and less-developed participants access to large-scale testing facilities.

ELSA's centerpiece is a large reaction wall which is 16 meters high; at its base the test area is 21 meters wide and 25 meters long. The wall is four meters thick and has a five meter lip.

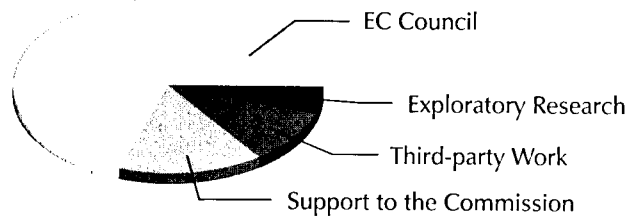
Instrumentation and controls are all state of the art, with full digital control and data acquisition. Designed to resist the force, typically several hundred tons, which is necessary to deform and seriously damage full-scale test models of structures, the



Setting up reaction wall hydraulic actuators for an R/C beam bending test at the European Laboratory for Structural Assessment (ELSA), part of the EC's Joint Research Center.

ELSA reaction-wall is one of the largest facilities of its type in the world, only exceeded in Japan. In addition to static and cyclic tests on large structures and components, the facility is equipped to perform tests utilizing the pseudo-dynamic (PSD) test technique which enables the simulation of earthquake loading of full-scale buildings. The Joint Center's large computational facilities are available to the laboratory.

FIGURE F-5
Work Performed at ELSA



The laboratory offers special capabilities which are not available in its member laboratories. The laboratory is not intended to compete with consultants, but instead support them for activities they could not undertake alone. Figure F-5 shows a relative comparison of the types of work performed at ELSA.

One of the laboratory's major concerns is how to encourage use of its research in practice. It is currently searching for new methods to accomplish that goal, as the laboratory does not have any organized marketing activity. Dissemination of information is left up to the individual researchers.

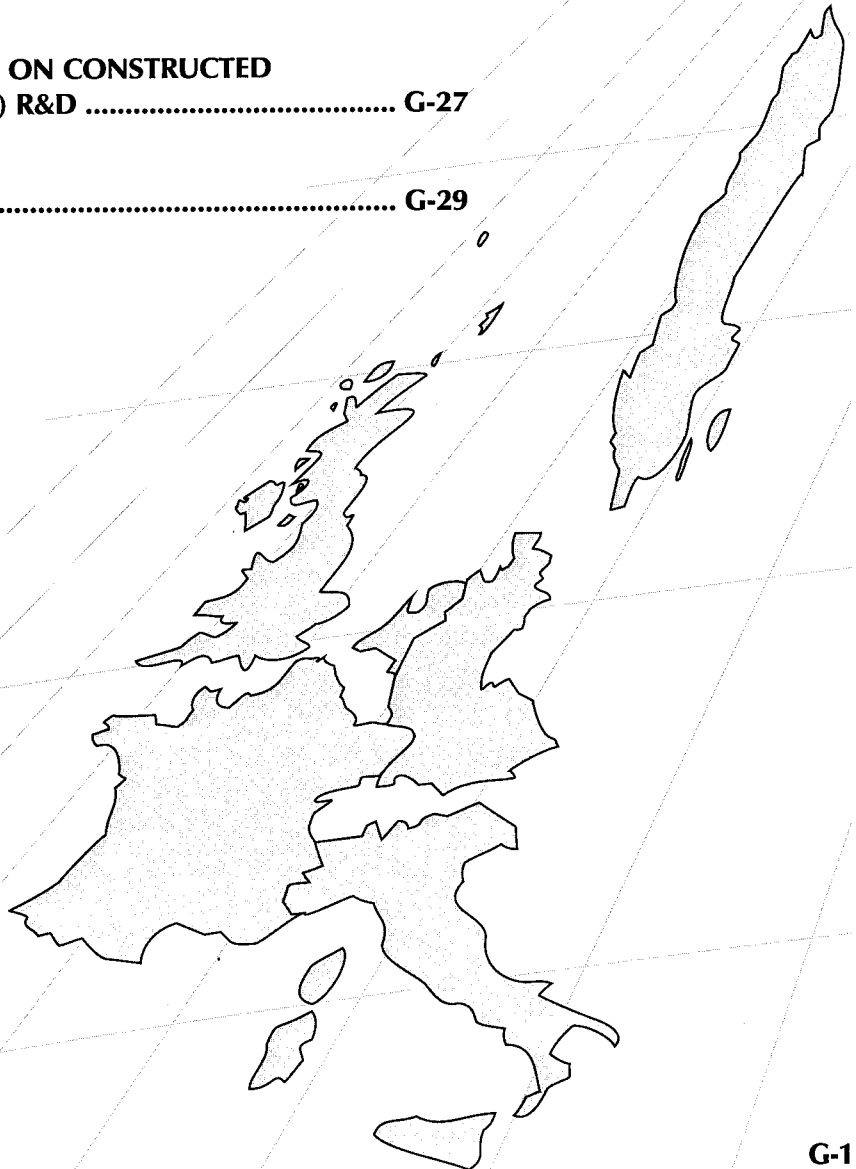
Projects which use the large reaction wall are determined by the European Association of Structural Mechanics Laboratories (EAMSL). Working groups define research activities. Major activities have been defined for reinforced concrete structures, composite steel-concrete structures, and masonry structures. Primary emphasis is on the use of the pseudo-dynamic method of testing. The sequence followed is to first carry out analytical and experimental studies of members and small assemblages. This helps to define large-scale test models. Large-scale models will be tested and information disseminated to the participating groups. Current plans include testing a three-story steel frame with reinforced concrete slabs, a four-story reinforced concrete frame, a three-story composite structure, an irregular building (with and without infill walls), and an irregular bridge structure.

The total budget for the Joint Center is approximately US\$250 million per year, with the budget for the mechanics institute about US\$45 million per year.

Appendix G

TASK FORCE TEAM MEMBER & TRIP LOGISTICAL INFORMATION

<i>Appendix G-1</i>	WESTERN EUROPE TASK FORCE TEAM STRUCTURE	G-3
<i>Appendix G-2</i>	BIOGRAPHIES OF WESTERN EUROPE TASK FORCE MEMBERS	G-5
<i>Appendix G-3</i>	PARTICIPATING EUROPEAN ORGANIZATIONS	G-11
<i>Appendix G-4</i>	TASK FORCE TEAM ITINERARIES	G-19
<i>Appendix G-5</i>	AGENDA FOR CERF'S BRUSSELS FORUM ON CONSTRUCTED CIVIL INFRASTRUCTURE SYSTEMS (CCIS) R&D	G-27
<i>Appendix G-6</i>	BRUSSELS FORUM ATTENDEES	G-29



Appendix G-1

WESTERN EUROPE TASK FORCE TEAM STRUCTURE

<i>Task Force Chairman/Coordinator</i>	Harvey M. Bernstein, President, Civil Engineering Research Foundation
<i>CERF Report Panel Chairman</i>	Neil Hawkins, Head of Civil Engineering Dept., University of Illinois
<i>WTEC/JTEC Report Panel Chairman</i>	Richard L. Tucker, Director, Construction Industry Institute, Univ. of Texas

TEAM A – UNITED KINGDOM & SWEDEN

TEAM A1

<i>Team A1 Leader</i>	Richard W. Karn, Senior Vice President, Greiner Engineering, Inc.
<i>CERF Panel Recorder</i>	Richard N. Wright, Director, Building and Fire Research Laboratory, National Institute of Standards and Technology
<i>WTEC/JTEC Panel Recorder</i>	Victor C. Li, Professor, University of Michigan
<i>Monitor/Sponsor</i>	Paul Herer, Sr. Advisor, National Science Foundation
<i>Task Force Members</i>	Balvant Rajani, National Research Council, Canada

TEAM A2

<i>Task Force Chair/Coordinator and Team A & A2 Leader</i>	Harvey M. Bernstein, President, Civil Engineering Research Foundation
<i>CERF Panel Recorder</i>	Andrew C. Lemer, President, The Matrix Group, Inc.
<i>WTEC/JTEC Panel Recorder</i>	J.L. (Jim) Harrison, Director, Fluor Daniel, Inc.
<i>Task Force Members</i>	William Roper, Director, U.S. Army Corps of Engineers F.H. (Bud) Griffis, Professor, National Center for Infrastructure Studies, Columbia University

