CONTRIBUTIVE RESEARCH & DEVELOPMENT VOLUME 123, OPPORTUNITIES FOR INTERNATIONAL PARTNERSHIPS AND TECHNOLOGY TRANSFER TO SUPPORT RACER DEVELOPMENT

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Preface and Acknowledgements

This research project was conducted under Air Force Contract F33615-94-C-5804, "Contributive Research and Development," Task 168, sponsored by Air Force Research Laboratory, Materials and Manufacturing Directorate, Airbase Technology Branch (MLQC) at Wright-Patterson AFB, Ohio. The Air Force Program Manager was Mr. Philip Mykytiuk. The Air Force Technical Manager was Mr. Allen Nease. The Principal Investigator was Dr. Rita A. Gregory. The Systran Corporation Program Manager was Dr. V. Nagarajan.

This effort was co-sponsored by the Air Force Research Laboratory, Air Base Technology Branch, Georgia Institute of Technology, Georgia Tech Research Corporation, Georgia Tech Foundation, and the National Science Foundation. Special thanks are extended to Delta Air Lines, Environmental Operations Department, for providing transportation for the supporting elementary school teacher and to Systran Corporation for managing the contractual arrangements for Air Force Research Laboratory.

Summary

This report summarizes investigation for international partnerships and technology transfer to with various European Countries. The technologies cover a wide variety of interests in the fields of Civil and Environmental Engineering, with particular interest in automation and robotics, construction engineering, and cost engineering and management. The work was conducted by means of visits, discussions with technical leaders and managers, and supporting documentation reviews when documents were made available. On an individual basis, everyone contacted was interested in collaborating research efforts. The following summaries planned follow-up actions:

a. Researcher will discuss network of universities for laboratory courses with GA TECH faculty. Response will be conveyed directly to Mr. Carrouth. The researcher anticipates no follow-up on the runway problem.
b. Investigate potential for exchange program between GA TECH and CERAM.
c. Coordinate and prepare invitation letter for Mr. Caccavelli, Centre Scientifique et Technique du Batiment (CSTB).
d. Coordinate distinguished visitor visit to AFRL robot display. Offer support in proposal preparation for Princess Diana funds. Coordinate and prepare letter of invitation for Mr. Douglas.

1. Introduction

This report summarizes investigation for international partnerships and technology transfer with various European Countries for AFRL/MLQC and GA TECH. AFRL (formerly Wright Laboratory) formalized an Education Partnership Agreement in 1997. Additional goals for this summer research were to improve and/or enhance the Remedial Action Cost Engineer and Requirements (RACER) System to support the cost engineering studies for the AFRL/MLQC Automation and Robotic Program. The technologies cover a wide variety of interests in the fields of Civil and Environmental Engineering, with particular interest in automation and robotics, construction engineering, and cost engineering and management. In addition, a parallel study included an elementary school curriculum developer to help design technology integration in K-12 curricula in an effort to attract and prepare more U.S. students in engineering and sciences. The work was conducted by means of visits, discussions with technical leaders and managers, and supporting documentation reviews when documents were made available. Visits were conducted during the summer 1998. Organizations contributing to and interested in this effort include the Air Force Research Laboratory, Air Base Technology Branch, Georgia Institute of Technology, Georgia Tech Research Corporation, Georgia Tech Foundation, and the National Science Foundation.

The findings are organized by location, technology investigated, points of contact, joint research opportunities, and follow up actions or recommendations. Because this was a investigative search and involved multiple countries and cultures, each technology will be discussed independently without establishing a common thread or pattern of application.

2. Spangdahlem AFB, Germany

Spangdahlem AFB is an operating location for the United States Air Force. It has incorporated the supporting functions and infrastructure of Bitburg AFB that was closed in the recent Base Realignment and Closure processes. The Housing Officer, Mr. Mike Wilson and the Deputy Base Civil Engineer, Mr. John Carrouth, hosted the researcher. Mr. Wilson provided detailed tours of housing renovations and discussed in detail the planning and programming efforts under the new "1 plus 1" and 2 plus 2" dormitory design concepts. Innovative designs and construction are being implemented in the renovations to provide an updated quality of life standard to officer and enlisted quarters. See Photographs A-1 and A-2. Renovation of older

building requires approval by municipalities and part of the facility must be retained in the new facility. Photograph A-3 shows the new construction connected to the portion of the old building retained. Photograph A-4 shows the renovation of a dairy barn to be architecturally compatible with the adjacent housing.

Two major concerns were discussed. Spangdahlem had recently completed an extensive runway rebuild and repair. The new surface was disintegrating. The contractor and the base engineers speculated that the problem was in the mixture, but no analysis had provided conclusive evidence. The researcher informed them about the Air Force Pavements Team and the pavements laboratory at Tyndall AFB. The researcher suggested they contact Mr. Jim Greene, the team leader, at (850) 283-6342. In follow-up phone calls, the researcher was informed that the pavements team had responded and were holding meetings with the base engineers and the contractor.

