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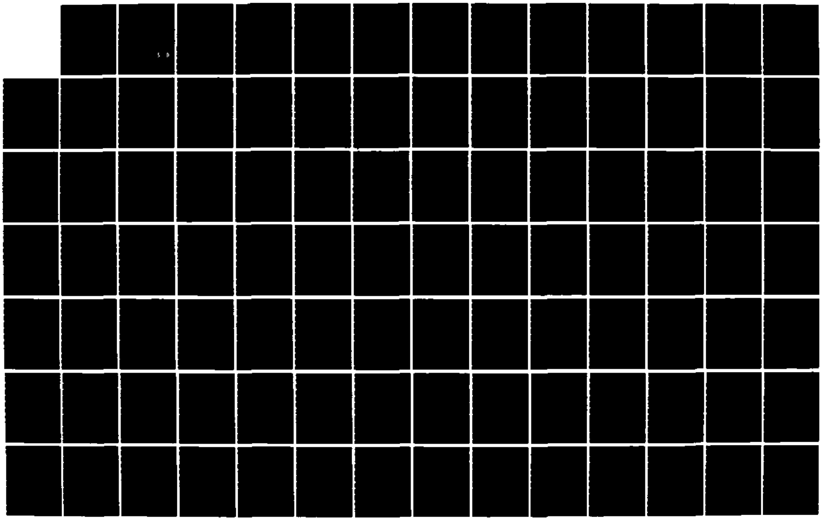

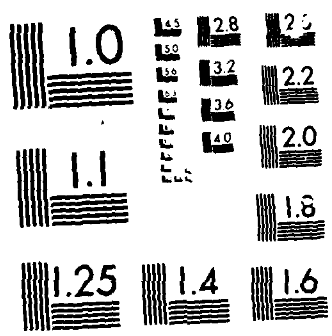

MICROCOPY RESOLUTION TEST CHART

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An Investigation By Kansas State University
Manhattan, KS
Sponsored By Naval Facilities
Engineering Command

NCEL
Contract Report

FRACTURE MECHANICS: APPLICABILITY TO CRACKING AND FRACTURE OF CONCRETE

ABSTRACT This report contains a state-of-the-art summary of past and current research activities in the application of fracture mechanics methodologies to cracking and fracture of concrete as well as contains recommendations of a fracture model to determine the fracture process in concrete. Despite known problems, it is recommended that linear elastic fracture mechanics provides a suitable model. A detailed testing procedure and data evaluation are given using a three-point-loaded cracked beam specimen.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

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METRIC CONVERSION FACTORS

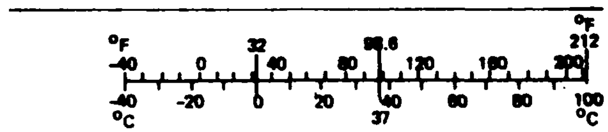
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains a state-of-the-art summary of past and current research activities in the application of fracture mechanics methodologies to cracking and fracture of concrete as well as contains recommendations of a fracture model to determine the fracture process in concrete. Despite known problems, it is recommended that linear elastic fracture

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) mechanics provides a suitable model. A detailed testing procedure and data evaluation are given using a three-point-loaded cracked beam specimen.

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INTRODUCTION

This report was generated within work unit ZR023.03.03.01.009, Fracture and Fatigue of Concrete, in the Structural Modeling Project, which is part of NAVFAC's 6.1 Basic Research Program Subelement 23, Mechanics, of Program Element 61153N. Application of fracture mechanics to concrete will impact the design of jet engine test cells, pier and pile structures, and other reinforced concrete structures in corrosive environments where current concrete design criteria based on ultimate compressive strength is not adequate. This work unit continues with the development of criteria for crack control in plate elements based on experimental and analytical results gathered in FY86 and FY87. This work unit is planned to be transitioned to 6.2 Exploratory Development in FY88.

This report contains a state-of-the-art summary of past and current activities by researchers in the application of fracture mechanics methodologies to cracking and fracture of plain and reinforced concrete.

The report consists of two major tasks. Task 1 is concerned with a review of available literature. While this is essentially never-ending because of continuing research activity, citations up to June 1985 are included here and updates can be performed readily since the entire file is formatted for use on a microcomputer. The report contains this file with some 780 entries. This is given by a printout and the appropriate data sets on diskettes along with non-proprietary software. Additionally, the available abstracts are printed out and may be made available on magnetic tape.

Task 2 contains recommendations of a fracture mechanics model to determine the fracture process in concrete. Also contained in this section of the report is a brief summary of the developments in fracture mechanics and the necessary adaptations, and problems, associated with applications to concrete. It is recommended that linear elastic fracture mechanics provides a suitable model - despite the known problems - but other models are also described and recommended. A detailed testing procedure and data evaluation are also given. This task has focused primarily on the aspects of testing to obtain valid fracture data because numerous methods of application to analysis and design already exist but are essentially nonfunctional due to lack of a reliable testing method.

Notation

A	One half the cracked area of a plate subjected to tension.
A_1-A_5	Coefficients defining K_I in Eq.5.
A_b	Cross-sectional area of a test beam.
a, a_o, a_e	Actual crack length, initial crack length and effective crack length, resp.
a_1, a_3, a_5	Coefficients describing normal stress σ_π in Eq. 2.
B, W, S, L	Width, depth, span, overall length resp. of a beam test specimen.
C	Compliance of test specimen (Fig. 10).
C_A	Roughness coefficient of cracked surface for concrete beams.
CLWL-DCB	Crack-line, wedge-loaded, double cantilever beam specimen (Fig. 14).
CMOD	Crack-mouth-opening displacement (Figs. 5, 9).
COD	Crack-opening-displacement for CLWL-DCB specimen (Fig. 14).
CTOD, $CTOD_c$	Crack-tip-opening-displacement and critical crack-tip-opening displacement, resp. (Figs. 5, 8).
c	Crack extension length from a starter notch.
d_a	Maximum aggregate size.
E, E_c	Modulus of elasticity--general, concrete, resp.
G_I, G_{IC}	Mode I energy release rate and critical value of this resp.
G_f or G_c	Fracture energy per unit area.
J, J_{IC}	J-integral (Eq. 11) and critical value for mode I fracture, resp.
K_I, K_{II}, K_{III}	Opening mode (I), sliding mode, in-plane (II) and tearing mode, out-of-plane (III) stress intensity factors.
K_{IC}, K_{IC}^S	Critical values of opening mode stress intensity factors, also called fracture toughness.

LEFM	Linear elastic fracture mechanics.
LPD = v	Load point displacement.
ℓ_p	Length of process zone (Figs. 2, 4).
M	Applied beam bending moment.
mg	Beam weight.
P	Applied beam load.
δQ	Change in energy required to grow a crack.
R	Crack resistance energy.
r,θ	General coordinates (Figs. 1, 2).
r_p	Size of plastic zone preceeding crack tip (Fig. 1).
SEN	Single edge notch.
T_i, u_i	Tension traction and associated displacement on any contour Γ surrounding the crack tip.
$U, \delta U$	Strain energy or fracture energy and change in strain energy associated with an initial crack and its extension, resp.
u	Elongation of infinitely-wide plate subjected to uniaxial tension (Fig. 6)
u_θ	Displacement in θ direction.
v_1, v_2	Displacements measured normal to crack in CLWL-DCB specimen (Fig. 14).
x_1, x_2	Local coordinate system associated with a contour Γ around the crack tip.
$z = 1 - \frac{a}{W}$	Parameter used to determine K_I (Eq. 5).
δ, δ_R	Displacement across crack zone in uniaxial tension specimen and value of this at maximum stress, σ_R (Figs. 3, 4).
δ_o	Final beam displacement of failure.
σ, σ_R	Uniaxial tensile stress and peak value obtained in test, resp.
$\sigma_{ij}, \epsilon_{ij}$	Stress and strain tensor respectively within region of crack tip bounded by contour Γ .

σ_r, σ_θ, $\tau_{r\theta}$	Radial and tangential normal stresses and associated shear stress, resp. (Fig. 1).
σ_η	Stress normal to axis $\theta = \pi$ (Fig. 1).
ν	Poisson's Ratio.

Task 1.0 Literature Review

This task involved searching and compiling pertinant references. A description of the sources searched is contained herein, as well as a description of the compiled lists of references and citations and a computerized method to implement these compilations.

1.1.1 Description of Sources

References were obtained using the library's computer search facilities; an already publicized, annotated bibliography on the subject; and various collections of literature including material from the Lund Institute of Technology and the Swedish Detonic Research Foundation.

Use of the library's computer search facilities enabled a general selection of references from 7 different databases: COMPENDEX, TRIS, NTIS, FRIP, ISMEC, EI Meetings and Dissertations Abstracts.

The COMPENDEX database is the machine - readable version of the Engineering Index. This database provides abstracted information from approximately 3500 journals, publications of engineering societies and organizations, papers from conference proceedings, selected government reports and books in 26 different languages for the years 1970 to present.

TRIS is the Transportation Research Information Service database providing all types of transportation research information from the United States Department of Transportation and the Transportation Research Board for the years 1970 to present.

NTIS is the National Technical Information Service database which consists of government sponsored research, development and engineering over the years 1964 to present.

FRIP is the Federal Research in Progress database. Only 3 citations were retrieved - however, this file contains data only for two years after a project is completed.

ISMEC is the Information Service in Mechanical Engineering database covering all aspects of mechanical engineering in 250 journals published throughout the world for the years from 1973 to present.

The EI Meetings database provides coverage of over 2000 published proceedings of conferences, meetings and symposia each year. It has been available since 1982 and is updated with approximately 8000 records each month.

The Dissertation's Abstracts database contains more than 800,000 dissertations dating back to 1861. More than 30,000 dissertation citations and 2500 masters thesis citations are added each year covering most U.S. Universities.

The computer search used several select descriptors to determine a subset of each database which pertains to concrete cracking and fracture.

The publicized, annotated bibliography was the one by S. Mindess entitled "The Cracking and Fracture of Concrete: An Annotated Bibliography 1928-1981" appearing in the volume Fracture Mechanics of Concrete, edited by Folker H. Wittmann, Elsevier Science Publishers B. V., 1983. It contained 405 citations with abstracts for the years prior to 1982.

1.1.2 Description of Literature File Implementation

Having a great quantity of bibliographic information and a need to scan and categorize this information quickly, a decision was made to utilize a database manipulation software available for a microcomputer.

The data manipulation software package selected for this was DBASE III by Ashton-Tate. A number of different packages were investigated.

DBASE III was selected primarily because of the availability in the College of Engineering of a data-manipulation program oriented toward use with a bibliography written with DBASE II. Since DBASE III is an advanced - and faster - version of this it was purchased using funds available from a related project.

This software is a relational, data base management system for 16-bit micro-computers. It is being implemented on the Civil Engineering Department's Zenith Z-150 computer. It has full relational and programming features for interactive use and programmed applications development. Its capabilities include 128 fields, 4000 bytes per record and up to one billion records per file with fast sorting, indexing and searching.

The bibliography program written with DBASE II has been converted and debugged for present use. This program provides help menus for the creation, maintenance and searching of a bibliography data base.

Following is a description of the installation and use of the program.

To install the bibliography program on a hard disk system, copy BIBLI.PRG and PROC.PRG from the diskette to the hard disk; on a two drive system, make sure the diskette with BIBLI.PRG and PROC.PRG along with DBASE.COM is in drive A.

To use the bibliography program - get into DBASE III by typing DBASE while logged on the same drive as DBASE.COM. The prompt symbol for DBASE III is a period. At the prompt, type DO BIBLI. This activates the program contained in files BIBLI.PRG and PROC.PRG. The screen will display the program title, ask for confirmation that the printer is on and request the file name and index files (see p. 70-71 in Appendix I). Type BIBL1 or BIBL2 in response as these are the concrete fracture mechanics bibliography databases on Diskette 1 and Diskette 2. The index files keyed on year and author are BIBL1.NDX or BIBL2.NDX depending which database file is in use; type BIBL1 or BIBL2. Type AUTH1 or AUTH2 for the author keyed index file and TITLE1 or TITLE2 for the title index. These index files must be on Drive A of a two drive system. The first record of the database will be displayed, along with the main menu of commands as given on p. 72 .

The display contains the Author(s), Title and Reference for each article. If there exists an abstract in the abstract list then there will be a list of keywords taken from the abstract and included on the screen display. The FLAG entry on the screen can contain any 5 character code to facilitate printing the reference or creating a text file of those citations particularly of interest.

At the lower right of the screen is displayed the record number, the status and an entry location labeled OPTION. The STATUS is OK if not deleted. STATUS displays DELETED if the record is marked for deletion.

OPTION is the prompt for a command.

To move within the database type f for forward or b for backward. This enables a one record at a time movement either in ascending or descending order of record numbers.

To print a record type p.

To delete a record type d. This actually marks the record for deletion. To purge the record from the memory two more steps are required: type m for the maintenance menu p. 73 and type the number 1 to verify that the records marked for deletion are not mistaken. As you verify the deletes type d to recall a record from being deleted if so desired. After verification type 2 on the maintenance menu to remove the records marked for deletion from the file permanently. A warning will be displayed which suggests a safer alterative than removing the records as described, p. 74 .

The report option is enabled by typing r. A Report Options menu is displayed which offers 6 more options dealing with the FLAG field (p. 75).

The Maintenance Menu is enabled by typing m on the main menu. It offers 7 options dealing with deletions, new entries or duplicate entries. The "Flag Duplicate Entries" option can be used only if there exists a title index file. The name of the title index file should be typed when prompted.

To quit the bibliography session type q on the main menu. This will return control to DBASE. To return to MSDOS type QUIT at the dot prompt (p. 76).

The locate option on the main menu is perhaps the most useful of the options. Type the letter l on the main menu to enable locating. The screen will display two additional options: locate entry by principal author and search for entry by a field as on p. 77 . The first option enables a quick search for a particular name listed first in the authors field of any record. Type the letter l to use this option and then type in the first five characters of the name when prompted. An index file indexed on the first 5 letters of the Author field must be available on the working drive. The second option, S, provides a means to look for a particular word within any field. When S is chosen the screen displays a choice of fields to search: authors field, keyword field, title field or reference field. After choosing the field to search the screen will prompt for a character string to search for. If the keyword field is chosen the screen will display a message prompting, for a logical operand and three character strings (p. 78-79). If all three strings are not needed hit return when prompted for the second or third string. After a record is located that contains the desired string a locate menu prompts for continuance of the search, "return to main menu, print the record or set" flag. See pg. 80.

The add option enabled by typing a on the main menu, facilitates a means to add records to the database. See p. 81-82.

The edit option, enabled by typing e, facilitates a means to edit the record displayed on the screen. See p. 83-84.

It should be noted that in both the edit and add modes the complete record including every field is shown along with a help menu. This is not true when the record is viewed with the main menu. One field, CODE, displayed by depressing ^PgDn on the keyboard, is included to facilitate insertion of decimal numbers as record numbers, thereby enabling later additions to the file sequence in the correct order of year and author name. For this reason, the DBASE III record number as shown on the top of the add and edit menus is different from the record number with the Citation and Abstract Listings, and as viewed with the main menu. When adding records care should be taken to determine the correct record number for entry in the field CODE and insertion into the Citation and Abstract Listings sequence.

A complete program listing is included starting on p. 53 of Appendix I

1.1.3 Description of Diskettes and Listings

Three diskettes contain the complete bibliography database, related index files and bibliography programs.

Diskette #1 contains, BIBL1.DBF, the first half of the bibliography database. (Records 1 to 390)

Diskette #2 contains, BIBL2.DBF, the second half of the database. (Records 391 to 783)

Diskette #3 contains the author, title and citation index files, AUTH1.NDX, etc.; the keywords database, KWDS.DBF; and the bibliography programs BIBLI.PRG and PROC.PRG.

The diskettes have been formatted for 9 sectors per track.

The authors, titles and sources with a related reference number are contained on one printout listing in Appendix II.

The citations are listed in order of the year the paper was published or given with authors listed alphabetically for each year. The reference number is a 4 digit decimal number allowing future additions in the present sequence.

Task 2.0 Recommendation of a Fracture Mechanics Model to Determine the Fracture Process in Concrete

In this task the developments leading up to the current state-of-the-art will be reviewed and examined. Recommendations for numerical models and necessary testing methods to obtain the appropriate material parameters to implement these models will be made with justification.

2.1 Current Fracture Models

2.1.0 Introduction

The successful application of the methods of Linear Elastic Fracture Mechanics (LEFM) to life estimates in metals and to prediction of failure in brittle materials such as glass and rock has encouraged researchers to attempt a similar application to concrete. Concrete is a brittle material and all of its constituents - rock, sand, hardened cement paste - are as well. No material fails for lack of compressive strength - with the exception of nuclear fusion. The failure mode is either tensile, or shear or a combination of both. Therefore, a unified approach to account for the actual failure mode, regardless of the state of imposed stress, is highly desirable.

2.1.0.1 Stress Distribution - Crack-Opening Mode

For a notched or cracked beam in bending with no shear the elastic stress distribution, as shown in Fig. 1, may be represented by (452,578)

$$\sigma_\theta = \sum_{n=1}^{\infty} (\frac{n}{2} + 1)(\frac{n}{2}) r^{\frac{n}{2} - 1} \{ a_n [\sin (\frac{n}{2} - 1) \theta - \frac{n-2}{n+2} \sin (\frac{n}{2} + 1) \theta] + b_n [\cos (\frac{n}{2} + 1) \theta \qquad (1)$$

Or, for $\theta = \pi$

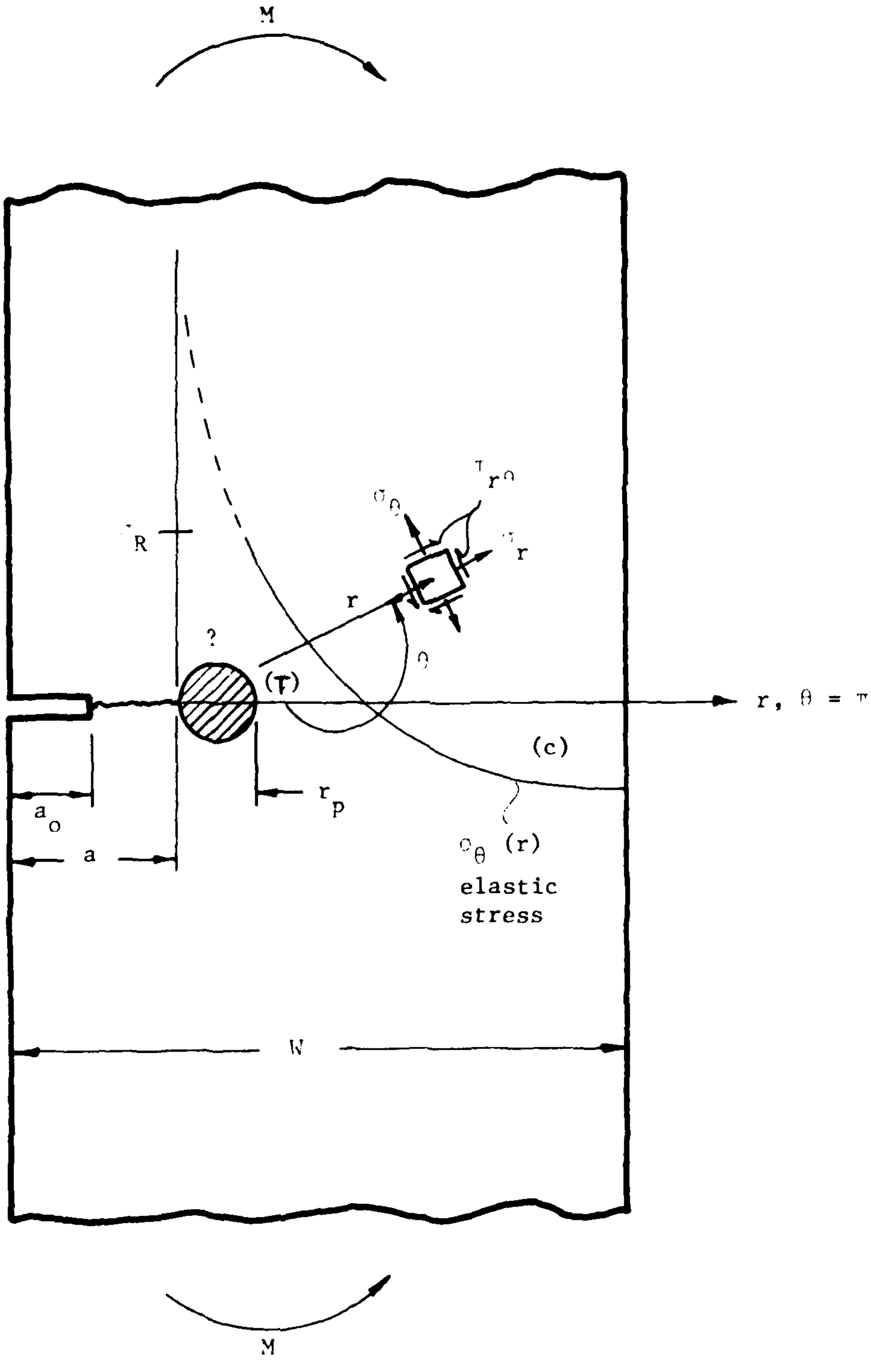


Fig. 1 Elastic Stress Distribution

$$\sigma_{\pi} = -a_1 r^{-1/2} + 3a_3 r^{1/2} - 5a_5 r^{3/2} + \dots \qquad (2)$$

where a_1, a_3, a_5 are coefficients which may be evaluated by finite element (587) or collocation (670) techniques.

From the definition of the opening-mode, stress intensity factor (124)

$$K_I = \lim_{r \to o} \sigma_\theta \, (r, \theta = \pi) \cdot \sqrt{2\pi r} \qquad (3)$$

it is seen that the first coefficient in the series, a_1, is related to K_I as

$$a_1 = -\frac{K_I}{\sqrt{2\pi}} \qquad (4)$$

Thus, near the region of the crack tip, as $r \to 0$, the stress distribution is proportional to K_I, while away from the crack tip the stress distribution is still given by Eq. 1 or Eq. 2 after evaluation of the remaining constants.

Obviously, $\sigma_\pi \to \infty$ as $r \to 0$ and the elastic stress distribution is no longer correct. For metals, a zone of plasticity, denoted by r_p, is considered to precede the actual crack tip (655).

For concrete, the current thinking is that the crack tip is composed of an aggregate interlock region and a zone of microcracking which together are frequently called the process zone, ℓ_p (21, 86, 198, 359, 407, 408,

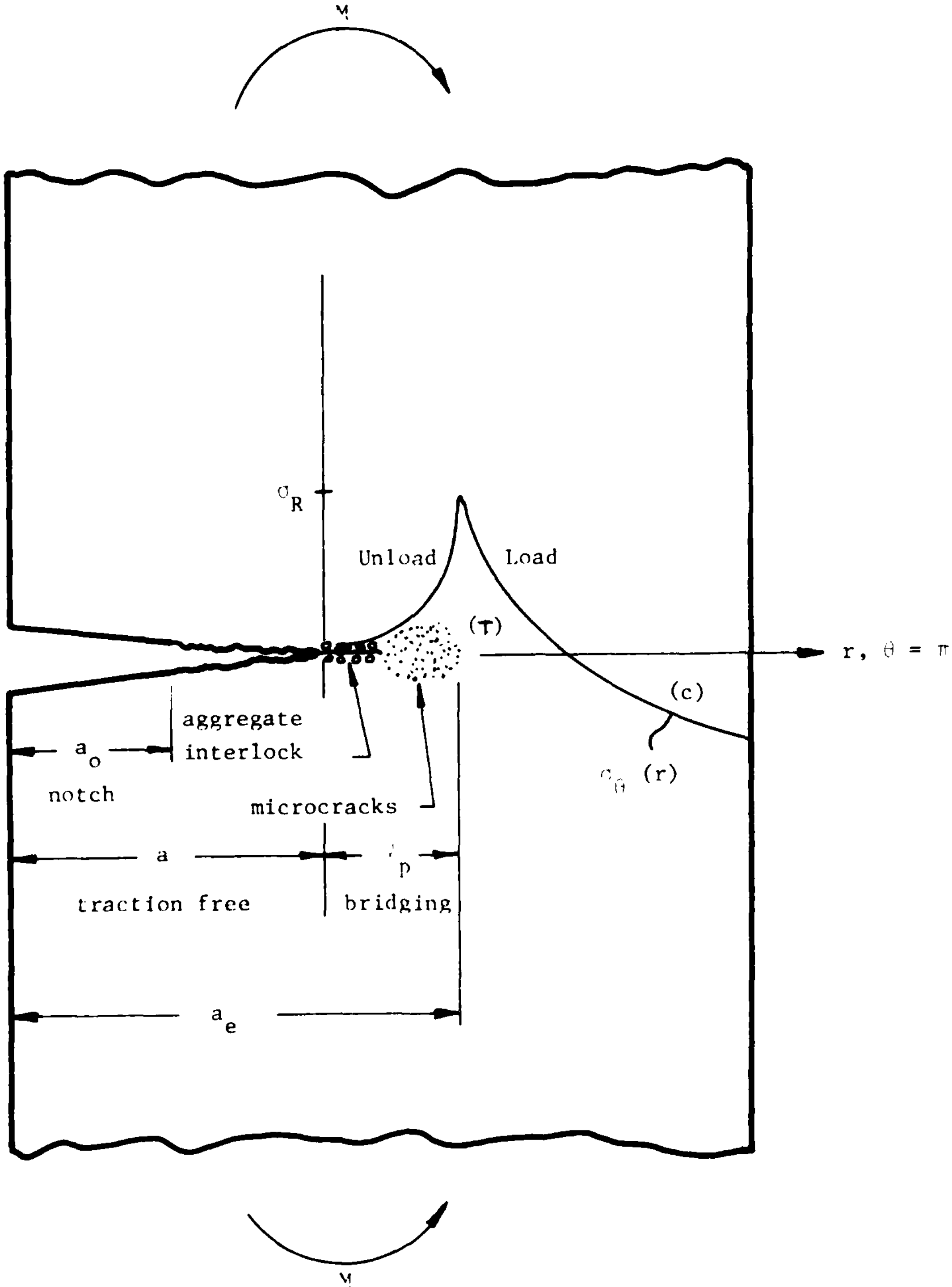


Fig. 2 Influence of Process Zone on Stress Distribution, Cementitious Material

467, 470, 550, 627, 629, 630, 631, 657, 659, 664, 667, 691, 694, 697, 705, 724, 736, 737, 747, 756, 757, 761, 762, 766, 771).

As described in Fig. 2, the elastic stress distribution is valid up to some stress level σ_R which corresponds to the beginning of the zone of microcracking.

As shown in Fig. 3, which corresponds generically to test results reported (470, 672, 761, 761.1) for direct tension of plain concrete, the stress σ_R is attained at a deformation denoted by δ_R and then the material unloads as σ decreases with increasing δ. The unloading response, which is called "strain-softening", is related to the type of test control - either load or deformation - and in the former case and sometimes the latter case is also related to machine stiffness vis-a-vis specimen stiffness.

It is seen then that the shape of the unload diagram given in Fig. 2 which occurs over the bridging length ℓ_p, or process zone, is related to the strain-softening response of the material.

As shown in Fig. 4, the length of the process zone is related not only to the strain-softening response of the material but also to the rate of change of deformation, δ , within this zone. Thus a short process zone implies a more rapid change in δ as compared to a long process zone.

Furthermore, the length of the process zone is directly related to the fundamental question - is LEFM a suitable method?

2.1.0.2 Fundamental LEFM Relations

For linear elastic fracture mechanics the development usually presented starts with the work of Griffith (655) which describes an infinitely-wide plate with a central flaw (crack, notch) subjected to a nominal state of stress of uniaxial tension.

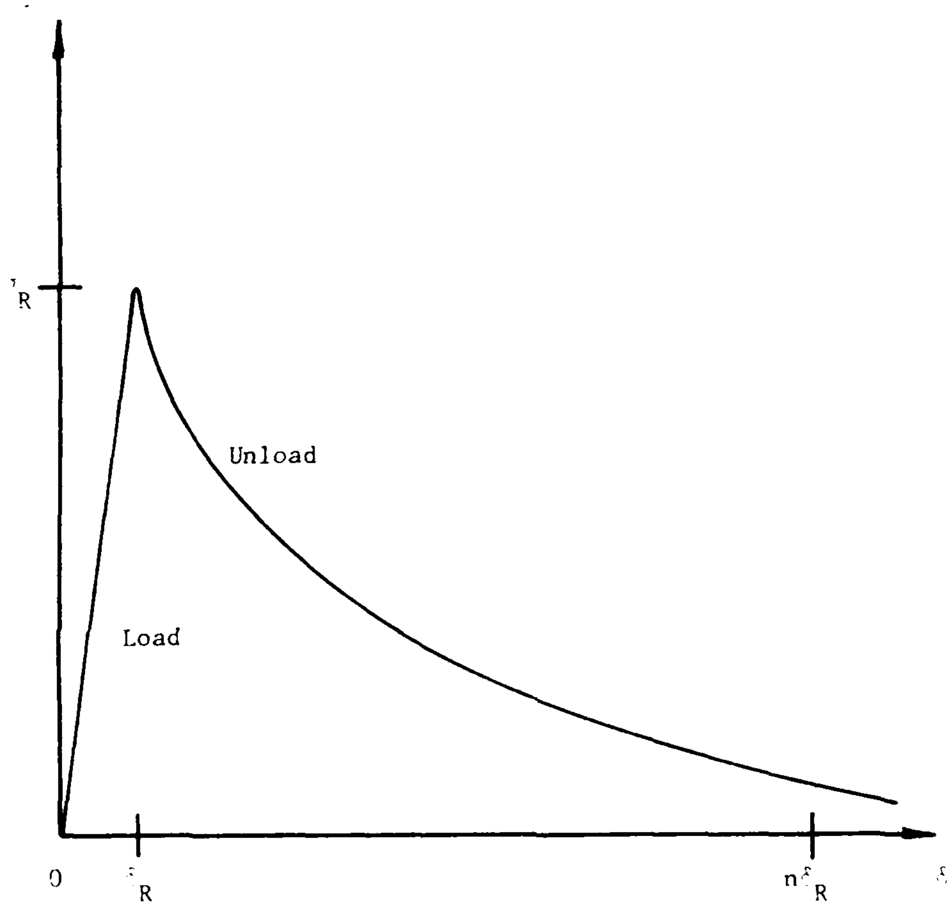
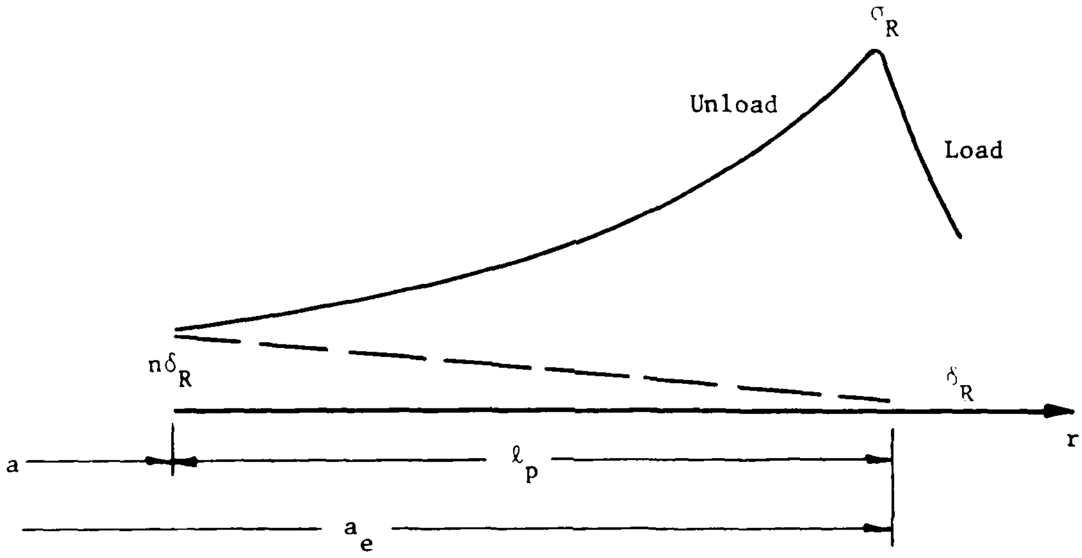
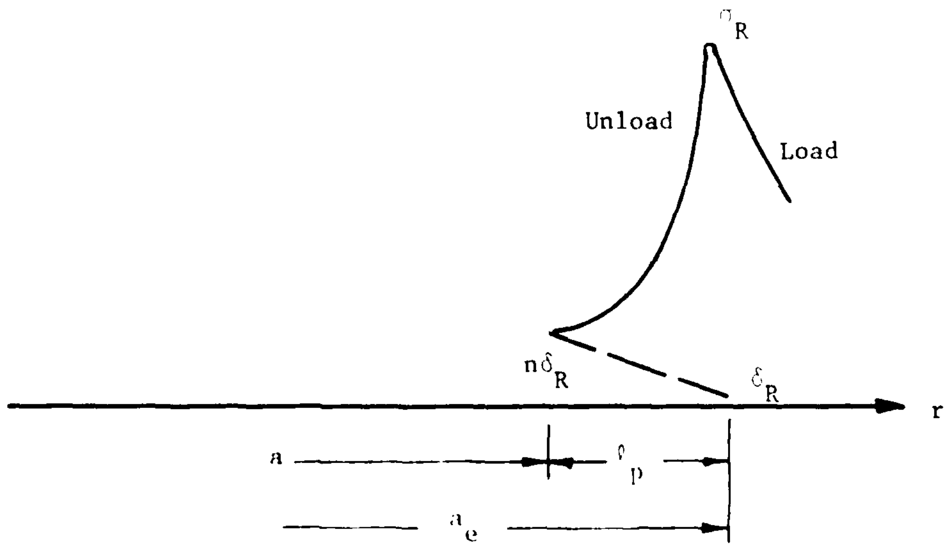


Fig. 3 Cementitious Material Tensile σ-ε Response



a. Long Process Zone



b. Short Process Zone

Fig. 4 Possible Unloading Cases For Different Length Process Zones for a Cementitious Material

However, here it is convenient to present the fundamental relationships for three-point, beam bending specimens with a single-edge-notch (SEN). Historically, this type of specimen was found to be attractive to those working in metals because of their familiarity with the Charpy Impact specimen. In concrete testing, the short span, modulus of rupture specimen is popular although this is a beam subjected to four-point bending.

Throughout this report, specific relationships for SEN beam specimens in three-point bending as shown in Fig. 5 will be given. Reference to equivalent expressions for other types of test specimens will be made via the Bibliography.

2.1.0.2.1 Stress Intensity Factors

The opening mode stress intensity factor K_I as defined in Eq. 3 is associated with a displacement which is parallel to the beam axis and near the crack tip. Specifically, with reference to Fig. 1 it is denoted u_θ $(r, \theta = \pi)$. Displacements which are measured are the crack mouth opening displacement (CMOD) at the edge of the beam and across the notch (Fig. 5) and crack tip opening displacement (CTOD) at the crack tip.

It is noted that other stress intensity factors exist for shearing mode deformations. These are denoted K_{II} (sliding mode-in plane) and K_{III} (tearing mode out of plane) (cf. References 124, 655).