TEAM B – GERMANY & NETHERLANDS

TEAM B1

<i>Team B1 Leader and WTEC/JTEC Panel Recorder</i>	Thomas J. Pasko, Jr., Director, Federal Highway Administrator
<i>CERF Panel Recorder</i>	K. Thirumalai, President, Science & Technology Institute, Inc.
<i>Task Force Members</i>	Michael Kavanagh, Senior Vice President, Montgomery Watson Americas William J. Palmer, Partner, Ernst & Young

TEAM B2

<i>Team B & B2 Leader</i>	Stephen C. Mitchell, Chairman, Lester B. Knight & Associates
<i>CERF Panel Recorder</i>	Kyle E. Schilling, Director, Institute for Water Resources
<i>WTEC/JTEC Panel Recorder</i>	Richard L. Tucker, Director, Construction Industry Institute, Univ. of Texas
<i>Task Force Members</i>	Guy Felio, National Research Council, Canada William Michael Lackey, Assistant Secretary, Kansas Department of Transportation

TEAM C - FRANCE & ITALY

TEAM C1

Team C & C1 Leader

CERF Panel Recorder

WTEC/JTEC Panel Recorder

Monitor/Sponsor

Task Force Member

Dean E. Stephan, President, Charles Pankow Builders, Ltd.

Neil Hawkins, Head of Civil Engineering Dept., University of Illinois

John Fisher, Director, ATLSS Engineering Research Center, Lehigh University

Ken Chong, Program Director, National Science Foundation

Glenn S. Tarbox, Vice President and Manager for Engineering & Construction Technology, Bechtel Corporation

TEAM C2

Team C2 Leader

CERF Panel Recorder

WTEC/JTEC Panel Recorder

Task Force Member

C. Leslie Weirson, Senior Vice President, CH2M Hill

Michael O'Connor, Chief of Infrastructure Laboratory, U.S. Army Construction Engineering Research Laboratories

Michael P. Gaus, Professor, State University of New York at Buffalo

Robin S. Godfrey, President, Scharf-Godfrey, Inc.

Appendix G-2

BIOGRAPHIES OF WESTERN EUROPE

TASK FORCE TEAM MEMBERS

Mr. Harvey M. Bernstein, President of the Civil Engineering Research Foundation (CERF), was brought on by the American Society of Civil Engineers (ASCE) in 1989 to establish CERF, its new research affiliate. Mr. Bernstein has published numerous reports and articles focusing on barriers to implementing innovative technologies in the design and construction industry. He organized a 1991 task force trip to Japan that resulted in the publication of the report *Transferring Innovation into Practice: Lessons from the Japanese Construction Industry*. For the past 25 years Mr. Bernstein has planned and managed a variety of research programs. He started his career with Goodkind & O'Dea on the design of bridges and highways, then shifted to structures R&D while working for Bell Helicopter Company and the Naval Ship Engineering Center. Prior to CERF, Mr. Bernstein was vice president of Applied Management Sciences and managed their energy and environmental consulting practice. Mr. Bernstein holds an M.B.A. from Loyola College, a M.S. in Engineering from Princeton University, and a B.S. in Civil Engineering from Newark College of Engineering (now New Jersey Institute of Technology).

Dr. Ken Chong is the Director of Structural Systems and Construction Processes at the National Science Foundation. He formulates and administers the U.S. policy and research/educational programs in structures, construction, materials, engineering mechanics, NDE, CAD and KBES. Dr. Chong has published over 100 refereed technical publications and co-authored many books including, *Elasticity in Engineering Mechanics and Approximate Solution Methods in Engineering Mechanics*. Prior to moving to NSF, he was six years as chairman of Structures/Solid Mechanics Group at the University of Wyoming for six years, where he had been the principal investigator of over a dozen federally funded research projects. Dr. Chong received a B.S. degree in Civil Engineering from Taiwan National Cheng Kung University, a M.S. in Structural Engineering from the University of Massachusetts and a M.S.E., M.A. and Ph.D. in Structures & Solid Mechanics from Princeton University.

Dr. Guy Felio is the Head of the Infrastructure Laboratory at the Institute for Research in Construction (IRC) of the National Research Council of Canada (NRCC). At IRC, his research focuses on soil-structure interaction problems for buried utilities, with special attention to diagnostic tools. In his prior experience, he was involved in pavement management, forensic analysis and geo-environmental studies. The Infrastructure Laboratory activities include research on surface and buried services, including frost damage to sidewalks and water mains, corrosion detection, and protection and the effects of trench reinstatement on surface and buried structures. He obtained his Ph.D. in Civil Engineering from Texas A&M University, his M. Eng. from Carleton University (Ottawa) and his B.A.Sc. from the University of Ottawa.

Dr. John W. Fisher, Director of the National Science Foundation's Engineering Research Center of Advanced Technology for Large Structural Systems (ATLSS) and Professor of Civil Engineering at Lehigh University, specializes in structural connections and the fatigue and fracture resistance of riveted, bolted and welded structures. He has written two books and contributed over 185 articles to various

scientific and engineering journals. In 1989 he was elected an Honorary Member of the American Society of Civil Engineers and a Corresponding Member of the Swiss Academy of Engineering Sciences. Dr. Fisher is a graduate of Washington University (BSCE) and received his M.S. and Ph.D. degrees from Lehigh University. He was awarded Docteur Honoris Causa by the Swiss Federal Institute of Technology in Lausanne, Switzerland in 1988.

Dr. Michael P. Gaus is a professor of Civil Engineering at the State University of New York at Buffalo, where he focuses his research and teaching in the areas of Construction, Infrastructure, GIS Applications and Natural Hazard Engineering. Before joining the faculty at SUNY/Buffalo, Dr. Gaus was affiliated with the National Science Foundation for over 25 years where he directed Divisions and Programs which established national research efforts such as Earthquake Engineering, Wind and Natural Hazard Engineering and many other research initiatives. Dr. Gaus has been affiliated with the Boeing Airplane Company and Skidmore, Owings & Merrill. Dr. Gaus is a graduate of the University of Illinois in Champaign-Urbana.

Ms. Robin S. Godfrey is President and CEO of Scharf-Godfrey Inc., a construction cost consulting firm. SGI's activities include cost estimating, scheduling, life-cycle costing, litigation, and value engineering for a wide range of construction projects. Ms. Godfrey has over 18 years experience in the construction industry and is an active constituent for the industry. She wrote the chapter on Cost Estimating for the *Encyclopedia of Architecture, Design, Engineering and Construction* (pub. John Wiley & Sons, Inc.) and served as President of the Washington DC Chapter for the American Association of Cost Engineers (1985-1986, 1986-1987). She is currently a member of the editorial board of "Construction Business Review" (CBR), is an active member of the American Association of Cost Engineers (AACE) and the Society of American Value Engineers (SAVE). She received a Bachelors degree in American Institutions from the University of Wisconsin.

Dr. F. H. (Bud) Griffis is the Director of the National Center for Infrastructure Studies at Columbia University and heads the Construction Engineering Program. In addition, Dr. Griffis is a principal in the firm of Robbins, Pope and Griffis, P.C. of New York. Dr. Griffis has Program Management oversight of the JFK Redevelopment Program and Area Engineer and Contracting Officer for Ramon Airforce Base in Israel, which was the largest cost-plus contract awarded in the history of the Corps of Engineers. Dr. Griffis holds a B.S. degree from the U.S. Military Academy at West Point, two M.S. degrees, one in Construction and the other in Industrial Engineering and a Ph.D. in Civil Engineering (Construction) from Oklahoma State University. He is also a graduate of the U.S. Army War College.

Mr. J. L. (Jim) Harrison is Director of Constructability, Methods & Technology for Fluor Daniel, Inc. and is responsible for providing a corporate focus in areas of technology. Mr. Harrison has 37 years of construction and engineering experience on a variety of facilities in several industries. His primary experience has been in the power generation industry, but his diverse background ranges from journeyman electrician to research engineer to significant management and technical positions on nuclear, fossil and cogeneration projects. Thirteen years of his experience has been in management across every facet of construction and engineering. Mr. Harrison received a B.S. in electrical engineering from Auburn University.