The second issue was university education opportunities for the military people stationed at Spangdahlem and other military locations in Europe. The researcher was told there are adequate opportunities for management courses from U.S. universities with extension campuses on military locations, and some opportunity for science and technical courses. The need was for laboratory courses to support U.S. university science and technical courses, such as environmental sciences and geophysics laboratories. For example, if a military member or dependent could take a distance learning course in environmental sciences or geophysics there is a need for supervised laboratory experiments, acceptable to the main university. The researcher proposed to discuss this issues with the GA TECH professors and try to establish a network with a local university, such a GA TECH and University of Trier.

2.1. Follow-up Action:

Researcher will discuss network of universities for laboratory courses with GA TECH faculty. Response will be conveyed directly to Mr. Carrouth. The researcher anticipates no follow-up on the runway problem.

3. CERAM International Business School, Sophia Antipolis, France

Lars Christian Smith, Director of the Master of Business Administration (MBA) Program hosted the visit with Dr. Rita Gregory, Mr. Jim Dreger, and Ms. Becky Hudson. CERAM is designed to provide advanced education to experienced business managers and leaders. Part of

the acceptance requirements considers number of years experience and previous organizational/decision making positions. Mr. Smith is interested in exchanging students and providing student intern positions for American students in the Sophia Antipolis Technical Center (sometimes called the Silicon Valley of Europe.)

3.1. Follow-up Action:

Investigate potential for exchange program with GA TECH.

4. Sediver Glass Plant, Vichey/St. Lorre, France.

Dr. Claude de Tourreil, Director of Research and Engineering, hosted the tour. Sediver makes specialized "toughen" glass insulators for power lines. The plant is fully automated and uses real-time quality control feedback to adjust the component portions for the glass mixtures. The kiln operates continuously 24-hours per day with a life of approximately five years, when it is replaced. Design and construction of the replacement kiln is pre-planned and construction materials are delivered on site in as-need order to minimize the down time while under replacement construction. The Construction Industry Institute Research on "just-in-time" materials management may have some application to their replacement construction.

The main research thrust at Sediver is in composite materials for insulators. Adhesives and bonding properties are the major technical challenges. They are researching bonding metal to glass using a special alumina cement and water bath to set the cement. Dr. Sadrine Prat who completed her Ph.D. defense the day we arrived discussed her research in composite bonding and her Ph.D. process in France. Dr. de Tourreil is an adjunct professor and was on her committee. The composites provide a major advantage of eight or ten to one in weight, but are expected to have 20 life expectancy compared to 40 years for glass. Little is known about the decay properties in outside air and sunlight to the composite insulators, so the 20-year life expectancy is still to be proven.

The advantage of the toughen glass is especially relevant in operations and management and yarding of the insulators. The toughed glass will shatter (catastrophic failure) this is readily found by visual inspection of the insulator, even with drive-by inspection of power lines. Similarly, visual inspection of insulators in yard storage is sufficient quality control. In contrast, ceramic insulators can chip or have imbedded faults that cause spillovers, detectable only with extensive trouble shooting measures. Similarly composite insulators require trouble shooting of

the whole series to identify a fault. The visual inspection is a major cost savings in operations and management costs. No work has been done to compare the cost advantages of glass versus composite insulators. See Photograph A-5.

The government and industry (Sediver) jointly funded the Ph.D. program for Dr. Sadrine Prat. It took four years of research but required no further course work beyond the undergraduate degree. It is standard procedure in this program for a Ph.D. committee to include an industry member. And, it is a requirement for at least one committee member be from another university. According to Dr. de Tourreil these requirements were designed to encourage industry to advance research, with government financial support, and to break down unnecessary competition by encouraging information sharing among universities in France. Dr. de Tourreil has coordinated some research on the performance of composite insulators with Dr. Ravi Gorur, Electrical Engineering, Arizona State at Tempe, AZ.

4.1. Follow-up Action:

None.

5. Mercedes Plant, Rastatt, Germany

This visit was hosted by Mr. Burkhardt Wolff, a graduate of the GA TECH Masters of Civil Engineering in Construction Engineering and Management. Dr. Gregory was joined by Ms Kelly Hudson, an industrial and electrical engineer, from the F-16 Test Wing at Edwards AFB, CA. Ms Hudson is a graduate of the GA TECH, School of Industrial Systems Engineering and earned an MBA from Xavier University, Cincinnati, OH. Prior to joining USAF civil service, Ms Hudson had industry experience planning, programming, installing and operating robots on a U.S. production line.

Although the robotic applications in this plant were state-of-the-art, they were pre-programmed production line applications and we saw no applications of artificial intelligence or decision making. The car frames were bar-coded and a sensor read the bar code to select options and colors. The assembly was termed "fishbone assembly" to reflect the placement of component parts and simultaneous assembly from both sides. We were briefed that because of advanced robotic applications, the combinations of colors and options were relatively unlimited, as compared to only five combinations available in the Alabama Mercedes plant.

An innovative placement for this plant contributed to major cost management savings and forms a model for sustainable designs. Mercedes in establishing this plant purchased enough land to

co-located their major subcontractors and suppliers. They estimate they save 110 trucks per day in direct costs and substantially more in indirects, such as coordination among suppliers and impact on the environment.

The concept of applying the AFRL/MLQC robotic technology to ground support equipment was discussed in detail with Ms Hudson. Her opinion was that in non-threatening, peacetime operations, the cost of robots could not be justified. Under heavy threat conditions or prepositioning for remote contingency, robots might be cost effective. But she felt that the concept would be very scenario dependent for cost-effectiveness.