Expressions are available to evaluate K_I for the specimen geometry of Fig. 5 and with central load P. These are of the form

$$K_I = \frac{M}{BW^{1.5}} (A_1 Z^2 + A_2 Z + A_3 + A_4 Z^{-1} + A_5 Z^{-2}) \qquad (5)$$

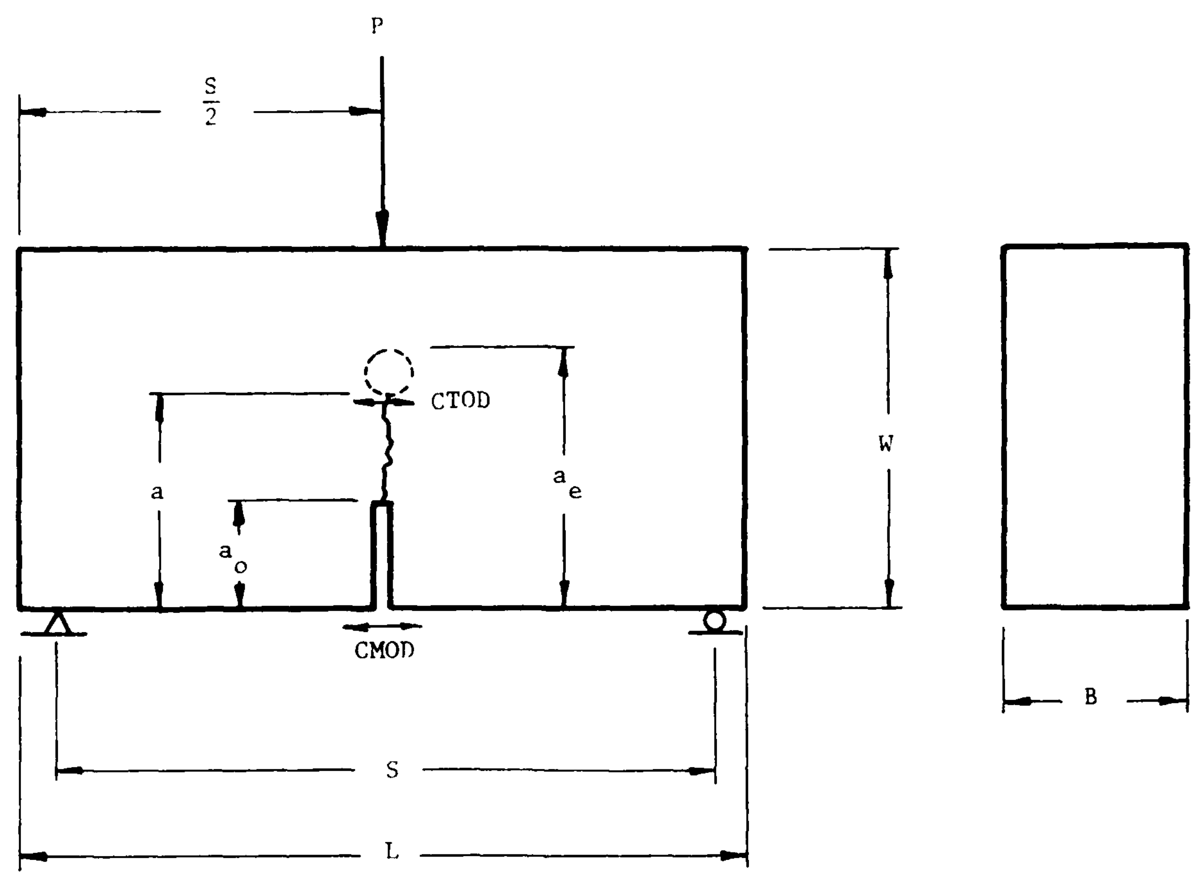


Fig. 5 SEN Beam Geometry

where $Z = 1 - \frac{a}{W}$, $A_1 - A_5$ depend on specimen proportions, and M = 1/4 PS. Values of these coefficients for various ratios of $\frac{S}{W}$ are given in Reference 670 and were obtained by solving Eq. 1 using a collocation technique.

A different form of Eq. 5, given by Srawley (655) for $\frac{S}{W} = 4$ and used in ASTM E 399 (558) is

$$K_I = \frac{PS}{BW^{3/2}} \left[2.9\left(\frac{a}{W}\right)^{1/2} - 4.6\left(\frac{a}{W}\right)^{3/2} + 21.8\left(\frac{a}{W}\right)^{5/2} - 37.6\left(\frac{a}{W}\right)^{7/2} + 38.7\left(\frac{a}{W}\right)^{9/2}\right] \quad (6)$$

In application, the stress intensity factor defines the stress field outside of the zone of plasticity and is a measure of the stresses and strains. Crack extension will occur when these stresses and strains at the crack tip reach a critical value. In other words, fracture will be expected to occur when K_I reaches some critical value, called K_{IC}. This quantity is called the material fracture toughness and is considered to be a material parameter.

If this is the case, the implication is that for crack lengths greater than the critical length frequently considered to be the length associated with unstable crack growth - the value of $K_I = K_{IC}$ should be invariant with length. Furthermore, the value of K_{IC} obtained from a certain size of test specimen should agree with that obtained from a different size if the relative proportions of dimensions are equal.

For LEFM the procedure to find K_{IC} is to determine K_I for different values of (P, a) until invariance is established. In practice, ASTM E399 (558) describes a testing procedure using a plot of P versus displacement (usually CMOD) from which an estimate of P at critical crack length can be made.

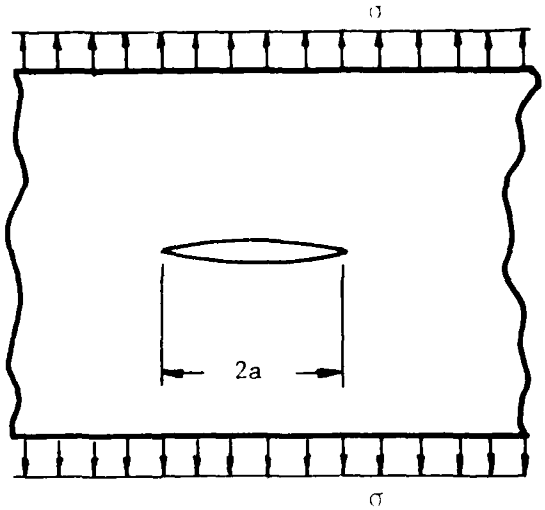
This procedure has been used by a number of investigators with concrete specimens with essentially no success (35, 54, 78, 81, 86, 99, 111, 214, 230, 278). Because of this, the general conclusion has been reached (not yet shared by this writer) that LEFM is not a valid method to be used to characterize cracking and fracture of concrete. However, the vast majority of these investigators have failed to satisfy one of the requirements necessary for valid results using this approach, to wit., the generation of a true, sharp crack prior to obtaining fracture data. Some other errors include use of specimen geometry which does not satisfy that imposed by Eq. (6), i.e., $\frac{S}{W} = 4$; failure to measure the crack length properly - or at all; failure to consider the difference between slow and rapid crack growth.

As will be reported later herein, in the last few years all of these effects are being considered, with consequently an improvement in consistency of results and some revival in interest in LEFM (by those who had abandoned it).

Other types of test specimens include: double-cantilever (325, 548, 614, 627) direct tension (21, 35, 78, 81, 86, 672, 761, 761.1); crack line, wedge-loaded double-cantilever beam (CLWL) (697, 756) and double-torsion (143.1, 300.1, 407, 550). Expressions for K_I for all these geometries, similar to Eqs. 5 and 6 are given.

2.1.0.2.2 Energy-Release-Rate

The Griffith criterion as described in Reference 655 may be established by considering Fig. 6 in which an infinitely-wide plate a.



b.

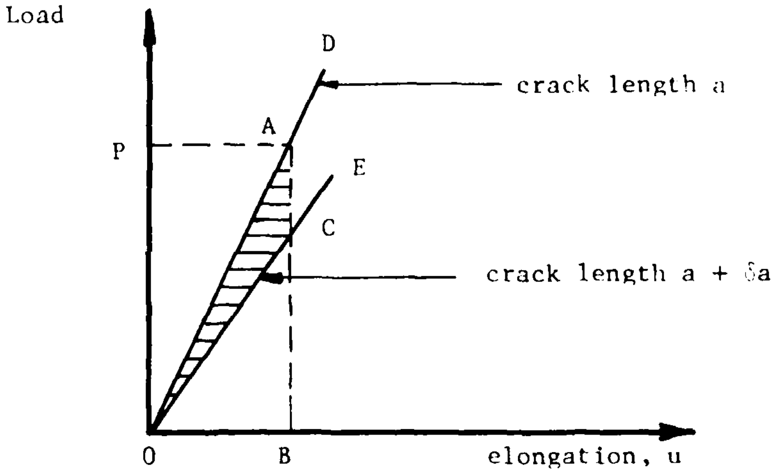


Fig. 6 Griffith Criterion for Fixed Edges

a. Plate with flaw or notch 2a
b. Elastic energy

containing a flaw of length 2a is shown along with its elastic load-deformation response.

The elastic energy, U_A = area O A B up to a given load level for the body with cracked area = a B. The elastic energy up to the same level of deformation for a crack length = a + δa is $U_{A+\delta A}$ = area O C B.

Then the change in strain energy corresponding to the change in crack length, δa, is

$$\delta U = U_A - U_{A+\delta A}$$

and is represented by the shaded area in the figure. Since the boundaries are fixed δU represents a release in elastic energy corresponding to the increase in crack length, δa.

If δU exceeds the energy, δQ, required to grow the crack, then the crack will propagate. The fracture criterion is

$$\frac{dU}{dA} \geq \frac{dQ}{dA}$$

or, since

$$A = aW \qquad (7)$$

$$\frac{dU}{da} \geq \frac{dQ}{da} \qquad (8)$$

Define

$$G_I = \frac{dU}{da}$$

called the mode I energy release rate (per unit area of crack extension) and define

$$R = \frac{dQ}{da} \qquad (9)$$

the energy consumed per unit area during crack propagation and called the crack resistance. The critical value of G_I is G_{IC} = R.

For an elliptic crack of length 2a, it is found that

$$G_I = \frac{1-\nu^2}{E} \quad K_I \qquad (10)$$

for plane strain.

This relationship is considered to be valid for other specimen geometries and loads (655). Thus if K_{IC} is known, G_{IC} is also known and vice versa.

This is of great practical importance from an experimental viewpoint as it permits an independent method for determining the material fracture parameter.

In practice, G_I can be determined directly from load-deformation diagrams provided the crack length - deformation relationship is known.

2.1.0.2.3 J-Integral Method

The methods described above are based entirely on the assumption of linear material behavior. For concrete, this implies two requirements: 1. linear material response, 2. complete absence of a process zone.

Neither of these assumptions is satisfied completely. In the case of the material assumption, the non-linearities are, in fact, very small for the stress levels considered. For uniaxial tension, the material may be considered linear up to the point of maximum stress. For uniaxial compression, the material is also almost linear up to about 1/2 its compressive strength, f'c, which is a stress level much higher than that associated with crack propagation.

The second consideration - the process zone - is currently the focus of much research activity. If the process zone is small, the following method should be applicable (655).

The J-Integral concept was developed to try to overcome the problem of plasticity present at the crack tip in metal specimens. As presented by Rice (45, 655), the following integral taken around any contour Γ which includes the crack tip is an invariant:

$$J = \int_{\Gamma} \{ [\int_{o}^{\varepsilon} \sigma_{ij} \, d\varepsilon_{ij}] \, dx_1 - T_i \frac{\partial u_i}{\partial x_2} \, ds \} \qquad (11)$$

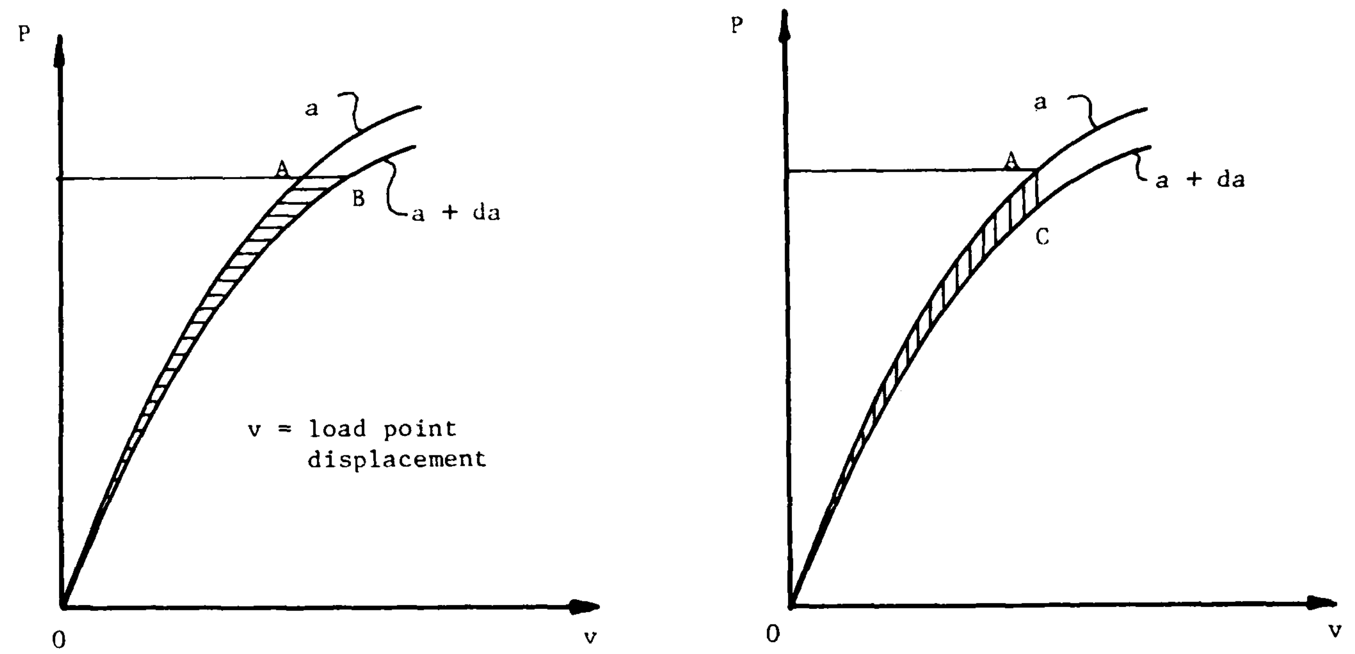
in which (x_1, x_2) is a coordinate system with x_1 in the direction of crack propagation, σ_{ij} is the stress tensor, ε_{ij} is the strain tensor, T_i is the tension traction on Γ and u_i is the displacement in the T_i direction.

It is shown by Rice that for a linear-elastic material $J = G_I$. Thus, it has been postulated that crack growth, or fracture occurs if J exceeds a critical value J_{IC} which is analogous to G_{IC}. If the process zone is small, then even for the elastic-plastic case $J_{IC} \approx G_{IC}$.

Thus, another measure of the fracture energy release rate can be obtained independently and the J-Integral approach also will allow consideration of the influence of plasticity.

The method of implementation of this approach may be considered first by examining Fig. 7. In this it is seen that J may be essentially the same value if load control is used or displacement control is used, even though the response is non-linear. This is the basis for a test method (418) in which one uses load-displacement curves for different crack lengths. The area between the curves for two cracks of slightly different size is determined. This is considered to be approximately J B da. Values of J obtained this way can be plotted versus a to determine J_{IC}.

An alternative procedure for concrete was suggested by Go (578) in which the fracture energy U is measured for specimens with different crack lengths and plotted versus a. The slope of the best straight-line



Area OAB $\approx$ Area OAC

Fig. 7 Energy Change With da Using Load Control or Displacement Control fit of these points is

$$J_{IC} = -\frac{dU}{\partial a}\frac{1}{B} \qquad (12)$$

and this value is compared to G_{IC}.

2.1.0.2.4 Crack Tip Opening Displacement

As shown in Fig. 8, a parameter considered to be of possible usefulness is the crack tip opening displacement (CTOD) associated with the end of the traction-free crack (length a). It is felt that this is a constant for a propagating crack and as such is a material constant. For LEFM it can be related to K_{IC} and G_{IC} but its primary value would be in materials with high plasticity or a large process zone. In this case it still would be possible to obtain a fracture parameter which is representative of the material and which can be used in design.

Proposed expressions to obtain the CTOD for concrete are given in References 671, 765 for beams and double-cantilever specimens and in Reference 417 for CLWL specimens.

2.1.0.3 Summary

By way of a brief summary of the concepts described above, the following considerations are presented as necessary for the validity of LEFM to concrete.

1. A "process zone", if it exists, must be relatively small compared to specimen dimensions and crack length. It may be a function of the size of aggregate - perhaps up to three times this size.
2. A critical value of K_I called K_{IC} or fracture toughness exists. This is associated with the onset or continuation of unstable crack growth.

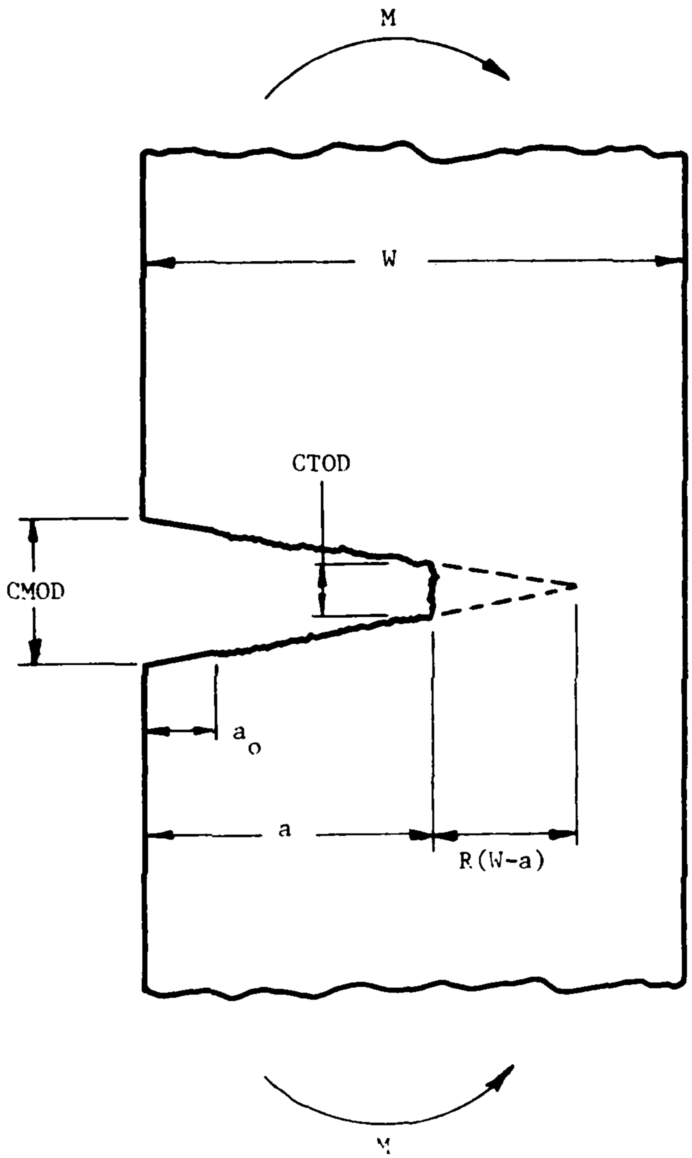


Fig. 8 Crack-Mouth-Opening-Displacement (CMOD) and Crack-Tip-Opening-Displacement (CTOD)

3. K_{IC} is independent of crack length a, or a_e, but not notch length a_o, beyond some length.

4. K_{IC} is independent of specimen size - beyond some size (which is probably related to the maximum size of aggregate).

5. K_{IC} is equivalent to G_{IC}, the energy release rate associated with unstable crack growth, e.g.

$$G_{IC} = \frac{1-\nu^2}{E} K^2_{IC}$$

6. The J-Integral approach should give results which are identical to G_{IC}.

If LEFM is not a valid approach, the general concept is still used in which non-linear effects are considered. Two such approaches in which a single parameter is sought are the J-Integral Method and Determination of the CTOD.

2.1.1 Experimental Methods Proposed to Determine Fracture Parameters for Concrete

2.1.1.0 Introduction

A number of investigations directed toward measuring the fracture toughness of cement pastes, mortars and concretes are reported (17, 21, 26, 35, 42, 54, 61, 78, 81, 86, 87, 90, 99, 111, 112, 117, 131, 133, 140, 159, 189, 194, 196, 197, 202, 204, 214, 220, 230, 276, 278, 303, 304, 325, 327, 383, 384, 391, 400, 402, 407, 408, 426, 441, 449, 450, 452, 470, 474, 528, 531, 544, 548, 578, 584, 624, 637, 669, 685, 686, 697, 716, 743, 751, 756, 761, 763, 777), as well as for rock (122, 181, 207, 231, 263, 380, 381, 454, 527, 535, 591, 597, 605, 701, 702, 709, 730, 741, 745). These investigations used beam bending specimens (54, 86, 99, 111, 158, 189, 197, 214, 230, 245.1, 278, 361, 383, 384, 385, 400, 441, 452, 531, 544, 578, 584, 651, 669, 685, 687, 694, 713, 743, 751, 777), double cantilever beam specimens (276, 325, 548, 614, 627), plate tension specimens (21, 35, 78, 81, 86, 672, 761), torsion specimens (143.1, 300.1, 407, 550), and CLWL specimens (697, 756). These were all concerned with Type I deformation. A limited number of investigations have been concerned with Type II deformation (418.1, 559, 560, 561).

The investigations can be conveniently categorized as those which used notched specimens with no consideration of precracking or influence of prior crack growth (35, 54, 78, 81, 111, 189, 197, 214, 230, 383, 384, 385, 531, 584, 651, 685, 687, 713, 751); and those which did consider precracking on estimates of fracture toughness or other fracture parameters (78, 99, 158, 194, 197, 245.1, 278, 361, 400, 441, 452, 544, 578, 669, 694, 743, 777). It was observed by Schmidt (207) in tests on limestone beams (1976) subjected to repeated loads that crack closure occurred upon load removal. Upon subsequent re-application of the load the material compliance was reduced until the crack re-opened. Thus, it was concluded that " ...a crack probably cannot be adequately simulated by a sharp saw cut for the purpose of measuring fracture toughness. Even if the cut could be made sufficiently sharp so as to provide a stress singularity similar to that of a natural crack, the closure stresses would still be non-existant." The writer, in performing numerous beam tests has observed the same phenomenon (245.1, 278, 361, 400, 402, 544, 579, 669, 743, 777).

Furthermore, it has been shown for beams in three-point and four-point bending (441, 544) that failure loads and fracture toughness values are considerably higher for pre-cracked beams which are loaded to failure as compared with notched beams.

In fairness to those early investigators who used notched beams it should be mentioned that a major difficulty in the test is to estimate the crack length at the onset of unstable crack growth. The easiest approach is to simply notch the beam - or cast in a notch - and assume that this length (denoted a_o in Figs. 1 and 2) is essentially the same as the critical crack length. Furthermore, the availability of displacement-controlled testing equipment of sufficient sensitivity, which is necessary to precrack (but not fail) plain-concrete beams did not exist, until the early 1970's.

The first work known to the writer in which commercial equipment was used to control the cracking process in plain concrete was his work performed with colleagues at Kansas State University in 1976, presented in 1977 (245.1), and published in 1978 (278). Since that time the compliance - calibration method for estimating crack length has been modified on the basis of actual crack measurements using dye-penetrant (578, 743). Thus, a major impediment to the determination of valid fracture data has been overcome. At the same time, it was found that surface measurements are not necessarily suitable as the crack front is not uniform except in the interior (743).

The writer feels strongly that many of the contradictory results obtained by earlier investigators which led to their pessimistic conclusion that fracture mechanics concepts (linear or non-linear) would not apply to concrete were caused by

a. lack of appreciation of the behavior of a true crack, and
b. inability to estimate accurately the true crack length at various stages of crack growth.

The tremendous increase in research activities in the 1980's supports this viewpoint although most investigators still argue against the suitability of LEFM.

Another major consideration - first elucidated by Shah and McGarry (86) - is what has come to be called the influence of the process zone. As shown in Fig. 2 and described earlier, this zone consists of a combination of aggregate interlock behind the crack tip and microcracking proceeding around and through the aggregate in front of the crack tip. This zone could play a role in fracture mechanics calculations similar to that of the zone of plasticity which occurs in ductile metals.

This, in fact, is what most investigators attribute to the lack of consistency in test results for fracture toughness and the energy release rate (86, 503, 631, 649, 658, 691, 705, 747). As a result, there is some work being done by the writer and others to determine the size of this zone.

Based on dye measurements (578, 743, 777) the writer believes this zone to be fairly small - limited in depth to about the size of the largest aggregate. Few other direct measurements of the interior have been made but indirect measurements using acoustic emission with large, double-cantilever specimens have been made (325). These investigators state the process zone to be at least one meter (39 in.) long.

Recently, surface measurements obtained from high sensitivity Moiré interferometry have been reported by Cedolin, et.al., using fairly small tension specimens with single or double edge notches (571). The process zone appears to be about 15mm for specimens with a maximum aggregate size of 10mm.

The most recent results known to the writer are those presented by Barker, et.al. (756), on CLWL specimens in which they used a surface inspection technique and also cut sections through the interior. They report "There was no evidence of the small microcracks or multiple branches normally postulated as existing in the process zone ahead of the main crack".

These results tend to reaffirm the writer's opinion stated previously that the source of error in applying LEFM to concrete lies in the area of crack length measurement and interpretation of the test record of load versus displacement.

2.1.1.1 SEN Bending Specimens and Test Methods

The bending specimen with a single edge notch subjected to either one or two concentrated loads has been by far the most popular as evidenced by the large number of investigations and test data which appear in the literature for over fifteen years (54, 86, 111, 158, 189, 197, 214, 230, 245.1, 278, 361, 383, 384, 385, 400, 441, 452, 531, 544, 578, 584, 651, 669, 685, 687, 694, 713, 743, 751, 777).

The writer has tested specimens in 3-point bending, 4-point bending, statically-precracked and pre-cracked in fatigue. His beam specimens were all 3 in. (76mm) wide and most of them had a depth of 4 in. (102mm), although some had a depth of 8 in. (203mm). It is conjectured by a number of investigators (214, 470, 503, 631, 658, 691) that valid test data cannot be obtained unless beams with depths 12 in. (305mm) or greater are used. The RILEM Committee on Fracture Mechanics of Concrete has recommended in a proposed testing specification (531) beam depths of 100mm, 200mm and 300mm. The writer is currently investigating further the influence of size with 8 in. and 12 in. deep beams to supplement data taken on 4 in. deep beams (669, 777).

The beam proportions generally specified (531, 655) are $\frac{S}{W} = 4.0$. This is primarily because formulas such as Eq. 6 by Srawley (558, 655) require this ratio. The writer is using $\frac{S}{W} = 3.75$. The only requirement here is that a ratio be used for which a stress intensity factor fracture toughness formula exists. Some investigators feel $\frac{S}{W} \geq 8$ is more suitable because of reduced shear, or "deep beam" effects.

Following the ideas expressed in Reference 579 the following specimen and test procedure is recommended. This recommendation does not preclude others which will be described later. However, since considerable research activity by the writer and others is currently underway, all the proposals reported herein are tentative and subject to further confirmation.

2.1.1.1.1 Recommendation. KSU Specimans, Test Setup, and Method

a. Referring to Fig. 5, the following proportions are recommended:

$$\frac{S}{W} \geq 4, \ W \geq 8 \times \text{(Maximum aggregate size)}$$

$$B \geq 4 \times \text{(Maximum aggregate size)}$$

For 3/4 in. aggregate a beam with S = 30 in. (760mm), W = 8 in. (203mm) and B = 3 in. (76mm) will satisfy the stated requirements and also will not be too heavy to handle conveniently (wt. $\approx$60 lb = 267 N).

The depth requirement will allow a fairly large amount of crack propagation before the process zone - presumed to be about 1 in. long - will interact with the compression face.

a.1 Alternatively, a beam with W = 12 in. (305mm), S = 45 in. (1.14m), B = 3 in. (76mm) may be used but to date there is very little experimental evidence to justify this size of beam.

b. Testing should be conducted using an electro-hydrodynamic machine. If load control is used a fairly stiff frame is needed (470). If strain control is used this requirement can be relaxed (761).

c. Test Setup

A conventional test setup in which the beam is configured as shown in Fig. 5 has been used extensively (245.1, 278, 400, 544, 579, 777). However, in order to use dye to reveal the crack front it is necessary to precrack the beam, remove it and turn it upside down, insert the dye, again turn the beam over, place in the setup and load to failure.

Therefore, it is recommended that the testing fixture be designed to allow the tension face of the beam with the exposed crack to be the top surface. Such a fixture is shown in Fig. 9 and is presently being used at KSU.

It will be necessary to monitor continously load P versus crack-mouth-opening-displacement, CMOD and load P versus load-point-displacement, LPD. Thus, two displacement gages and two plotters are required.

A commercially - available displacement gage of sufficient sensitivity is MTS 632.05 which has a sensitivity of 2×10^{-4} in. / V output. When used with the plotter a direct, least reading of 1×10^{-6} in. (25×10^{-9} m) is obtained.

The gage used to monitor CMOD may be easily attached to the beam using a yoke or frame arrangement described in Reference 402, while the gage to monitor LPD can be attached in a variety of ways, one of which is described in Reference 668.

d. Specimen Preparation

After casting, the beams should be wet-cured using a 100% humidity chamber or lime water bath. It has been argued by some that at the time of

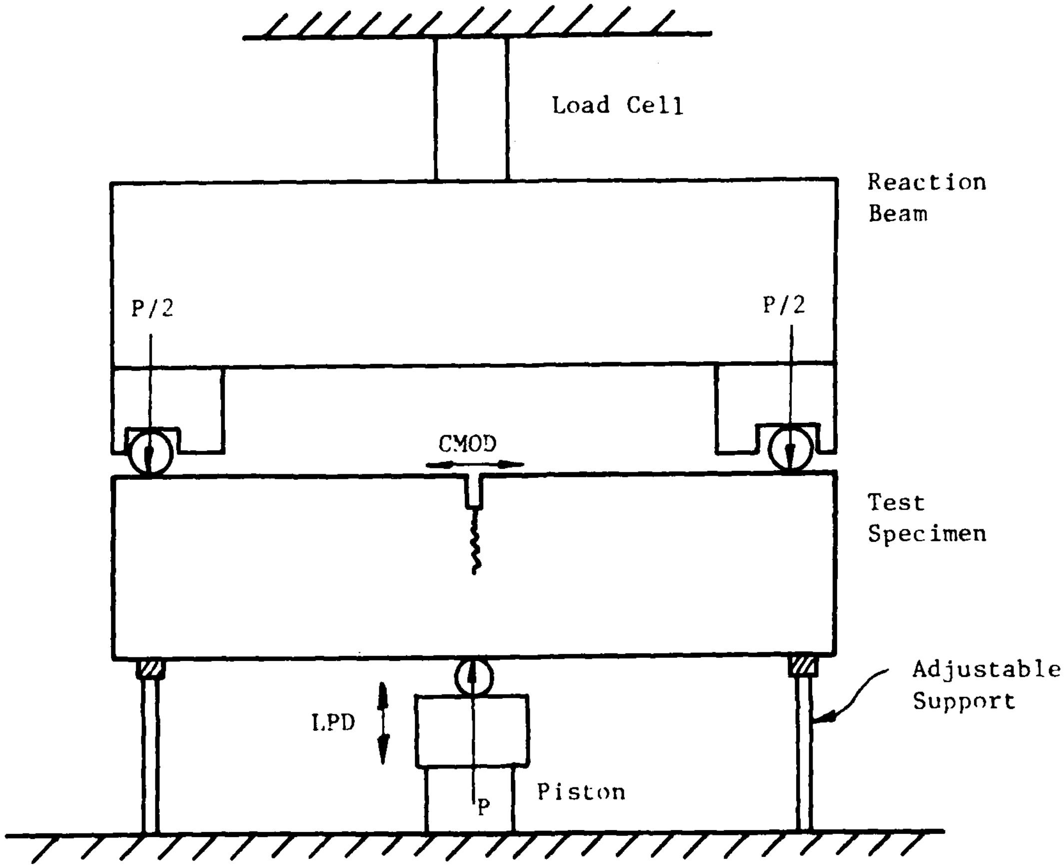


Fig. 9 Schematic of KSU Testing Arrangement For 8 in. and 12 in. Beam Specimens

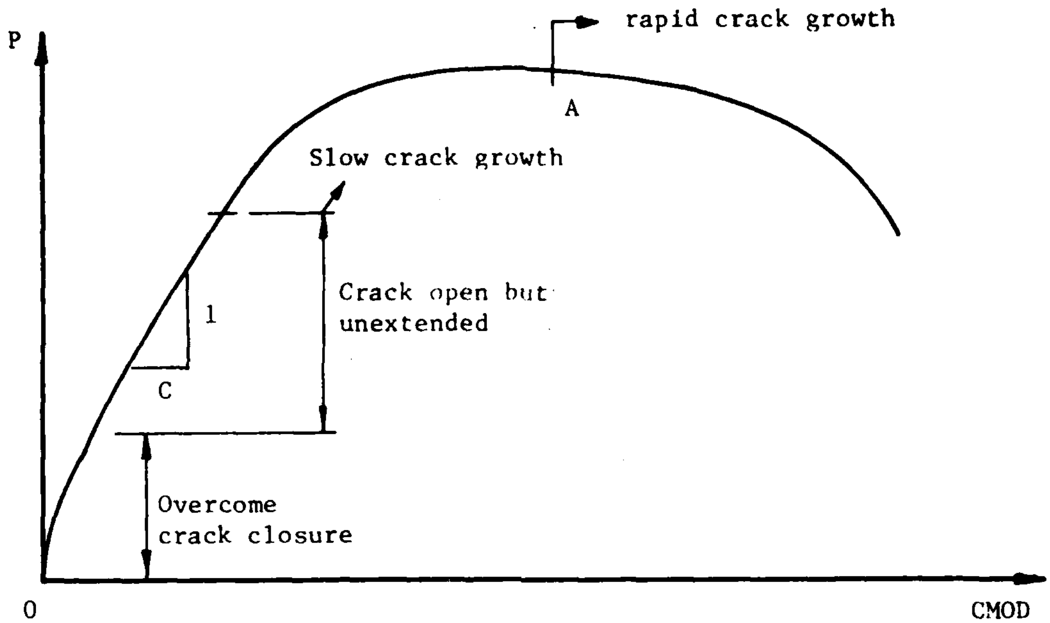
testing the beams should be wet, i.e. every precaution should be made to prevent any drying before or during the test (470, 531). Obviously, rather elaborate preparations are needed to assure this. The reason for doing this is to prevent shrinkage cracking due to drying.

The writer feels that while that is true, the resulting data is not representative of the behavior of most concrete structures. Perhaps for marine structures this would be an important consideration. However, in general, it is recommended that all specimens be air-dried after at least a 28 day wet cure and for one week prior to testing. The air-dry environment need not be high humidity but should be humidity controlled.

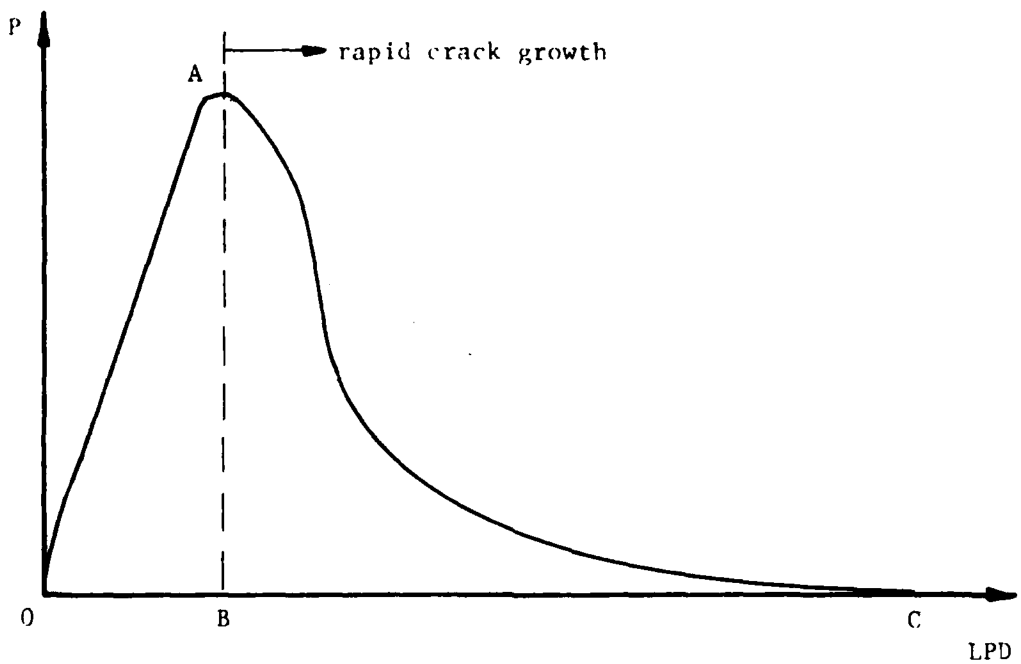
The other preparation needed for the specimens is to create a starter notch at the desired crack location - usually at midspan. At the present time, while research is still going on with regard to notch preparation, it appears to be reasonable to use a concrete saw to cut the notch (278, 531). The writer uses a saw with a cutting width of 0.13 in. (3.4mm) and cuts to a depth of $\frac{a_o}{W} = 0.1$.

e. Testing Procedure

1. Modified compliance calibration. The technique used previously by the writer (278) and others (207) in which compliance measurements were taken from notched beams is not recommended because of the influence of surface roughness (743). Instead, it is recommended that specimens be precracked, dye inserted, then loaded to failure. The inverse slope of the P $\underline{V}$ CMOD trace taken immediately after crack closure is overcome will yield the compliance value C - see Fig. 10. The average crack length is obtained from inspection of the dyed surface, and compliance C and $\frac{a}{W}$ obtained in this way are plotted. This gives a single point on the plot. It



a. Load Versus Crack-Mouth-Opening-Displacement



b. Load Versus Load-Point-Displacement

Fig. 10 Typical Load-Deflection Traces

is recommended that this process be conducted for approximate values of $\frac{a}{W}$ = 0.2 thru 0.8 in 0.1 increments. Thus seven specimens are needed to obtain the compliance calibration curve - Fig. 11.

2. With the compliance information available, additional specimens can be precracked using strain control to pre-determined crack lengths. In practice this is done easily by drawing a straight line with the desired slope on the graph of the plotter to be used with the CMOD gage. Using the RAMP function and SPAN control the load is increased into the region of rapid crack growth but because of strain control the operator can stop and unload the beam at any stage. Upon reloading, and after overcoming crack closure, the slope of the reload line is compared to that drawn on the paper. When the slopes are equal, the beam has been precracked to the desired amount.