Dr. Neil Hawkins is Head of the Department of Civil Engineering at University of Illinois at Urbana-Champaign. Ranked among the top three civil engineering departments in the nation, Illinois has a faculty of 57. Dr. Hawkins has been an

engineering educator and researcher for many years, originally at the University of Sydney, Australia and then at the University of Washington, Seattle, where he was Chairman of Civil Engineering and Associate Dean for Research. Dr. Hawkins is a frequent consultant to government and private agencies on forensic issues. He is a former Director of the American Concrete Institute and of the Earthquake Engineering Research Institute. Dr. Hawkins received his B.S. and BSCE degrees from the University of Sydney and his M.S. and Ph.D. degrees in Structural Engineering from the University of Illinois.

Mr. Paul Herer is a Senior Advisor for Planning and Technology Evaluation, Directorate of Engineering at the National Science Foundation (NSF). Mr. Herer is the Chairman of the Engineering Strategic Planning Committee, in which he coordinates the strategic and long range planning for engineering. He is also the Chief Budget and Fiscal officer for the NSF engineering department. He organizes the budget, program analysis and fiscal management of engineering programs. Mr. Herer manages an NSF program focused on technology assessment and international coordination, which includes the Japanese Technology Evaluation Center (JTEC) and the World Technology Evaluation Center. Mr. Herer received a B.A. in Experimental Psychology and a M.B.A. from the University of Maine.

Mr. Richard W. Karn is Senior Vice President of Greiner Engineering, Inc., an international consulting engineering firm. Greiner's activities include, engineering for highways, bridges, light rail, land planning, development and surveying. Mr. Karn was founder of Bissell & Karn, Inc. in 1966 and directed the merger of B & K with Greiner in 1990. Mr. Karn served as National Director of the American Society of Civil Engineers from 1978 to 1981 and was the ASCE National President in 1984-85. In 1985 he was elected Honorary Fellow of the Institution of Civil Engineers United Kingdom and in 1990, he was the recipient of the Kenneth Andrew Roe Award. Mr. Karn received his B.S. in Civil Engineering from the University of California/Berkeley.

Dr. Michael Kavanaugh is Senior Vice President of Montgomery Watson Americas, where he is responsible for international projects in hazardous and industrial waste management. Dr. Kavanaugh has managed over ten major projects dealing with diverse groundwater and soil remediation problems at sites where the release of hazardous materials has occurred. He is also the Principal in Charge of waste minimization studies at six Air Force bases in Germany, England, Italy, and Turkey. Dr. Kavanaugh is a recognized national expert on water quality issues and groundwater treatment systems, including air stripping, activated carbon and advanced oxidation. Dr. Kavanaugh received his B.S. degree in Civil Engineering from Stanford University, his M.S. in Chemical Engineering and a Ph.D. in Sanitary Engineering from the University of California, Berkeley.

Mr. William Michael Lackey is the Assistant Secretary and State Transportation Engineer for the Kansas Department of Transportation. Over the past thirty years, he has served as a Resident Engineer, Construction Field Engineer, Chief of the Bureau of Construction and Maintenance and Director of the Division of Operations. Mr. Lackey was instrumental in securing State legislative approval for the Kansas Comprehensive Highway Program. He is an active member of the American Association of State Highway and Transportation Officials and the National Society of Professional Engineers. Lackey earned his undergraduate and graduate degrees in Civil Engineering from Kansas State University

Dr. Andrew C. Lemer is a consultant on development and infrastructure planning and policy. Since 1985, he has been President of the Matrix Group, Inc., and from

1988 to 1993 served as Director of the Building Research Board of the National Research Council, the operating unit of the National Academies of Sciences and Engineering. He was formerly Vice President with Alan M. Voorhees and Associates and Division Vice President with PRC Engineering, Inc. Dr. Lemer has served as a consultant to the World Bank, the U.S. Department of Transportation and the National Institute of Building Sciences. An engineer-economist and planner, Dr. Lemer received his B.S., M.S., and Ph.D. degrees in Civil Engineering from the Massachusetts Institute of Technology and a Loeb Fellowship at the Harvard University Graduate School of Design.

Dr. Victor C. Li, Professor of Civil Engineering and Director of the Advanced Civil Engineering Materials Research Laboratory (ACE-MRL) at the University of Michigan, Ann Arbor, is a specialist in applied mechanics and micro-mechanics of fiber reinforced cementitious materials. From 1983 to 1985, he held the Edgerton Chair for distinguished teaching and scholarship at the Massachusetts Institute of Technology, where he was a faculty member from 1981 to 1990. In recent years, Dr. Li has been an invited speaker, lecturer, or session chairman/organizer for the following organizations: ACI, ACerS, AFOSR, AFESC, ASCE, ASME, IUTAM, MRS, NATO, RILEM and SEM. He was the keynote speaker at the 4th RILEM Fiber Reinforced Concrete Conference in July, 1992, in Sheffield, England. Dr. Li has over seventy referred journal/proceeding papers to his credit. Dr. Li received his B.S. and M.S. in Civil Engineering and his Ph.D. in Solids and Structures from Brown University.

Mr. Stephen C. Mitchell is Chairman of Lester B. Knight & Associates, Inc., a Chicago-based international, professional services holding company. The firm provides engineering, architectural, and management consulting services through 25 offices in 15 countries. As a technical professional, Mr. Mitchell is involved in project development, design and management on a wide range of engineering, architectural and management consulting assignments. He is currently principal-in-charge of the Advanced Photon Source for Argonne National Laboratories, a synchrotron radiation light source. Mr. Mitchell holds a B.S. and a M.S. in Civil Engineering from the University of New Mexico. He also holds a MBA from the University of Chicago and is a registered professional engineer.

Dr. Michael J. O'Connor is Chief of the Infrastructure Laboratory at the U.S. Army Construction Engineering Research Laboratories (USACERL) in Champaign, IL. This laboratory consists of the Energy and Utility Systems Division, Engineering and Materials Division, and Facility Management Division. The laboratory's research ranges from diurnal energy storage systems to energy analysis models, from smart materials for roofing to structural dynamics for seismic vulnerability assessment and from computer aided concurrent engineering systems to maintenance and repair resource allocation models. Dr. O'Connor's construction management research has included expert systems for construction schedule analysis and construction contract claims analysis, a construction resource requirements estimating system for evaluating various basing modes for the Midgetman missile, development of a master plan for MX missile deployment construction, and a final design construction cost estimating system.

Mr. William J. Palmer is a Partner and the Chairman of Ernst & Young's National Construction Industry Group. He provides construction and accounting services to over 1,000 construction companies. Mr. Palmer has written numerous publications on construction accounting and litigation including the *McGraw Hill- Construction Management Book*, *Construction Litigation - Representing the Contractor and Businessman's Guide to Construction*. Mr. Palmer is serving his 5th year as

Chairman of the National Construction Industry Conference, which is co-sponsored by the National Association of Surety Bond Providers, the American Institute of Certified Public Accountants and the Construction Financial Management Association. Mr. Palmer graduated from the University of California at Berkeley after six years as a naval aviator.

Mr. Thomas J. Pasko, Jr., is the Director of the Office of Advance Research at the U.S. Department of Transportation, Federal Highway Administration. Mr. Pasko has been with the research offices of the Federal Highway Administration since 1961 and has held management positions since 1976 in materials, pavements, and structures, and has been part of several significant innovations in deicers, binders, pavements, steel protection, and concretes. For the past four years, he has been active as the United States member of the Flexible Roads Committee of the Permanent International Associate of Road Congresses (PIARC). Mr. Pasko received a B.S. and M.S. in Civil Engineering from Penn State University.

Dr. Balvant Rajani is a Research Officer in the Infrastructure Laboratory at the Institute for Research in Construction (IRC) of the National Research Council, Canada (NRCC). Dr. Rajani has broad expertise in soil-structure interaction and he is currently coordinating municipal and private sector interests in R&D and technology transfer within Canada to evaluate the long-term performance, rehabilitation and repair of distribution systems for water, sewers and natural gas. Dr. Rajani obtained his Ph.D. in Civil Engineering from the University of Alberta, M. Eng. from McGill University and B.Sc. from Imperial College, London.

Dr. William Roper is the Assistant Director of Research and Development (Civil Works) for the U.S. Army Corps of Engineers. Dr. Roper manages the Corps' worldwide Civil Works R&D Program. This research is directed toward improving Corps of Engineers activities through new technology application to achieve an effective, economical National Water Resources and Navigation Program that is environmentally sensitive, efficient and safe. Dr. Roper's professional experience includes senior management positions in the U.S. Department of Transportation, U.S. Environmental Protection Agency, and the U.S. Department of the Army. Dr. Roper received his B.S. in Mechanical Engineering and M.S. in Agricultural Engineering from the University of Wisconsin and his Ph.D. in Environmental Engineering from Michigan State University.