5.1. Follow-up Action:

None.

6. Centre Scientifique et Technique du Batiment (CSTB), Multiple Offices in Paris and Marne-La_Vallee, France

Mr. Jean-Luc Salanac and Mr. Dominique Caccavelli hosted visit. CSTB was established shortly after World War II. In France, CSTB is roughly equivalent, for buildings, to the U.S National Institute of Standards and Technology (NIST). CSTB employees approximately 500 people and has offices in five locations. They conduct evaluation of construction products and provide technical advice. Much of their work is used by insurance companies to assess quality and estimate years of life. Their base budget (approximately 25%) is provided by the government and is dedicated to issues of common interest. Much of the technical advice and product evaluation funded by the industry. Developers want one source of certification and are pushing to have one source for Europe.

CSTB is using human/social scientists to research how people become familiar with and accept new technologies. They are using knowledge industry to study the dissemination of information and the improvements brought on by new building technologies on organizations and society.

The French building codes apply to new construction not to renovation of older or "sick" buildings. Most construction projects try to improve or update the older buildings, but there are no code or quality requirements. In limited areas current codes will apply for human safety or fire safety. For example, if the window is located where a window guard is required then the renovated building must install a window guard. Many "sick" buildings are also seen as social problems, with a link between social and technical problems. An example given was that the tilt-

up construction used in the social housing sector in the 1970's has structural and water tightness problems. The building codes can have some influence on owners who repair to rent, but condominiums present special problems because they are in the private domain and require coordination of all the owners. Owners who live in the buildings may be given tax incentives to improve or bring the building up to code standards. Mr. Salanac conceded that France and the U.S. have similar problems with moisture damages (such as humidity, capillary action and fungus), lead-based paint, and volatile products, but he thinks French building codes (especially in health, fire and safety) are more homogenous than across the fifty states, municipal, local codes and federal building codes.

Mr. Salanac was previously very active on international committees for robotics in construction. He stated that there is almost no work on construction robots and interest is declining. He said development and implementation of construction robots are too expensive and "too hard." He said the automotive accident rate in France is 30 times higher than construction accidents. Thus, the standard justification to use robots in high-risk construction jobs to prevent accidents and deaths is not the main research focus in France. Another reason was the French labor market was against robots for fear of manpower replacement in the current high unemployment market.

Mr. Caccavelli discussed the "Energy Performance, Indoor Environment, Quality Retrofit, (EPIQR)" project. This project was a coordinated effort among fifteen countries of the European Union (one exception is Switzerland) to develop a common cost structure for collecting data and case studies on building renovation. Three different topics—state of degradation, energy performance, and indoor air quality—formed to core of the case study and data collection. He said, as of July, 800 rehabilitation solutions have been costed, with supporting data by professional fees, building cost indices, cost weights, and detailed data bases on products used. During the diagnostic stage, guidelines are provided, including text and images, to assess 50 elements such as, 1) surroundings, 2) load bearing, 3) façade finish . . . 33) electrical, . . . 48) ventilation, etc. Codes for repair levels include a = nothing to do/normal maintenance, b = small degradation/minor repair, c = medium repair, and d = replace or complete change. Mr. Caccavelli was very pessimistic when asked if a U.S. member might be included on the 15 Nation working group. However, he is very interested in collaboration with the RACER and PACES (Parametric Automated Cost Engineering System) technologies. (The USAF owns the

patent covering the technologies of the RACER and PACES systems). He would positively entertain an invitation hosted by GA TECH for an extended exchange to coordinate research efforts.

6.1. Follow-up Action:

Coordinate and prepare invitation letter for Mr. Caccavelli.

7. Renovation of Bridges and Buildings, Multiple Locations

A planned improvement to the RACER/PACES technologies is adding the requirements and cost modules for renovation bridges with fiber reinforced polymers. An understanding of the damage to be repaired and the preparation for adhesives, such as acid washing or sand blasting is needed. Bridge renovation, especially under heavy or congested traffic could present another application for construction robotics. Photograph A-6 is a typical bridge that might be repaired with fiber reinforced polymers. Photograph A-7 provides a closer view of piling degradation. Photograph A-8 shows concrete spalling around metal components that could be repaired with fiber reinforces polymers.

7.1. Follow-up Action:

Continue research.

8. Scottish Borders Enterprises (SBE), Galashiels, Scotland

The visit as hosted by David Douglas, SBE Chief executive, Mrs. Julia Latto, Personal Assistant to the Chief Executive, and Mr. Gordon Cox, Senior Business Development Executive. SBE is a pseudo-governmental organization established and partially funded by the government but operating as a private business with a board of directors and a long-term goal to be totally self-sustaining. It was established due to the decline in the traditional industry, textiles, in the central belt of Scotland. Their main goals are economic development—specifically job creation, environmental improvement, and training. In 1993 they selected 13 business plans to establish local enterprises. These include diverse businesses such as organic farming, information technology, environmental analysis laboratory, co-generation of power, electronic tagging for livestock, waste water treatment, ground water wells, bio-fuels, and architectural design and building products. Photograph A-9 shows a house built from a new building technology that uses sandwiched wood panels made with foam insulation from rapeseed oil. The panels are

assembled under stress resulting in a self-supporting structure requiring no roof trusses. The blowing agent for the foam insulation agent is water and, therefore more environmentally friendly than traditional foam insulation development.