   After the beam has been precracked, dye is inserted and allowed to stabilize.

3. Following this operation the beam is then loaded to failure. This can be done using either strain control or load control with virtually no difference in shape of the descending (strain softening) portion of the load-deformation diagram provided a very low rate of loading is used. Typically this should be set so that the peak load is reached in 30 sec. or more.

   Typical diagrams of load versus CMOD and load versus LPD are given in Fig. 10.

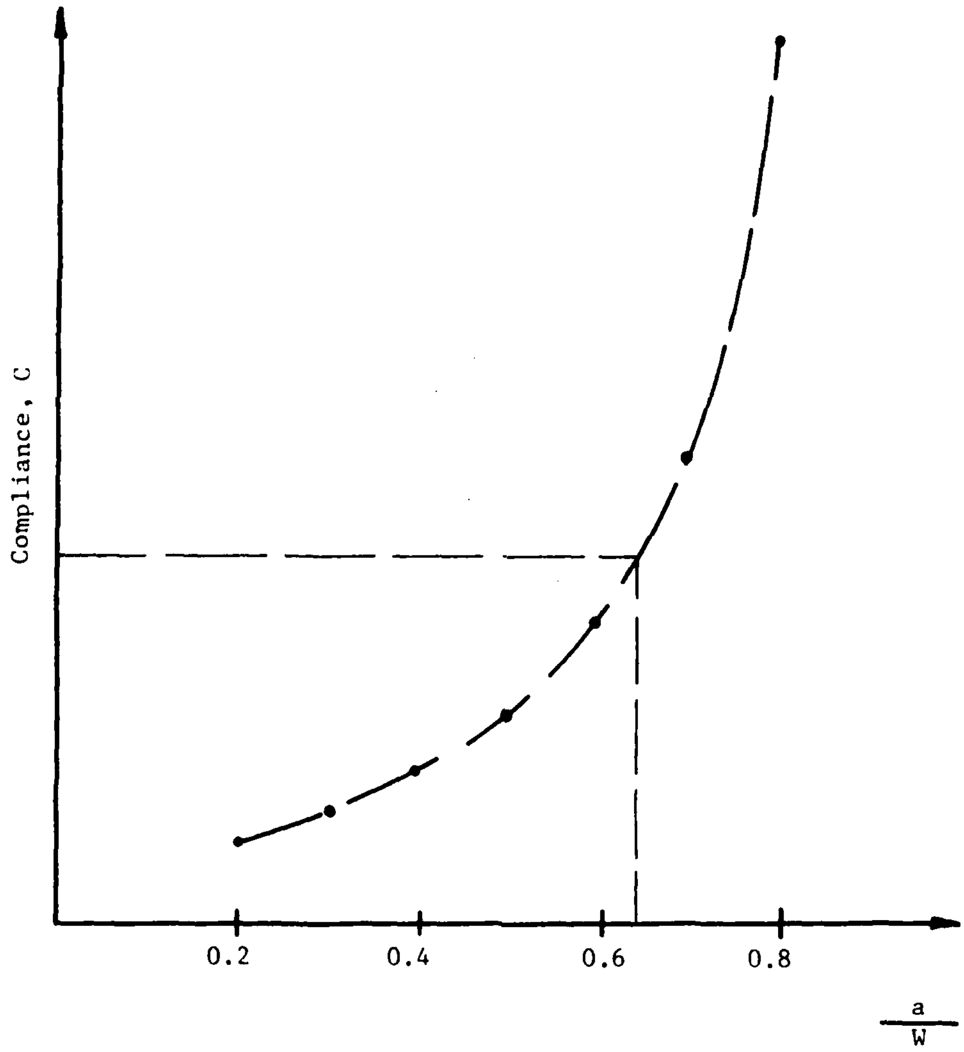


Fig. 11 Typical Compliance Calibration Curve

f. Data Interpretation

Steps e.2 and e.3 should be done with $\frac{a}{W}$ = 0.5 and 0.7, thus at least two beams need to be tested. We prefer to test at least five beams at each ratio to obtain average values with some confidence in a statistical sense.

As a lower bound on the energy absorption measurement and in keeping with the principles of LEFM (669), the energy absorbed up to the onset of rapid crack growth, that is U = Area OAB in Fig. 10.b, is determined using a planimeter.

With this data the energy release rate G_{IC} can be determined two ways.

1. $$G_{IC} = \frac{\text{Area OAB}}{C_A BW\,(1-\frac{a}{W})}$$

in which C_A = a surface roughness coefficient of about 1.15 (578) and, $\frac{a}{W}$ = crack length ratio at point of onset of rapid crack growth.

The crack length a at the onset of rapid crack growth is obtained from the compliance slope of a line drawn from the origin to the point of instability of the P - CMOD curve - or a line from O to A in. Fig. 10 a. - and then estimated from the compliance calibration curve. This approach is admittedly approximate but does yield fairly consistent G_{IC} values which are independent of $\frac{a}{W}$ (669, 777).

2. The recommended method is to plot U versus $\frac{a}{W}$ based on the <u>initial</u> crack length. Such a plot is shown in Fig. 12. In this and from Eq. (12) it is seen that

$$J_{IC} = G_{IC} = -\frac{\frac{dU}{d(\frac{a}{W})}}{C_A BW} = -\frac{\text{slope}}{C_A A_b}$$

where A_b = beam area.

Also shown in Fig. 12 is a plot based on using the extended crack length. In theory, the slopes should be the same since they represent the energy change per unit crack extension.

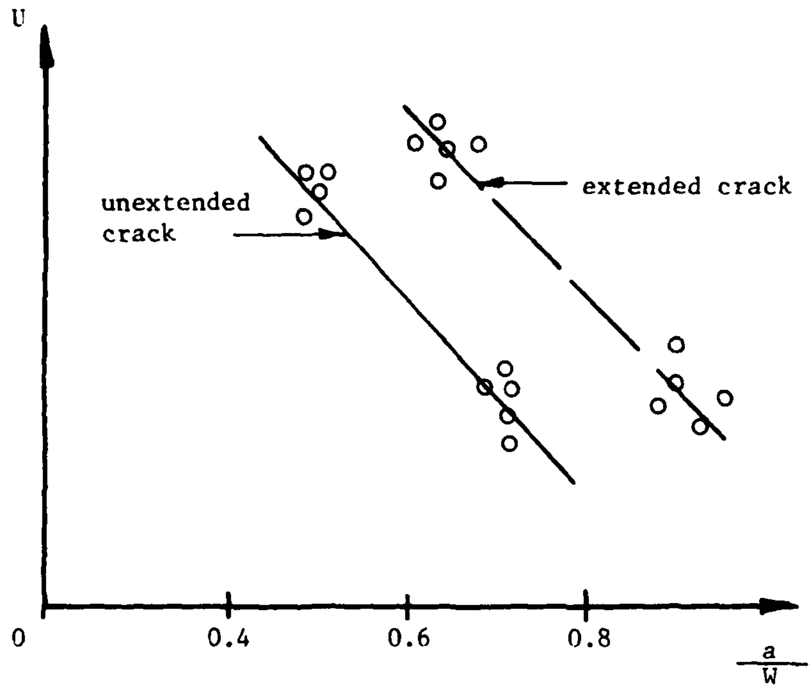


Fig. 12 U v $(\frac{a}{W})$ Using Unextended Crack (Initial Crack) and Extended Crack (Estimated at Onset of Rapid Crack Growth)

As described in References 669, 777 the results of tests on small beams (W = 4 in.) indicate very good agreement in results for G_{IC} obtained by either of these methods of data interpretation.

Note also that if the second method is used, it should be possible to avoid using the compliance calibration technique if only the initial crack length is considered since that is measured directly from the dyed surface.

2.1.1.1.2 Other Methods Using SEN Beams

The other proposed methods for beams typically use the three-point bending configuration of Fig. 5 although some use the "upside-down" setup of Fig. 9. These methods all consider the fracture relationship to be of a non-linear nature.

2.1.1.1.3 Proposed RILEM Recommendation. (531)

This recommendation is made by RILEM TC 50 Fracture Mechanics of Concrete. The dimensions of the bending specimen to be used are proposed to be

B = 100 ± 5mm (ca 4 in.)

W = 100 ± 5mm (ca 4 in.)

L = 840 ± 5mm (ca 33 in.)

S = 800 mm (ca 31 in.)

a_o = 50 ± 5mm ($\frac{a}{W}$ = 0.5)

Notch width < 10mm (0.4 in.)

This size is to be used with maximum aggregate size not more than 32mm (1.26 in.).

When larger aggregate is to be used the dimensions shall be increased uniformly. Also, the number of replicate tests varies with aggregate size from six for maximum size less than 10mm to twenty-four for maximum size greater than or equal to thirty-two.

The specimens are to be cured in a 100% humidity environment and stored in lime-water. They are not to be removed until 15 min. before testing.

The test should be performed in a stiff machine using displacement control such that the peak load is reached in 30-60 sec. from the start of the test. The test record is a continuous trace of load versus load-point-displacement - eg. P $\underline{V}$ LPD in Fig. 10b.

The energy represented by the entire area under the curve - area O A C in Fig. 10b. is measured and the fracture energy per unit area is

$$G_f = \frac{U + mg\ \delta_o}{BW\ (1 - \frac{a_o}{W})}$$

in which U = area under the curve,

δ_o = final displacement at failure,

mg = weight of the specimen,

a_o = initial notch length.

The term mg δ_o represents a correction factor due to energy associated with the beam's self weight. The writer and others (713) have found this term to be negligible.

The primary criticism the writer has with this method is that the initial conditions imposed are wrong - namely that the beams are not cracked initially.

This method has been used extensively in a series of round-robin tests using beams of different sizes. The results of these tests indicate that the energy G_f is not independent of a_o nor independent of beam size (584, 685, 686, 713, 763).

2.1.1.1.4 Recent method proposed by Jenq and Shah (766).

In this method the specimens and testing procedure are virtually identical to those given in the recommended method stated in 2.1.1.1.1 above. However, the compliance - calibration portion is not needed as all data is obtained from a single test of a notched, but non-precracked, beam. The method attempts to account for the non-linearity by using two parameters: the critical stress intensity factor, K^s_{IC} and the elastic critical crack tip opening displacement $CTOD_c$. Both of these are evaluated using a plot of load versus CMOD and LEFM.

Using this plot - again that shown in Fig. 10 is typical - the value of the effective, elastic crack is determined such that the calculated CMOD is equal to the measured one. The calculated CMOD is determined from

$$CMOD = \frac{24\ Pa}{BW\ E}\{0.76 - 2.28\left(\frac{a}{W}\right) + 3.87\left(\frac{a}{W}\right)^2 - 2.04\left(\frac{a}{W}\right)^3 + \frac{0.66}{[1 - (\frac{a}{W})^2]}\} \quad (16)$$

This equation is used to determine a and then K^s_{IC} is determined from

$$K^S_{IC} = \frac{6\ P\sqrt{a}}{BW}\ \frac{1.99 - (\frac{a}{W})(1 - \frac{a}{W})[2.15 - 3.93(\frac{a}{W}) + 2.7(\frac{a}{W})^2]}{[1 + 2(\frac{a}{W})][1 - \frac{a}{W}]^{3/2}} \quad (17)$$

Finally, $CTOD_c$ is determined from a similar equation which requires an estimate of the location of the crack tip opening displacement relative to the end of the crack - and is highly sensitive to this. For instance, if this location is at the crack tip itself, the value of $CTOD_c$ is zero.

The writer believes the proposed method for determining K^s_{IC} is reasonable but to date very little experimental data is available to verify it.

2.1.1.1.5 Method Proposed Recently by Bazant (642).

This method is entitled "Fracture Energy of Concrete from Maximum Loads of Specimens of Various Sizes"and is based on the use of dimensional theory (573, 759). Three groups of beams of different depths and spans but the same width are to be tested in three-point bending.

All beams are notched at midspan, using a diamond saw, to a depth a_o. The recommended ranges of parameters are (cf Fig. 5):

$$\frac{S}{W} \geq 4.0$$

$$0.3 \leq \frac{a_o}{W} \leq 0.5$$

B, W $\geq$ 3 times the maximum aggregate size d_a.

Of the three beam sizes the minimum depth should be $\leq$ $5d_a$ and the largest depth $\geq$ $15d_a$. Also, the ratio of maximum depth to minimum depth must be at least four.

As an example, consider a concrete with d_a of 3/4 in. Then

$$B, W \geq 2.25 \text{ in.}$$

$$W_{min} \leq 3.75 \text{ in.}$$

$$W_{max} \geq 11.25 \text{ in.}$$

and $$\frac{W_{max}}{W_{min}} \geq 4.$$

Beam specimen dimensions that satisfy these requirements would be:

Smallest beam B = 3 in., W = 3 in., S = 12 in., a_o = 1.5 in.

Largest beam b = 3 in., W = 12 in., S = 48 in., a_o = 6 in.

The specimens are loaded in three-point bending and only the failure load is recorded - no trace of load versus displacement is required. Furthermore, there are no restrictions imposed upon testing machine stiffness nor use of deformation control. However, it is recommended that load rates be such that the peak load is reached in 1 to 10 min.

Duplicate tests are conducted and average values of P and W obtained for each group of beams. The value of P is to be adjusted to account for the beam self-weight.

These results are then plotted with $(\frac{BW}{P})^2$ as the ordinate and W as the abscissa. The measured slope of this line is denoted A.

Then, the fracture energy G_f is given as

$$G_f = \frac{g\ (\alpha_o)}{E_c\ A}$$

in which E_c = modulus of elasticity of concrete, $\alpha_o = \frac{a}{W}$ and $g\ (\alpha_o)$ is called the nondimensional energy release rate.

This is given by

$$g\ (\alpha_o) = (\frac{S}{W})^2\ \pi\ \alpha_o\ [1.5\ F\ (\alpha_o)]^2 \qquad (20)$$

and

$$F\ (\alpha_o) = 1.090 - 1.735\ \alpha_o + 8.20\ \alpha_o^2 - 14.18\ \alpha_o^3 + 14.57\ \alpha_o^4 \qquad (21)$$

for $\frac{S}{W} = 4$.

Other functions of $F\ (\alpha_o)$ are avilable for other span/depth ratios.

This method appears also to be potentially useful, but again to date there is very little confirmation with test data.

As stated previously, the writer, at present, is conducting research on size effects in beams with the following dimensions:

Small: B = 3 in., W = 4 in., S = 15 in.

Intermediate: B = 3 in., W = 8 in., S = 30 in.

Large: B = 3 in., W = 12 in., S = 45 in.

The values of $\frac{a}{W}$ range as 0.3, 0.5, 0.7. Thus the current testing program will yield data which will be useful in evaluating the validity of this proposed method.

2.1.1.1.6 Summary of SEN Beam Methods

The first - and recommended - method has been proposed here for the first time. It is based on an extensive amount of data obtained by the writer and was first suggested by Go (578). Work is continuing to review other experimental data in light of this method to obtain further confirmation of its validity. At the same time, it is recognized that the testing method is cumbersome. Therefore, the other proposed methods may become more popular.

The writer cannot recommend the proposed RILEM method for the reasons stated.

The methods proposed by Shah and Bazant both appear reasonable and have limited experimental justification. The writer currently is directing research to evaluate these methods using earlier data obtained at KSU as well as new data on different sizes of beams. Both of these methods are easier to implement than the writer's method - especially that of Bazant.

Although there has been an extensive amount of research carried out using beam specimens, the test specimens and methods given by the writer, RILEM and Bazant are the only one actually proposed for a standard.

Before leaving the subject of SEN beams, one other method should be mentioned even though it has not been proposed as a standard. This method is the R-Curve analysis approach which has been used by many investigators (354, 629, 631, 649). In this method it is assumed the fracture energy, G_f, is not independent of crack length until a sufficiently long crack is developed. If G_f is plotted as an ordinate against crack length a as the abscissa then the resulting curve can be considered an envelope of curves satisfying the requirements that (649)

$$G_f(a) = F(c) \qquad (22)$$

and $$\frac{dR}{dc} = \frac{dG}{da}$$

where R = the energy required for crack growth (not necessarily a constant)

and c = the crack extension length from a starter notch.

Such an envelope can be constructed from test data by evaluating G_f from LEFM using the failure load P and crack length a. Results of this approach are given by Bazant, et.al. (651) based on test data from Jeng and Shah (694).

This approach also shows considerable promise and is currently being implemented by the writer using KSU data.

2.1.1.2 Other Types of Specimens

Over the years the following specimen geometries have been tried: plate or bar in tension, double cantilever beams in bending, double torsion beams. In no case has any of these actually been proposed to be a standard test specimen. All the proposed test standards, to the writer's knowledge, have been for SEN beams as described in the previous section.

Additionally, while some of the test results for these other geometries look promising, there is not a great deal of experimental data reported for any of them. Therefore, none of these methods are recommended at present.

2.1.1.2.1 Plate or Bar in Tension

Historically, the plate in which a central flaw is placed and loaded in direct tension has been one of the earliest specimens tried (21). It is still being evaluated today (761.1). It is potentially a useful specimen but does have the disadvantage of needing a fairly elaborate and carefully aligned testing fixture.

2.1.1.2.2 Double Cantilever Beam

This type of specimen - shown in Fig. 13 - has been used extensively over the years (276, 325, 548, 614, 627, 631). The geometry is such that

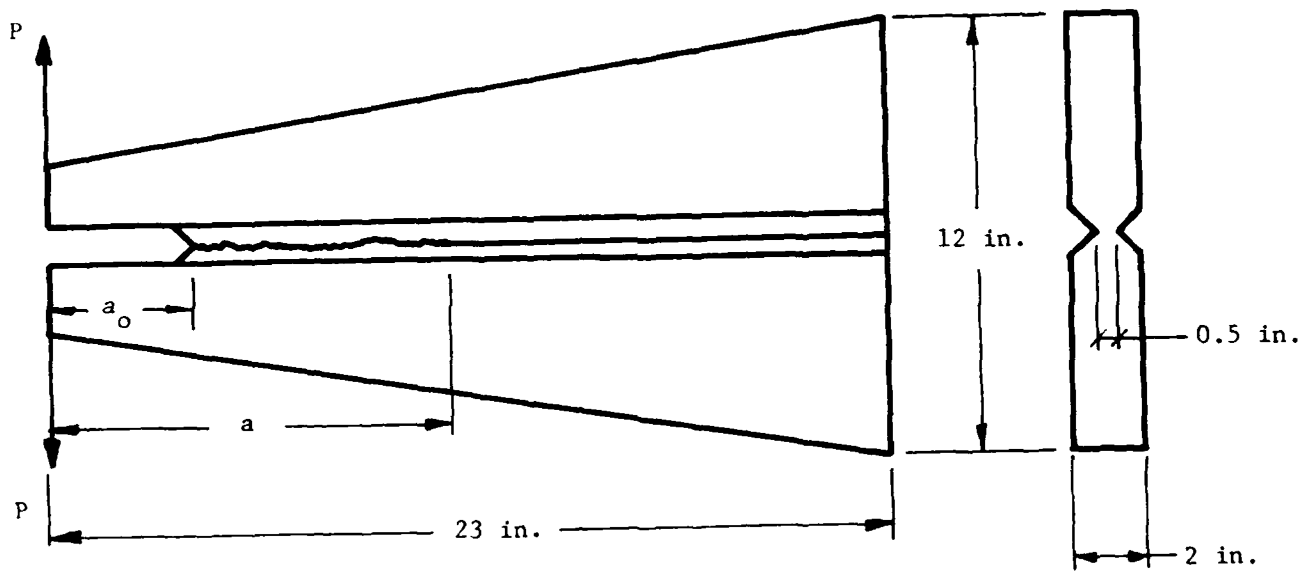


Fig. 13 Double Cantilever Beam Specimen Dimensions From Reference 631

crack propagation is contained and can easily be measured. Further, it is fairly easy to control the cracking process.

However, this type of specimen has one serious limitation. In order to test concrete with a typical size of aggregate - say one inch - and if a minimum dimension of say three times the aggregate size is needed, then the specimen overall size becomes very large. For instance, if the specimen geometry of reference 325 is used, then the overall size would change from 23 in. to 192 in. Some investigators have claimed that indeed this size of specimen is needed (691). Unfortunately, this size does not lend itself well to a routine testing situation.

Within this category may also be considered the crack line, wedge-loaded, double cantilever beam specimen (CLWL-DCB) as defined in ASTM E 561-81 (417) and proposed for use in concrete by Barker, et.al. (756). The geometry for the larger specimens they tested is shown in Fig. 14.

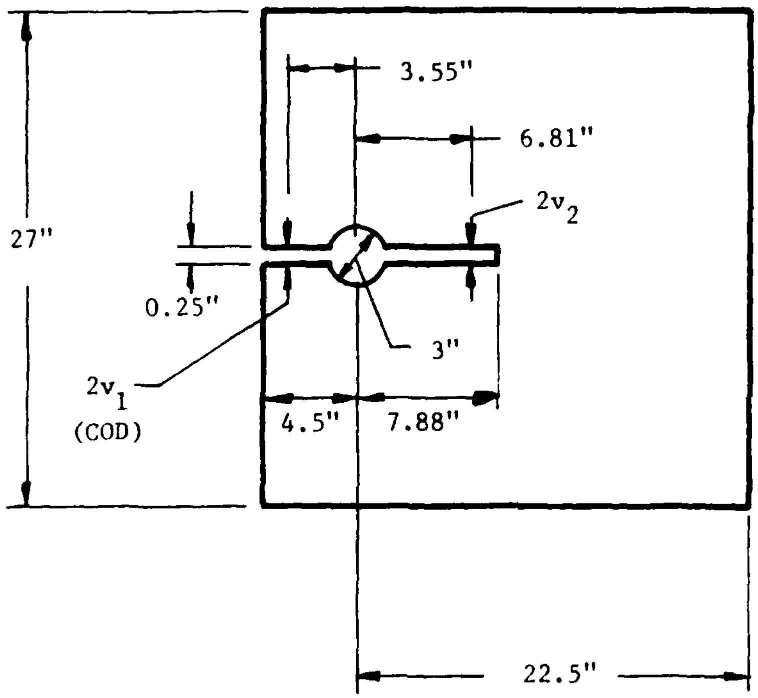
This specimen is loaded through the circular hole by a wedge which creates the relative movements indicated by v_1 and v_2. The results they present indicate this may also be a viable candidate for a standard test specimen. Note that the crack is allowed to propagate naturally and the specimen thickness is suitable for concrete.

2.1.1.2.3 Double Torsion Beam (407)

These specimens have a geometry similar to the double cantilever beam but the loading is such that each "leg" is placed in torsion while the crack propagates along a central groove. This type of specimen suffers from the same limitation as the double cantilever beam specimen of Fig. 13.

2.1.2 Models for Crack Propogation and Fracture of Concrete

Many of the test methods presented above are based upon, or were used



Thickness = 3"

Fig. 14 CLWL-DCB Specimen
Used in Reference 756

to verify, analytical models for crack propagation in concrete. To date, most of these models are directed to unreinforced concrete.

Almost all of these models are based on the finite-element discretization of the cracked concrete with a combination of "super" or crack-tip element along with regular elements.

As may be expected, the early, analytical, models were based entirely on LEFM concepts in which crack propagation would occur if the state of stress at the crack tip corresponded to a critical value of K_I (or a combination of K_I, K_{II}, and K_{II}). Bazant (342, 343) indicates that in fact the crack propagation is dominated by the K_I mode but this has been disputed by others. The writer's co-workers and others have developed finite element models of this type (361, 587).

However, as it became considered by many that LEFM might not be valid, a number of models have appeared, again using the finite element approach, in which attempts to account for crack closure and the presence of a process zone are made. These include models by Ingraffea (691, 765), Hillerborg (198, 305, 359), Petersson (205, 386, 470), Wecharatana and Shah (631), Bazant (342, 343.1, 564, 569, 750), others (657, 710, 725) in which fictitious stresses are employed, the critical crack tip opening displacement is used ($CTOD_c$), or the crack driving process is controlled by the fracture energy G_c.

These models are lacking only valid experimental fracture data to become useful in the analysis and design of concrete structures.

At the present time, research activity is directed toward practical application of these models to reinforced concrete structures. In particular, work has appeared with regard to bond problems and crack growth in reinforced concrete beams (475, 658, 692). Ingraffea has successfully applied LEFM concepts to the cracking of a concrete dam (434). Hawkins has indicated numerous areas within the ACI Building Code in which fracture mechanics concepts might be applied (684), see also Gustafsson and Hillerborg (676). Earlier he also attempted to apply LEFM to shear cracking of concrete beams (229) (with limited success).

The writer has no specific recommendations to make with regard to analytical models except to note that the ones by Ingraffea (765), Hillerborg (305), Bazant (564), Wecharatana and Shah (631) among others all appear to be valid. Extensive work still needs to be done to verify any of these with test results from both plain and reinforced concrete specimens.

2.2 Summary and Recommendations

The current state-of-the-art of fracture mechanics applications to concrete has been reviewed very briefly with the major emphasis being on testing methods to determine the appropriate fracture parameters. Historically, these methods evolved from previous experience obtained in metals which relied on the suitability of linear elastic fracture mechanics. The present thinking by most investigators is that non-linear effects - primarily associated with a process zone presumed to exist at the front of the crack - dominate the crack propogation mechanism. Nevertheless, the methods, equations and appropriate parameters from LEFM are still used by these investigators in one form or another to predict these non-linear effects.

As stated earlier, the writer still believes LEFM to be valid on the basis of test results obtained at KSU using the testing method described in section 2.1.1.1.1. This method of testing is recommended. A related test method described in section 2.1.1.1.4 by Shah at Northwestern University may also be appropriate.

The method proposed by Bazant which uses different beam sizes which is described in section 2.1.1.1.5 may also be valid.

All of these methods use beam bending specimens with edge notches and subjected to three point bending.

The parameters which are obtained and which characterize the crack growth and failure are the fracture toughness K_{IC}, critical energy release rate G_{IC}, the J-Integral J_{IC}. For LEFM these are all equivalent. If, in fact, non-linear effects are severe, it is expected that G_{IC} and J_{IC} will still be valid fracture parameters. In addition, for this case, the critical crack tip opening displacement, $CTOD_c$ is expected to be a pertinant parameter.

Of the other test methods and specimens described in this report the writer feels that the one most likely to be useful and accepted as a standard method is the crackline, wedge-loaded, double cantilever specimen, CLWL-DCB and associated test procedure described by Barker, Hawkins, Jeang, Cho and Kobayashi.

Appendix I

Bibliography Database Program

```
*!!*        dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
F>
SET HEADING OFF
SET SAFETY OFF
* main.prg
SET PROCEDURE TO PROC
public del,dn,fn,sno,command,mreference,mauthors,mtitle,mflag,mkeywords,mode
do init
restore from add
set intensity off
*!! Logical constant converted.
do while .t.
   do delcheck
   set format to saydata
   store "a)dd       b)ackward  d)elete/recall   e)dit         " to prompt1
   store "f)orward   h)elp      l)ocate          m)aintenance" to prompt2
   store "p)rint     q)uit      r)eport          s)et flag     " to prompt3
   store "**** MAIN MENU ****" to mode
   store " " to command
*!! 'set screen on' is no longer valid.
set device to screen
*!!    set screen on
   do delcheck
read
do case
   case upper(command) = "S"
      do flag
   case upper(command) = "A"
      do add
   case upper(command) = "B"
      skip -1
   case upper(command) = "D"
      do delete
   case upper(command) = "E"
      do eddit
      do delcheck
   case upper(command) = "F"
      skip
   case upper(command) = "H"
      do help
   case upper(command) = "M"
      do maintain
   case upper(command) = "R"
      do reports
   case upper(command) = "L"
      do locate
   case upper(command) = "Q"
      CLOSE PROCEDURE
      cancel
```

```
   case upper(command) = "P"
      do print
endcase
enddo
CLOSE PROCEDURE
```

```
procedure verifyne
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* verifynew.prg
CLEAR
go top
locate for new
*!! Logical constant converted.
store .t. to more
do while more .and. (.not. EOF())
   set format to saydate
   store "VERIFY NEW RECORDS" TO mode
   store "a)ccept,   c)ontinue,   d)elete/recall" TO prompt1
   store "e)edit,    p)rint,      q)uit" TO prompt2
   store " " to prompt3
   store " " to command
   do delcheck
   read
   store UPPER(command) to command
   do case
      case command = "A"
*!! Logical constant converted.
         REPLACE new WITH .f.
         CONTINUE
      case command = "E"
         do eddit
      case command = "Q"
*!! Logical constant converted.
         store .f. to more
      case command = "C"
         continue
      case command = "P"
         do print
      case command = "D"
         do delete
   endcase
enddo
*!! Logical constant converted.
store .t. to more
store "4" to command
return
procedure eddit
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* eddit.prg
set format to
set menu on
set intensity on
edit
do delcheck
return
procedure add
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
```

```
*
SET HEADING OFF
SET SAFETY OFF
* add.prg
close format
store " " to nn
*!! Logical constant converted.
store .t. to more
CLEAR
@ 4,6 say "DISPLAY KEYWORDS (y,n)"
set console off
wait to nn
set console on
if UPPER(nn) = "Y"
sele 3
use kwds
disp off wd while .not. eof()
use
sele 1
endif
set intensity on
set menu on
append
release
return
procedure maintain
*!!*       dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* maintain.prg
*!! Logical constant converted.
store .t. to more
do while more
   set format to mtain
   store " " to command
   read
   do case
      case command = "1"
         do verifyde
      case command = "2"
         do purge
      case command = "3"
         do dupchk
      case command = "5"
         CLEAR
         set DEVICE to screen
         clear ALL
         cancel
      case command = "6"
         set console off
         quit
      case command = "7"
*!! Logical constant converted.
         store .f. to more
      case command = "4"
        do verifyne
  endcase
enddo
```

```
release more
store " " to command
return
procedure newtext
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* newtext.prg
CLEAR
?
?
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT FILE NAME (without extension) " to ofn
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT DRIVE (a, b, c, etc.) " to ofd
CLEAR
store ofd+":"+trim(ofn) to ofn
set alternate to &ofn
set alternate on
set talk off
go top
do while .not. EOF()
if new
        ? trim(authors)
        ? trim(title)
        ? trim(reference)
        ? trim(keywords)
endif
skip
enddo
set alternate off
release ofn
release ofd
store " " to command
return
procedure locate
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* locate.prg
private prompt1,prompt2,prompt3
CLEAR
go top
store " " to ano
store " " to command
store "                              " to pra
?
?
?
?
? "        L.  LOCATE ENTRY BY PRINCIPAL AUTHOR"
? "        S.  SEARCH FOR ENTRY BY ANY FIELD"
?
? "        Select l or s"
set console off
wait to ano
```

```
set console on
store UPPER(sno) to sno
? "                                                   "+sno
if sno = "L"
   ?
   ?
   ? "  Enter up to the first five characters of the last name"
   ? "  of the principal author."
   accept to pra
*!! EOF() will be true if NO FIND, and RECNO() will equal BOTTOM, not 0.
*  find &pra
locate for upper(authors)=upper(pra)
        if (EOF() .OR. BOF())
                ? "NO FIND"
                ?
                ? "STRIKE ANY KEY TO CONTINUE"
                set console off
                wait
                set console on
                go top
        endif
else
   ?
   ?
   ? "        a. author search"
   ? "        k. keyword search"
   ? "        t. title search"
   ? "        r. reference search"
   ?
   ? "        Choose a, k, t, or r"
   set console off
set index to bibl,title,auth
wait to sno
set console on
store UPPER(SNO) to sno
?"                                 "+sno
?
if sno="K"
?"DISPLAY KEYWORDS(Y/N)"
SET CONSOLE OFF
wait to dkw
set console on
if upper(dkw)="Y"
 if .not. file("kwds.dbf")
  clear
  @ 2,10 say "SORRY, KEYWORD FILE NOT IN USE"
  @ 4,15 SAY "STRIKE ANY KEY TO CONTINUE"
  SET CONSOLE OFF
  wait
  set console on
 else
sele 3
use kwds
disp off wd while .not. eof()
use
sele 1
  clear
```

```
 endif
endif
clear
store " " to opnd
store " " to sg1
store " " to sg2
store " " to sg3
?
?"This routine will search through keywords for up to three
strings, as"
?
?"        string1 .AND. (string2 .AND. or .OR. string3)"
?
?"You will be asked for three strings and the logic .AND. or
.OR."
?
?"Null characters may be entered for strings, as they will return
TRUE"
?
?
?"Which logic for second operand: (a/o) for (AND/OR)?"
set console off
wait to opnd
set console on
clear
?
accept "Enter string1 " to sg1
?
accept "Enter string2 " to sg2
?
accept "Enter string3 " to sg3
clear
@ 4,20 say "SEARCHING"
if upper(opnd)="A"
 locate for sg1$(keywords) .and. (sg2$(keywords) .and.
sg3$(keywords))
endif
if upper(opnd)="O"
  locate for sg1$(keywords) .and. (sg2$(keywords) .or.
sg3$(keywords))
endif
?chr(7)
endif for sno
if sno="A"
accept "  Enter exact search string <return>" to pra
store upper(pra) to pra
  locate for pra$(upper(authors))
?chr(7)
endif
if sno="T"
accept "  Enter exact search string <return>" to pra
store upper(pra) to pra
 locate for pra$(upper(title))
?chr(7)
endif
if sno="R"
accept "  Enter exact search string <return>" to pra
store upper(pra) to pra
 locate for pra$(upper(reference))
?chr(7)
endif
```

```
endif
do while .t.
 store code to rnum
do delcheck
 clear
 set format to saydata
store 'LOCATE MENU' to mode
store "            c. continue     r. return     p. print" to
prompt2
 store " " to prompt1
 store "            s. set flag" to prompt3
 store " " to command
read
 if upper(command)="C"
  continue
  ?chr(7)
  if eof()
clear
?'                    **** NO FIND ****'
?
?'                STRIKE ANY KEY TO CONTINUE'
SET CONSOLE OFF
wait
set console on
   goto rnum
  endif
loop
 endif
 if upper(command)="S"
  do flag
 endif
 if upper(command)="R"
  release pra,sno,opnd,sg1,sg2,sg3
set index to bibl,title,auth
  return
 endif
 if upper(command)="P"
  do print
 endif
enddo
set index to bibl,title,auth
RETURN
PROCEDURE INIT
*!!*       dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* init.prg
set talk off
set DELIMITER off
set bell off
set margin to 5
set console off
set DEVICE to print
set print on
```

```
? chr(15)
set print off
set DEVICE to screen
set console on
store " " to sno
store " " to dn
store " " to fn
CLEAR
?
?
*!! Unrecognized command.
?"                      __________________________________"
*!! Unrecognized command.
?"                      |                                  |"
*!! Unrecognized command.
?"                      |      B I B L I O G R A P H Y     |"
*!! Unrecognized command.
?"                      |          D A T A B A S E         |"
*!! Unrecognized command.
?"                      |__________________________________|"
?
?
?
? "       * * *  C O N F I R M   T H A T  P R I N T E R  I S  ON * * * "
?
?
?
? "                      Enter Filename without Drive"
? "                      Designation or File Extension"
?
?
?
accept to fn
?
*"                      Have data and index files been"
* set console off
* wait to zz
* set console on
* if !(zz) = "Y"
*       store "d" to dn
store 'd:'+fn to dn
use &dn
?"                     Name of index file keyed on year and author "
?"                     without extension.........."
accept to bibl
?"                     Name of index file keyed on authors........"
accept to auth
?"                     Name of index file keyed on title........."
accept to title
set index to bibl,title,auth
if .not. file ('d:add.mem')
 store ' ' to c
store 'ok'  to del
 store 1 to index
```

```
 do while index <=79
  store c+' ' to c
 store index+1 to index
 enddo
 store c to mkeywords
 store c+c to mreference
 store c+c to mauthors
 store c+c to mtitle
 store '     ' to mflag
 store '@' to flg
 release c, index
 save to add
*!! Unrecognized command.
endif
RETURN
PROCEDURE FLAG
*!!*       dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* flag.cmd
* sets flag symbol
if flag = "     "
     CLEAR
     @ 10,1 say "Enter characters for flag "
     ?
     accept to flg
     replace flag with flg
else
     replace flag with "     "
endif
RETURN
PROCEDURE PURGE
*!!*       dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* purge.prg
CLEAR
?
? "*************    WARNING    *************"
?
?
? "This will PERMANENTLY remove any deleted entries."
?
? "It is recommended that this command be aborted and that"
? "the COPY command be used under native dBASE [see manual]."
?
? "Type 'y' to continue.  Type any other key to abort."
set console off
wait to next
set console on
if UPPER(next) = "Y"
   CLEAR
   ?
   ?
   ? "Records are now being removed from file."
   pack
```

```
endif
release next
RETURN
PROCEDURE DELCHECK
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* delcheck.prg
if DELETEd()
   store "Deleted" to del
else
   store "Ok" to del
endif
RETURN
PROCEDURE FLAGCH
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* flagch.prg
* changes flag symbol
CLEAR
*!! There will be no automatic colon following this prompt string.
accept "ENTER NEW FLAG SYMBOL " TO flg
store " " to command
CLEAR
RETURN
PROCEDURE REMFLG
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF

* remflg.prg


CLEAR
@ 4,10 say "FLAGS ARE BEING REMOVED"
go top
do while .not. EOF()
if flag <> "     "
```

```
   replace flag with " "
endif
skip
enddo
RETURN
PROCEDURE DELETE
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* delete.prg
if DELETE()
   recall
else
   delete
endif
RETURN
PROCEDURE FLAGDB
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* flagdb.prg
CLEAR
?
?
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT FILE NAME (without extension) " to ofn
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT FILE DRIVE (a, b, c, etc.) " to ofd
CLEAR
store ofd+":"+trim(ofn) to ofn
set talk off
copy to &ofn for flag <> "     "
release ofn
release ofd
store " " to command
RETURN
PROCEDURE REPORTS
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* reports.prg
*!! Logical constant converted.
store .t. to more
do while more
set format to rpts
store " " to command
read
do case
        case command = "1"
                do remflg
        case command = "2"
                do newtext
        case command = "3"
                do flagdb
        case command = "4"
```

```
                do flagtext
        case command = "5"
                do flagch
        case command = "6"
*!! Logical constant converted.
                store .f. to more
endcase
enddo
release more
store " " to command
RETURN
PROCEDURE DUPCHK
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
*dupchk.prg
*D.J.Roufa-8/16/84
save to dup
?"      Enter name of title index.........."
accept to dex
set index to &dex
go top
*!! Logical constant converted.
store .t. to more
do while more .and. (.not. EOF())
CLEAR
?
?
?
*!! Unrecognized command.
?" SEARCHING FOR DUPLICATED RECORDS...."
store "* * * S I M I L A R   F I L E S * * *" to mode
store "C(ontinue)  D(elete)  P(rint)  E(dit)  Q(uit)" to prompt1
store substr(authors,1,5) to authors1
store SUBSTR(title,1,20) to title1
skip
if upper(SUBSTR(title,1,20)) = upper(title1) .and. (.not. EOF()) .and. upper(substr(
authors,1,5))=upper(authors1)
  do duprem
endif
enddo
set index to
rest from dup
store " " to command
RETURN
PROCEDURE DUPREM
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
*  duprem.prg
*  d.j. roufa - 16-8-84
store authors to authors2
store title to title2
store reference to reference2
store CODE to recnum2
```

```
do delcheck
store del to del2
skip-1
store authors to authors1
store reference to reference1
store title to title1
store CODE to recnum1
do delcheck
store del to del1
*!! Logical constant converted.
store .t. to more
do while more
   set format to shotwo
      store "C" to command
      store "A" to aorb
      read
      store UPPER(command) to command
      store UPPER(aorb) to aorb
   if aorb = "B"
         skip
   endif
   do case
      case command = "Q" .or. command="C"
*!! Logical constant converted.
         store .f. to more
      case command = "E"
         do eddit
      case command = "D"
         do delete
         if aorb = "A"
            store "Deleted" to del1
         else
            store "Deleted" to del2
         endif
      case command = "P"
         do print
   endcase
if aorb = "A"
   skip
endif
enddo
if command = "C"
*!! Logical constant converted.
   store .t. to more
endif
RETURN
PROCEDURE PRINT
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* print.prg
set console off
set DEVICE to print
set print on
if len(trim(authors)) > 120
```

```
  ? SUBSTR(authors,1,120)
  ? SUBSTR(trim(authors),121)
else
  ? trim(authors)
endif
if len(trim(title)) > 120
  ? SUBSTR(title,1,120)
  ? SUBSTR(trim(title),121)
else
  ? trim(title)
endif
if len(trim(reference)) > 120
  ? SUBSTR(reference,1,120)
  ? SUBSTR(trim(reference),121)
else
  ? trim(reference)
endif
? trim(keywords)
?
set print off
set DEVICE to screen
set console on
RETURN
PROCEDURE HELP
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* help.prg
CLEAR
store " " to ano
@ 5,10 say "?????????????????????????????????????????????????????????"
@ 10,10 say "SORRY, YOU'LL JUST HAVE TO WORK IT OUT FOR YOURSELF!!!"
@ 15,20 say "Hit any key to continue..."
@ 20,10 say "?????????????????????????????????????????????????????????"
set console off
wait to ano
set console on
release ano
RETURN
PROCEDURE FLAGTEXT
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* flagtext.prg
CLEAR
?
?
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT FILE NAME (without estension) " to ofn
*!! There will be no automatic colon following this prompt string.
accept "OUTPUT FILE DRIVE (a, b, c, etc.) " to ofd
CLEAR
store ofd+":"+trim(ofn) to ofn
```

```
set alternate to &ofn
set alternate on
set talk off
go top
do while .not. EOF()
if flag <> "     "
        ? trim(authors)
        ? trim(title)
        ? trim(reference)
        ?
endif
skip
enddo
release ofn
release ofd
set alternate off
RETURN
PROCEDURE VERIFYDE
*!!*      dBASE CONVERT - dBASE III File Conversion Aid  v1.09 12/17/84
*
SET HEADING OFF
SET SAFETY OFF
* verifydel.prg
CLEAR
?
?
?
? " SEARCHING FOR DELETED RECORDS...."
locate for DELETE()
*!! Logical constant converted.
store .t. to more
do while more .and. (.not. EOF())
   set format to saydata
   store "VERIFY DELETES" to mode
   store "c)ontinue, e)dit, d)elete/recall, q)uit" to prompt2
   store " " to prompt1
   store " " to prompt3
   store " " to command
   do delcheck
   read
   store UPPER(command) to command
   do case
      case command = "D"
         do delete
      case command = "E"
         do eddit
      case command = "Q"
*!! Logical constant converted.
         store .f. to more
      case command = "C"
         continue
   endcase
enddo
*!! Logical constant converted.
store .t. to more
store "2" to command
RETURN
```