Mr. Kyle E. Schilling is Director of the U.S. Army Corps of Engineers' Institute for Water Resources. The Institute's program consists of a broad range of rapidly responsive national scope policy studies analysis and research relating to current issues in the changing national water resources environment. Its focus is improved planning methodologies and adaptive strategies to address economic, sociological, institutional, and environmental needs in water resources. For ten years prior to assuming the Director's position, Mr. Schilling served as Chief of the Institute's Policy Studies Program. He received a B.S. in Civil Engineering from Pennsylvania State University.

Mr. Dean E. Stephan is President of Charles Pankow Builders, Ltd. and is actively involved in the design, construction, cost estimating, marketing and overall management of construction projects for major commercial structures throughout the United States. Mr. Stephan is the Vice President of the American Concrete Institute (ACI) and a member of the ACI Board of Directors. He has authored several construction publications such as, "Tolerance for Concrete Construction", ACI Journal; "Constructability of Concrete Ductile Frames", Concrete International. Mr. Stephan holds a B.S. in Civil Engineering from Stanford University and a B.A. in Business Administration from Claremont McKenna College.

Mr. Glenn S. Tarbox is Vice President and Manager of Engineering and Construction Technologies in Research and Development at the Bechtel Corporation. Mr. Tarbox has broad expertise in water resource development and has worked on such projects worldwide. He has authored or co-authored more than 30 technical articles, papers and books on the subject of dams and their foundations. Mr. Tarbox is a member of numerous organizations including the American Concrete Institute, USCOLD Board of Directors, and the Earthquake Engineering Research Institute. He holds a B.S. in Civil Engineering from the University of Maryland.

Dr. K. Thirumalai is currently Program Manager for the Innovative Technology Development (IDEA) Program for transportation systems with the Transportation Research Board (TRB) of the National Research Council. From 1987-1993 he managed a similar and highly successful innovations program for highway technologies under the five year Strategic Highway Research Program (SHRP). He graduated from Berg Academy Freiberg in Germany. He is author of 150 research and technical publications in mechanics of materials, structures, underground stability, nuclear waste disposal, safety systems, technology development and transfer, and highway and transportation technologies. He is president of Science Technology Institute, a consulting research firm.

Dr. Richard L. Tucker is Director of the Construction Industry Institute (CII) at the University of Texas/Austin, which is recognized as the world's leading construction forum and is used as the model for counterpart organizations being established in Europe, Australia and other regions. Dr. Tucker is a founding officer of the International Association for Automation and Robotics in Construction (IAARC). Among his many recognitions, he was the first recipient of both the ASCE Peurifoy Award for Construction Research and the Ronald Reagan Award for Individual Initiative. He recently received the Outstanding Construction Educator Award from the National Society of Professional Engineers. A native Texan, Dr. Tucker earned his undergraduate, M.S. and Ph.D. degrees from the University of Texas at Austin.

Mr. C. Leslie Wierson is Senior Vice President for CH2M Hill Companies, Ltd. and has served twelve years on CH2M Hill's Board of Directors. He is also Director of Infrastructure Programs and the founder of CH2M Hill International in 1974. His international assignments included two years in Alexandria, Egypt as Project Director for wastewater improvements. Over his 35-year career with CH2M Hill, he has also been Regional Manager in Portland, Oregon and District Manager for the Northeast and Northwest Districts. Mr. Wierson is a Diplomate of the American Academy of Environmental Engineers and a registered professional engineer. He holds a B.S. in Civil Engineering from Oregon State University.

Dr. Richard N. Wright is Director of the Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology. BFRL is the national laboratory concerned with increasing the safety and environmental quality of constructed facilities, improving the productivity and international competitiveness of the construction industry, and reducing the human and economic costs of unwanted fires. Dr. Wright has been president of both the International Council for Building Research, Studies and Documentation (CIB) and the Liaison Committee of International Civil Engineering Organizations and serves on the Bureau and General Council of the International Union of Testing and Research Laboratories for Materials and Structures (RILEM). Dr. Wright received his B.S. and M.S. in Civil Engineering from Syracuse University and a Ph.D. in Civil Engineering from the University of Illinois.

Appendix G-3

PARTICIPATING EUROPEAN ORGANIZATIONS

UNITED KINGDOM

Institution of Civil Engineers (ICE), Westminster, London

Founded in 1818, the ICE is an authoritative body on infrastructure issues, whose opinions are often sought by policy makers and key decision makers. Almost 25 percent of its 80,508 members are overseas. It promotes and disseminates knowledge of civil engineering by holding meetings and conferences, publishing periodicals, reports, and books, and maintaining a large technical library. It is the qualifying body for the professional qualifications in civil engineering in the U.K. The ICE maintains close contacts with fellow engineering institutions in over 155 countries around the world.

London Water Ring Main, Thames Water offices

Thames Water PLC is a major international water company with operations based in fifteen countries. In addition to being the U.K.'s largest water utility, Thames Water has many other businesses based on its core skills and expertise in water and waste water operations. The Thames Water Ring Main is the largest project group within Thames Water Utility companies. The engineering department is responsible for the design and implementation of 80km of tunnel, pumping station, and associated works to provide water to 6 million customers in the London area.

Building Research Establishment (BRE), Watford

BRE is a national research laboratory which develops advanced building technology for building and construction and for the prevention and control of fires. BRE performs research in civil engineering, geotechnical engineering, construction, fire protection, building regulations, energy conservation, thermal engineering, acoustics, lighting, building services, materials, concrete, and information systems. BRE is government funded with some private industry sponsorship.

Construction Industry Research and Information Association (CIRIA), London

CIRIA identifies research needs, manages research and disseminates results for the construction industry. CIRIA performs work in structural design, civil engineering, construction, foundation engineering, and underground and offshore construction. CIRIA is privately funded through fees and subscriptions.

Water Research center (WRc), Swindon

WRc's objective is to be the leading independent European research and consultant organization in the fields of water, waste water and environmental management. It provides integrated and cost-effective solutions. Customers include governments, regulatory authorities, water utilities and industry. It operates from two science and technology centers worldwide.

Science and Engineering Research Council (SERC), Swindon

Five strategic aims of SERC are the training of skilled scientists and engineers; the improvement of knowledge transfer between disciplines and fields of

application, and between the science and engineering base and industry; the promotion of effective international collaboration; improving the economy, efficiency and effectiveness of all of SERC's operations; and increased public awareness. SERC employs a staff of over 2,000. The majority of SERC's income comes from the government's science budget.

Transport Research Laboratory (TRL), Crowthorne

The mission of TRL is to advance technology to formulate, develop, and implement government road and transport policies. TRL is government funded and performs research in civil engineering, construction engineering, highway engineering, urban and regional planning, and economics.

Building Services Research and Information Association (BSRIA), Bracknell

BSRIA is an independent, non-profit distributing, member based research organization formed in 1955. It can give support in any area of building services. The Association provides a member program, a research program, technical services, research and consultation for both member and non-member clients including research, application and design studies, system and equipment testing, UK and European market research, and publications and multi-client studies.

Institution of Structural Engineers (IStructE), London

The Institution was granted its royal charter in 1934 and is one of the nominated bodies of the Engineering Council which liaises between and coordinates the activities of professional engineering bodies in the U.K. With over 22,000 members (12,000 of which are corporate), the Institution maintains a dual role as a learned society and a qualifying body and has recently established its own trading organization in order to extend the range of services available to members. The primary objectives are to promote the science and art of structural engineering in all its forms and through the activities of its membership, contribute towards the achievement of excellence in construction; and to further the education, training and competence of all who seek to become members.

University College, London

The mission of the University College at London is to advance civil engineering technologies through education. University College performs government and university funded research programs in geotechnical engineering, structural mechanics, offshore structural engineering, concrete and concrete structures, and fluid mechanics.

Imperial College of Science, Technology & Medicine, London

The mission of the Imperial College of Science and Technology is to teach and advance the state of civil engineering and building technology. The college is government and industry funded and programs include research on steel and concrete structures (on and offshore), soil mechanics, earthquake engineering, hydraulics and water technology.