Scotland and the Scottish Borders Region are being faced with the closing of a large portion of their Territorial Army bases. SBE is very interested in collaborating on the RACER program to estimate and the AFRL robot program to clean up these bases. They requested our collaboration in preparing a proposal to request support from the Princess Diana funds. They offered to contact Lord Selfridge and the Honorable John Majors and request their visit to the AFRL robot display at the Farnborough Air Show.

SBE offers modern conference facilities with state-of-the-art projection and communication equipment. Communication equipment includes simultaneous language translations and support for the hearing impaired. Banquet facilities can seat 60 people for dinner or 100 for buffet servings.

Mr. Douglas will positively entertain an invitation for an exchange tour to collaborate the efforts of the GA TECH Center for Sustainable Technology and the AFRL robot program.

8.1. Follow-up Action:

Coordinate distinguished visitor visit to AFRL robot display. Offer support in proposal preparation for Princess Diana funds. Coordinate and prepare letter of invitation for Mr. Douglas.

9. High Speed Data Bus User Group and Vitronics, Nuremberg and Dresden, GE

This visit was lead by Mr. Ed Brown, AFRL/MLQC. Mr. John Wetzel, Applied Research Associates, and DR. Rita Gregory, GA TECH accompanied Mr. Brown. Hans-Josef Maas, Chairman of the International High Speed Data Bus User Group on Vitronics, hosted the meeting. Mr. Mass is from the Federal Republic of Germany, Federal Office of Defense Technology and Procurement. Other attendees included Mr. Chris Hughes, Trisennet corporation--Consultant to Mr. Mass form San Diego, CA; Peter Hallin and Marie Aubochon representing the Swedish Army; and Dr. Dirk Schimdt, Diehl, support contractor to Mr. Maas.

The main purpose of this meeting was to plan the fourth Joint meeting of Study Teams combined with the Plenary Meeting 1998 and their symposium "Vitronics For Military Platforms of the 21st Century," to be hosted by the German Armed Forces Administration Center, Dresden

Germany 29 September – 02 October 1998 in Dresden Germany. After the initial planning session at Diehl in Nuremberg, the team continued the meeting on the train to Dresden and reviewed the conference facilities and display yards.

Additional conversations centered on potential international partnership and areas of technical exchange with AFRL/MLQC. Details of these conversations and plans of action can be obtained from AFRL/MLQC. In brief, the plans are the Germans will develop the beta version of the high-speed data bus, the Swedes will provide the tank as the test bed and will represent the end users, and AFRL will provide the test and integration platform for the beta test version. The current status is the user group, lead by Germany, is developing the hardware specifications and software code.

9.1. Follow-up Action:

None.

10. Office National d'Etudes et de Recherches Aerospatiales (ONERA), Toulouse, FR

This visit was lead by Mr. Ed Brown AFRL/MLQC. Dr. Rita Gregory accompanied Mr. Brown. Philippe Pannetier, Deputy Director, hosted the visit for Systems and Equipments, Strategy and marketing Directorate, Chatillon Office. ONERA speakers were Francois Jouaillec, Director of Studies and Research; Jean-Pierre Jung, Director System control and Flight Dynamics Department; Claude Barrouil, Research Scientist, Management and Decision Group; Claude Reboulet, Research Scientist, Control and Integration Group; Florent Christophe, Deputy Director, Electromagnetism and Radar Department; Patrick Millot, Research Engineer, Radar Applications and Countermeasures Research Unit; Marc Labarrere, Deputy Director for Aircraft Strategy and Marketing Directorate; and Catherine Tessier, Research Scientist, Control and Decision Group (whose paper was presented, but she was not in attendance.) ONERA is a government organization operated under Industrial Management Standards (industrial funding, non-profit) under the Minister of Defense. They are 50/50 funded by a government grant and industry contracts. ONERA capitalizes on the second largest student population in France located in Toulouse (approximately 700 students, 180 research engineers, 120 faculty, and 90 doctoral students.

Areas of interest for technical exchange are robotics, command and control, and sensor fusion. Their work, presented by Ms. Tessier's paper in "perception" processing loop

algorithms. This work investigates the interpretation of signals. For example in parking lot monitoring, perception interprets "what are they doing and what are their intentions?" Based on signal interpretation it tries to distinguish between an car owner versus a robber. Based on discussions, this work appears to have major application in interpreting the sensor fusion with the robot; e.g. is it a rock or bomb?

Another area of interest is in the ground penetrating radar and synthetic aperture radar testing, image processing, and soil characterization. The data based developed from their fixed test stand could provide valuable information for training the neural nets for the AFRL robot. ONERA is interested in coordinated testing and data collection using the AFRL/MLQC instrumented range ("sandbox"). Dr. David Frost, GA TECH Director of Geosystems Engineering, has been conducting similar research in sensor interpretation and soil characterization.

10.1. Follow-up Action:

None

11. Royal Air Force, Logistics Support Services, Huntingdon, UK

Group Captain P.D. Rawson, Wing Commander John V. Morgan, Squadron Leader Dave Young, and Life Cycle officer Frank Boydell hosted visit. Mr. Ed Brown, AFRL, accompanied Dr. Gregory.