B I B L I O G R A P H Y
D A T A B A S E

* * * C O N F I R M   T H A T   P R I N T E R   I S   ON * * *

Enter Filename without Drive
Designation or File Extension

bibl

```
|    B I B L I O G R A P H Y    |
|         D A T A B A S E       |
|_______________________________|


* * *  C O N F I R M   T H A T   P R I N T E R   I S   ON  * * *


                    Enter Filename without Drive
                    Designation or File Extension


bibl

                    Name of index file keyed on year and author
                    without extension..........
bibl
                    Name of index file keyed on authors........
auth
                    Name of index file keyed on title.........
title
```

AUTHORS: Richart, F.E., A. Brandtzaeg and R.L. Brown

TITLE: A Study of the Failure of Concrete Under Combined Compressive Stresses

REFERENCE: Bulletin No. 185, Engineering Experiment Station, Univerisity of Illinois, 1928

KEYWORDS:

FLAG:

a)dd	b)ackward	d)elete/recall	e)dit	RECORD NO.	1
f)orward	h)elp	l)ocate	m)maintenance	STATUS: Ok	
p)rint	q(uit)	r)eport	s)et flag	OPTION	

**** MAIN MENU ****

```
*****************************************************************
*                                                               *
*                    FILE MAINTENANCE MENU                      *
*                                                               *
*****************************************************************
*                                                               *
*                                                               *
*              1.  Verify Deleted Entries                       *
*              2.  Remove Entries Marked For Deletion           *
*              3.  Flag Duplicate Entries                       *
*              4.  Verifiy New Entries                          *
*              5.  Quit To dBASE II                             *
*              6.  Quit To DOS                                  *
*              7.  Return To Main Menu                          *
*                                                               *
*                                                               *
*****************************************************************
*                                                               *
*         PLEASE CHOOSE AN OPTION                               *
*                                                               *
*****************************************************************
```

************* WARNING ************

This will PERMANENTLY remove any deleted entries.

It is recommended that this command be aborted and that the COPY command be used under native dBASE (see manual).

Type 'y' to continue. Type any other key to abort.

```
REPORT OPTIONS

1. Remove all flags.
2. Copy new entries to text file (with keywords).
3. Copy flagged entries to dBASE file.
4. Copy flagged entries to text file (without keywords).
5. Change flag character.
6. Return to main menu.

                              SELECT AN OPTION:
```

AUTHORS: Richart, F.E., A. Brandtzaeg and R.L. Brown

TITLE: A Study of the Failure of Concrete Under Combined Compressive Stresses

----

REFERENCE: Bulletin No. 185, Engineering Experiment Station, Univerisity of Illi
nois, 1928

KEYWORDS:

FLAG:

==

```
  a)dd       b)ackward  d)elete/recall    e)dit            RECORD NO.         1
  f)orward   h)elp      l)ocate           m)maintenance    STATUS:   Ok
  p)rint     q(uit)     r)eport           s)et flag        OPTION q
```

==

**** MAIN MENU ****

Do cancelled
. quit

```
L.  LOCATE ENTRY BY PRINCIPAL AUTHOR
S.  SEARCH FOR ENTRY BY ANY FIELD

Select l or s
```

```
L.  LOCATE ENTRY BY PRINCIPAL AUTHOR
S.  SEARCH FOR ENTRY BY ANY FIELD

Select l or s
                                            S

a. author search
k. keyword search
t. title search
r. reference search

Choose a, k, t, or r
```

```
L.  LOCATE ENTRY BY PRINCIPAL AUTHOR
S.  SEARCH FOR ENTRY BY ANY FIELD

Select l or s
                                            S

a. author search
k. keyword search
t. title search
r. reference search

Choose a, k, t, or r
                          A

Enter exact search string <return>Swartz
```

```
This routine will search through keywords for up to three strings, as
        string1 .AND. (string2 .AND. or .OR. string3)
You will be asked for three strings and the logic .AND. or .OR.
Null characters may be entered for strings, as they will return TRUE

Which logic for second operand: (a/o) for (AND/OR)?
```

```
Enter string1 beams
Enter string2 cantilever
Enter string3 double cantilever
```

AUTHORS: Swartz, S.E., K-K. Hu and G.L. Jones

TITLE: Compliance Monitoring of Crack Growth in Concrete

REFERENCE: Journal of the Engineering Mechanics Division, ASCE, Vol. 104, 1978, pp. 789-800

KEYWORDS:

FLAG:

c. continue   r. return   p. print   RECORD NO. 278
s. set flag   STATUS: Ok
OPTION

LOCATE MENU

```
Record No.     783                                                                  2:46:47pm
IMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMM;
: CURSOR    <-- -->  :            UP     DOWN     :      DELETE      : Insert Mode:   Ins    :
          : Char:   Del    : Exit:              ^End   :
:   Word:   Home End  : Page:   PgUp   PgDn    : Field:   ^Y     : Abort:           Esc   :
:                     : Help:    F1            : Record: ^U      : Memo:           ^PgDn  :
HMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMM<
CIT_NUM
TITLE


AUTHORS

REFERENCE


KEYWORDS
```

```
Record No.      783                                                               2:47:17pm
IMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMM;
: CURSOR    <-- -->  :          UP    DOWN    :       DELETE     : Insert Mode:  Ins   :
          : Char:  Del    : Exit:           ^End    :
:  Word:  Home End  : Page:  PgUp   PgDn    : Field:  ^Y    : Abort:           Esc   :
:                   : Help:   F1            : Record: ^U    : Memo:          ^PgDn  :
HMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMM<
KEYWORDS



FLAG
NEW            ?
YEAR
FOREIGN        ?
COPY           ?
CODE              .
```

```
Record No.        1                                                    2:44:05pm
IMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMM;
: CURSOR    <-- -->  :          UP    DOWN    :    DELETE    : Insert Mode:  Ins  :
          : Char:  Del    : Exit:           ^End   :
:  Word:   Home End  : Page:   PgUp  PgDn    : Field:   ^Y    : Abort:        Esc  :
:                    : Help:    F1           : Record: ^U    : Memo:        ^PgDn :
HMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMM<
CIT_NUM      1
TITLE        A Study of the Failure of Concrete Under Combined Compressive Stress
             es


AUTHORS      Richart, F.E., A. Brandtzaeg and R.L. Brown


REFERENCE    Bulletin No. 185, Engineering Experiment Station, University of Illi
             nois, 1928


KEYWORDS     bond,compress,cracking,microcrack,strain,tensile,
```

```
Record No.          1                                                        2:46:02pm
IMMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMKMMMMMMMMMMMMMMMMMMMMMM;
: CURSOR    <-- -->  :          UP    DOWN    :      DELETE     : Insert Mode:  Ins   :
          : Char:   Del    : Exit:           ^End   :
:  Word:  Home End  : Page:  PgUp  PgDn   : Field:   ^Y    : Abort:          Esc   :
:                   : Help:   F1          : Record: ^U     : Memo:          ^PgDn  :
HMMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMJMMMMMMMMMMMMMMMMMMMMMM<
KEYWORDS     bond,compress,cracking,microcrack,strain,tensile,


FLAG
NEW          t
YEAR         1928
FOREIGN      F
COPY         F
CODE            1.0
```

Appendix II

Bibliography

1.0
Richart, F.E., A. Brandtzaeg and R.L. Brown, A Study of the Failure of Concrete Under Combined Compressive Stresses, Bulletin No. 185, Engineering Experiment Station, University of Illinois, 1928

2.0
Richart, F.E., A. Brandtzaeg and R.L. Brown, The Failure of Plain and Spirally Reinforced Concrete in Compression, Bulletin No. 190, Engineering Experiment Station, University of Illinois, 1929

3.0
Wittmann, F. H., Zum Einfluss der Oberflachenenergie auf die Festigkeit eines porosen Stoffes. (On the Influence of the Surface Energy on the Strength of Porous Materials), Z. Agnew, Phys., Vol. 25, 1950, pp. 160

4.0
Jones, R., Testing of Concrete by Ultrasonic-Pulse Technique, Highway Research Board Proceedings, Vol. 32, 1953, pp. 258-275

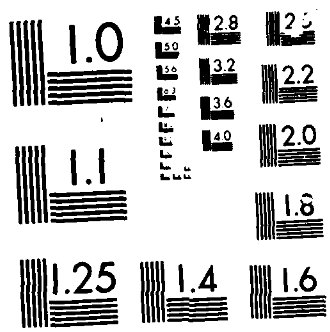
5.0
Blakey, F.A. and F.D. Beresford, A Note on Strain Distribution in Concrete Beams, Civil Engineering and Public Works Review, Vol. 50, 1955, pp. 415-416

6.0
Blakey, F. A., Some Considerations of the Cracking or Fracture of Concrete, Civil Engineering and Public Works Review, Vol. 52, 1957, pp. 1000-1003

7.0
Dantu, P., Etude des Contraintes dans les Milieux Heterogenes. Application au Beton, Annales de L'Institut Technique de Batiment et des Travaux Publics, Vol. 11, 1958, pp. 55-77

AD-A165 639 APPLICABILITY OF FRACTURE MECHANICS METHODOLOGY TO CRACKING AND FRACTURE O..(U) KANSAS STATE UNIV MANHATTAN DEPT OF CIVIL ENGINEERING S E SWARTZ FEB 86 2/3

UNCLASSIFIED NCEL-CR-86.006 N62583-85-M-T239 F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART

8.0
Hori, M., Statistical Aspects of Fracture in Concrete, I. An Analysis of Flexural Failure of Portland Cement Mortar from the Standpoint of Stochastic Theory, Journal of the Physical Society of Japan, Vol. 14, 1959, pp. 1444-1452

9.0
Neville, A. M., Some Aspects of the Strength of Concrete, Civil Engineering (London), Vol. Part III: 54, 1959, pp. 1435-1439

10.0
Arcan, M. and M. Tannenbaum, Photoelastic Model Studies on Cracked Reinforced Concrete Beams, Revue de Mecanique Appliquee, Extrait, Tome V, No. 4, 1960

11.0
Kaplan, M. F., Crack Propagation and the Fracture of Concrete, Journal of the American Concrete Institute, Vol. 58, 1961, pp. 591-610

12.0
Blakey, F. A. and F. D. Beresford, Discussion of the Paper, Crack Propagation and the Fracture of Concrete, by M.F. Kaplan, (JACI, Vol. 58, 1961, pp. 591-610), Journal of the American Concrete Institute, Vol. 59, 1962, pp. 919-923

13.0
Brunauer, S., Tobermorite Gel - The Heart of Concrete, American Scientist, Vol. 50, 1962, pp. 210-229

14.0
Glucklich, J., Discussion of the Paper, Crack Propagation and the Fracture of Concrete, by M.F. Kaplan, (JACI, Vol. 58, 1961, pp. 591-610), Journal of the American Concrete Institute, Vol. 59, 1962, pp. 919-923

15.0
Irwin, G. R., Discussion of the Paper, Crack Propagation and the Fracture of Concrete, by M.F. Kaplan, (JACI, Vol. 58, 1961, pp. 591-610), Journal of the American Concrete Institute, Vol. 59, 1962, pp. 929

16.0
Lyubimova, T. Yu and E. R. Pinus, Crystallization Structure in the Contact Zone Between Aggregate and Cement in Concrete, Kolloidnyi Zhurnal, Vol. 24, 1962, pp. 578-587

17.0
Glucklich, J., Fracture of Plain Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 89, 1963, pp. 127-138

18.0
Hsu, T. T. C., F. O. Slate, G. M. Sturman and G. Winter, Microcracking of Plain Concrete and the Shape of the Stress-Strain Curve, Journal of the American Concrete Institute, Vol. 60, 1963, pp. 209-224

19.0
Kaplan, M. F., Strains and Stresses of Concrete at Initiation of Cracking and Near Failure, Journal of the American Concrete Institute, Vol. 60, 1963, pp. 854-879

20.0
Romualdi, J. P. and G. B. Batson, Behaviour of Reinforced Concrete Beams with Closely Spaced Reinforcement, Journal of the American Concrete Institute, Vol. 60, 1963, pp. 775-790

21.0
Romualdi, J. P. and G. B. Batson, Mechanics of Crack Arrest in Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 89, 1963, pp. 147-168

22.0
Romualdi, J. P. and J. A. Mandel, Tensile Strength of Concrete Affected by Uniformly Distributed and Closely Spaced Short Lengths of Wire Reinforcement, Journal of the American Concrete Institute, Vol. 61, 1964, pp. 657-670

23.0
Wright, W. and J. G. Byrne, Stress Concentration in Concrete, Nature, Vol. 203, 1964, pp. 1374-1375

24.0
Glucklich, J., Static and Fatigue Fractures of Portland Cement Mortar in Flexure, in Proceedings of the First International Conference on Fracture, Japan, 1965, The Japanese Society for Strength and Fracture of Materials, 1966, Vol. 3, pp. 1343-1382

25.0
Glucklich, J., The Effect of *Microcracking* on Time-Dependent Deformations and the Long-Term Strength of Concrete, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 176-189

26.0
Kaplan, M. F., The Application of Fracture Mechanics to Concrete, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, pp. 169-175

27.0
Newman, K., Criteria for the Behavious of Plain Concrete Under Complex States of Stress, in A.E. Brooks, and K. Newman (eds.), The Structure of Concrete, *Proceedings of an International* Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 255-274

28.0
Robinson, G. S., Method of Detecting the Formation and Propagation of Microcracks in Concrete, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 131-145

29.0
Romualdi, J. P., The Static Cracking Stress and Fatigue Strength of Concrete Reinforced with Short Pieces of Thin Steel Wire, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 190-201

30.0
Ruetz, W., The Two Different Physical Mechanisms of Creep in Concrete, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, 1965, Cement and Concrete Association, London, 1968, pp. 146-153

31.0
Shah, S. P. and F. O. Slate, Internal Microcracking, Mortar-Aggregate Bond and the Stress-Strain Curve of Concrete, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 82-92

32.0
Vile, G. W. D., The Strength of Concrete Under Short-Term Static Biaxial Stress, in A.E. Brooks and K. Newman (eds.), The Structure of Concrete, Proceedings of an International Conference, London, 1965, Cement and Concrete Association, London, 1968, pp. 275-288

33.0
Yokomichi, H., K. Matsuoka, and N. Takada, Some Tests on Cracking of Concrete, in Review of the Nineteenth General Meeting, Cement Association of Japan, Tokyo, 1965, pp. 246-249

34.0
Kamiyama, S., An Effect of Notch for Uni-Axial Tensile Strength of Mortar and Concrete, in Review of the Twentieth General Meeting, The Cement Association of Japan, Tokyo, 1966, pp. 153-156

35.0
Lott, J. and C. E. Kesler, Crack Propagation in Plain Concrete, in Symposium on Structure of Portland Cement Paste and Concrete, Special Report 90, Highway Research Board, Washington, D.C., 1966, pp. 204-218

36.0
Yarema, S. Ya. and G. S. Krestin, Determination of the Modulus of Cohesion of Brittle Materials by Compressive Tests on Disc Specimens Containing Cracks, Fiziko-Khimicheskaya Mekhanika Materialov, Vol. 2 , 1966, pp. 10-14: English translation in Soviet Materials Science, Vol. 2, 1966, pp. 7-10

37.0
Dougill, J. W., A Mathematical Model for the Failure of Cement Paste and Mortars, Magazine of Concrete Research, Vol. 19, 1967, pp. 135-142

38.0
Glucklich, J. and L. J. Cohen, Size as a Factor in the Brittle-Ductile Transition and the Strength of Some Materials, International Journal of Fracture Mechanics, Vol. 3, 1967, pp. 278-279

39.0
Mostovoy, S., P.B. Crosley and E.J. Ripling, Use of Crack-Line-Loaded Specimens for Measuring Plane-Strain Fracture Toughness, Journal of Materials Science, Vol. 2, No. 3, September 1967, pp. 661-681

40.0
Evans, R. H. and M. S. Marathe, Microcracking and Stress-Strain Curves for Concrete in Tension, Materiaux et Constructions, Vol. 1, 1968, pp. 61-64

41.0
Evans, R. H. and M. S. Marathe, Stress Distribution Around Holes in Concrete, Materiaux et Constructions, Vol. 1, 1968, pp. 57-60

42.0
Hansen, T. C., Cracking and Fracture of Concrete and Cement Paste, in Causes, Mechanism, and Control of Cracking in Concrete, American Concrete Institute, SP-20, Detroit, 1968, pp. 43-66

43.0
Johnston, C.D. and E.H. Sidwell, Testing Concrete in Tension and in Compression, Magazine of Concrete Research, Vol. 20, No. 65, 1968, pp.221-228

44.0
Kato, K., Cracking Patterns in Plain Concrete, in Review of the Twenty-Second General Meeting, The Cement Association of Japan, Tokyo, 1968, pp. 177-178

45.0
Rice, J.R., A Path Independent Integral and the Approximate Analysis of Strain Concentrations by Notches and Cracks, Journal of Applied Mechanics, June 1968, pp. 379-386

46.0
Romualdi, J.P., M. Ramey and S.C. Sanday, Prevention and Control of Cracking by Use of Short Random Fibres, in Causes, Mechanism and Control of Cracking in Concrete, SP-20, American Concrete Institute, Detroit, Michigan, 1968, pp. 179-203

47.0
Shah, S. P. and G. Winter, Inelastic Behaviour and Fracture of Concrete, in Causes, Mechanism and Control of Cracking in Concrete, American Concrete Institute, SP-20, Detroit, 1968, pp. 5-28

48.0
Wittmann, F. H., Surface Tension, Shrinkage and Strength of Hardened Cement Paste, Materiaux et Constructions, Vol. 1, 1968, pp. 547-552

49.0
de Sousa Coutinho, A., Note sur la Rupture de Beton Maintenu a une Contrainte Constante. (A Note on the Rupture of Concrete Subjected to a Constant Stress), Materiaux et Constructions, Vol. 2, 1969, pp. 49-57

50.0
Husask, A. D., Static Fatigue of Portland Cement Concrete, Ph.D. Thesis, Carnegie-Mellon University, Pittsburgh, 1969

51.0
McCreath, D. R., J. B. Newman and K. Newman, The Influence of Aggregate Particles on the Local Strain Distribution and Fracture Mechanism of Cement Paste During Drying Shrinkage and Loading to Failure, Materiaux et Constructions, Vol. 2, 1969, pp. 73-84

52.0
Moavenzadeh, F. and R. Kuguel, Fracture of Concrete, Journal of Materials, Vol. 4, 1969, pp. 497-519

53.
Moavenzadeh, F. and T. W. Bremner, Fracture of Portland Cement Concrete, in MK. Te'eni (ed.), Structure, Solid Mechanics and Engineering Design, Proceedings of the Southampton 1969 Civil Engineering Materials Conference, Wiley-Interscience, 1971, pp. 997-1007

54.0
Naus, D. J. and J. L. Lott, Fracture Toughness of Portland Cement Concretes, Journal of the American Concrete Institute, Vol. 66, 1969, pp. 481-489

55.0
Newman, K. and J.B. Newman, Failure Theories and Design Criteria for Plain Concrete, in M. Te'eni (ed.), Structure, Solid Mechanics and Engineering Design; Proceedings of the Southampton 1969 Civil Engineering Materials Conference, Wiley - Interscience, 1971, pp. 963-995

56.0
Niwa, Y., S. Kobayashi and A. Miyaji, Some Considerations on Fracture Criteria of Cement Mortar Subjected to Multiaxial Compression, in Review of the Twenty-Third General Meeting, The Cement Association of Japan, Tokyo, 1969, pp. 163-168

57.0
Niwa, Y., S. Kobayashi, W. Koyanagi and K. Nakagawa, Microcracks of Concrete Under Triaxial Compression, in Review of the Twenty-Third General Meeting, The Cement Association of Japan, Tokyo, 1969, pp. 168-172

58.0
Popovics, S., Fracture Mechanism in Concrete: How Much Do We Know?, Journal of the Engineering Mechanics Division, ASCE, Vol. 95, 1969, pp. 531-544

59.0
Shah, S.P., Micromechanics of Concrete and Fibre Reinforced Concrete, in M. Te'eni (ed.), Structure, Solid Mechanics and Engineering Design, Proceedings of the Southampton 1969 Civil Engineering Materials Conference, Wiley - Interscience, 1971, pp. 367-376

60.0
Swamy, R.N., Aggregate-Matrix Interaction in Concrete Systems, in M. Te'eni (ed.), Structure, Solid Mechanics and Engineering Design, Proceedings of the Southampton 1969 Civil Engineering Materials Conference, Wiley - Interscience, 1971, pp. 301-315

61.0
Welch, G. B. and B. Haisman, The Application of Fracture Mechanics to Concrete and the Measurement of Fracture Toughness, Materiaux et Constructions, Vol. 2, 1969, pp. 171-177

62.0
Yokomichi, H., Y. Kakuta and K. Ayuta, On Critical Points in Deformation of Concrete, in Review of the Twenty-Third General Meeting, The Cement Associaiton of Japan, Tokyo, 1969, pp. 156-160

63.0
Anon, Tentative Method of Test for Plane-strain Fracture Toughness of Metallic Materials, Standard E399-70T, Annual Book of ASTM Standards, Part 31, 1970, pp.911-927

64.0
Darwin, D. and F. O. Slate, Effect of Paste-Aggregate Bond Strength on Behaviour of Concrete, Journal of Materials, Vol. 5, 1970, pp. 86-98

65.0
Feldman, R. F. and P. J. Sereda, A New Model for Hydrated Portland Cement and its Practical Implications, Engineering Journal (Canada), Vol. 53, 1970, pp. 53-59

66.0
George, K. P., Theory of Brittle Fracture Applied to Soil Cement, Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 96, 1970, pp. 991-1010

67.0
Hoff, G. C., Crack Extension Force Concept Applied to the Compressive Failure of Portland-Cement-Based Mortars, Miscellaneous Paper C-70-19, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 1970

68.0
Imbert, I.D.C., The Effect of Holes on Tensile Deformations in Plain Concrete, Highway Research Record, No. 324, Highway Research Board, Washington, D.C., 1970, pp. 54-65

69.0
Knox, W. R. A, Fracture Mechanisms in Plain Concrete Under Compression, Fracture Toughness of High Strength Materials, Iron and Steel Institute, London, 1970, pp. 158-162

70.0
Krokosky, E. M., Strength vs. Structure. A Study for Hydraulic Cements, Materiaux et Constructions, Vol. 3, 1970, pp. 313-323

71.0
Rosenthal, I. and J. Glucklich, Strength of Plain Concrete Under Biaxial Stress, Journal of the American Concrete Institute, Vol. 67, 1970, pp. 903-914

72.0
Shah, S.P. and S. Chandra, Fracture of Concrete Subjected to Cyclic and Sustained Loading, American Concrete Institute Journal and Proceedings, Proc. Vol. 67, No. 10, 1970, pp. 816-825

73.0
Anon, Velocity Control of Crack Growth in Materials Testing, Closed Loop, Vol. 1, No. 5, 1971

74.0
Diaz, Samuel Isaac, Fracture Mechanisms of Concrete Under Static, Sustained, and Repeated Compressive Loads, Ph.D. Dissertation, University of Illinois at Urbana-Champaign, 1971, 216 pp.

75.0
Dougill, J. W., Further Consideration of a Mathematical Model for Progressive Fracture of a Heterogeneous Material, Magazine of Concrete Research, Vol. 23, 1971, pp. 5-10

76.0
Glucklich, J., The Strength of Concrete as a Composite Material, in Mechan cal Behaviour of Materials, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 104-112

77.0
Husak, A. D. and E. M. Krokosky, Static Fatigue of Hydrated Cement Concrete, Journal of the American Concrete Institute, Vol. 68, 1971, pp. 263-271

78.0
Kesler, C. E., D. J. Naus and J. L. Lott, Fracture Mechanics - Its Applicability to Concrete, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 113-124

79.0
Koyanagi, W. and K. Sakai, Observations on the Crack Propagation Process of Mortar and Concrete, in Review of the Twenty-Fifth General Meeting, The Cement Association of Japan, Tokyo, 1971, pp. 153-157

80.0
Krishnaswamy, K. T., Mechanism of Failure and Microcracking of Plain Concrete Under Uniaxial Tensile Loading, Indian Concrete Journal, Vol. 45, 1971, pp. 204-208, 222

81.0
Naus, Dan Jay, Applicability of Linear-Elastic Fracture Mechanics to Portland Cement Concretes, Ph.D. Dissertation, University of Illinois at Urbana-Champaign, 1971, 103 pp.

82.0
Okada, K. and W. Koyanagi, Effect of Aggregate on the Fracture Process of Concrete, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 72-83

83.0
Parimi, S. R. and J. J. S. Rao, Effectiveness of Random Fibres in Fibre-Reinforced Concrete, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. V, pp. 176-186

84.0
Rao, C. V. S. K. and J. K. S. Rao, Statistical Aspects of Strength and Fracture Behaviour of Concrete, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 53-62

85.0
Sasse, H.R., On the Problem of Fracture Behaviour of Concrete-Like Two-Phase Systems, Forschungsberichte des Landes Nordrheim-Westfalen, Nr. 2192, Westedeutscher Verlag-Opladen, 1971, 93 pp. In German.

86.0
Shah, S. P. and F. J. McGarry, Griffith Fracture Criterion and Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 97, 1971, pp. 1663-1676

87.0
Swamy, R. N., Fracture Phenomena of Hardened Paste, Mortar and Concrete, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 132-142

88.0
Wittmann, F. H. and Ju. Zaitsev, Behaviour of Hardened Cement Paste and Concrete Under High Sustained Load, in Mechanical Behaviour of Materials, Proceedings of the International Conference on Mechanical Behaviour of Materials, Kyoto, 1971, The Society of Materials Science, Japan, 1972, Vol. IV, pp. 84-89

89.0
Wittmann, F.H. and J. Zaitsev, Versuche zur Bestimmung der Dauerfestigkeit des Zementsteins. (Research into the Determination of the Durability of Hardened Cement Paste), Zement-Kalk-Gips, Vol. 24, 1971, pp. 160

90.0
Wyss, Andreas Niklaus, Application of Fracture Mechanics to Cracking of Concrete Beams, Ph.D. Dissertation, University of Washington, 1971, 115 pp.

91.0
Zaitsev J. and F. H. Wittmann, Zur Dauerfestigkeit des Betons unter konstater Belastung, Bauingenieur, Vol. 46, 1971, pp. 84

92.0
Zaitsev, Ju. V., Deformation and Failure of Hardened Cement Paste and Concrete Subjected to Short Term Load, Cement and Concrete Research, Vol. 1, 1971, pp. 123-137

93.0
Zaitsev, Ju. V., Deformation and Failure of Hardened Cement Pastes and Concrete Under Sustained Load, Cement and Concrete Research, Vol. 1, 1971, pp. 329-344

94.0
Zaitsev, Ju.V., Experimental Investigation to Determine the Behaviour of Hardened Cement Paste and Plaster of Paris Under High Load, Cement and Concrete Research, Vol. 1, 1971, pp. 437-447

95.0
Ali, M.A., A.J. Majumdar and D.L. Rayment, Carbon Fibre Reinforcement of Cement, Cement and Concrete Research, Vol. 2, 1972, pp. 201-212

96.0
Barrick, J. E., II, The Effects of Temperature and Relative Humidity on Static Fatigue of Hydrated Portland Cement, Ph.D. Thesis, Carnegie-Mellon University, Pittsburgh, 1972

97.0
Berger, R. L., Calcium Hydroxide: Its Role in the Fracture of Tricalcium Silicate Paste, Science, Vol. 175, 1972, pp. 626-629

98.0
Brown, E. T. and J. A. Hudson, Discussion of S.P. Shah and F.J. McGarry, Griffith Fracture Criterion and Concrete, (J. Eng. Mech. Div., Vol. 97, 1971, pp. 1663-1676), Journal of the Engineering Mechanics Division, ASCE, Vol. 98, 1972, pp. 1310-1312

99.0
Brown, J. H., Measuring the Fracture Toughness of Cement Paste and Mortar, Magazine of Concrete Research, Vol. 24, 1972, pp. 185-196

100.0
Chir, R. K. and C. M. Sangha, A Study of the Relations Between Time, Strength, Deformation and Fracture of Plain Concrete, Magazine of Concrete Research, Vol. 24, 1972, pp. 197-208

101.0
Cooper, A. G. and J. Figg., Fracture Studies of Set Cement Paste, Journal of the British Ceramic Society, Vol. 71, 1972, pp. 1-4

102.0
Harris, B., J. Varlow and C. D. Ellis, The Fracture Behaviour of Fibre Reinforced Concrete, Cement and Concrete Research, Vol. 2, 1972, pp. 447-461

103.0
Lamkin, M. S. and V. I. Paschenko, Determination of the Critical Stress Intensity Factor of Concrete, Izvestiya VNIIG im. B. E. Vedeneeva, Leningrad, Vol. 99, 1972, pp. 234-239. In Russian.

104.0
Lim, T. C. Y., A. H. Nilson and F. O. Slate, Stress-Strain Response and Fracture of Concrete in Uniaxial and Biaxial Compression, Journal of the American Concrete Institute, Vol. 69, 1972, pp. 291-295

105.0
Majidzadeh, K. and D.V. Ramsamooj, Development of Testing Procedures and a Method to Predict Fatigue Failure of Asphalt Concrete Pavement Systems, Ohio State University, Contract No.: DOT-FH-11-7281

106.0
Miranda, Esteban Eulogio, Deformation and Fracture of Concrete Under Uniaxial Impact Loading, Ph.D. Dissertation, University of Missouri - Rolla, 1972, 153 pp.

107.0
Ono, Koichi, The Use of Mathematical Models in Fracture Mechanics With Special Reference to Cement Paste, Concrete and Reinforced Concrete, Ph.D. Dissertation, University of Toronto, Canada, 1972

108.0
Rolfe, Stanley T., Fracture Mechanics in Bridge Design, Civil Engineering, ASCE, August 1972, pp. 37-41

109.0
Schroedl, M.A. and C.W. Smith, Local Stresses Near Deep Surface Flaws Nuder Cylindrical Bending Fields, Virginia Polytechnic Institute and State University for the U.S. Army, Contract No. DAA-F07-69-C-0444, August 1972, 51 pp.

110.0
Stockl, S., Strength of Concrete Under Uniaxial Sustained Loading, in Concrete for Nuclear Reactors, SP-34, American Concrete Institute, Detroit, Vol. 1, 1972, pp. 313-326

111.0
Walsh, P. F., Fracture of Plain Concrete, Indian Concrete Journal, Vol. 46, 1972, pp. 469-470, 476

112.0
Yoshimoto, A. and M. Kawakami, Microcracking in Cement Paste Under Flexure-Tension, in Review of the Twenty-Sixth General Meeting, The Cement Association of Japan, Tokyo, 1972, pp. 165-166

113.0
Yoshimoto, A., S. Ogino and M. Kawakami, Microcracking Effect on Flexural Strength of Concrete After Repeated Loading, Journal of the American Concrete Institute, Vol. 69, 1972, pp. 233-240

114.0
Berger, R. L., F. V. Lawrence, Jr. and J. F. Young, Studies on the Hydration of Tricalcium Silicate Pastes II. Strength Development and Fracture Characteristics, Cement and Concrete Research, Vol. 3, 1973, pp. 497-508

115.0
Blight, G.E., Fracture of Pavement Materials, Transportation Engineering Journal of ASCE, Proceedings of ASCE, Vol. 99, No. TE4, 1973, pp. 801-819

116.0
Brown, J. H., The Failure of Glass-Fibre-Reinforced Notched Beams in Flexure, Magazine of Concrete Research, Vol. 25, 1973, pp. 31-38

117.0
Brown, J. H. and C. D. Pomeroy, Fracture Toughness of Cement Paste and Mortars, Cement and Concrete Research, Vol. 3, 1973, pp. 475-480

118.0
Carmichael, G. D. T. and K. Jerram, The Application of Fracture Mechanics to Prestressed Concrete Pressure Vessels, Cement and Concrete Research, Vol. 3, 1973, pp. 459-467

119.0
Chung, Hyung Sik, A Study of Failure Mechanism of Rock, Ph.D. Dissertation, Purdue University, 1973, 221 pp.

120.0
Clark, L.A., Flexural Cracking in Slab Bridges, Cement and Concrete Association Technical Report, May 1973, 12 pp.

121.0
Clyde, D.H., On Crack Direction in Relation to Griffith's Bi-Axial Failure Criterion, Cement and Concrete Research, Vol. 3, 1973, pp. 537-547

122.0
Hardy, Michael Peter, Fracture Mechanics Applied to Rock, Ph.D. Dissertation, University of Minnesota, 1973, 249 pp.