George Wimpey, London

George Wimpey is a private company invested in international construction, civil engineering and related activities, property management and development, mining, waste management, time share developments, consultant services, insurance, mechanical and electrical engineering, quarrying, home building, and travel services.

Ove Arup & Partners, London

Ove Arup & Partners, founded in 1946, provides a complete range of engineering skills relating to civil, industrial and building work. Their services cover full multi-disciplinary engineering design, project management, specialist skills and technical advice. They have 53 offices in 23 countries and more than 3500 staff members. A strong characteristic of the firm is the multi-disciplinary approach to engineering which promotes an amalgam of the most effective range of expertise for each project.

Taywood Engineering Ltd., London

Established in 1973, TEL specializes in offering a wide range of high technology-based consulting services to the construction industry. TEL's NAMAS accredited laboratories are the largest of their type in the private sector and have developed an international reputation for construction-related R&D. Through the development of technology and its subsequent application to the design process, TEL is recognized for its capabilities in such sectors as nuclear power, offshore oil and gas, tunneling, cryogenic storage. TEL's worldwide team is over 350 strong and features a growing presence in key regions throughout Asia-Pacific and the Middle East.

SWEDEN

Bygghorskningsradet, The Swedish Council for Building Research, Stockholm

Bygghorskningsradet is a government funded sectorial research agency under the auspices of the Ministry of Housing and Physical Planning. It is responsible for the initiation, coordination, funding and evaluation of R&D in the building and housing sector. Work is entrusted to universities, institutes of technology, socialized research institutes, public authorities, private companies, and individual researchers. Bygghorskningsradet supports R&D in the fields of urban design and management, building technology and energy conservation, and energy end-use in buildings.

Royal Swedish Academy of Engineering Sciences (IVA), Stockholm.

IVA is an academic institution which was founded in 1919 to promote the engineering sciences through the establishment of new research facilities and also acts as a clearinghouse for scientific information.

Vagverket (Swedish National Road Administration), Borlange

The Swedish National Road Administration is a government organization.

Bonverket (Swedish National Rail Administration), Borlange

The Swedish National Rail Administration is a government organization.

THE NETHERLANDS

Ballast Nedam Beton en Waterbauw, Amstelveen

Ballast Nedam specializes in concrete construction for waterways and marine structures and is recognized internationally for its large contracts on dredging operations and subsurface pipeline construction. The corporation ranks as one of the top five civil engineering construction firms in the Netherlands and has a modest research activity specializing in water retaining structures. The firm is known for its ability to apply advanced technologies to construction, specifically for the design and construction of hydraulic structures under difficult ground conditions, tunnel support, pipeline and conduits construction.

Delft Geotechnics, Delft

Delft Geotechnics is an independent engineering institute that has an international reputation for significant geotechnology developments. It provides geotechnical engineering and construction services both at home and through its European subsidiaries. Delft Geotechnics is the key developer of several major ground modification technologies and foundation support systems and is credited with numerous developments for stabilizing and protecting ground structures in the Netherlands from the impact of the North Sea. The institute is highly active in geo-environmental areas and in waste disposal engineering.

Delft University of Technology, Delft

The university is the largest university of technology in the Netherlands and is part of the "grandstand" of urban agglomerations that the Netherlands boasts. The university specializes in technology research and has a special R&D transfer bureau that specifically deals with the transfer of university developed technologies to industries and cooperatively establishes research tasks to be performed by the faculties. Research at the Delft University of Technology is carried out in 12 faculties subdivided into 60 departments. Their major faculties deal with construction engineering: 1) Faculty of Architecture, Urban Planning and Housing; 2) Faculty of Material Science and Technology; 3) Faculty of Civil Engineering. The university is financed by the Dutch government and has approximately 13,000 students and 3,800 faculty. An executive board oversees the management of the university through a university appointed council.

Hollandsche Beton Groep NV, Rijswijk

This organization is the largest civil engineering construction firm in the Netherlands and is one of the leading firms in the European construction market, with a workforce of about 18,000 employees, operating in 40 countries with an annual turnover of about 5 billion NLG. The group operates with several independent subsidiaries each specializing in different areas of construction. This corporate structure enables Hollandsche Beton to focus individual groups on specialized construction projects and jointly compete for large scale construction projects. Major areas of Hollandsche Beton construction include: 1) highway and transportation infrastructure construction; 2) industrial, commercial and public housing; 3) civil and maritime engineering construction; and 4) energy and environment. The group has a strong design and engineering research team contributing to the engineering success in mainstream construction activities, as well as in specialized construction of bridges, viaducts, pipelines and hydraulic structures.

TNO Building & Construction, Delft

The Netherlands Organization for Applied Scientific Research, TNO employs almost 5000 scientists, engineers and technicians working in 30 different institutes. TNO's main fields of activity are: industrial technology, construction materials, energy, the environment, nutrition, food, health, defense and building sciences. The center is recognized for its progress in precast concrete construction and application of high technology developments such as CAD-CAM and robotics. The organization is funded by the Dutch government and cost-shared by construction industries.

Koninklijk Instituut van Ingenieurs (KIVI)

KIVI is the single major professional organization for engineers in the Netherlands and includes members from the civil engineering and construction community.

DHV

DHV is an engineering consulting firm with 1500 employees. DHV is internationally recognized as one of the leaders in their field.

GERMANY

Philipp Holzmann AG, Neu Isenburg-Frankfurt

Philipp Holzmann is the largest industrial, commercial and infrastructure construction corporation in Germany and ranks within the first seven large corporations in Europe. Compared with other companies in Germany, Philipp Holzmann makes a high investment in construction R&D and has a strong internal R&D group. The corporation is highly active in international construction projects and owns major operations in the U.S. The corporation is nationally recognized in Germany for technological contributions in construction, specifically in subsurface excavation and construction, soil treatments, prestressed concrete, construction materials development, modern and modified construction technologies, environmental hazards abatement and recycling.

Hauptverband der Deutschen Bauindustrie, Frankfurt

Hauptverband der Deutschen Bauindustrie is a private construction company.

Technische Hochschule, Darmstadt

The Technical University in Darmstadt is one of the largest engineering institutions in Germany. The University is known for its contributions in construction robotics and structural engineering. The University has separate institutes devoted to structures, construction technology and materials testing for construction. The major departments at the University include civil engineering, geotechnology, water and hydraulic transport systems, construction engineering and architecture.

ASCE-Deutschland International Group (ASCE-DIG), Eschborn

ASCE-DIG is comprised of civil engineers who are German members of the American Society of Civil Engineers (ASCE).

Federal Ministry of Planning and Construction, Bonn

In the German system all applied research is performed by the various institutes under the Fraunhofer Society widely known as FhG, which funds large national centers of excellence for engineering developments. FhG funds about 30 national engineering centers, some of them in cooperation with industries. These institutes fill the gap between basic research and industrial research. Ministries responsible for the various aspects of civil engineering research and construction include Ministry of Transportation (BMV), Ministry for Construction (BMBau) and Ministry for Research and Technology (BMFT).

Deutsche Forschungsgemeinschaft (DFG), Bonn

The DFG is a German research grants agency (in some ways similar to NSF) and is supported by states and the federal government. DFG provides grants for small projects of technical excellence by cooperative funding process. DFG has a cooperative funding system with state governments and focuses on scientific and technical excellence in basic and engineering research.

University of Karlsruhe, Karlsruhe

Karlsruhe is the oldest engineering institution in Germany. The University is well known for its contributions in special structures research such as tubular

structures, innovative structural fastening and connecting systems and construction of structures under difficult ground conditions. The structural engineering department has a materials testing and approval section. The section provides an extensive array of technical services in civil engineering construction to regional governments.

Bilfinger and Berger, Mannheim

Bilfinger and Berger specializes in both surface and underground construction and complex construction projects which involve site specific construction techniques. The corporation has holding companies in the United States operating out of Ballwin, Missouri and active overseas construction operations in Asia, Africa and Latin America. The corporation carries out construction development and design services for infrastructures and is recognized for construction safety process developments and services. The corporation works with regional infrastructure construction projects including waterways, pipeline construction and concrete building structures.