We were briefed on the Logistics Support Services (LSS) and the Logistics Operations and Repair Analysis (LORA) model. We were particularly interested in collaborating on methodologies to evaluate manpower requirements for robotic ground support equipment. Mr. Boydell explained that most reliability factors are not used to project manpower requirements for the Royal Air Force. Manpower requirements use scaling factors that would not be used to estimate the cost of robotic ground support equipment.

The LSS organization is very interested in RACER to analyze the cost of environmental impacts of their weapon system acquisition. They also anticipate a visit to the AFRL robot display at the Farnborough Air Show.

11.1. Follow-up Action:

Coordinate demonstration of RACER technologies.

12. **Royal Ministry of Defense, Defense Evaluation and Research Agency (DERA), Hampshire**, UK

Dr. Jordan Giddens and Mr. Charles Murton hosted visit. Mr. Frank Boydell accompanied Dr. Gregory from the RAF LSS. DERA has 12,000 employees and appears to be organizationally equivalent to our OSD/PA&E. Their studies include threat analyses and "right sizing" of the military.

Many areas of potential collaboration were discussed, including policy and planning analyses, operational exercise evaluation, wargaming and combat analyses, balance of investment methodologies, command and control, system dynamics and influence diagrams, and computer based training. Dr. Giddens is planning a trip to Waterways Experiment Station (WES) in October/November time frame and asked Dr. Gregory to meet him there.

12.1. Follow-up Action:

Coordinate visit to AFRL display at the Farnborough Air Show and WES. Dr. Giddens and Mr. Murton agreed to coordinate other points of contact within DERA that may have specific interest in GA TECH and AFRL research thrusts.

13. Davis Langdon Consultancy, London, UK

Mr. Jim Meikle and Paul Thomas hosted visit. Several areas of collaboration are anticipated in facility life cycle costing and international construction area cost factors. GA TECH, Building Construction Program has requested several publications listed in the references.

13.1. Follow-up Action:

Coordinate demonstration of RACER/PACES models.

14. Construction Industry Research and Information Association (CIRIA), London, UK

David Churcher and Robert Dent hosted visit. Several areas of potential collaboration were discussed. See references for list of publications purchased by GA TECH.

14.1. Follow-up Action:

None

15. The Institute of Civil Engineers, London, UK

No single point of contact was established. The research visited their extensive library and reviewed several United Kingdom publications on cost management and renovation of "sick" buildings.

15.1. Follow-up Action:

None

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Figure A-1
Spangdahlem –AFB Housing Renovation