123.0
Harma, A.E. and C.W. Smith, Stress Intensity Factors for Long, Deep Surface Flaws in Plates under Extensional Fields, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University for NASA Contract No. NGR 47-004-076, February 1973

124.0
Kobayashi, Albert S. (ed.), Experimental Techniques in Fracture Mechanics, Monograph No. 1, Society for Experimental Stress Analysis, 1973

125.0
Krokosky, E.M., Static Fatigue in Hydrated Portland Cement, Materiaux et Constructions, Vol. 6, 1973, pp. 447-452

126.0
Lamkin, M.S., V.I. Paschenko and L.P. Trapesnikov, Application of the Brittle Fracture Theory to Determination of the Size of the Thermal Cracks in Elements of Concrete Structures, Trudy Koordinatsyionnykh Sovyeshchanii po Gidrotekhnikie, Energya, Leningrad, Vol. 82, 1973, pp. 68-73. In Russian.

127.0
Lin, Si-Tsai and E.S. Folias, On the Fracture of Highway Pavements, International Journal of Fracture, Vol. 11, No. 1, 1975, received Sept. 11, 1973, pp. 93-106

128.0
Lundquist, Robert Gary, A Progressive-Failure Model of Rock, Ph.D. Dissertation, The University of Wisconsin - Madison, 1973, 163 pp.

129.0
Mal'tsov K. A. and L. A. Shiryaeva, On the Character of Concrete Failure in Compression and in Tension, Trudy Koordinatsyionnykh Sovyeshchanii po Gidrotekhnikie, Energya, Leningrad, Vol. 82, 1973, pp. 29-33. In Russian.

130.0
Naaman, S. R., A. S. Argon and F. Moavenzadeh, A Fracture Model for Fibre Reinforced Cementitious Materials, Cement and Concrete Research, Vol. 3, 1973, pp. 397-411

131.0
Naus, D., Fracture Mechanics Applicability to Portland Cement Concretes, Technical Manuscript M-42, Construction Engineering Research Laboratory, Champaign, Illinois, 1973

132.0
Palaniswamy, Rangaswamy Gounder, Fracture and Stress-Strain Law of Concrete Under Triaxial Compressive Stresses, Ph.D. Dissertation, University of Illinois at Chicago Circle, 1973, 168 pp.

133.0
Radjy, F. and T. C. Hansen, Fracture of Hardened Cement Paste and Concrete, Cement and Concrete Research, Vol. 3, 1973, pp. 343-361

134.0
Rajagopalan, K., Discussion of the Paper, Fracture of Plain Concrete, by P.F. Walsh, (Ind. Conc. J., Vol. 46, 1972, pp. 469-470, 476), Indian Concrete Journal, Vol. 47, 1973, pp. 211, 224

135.0
Santiago, S. D. and H. K. Hilsdorf, Fracture Mechanisms of Concrete Under Compressive Loads, Cement and Concrete Research, Vol. 3, 1973, pp. 363-388

136.0
Spooner, D. C. and C. D. Pomeroy, Energy Dissipating Processes in the Compression of Cement Paste and Concrete, Cement and Concrete Research, Vol. 3, 1973, pp. 481-486

137.0
Stroeven, P., Some Aspects of the Micromechanics of Concrete, Ph.D. Thesis, Stevin Laboratory, Technological University of Delft, 1973

138.0
Swamy, R. N. and C. V. S. K. Rao, Fracture Mechanism in Concrete Systems Under Uniaxial Loading, Cement and Concrete Research, Vol. 3, 1973, pp. 413-427

139.0
Tazawa, E. and S. Kobayashi, Properties and Applications of Polymer Impregnated Cementitious Materials, in Polymers in Concrete, SP-40, American Concrete Institute, Detroit, 1973, pp. 57-92

140.0
Togawa, K., T. Satoh and K. Araki, Parameters on the Fracture Toughness of Mortar and Concrete, in Review of the Twenty-Seventh General Meeting, The Cement Association of Japan, Tokyo, 1973, pp. 117-120

141.0
Trapesnikov, L. P., On the Question of Creep Effect in the Crack Development in Concrete, Trudy Koordinatsyionnykh Sovyeschanii po Gidrotekhnike, Energya, Leningrad, Vol. 112, 1976, pp. 64-67. In Russian.

142.0
Walsh, P. F., Discussion of the Paper, Measuring the Fracture Toughness of Cement Paste and Mortar, by J.H. Brown, (Mag. Concr. Res., Vol. 24, 1972, pp. 185-196), Magazine of Concrete Research, Vol. 25, 1973, pp. 220-221

143.0
Weiss, V., Crack Development in Concrete with Closely-Spaced Reinforcement and in Similar Materials, Cement and Concrete Research, Vol. 3, 1973, pp. 184-205

143.1
William, D.B. and A.G. Evans, A Simple Method for Studying Slow Crack Growth, Journal of Testing and Evaluation, ASTM, Vol. 1, No. 4, July 1973, pp. 264-270

144.0
Yokomichi, H., Y. Fujita and N. Saeki, Experimental Researches on Crack Propagation of Plain Concrete, in Review of the Twenty-Seventh General Meeting, The Cement Association of Japan, Tokyo, 1973, pp. 144-147

145.0
Zaitsev, Ju. V. and F. H. Wittman, Fracture of Porous Viscoelastic Materials Under Multiaxial State of Stress, Cement and Concrete Research, Vol. 3, 1973, pp. 389-395

146.0
Auskern, A. and W. Horn, Fracture Energy and Strength of Polymer Impregnated Cement, Cement and Concrete Research, Vol. 4, 1974, pp. 785-795

147.0
Beskos, D. E., Fracture of Plain Concrete Under Biaxial Stress, Cement and Concrete Research, Vol. 4, 1974, pp. 979-985

148.0
Bishara, A. G. and P. Tantayonondkul, Use of Latex in Concrete Bridge Decks, Final Report EES 435, Engineering Experiment Station, Ohio State University, Columbus, Ohio, 1974

149.0
Blight, G. E., Possible Applications of an Energy Approach to Design in Non-Metallic Construction Materials, in First Australian Conference on Engineering Materials, University of New South Wales, 1974, pp. 757-789

150.0
Briggs, A., D. H. Bowen and J. J. Kollek, Mechanical Properties and Durability of Carbon-Reinforced Cement Composites, in Proceedings, International Conference on Carbon Fibres, Their Place in Modern Technology, The Plastic Institute, London, Paper No. 17, 1974

151.0
Cook, D. J. and M. N. Haque, Strength Reduction and Length Changes in Concrete and Mortar on Water and Methanol Sorption, Cement and Concrete Research, Vol. 4, 1974, pp. 735-744

152.0
Cook, D. J. and M. N. Haque, The Effect of Sorption on the Tensile Creep and Strength Reduction of Dessicated Concrete, Cement and Concrete Research, Vol. 4, 1974, pp. 367-379

153.0
Cook, D. J. and M. N. Haque, The Tensile Creep and Fracture of Dessicated Concrete and Mortar on Water Sorption, Materiaux et Constructions, Vol. 7, 1974, pp. 191-196

154.0
Dhir, R. K. and C. M. Sangha, Development and Propagation of Microcracks in Plain Concrete, Materiaux et Constructions, Vol. 7, 1974, pp. 17-23

155.0
Domone, P. L., Uniaxial Tensile Creep and Failure of Concrete, Magazine of Concrete Research, Vol. 26, 1974, pp. 144-152

156.0
Glucklich, J., U. Korin and F. Shauer, The Reinforcement of Concrete by Polymers, Final Report, TDM 74-14, Technion, Israel Institute of Technology, Department of Mechanics, Haifa, Israel, 1974

157.0
Mindess, S., J. S. Nadeau and J. M. Hay, Effects of Different Curing Conditions on Slow Crack Growth in Cement Paste, Cement and Concrete Research, Vol. 4, 1974, pp. 953-965

158.0
Nadeau, J. S., S. Mindess and J. M. Hay, Slow Crack Growth in Cement Paste, Journal of the American Ceramic Society, Vol. 57, 1974, pp. 51-54

159.0
Naus, D. J., G. B. Batson and J. L. Lott, Fracture Mechanics of Concrete, in Fracture Mechanics of Ceramics, Plenum Press, New York, Vol. 2, 1974, pp. 469-482

160.0
Radjy, F., Fracture of Hardened Cement Paste in Relation to Surface Forces and Porosity, Journal of the American Ceramic Society, Vol. 57, 1974, pp. 88-89

161.0
Setzer, M. J. and F. H. Wittman, Surface Energy and Mechanical Behaviour of Hardened Cement Paste, Applied Physics, Vol. 3, 1974, pp. 403-409

162.0
Walsh, D., M. A. Otooni, M. E. Taylor, Jun., and M. J. Marcinkowdki, Study of Portland Cement Fracture Surfaces by Scanning Electron Microscopy Techniques, Journal of Materials Science, Vol. 9, 1974, pp. 423-429

163.0
Wittmann, F. H., Bestimmung physikalischer Eigenschaften des Zementsteins. (Determination of the Physical Properties of Hardened Cement Paste), Schriftenreihe Deutscher Ausschuss fur Stahlbeton, Vol. 232, 1974

164.0
Wittmann, F. H. and J. Zaitsev, Verfomung und Bruchvorgang poroser Baustoffe bei kurzzeitiger Belastung und Dauerlast. Schriftenreihe Deutscher Ausschuss fur Stahlbeton, vol. 232, 1974

165.0
Zaitsev J. and F. H. Wittman, A Statistical Approach to the Study of the Mechanical Behaviour of Porous Materials Under Multi-axial State of Stress, in Proceedings of the 1973 Symmposium of Mechanical Behaviour of Materials, The Society of Materials Science, Japan, 1974, pp. 105-109

166.0
Zaitsev, J. and F. H. Wittmann, Eine theoretische Studie des Verhaltens von Beton unter kurzzeitiger ein-und zweiachsiger Belastung. (A Theoretical Study of the Behavior of Concrete Under Short-term Uniaxial and Biaxial Loads), Materialsprufung, Vol. 16, 1974, pp. 170

167.0
Al-Kubaisy, M. A. and A. G. Young, Failure of Concrete Under Sustained Tension, Magazine of Concrete Research, Vol. 27, 1975, pp. 171-178

168.0
Aleszka, J. and G. Schnittgrund, An Evaluation of the Fracture of Plain Concrete, Fibrous Concrete, and Mortar Using the Scanning Electron Microscope, Technical Report M-122, Construction Engineering Research Laboratory, Champaign, Illinois, 1975

169.0
Aleszka, J. C. and P. W. R. Beaumont, The Work of Fracture of Concrete and Polymer Impregnated Concrete Composites, in Proceedings, First International Congress on Polymers in Concrete, 1975, The Construction Press Ltd., Lancaster, England, 1976, pp. 269-275

170.0
Argon, A. S. and W. J. Shack, Theories of Fibre Cement and Fibre Concrete, in Fibre Reinforced Cement and Concrete, Rilem Symposium, 1975, pp. 39-53

171.0
Bhargava J. and A. Rehnstrom, High Speed Photography for Fracture Studies of Concrete, Cement and Concrete Research, Vol. 5, 1975, pp. 239-248

172.0
El-Din Salah, A. S. and M. M. El-Adawy Nassef, A Modified Approach for Estimating the Cracking Moment of Reinforced Concrete Beams, Journal of the American Concrete Institute, Vol. 72, 1975, pp. 356-360

173.0
Entov, V. M. and V. I. Yagust, Experimental Investigation of the Regularities of Quasistatic Development of Macrocracks in Concrete, Izvestiya Akademii Nauk SSR, Mekhanika Tverdogo Tela., Vol. 4, 1975, pp. 93-103

174.0
Entov, V.M. and V.I. Yagust, Experimental Investigation of Laws Governing Quasi-Static Developement of Macrocracks in Concrete, Mechanics of Solids, Vol. 10, No. 4, 1975, pp. 87-95

175.0
Esaki, T. and Y. Tokumitsu, Time-Dependent Deformation Fracture of Concrete Under High Sustained Stress, Review of the Twenty-Ninth General Meeting, The Cement Association of Japan, Tokyo, 1975, pp. 207-209

176.0
Glucklich, J. and U. Korin, Effect of Moisture Content on Strength and Strain Energy Release Rate of Cement Mortar, Journal of the American Ceramic Society, Vol. 58, 1975, pp. 517-521

177.0
Kobayashi, T. and V. Der, A Simplified Procedure For Establishing the Dynamic Stress Intensity Factor and Crack Velocity Relationship and Results for Granite Rock, Department of Mechanical Engineering, University of Maryland for NSF-RANN grant APR-73-07908-A01, 1975

178.0
Ngo, De, A Network-Topological Approach to the Finite Element Analysis of Progressive Crack Growth in Concrete Members, Ph.D. Dissertation, University of California, Berkeley, 1975, 295 pp.

179.0
Okamura, H., L. Watanabe and T. Takano, Deformation and Strength of Cracked Member under Bending Moment and Axial Force, Engineering Fracture Mechanics, Vol. 7, 1975, pp. 531-539

180.0
Patterson, W.A. and H. C. Chan, Fracture Toughness of Glass Fibre-Reinforced Cement, Composites, Vol. 6, 1975, pp. 102-104

181.0
Schmidt, Richard A., Fracture Toughness Testing of Rock, Closed Loop - The Magazine of Mechanical Testing, Vol. 5, No. 2, November 1975, pp. 3-12

182.0
Spooner, D. C., C. D. Pomeroy and J. W. Dougill, The Deformation and Progressive Fracture of Concrete, Proceedings of the British Ceramic Society, Vol. 25, 1975, pp. 101-107

183.0
Tanigawa, Y. and Y. Kosaka, Mechanism of Fracture and Failure of Concrete as a Composite Material, Memoirs of the Faculty of Engineering, Nagoya University (Japan), Vol. 27, 1975, pp. 208-263

184.0
Walsh, P. F., Cracks, Notches and Finite Elements, in J. M. Corum and S. E. Benzley (eds.), Computational Fracture Mechanics, Symposium of the Computational Technical Committee, 2nd National Congress on Pressure Vessels and Piping, ASME, New York, 197

185.0
Yoshimoto, A., K. Kawasaki and M. Kawakami, Studies of Formation of Continuous Crack in Concrete by Using a Slow-Motion Picture, in Review of the Twenty-Ninth General Meeting, The Cement Associatoin of Japan, Tokyo, 1975, pp. 243-244

186.0
Argyris, J.H., G. Faust and K.J. Willam, Limit Load Analysis of Thick-walled Concrete Structures - A Finite Element Approach to Fracture, Computer Methods in Applied Mechanics and Engineering, Vol. 8, 1976, pp.215-243

187.0
Barnes, B. D., Morphology of the Paste-Aggregate Interface, Ph.D. Thesis, School of Civil Engineering, Purdue University, West Lafayette, Indiana, 1976

188.0
Barnes, B. D. and S. Diamond, Initiation and Propagation of Cracks near Portland Cement Paste-Aggregate Interfaces, in Proceedings of the 2nd International Conference on Mechanical Behaviour of Materials, ASM, Metals Park, Ohio, 1976, pp. 1414-1417

189.0
Barr, B. and T. Bear, A Simple Test of Fracture Toughness, Concrete, Vol. 10, 1976, pp. 25-27

190.0
Barrick, J. E., II, and E. M. Krokosky, The Effects of Temperature and Relative Humidity on Static Strength of Hydrated Portland Cement, Journal of Testing and Evaluation, Vol. 4, 1976, pp. 61-73

191.0
Bazant, Z. P., Instability, Ductility, and Size Effect in Strain-Softening Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 102, 1976, pp. 331-344

192.0
Clifton, J. R., J. E. Fearn and E. D. Anderson, Polymer Impregnated Hardened Cement Pastes and Mortars, NBS-BSS 83, National Bureau of Standards, Washington, D.C., 1976

193.0
Derucher, Kenneth Noel, Observations of Microcracks in Concrete Under Application of Compressive Stress Fields, Ph.D. Dissertation, Virginia Polytechnic Institute and State University, 1976, 133 pp.

194.0
Evans, A. G., J. R. Clifton and E. Anderson, The Fracture Mechanics of Mortars, Cement and Concrete Researach, Vol. 6, 1976, pp. 535-548

195.0
Higgins, D. D. and J. E. Bailey, A Microstructural Investigation of the Failure Behaviour of Cement Paste, in Hydraulic Cement Pastes: Their Structure and Properties, Proceedings of a Conference at University of Sheffield, 1976, Cement and Concrete Association, Wexham Springs, 1976, pp. 283-296

196.0
Higgins, D. D. and J. E. Bailey, Fracture Measurements on Cement Paste, Journal of Materials Science, Vol. 11, 1976, pp. 1995-2003

197.0
Hillemeier, B., Bruchmechanische Untersuchungen des Rissfortschritts in Zementgebundenen Werkstoffen. (Fracture Mechanics Investigation of Crack Propagation in Cementitious Materials), Ph. D. Thesis, Karlsruhe University, 1976

198.0
Hillerborg, A., M. Modeer and P. E. Petersson, Analysis of Crack Formation and Crack Growth in Concrete by Means of Fracture Mechanics and Finite Elements, Cement and Concrete Research, Vol. 6, 1976, pp. 773-782

199.0
Kelly, A., Fibre Reinforcement of Brittle Matrices, In G. Piatti (ed.), Proceedings of a Seminar on Advanced Composite Materials, Applied Science, Barking, England, 1976, pp. 113-129

200.0
Kishitani, K. and K. Maeda, Compressive Fracture of Cracked Mortar, in Review of the Thirtieth General Meeting, The Cement Association of Japan, Tokyo, 1976, pp. 216-217

201.0
Kitagawa, H. and M. Suyama, Fracture Mechanics Study on the Size Effect for the Strength of Cracked Concrete Materials, in Proceedings, Nineteenth Japan Congress on Materials Research, The Society of Materials Science, Tokyo, 1976, pp. 156-159

202.0
Kitagawa, H., S. Kim and M. Suyama, Determination of Fracture Toughness of Concrete Materials by Diametral Compression Tests, in Proceedings, Nineteenth Japan Congress on Materials Research, The Society of Materials Science, Tokyo, 1976, pp. 160-163

203.0
Maher, A. and D. Darwin, A Finite Element Model to Study the Microscopic Behaviour of Plain Concrete, CRINC Report-SL-76-02, The University of Kansas Center for Research, Inc., Lawerence, Kansas, 1976

204.0
Mindess, S. and J. S. Nadeau, Effect on Notch Width on Kic for Mortar and Concrete, Cement and Concrete Research, Vol. 6, 1976, pp. 529-534

205.0
Petersson, Per-Erik and Matz Modeer, Brottmekanisk Modell for Berakning av Sprickutbredning i Betong (Model Based on Fracture Mechanics for the Calculation of Crack Propagation in Concrete), Institutionen for Byggnadsteknik, Tekniska Hogskolan i Lund, Sweden, Rapport 70, 1976

206.0
Scerbakov, E. N. and Ju. V. Zaitsev, Voraussage der Verformungs - und Festigkeitseigenschaften von Beton unter Dauerlast. (Predictions of the Deformational and Strength Characteristics of Concrete Subjected to Sustained Loads), Cement and Concrete Research, Vol. 6, 1976, pp. 515-528

207.0
Schmidt, R.A., Fracture Toughness Testing of Limestone, Experimental Mechanics, Vol. 16, No. 5, 1976, pp. 161-167

208.0
Setzer, M. J., A Method for Description of Mechanical Behaviour of Hardened Cement Paste by Evaluation Adsorption Data, Cement and Concrete Research, Vol. 6, 1976, pp. 37-48

209.0
Spooner, D. C., C. D. Pomeroy and J. W. Dougill, Damage and Energy Dissipation in Cement Pastes in Compression, Magazine of Concrete Research, Vol. 28, 1976, pp. 21-29

210.0
Spurrier, J. and A. R. Luxmoore, The Critical Constrained Crack Length in Fibre-Reinforced Cementitious Matrices, in Fibre Science and Technology, Applied Science Publishers Ltd., England, Vol. 9, 1976, pp. 225-236

211.0
Stroeven, P., Structural Loosening of Plain Concrete in Uniaxial Compression, in Proceedings of the First National Conference on Mechanics and Technology of Composite Materials, Varna, 1976, Bulgarian Academy of Sciences, Sofia, 1977, pp. 627-632

212.0
Stucke, M. S. and A. J. Majumdar, Microstructure of Glass Fibre-Reinforced Cement Composites, Journal of Materials Science, Vol. 11, 1976, pp. 1019-1030

213.0
Turner, Dean Hudson, Cracking of Concrete Due to Corrosion of Various Embedded Metals, M.S.E., Florida Atlantic University, 1976, 67 pp.

214.0
Walsh, P. F., Crack Initiation in Plain Concrete, Magazine of Concrete Research, Vol. 28, 1976, pp. 37-41

215.0
Wittmann, F. H., The Structure of Hardened Cement Paste - A Basis for a Better Understanding of the Materials Properties, in Hydraulic Cement Pastes: Their Structure and Properties, Proceedings of a Conference held at University of Sheffield, 1976, Cement and Concrete Association, Wexham Springs, 1976, pp. 96-117

216.0
Yoshimoto, A., K. Kawasaki and M. Kawakami, Microscopic Cracks in Cement Matrix and Deformation Behaviour of Concrete, in Proceedings, Nineteenth Japan Congress on Materials Research, The Society of Materials Science, Japan, 1976, pp. 126-131

217.0
Akers, S. A. S., G. G. Garrett and R. B. Tait, In Situ Scanning Electron Microscope Observations of Flexural Failure of Asbestos Cement, Electronmicroscopy Society of South Africa, Vol. 7, 1977, pp. 57-58

218.0
Barr, B. and T. Bear, Fracture Toughness, Concrete , Vol. 11, 1977, pp. 30-32

219.0
Batson, G. B., Strength of Steel Fibre Reinforced Concrete in Adverse Environments, Special Report M-218, Construction Engineering Research Laboratory, Champaign, Illinois, 1977

220.0
Bear, T. J., and B. Barr, Fracture Toughness Tests for Concrete, International Journal of Fracture, Vol. 13, 1977, pp. 42-46

221.0
Briggs, A., Review. Carbon Fibre-Reinforced Cement, Journal of Materials Science, Vol. 12, 1977, pp. 384-404

222.0
Desayi, P., Fracture of Concrete in Compression, Materiaux et Constructions, Vol. 10, 1977, pp. 139-144

223.0
Esaki, T. and Y. Tokumitsu, Study on Mechanism of Time-Dependent Deformation and Failure of Concrete, in Review of the Thirty-First General Meeting, The Cement Association of Japan, Tokyo, 1977, pp. 145-146

224.0
Fujita, Y., N. Saeki, N. Takada, and H. Nara, On Properties of Cracking of Plain Concrete, in Review of the Thirty-First General Meeting, The Cement Association of Japan, Tokyo, 1977, pp. 147-149

225.0
George, K. P., Fracture Mechanics Approach to Cracking in Pavements, presented at the 2nd ASCE Engineering Mechanics Division Specialty Conference, Raleigh, North Carolina, May 23-25, 1977

226.0
Gjorv, O. E., S. I. Sorensen and A. Arnesen. Notch Sensitivity and Fracture Toughness of Concrete, Cement and Concrete Research, Vol. 7, 1977, pp. 333-344

227.0
Grimes, William Darwin, The Mechanism of Concrete Cracking in Seawater Due to Embedded Metal Corrosion, M.S.E., Florida Atlantic University, 1977, 109 pp.

228.0
Gustafsson, P. J., Brottmekaniska Studier; Lattbetong och Fiber-Armerad Betong, Rapport TVBM-5001, Dept. of Building Materials, The Lund Institute of Technology, 1977, 131 pp.

229.0
Hawkins, N. M., A. N. Wyss and A. H. Mattock, Fracture Analysis of Cracking in Concrete Beams, *Journal of the Structural* Division, ASCE, Vol. 103, 1977, pp. 1015-1030

230.0
Hillemeier, B. and H. K. Hilsdorf, Fracture Mechanics Studies on Concrete Compounds, Cement and Concrete Research, Vol. 7, 1977, pp. 523-536

231.0
Ingraffea, Anthony Richard, Discrete Fracture Propagation in Rock: Laboratory Tests and Finite-Element Analysis, Ph.D. Dissertation, University of Colorado at Boulder, 1977, 374 pp.

232.0
Khrapkov, A. A., L. P. Trapenanikov, G. S. Geinats, V. I. Paschenko and A. P. Pak, The Application of Fracture Mechanics to the Investigation of Cracking in Massive Concrete Construction Elements of Dams, in Fracture 1977, ICF4, Vol. 3, Waterloo, Ontario, 1977, pp. 1211-1217

233.0
Kim, S.C. and H. Kitagawa, A Method of Determination of Mixed Mode Fracture Toughness of Brittle Materials Under Compression, in Fracture Mechanics and Technology, Proceedings of an International Conference, Vol. II, Hong Kong, 1977, pp. 1011-1019

234.0
Kotsovos, M. D. and J. B. Newman, Behaviour of Concrete Under Multiaxial Stress, Journal of the American Concrete Institute, Vol. 74, 1977, pp. 443-446

235.0
Maher, A. and D. Darwin, Microscopic Finite Element Model of Concrete, in Proceedings, First International Conference on Mathematical Modelling, St. Louis, MO, Vol. 3, 1977, pp. 1705-1714

236.0
Marchese, B., SEM Topography of Twin Fracture Surfaces of Alite Pastes 3 Years Old, Cement and Concrete Research, Vol. 7, 1977, pp. 9-18

237.0
Mazars, J., Existence of Critical Strain Energy Release Rate for Concrete, in Fracture 1977, ICF4, Vol. 3, Waterloo, Ontario, 1977, pp. 1205-1209

238.0
Mihashi, H. and M. Izumi, A Stochastic Theory for Concrete Fracture, Cement and Concrete Research, Vol. 7, 1977, pp. 411-422

239.0
Mindess, S. and J. S. Nadeau, Effect of Loading Rate on the Flexural Strength of Cement and Mortar, American Ceramic Society Bulletin, Vol. 56, 1977, pp. 429-430

240.0
Mindess, S., F. V. Lawrence, Jr., and C. E. Kesler, The J-Integral as a Fracture Criterion for Fibre Reinforced Concrete, Cement and Concrete Research, Vol. 7, 1977, pp. 731-742

241.0
Nagamatsu, S. and Y. Sato, Experimental Studies of Creep Rupture and Deformation of Cement Mortar Under High Structural Compressive Load, in Review of the Thirty-First General Meeting, The Cement Association of Japan, Tokyo, 1977, pp. 196-198

242.0
Okada, K., W. Koyanagi and K. Rokugo, Energy Transformation in the Fracture Process of Concrete, in Memoirs of the Faculty of Engineering, Kyoto University, Kyoto, Japan, Vol. 34, Part 3, 1977, pp. 389-402

243.0
Pak, A. P., L. P. Trapesnikov, T. P. Sherstobitova and E. N. Yakovleva. In Russian., Experimental and Analytical Determination of the Critical Length of Crack in Concrete, Inzvestiya VNIIG im. B. E. Vedeneeva, Vol. 116, 1977, pp. 50-54

244.0
Strange, P. C., The Fracture of Plain and Fibre Concrete, Ph.D. Thesis, Department of Civil Engineering, University of Auckland, New Zealand, 1977

245.0
Swamy, R. N. and C. V. S. K. Rao, Toughness and Ductility of Fibre Reinforced Concrete Composites in Flexure, in Fibre Reinforced Materials, Institution of Civil Engineers, London, 1977, pp. 77-86

245.1
Swartz, Stuart E., K.K. Hu and Gary L. Jones, Use of Compliance Measurements to Monitor Crack Growth in Plain Concrete, presented at the ASCE National Meeting, Dallas, TX, April 28, 1977

246.0
Testa, R. B. and N. Stubbs, Bond Failure and Inelastic Response of Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 103, 1977, pp. 296-310

247.0
Walton, P. L. and A. J. Majumdar, Fracture Energy of Plain and Glass-Reinforced Gypsum Plaster, Journal of Materials Science, Vol. 12, 1977, pp. 831-836

248.0
Wittmann, F.H., Grundlagen eines Modells zue Beschreibung Charakteristischer Eigenschaften des Betons. (The Basis for a Model to Describe the Characteristic Properties of Concrete), Schriftenreihe Deutscher Ausshuss fur Stahlbeton, Vol. 290, 1977, pp. 43-101

249.0
Zaitsev, Ju. V. and E.N. Scerbakov, Creep Fracture of Concrete in Prestressed Concrete Members During Manufacture, in Fracture 1977, ICF4, Vol. 3, Waterloo, Ontario, 1977, pp. 1214-1222

250.0
Zaitsev, Ju. V. and F.H. Wittman, Crack Propagation in a Two-Phase Material Such as Concrete, in Fracture 1977, ICF4, Vol. 3, Waterloo, Ontario, 1977, pp. 1197-1203

251.0
Zech, B. and F.H. Wittmann, A Complex Study on the Reliability Assessment of the Containment of a PWR, Part II: Probabilistic Approach to Describe the Behavior of Materials, Transactions of the 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, California, 15-19 August 1977, Vol. J(a), Paper J 1/11, 1977

252.0
Beaumont, P.W.R. and J.C. Aleszka, Cracking and Toughening of Concrete and Polymer-Concrete Dispersed with Short Steel Wires, Journal of Materials Science, Vol. 13, 1978, pp. 1749-1760

253.0
Beredichevskii, G.Yu. and V.L. Chernyavskii, On Modelling of Cracking in Concrete Constructions, Materialy Konf. i Soveschanii po Gidrotkhnike. Energya, Leningrad, Vol. 119. 1978, pp. 83-97. In Russian.

254.0
Bunsell. A.R., The Nature of Crack Growth in Composite Materials, in G.C. Sih and V.P. Tamuzs (eds.), Fracture of Composite Materials, Proceedings of the First USA-USSR Symposium, Riga, 1978, Sijthoff and Noordhoff, the Netherlands, 1979, pp. 349-359

255.0
Carpinteri, A., Di Tommaso and E. Viola, Stato Limite Di Frattura Nei Materiali Fragili. (Limit States for Fracture of Brittle Materials), Giornale del Genio Civile (Italy). 1978, pp. 201-224

256.0
Cook, D.J. and G. Crookham, A Discussion of the Paper, Notch Sensitivity and Fracture Toughness of Concrete, by O.E. Gjorv, S.I. Sorensen and A. Arnesen, (Cement and Concrete Research, Vol. 7, 1977, pp. 333), Cement and Concrete Research, Vol. 8, 1978, pp. 387-388

257.0
Cook, D.J. and G.D. Crookham, Fracture Toughness Measurements of Polymer Concretes, Magazine of Concrete Research, Vol. 30, 1978, pp. 205-214

258.0
Darwin, D., Discussion of Bond Failure and Inelastic Response of Concrete, by R.B. Testa and N. Stubbs (J. Eng. Mech. Div., ASCE, Vol. 103, 1977, pp. 246-310), Journal of the Engineering Mechanics Divisions, ASCE, Vol. 104, 1978, pp. 507-509

259.0
Der, V.K., D.C. Holloway and T. Kobayashi, Techniques for Dynamic Fracture Toughness Measurements, Performed by Mechanical Engineering Department, University of Maryland for the National Science Foundation, January 1978

260.0
Dikovskii, I.A., On Fracture Toughness of Concrete, Rabotosposobnost' Stroit. Materialov v Usloviakh Vozd. Razlichnykh Expluat. fakturov. Mezhvuzovsky Sbornik, Kazan, K.Kh.T.I. an S.M. Kirova, Vol. 1, 1978, pp. 17-18. In Russian.

261.0
Hillerborg, A., A Model for Fracture Analysis, Report TVBM-3005, Division of Building Materials, Lund Institute of Technology, Lund, Sweden, 1978

262.0
Kawamura, M., Internal Stress and Microcrack Formation Caused by Drying in Hardened Cement Pastes, Journal of the American Ceramic Society, Vol. 61, 1978, pp. 281-283

263.0
Kobayashi, T. and W.L. Fourney, Experimental Characterization of the Development of Micro-Crack Process Zone at a Crack Tip in Rock under Load, in Proceedings of the 19th U.S. National Symposium on Rock Mechanics, Reno, May 1978

264.0
Lung-An, Ying, The Infinite Similar Element Method for Calculating Stress Intensity Factors, Scientia Sinica, Vol. 21, No. 1, 1978, 25 pp.

265.0
Marchukaitis, G.V., The Calculation of Strength Increase of the Polymer Impregnated Concrete, Rabotosposohnost' Stroit. Materialov v Usloviakh Vozd Razlichnykh Expluataatsionykh Faktorov. Mezhuvuzovsky Sbor. , Kazan, Vol. 1, 1978, pp. 82-85. In Russian.

266.0
Mizutani, K., An Indirect Tension Test with Applications to Fracture of Brittle Materials, Ph.D. Thesis, Purdue University, West Lafayette, Indiana, 1978

267.0
Morita, K. and K. Kato, Fundamental Study on Fracture Toughness and Evaluation by Acoustic Emission Technique of Concrete, In Review of the Thirty-Second Meeting, The Cement Association of Japan, Tokyo, 1978, pp. 138-139

268.0
Munoz-Escalona, A. and C. Ramos, Fracture Morphology and Mechanical Properties of Thermocatalytically Polymerized MMA-Impregnated Mortar, Journal of Material Science, Vol. 13, 1978, pp. 301-310

269.0
Nishioka, K., S. Yamakawa, K. Hirakawa and S. Akihama, Test Method for the Evaluation of the Fracture Toughness of Steel Fibre Reinforced Concrete, in Testing and Test Methods of Fibre Cement Composites, RILEM Symposium 1978, The Construction Press, Lancaster, England, 1978, pp. 87-98

270.0
Ohigashi, T., Measurement of Effective Fracture Energy of Glass Fibre Reinforced Cement, in Testing and Test Methods of Fibre Cement Composites, RILEM Symposium 1978, The Construction Press, Lancaster, England, 1978, pp. 67-78

271.0
Pak, A.P., L.P. Trapesnikov, E.N. Yakovleva, On the Determination of the Critical Crack Length for Concrete, Izvestyia VNIIG im. B.E. Vedeneeva, Vol. 120, 1978, pp. 26-29. In Russian.

272.0
Pak, A.P., L.P. Trapesnikov, T.P. Sherstobitova and E.N. Yakovleva, The Verification of the Hypothesis of Generalized Normal Fracture for the Sand Cement Specimens, Materaily Konf. i Soveschanii po Gidrotekhnike, Energya, Leningrad, Vol. 119, 1978, pp. 66-70. In Russian.

273.0
Peresypkin, E.N., Stress Intensity Factors and Crack Opening in Reinforced Concrete Elements, Beton i Zhelezobeton, Vol. 12, 1978, pp. 27-34. In Russian.

274.0
Peresypkin, E.N. and L.P. Trapesnikov, Stress Intensity Factor in Cracked Reinforced Concrete Elements, Izvestiya VNIIG im. B.E. Vedeneeva, Vol. 121, 1978, pp. 13-18. In Russian.

275.0
Rice, James R., The Mechanics of Quasi-static Crack Growth, Division of Engineering, Brown University, Providence, RI, 1978

276.0
Sok, C., Etude de la Propagation d'une Fissure dans un Beton non Arme. (Study of Crack Propagation in Unreinforced Concrete), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, Vol. 98, 1978, pp. 73-84

277.0
Stein, N.H., De Sterkte van Verhard Cement, Kleien Keramiek, Vol. 28, 1978, pp. 22-33. In Dutch.

278.0
Swartz, S.E., K-K. Hu and G.L. Jones, Compliance Monitoring of Crack Growth in Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 104, 1978, pp. 789-800

279.0
Wataon, K.L., The Estimation of Fracture Surface Energy as a Measure of the Toughness of Hardened Cement Paste, Cement and Concrete Research, Vol. 8, 1978, pp. 651-656

280.0
Wischers, G., Aufnahme und Auswirkungen von Druckbeans-pruchungen auf Beton. (Review of the Influence of Compressive Stresses), in Beton Techniche Berichte, 1978, Beton-Verlag GmbH, Dusseldorf, 1979, pp. 31-56. In German.