German Highway Center (BASt), Bergisch Gladbach

The institute is a technical and scientific arm of the German government, with approximately 500 researchers performing activities related to highway construction, improvement of highway capacity and traffic safety. In 1970, the German government also established the Accident Research Center as part of BASt. The center acts as a scientific advisor on technical matters and also develops transportation policies. An advisory board composed of leaders in the fields of science, commerce, industry and the public sector provides oversight for all BASt activities.

Strabag Bau AG, Koln

Strabag is one of the rapidly growing civil infrastructure construction corporations in Germany. Its activities include building, civil engineering structures, and highway construction, and their subsidiary DEUTAG is well-known in Germany for asphalt pavement construction. Strabag Bau has a high level of research investment in construction materials development. The company offers turnkey construction and operation services throughout Europe, including services for waterways and subsurface facilities. Strabag Bau is gaining recognition for integrated construction contracts for environmental control.

Information Center for Planning and Construction (IRB), Stuttgart

IRB is part of the Fraunhofer-Gesellschaft (FhG). The center provides clearinghouse services for all construction related technical information and literature. It also serves as an information agency for regional planning and construction on behalf of the German government. The center maintains three major national construction databases: 1) BAUF0 - a summary of on-going building research projects; 2) RSWWB - a regional database for construction projects; and 3) ICONDA - the international database on civil engineering and construction projects. IRB releases periodicals and special reports which are widely used by engineering professionals.

Aachen Technical University, Aachen

The University is considered to be one of the best among European engineering institutions, with large construction research projects funded by industries and through the government. The department of Civil Engineering and Architecture is nationally known for its contributions in construction design and technology development. The Building Research Institute of the University is one of the

leaders in materials research and in the development of test methods and procedures for performance and durability testing of structures and for developing inspection procedures for construction.

Hochtief AG, Essen

Hochtief is one of the largest civil engineering construction corporations in Germany. The corporation is recognized for its pre-cast construction technologies and sewer systems construction. It has a division specializing in technology application including construction material processes, subsurface construction and sea bed construction.

FRANCE

Laboratoire Central des Ponts et Chaussees (The Road and Bridge Central Laboratory), Paris

The laboratory provides service on behalf of the Ministry of Town Planning and Housing and serves as the central laboratory for roads, structures, bridges, civil engineering materials, and the environment. Research programs include the following areas: materials, structural analysis, painting, geotechnical, soil and rock mechanics, water and environment, inspection and pathology of construction works and documentation of scientific technical information.

Dumez, Paris

Dumez is a private company whose principal activities are civil engineering and public works construction, general contracting and project management. Dumez consists of approximately 36,000 employees.

Conseil National des Ingenieurs et des Scientifiques de France (CNISF), Paris

The CNISF has 150,000 members and represents all engineers and scientists in France. In 1860 the French government granted it the status of "Association d'utilité publique." CNISF's primary objectives are to promote engineers' moral, cultural, and socioeconomic interests. Within the EC, CNISF is hoping to work and to develop joint ventures with the engineering associations from neighboring countries.

S.E.T.R.A. (Roads & Highway Engineering Center), Paris

SETRA is a government funded organization whose major responsibilities include the engineering of roads and highways.

CEBTP within the organization SPETRF, Paris

A professional union of public works contractors (an industrial association).

Bouygues, Paris

Bouygues is a private organization, well known for organizing research teams from external research centers and/or laboratories. A report published in the Ministry of Research and Technology classified Bouygues as one of the private companies with the highest R&D potential.

Spie Batignolle, Paris

Spie Batignolle is a private company whose strategy is to focus R&D resources to selected targets by coordinating and creating synergy through project teams. As a result of a reorganization in 1986 the research department was suppressed and currently all of the R&D activities are subcontracted to external research centers. About 50% of their work involves engineering, civil works and construction.

École Nationale des Ponts et Chaussées (ENPC), Paris

ENPC (the Civil Engineering College) is known as one of the top universities in France. ENPC operates several research centers throughout France and is a government funded operation. ENPC's primary research areas include industrial engineering, structural analysis, construction materials, and engineering management.

ITALY

Consiglio Superiore dei Lavori Pubblici (CSLLPP), Rome

CSLLPP is the highest consulting organism to the Ministry of Public Works. This advisory board studies and evaluates all CCIS projects that are undertaken in Italy.

Istituto Sperimentale Modelli e Strutture (ISMES, S.p.A.), Bergamo and Rome

ISMES is a joint stock company operating in the field of structural and civil engineering in support of firms in the sector. ISMES's major fields of work are energy, environment, construction, transportation, and structural restoration.

Building and Civil Engineering Tests and Research Institute (ISTEDIL), Rome

ISTEDIL was established on the initiative of the Italian Association of Building Contractors to perform building control tests and certification. Primary work and research activities include civil engineering and building technology, testing services, agreements for materials and components, and the conduction of courses and seminars.

Istituto Centrale per la Industrializzazione e la Tecnologia Edilizia (ICITE-CNR), Milan

ICITE is a research and technical center attached to a government agency.

Polytechnic Institute of Milan, Milan

The Polytechnic Institute of Milan has a wide variety of departments within the civil engineering field, including: structural engineering, hydraulics, environment, and topography.

European Laboratory for Structural Assessment (ELSA), Ispra

The Safety Technology Institute (STI) of the Joint Research Centre (JRC) of the Commission of the European Communities has built a structural assessment laboratory, ELSA, based on a 16m. high, 21m. wide reaction-wall. ELSA will be used within the framework of Community-wide integrated research programs, thus making full use of the existing expertise and facilities within the Member-states. The facility is available to external customers for performing demonstration and qualification tests on large-scale prototypes and/or validating innovative constructions. This is intended to offer a major opportunity to the European construction industry to enhance its competitive position in world-wide markets, especially in countries with high seismic risk.

ASCE Italy International Group (ASCE-IIG), Rome

ASCE-IIG is comprised of civil engineers who are Italian members of the American Society of Civil Engineers (ASCE); there are many representatives from private consulting firms and private construction corporations.

Appendix G-4

TASK FORCE TEAM ITINERARIES

TEAM A – TASK FORCE VISITS IN UNITED KINGDOM

SUNDAY JUNE 6, 1993 – TEAMS A1 & A2 – London

Optional Channel-Tunnel Visit

- 10:00 a.m. Team arrives at Translink Joint Venture office for tour of Channel-Tunnel project
- 12:30 p.m. Afternoon visit to EuroTunnel Exhibition Center

MONDAY JUNE 7, 1993 – TEAMS A1 & A2 – London & Reading

- 8:40 a.m. Teams A1 and A2 have overview seminar at **The Institution of Civil Engineers (ICE)**
- 9:05–10:45 a.m. *Background & Purpose of the CERF Visit and Introduce the Delegation.* Harvey M. Bernstein, CERF President
- The Overall View in the UK.* Dr. Edmund Hambly, ICE Vice President
- The Public Sector Involvement.* Dr. R. Thorogood, DoE/SERC
- Transport Infrastructure.* Dr. Richard Robinson, Rendel, Palmer & Tritton
- Structures & Buildings.* Mr. Chris Symonds, W.S. Atkins & Partners
- The Contractor's Involvement.* Mr. Charles Barber, John Laing plc.
- University Research Activity.* Professor Roy Severn, Bristol University
- 11:30 a.m. Team A1 meets with **Department of Environment**
Team A2 meets with **Department of Transport**
- 2:30 p.m. Team A1 meets at **London Water Ring Main, Thames Water offices**
Team A2 meets with **Building Research Establishment (BRE)**
- 7:00 p.m. Reception at ICE. Presentation by **Construction Industry Research & Information Association (CIRIA).**

TUESDAY JUNE 8, 1993 – TEAMS A1 & A2 – Swindon & London

- 7:50 a.m. Team A1 attends meeting at: **Water Research center (WRc)**
Team A2 attends meeting at: **Transport Research Laboratory (TRL)**
- 2:00 p.m. Team A1 meets with **Science & Engineering Research Council (SERC)** & representatives of British Universities
Team A2 meets with **Building Services Research & Information Association (BSRIA)**

- 4:00 p.m. Teams A1 & A2 attend presentations at **Institution of Structural Engineers**
- CIC Work in R&D.* Sir Andrew Derbyshire, Chairman CIC R&D Committee
- ICE Work in R&D.* Mr. Reg Clare, Chairman R&D Panel
- IStructE Work in R&D.* Prof. Patrick Dowling, Chairman R&D Committee
- 8:00 p.m. Dinner hosted by the **Institution of Structural Engineers**