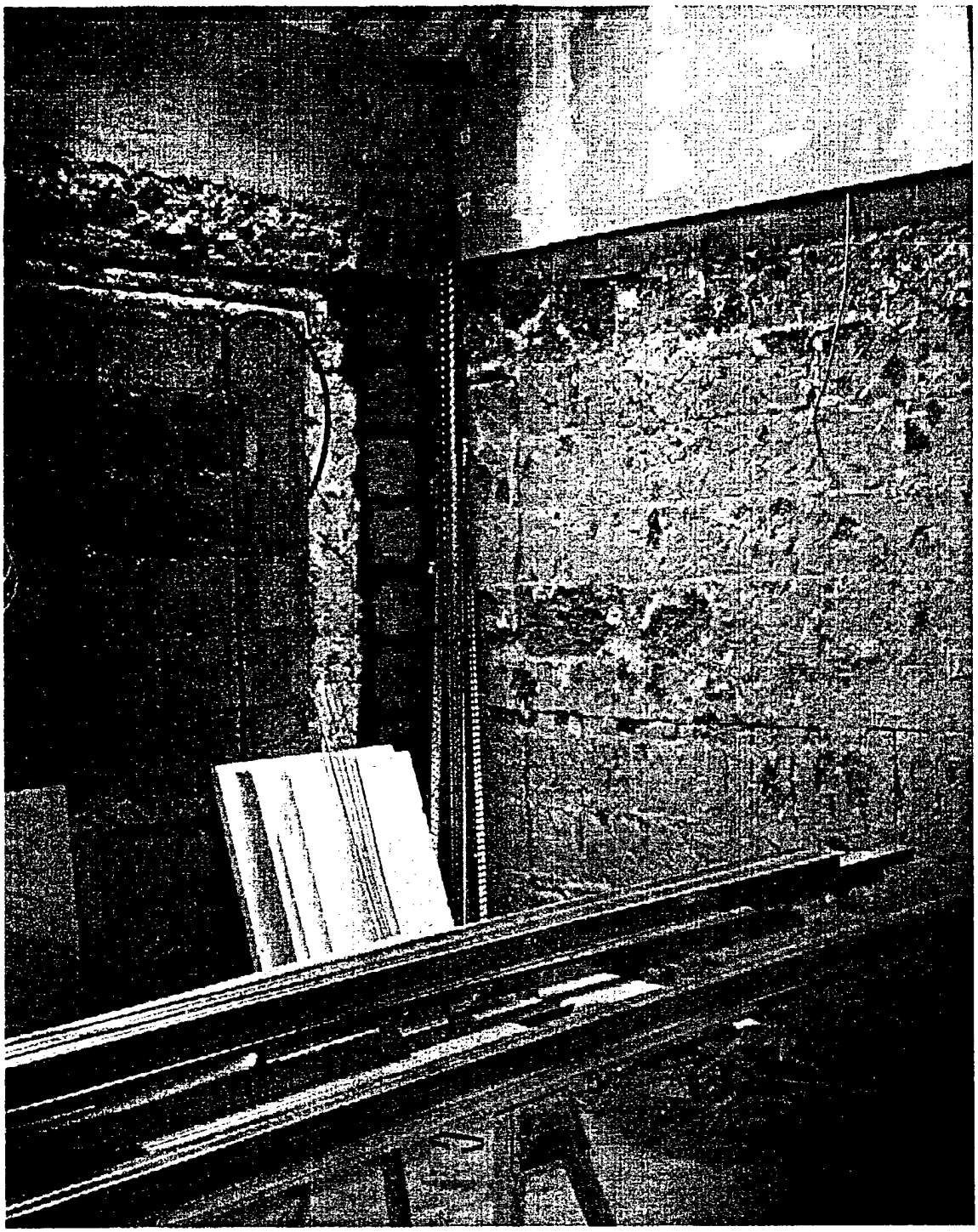

Figure A-2
Spangdahlem AFB Housing Renovation (interior)