281.0
Alford, N. McN. and A.B. Poole, The Effect of Shape and Surface Texture on the Fracture Toughness of Mortars, Cement and Concrete Research, Vol. 9, 1979, pp. 583-589

282.0
Andonian, R., Y.W. Mai and B. Cotterell, Strength and Fracture Properties of Cellulose Fibre Reinforced Cement Composites, International Journal of Cement Composites, Vol. 1, 1979, pp. 151-158

283.0
Anonymous, Study on the Cracking Strength and Maximum Crack Width in Reinforced Concrete Members, Journal of the Dalian Institute of Technology (China), 1979, pp. 67-80

284.0
Argyris, J.H., G. Faust and K.H. William, Finite Element Analysis of Concrete Cracking, Inst. Fuer Statik und Dynamik, Stuttgart University, Report ISD-256, 1979, 28 pp.

285.0
Bakhtibaev, A.N., V.I. Betekhtin, A.D. Kadyrbekov and V.R. Regel, Time and Temperature Dependences of the Strength of Cement With Contacts of Crystallization or Coagulation Type, Fiz. Prochn. Kompoz. Mater., (Mater. Vses. Semin.) 3rd, 1979, pp. 112-117

286.0
Barnes, B.D., S. Diamond and W.L. Dolch, Micromorphology of the Interfacial Zone Around Aggregates in Portland Cement Mortar, Journal of the American Ceramic Society, Vol. 62, 1979, pp. 21-24

287.0
Bazant, Z.P and A.B. Wahab, Instability and Spacing of Cooling or Shrinkage Cracks, Journal of the Engineering Mechanics Division, ASCE, Vol. 105, 1979, pp. 873-889

288.0
Bazant, Z.P., Material Behavior Under Various Types of Loading, in S.P. Shah (ed.), High Strength Concrete, Proceedings of a Workshop held at the University of Illinois at Chicago Circle, Dec. 2-4, 1979, 1980, pp. 79-92

289.0
Bazant, Z.P. and L. Cedolin, Blunt Crack Band Propagation in Finite Element Analysis, Journal of the Engineering Mechanics Division, ASCE, Vol. 105, 1979, pp. 297-315

291.0
Benouniche, S., A Model for the Compressive Microcracking Damage of Concrete, These 3eme Cycle, University Paris VI, December, 1979. In French.

292.0
Bowling, J. and G.W. Groves, The Propagation of Cracks in Composites Consisting of Ductile Wires in a Brittle Matrix, Journal of Materials Science, Vol. 14, 1979, pp. 443-449

293.0
Bradt, R.C., Fracture of Refractory Concretes, In Proceedings of the 4th Annual Conference on Materials for Coal Conversion and Utilization, 1979, pp. 4/39-4/41

294.0
Brandt, A.M. and J. Kasperkiewicz, Crack Propagation Energy in SFRC (Steel Fibre Reinforced Concrete), In Seminar on Fracture Mechanics of Fibre Reinforced Cement-Based Composites, Delft, 1979, pp. D1-31

295.0
Brown, C.B., Micromechanics of Achieving High Strength and Other Superior Properties, in S.P., Shah (ed.), High Strength Concrete, Proceedings of a Workshop Held at the University of Illinois at Chicago Circle, Dec. 2-4, 1979, pp. 31-35

296.0
Bubsey, Raymond T. and Melvin H. Jones, Deflectometer for Precracked Charpy and Jic Bend Tests, NASA Technical Briefs, Fall 1979, pp. 404-405

297.0
Coutts, R.S.P., Wood Fibre Reinforced Cement Composites, In Institute of Industrial Technology Research Review, C.S.I.R.O., Division of Chemical Technology, Australia, 1979, pp. 1-16

298.0
Coutts, R.S.P. and M.D. Campbell, Coupling Agents in Wood Fibre-Reinforced Cement Composites, Composites, Vol. 10, 1979, pp. 228-232

299.0
de Haan, Y.M., Basic Elements of Fracture Mechanics, in Seminar on Fracture Mechanics of Fibre Reinforced Cement-Based Composites, Delft, 1979, pp. A1-12

300.0
Djabarov, N., A. Wehrstedt, H.-J. Weiss and K. Yamboliev, Investigations on the Fracture Behavior of Steel Fibre Reinforced Concrete, in Proceedings of the Second National Conference on Mechanics and Technology of Composites Materials, Varna 1979, Sofia, Bulgaria, 1979, pp. 593-596

300.1
Fuller, E.R., An Evaluation of Double Torsion Testing - Analysis, in Proceedings of the Eleventh National Symposium on Fracture Mechanics, Part II, S.W. Frieman, Ed., ASTM-STP 678, 1979

301.0
Garrett, G.G., H.M. Jennings and R.B. Tait, The Fatigue Hardening Behavior of Cement-Based Materials, Journal of Materials Science, Vol. 14, 1979, pp. 296-306

302.0
George, K.P., Application of Fracture Mechanics to Crack Growth Damage in Pavements, In G.C. Sih and S.R. Valluri (eds.), International Conference on Fracture Mechanics in Engineering Applications, Bangalore, 1979, Sitjthoff, Aalphen aan den Rijn, 1979, pp. 849-860

303.0
Grudemo, A., Microcracks, Fracture Mechanism and Strength of the Cement Paste Matrix, Cement and Concrete Research, Vol. 9, 1979, pp. 19-34

304.0
Halvorsen, G.T., Toughness of Portland Cement Concrete, Ph.D. Thesis, University of Illinois, Urbana, 1979

305.0
Hillerborg, A., The Fictitious Crack Model and its Use in Numerical Analyses, Presented at the International Conference on Fracture Mechanics in Engineering Applications, Bangalore, India, 1979

306.0
Javan, L. and B.L. Dury, Fracture Toughness of Fibre Reinforced Concrete, Concrete, Vol. 13, 1979, pp. 31-33

307.0
Jayatilaka, A. de S., Concrete, in Fracture of Engineering Brittle Materials, Applied Science Publishers Ltd., London, 1979, pp. 281-328

308.0
Jujii, K., K. Haga and S. Fujii, A Study on Progressive Failure of Brittle Materials by Fracture Mechanics, Memoirs of the Faculty of Engineering, Tokushima University, Vol. 24, 1979, pp. 1-11

309.0
Kayyali, O.A., C.L. Page and A.G.B. Ritchie, Frost Action on Immature Cement Paste - Effects on Mechanical Behavior, Journal of the American Concrete Institute, Vol. 76, 1979, pp. 1217-1225

310.0
Lenain, J.C. and A.R. Bunsell, The Resistance to Crack Growth of Asbestos Cement, Journal of Materials Science, Vol. 14, 1979, pp. 321-322

311.0
Mai, Y.W., Discussion of the Paper The Estimation of Fracture Surface Energy as a Measure of the Toughness of Hardened Cement Paste, by K.L. Watson (Cement and Concrete Research, Vol. 8, 1978, pp. 651), Cement and Concrete Research, Vol. 9, 1979, pp. 537-539

312.0
Mai, Y.W., Strength and Fracture Properties of Asbestos-Cement Mortar Composites, Journal of Materials Science, Vol. 14, 1979, pp. 2091-2102

313.0
Mihashi, H., T. Sasaki and M. Izumi, Failure Process of Concrete: Crack Initiation and Propagation, in Proceedings of the Third International Conference on Mechanical Behavior of Materials, Cambridge, Pergamon Press, London, Vol. 3, 1979, pp. 97-107

314.0
Mindess, S., Application of Fracture Mechanics to Cement and Concrete, in Mechanics of Concrete-Like Composites, Proceedings of a Study Session at Jablonna, Poland, 1979

315.0
Mindess, S., The Fracture of Cement and Concrete, in Proceedings of the Engineering Foundation Conference on Cement Production and Use, Rindge, N.H., 1979, pp. 175-185

316.0
Modeer, M., A Fracture Mechanics Approach to Failure Analysis of Concrete Materials, Report TVBM-1001, Division of Building Materials, University of Lund, Sweden, 1979

317.0
Morita, K. and K. Kato, Fundamental Study on Evaluation of Fracture Toughness of Artificial Lightweight Aggregate Concrete, In Review of the Thirty-Third General Meeting, The Cement Association of Japan, Tokyo, 1979, pp. 175-177

318.0
Morton, J., The Work of Fracture of Random Fibre Reinforced Cement, Materiaux et Constructions, Vol. 12, 1979, pp. 393-396

319.0
Naaman, A.E. and S.P. Shah, Fracture and Multiple Cracking of Cementitious Composites, in S.W. Frieman, (ed.), Fracture Mechanics Applied to Brittle Materials, ASTM STP 768, A.S.T.M., Philadelphia, PA, 1979, pp. 183-201

320.0
Nagamatsu, S. and Y. Sato, Study on Creep Fracture Strength. Probability Distribution of Creep Fracture Strength and the Effects of Water Content, in Review of the Thirty-Third General Meeting, The Cement Association of Japan, Tokyo, 1979, pp. 230-232

321.0
Rokugo, K., Experimental Evaluation of Fracture Toughness Parameters of Concrete, M.S. Thesis, Dept. of Civil Engineering, University of Illinois at Urbana - Champaign, 1979

322.0
Saeki, N., N. Takada and S. Hataya, On Studies for Cracking and Failure of Concrete by Acoustic Emission Techniques, in Review of the Thirty-Third General Meeting, The Cement Association of Japan, Tokyo, 1979, pp. 234-235

323.0
Shah, S.P., Whither Fracture Mechanics in Concrete Design?, in Proceedings of a Seminar on Fracture Mechanics of Fibre-Reinforced Cement-based Composites, Delft, 1979; also, in Proceedings of the Engineering Foundation Conference on Cement Production and Use,

324.0
Simonds, Robert A., Crack Opening Displacement Transducer, NASA Technical Briefs, Fall 1979, pp. 400

325.0
Sok, C., J. Baron and D. Francois, Mecanique de la Rupture Appliquee au Beton Hydraulique. (Fracture Mechanics Applied to Hydraulic Concrete), Cement and Concrete Research, Vol. 9, 1979, pp. 641-648. In French.

326.0
Somayaji, Shantharama, Composite Response, Bond Stress-Slip Relationships and Cracking in Ferrocement and Reinforced Concrete, Ph.D. Dissertation, University of Illinois at Chicago Circle, 1979, 422 pp.

327.0
Strange, P.C. and A.H. Bryant, Experimental Tests on Concrete Fracture, Journal of the Engineering Mechanics Division, ASCE, Vol. 105, 1979, pp. 337-343

328.0
Strange, P.C. and A.H. Bryant, The Role of Aggregate in the Fracture of Concrete, Journal of Materials Science, Vol. 14, 1979, pp. 1863-1868

329.0
Stroeven, P., Geometric Probability Approach to the Examination of Microcracking in Plain Concrete, Journal of Materials Science, Vol. 14, 1979, pp. 1141-1151

330.0
Stroeven, P., Mechanics of Microcracking in Concrete Subjected to Fatigue Loading, in Proceedings of the Third International Conference on Mechanical Behavior of Materials, Cambridge, Pergamon Press, Vol. 3, 1979, pp. 141-150

331.0
Swamy, R. N., Fracture Mechanics Applied to Concrete, in F.D. Lydon (ed.), Developments in Concrete Technology-1, Applied Science Publishers Ltd., London, 1979, pp. 221-281

332.0
Takeda, J. and H. Hinayama, Crack Propagation in Concrete Subjected to High Rate of Loading, in Review of the Thirty-Third General Meeting, The Cement Association of Japan, Tokyo, 1979, pp. 232-233

333.0
Trapesnikov, L.P., Two-Parameter Model of Fracture of Concrete Under Tension, Taking into Account the Structure and the Creep. Description of the Model, Izvestyia VNIIG im B.E. Vedeeva, Vol. 128, 1979, pp. 93-103. In Russian.

334.0
Trapesnikov, L.P., Two-Parameters Model of Fracture of Concrete. Application to the Long Term Strength Under Axial Tension, Izvestyia VNIIG im B.E. Vedeeva, Vol. 129, 1979, pp. 101-108. In Russian.

335.0
Velazco, G., K. Visalvanich, S.P. Shah and A.E. Naaman, Fracture Behavior and Analysis of Fiber Reinforced Concrete Beams, University of Illinois at Chicago Circle for National Science Foundation Grant No. ENG 77-23534, March 1979

336.0
Watson, K.L., Reply to a Discussion of The Estimation of Fracture Surface Energy as a Measure of 'Toughness' of Hardened Paste, by Y.W. Mai (Cement and Concrete Research, Vol. 9, 1979, pp. 537), Cement and Concrete Reaserch, Vol. 9, 1979, pp. 541-544

337.0
Weisinger, R., L.S. Costin and T.J. Lutz, Kic and J-resistance-curve Measurements on Nevada Tuff, paper presented at 1979 Society for Experimental Stress Analysis Spring Meeting, San Fransisco, CA, May 20-25, 1979

338.0
Wittmann, F.H., Micromechanics of Achieving High Strength and Other Superior Porperties, in S.P. Shah (ed.), High Strength Concrete, Proceedings of a Workshop Held at the University of Illinois at Chicago Circle, December 2-4, 1979, published 1980, pp. 8-30

339.0
ACI Committee 224, Control of Cracking in Concrete Structures, Concrete International, Vol. 2, 1980, pp. 35-76

340.0
Barr. B., W.T. Evans, R.C. Dowers and B.B. Sabir, Fracture Toughness of Concrete, in Numerical Methods in Fracture Mechanics, Proceedings of the 2nd International Conference, Swansea, Wales, 1980, Pineridge Press, Swansea, 1980, pp. 737-749

341.0
Bazant, Z.P. and A.B. Wahab, Stability of Parallel Cracks in Solids Reinforced by Bars, International Journal of Solids and Structures, Vol. 16, 1980, pp. 97-105

342.0
Bazant, Z.P. and L. Cedolin, Fracture Mechanics of Reinforced Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 106, 1980, pp. 1287-1306

343.0
Bazant, Z.P. and L. Cedolin, Fracture Mechanics of Reinforced Concrete, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of an ASCE Session, Florida, 1980, pp. 28-35

343.1
Bazant, Z.P. and Pietro Gambarova, Rough Cracks in Reinforced Concrete, Journal of Structural Division, Proceedings of ASCE, Vol. 106, No. ST4, 1980, pp. 819-841

344.0
Brandt, A.M., Crack Propagation Energy in Steel Fibre Reinforced Concrete, International Journal of Cement Composites, Vol. 2, 1980, pp. 35-42

345.0
Carpinteri, A., Notch Sensitivity in Fracture Testing of Aggregate Materials, Nota Tecnica n.45, I.S.C.B.-Gennaio 1980, Universita Di Bologna, Facolta Di Ingegneria. Engineering Fracture Mechanics, 1980

346.0
Carrasquillo, Ramon Luis, Microcracking and Engineering Properties of High-Strength Concrete, Ph.D. Dissertation, Cornell University, 1980, 270 pp.

347.0
Carrato, J.L., Experimental Evaluation of the J-Integral, M.S. Thesis, Dept. of Civil Engineering, University of Illinois at Urbana-Champaign, 1980

348.0
Cedolin, L. and Z.P. Bazant, Effect of Finite Element Choice in Blunt Crack Band Anlysis, in Computer Methods in Applied Mechanics and Engineering 24, North-Holland Publishing Company, 1980, pp. 305-316

349.0
Cedolin, L. and Z.P. Bazant, Fracture Mechanics of Crack Band in Concrete, in ASTM STP 745, American Society for Testing and Materials, Philadelphia, 1980

350.0
Chtchourov, A.F., Microtexture et Resistance Mecanique du Ciment Durci. (Microtexture and Mechanical Resistance of Hardened Cement Paste), in Proceedings of the Seventh International Congress on the Chemistry of Cement, Paris, Vol. IV, 1980, Editions Septima, 1981, pp. 404-410

351.0
Dalgleish, P.L. Pratt and R.I. Mass, Preparation Techniques and the Microscopical Examination of Portland Cement Paste and Tricalcium Silicate, Cement and Concrete Research, Vol. 10, 1980, pp. 665-676

352.0
Dey, Thomas Nathaniel, Brittle Failure of Crystalline Rock: Experiment and Analysis, Ph.D. Dissertation, University of California, Berkeley, 1980, 179 pp.

353.0
Diamond, S. and S. Mindess, Scanning Electron Microscopics Observatios of Cracking in Portland Cement Paste, in Proceedings of the Seventh International Congress on the Chemistry of Cement, Paris, Vol. III, 1980, Editions Septima, 1980, pp. 114-119

354.0
Foote, R.M.L., B. Cotterell and Y.W. Mai, Crack Growth Resistance Curve for a Cement Composite, in Advances in Cement-Matrix Composites, Proceedings, Materials Research Society, Symposium L,

Boston, Nov. 1980, 1980, pp. 135-144

355.0
Guofan, Z., G. Junsheng, L. Wanqing and W. Qingxiang, Experiments and Calculating Method for the Cracking Strength and Maximum Crack Width in Reinforced Concrete Members, Journal of Building Structures, Beijing, China, Vol. 1, 1980, pp. 1-17

356.0
Gylltoft, K., Bond Failure in Reinforced Concrete Under Cyclic Loading. A Fracture Mechanics Approach, Research Report Tulea 1980:29, Division of Structural Engineering, University of Tulea, Sweden, 1980

357.0
Halvorsen, G.T., J-Integral Study of Steel Fibre Reinforced Concrete, International Journal of Cement Composites, Vol. 2, 1980, pp. 13-22

358.0
Halvorsen, G.T., Jm Toughness Comparison for Some Plain Concretes, International Journal of Cement Composites, Vol. 2, 1980, pp. 143-148

359.0
Hillerborg, A., Analysis of Fracture by Means of the Fictitious Crack Model, Particularly for Fibre Reinforced Concrete, International Journal of Cement Composites, Vol. 2, 1980, pp. 177-184

360.0
Hsieh, S.S., E.C. Ting and W.F. Chen, A Plastic Fracture Model for Concrete, in Proceedings, Engineering Mechanics Division, ASCE, Hollywood, Florida, 1980, pp. 50-64

361.0
Huang, C.M., S.E. Swartz and K.K. Hu, On the Experimental and Numerical Analysis of Plain Concrete Beams, presented at the ASTM Symposium on Fracture Mechanics Methods for Ceramics, Rocks and

Concrete, Chicago, IL, 1980

362.0
Kayyali, O.A., C.L. Page and A.G.B. Ritchie, Frost Action on Immature Cement Paste - Microstructure Features, Journal of the American Concrete Institute, Vol. 77, 1980, pp. 264-268

363.0
Kim, M.M., H.-Y. Ko and K.H. Gerstle, Determination of Fracture Toughness of Concrete, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of an ASCE Session, Florida, 1980, American Society of Civil Engineers, New York, 1980, pp. 1-14

364.0
Lemaitre, J. and J. Mazars, A Model for the Behavior and Fracture of Concrete, in 4eme Symposium Franco-Polonais de Mecanique, Marseille, 1980. In French.

365.0
Loland, K.E., Continuous Damage Model for Load-Response Estimation of Concrete, Cement and Concrete Research, Vol. 10, 1980, pp. 395-402

366.0
Loland, K.E. and O.E. Gjorv, Ductility of Concrete and Tensile Behavior, Research Report BML 80.613, University of Trondheim, NTH, Division of Building Materials, Trondheim, Norway, 1980

367.0
Loland, K.E. and T. Hustad, Load Response of C-25 Concrete With and Without Addition of Silica Fume, Research Report STF65 A80048, Cement and Concrete Research Institute, University of Trondheim, NTH, Norway, 1980. In Norwegian.

368.0
Maher, A. and D. Darwin, Mortar Constituent of Concrete Under Cyclic Compression, Structural Engineering and Engineering Materials SM Report No.5, The University of Kansas Center for

Research, Inc., Lawrence, Kansas, 1980

369.0
Mai, Y.W., R.M.L. Foote and B. Cotterell, Size Effects and Scaling Laws of Fracture in Asbestos Cement, International Journal of Cement Composites, Vol. 2, 1980, pp. 23-34

370.0
McGowan, J.J. (Ed.), A Critical Evaluation of Numerical Solutions to the Benchmark Surface Flaw Problem, Fracture Committee, Society for Experimental Stress Analysis, 1980

371.0
Mihashi, H. and F.H. Wittmann, Stochastic Approach to Study the Influence of Rate of Loading on Strength of Concrete, Heron, Vol. 25, 1980

372.0
Minch, Maciej, Metoda Teoretycznego Wyznaczania Naprezen w Zelbetowych Tarczach Zarysowanych. (Method of Theoretical Determination of Stresses in Cracked Reinforced Concrete Plates), Rozprawy Inzynierski, Vol. 28, No. 3, 1980, pp. 445-468. In Polish.

373.0
Mindess, S., The Fracture of Fibre-Reinforced and Polymer Impregnated Concretes, International Journal of Cement Composites, Vol. 2, 1980, pp. 3-11

374.0
Mindess, S. and S. Diamond, A Preliminary SEM Study of Crack Propagation in Mortar, Cement and Concrete Research, Vol. 10, 1980, pp. 509-519

375.0
Mindess, S. and S. Diamond, Observed Energy-Dissipative Features of Crack Propagation in Mortar, in P.C. Dreijger (ed.), Proceedings of the NATO Advanced Research Institute, Adhesion Problems in the Recycling of Concrete, Saint-Remy-Les-Chevreuse,

1980, Plenum Publishing Corp., New York, 1981, pp

376.0
Mindess, S. and S. Diamond, The Cracking and Fracture of Mortar, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of an ASCE Session, Florida, 1980, pp. 15-27

377.0
Morita, K., Evaluation of Fracture Toughness by Means of the Work of Fracture, The 35th Annual Meeting of the Civil Engineering Institute of Japan, Vol. 5, 1980, pp. 269-270

378.0
Morita, K., Influence of Concrete Parameters on Fracture Toughness, Proceedings of the 34th General Meeting, The Cement Association of Japan, Tokyo, 1980, pp. 246-249

379.0
Okada, K., W. Koyanagi and K. Rokugo, Energy Approach to Flexural Fracture Process of Concrete, Transactions of the Japan Society of Civil Engineers, Vol. 11, 1980, pp. 301-304

380.0
Ouchterlony, Finn, A New Core Specimen for the Fracture Toughness Testing of Rock, Report DS1980:17, Swedish Detonic Research Foundation, Stockholm, Sweden, 1980

381.0
Ouchterlony, Finn, Review of Fracture Toughness Testing of Rock, Report DS1980:15, Swedish Detonic Research Foundation, Stockholm, Sweden, 1980

382.0
Petersson, P.-E., A Reply to S. Somayaji's Discussion of Fracture Energy of Concrete: Practical Performance and Experimental Results and Method of Determination, Cement and Concrete Research, Vol. 10, 1980, pp. 475-476

383.0
Petersson, P.E., Fracture Energy of Concrete: Practical Performance and Experimental Results, Cement and Concrete Research, Vol. 10, 1980, pp. 91-101

384.0
Petersson, P.E., Fracture Energy of Concrete: Method of Determination, Cement and Concrete Research, Vol. 10, 1980, pp. 79-89

385.0
Petersson, P.E., Fracture Mechanical Calculations and Tests for Fibre-Reinforced Cementitious Materials, in Advances in Cement-Matrix Composites, Proceedings, Materials Research Society, Sympossium L, Boston, Nov. 1980, 1980, pp. 95-106

386.0
Petersson, P.E. and P.J. Gustavsson, Model for Calculation of Crack Growth in Concrete-Like Materials, in Numerical Methods in Fracture Mechanics, Proceedings of the 2nd International Conference, Swansea, Wales, 1980, Pineridge Press, Swansea, 1980, pp. 707-719

387.0
Piva, A. and E. Viola, Stress-Strain Response of a Concrete Mathematical Model, in Proceedings, 5th Congresso Nazionale Di Meccanica Teorica ed Applicata, Palermo, Italy, 1980, pp. 237-248

388.0
Piva. A. and E. Viola, Two Arc Cracks Around a Circular Rigid Inclusion, Meccanica, 1980, pp. 166-176

389.0
Radu, C., I. Rugina, G. Winter and V. Winter, Brittle Rock Behaviour Under Compressive Load, in Proceedings of the 17th Assembly of the European Seismological Commission, Budapest, Hungary, 1980, Developments in Solid Earth Geophysics 15. Published by Elsevier Scientific Publ. Co., Amsterdam

390.0
Reinhardt, H. W., Schaalwetten bij Proeven met Betonconstructies (Scaling Laws in Testing Reinforced Concrete), Technische Hogeschool, Delft, The Netherlands, Stevin Laboratory, Report No. 5-80-9, 1980, 43 pp. In Dutch.

391.0
Rokugo, K., C.E. Kesler and F.V. Lawrence, Evaluation of Fracture Toughness of Concrete by J-Integral Method, in Proceedings, JCI (Japanese Concrete Institute) Second Conference, 1980, pp. 125-128

392.0
Saeki, C. and N. Takada, Crack Propagation and COD of Concrete, The 35th Annual Meeting of the Civil Engineering Institute of Japan, Vol. 5, 1980, pp. 267-268

393.0
Saouma, V.E., A.R. Ingraffea and D.M. Catalano, Fracture Toughness of Concrete - Kic Revisited, Report 80-9, Department of Structural Engineering, Cornell University, Ithaca, New York, 1980

394.0
Shah, S.P., Fracture in Fibre Reinforced Concrete, in Advances in Cement-Matrix Composites, Proceedings, Materials Research Society, Symposium L, Boston, 1980, pp. 83-89

395.0
Somayaji, S., A Discussion of the Papers: Fracture Energy of Concrete: Practical Performance and Experimental Results; Methods of Determination, by P.E. Petersson, (Cement and Concrete Research, Vol. 10. 1980, pp, Cement and Concrete Research, Vol. 10, 1980, pp. 471-474

396.0
Somayaji, S., Influence of Notch Dimensions on the Effective Surface Energy and Notch-Sensitivity of Cement Compounds, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of

an ASCE Session, Florida, 1980, pp. 36-49

397.0
Stroeven, P., Crack Development in Concrete as Influenced by the Addition of Short Steel Fibres, Technische Hogeschool, Delft The Netherlands, Stevin Laboratory, Report No. 1-80-6, 1980, 50 pp.

398.0
Sugama, T., L.E. Kukacka and, W. Horn, The Effects of Beta-Dicalcium Silicate/Class H Cement Mixed Fillers on the Kinetics and Mechanical Properties of Polymer Concrete, Cement and Concrete Research, Vol. 10, 1980, pp. 413-424

399.0
Swamy, R.N., Influence of Slow Crack Growth on the Fracture Resistance of Fibre Cement Composites, International Journal of Cement Composites, Vol. 2, 1980, pp. 43-53

400.0
Swartz, Stuart E., James Huang and K.K. Hu, Crack Growth and Fracture in Plain Concrete, Static Versus Fatigue Loading, presented at the ACI Committee 215 Symposium on Fatigue of Concrete, San Juan, Puerto Rico, 1980. Also, Fatigue of Concrete Structures, Paper SP753, ACI Special Publication SP75, American Concrete Ins

401.0
Swartz, Stuart E., James Huang and K.K. Hu, Fracture Toughness of Concrete Beams, presented at the ASCE Annual Convention, Hollywood, FL, 1980

402.0
Swartz, Stuart E., K.K. Hu and James Huang, Displacement Gage Mount for Concrete Beams, Experimental Techniques, Vol. 4, No. 2, 1980

403.0
Tait, R.B. and H. Bohm, In-Situ Scanning Electron Microscope Observations of Double Torsion Fracture of Concrete, Proceedings, Electron Microscopy Society of Southern Africa, Vol. 10, 1980, pp. 17-18

404.0
Togawa, K. and J. Nakamoto, Study on the Surface Fracture and the Impact Wear of Mortar and Concrete, Transactions of the Japan Society of Civil Engineers, Vol. 11, 1980, pp. 289-290

405.0
Velazco, F., K. Visalvanich and S.P. Shah, Fracture Behavior and Analysis of Fibre Reinforced Concrete Beams, Cement and Concrete Research, Vol. 10, 1980, pp. 41-51

406.0
Visalvanich, K. and A.E. Naaman, Evaluation of Fracture Techniques in Cementitious Composites, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of an ASCE Session, Florida, 1980, pp. 65-81

407.0
Wecharatana, M. and S.P. Shah, Double Torsion Tests for Studying Slow Crack Growth of Portland Cement Mortar, Cement and Concrete Research, Vol. 10, 1980, pp. 833-844

408.0
Wecharatana, M. and S.P. Shah, Resistance to Crack Growth in Portland Cement Composites, in W.F. Chen and E.C. Ting (eds.), Fracture in Concrete, Proceedings of an ASCE Session, Florida, 1980, pp. 82-105

409.0
Youdovitch, B., B.D. Klichanis, Ou. I. Papiachvili and V.G. Abramova, Portland Cement Strength Depending on Technological Factors. Micromechanism of Destruction, in Proceedings of the Seventh International Congress on the Chemistry of Cement, Vol. IV, Paris, 1980, Editions Septima, 1980, pp. 216-219

410.0
Zaitsev, Yu., Influence of Structure on Fracture Mechanism of Hardened Cement Paste, in Proceedings of the Seventh International Congress on the Chemistry of Cement, Vol. III, Paris, 1980, Editions Septima, 1980, pp. VI. 176-180

411.0
Zech, B. and F.H. Wittmann, Variability and Mean Value of Strength of Concrete as Function of Load, Journal of the American Concrete Institute, Vol. 77, 1980, pp. 358-362

412.0
Ziegeldorf, H.S., H.S. Muller and H.K. Hilsdorf, A Model Law for the Notch Sensitivity of Brittle Materials, Cement and Concrete Research, Vol. 10, 1980, pp. 589-599

413.0
Aitmatov, I. T. and S. K. Kanaun, Ellipsoidal Crack in Homogeneous Elastic Medium, Soviet Mining Science, Vol. 17, No. 2, 1981, pp. 87-97

414.0
Alvord, N. McN., A Theoretical Argument for the Existence of High Strength Cement Pastes, Cement and Concrete Research, Vol. 11, 1981, pp. 605-610

415.0
Andren, Robert C., Thomas J. Powell, Frederick V. Lawrence and Clyde E. Kesler, Evaluation of the Fracture Behavior of Concrete with the J-Integral, Illinois University at Urbana-Champaign, Dept. of Civil Engineering, Report No. NSF/ECS-81003, National Science Foundation, Washington, DC, Office of Planning and Resources Management, 1981, 150 pp.

416.0
Anon, IABSE Colloquium Delft: Advanced Mechanics of Reinforced Concrete (International Association for Bridge and Structural Engineering), 1981, Rep Work Comm Int Assoc for Bridge and Struct

Enq. Vol. 33 & 34, Introduction & Final Report, Delft, The Netherlands, June 2-4, 1981, Publ. by IABSE, Zurich, Switzerland, 1981, 2 Volumes, 905 pp.

417.0
Anon, Standard Practice for R-Curve Determination, Standard E561-81, Annual Book of ASTM Standards,

418.0
Anon, Standard Test Method for Jic, A Measure of Fracture Toughness, Standard E813-81, Annual Book of ASTM Standards,

418.1
Arrea, M. and A.R. Ingraffea, Mixed-Mode Crack Propagation in Mortar and Concrete, Dept. of Structural Engineering Report 81-13, School of Civil and Environmental Engineering, Cornell University, Ithaca, NY, 1981

419.0
Bailey, J.E. and D.D. Higgins, Discussion of Flexural Strength and Porosity of Cements by J.D. Birchall, A.J. Howard and K. Kendall, (Nature, Vol. 289, 1981, pp. 388-390), Nature, Vol. 292, 1981, pp. 89

420.0
Barr, B.I.G., W.T. Evans and R.C. Dowers, Fracture Toughness of Polypropylene Fibre Concrete, International Journal of Cement Composites and Lightweight Concrete, Vol. 3, 1981, pp. 115-122

421.0
Bazant, Z.P., Anelasticity and Fracture of Concrete, in A.P.S. Selvadurai (ed.), Mechanics of Structured Media, Part B, Proceedings of the International Symposium on the Mechanical Behaviour of Structured Media, Ottawa, 1981, Elsevier Scientific Publish

422.0
Bazant, Z.P. and B.H. Oh, Concrete Fracture Via Stress-Strain Relations, Centre for Concrete and Geomaterials, The Technological Institute, Northwestern University, Evanston, Illinois, Report No. 81-10/665C, 1981

423.0
Bazant, Z.P. and L. Cedolin, Propagation of Crack Bands in Heterogeneous Materials, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1523-1529

424.0
Bergues, J. and M. Terrien, Study of Concrete's Cracking Under Multiaxial Stress, in Advances in Fracture Research, Vol. 5, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2253-2260

425.0
Birchall, J.D., A.J. Howard and K. Kendall, Flexural Strength and Porosity of Cements, Nature, Vol. 289, 1981, pp. 388-390

426.0
Bressi, D.R. and G. Ferrara, Experimental and Numerical Determination of Kic and Gic for Microconcrete, in Proceedings of the 5th International Conference on Fracture, Cannes, April 1981

427.0
Bressi, Domenico Roberto and Gerardo Ferrara, I Parametri di Tenacita Alla Frattura per il Calcestruzzo. Indagini Teorico-Sperimentali. (Fracture Toughness Parameters for Concrete. Theoretical and Experimental Analysis), L'Energia Elettrica, Vol. 58, No. 11, 1981, pp. 478-484. In Italian.

428.0
Bundaev, V. V., Dependence of the Stress-strain State of an Elastic Half-plane With a Recess on the Bluntness of a Rigid Wedge, Soviet Mining Science, Vol. 17, No. 3, 1981, pp. 257-261

429.0
Carpinteri, A., A Fracture Mechanics Model for Reinforced Concrete Collapse, in Colloquium on Advanced Mechanics of Reinforced Concrete, Delft, June, 1981

430.0
Carpinteri, A., Experimental Determination of Fracture Toughness Parameters Kic and Jic for Aggregative Materials, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1491-1498

431.0
Carpinteri, A., Static and Energetic Fracture Parameters for Rocks and Concrete, Materiaux et Constructions, Vol. 14, 1981, pp. 151-162

432.0
Carrasquillo, R.L., F.O. Slate and A.H. Nilson, Micro-cracking and Behavior of High Strength Concrete Subject to Short-Term Loading, Journal of the American Concrete Institute, Vol. 78, 1981, pp. 174-186

433.0
Cedolin, L., S. Dei Poli and I. Iori, Analisi Sperimentale del Processo di Formazione Della Frattura nel Calcestruzzo. (Experimental Analysis of the Process of Fracture Formation in Concrete), Corso de Perfezionamento per le Costr in Cem Armato, Fratelli Pesenti, Publ. by Politecnico de Milano (Studi e Richerche n 3 1981), Milan, Italy, 1982, pp. 47-74. In Italian.

434.0
Chappell, J.F. and A.R. Ingraffea, A Fracture Mechanics Investigation of the Cracking of Fontana Dam, Department of Structural Engineering, Cornell University, Ithaca, New York, Report No. 81-7, 1981

435.0
Chatterji, S., Discussion of Flexural Strength and Porosity of Cements by J.D. Birchall, A.J. Howard and K. Kendall, (Nature, Vol. 289, 1981, pp. 388-390), Nature, Vol. 292, 1981, pp. 89

436.0
Chen, E.Y., Numerical Simulation of Reinforced Concrete Subjected to Multiaxial Stress Conditions, Ph. D. Dissertation, University of Illinois at Urbana-Champaign, 1981, 197 pp.

437.0
Cook, D.J. and G.D. Crookham, Evaluation of Polymer Concretes Using the Method of Energy Dissipated in Damage, The International Journal of Cement Composites and Lightweight Concrete, Vol. 3, 1981, pp. 247-254

438.0
Cook, D.J. and P. Chindaprasirt, A Mathematical Model for the Prediction of Damage in Concrete, Cement and Concrete Research, Vol. 11, 1981, pp. 581-590

439.0
Dei Poli, Sandro, Le Prove a Trazione su Calcestruzzi Ordinari, Alcune Risultanze Sperimentali di Interesse per la Meccanica Della Fratture. (Tensile Tests on Ordinary Concretes. Some Experimental Results of Interest, Corso de Perfezionamento per le Costr in Cem Armato, Fratelli Pesenti, Publ. by Politecnico de Milano (Studi e Richerche n 3 1981), Milan, Italy, 1982, pp. 5-46. In Italian.