WEDNESDAY JUNE 9, 1993 – TEAMS A1 & A2 London & Stockholm

- 8:40 a.m. Team A1 attends meeting at **University College London**
Dept. of Civil & Environmental Engineering
- 9:15 a.m. Team A2 attends meeting at **Ove Arup & Partners**
- 10:45 a.m. Team A1 attends meeting at **Imperial College of Science, Technology & Medicine**
- 2:00 p.m. Team A1 attends meeting and tour at **John Laing plc.** corporate facilities
- Team A2 attends meeting and tour at **Taywood Engineering, Ltd.** corporate facilities

TEAM A – TASK FORCE VISITS IN SWEDEN/BELGIUM

THURSDAY JUNE 10, 1993 – Teams A1 & A2 – Stockholm

- 9:00 a.m. Teams A1 & A2 have overview seminar at **Bygghorskningsradet, The Royal Institute of Technology (BFR)**
- 11:30 a.m. Lunch hosted by **BFR** with video presentation on “The Ring”—the planned circular highway around Stockholm & the planned railroad tracks across the city
- 1:00 p.m. Teams A1 & A2 take guided tour of “The Ring”
- 3:00 p.m. Teams A1 & A2 attend meetings and tour of **Skanska** corporate facilities
- 5:00 p.m. Teams A1 & A2 attend meeting, discussion, and dinner with **The Royal Swedish Academy of Engineering Sciences (IVA)**

FRIDAY JUNE 11, 1993 – TEAMS A1 & A2 – Borlange

- 8:00 a.m. Team A1 attends meeting at: **The Swedish National Road Administration (Vagverket) and The Swedish National Rail Administration (Banverket)**
- 11:15 a.m. Team A2 has lunch, meeting and demonstration at: **The Swedish Road & Traffic Research Institute (VTI)**
- Dr. Karl-Olov Hedman & Mr. Tord Lindahl give presentation on the *VTI Institute and R&D Projects* to Team A2

1:45 p.m. Team A2 visits the VTI laboratories, including a demonstration of the VTI driving simulator and information about the use of the simulator for the "Stockholm Ring" project, presented by Prof. Staffan Nordmark

SATURDAY JUNE 12, 1993

Open day for Teams A1 & A2

SUNDAY JUNE 13, 1993 – TEAMS A1 & A2 – Brussels

9:00–12:00 noon Task Force chairs/recorders meet to plan Forum

3:00–5:00 p.m. Task Force members meet with recorders to discuss issues.

MONDAY JUNE 14, 1993 – Brussels

8:00–12:00 noon CERF Forum on CCIS

TEAM B – TASK FORCE VISITS IN GERMANY

MONDAY JUNE 7, 1993 – TEAM B1 – Frankfurt & Darmstadt

8:30 a.m. Team B1 attends orientation meeting and tour at **Philipp Holzmann AG Headquarters**

1:50 p.m. Team B1 meets at: **Technische Hochschule – Institut für Wasserbau (Institute for Hydraulic Structures)**

Presentation of example of academic research, collaboration with industry & technology transfer in the subject of concrete structure by Prof. Dr.-Ing. König

Presentation of examples in water resources research by Prof. Dr.-Ing. Mock and Prof. Dr.-Ing. Ostrowski

Presentation of examples in steel construction by Prof. Ir. Bouwkamp

4:00 p.m. Visit of models in the 3 institutes

6:30 p.m. Team B1 attends dinner, discussion and CERF presentation with **ASCE-Deutschland International Group (ASCE-DIG) and Verein Deutscher Ingenieure (VDI-Bau)**

MONDAY JUNE 7, 1993 – TEAM B2 – Bonn

9:30 a.m. Team B2 attends meeting at **Der Bundesminister für Forschung & Technologie (BMFT)**

1:30 p.m. Team B2 attends meeting and tour at **Deutsche Forschungsgemeinschaft (DFG)**

TUESDAY JUNE 8, 1993 – TEAM B1 – Karlsruhe & Mannheim

7:15 a.m. Team B1 attends meeting and tour at **University of Karlsruhe**

12:30 p.m. Team B1 attends meeting at **Bilfinger and Berger. Dr. Ing. Thomas Bork discusses *Robotics in Construction.***

6:00 p.m. Teams B1 and B2 attend presentation and dinner at local winery hosted by **Bilfinger and Berger**

TUESDAY JUNE 8, 1993 – TEAM B2 – Bergisch Gladbach & Koln

8:00 a.m. Team B2 attends meeting and tour at **German Highway Center (BASt)**

3:00–6:00 p.m. Meeting and tour at **Strabag Bau AG** with Mr. Manfred Schlosser, Joint Manager Director of the Building & Civil Engineering Division

DICAD—Computer Operated Design. Mr. Marx

SICOM—Fiber Reinforcement and Monitoring with Optical Fibers. Dr. Wolff

Waste Disposal and Fill. Mr. Fensch

Recycling Building Materials. Mr. Schauberer

Test Tracks and Slope Paving. Dr. Geiseler

Waste and Waste Water. Mr. Adler

WEDNESDAY JUNE 9, 1993 – TEAM B1 – Stuttgart & Amsterdam

9:08 a.m. Arrive in Stuttgart for meeting at **Information Center for Planning and Construction (IRB)**

5:30 p.m. Team B1 arrives in Amsterdam

WEDNESDAY JUNE 9, 1993 – TEAM B2 – Aachen & Amsterdam

7:00 a.m. Team B2 attends meeting and tour at **Aachen University of Technology**

Topic 1: Groundwater - Environmental - Ecology - GIS

Topic 2: Construction Engineering

10:30–10:45 a.m. Transfer to the test facility

Topic 3: River Engineering - Environmental - Ecology - GIS - Sedimentation

5:50 p.m. Arrive in Amsterdam

TEAM B – TASK FORCE VISITS IN THE NETHERLANDS/BRUSSELS

THURSDAY JUNE 10, 1993 – TEAMS B1 & B2 – The Hague & Amsterdam

9:15 a.m. Teams B1 and B2 attend overview seminar at **Koninklijk Instituut van Ingenieurs (KIVI)**

Welcome & Introductions by prof.ir. H.P. Subhan van Lohuizen, Vice-Chair, KIVI

Introduction to the CERF Task Force by Task Force Chairman

The Dutch Infrastructure for CE Research and Technology Transfer by ir. Kees Nije, Director, Center for Research and Contract Standardization in Civil & Traffic Engineering (C.R.O.W.)

Mechanisms to Put Innovation into Practice by ir. Andre R. van Bennekom, Director, Road & Hydraulic Engineering Division, Rijkswaterstaat, Ministry of Transport, Public Works and Water Management

The Industry's Perspective by prof.ir. Charles J. Vos, DMC, Hollandsche Beton Groep

Dutch Research in European Perspective by ir. Hans J. van Leuven, Division of International Transport Affairs, Ministry of Transport, Public Works and Water Management

1:30 p.m. Team B1 attends meeting and tour of *Underground Railway* at KLS Office

Team B2 departs for Delft Geotechnics

5:00 p.m. Teams leave for presentation and reception with CIB hosted by Stichting Bouwresearch

FRIDAY JUNE 11, 1993 – Teams B1 & B2 – Delft, Rijswijk & The Hague

8:15 a.m. Team B1 attends meeting and tour at Delft University of Technology
Team B2 attends meeting and tour at TNO Building & Construction Research

9:15 a.m. Team B2 attends presentations by TNO:
Welcome and introduction to TNO Building & Construction Research by Prof.ir. J.W.B. Stark, Deputy Director
Scope of activities of the Department of Structural Engineering by Prof.ir. A.C.W.M. Vrouwenvelder
Visit to the laboratory of the Department of Structural Engineering, building #75

DIANA finite-element analysis, presentation by Ir. G.A.M. Kusters, Head of the Department of Computational Engineering

11:30 a.m. Team B2 visits to the Centre for Fire Research by Ir. J.C.A. van de Weijert, building #55

12:30–3:30 p.m. Team B1 attends presentations on HBG: organization, activities, strategy in civil engineering and technology and innovation. Tours construction site of Bouwkombinatie Maeskant Kering (BMK) project, a storm surge barrier, Rotterdamse Waterweg

1:00–4:30 p.m. Team B2 attends tour and presentations at DHV:
Welcome & Introductions by drs. A.M. Schouten, member of Board of Directors of the DHV Group

Transportation Planning and Traffic Forecasting by ir. E. Hoere, Managing Director Dept. of Transportation Planning, DHV Environment & Infrastructure

Highway and Railway Engineering by ir. J.M. van Geeat, Managing Director Dept. of Infrastructure, DHV Environment & Infrastructure

Audiovisual DHV Group

Water Resources by ir. E. Eggers, Director Technology, DHV Water

Environmental Impact Assessment by drs. J.J.F.M. van Haeren, Project Director Dept. of Environmental Management, DHV Environment & Infrastructure

4:00 p.m. Team B1 attends presentation at HSM. Schiedam—*Impression of Parts of Steel Structures for the Storm Surge Barrier*

6:30 p.m. Teams B1 & B2 attend presentation and dinner hosted by Knight Wendling

SATURDAY JUNE 12, 1993

Open day for Teams B1 & B2

SUNDAY JUNE 13, 1993 – TEAMS B1 & B2 – Brussels

9:00–12:00 noon Task Force chairs/recorders meet to plan Forum

3:00–5:00 p.m. Task Force members meet with recorders to discuss issues.