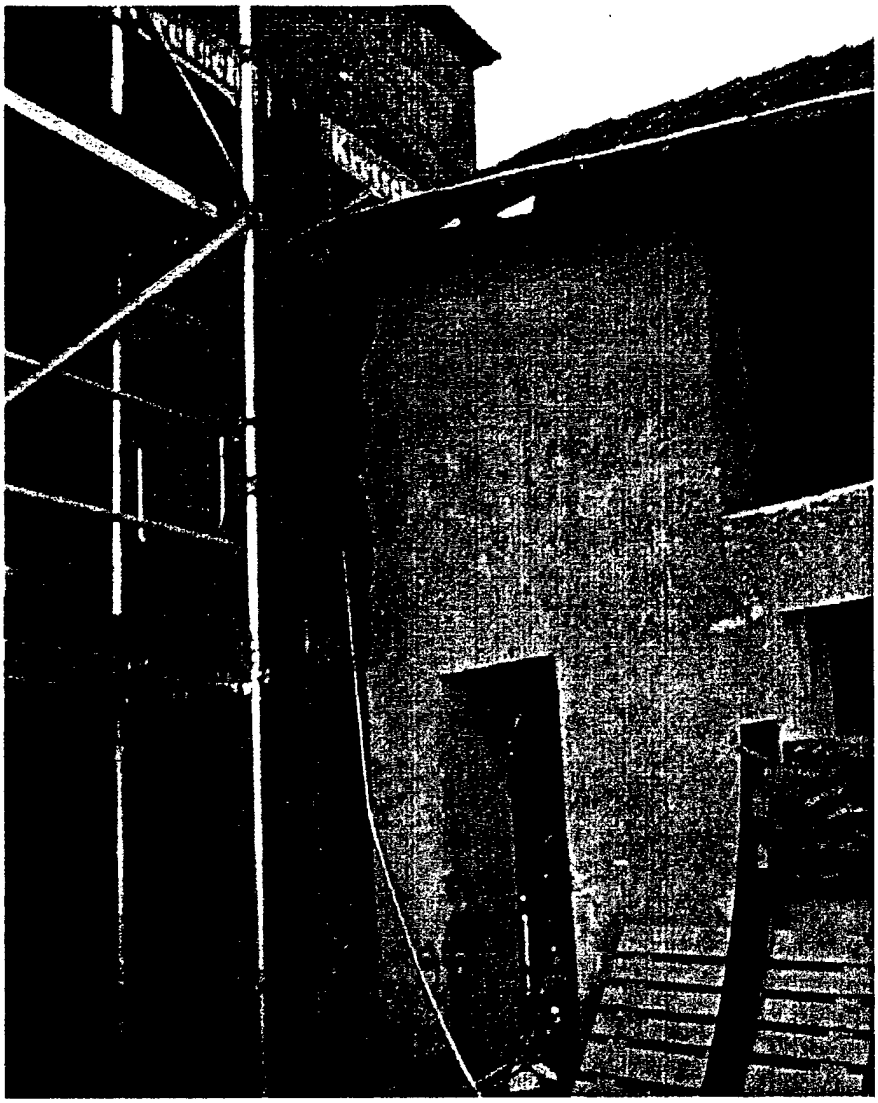

Figure A-3
Historic Housing Renovation

Figure A-4
Historic Building Renovation

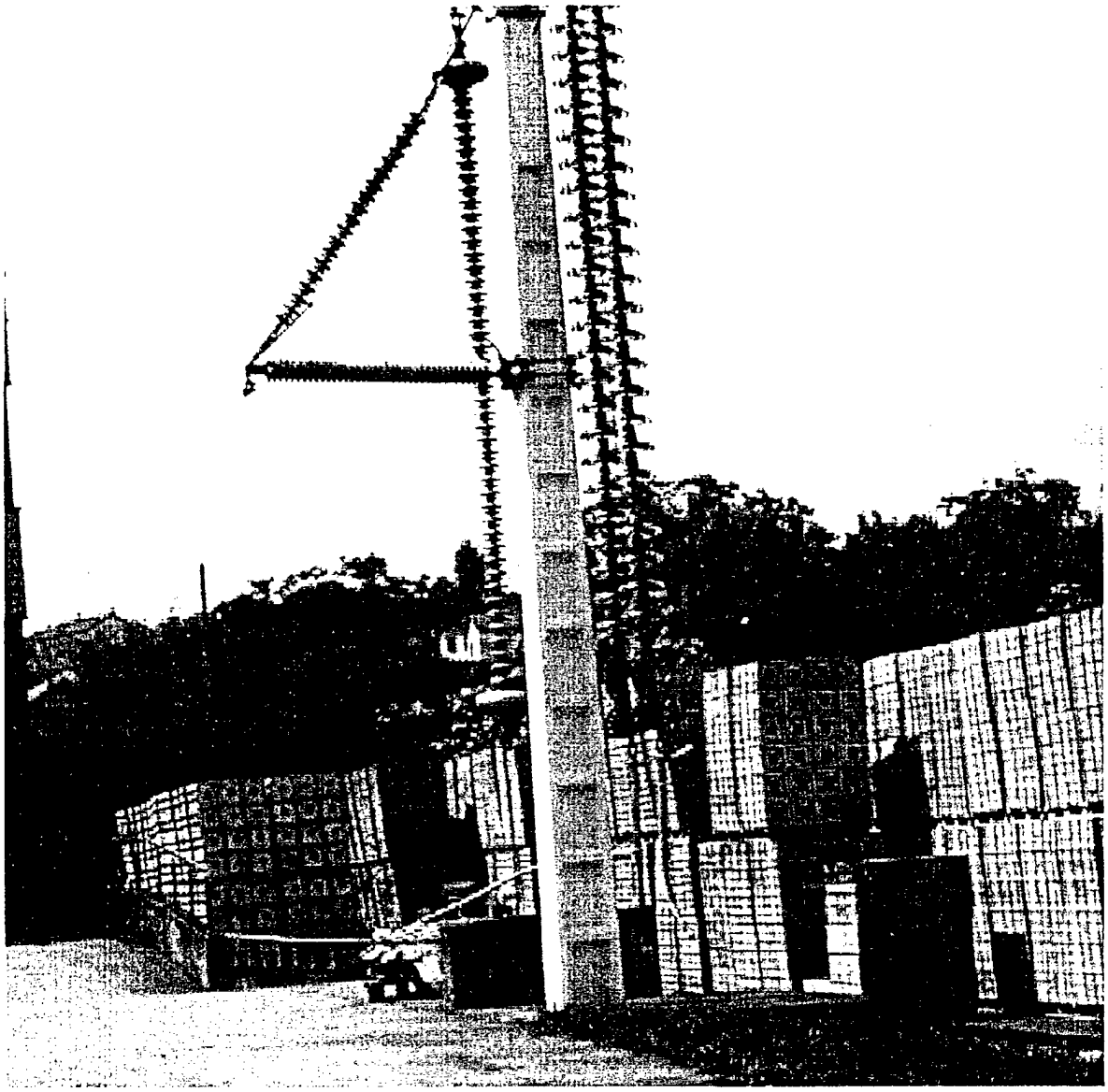

Figure A-5
Glass and Composite Insulators

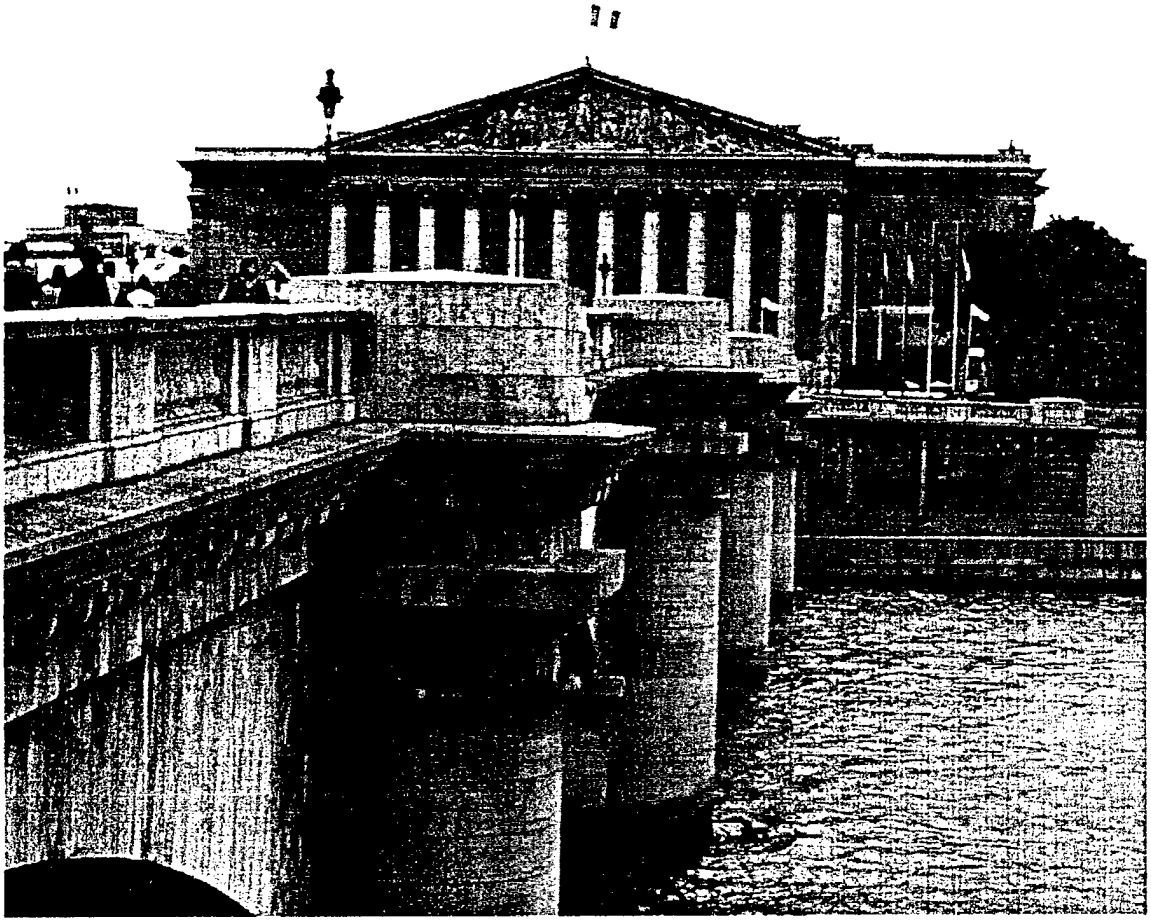