440.0
Elkholy, I.A., Effect of Slip in Reinforced Concrete Beams, Ph. D. Dissertation, McMaster University, Canada, 1981

441.0
Fartash, Mojtaba, Stress Intensity Values for Prenotched and Precracked, Plain Concrete Beams, Master's Thesis, Kansas State University, 1981

442.0
Fujii, Fumio, On the Dome Action in Cracked Reinforced Concrete Slabs, Transactions of the Japan Society of Civil Engineering, Vol. 12, 1981, pp. 56-58

443.0
Gambarova, Pietro G., Gli Effetti Dell'Armatura Sul Comportamento Meccanico Delle Fessure in Elementi Piani Di C.A., In Presenza Di Taglio.(Effects of Reinforcement on Mechanical Behavior of Cracks in Plain Reinforced Conc, Corso De Perfezionamento per le Costr in Cem Armato, Fratelli Pesenti Publ. by Politecnico de Milano (Studi e Richerche No.3, 1981), Milan, Italy, 1982, p 107-141. In Italian.

444.0
Gambarova, Pietro G. and Cengiz Karakoc, In Tema Di Aderenza Fra Barre Nervate E Calcestruzzo, In Presenza Di Fessure Longitudinali Da Spacco. (Adhesion Between Stiffened Bars and Concrete in the Presence of Longitudinal Splitting Cracks), Corso de Perfezionamento per le Costr in Cem Armato, Fratelli Pesenti Publ. by Politecnico de Milano (Studi e Richere, No. 3, 1981), Milan, Italy, 1982, pp. 143-176. In Italian.

445.0
Giuriani, Ezio, On the Effective Axial Stiffness of a Bar in Cracked Concrete, Corso de Perfezionamento per le Costr in Cem Armato, Fratelli Pesenti, Publ. by Politecnico de Milano (Studi e Richerche, No. 3, 1981), Milan, Italy, 1982, pp. 205-226. In Italian.

446.0
Haque, M.N., Influences on Flexural Strengths, Concrete, Vol. 15, 1981, pp. 26

447.0
Harada, M., S. Niizeki and M. Satake, Analyses of Crack Propagation in Brittle Materials, The 36th Annual Meeting of the Civil Engineering Institute of Japan, Vol. III, 1981

448.0
Hartmann, H.R. and R.W. Churchill, Krak-gage, A New Transducer for Crack Growth Measurement, in Proceedings, 1981 Society for Experimental Stress Analysis Fall Meeting at Keystone, Colorado, 1981, pp. 14-21

449.0
Hillerborg, A. and P.E. Petersson, Fracture Mechanics Calculations, Test Methods and Results for Concrete and Similar Materials, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1515-1522

450.0
Hilsdorf, H.K. and S. Ziedgeldorf, Fracture Energy of Concrete, in P.C. Kreijger (ed.), Proceedings of the NATO Advanced Research Institute, Adhesion Problems in the Recycling of Concrete, Saint-Remy-Les-Chevreuse, 1980, Plenum Publishing Corp., New York, 1981, pp

451.0
Hsieh, Shyi-Shing, Elastic-Plastic-Fracture Analysis of Concrete Structures, Ph.D. Dissertation, Purdue University, 1981, 146 pp.

452.0
Huang, C.M.J., Finite Element and Experimental Studies of Stress-Intensity Factors for Concrete Beams, Ph. D. Dissertation, Kansas State University, 1981, 150 pp.

453.0
Hungspreug, S., Local Bond Between a Reinforcing Bar and Concrete Under High Intensity Cyclic Load, Ph. D. Dissertation, Department of Structural Engineering, Cornell Universty, Ithaca, New York, 1981

454.0
Kachanov, Mark Lazar, Microcrack Model for Rock Inelasticity. Ph.D. Dissertation, Brown University, 1981, 128 pp.

455.0
Kato, K., Deformation and Physical Properties of Plain Concrete. in Advances in Fracture Research, Vol. 5, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2275-2280

456.0
Khrapkov, A.A. and V.A. Seiliger, On Crack Propagation in Rock Foundations of Massive Concrete Dams, in Advances in Fracture Research, Vol. 2, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 661-666

457.0
Kmita, Jan and Jan Biliszczuk, Some Problems of the Construction of Theoretical Models of Reinforced Concrete, Studia Geotechnica et Mechanica , Vol. 3, No. 2-4, 1981, pp. 75-99

458.0
Kotsovos, M.D. and J.B. Newman, Fracture Mechanics and Concrete Behaviour, Magazine of Concrete Research, Vol. 33, 1981, pp. 103-112

459.0
Kowallis, Bart Joseph, Velocity Behavior of Rocks Related to Microcracks, Micropores, and Pore-Fillings, Ph.D. Dissertation, The University of Wisconsin-Madison, 1981, 160 pp.

460.0
Mazars, J., Mechanical Damage and Fracture of Concrete Structures, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1499-1506

461.0
Meiser, M.D. and R.E. Tressler, Mechanical Properties of a Low Density Aluminous Cement/Perlite Composite, American Ceramic Society Bulletin, Vol. 60, 1981, pp. 901-905

462.0
Mihashi, H. and F.H. Wittmann, Probabilistic Concept to Describe the Influence of Rate of Loading on Strength of Concrete, Transactions, 6th International Conference on Structural Mechanics in Reactor Technology (SMIRT), Paris, France, Vol. J(b), Paper J 6/4, 1981

463.0
Morris, A. D. and G. G. Garrett, Comparative Study of the Static and Fatigue Behaviour of Plain and Steel Fibre Reinforced Mortar in Compression and Direct Tension, International Journal of Cement Composites and Lightweight Concrete, Vol. 3, No. 2, 1981, pp. 73-91

464.0
Nadeau, J.S., R. Bennett and S. Mindess, Acoustic Emission in the Drying of Hardened Cement Paste and Mortar, Journal of the American Ceramic Society, Vol. 64, 1981, pp. 410-415

465.0
Neerhoff, A., Correlation Between Fracture Toughness and Zeta Potential of Cement Stone, in P.C. Kreijger (ed.), Proceedings of the NATO Advanced Research Institute, Adhesion Problems in the Recycling of Concrete, Saint-Remy-Les-Chevreuse, 1980, Plenum Publishing Corp., 1981, pp. 267-284

466.0
Newman, J.C. Jr., Stress Intensity Factors and Crack-Opening-Displacements for Round Compact Specimens, International Journal of Fracture, Vol. 17, No. 6, 1981

467.0
Ngab, A.S., F.O. Slate and A.H. Nilson, Microcracking and Time-Dependent Strains in High Strength Concrete, Journal of the American Concrete Institute, Vol. 78, 1981, pp. 262-268

468.0
Pak, A.P. and L.P. Trapeznikov, Experimental Investigations Based on the Griffith-Irwin Theory Processes of the Crack Development in Concrete, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1531-1539

469.0
Panasyuk, V.V., L.T. Berezhnitsky and V.M. Chubrikov, Estimation of Cement Concrete Crack Resistance According to the Failure Viscosity, Beton i Zhelezobeton, Moscow, 1981, pp. 19-20. In Russian.

470.0
Petersson, P.E., Crack Growth and Development of Fracture Zones in Plain Concrete and Similar Materials, Ph. D. Dissertation, Lund Institute of Technology, Sweden, 1981, Division of Building Materials, Report TVBM-1006, Lund, Sweden, 1981

471.0
Popov, L.N. and E.N. Ippolitov, Fracture of Fine-Corned Concrete Under Short-Time Compressive Load, in Advances in Fracture Research, Vol. 5, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2287-2291

472.0
Ratigan, Joe Lawrence, A Statistical Fracture Mechanics Approach to the Strength of Brittle Rock, Ph.D. Dissertation, University of California, Berkeley, 1981, 97 pp.

473.0
Riggs, Harry Ronald, A Crack Model for Finite Element Analysis of Concrete, Ph.D. Dissertation, University of California, Berkeley, 1981, 166 pp.

474.0
Sangha, C.M., M.K. Isles, F.H. Hubbard and R.K. Dhir, Fracture Micromechanics of Plain Concrete, in Second Austrailian Conference on Engineering Materials, Sydney, 1981, pp. 73-83

475.0
Saouma, V., Interactive Finite Element Analysis of Reinforced Concrete: A Fracture Mechanics Approach, Ph. D. Dissertation, Department of Structural Engineering, Cornell University, Ithaca, New York, 1981. (Department of Structural Engineering Report 81-5)

476.0
Saouma, V.E., FEFAP. Finite Element Fracture Analysis Program Version 2-0, SETEC-CE-81-055, Department of Civil Engineering, University of Pittsburgh, Pittsburgh, PA, 1981

477.0
Saouma, V.E. and A.R. Ingraffea, Fracture Mechanics Analysis of Discrete Cracking, in Advanced Mechanics of Reinforced Concrete, Proceedings of the IABSE Colloquium, Delft, 1981

478.0
Sia, T.K., Y.W. Mai and B. Cotterell, Strength and Fracture Properties of Epoxy-Cement Composites, in Second Austrailian Conference on Engineering Materials, Sydney, 1981, pp. 515-529

479.0
Sok, C., M.E. Benkirane, J. Baron and D. Francois, Crack Propagation in Prestressed Concrete. Interaction with Reinforcement, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981pp. 1507-1514

480.0
Somayaji, S., A Discussion of the Paper, A Model Law for the Notch Sensitivity of Brittle Materials by S. Ziegeldorf, H.S. Muller and H.K. Hilsdorf, (Cement and Concrete Research, Vol. 10, 1980, pp. 589-599), Cement and Concrete Research, Vol. 11, 1981, pp. 479-482

481.0
Swartz, S.E. and A.K. Noory, Photoelastic Coatings to Monitor Crack Growth in Concrete, Experimental Techniques, Vol. 5, No. 3, 1981

482.0
Tait, R.A. and W. Keenliside, Toughness of Cellulose Cement Composites, in Advances in Fracture Research, Vol. 2, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1099-1108

483.0
Tanigawa, Y., K. Yamada and S.-I Kiriyama, Power Spectra Analysis of Acoustic Emission Wave of Concrete, Proceedings of the Second Austrailian Conference on Engineering Materials, Sydney, 1981, pp. 97-108

484.0
Trapeznikov, L. P., At Construction Projects of the Five-year Plan, Hydrotechnical Construction, Vol. 15, No. 7, 1981, pp. 383-391

485.0
Viola, Erasmo, Modelli Matematici per lo Studio del Comportamento del Calcestruzzo. (Mathematical Models for the Study of the Behavior of Concrete), Tecnica Italiana, No. 6, November-December 1981, pp. 233-255. In Italian.

486.0
Visalvanich, K. and A.E. Naaman, Fracture Methods in Cement Composites, Journal of the Engineering Mechanics Division, ASCE, Vol. 107, 1981, pp. 1155-1171

487.0
Wittmann, F.H., Mechanisms and Mechanics of Fracture of Concrete, in Advances in Fracture Research, Vol. 4, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 1467-1487

488.0
Wittmann, F.H. and Yu. V. Zaitsev, Crack Propagation and Fracture of Composite Materials Such as Concrete, in Advances in Fracture Research, Vol. 5, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2261-2274

489.0
Yam, A., Effect of Fibre Reinforcement on the Crack Propagation in Concrete, M.A.Sc. Thesis, Department of Civil Engineering, University of British Columbia, Vancouver, British Columbia, 1981

490.0
Yam, Anthony Sze-Tong, Effect of Fibre Reinforcement on the Crack Propagation in Concrete, Department of Civil Engineering, University of British Columbia, Materials Research Series Report No. 3, July 1981

491.0
Zaitsev, J. and F.H. Wittmann, Simulation and Crack Propagation and Failure of Concrete, Materiaux et Constructions, Vol. 14, 1981, pp. 357-365

492.0
Zaitsev, Yu.V., Fracture Mechanism and Strength of Concrete Under Triaxial Compression, in Advances in Fracture Research, Vol. 5, Proceedings of the 5th International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2281-2286

493.0
Ziegeldorf, S., H.S. Muller and H.K. Hilsdorf, A Reply to S. Somayaji's Discussion of A Model Law for the Notch Sensitivity of Brittle Materials, (Cement and Concrete Research, Vol. 11, 1981, pp. 479-482), Cement and Concrete Research, Vol. 11, 1981, pp. 483-484

494.0
Ziegeldorf, S., H.S. Muller and H.K. Hilsdorf, Effect of Aggregate Particle Size on Mechanical Properties of Concrete, in Advances in Fracture Research, Vol. 5, Proceedings of the 5th

International Conference on Fracture, Cannes, 1981, Pergamon Press, 1981, pp. 2243-2251

495.0
Advani, S.H., J.K. Lee and H.F. Wang, Thermo-Elastic Responses Associated with Cavities and Cracks in Infinite Media, Journal of Energy Resource Technology Transactions, ASME, Vol. 104, No. 4, 1982, pp. 377-383

496.0
Anon, Standard Terminology Relating to Fracture Testing, Standard E616-82, Annual Book of ASTM Standards, Vol. 03.01, 1983, pp. 671-684

497.0
Arcan, M. and L. Banks-Sills, Mode II Fracture Specimen - Photoelastic Analysis and Results, Department of Solid Mechanics, Materials and Structures, School of Engineering, Tel-Aviv University, Israel, 1982

498.0
Banks-Sills, L., M. Arcan and H. Gabay, A Mode II Fracture Specimen - Finite Element Analysis, Department of Solid Mechanics, Materials and Structures, School of Engineering, Tel-Aviv University, Israel, 1982

499.0
Barr, B.I.G. and K. Liu, Fracture of GRC Materials, International Journal of Cement Composites and Lightweight Concrete, Vol. 4, No. 3, 1982, pp. 163-171

500.0
Bazant, Zdenek and Warren, J. Raftshol, Effect of Cracking in Drying and Shrinkage Specimens, Cement and Concrete Research, Vol. 12, No. 2, 1982, pp. 209-226

501.0
Bazant, Zdenek P., Crack Band Model for Fracture of Geomaterials, in Proceedings of the Fourth International Conference on Numerical Methods in Geomechanics, Alberta, Canada, 1982, pp. 1137-1152

502.0
Brandt, Andrzej M., O Skladowych Energii Zniszczenia w Zginanych Elementach Fibrobetonowych (SFRC). (Components of the Fracture Energy in Steel Fiber Reinforced Concrete (SFRC) Elements), Archiwum Inzynierii Ladowej , Vol. 28, No. 3-4, 1982, pp. 271-279. In Polish.

503.0
Carpinteri, Alberto, Application of Fracture Mechanics to Concrete Structures, Journal of the Structural Division, ASCE, Vol. 108, No. ST4, 1982, pp. 833-848

504.0
Carpinteri, Alberto, Sensitivity and Stability of Progressive Cracking in Plain and Reinforced Cement Composites, International Journal of Cement Composites and Lightweight Concrete, Vol. 4, No. 1, 1982, pp. 47-56

505.0
Darroudi, Taghi, Fracture of Refractory Concretes, Ph.D. Dissertation, The Pennsylvania State University, 1982, 380 pp.

506.0
Dhir, R.K., F.H. Hubbard, M.K. Isles and C.M. Sangha, Application of Fracture Mapping to the Study of Coarse Aggregate Influence on Microfracturing in Concrete, Research Mechanica: International Journal of Structural Mechanics and Materials Sciences, Vol. 5, No. 3, 1982, pp. 183-201

507.0
Freiman, S. W., Effects of Chemical Environments on Slow Crack Growth in Glasses and Ceramics, Chemical Effects of Water on the Deformation and Strengths of Rocks, Carmel, California, USA,

1982, Journal of Geophysical Research, Vol. 89, No. B6, 1984, pp. 4072-4076

508.0
Friede, Helmuth, Rechnerische Abschaetzung der Reissneigung von Jungem Beton. (Mathematical Evaluation of the Tendency of Fresh Concrete to Crack), Beton Herstellung Verwend, Vol. 32, No. 7, 1982, pp. 261-264. In German

509.0
Hashimoto, Toshihide, Evaluation of Fracture Toughness of Concrete, Chubu Kogyo Daigaku Kiyo Shirizu A, Vol. 18-A, October 1982, pp. 105-109. In Japanese.

510.0
Hillier, K., Application of Fracture Mechanics, Concrete, Vol. 16, No. 6, 1982, pp. 43-44

511.0
Ho, J. L. K. and R. T. Woodhams, Fracture Toughness of Fiber Reinforced Sulphur Concrete, Journal of the American Concrete Institute, Vol. 79, No. 4, 1982, pp. 288-295

512.0
Hoeptner, Markus and Rolf Adler, Zum Rissbreitennachweis im Spannbeton. (Fissure Width Proved in Prestressed Concrete), Bauplanung Bautech, Vol. 36, No. 11, 1982, pp. 501-505. In German.

513.0
Hsieh, S. S., E. C. Ting and W. F. Chen, Plastic-Fracture Model for Concrete, International Journal of Solids and Structures, Vol. 18, No. 3, 1982, pp. 181-197

514.0
Jiang, D. H., S. P. Shah and A. T. Andonian, Study of Flexural Bond in Reinforced Concrete, Northwestern University, Evanston, IL, Dept. of Civil Engineering, Report No. NSF/CEE-82100, National Science Foundation, Washington, DC, 1982, 81 pp.

515.0
Kalthoff, J.F., N. Bohme and S. Winkler, Analysis of Impact Fracture Phenomena by Means of the Shadow Optical Method of Caustics, Fraunhofer-Institut fur Werkstoffmechanik, Rosastrasse 9, 7800 Freiburg/Brsg., West Germany; sponsored by Deutsche Forschungsgemeinschaft and European Research Office of U.S. Army, Contract DAJA37-81-

516.0
Lemaitre, Jean and Jacky Mazars, Application de la Theorie de L'endommagement au Comportement Non Lineaire et a la Rupture du Beton de Structure. (Application of the Theory of Damage to the Non-linear and Failure Behavior of Structu, Ann Inst Tech Batim Trav Publics , No. 401, 1982, pp. 113-138. In French.

517.0
Lozinski, Wojciech and Bogdan Michalski, Zastosowanie Elastooptycznej Warstwy Powierzchniowej do Badania Zarysowania w Betonie. (Use of a Photoelastic Surface Layer for Studying Cracking in Concrete), Archiwum Inzynierii Ladowej, Vol. 28, No. 3-4, 1982, pp. 281-293. In Polish.

518.0
Mai, Y.W. and B. Cotterell, Slow Crack Growth and Fracture Instability of Cement Composites, International Journal of Cement Composites and Lightweight Concrete, Vol. 4, No. 1, 1982, pp. 33-37

519.0
Mehta, P. Kumar and Ben C. Gerwick, Jr., Cracking - Corrosion Interaction in Concrete Exposed to Marine Environment, Concrete International, American Concrete Institute, Vol. 4, No. 10, 1982, pp. 45-51

520.0
Mindess, S. and S. Diamond, Cracking and Fracture of Mortar, Materiaux et Constructions, Materials and Structures, Vol. 15, No. 86, 1982, pp. 107-113

521.0
Mindess, Sidney and Sidney Diamond, *Device for Direct Observation of Cracking of Cement Paste or Mortar Under Compressive Loading Within a Scanning Electron Microscope*, Cement and Concrete Research, Vol. 12, No. 5, 1982, pp. 569-576

522.0
Molina, J. P. and B. Wack, Crack Field Characterization by Ultrasonic Attenuation - Preliminary Study on Rocks, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 19, No. 6, 1982, pp. 267-278

523.0
Montague, P.and K. Kormi, Constitutive Relationships and a Failure Criterion for Concrete Based on Fundamental Material Properties, Magazine of Concrete Research, Vol. 34, No. 118, 1982, pp. 35-43

524.0
Nesvizhekii, E. G., Use of the Phase Method for Evaluating Defects in the Form of Developing Microcracks, Soviet Journal of Nondestructive Testing, Vol. 18, No. 6, 1982, pp. 453-454

525.0
Noorishad, J., M. S. Ayatollahi and P. A. Witherspoon, Finite-Element Method for Coupled Stress and Fluid Flow Analysis in Fractured Rock Masses, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 19, No. 4, 1982, pp. 185-195

526.0
Oh, B.H., Mathematical Models For Inelastic Behavior and Cracking of Concrete Structures, Ph. D. Dissertation, Northwestern University, 1982, 215 pp.

527.0
Ouchterlony, F., Review of Fracture Toughness Testing of Rock, Solid Mechanics Archives, Vol. 7, No. 2, 1982, pp. 131-211

528.0
Pathan, I. A., Fracture Toughness of Hardened Cement Paste and Concrete, Mehran University Research Journal of Engineering and Technology, Vol. 1, No. 4, 1982, pp. 7-13

529.0
Pathan, I. A., Prediction of the Cracking Strains and Stresses of Wire Reinforced Concrete by Multiple Fracture Theory and Comparison with Test Results, Mehran University Research Journal of Engineering and Technology, Vol. 1, No. 1, 1982, pp. 1-4

530.0
Pathan, I. A. and M. A. Qureshi, Theoretical Prediction of the Cracking Stress of Three Dimensional Randomly Distributed Steel Fibre Reinforced Concrete, Mehran University Research Journal of Engineering and Technology, Vol. 1, No. 3, 1982, pp. 17-27

531.0
Petersson, P.E., Determination of the Fracture Energy of Mortar and Concrete by Means of Three-point Bend Tests on Notched Beams, Proposed RILEM Recommendation, January 29, 1982, revised June 1982

532.0
Petersson, Per-Erik, Comments on the Method of Determining the Fracture Energy of Concrete by Means of Three-point Bend Tests on Notched Beams, Report TVBM-3011, Lund Institute of Technology, Lund, Sweden, 1982

533.0
Polishchuk, V. P., Raschet Sborno-monolitnykh Konstruktsii po Obrazovaniyu Normal'nykh Treshchin s Uchetom Neuprugikh Deformatsii. (Calculation of Precast and Cast-in-situ Structures for Regular Formation of Cracks Tak, Beton Zhelezobeton, Vol. 323, No. 3, 1982, pp. 40-41. In Russian.

534.0
Reinhardt, H. W., Length Influence on Bond Shear Strength of Joints in Composite Precast Concrete Slabs, International Journal of Cement Composites and Lightweight Concrete, Vol. 4, No. 3, 1982, pp. 139-143

535.0
Rossmanith, H. P. and W. L. Fourney, Fracture Initiation and Stress Wave Diffraction at Cracked Interfaces in Layered Media - 1. Brittle/Brittle Transition, Rock Mechanics, Vol. 14, No. 4, 1982, pp. 209-233

536.0
Saeki, Noboru, Nobuyuki Takada and Yoshio Fujita, Behaviour of Deformation and Failure of Plain Concrete Under Compression and Torsion, Transactions of the Japan Society of Civil Engineering, Vol. 13, 1982, pp. 327-329

537.0
Saouma, V. E., A. R. Ingraffea and D. M. Catalano, Fracture Toughness of Concrete: K_{Ic} Revisited, Journal of Engineering Mechanics Division, ASCE, Vol. 108, No. EM6, 1982, pp. 1152-1166

538.0
Sarja, Asko and Pekka Nykyri, Use of the Real Failure Mechanism and Rotational Equilibrium for Calculation Model of the Shear Capacity of Prestressed and Reinforced Concrete Structures, Nord. Concrete Res., No. 1, December 1982, 13 pp.

539.0
Schwer, Leonard E. (Ed.), Nonlinear Numerical Analysis of Reinforced Concrete, Presented at the Winter Annual Meeting of ASME, Phoenix, Arizona, USA, 1982, Publ. by ASME, New York, NY, USA, 1982, 123 pp.

540.0
Sharma, S., M. Reich, T.Y. Chang and S. Shteyngart, Failure Evaluation of a Reinforced Concrete Mark III Containment Structure under Uniform Pressure, Brookhaven National Laboratory,

Upton, NY, Report No. BNL-NUREG-51543, Nucleur Regulatory Commision, Washington, DC, Office of Nucleur Regulatory Research; Dept. of Energy, Washington, DC, 1982, 70 p

541.0
Steven, G.P., Finite Element Modelling of Fibre Pull-Out in Cracked Cement Composites, Proceedings of the Fourth International Conference in Australia on Finite Element Methods in Engineering, 1982, pp. 200-204

542.0
Stone, William C., Internal Strain, Deformation, and Failure of Large Scale Pullout Tests in Concrete, Report No. NBSIR-82-2484, National Bureau of Standards, Washington, DC, May 82, 177 p.

543.0
Swartz, S.E., K.K. Hu and G.L. Jones, Techniques to Monitor Crack Growth in Plain Concrete Beams, Experimental Techniques, Vol. 6, No. 6, 1982

544.0
Swartz, S.E., K.K. Hu, M. Fartash and C.M.J. Huang, Stress-Intensity Factor for Plain Concrete in Bending - Prenotched Versus Precracked Beams, Experimental Mechanics, Vol. 22, No. 11, 1982, pp. 412-417

545.0
Visalvanich, K., Fracture Behavior and Fracture Modeling of Fiber Reinforced Cementitious Composites, Ph. D. Dissertation, University of Illinois at Chicago Circle, 1982, 284 pp.

546.0
Visalvanich, Kitisak and Antoine E. Naaman, Fracture Modeling of Fiber Reinforced Cementitious Composites, Illinois University at Chicago Circle, Dept. of Materials Engineering, Progress Report No. NSF/CEE-82101, National Science Foundation, Washington, DC., 1982, 102 pp.

547.0
Wecharatana, M., Fracture Resistance in Cementitious Composites, Ph. D. Dissertation, University of Illinois at Chicago, 1982, 297 pp.

548.0
Wecharatana, M. and S.P. Shah, Experimental Methods to Determine Fracture Parameters for Concrete, Department of Civil Engineering, Northwestern University, Evanston, IL, 1982

549.0
Wecharatana, M. and S.P. Shah, Experimental Methods to Determine Fracture Parameters for Concrete, presented at the Suminar, Fracture Mechanics, College International des Sirences de la Construction, France, June 8-11, 1982

550.0
Wecharatana, Methi and Surendra P. Shah, Slow Crack Growth in Cement Composites, Journal of the Structural Division, ASCE, Vol. 108, No. ST6, 1982, pp. 1400-1413

551.0
Xiao, You-Gu and Guo-Hao Huang, On the Compatibility Between J-integral and Crack Opening Displacement, Engineering Fracture Mechanics, Vol. 16, No. 1, 1982, pp. 83-94

552.0
Yam, Anthony Sze Tong and Sidney Mindess, Effects of Fibre Reinforcement on Crack Propagation in Concrete, International Journal of Cement Composites and Lightweight Concrete, Vol. 4, No. 2, 1982, pp. 83-93

553.0
Zielinski, Z. A., M. S. Troitsky and H. Christodoulou, Full-Scale Bearing Strength Investigation of Thin Wall-Ribbed Reinforced Concrete Panels, Journal of the American Concrete Institute, Vol. 79, No. 4, 1982, pp. 313-321

554.0
Abdun-Nur, Edward A., Cracking of Concrete - Who Cares?, Concrete International, American Concrete Institute, Vol. 5, No. 7, 1983, pp. 27-30

555.0
Al-Balbissi, A.H., Comparative Analysis of the Fracture and Fatigue Properties of Asphalt Concrete and Sulphlex, Ph. D. Dissertation, Texas A and M, 1983, 226 pp.

556.0
Alam, J. and A. Mendelsen, Effect of Crack Curvature on Stress Intensity Factors for ASTM Standard Compact Tension Specimens, International Journal of Fracture, Vol. 23, 1983, pp. 317-324

557.0
Andonian, A.T. and F. Ansari, Prediction of Crack Propagation in Reinforced Concrete with a Simplified Model, in Proceedings of the Society for Experimental Stress Analysis Spring Conference, Cleveland, Ohio, 1983, pp. 137-144

558.0
Anon, Standard Test Method for Plane-strain Fracture Toughness of Metallic Materials, Standard E399-83, Annual Book of ASTM Standards, Vol. 03.01, 1983, pp. 519-554

559.0
Banks-Sills, Leslie and Mircea Arcan, An Edge-cracked Mode II Fracture Specimen, Submitted to Experimental Mechanics, 1983

560.0
Banks-Sills, Leslie, M. Arcan and H.I. Bui, Toward a Pure Shear Specimen for KIIc Determination, Submitted to International Journal of Fracture, 1983

561.0
Barr, B.I.G. and K.L.W. Liu, Compact Shear Test Specimen, Journal of Material Science Letters, Vol. 2, No. 11, 1983, pp. 663-666

562.0
Bazant. Z.P. and J.K. Kim, Application of Fracture Mechanics to Reinforced Concrete, in Proceedings, Fourth Engineering Mechanics Division Specialty Conference, ASCE, West Lafayette, Indiana, Vol. 2, 1983, pp. 798-800

563.0
Bazant. Zdenek P. (Ed.), Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concretes, Soils, 1983, Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concr, Soils, Evanston, Illinois, USA, Sept. 11-15 1983, Publ. by Northwestern Univ., Evanston, Ill. USA, 1983, 664 pp.

564.0
Bazant, Zdenek P. and B.H. Oh, Crack Band Theory for Fracture of Concrete, Materiaux et Constructions, Materials and Structures, Vol. 16, No. 93, 1983, pp. 155-177

565.0
Bazant, Zdenek P. and Byung H. Oh, Crack Spacing in Reinforced Concrete: Approximate Solution, Journal of Structural Engineering, ASCE, Vol. 109, No. 9, 1983, pp. 2207-2212

566.0
Bazant, Zdenek P. and Byung H. Oh, Deformation of Cracked Net-Reinforced Concrete Walls, Journal of Structural Engineering, ASCE, Vol. 109, No. 1, 1983, pp. 93-108

567.0
Bazant, Zdenek P. and Byung H. Oh, Microplane Model for Fracture Analysis of Concrete Structures, Northwestern University, Evanston, IL. Technological Inst., 1983, 7 pp. from 'The Interaction of Non-Nucleur Munitions with Structures: Symposium Proceedings Held at U.S. Air Force Academy, CO, May

568.0
Bazant, Zdenek P. and Byung H. Oh, Spacing of Cracks in Reinforced Concrete, Journal of Structural Engineering, ASCE, Vol. 109, No. 9, 1983, pp. 2066-2085

569.0
Bazant, Zdenek P. and Luigi Cedolin, Finite Element Modeling of Crack Band Propagation, Journal of Structural Engineering, ASCE, Vol. 109, No. 1, 1983, pp. 69-92

570.0
Beaudoin, J. J., Fracture Toughness of Autoclaved Portland Cement/Silica Mixtures, Cement and Concrete Research, Vol. 13, No. 1, 1983, pp. 81-88

571.0
Cedolin, Luigi, Sandro Dei Poli and Ivo Iori, Experimental Determination of the Fracture Process Zone in Concrete, Cement and Concrete Research, Vol. 13, No. 4, 1983, pp. 557-567

572.0
Chamberlain, D.A. and L.F. Boswell, Numerical Methods in Fracture Mechanics, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 503-538

573.0
Chudnovsky, Alexander and Philip C. Perdikaris, On the Scale Effect of Fracture in Concrete, in Proceedings, 4th International Conference - Applications of Statistics and Probability in Soil and Structural Engineering. Florence, Italy, 1983, Vol. 1, Publ. by Pitagora Editrice, Bologna, Ital

574.0
Daoud, Osama, E. K. and J. M. Lovegrove, Effect of Concrete Bond on the Stress Intensity Factors for an Edge Crack in a Reinforcing Bar, Fatigue of Engineering Materials and Structures, Vol. 6, No. 3, 1983, pp. 257-269

575.0
Diederichs, U., U. Schneider and M. Terrien, Formation and Propagation of Cracks and Acoustic Emission, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 157-206

576.0
Gambarova, Pietro G., Analytical Models for Cracking of Concrete Subject to Shear, Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concretes, Soils, Evanston, IL, USA, 1983, Publ. by Northwestern University, Evanston, IL, USA, 1983, pp. 601-604

577.0
Gergely, P., R.N. White, J.W. Frenay and H.W. Reinhardt, Cooperative Research Between Institutions in the Netherlands and the U.S.A.: Concrete Mechanics, 3. Technische Hogeschool, 22-24 June 1983, Delft, The Netherlands, Report No. NSF/CEE-84002 for the National Science Foundation, Washington D.C., 1984, 166 pp.

578.0
Go, C.G., Fracture Toughness Techniques to Predict Crack Growth and Tensile Failure in Concrete, Ph. D. Dissertation, Kansas State University, 1983, 109 pp.

579.0
Go, Cheer Germ and Stuart E. Swartz, Fracture Toughness Techniques to Predict Crack Growth and Tensile Failure in Concrete, Report No. 154, Engineering Experiment Station, Kansas State University, July 1983

580.0
Gross, K. P., Neues Verfahren zur Bestimmung der Verformungen und Rissbreiten von Stahlbetontragteilen. (New Method for Determining Deformations and Crack Widths, of Reinforced Concrete Load Structures), Materialpruefung, Vol. 25, No. 6, 1983, pp. 193-197. In German.

581.0
Hanna, Y.G., Finite Element Modeling of Reinforced Concrete Structures, Ph. D. Dissertation, McGill University, Montreal, 1983

582.0
Hillerborg, A., Analysis of One Single Crack, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 223-250

583.0
Hillerborg, A., Examples of Practical Results Achieved by Means of the Fictitious Crack Model, Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concretes, Soils, Evanston, Ill., USA, 1983, Publ. by Northwestern University, Evanston, Ill., USA, 1983, pp. 611-614

584.0
Hillerborg, Arne, Concrete Fracture Energy Tests Performed by 9 Laboratories According to a Draft RILEM Recommendation, Report TVBM-3015 to RILEM TC50-FMC, Lund Institute of Technology, Lund, Sweden, 1983

585.0
Hinrichsmeyer, Konrad, U. Diederichs and U. Schneider, Thermal Induced Cracks and Acoustic Emission in Cement Paste, Mortar and Concrete, Science of Ceramics, Proceedings of the 12th International Conference, St. Vincent, Italy, 1983, Science of Ceramics, Vol. 12, 1984, pp. 667-674

586.0
Houde, Jules and Serge Meilleur, Adaptation des Procedes Stereologiques a la Mesure des Bulles D'air et des Fissures Dans le Beton. (Adaptation of Stereological Methods to the Measurement of Air Bubbles and Cracks in Concrete), Canadian Journal of Civil Engineering, Vol. 10, No. 3, 1983, pp. 415-428. In French.

587.0
Hu, K.K., C.M.J. Huang and S.E. Swartz, A Finite Element Model to Determine Ki, Journal of the Engineering Mechanics Division, ASCE, Vol. 109, No. 4, 1983

588.0
Jacquot, P. and P.K. Rastogi, Speckle Metrology and Holographic Interferometry Applied to the Study of Cracks in Concrete, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 113-156

589.0
Kasperkiewicz, Janusz, Modelling of Inhomogeneity in Certain Cement Based Composites, International Journal of Cement Composites and Lightweight Concrete, Vol. 5, No. 1, 1983, pp. 41-48

590.0
Koenig, Gert and Manfred Jahn, Ueber die Verschiedenen Erscheinungsformen der Betonzugfestigkeit und Ihre Bedeutung Fuer das Tragverhalten von Massivbauten (Various Manifestations of Tensile Strength of Concrete and its Importance , Beton Stahlebetonbau , Vol. 78, No. 10, 1983, pp. 281-286. In German.

591.0
Labuz, J.F., S.P. Shah and C.H. Dowding, Post Peak Tensile Load-Displacement Response and the Fracture Process Zone in Rock, in Proceedings of the 24th U.S. Symposium on Rock Mechanics, June 1983

592.0
Lierse, J. and M. Ringkamp, Investigations Into Cracked Reinforced Concrete Structural Elements with the Aid of Photoelastic Methods, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 95-112

593.0
Lorrain, M. and K.E. Loland, Damage Theory Applied to Concrete, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 341-370

594.0
Maekawa, Kohichi and Hajime Okamura, Deformational Behavior and Constitutive Equation of Concrete Using the Elasto-Plastic and Fracture Model, Journal of the Faculty of Engineering, the University of Tokyo, Series B, Vol. 37, No. 2, 1983, pp. 253-328

595.0
Mang, H.A., H. Floegl, F. Trappel and H. Walter, Wind-Loaded Reinforced-Concrete Cooling Towers: Buckling or Ultimate Load, Engineering Structures, Vol. 5, No. 3, 1983, pp. 163-180

596.0
Marchese, B., Morphology and Composition of Twin Fracture Surfaces of a Crack in Portland Cement Paste, Cement and Concrete Research, Vol. 13, No. 3, 1983, pp. 435-440

597.0
McLennan, J. D., J. C. Roegiers, R. P. Marcinew and D. J. Erickson, Rock Mechanics Evaluation of the Cardium Formation, Preprints-34th Annual Technical Meeting of the Petroleum Society of CIM, Banff, Alberta, Canada, 1983, Publ. by Petroleum Society of CIM, Montreal, Quebec, Canada, 1983, 18 pp.

598.0
Mihashi, H., A Stochastic Theory for Fracture of Concrete, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 301-340

599.0
Mindess, S., Application of Fracture Mechanics to Concrete, in Proceedings, Fourth Engineering Mechanics Division Specialty Conference, ASCE, West Lafayette, Indiana, Vol. 2, 1983, pp. 794-797

600.0
Mindess, S., The Application of Fracture Mechanics to Cement and Concrete: A Historical Review, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 1-30

601.0
Mindess, S., The Cracking and Fracture of Concrete: An Annotated Bibliography 1928-1981, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 539-662

602.0
Mindess, S., The Fracture of Fibre Reinforced and Polymer Impregnated Concretes - A Review, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 481-502

603.0
Naaman, A.E. and K. Visalvanich, Modeling Fracture in Fiber Reinforced Concrete, in Proceedings, Fourth Engineering Mechanics Division Specialty Conference, ASCE, West Lafayette, Indiana, Vol. 2, 1983, pp. 1307-1310

604.0
National Materials Advisory Board(NRC), Washington, DC, Fracture in Compression of Brittle Solids, Final Report No. NMAB-404, August 1983, 78 pp.