MONDAY JUNE 14, 1993 – Brussels

8:00–12:00 noon CERF Forum on CCIS

TEAM C – TASK FORCE VISITS IN FRANCE

SUNDAY JUNE 6, 1993 – Teams C1 & C2 – Calais

Optional Channel-Tunnel Visit

10:37 a.m. Teams C1 and C2 arrive in Calais and transport for tour of Channel-Tunnel project

5:00 p.m. Teams arrive in Paris

MONDAY JUNE 7, 1993 – Teams C1 and C2 – Paris

8:30 a.m. Teams C1 and C2 attend meeting and tour at Conseil National des Ingenieurs et des Scientifiques de France (CNISF)

2:30 p.m. Teams C1 and C2 attend meeting and tour at Dumez

8:00 p.m. Teams C1 and C2 attend presentation and dinner at Eiffel Tower hosted by CNISF with CNISF Chairman and Ministry officers.

TUESDAY JUNE 8, 1993 – Teams C1 and C2 – Paris

- 8:30 a.m. Team C1 attends meeting and tour at S.E.T.R.A. (Roads and Highway Engineering Center)
- Team C2 attends meeting and tour at C.E.B.T.P.
- 2:30 p.m. Teams C1 and C2 attend meeting and tour at Laboratoire Central des Ponts et Chaussées

WEDNESDAY JUNE 9, 1993 – Teams C1 and C2 – Paris and Rome

- 8:30 a.m. Teams C1 and C2 attend meeting and tour at Bouygues Group Headquarters "Challenger"
- 2:30 p.m. Teams C1 and C2 attend meeting and tour at École Nationale des Ponts et Chaussées

TEAM C – TASK FORCE VISITS IN ITALY/BELGIUM

THURSDAY JUNE 10, 1993 – TEAM C1 – Rome

- 9:30 a.m. Team C1 attends meeting at The National Research Council (CNR).
Presentations by:
- Prof. Claudio Cerruti, Director of CNR goal-oriented research program and Director of ICITE
- Prof. Giovanni Tortorici, Director of I.R.I.S., CNR Institute of Housing and Social Infrastructures
- Prof. Guglieimo Franzitta, Director of I.E.R.E.N., CNR Institute of Energy Saving and Building
- 4:00 p.m. Team C1 attends meeting and tour at Consiglio Superiore dei Lavori Pubblici
- 7:15 p.m. Team C1 attends meeting and dinner with CNR

THURSDAY JUNE 10, 1993 – TEAM C2 – Milan

- 8:45 a.m. Team C2 attends meeting at ICITE-CNR Central Institute for Building Industrialization and Technology
- 1:15 p.m. Team C2 attends meeting and tour at Istituto Sperimentale Modelle e Strutture (ISMES)

FRIDAY JUNE 11, 1993 – TEAM C1 – Rome

- 8:15 a.m. Team C1 attends meeting with representatives of ASCE Italy International Group (ASCE-IIG)

FRIDAY JUNE 11, 1993 – TEAM C2 – Milan

- 8:15 a.m. Team C2 attends meeting and tour at Polytechnic Institute of Milan
- 12:45 p.m. Team C2 meets at the Hotel Cairoli for transport to meeting and tour with Mr. J.P. Halleux at: ELSA (the EC Laboratory)

SATURDAY JUNE 12, 1993

Open day for Teams C1 & C2

SUNDAY JUNE 13, 1993 – TEAMS C1 & C2 – Brussels

9:00–12:00 noon Task Force chairs/recorders meet to plan Forum

3:00–5:00 p.m. Task Force members meet with recorders to discuss issues.

MONDAY JUNE 14, 1993 – Brussels

8:00–12:00 noon CERF Forum on CCIS

Appendix G-5

AGENDA FOR CERF'S BRUSSELS FORUM ON CONSTRUCTED CIVIL INFRASTRUCTURE SYSTEMS (CCIS) R&D

*HOTEL PRESIDENT WORLD TRADE CENTER
BOULEVARD E. JACQMAIN 180
1210 BRUSSELS, BELGIUM*

JUNE 14, 1993

8:30-9:00 a.m. **WELCOME, INTRODUCTION, AND PRESENTATION ON THE CURRENT STATUS OF U.S. R&D AND CCIS POLICY**

Harvey M. Bernstein
President, Civil Engineering Research Foundation
CERF Task Force Chairman and Coordinator

9:00-10:30 a.m. **U.S. TEAM BRIEFING AND DISCUSSION**

10-minute summary by each Task Force country team.
General discussion with European representatives to react to observations and get European perspectives on what impact the uniting of the European Community will have on construction industry related research and development programs, technology transfer processes, and future collaboration.

9:00-9:30 a.m. **U.K./SWEDEN TEAM BRIEFING AND DISCUSSION**

Dr. Richard N. Wright
Director, Building and Fire Research Laboratory
National Institute of Standards and Technology

9:30-10:00 a.m. **GERMANY/NETHERLANDS TEAM BRIEFING AND DISCUSSION**

Dr. Richard L. Tucker
Director, Construction Industry Institute
University of Texas at Austin

10:00-10:30 a.m. **FRANCE/ITALY TEAM BRIEFING AND DISCUSSION**

Dr. Neil Hawkins
Head of Civil Engineering Department
University of Illinois

10:30-10:45 a.m. **COFFEE BREAK**

10:45-12:00 noon **GENERAL DISCUSSION/CLOSING COMMENTS**

Harvey M. Bernstein, CERF Task Force Chairman and Coordinator

12:00 noon **FORUM ADJOURNED**

Appendix G-6

BRUSSELS FORUM ATTENDEES

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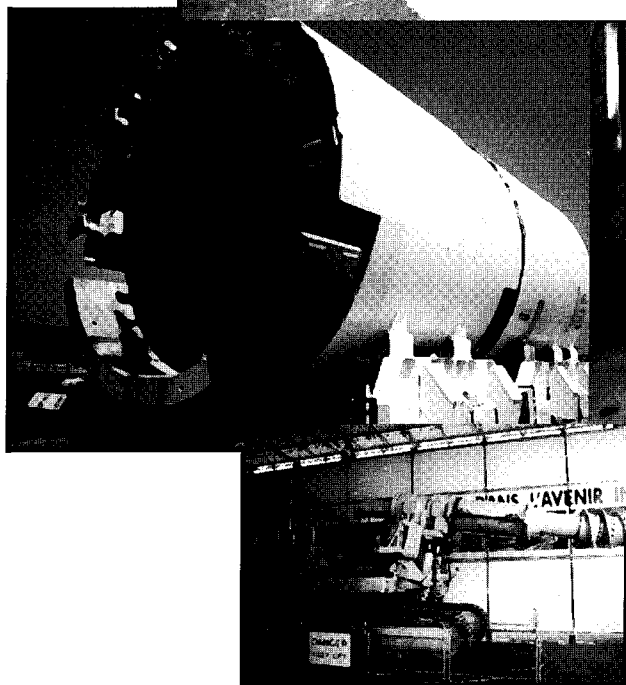
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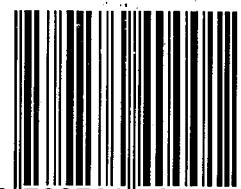
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