Figure A-6
Typical Bridge Renovation Requirement

Figure A-7
Bridge Degradation

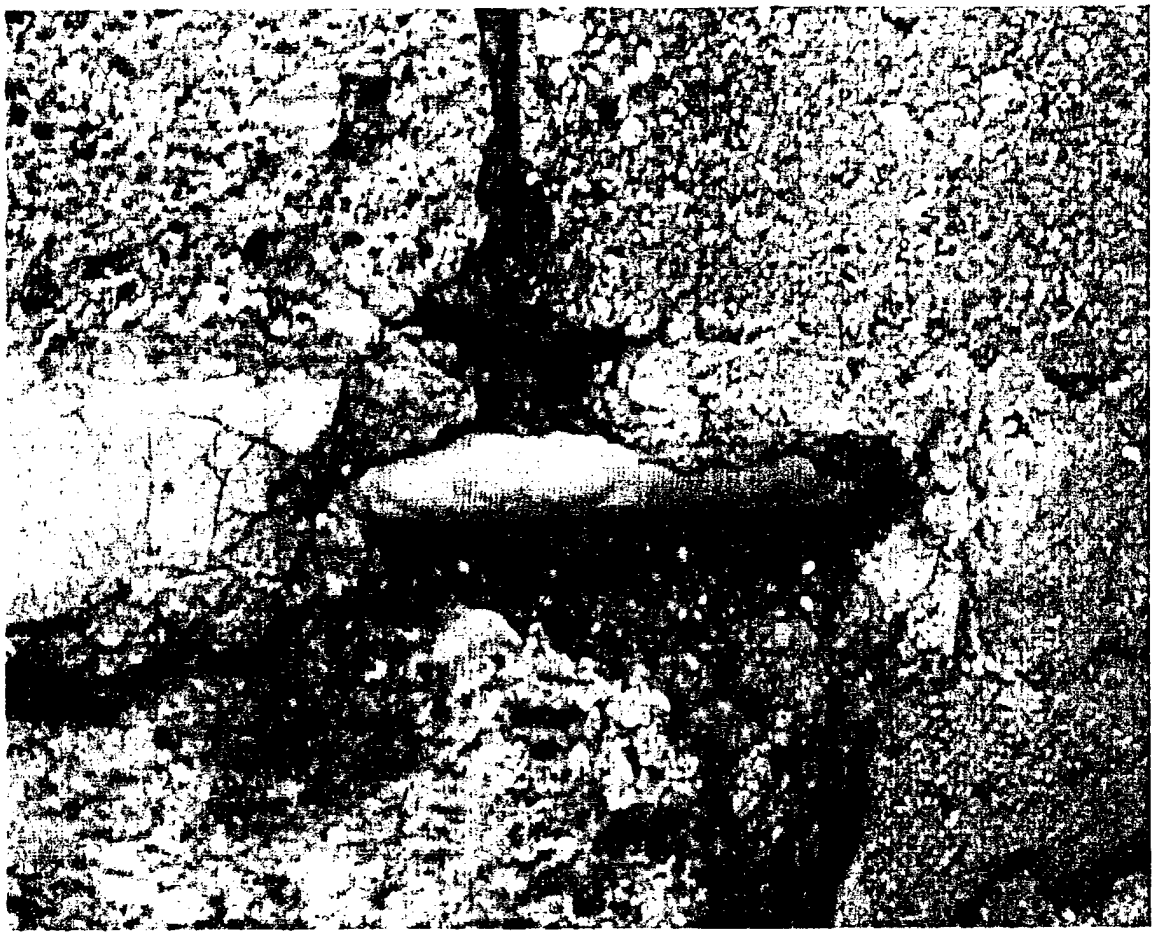

Figure A-8
Bridge Concrete Spalling

Figure A-9
Scottish Borders Enterprises Innovative Building Materials