605.0
Nilsson, L. and M. Oldenburg, On Tensile Fracture and Wave Propagation in Granular Materials, Scandinavian Journal of Metallurgy, Vol. 12, No. 6, 1983, Theoretical and Experimental Study of the Compaction of Granular Material, Tynningo, Sweden, 1983, pp. 299-301

606.0
Ouchterlony, Finn and Sun Zungqi, New Methods of Measuring Fracture Toughness on Rock Cores, Report DS1983:10, Swedish Detonic Research Foundation, Stockholm, Sweden, 1983

607.0
Peier, Walter H., Model For Pull-out Strength of Anchors in Concrete, Journal of Structural Engineering, ASCE, Vol. 109, No. 5, 1983, pp. 1155-1173

608.0
Reinhardt, H. W., Plain Concrete in Uniaxial Post-Peak Cyclic Tensile and Tensile-Compressive Loading, Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concretes, Soils, Evanston, Ill., USA, 1983, Publ. by Northwestern University, Evanston, Ill., USA, 1983, pp. 639-642

609.0
Rizkalla, S. H., L. S. Hwang and M. El Shahawi, Transverse Reinforcement Effect on Cracking Behavior of R. C. Members, Canadian Journal of Civil Engineering, Vol. 10, No. 4, 1983, pp. 566-581

610.0
Saji, Taiji, Yasunori Matsufuji, Shigehisa Taguchi and Takaaki Ohkubo, Experimental Study on Fracture of Mortar and Concrete Under Repeated Impulsive Bending Load, in Proceedings of the Twentyseventh Japan Congress on Materials Research. Tokyo, Japan, 1983, Published by the Society of Materials Science, Japan, Kyoto, 1984, pp. 215-218

611.0
Saouma, V.E. and A.R. Ingraffea, Discrete Crack Modelling in Reinforced Concrete, in Proceedings, Fourth Engineering Mechanics Division Specialty Conference, ASCE, West Lafayette, Indiana, Vol. 2, 1983, pp. 1005-1008

612.0
Sato, Ryoichi and Yukio Aoyagi, Studies on Deformation and Crack of Reinforced Concrete Flexural Members Under Low Temperature, Doboku Gakkai Rombun Hokokushu , No. 329, 1983, pp. 141-154

613.0
Schneider, U. and U. Diederichs, Detection of Cracks by Mercury Penetration Measurements, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 207-222

614.0
Shah, S.P. and M. Wecharatana, A Progress Report on Fracture Toughness of Fiber Reinforced Concrete, Northwestern University for the U.S. Air Force, Grant No. AFOSR-820243, June 1983

615.0
Sharma, S., M. Reich, S. Shteyngart and T. Y. Chang, Nonlinear Finite-Element Analysis of a Reinforced-Concrete Mark III Containment under Pressure and Gravity Loads (BWR), International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, USA, 1983, 17 pp.

616.0
Shimada, Mitsuhiko, Akio Cho and Hideo Yukutake, Fracture Strength of Dry Silicate Rocks at High Confining Pressures and Activity of Acoustic Emission, Tectonophysics, Vol. 96, No. 1-2, 1983, pp. 159-180

617.0
Shrive, N. G., Compression Testing and Cracking of Plain Concrete, Magazine of Concrete Research, Vol. 35, No. 122, 1983, pp. 27-39

618.0
Slate, F.O., Microscopic Observation of Cracks in Concrete, with Emphasis on Techniques Developed and Used at Cornell University, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 75-84

619.0
Slate, F.O., X-ray Technique for Studying Cracks in Concrete, With Emphasis on Methods Developed and Used at Cornell University, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 85-94

620.0
Stout, R. B., Deformation and Thermodynamic Response During Brittle Fracture, Preprints - William Prager Symposium on Mechanics of Geomaterials: Rocks, Concretes, Soils, Evanston, Ill, USA, 1983, Publ. by Northwestern University, Evanston, Ill, USA, 1983, pp. 595-598

621.0
Stout, R. B. and L. Thigpen, Modelling Microcrack Kinetics in Rocks, International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 7, No. 1, 1983, pp. 9-18

622.0
Suaris, W., Dynamic Behavior of Concrete: A Phenomenological Theory and Instrumented Impact Testing, Ph. D. Dissertation, Northwestern University, 1983, 174 pp.

623.0
Suzuki, H. and W. Chen, Elastic-Plastic-Fracture Analysis of Concrete Structures, Computers and Structures, Vol. 16, No. 6, 1983, pp. 697-706

624.0
Swamy, R.N., Linear Elastic Fracture Mechanics Parameters of Concrete, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 411-462

625.0
Toussi, Sassan and James T.P. Yao, Hysteresis Identification of Existing Structures, Journal of Engineering Mechanics, ASCE, Vol. 109, No. 5, 1983, pp. 1189-1202

626.0
Visalvanich, K. and A.E. Naaman, Fracture Model for Fiber Reinforced Concrete, Journal of the American Concrete Institute, Vol. 80, No. 2, 1983, pp. 128-138

627.0
Wecharatana, M. and S. P. Shah, Fracture Toughness of Fiber Reinforced Concrete, Northwestern University, Evanston, IL, Dept. of Civil Engineering, Progress Report No. AFOSR-TR-83-0876 for June 1982 to June 1983, Air Force Office of Scientific Research, Bolling AFB, DC, 1983, 84 p

628.0
Wecharatana, M. and S. P. Shah, Model for Predicting Fracture Resistance of Fiber Reinforced Concrete, Cement and Concrete Research, Vol. 13, No. 6, 1983, pp. 819-829

629.0
Wecharatana, M. and S. Shah, Nonlinear Fracture Mechanics Parameters, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 463-480

630.0
Wecharatana, M. and S.P. Shah, Nonlinear Fracture Process Zone in Concrete, in Proceedings, Fourth Engineering Mechanics Division Specialty Conference, ASCE, West Lafayette, Indiana, Vol. 2, 1983, pp. 993-996

631.0
Wecharatana, Methi and Surendra P. Shah, Predictions of Nonlinear Fracture Process Zone In Concrete, Journal of Engineering Mechanics, ASCE, Vol. 109, No. 5, 1983, pp. 1231-1246

632.0
Wittmann, F.H., Structure of Concrete with Respect to Crack Formation, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 43-74

633.0
Wittmann, F.H. (ed.), Fracture Mechanics of Concrete, Elsevier Science Publishers, Amsterdam, The Netherlands, 1983, 680 pp.

634.0
Wu Keru, Dozent, Das Tragverhalten von Beton - Ableitung eines Kennwertes fuer die Bruchzaehigkeit. (Loadbearing Behavior of Concrete - Derivation of a Characteristic Value for Fracture Toughness), Betonwerk und Fertigteil Technik, Vol. 48, No. 11, 1983, pp. 705-707. In German and English.

635.0
Yanada, H. and H. Homma, Study of Fracture Toughness Evaluation of FRP, Journal of Materials Science, Vol. 18, 1983, pp. 133-139

636.0
Zaitsev, Y.B., Crack Propagation in a Composite Material, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 251-300

637.0
Ziegeldorf, S., Fracture Mechanics Parameters of Hardened Cement Paste, Aggregates, and Interfaces, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 371-410

638.0
Ziegeldorf, S., Phenomenological Aspects of the Fracture of Concrete, in Fracture Mechanics of Concrete, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1983, pp. 31-42

639.0
Akai, Koichi, Yuzo Ohnishi and Atsushi Yashima, Fracture and Energy Dissipation of Soft Sedimentary Rock in Triaxial Compression, Transactions of the Japan Society of Civil Engineering, Vol. 14, March 1984, pp. 266-267

640.0
Ballarini, R., S.P. Shah and L.M. Keer, Crack Growth in Cement-based Composites, Engineering Fracture Mechanics, Vol. 20, No. 3, 1984, pp. 433-446

641.0
Bazant, Z. P. and J. C. Chern, Effect of Progressive Fracturing on the Creep of Concrete, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp.

642.0
Bazant, Z.P., Fracture Energy of Concrete from Maximum Loads of Specimens of Various Sizes, Proposal for RILEM Recommendation, Northwestern University, Evanston, IL, 1984

643.0
Bazant, Z.P., J.K. Kim and P. Pfeiffer, Determination of Nonlinear Fracture Parameters From Size Effect Tests, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 143-169

644.0
Bazant, Zdenek P., Numerical Simulation of Progressive Fracture in Concrete Structures: Recent Developements, Text of lecture presented at International Conference on Computer-aided Analysis and Design of Concrete Structures, Split, Yugoslavia, September 17-21, 1984

645.0
Bazant, Zdenek P., Size Effect in Blunt Fracture: Concrete, Rock, Metal, Journal of Engineering Mechanics, ASCE, Vol. 110, No. 4, 1984, pp. 518-535

646.0
Bazant, Zdenek P. and Byung H. Oh, Deformation of Progressively Cracking Reinforced Concrete Beams, Journal of the American Concrete Institute, Vol. 81, No. 3, 1984, pp. 268-278

647.0
Bazant, Zdenek P. and Byung H. Oh, Rock Fracture Via Strain-Softening Finite Elements, Journal of Engineering Mechanics, ASCE, Vol. 110, No. 7, 1984, pp. 1015-1035

648.0
Bazant, Zdenek P. and Jin-Keun Kim, *Size Effect in Shear Failure* of Longitudinally Reinforced Beams, Journal of the American Concrete Institute, Vol. 81, No. 5, 1984, pp. 456-468

649.0
Bazant, Zdenek P. and Luigi Cedolin, Approximate Linear Analysis *of Concrete Fracture by R-curves*, Journal of Structural Engineering, Vol. 110, No. 6, 1984, pp. 1336-1355

650.0
Bazant, Zdenek P. and Pietro G. Gambarova, Crack Shear in Concrete: Crack Band Microplane Model, Journal of Structural Engineering, ASCE, Vol. 110, No. 9, 1984, pp. 2015-2035

651.0
Bazant, Zdenek P., Jin-Keun Kim and Phillip Pfeiffer, Nonlinear Fracture Properties from Size Effect Tests, Northwestern University, Evanston, IL, 1984

652.0
Bentur, A and S. Diamond, Fracture of Glass Fiber Reinforced Cement, Cement and Concrete Research, Vol. 14, No. 1, 1984, pp. 31-42

AD-A165 639 APPLICABILITY OF FRACTURE MECHANICS METHODOLOGY TO CRACKING AND FRACTURE O..(U) KANSAS STATE UNIV MANHATTAN DEPT OF CIVIL ENGINEERING S E SWARTZ FEB 86 3/3

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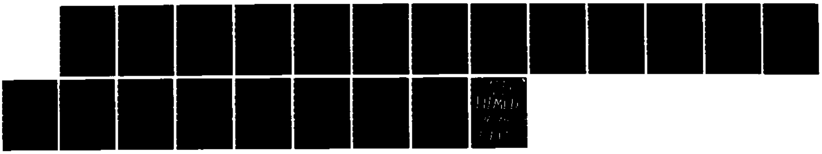

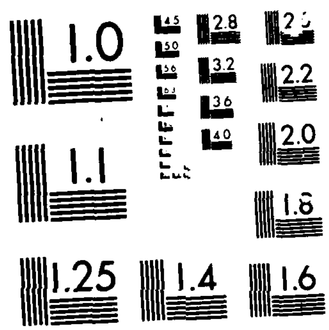

MICROCOPY RESOLUTION TEST CHART

653.0
Berthomieu, G., J. L. Cheissoux, J. L. Dabert and P. Jouanna, Stress Intensity Factor, Ki, Under Variable Thermal Conditions, in Proceedings, Third International Conference on Numerical Methods in Fracture Mechanics, Swansea, Wales, 1984, Published by Pineridge Press, Swansea, Wales, 1984, pp. 481-494

654.0
Bradford, L.G., S.B. Dong, D.A.C. Nicol and R.A. Westmann, A Central Crack Element in Fracture Mechanics, International Journal of Fracture, Vol. 24, 1984, pp. 197-207

655.0
Broek, David, Elementary Engineering Fracture Mechanics, 3rd Edition, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, 469 pp.

656.0
Carpinteri, A. and A.R. Ingraffea (Eds.), Fracture Mechanics of Concrete, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984

657.0
Carpinteri, A. and G.C. Sih, Damage Accumulation and Crack Growth in Bilinear Materials with Softening: Application of Strain Energy Density Theory, Ist. Sci. Constr., Univ. Bologna, Bologna, Italy

658.0
Carpinteri, Alberto, Stability of Fracturing Process in RC Beams, Journal of Structural Engineering, ASCE, Vol. 110, No. 3, 1984, pp. 544-558

659.0
Cho, K.Z., A.S Kobayashi, N.M. Hawkins, D.B. Barker and F.L.Jeang, Fracture Process Zone of Concrete Cracks, Journal of the Engineering Mechanics Division, ASCE, Vol. 110, No. 8, 1984, pp. 1174-1184

660.0
Cook, N. G. W., M. Hood and F. Tsai, Observations of Crack Growth in Hard Rock Loaded by an Indenter, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 21, No. 2, 1984, pp. 97-107

661.0
Darwin, David, Linda D. Leibengood and Robert H. Dodds, Structural Aspects of Tension Softening in Concrete, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp.

662.0
Derucher, K., Applications of the Scanning Electron Microscope to Concrete Failure (Axial, Biaxial, and Dynamic), Stevens Institute of Technology, Hoboken, NJ, for Air Force Office of Scientific Research, Bolling AFB, DC, Report No. AFOSR-TR-84-0431, 1984, 101 pp.

663.0
Diamond, S. and A. Bentur, On the Cracking in Concrete and Fiber Reinforced Cements, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 51-96

664.0
DiTommaso, A., Evaluation of Concrete Fracture, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 31-66

665.0
Dodds, Robert H., David Darwin and Linda D. Leibengood, Stress Controlled Smeared Cracking in R/C Beams, Journal of Structural Engineering, ASCE, Vol. 110, No. 9, 1984, pp. 1959-1976

666.0
El-Sayed, H.A. and G.M. Sherbini, Investigation of the Factors Inducing Early Deterioration of a Reinforced Concrete Construction, Surface Technology, Vol. 23, No. 3, 1984, pp. 291-300

667.0
Francois, D., Fracture and Damage Mechanics of Concrete, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 97-110

668.0
Gillespie, R. L., C. G. Go and S. E. Swartz, Vertical-Displacement Gate Fixture for Jic Testing, Experimental Techniques, Vol. 8, No. 5, 1984, pp. 32-33

669.0
Go, C.G. and S.E. Swartz, Energy Methods for Fracture Toughness Determination in Concrete, in Proceedings, V International Congress on Experimental Mechanics, Montreal, Canada, 1984, pp. 453-459

670.0
Go, C.G., S.E. Swartz and K.K. Hu, Stress Intensity Factors for Single-Edge-Notched Beam, Technical Note, Journal of Engineering Mechanics, ASCE, Vol. 110, No. 4, 1984

671.0
Go, Cheer Germ and Stuart E. Swartz, COD as a Fracture Criterion for Concrete, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 1, Publ. by ASCE, New York, NY, USA, 1984, pp.

672.0
Gopalaratnam, V. S. and S. P. Shah, Post-cracking Characteristics of Concrete in Uniaxial Tension, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering

Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp

673.0
Grimaldi, Gilbert, Gerard Olivier, and Andre Barral, Visualisation des Fissures des Betons par la Methode du Ressuage. (Visualization of Cracks in Concrete by the Bleeding Method), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 129, 1984, pp. 51-55. In French.

674.0
Gupta, Ajaya K. and Habibollah Akbar, Cracking in Reinforced Concrete Analysis, Journal of Structural Engineering, ASCE, Vol. 110, No. 8, 1984, pp. 1735-1746

675.0
Gur, Y., Z. Jaeger and R. Englman, Fragmentation of Rock by Geometrical Simulation of Crack Motion - I, Engineering Fracture Mechanics, Vol. 20, No. 5-6, 1984, pp. 783-800

676.0
Gustafsson, P.J. and A. Hillerborg, Improvements in Concrete Design Achieved Through the Application of Fracture Mechanics, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 487-500

677.0
Gylltoft, K., Fracture Mechanics Model for Fatigue in Concrete, Materiaux et Constructions, Materials and Structures, Vol. 17, No. 97, 1984, pp. 55-58

678.0
Hajek, Jan, Spad Pretvorenia pri Vypocte Medze Vzniku Trhlin Betonovych Prvkov. (Strain Gradient in Calculation of Cracking Limit of Concrete Elements), Stavebnicky Cas., Vol. 32, No. 10, 1984, pp. 695-710. In Slovak.

679.0
Hamajima, Ryokichi, Tadahiko Kawai, Morito Kusabuka and Kiyoaki Yamashita, Crack Propagation Analysis of Cracked Rock Media, Proceedings of the 3rd International Conference on Numerical Methods in Fracture Mechanics, Swansea, Wales, 1984, Publ. by Pineridge Press, Swansea, Wales, pp. 751-764

680.0
Han, D. J. and W. F. Chen, Constitutive Modeling in Analysis of Concrete Structures, Purdue University, School of Civil Engineering, Structural Engineering Technical Report CE-STR 84-40, Aug. 1984, 37 pp.

681.0
Hasebe, Norio, Mixed Boundary Value Problem of Plate with Crack, Journal of Engineering Mechanics, ASCE, Vol. 110, No. 1, 1984, pp. 37-48

682.0
Hashemi, S. and J.G. Williams, Size and Loading Mode Effects in Fracture Toughness Testing of Polymers, Journal of Materials Science, Vol. 19, 1984, pp. 3746-3759

683.0
Hawkins, N.M., Diagonal Tension Fracture of Concrete, Washington University, Dept. of Civil Engineering, Seattle, Washington, for National Science Foundation, 1984, Federal Research in Progress

684.0
Hawkins, N.M., The Role for Fracture Mechanics in Conventional Reinforced Concrete Design, in Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984

685.0
Hillerborg, Arne, Additional Concrete Fracture Energy Tests Performed by 6 Laboratories According to a Draft RILEM Recommendation, Report TVBM-3017 to RILEM TC50-FMC, Lund

Institute of Technology, Lund, Sweden, 1984

686.0
Hillerborg, Arne, Summary of Test Results from 7 Laboratories on the Influence of the Specimen Size on the Measured Value of the Fracture Energy, Preliminary Version, Lund, Sweden, August 17, 1984

687.0
Hilsdorf, H.K. and W. Brameshuber, Size Effects in the Experimental Determination of Fracture Mechanics Parameters, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 255-288

688.0
Horvath, Robert and Torbjorn Persson, The Influence of the Size of the Specimen on the Fracture Energy of Concrete, Report TVBM-5005, Lund Institute of Technology, Lund, Sweden, 1984

689.0
Houde, Jules, Microcracking of Concrete Submitted to Premature Freezing, in Proceedings of the 5th Engineering Mechanics Div. Specialty Conference, ASCE, Laramie, WY, USA, Vol. 2, 1984, pp. 1424-1427

690.0
Hsu, Thomas T. C., Fatigue and Microcracking of Concrete, Materiaux et Constructions, Materials and Structures, Vol. 17, No. 97, 1984, pp. 51-54

691.0
Ingraffea, A.R. and W.H. Gerstle, Non-Linear Fracture Models for Discrete Crack Propagation, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 171-209

692.0
Ingraffea, Anthony R., Walter H. Gerstle, Peter Gergely and Victor Saouma, Fracture Mechanics of Bond in Reinforced Concrete, Journal of Structural Engineering, ASCE, Vol. 110, No. 4, 1984, pp. 871-890

693.0
Jacquot, P., Interferometry in Scattered Coherent Light Applied to the Analysis of Cracking in Concrete, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 161-194

694.0
Jenq, Y.S. and S.P. Shah, Nonlinear Fracture Parameters for Cement Based Composites: Theory and Experiments, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 213-253

695.0
Kafka, Vratislav, Elastic Capacity Concept and Cumulative Damage, Acta Technica CSAV (Ceskoslovansk Akademie Ved), Vol. 29, No. 4, 1984, pp. 408-419

696.0
Knab, L.I., H.N. Walker, J.R. Clifton and E.R. Fuller,Jr., Fluorescent Thin Sections to Observe the Fracture Zone in Mortar, NBS, Washington, DC, USA

697.0
Kobayashi, A.S., N.M. Hawkins, D.B. Barker and B.M. Liaw, Fracture Process Zone of Concrete, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 25-47

698.0
Kolmar, Wolfgang and Gerhard Mehlhorn, Finite Element Modelling of Discrete Cracks in Reinforced Concrete by Contact Elements, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 1, Publ. by ASCE, New York, NY, USA, 1984, p

699.0
Kotsovos, M. D., Concrete. A Brittle Fracturing Material, Materiaux et Constructions, Materials and Structures , Vol. 17, No. 98, 1984, pp. 107-115

700.0
Krajcinovic, D., Mechanics of Solids with a Progressively Deteriorating Structure, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 323-348

701.0
Kuruppu, M. D. and K. P. Chong, Fracture Mechanics of Layered Rocks, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp.

702.0
Labuz, J. F., S. P. Shah and C. H. Dowding, Fracture Analysis of Subsize, Charcoal Granite Specimens, in Proceedings, 25th Symposium on Rock Mechanics: Rock Mechanics in Productivity and Protection, Evanston, Ill, USA, 1984, Publ. by Society of Mining Engineers of AIME, New York, NY, USA, 1984, pp. 7

703.0
Li, V.C., Fracture Resistance Parameters for Cementitious Materials and Their Experimental Determinations, NATO Advanced Research Workshop, Northwestern University, September 4-7, 1984

704.0
Lindqvist, P.A., H.H. Lai and O. Alm, Indentation Fracture Development in Rock Continuously Observed With a Scanning Electron Microscope, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 21, No. 4, 1984, pp. 165-182

705.0
Mai, Y.W., Fracture Measurements of Cementitious Composites, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 289-319

706.0
Mai, Y.W., and M.I. Hakeem, Slow Crack Growth in Cellulose Fibre Cements, Journal of Materials Science, Vol. 19, 1984, pp. 501-508

707.0
Majumdar, A.J. and P.L. Walton, Fracture Processes in Fibre Reinforced Cement Sheets, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 111-139

708.0
Mangat, P. S. and M. Motamedi Azari, Influence of Steel Fibre Reinforcement on the Fracture Behaviour of Concrete in Compression, International Journal of Cement Composites and Lightweight Concrete, Vol. 6, No. 4, 1984, pp. 219-232

709.0
Matsuki, Koji and Ryoji Kobayashi, Fracture Toughness of Rocks Under Bending, Zairyo, Vol. 33, No. 369, 1984, pp. 634-640. In Japanese.

710.0
Mazars, J. and J. LeMaitre, Application of Continuous Damage Mechanics to Strain and Fracture Behaviour of Concrete, Preprints of the Proceedings, NATO Advanced Research Workshop on

Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 375-388

711.0
Mindess, S., Fracture Toughness Testing of Cement and Concrete, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 67-110

712.0
Mindess, S., Rate of Loading Effects on the Fracture of Cementitious Materials, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 465-484

713.0
Mindess, Sidney, Effect of Specimen Size on the Fracture Energy of Concrete, Cement and Concrete Research, Vol. 14, No. 3, 1984, pp. 431-436

714.0
Minnetyan, L. and G.B. Batson, Dynamic Characteristics of Steel Fibrous Reinforced Concrete as Related to Aseismic Design, Clarkson College of Technology, Department of Civil and Environmental Engineering, Potsdam, NY, for the National Science Foundation, 1984, Federal Research in Progress

715.0
Montgomery, Denis and Sidney Diamond, Influence of Fly Ash Cenospheres on the Details of Cracking in Flyash-Bearing Cement Pastes, Cement and Concrete Research, Vol. 14, No. 6, 1984, pp. 767-775

716.0
Nallathambi, P., B. L. Karihaloo and B. S. Heaton, Effect of Specimen and Crack Sizes, Water/Cement Ratio and Coarse Aggregate Texture Upon Fracture Toughness of Concrete, Magazine of Concrete Research, Vol. 36, No. 129, 1984, pp. 227-236

717.0
Oda, Masanobu, Kenichiro Suzuki and Takuro Maeshibu, Elastic Compliance for Rock-like Materials With Random Cracks, Soils and Foundations, Vol. 24, No. 3, 1984, pp. 27-40

718.0
Ohigashi, T., Fracture Energy of Glass Fiber Reinforced Cement Composites: Method of Determination, Cement and Concrete Research, Vol. 14, No. 3, 1984, pp. 349-359

719.0
Pan, Yen C., Algirdas H. Marchertas and James M. Kennedy, Evaluations for the Blunt Crack and the Sharp Crack Models, in Proceedings of the 5th Engineering Mechanics Divisoin Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp.

720.0
Pathan, I. A., Improved Method to Determine the Cracking Stress, Cracking Strain and Young's Modulus of Plain Concrete in Direct Tension, Mehran University Research Journal of En ineering and Technology, Vol. 3, No. 1, 1984, pp. 1-6

721.0
Perdikaris, P.C. and A. Chudnovsky, New Approach to the Fracture Toughness of Concrete - Probabilistic Model, in Advances in Fracture Research, 6th International Conference on Fracture, Vol. 4, New Delhi, India, December, 1984, pp. 2769-2776

722.0
Perdikaris, Philip C., Alexander Chudnovsky and Majd T. Sharaf, Influence of Material Heterogeneity on the Fracture of Cement Mortar, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference, Engineering Mechanics in Civil Engineering, Vol. 2, 1984, pp. 1253-1256

723.0
Pitt, John M. and Loras A. Klostermann, In Situ Stress by Pulse Velocity Monitoring of Induced Fractures, in Proceedings, 25th Symposium on Rock Mechanics: Rock Mechanics in Productivity and Protection, Evanston, IL, USA, June 25-27, 1984, Publ. by Society of Mining Engineers of AIME, New York, NY, USA.

724.0
Reinhardt, H. W., Fracture Mechanics of an Elastic Softening Material Like Concrete, Heron, Vol. 29, No. 2, 1984, 42 pp.

725.0
Reinhardt, H.W., Tensile Fracture of Concrete at High Rates of Loading, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 413-439

726.0
Rizkalla, S. H. and L. S. Hwang, Crack Prediction for Members in Uniaxial Tension, Journal of the American Concrete Institute, Vol. 81, No. 6, 1984, pp. 572-579

727.0
Rizkalla, Sami H., Sidney H. Simmonds and James G. MacGregor, Cracking of P/C Nuclear Containment Structures, Journal of Structural Engineering, ASCE, Vol. 110, No. 9, 1984, pp. 2148-2163

728.0
Sammis, C. G. and M. F. Ashby, Failure of Porous Solids Under Compression, TR, Vol. 103, March 1984, 39 pp.

729.0
Seaman, L., J. Gran and D.R. Curran, A Microstatistical Approach to Fracture of Concrete, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 349-373

730.0
Senseny, P. E. and T. W. Pfeifle, Fracture Toughness of Sandstones and Shales, in Proceedings, 25th Symposium on Rock Mechanics: Rock Mechanics in Productivity and Protection, Evanston, Ill., USA, 1984, Publ. by Society of Mining Engineers of AIME, New York, NY, 1984, pp. 390-39

731.0
Shah, S. P., Fracture Toughness of Fiber Reinforced Concrete, Northwestern University, Evanston, IL, Dept. of Civil Engineering, Annual Report No. AFOSR-TR-84-1227 for June 1983 to November 1984, Air Force Office of Scientific Research, Bolling AFB, DC., 1984, 2

732.0
Shah, S.P., Dependence of Concrete Fracture Toughness on Specimen Geometry and on Composition, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 111-136

733.0
Shah, S.P., Predictions of Cumulative Damage for Concrete and Reinforced Concrete, Materiaux et Constructions, Materials and Structures, Vol. 17, No. 97, 1984, pp. 65-68

734.0
Shah, S.P. (Ed.), Application of Fracture Mechanics to Cementitious Composites, Proceedings, NATO Advanced Research Workshop, Northwestern University, 1984

735.0
Sierakowski, R.L., Dynamic Effects in Concrete Materials, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 391-411

736.0
Sih, G.C., Mechanics of Material Damage in Concrete, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 1-30

737.0
Sih, G.C., Non-Linear Response of Concrete: Interaction of Size, Loading Step and Material Property, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 3-23

738.0
Slate, F.O. and K.C. Hover, Microcracking in Concrete, in Fracture Mechanics of Concrete: Material Characterization and Testing, Martinus Nijhoff Publishers, The Hague, The Netherlands, 1984, pp. 137-160

739.0
Smith, R. L., Use of Surface Scanning Waves to Detect Surface-Opening Cracks in Concrete, NDT International, Vol. 17, No. 5, 1984, pp. 273-275

740.0
Steif, Paul S., Crack Extension Under Compressive Loading, Engineering Fracture Mechanics, Vol. 20, No. 3, 1984, pp. 463-473

741.0
Strauss, A. M., Microcracking of Rock and the Prediction of Fracture and Failure, in Proceedings, 25th Symposium on Rock Mechanics: Rock Mechanics in Productivity and Protection, Evanston, Ill, USA, 1984, Publ. by Society of Mining Engineers of AIME, New York, NY, USA, 1984, pp. 5

742.0
Suaris, W. and S. P. Shah, Rate-Sensitive Damage Theory for Brittle Solids, Northwestern University, Evanston, IL, Report No. ARO-19311.3-MS, Army Research Office, Research Triangle Park, NC,

1984. 14 pp. Publ. in Journal of Engineering Mechanics, ASCE, Vol. 110, No. 6, 1984

743.0
Swartz, S. E. and C. G. Go, Validity of Compliance Calibration to Cracked Concrete Beams in Bending, Experimental Mechanics, Vol. 24, No. 2, 1984, pp. 129-134

745.0
Takahashi, Hideaki, Toshiyuki Hashida, Kinji Tamakawa, Shuji Yuda and Masahiko Suzuki, Determination of Fracture Toughness of Granitic Rock by Means of AE Technique, Nippon Kogyo Kaishi, Vol. 100, No. 1151, 1984, pp. 17-21. In Japanese.

746.0
Vallejo, Luis E. and Eddy Pramono, Development of Fracture Regions in Brittle Materials, in Proceedings, 25th Symposium on Rock Mechanics: Rock Mechanics in Productivity and Protection, Evanston, Ill, USA, 1984, Publ. by Society of Mining Engineers of AIME, New York, NY, USA, 1984, pp. 4

747.0
Wecharatana, M., Size Effect on Fracture Process Zone in Concrete Using Notched Beam Specimen, in Proceedings of the 5th Engineering Mechanics Division Specialty Conference: Engineering Mechanics in Civil Engineering, Laramie, WY, USA, 1984, Vol. 2, Publ. by ASCE, New York, NY, USA, 1984, pp.

748.0
William, K.J., S. Sture, N. Bicanic, J. Christensen and B. Hurlbut, Identification of Strain-softening Properties and Computational Predictions of Localized Fracture, Colorado University at Boulder, Department of Civil, Environmental and Architectural Engineering for the Air Force Office of Scientific Research, Bolling AFB, DC, Report No. AFOSR-TR-84-0425, 1984, 19

749.0
William, Kaspar J., Bryan Hurlbut and Nenad Bicanic, Composite Damage Model for Localized Fracture, in Proceedings of the 5th Engineering Mechanics Div. Specialty Conference, ASCE, Laramie, WY, USA, Vol. 2, 1984, pp. 1385-1388

750.0
Wittmann, F.H., Influence of Time on Crack Formation and Failure of Concrete, Preprints of the Proceedings, NATO Advanced Research Workshop on Application of Fracture Mechanics to Cementitious Composites, Northwestern University, Evanston, IL, 1984, pp. 443-464

751.0
Wittmann, F.H. and I. Gheorghita, Fracture Toughness of Autoclaved Aerated Concrete, Cement and Concrete Research, Vol. 14, No. 3, 1984, pp. 369-374

752.0
Wium, D.J.W., O. Buyukozturk and V.C. Li, Hybrid Model For Discrete Cracks in Concrete, Journal of the Engineering Mechanics Division, ASCE, Vol. 110, No. 8, 1984, pp. 1211-1236

753.0
Wnuk, M.P., Z.P. Bazant and E. Law, Stable Growth of Fracture in Brittle Aggregate Materials, Theoretical Applied Fracture Mechanics, Vol. 2, No. 3, 1984, pp. 259-286

754.0
Ye, T.Q. and Richard H. Gallagher, A Singular Finite Element for Analysis of Plate Bending Problem in Fracture Mechanics, International Journal of Fracture, Vol. 24, 1984, pp. 134-147

755.0
Zielinski, A. J., Model for Tensile Fracture of Concrete at High Rates of Loading, Cement and Concrete Research, Vol. 14, No. 2, 1984, pp. 215-224

756.0
Barker, Donald B., Neil M. Hawkins, Fure-Lin Jeang, Kyu Zong Cho and Albert S. Kobayashi, Concrete Fracture in a CLWL Specimen, Journal of Engineering Mechanics, ASCE, Vol. 111, No. 5, 1985

757.0
Bazant, Z.P., Mechanics of Fracture and Progressive Cracking in Concrete Structures, in Fracture Mechanics of Concrete: Structural Application and Numerical Calculation, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985, pp. 1-94

758.0
Bazant, Zdenek P. and Byung H. Oh, Microplane Model for Progressive Fracture of Concrete and Rock, Journal of Engineering Mechanics, ASCE, Vol. 111, No. 4, 1985, pp. 559-582

759.0
Carpinteri, A., Scale Effects in Fracture of Plain and Reinforced Concrete Structures, in Fracture Mechanics of Concrete: Structural Application and Numerical Calculation, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985, pp. 95-140

760.0
Elices, M., Fracture of Steels for Reinforcing and Prestressing Concrete, in Fracture Mechanics of Concrete: Structural Application and Numerical Calculation, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985, pp. 226-271

761.0
Gopalaratnam, V.S. and S.P. Shah, Tensile Softening of Brittle Composites, in Proceedings, 1985 Society for Experimental Mechanics Spring Conference on Experimental Mechanics, Las Vegas, Nevada, 1985, pp. 486-493

761.1
Gopalaratnam, V.S. and Surendra P. Shah, Softening Response of Plain Concrete in Direct Tension, Journal of the American Concrete Institute, Vol. 82, May-June 1985

762.0
Hillerborg, A., Numerical Methods to Simulate Softening and Fracture of Concrete, in Fracture Mechanics of Concrete: Structural Application and Numerical Calculation, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985, 141-170

763.0
Hillerborg, Arne, Influence of Beam Size on Concrete Fracture Energy Determined According to a Draft RILEM Recommendation, Report TVBM-3021 to RILEM TC50-FMC, Lund Institute of Technology, Lund, Sweden, 1985

764.0
Huang, Jian-An and Wang Sijing, Experimental Investigation Concerning the Comprehensive Fracture Toughness of Some Brittle Rocks, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 22, No. 2, 1985, pp. 99-104

765.0
Ingraffea, A.R. and V. Saouma, Numerical Modeling of Discrete Crack Propagation in Reinforced and Plain Concrete, in Fracture Mechanics of Concrete: Structural Application and Numerical Calculation, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985, pp. 171-225

766.0
Jenq, Y.S. and S.P. Shah, A Two Parameter Fracture Model for Concrete, Department of Civil Engineering, Northwestern University, Evanston, IL, accepted for publication, ASCE, EMD, April 1985

767.0
Labuz, J.F., S.P. Shah and C.H. Dowding, Experimental Analysis of Crack Propagation in Granite, International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol. 22, No. 2, 1985, pp. 85-98

768.0
Nallathambi, P., B.L. Karihaloo and Heaton, Various Size Effects in Fracture of Concrete, Cement and Concrete Research, Vol. 15, No. 1, 1985, pp. 117

769.0
Perdikaris, Philip C., Anthony Calomino and Alexander CHudnovsky, Effect of Fatigue on the Fracture Toughness of Concrete, to be submitted for publication to the Journal of Engineering Mechanics, ASCE

770.0
Perdikaris, Philip C., Said Hilmy and Richard N. White, Extensional Stiffness of Precracked R/C Panels, Journal of Structural Engineering, ASCE, Vol. 111, No. 3, 1985, pp. 487-504

771.0
Reinhardt, H.W., Crack Softening Zone in Plain Concrete Under Static Loading, Cement and Concrete Research, Vol. 15, No. 1, 1985, pp. 45-52

772.0
Rots, J.G., P. Nauta, G.M.A. Kusters and J. Blaauwendraad, Smeared Crack Approach and Fracture Localization in Concrete, Heron, Vol. 30, No. 1, 1985, 48 pp.

773.0
Shah, S.P., Fiber Reinforced Concrete-Mechanical, Fracture and Bond Properties, Northwestern University, Department of Civil Engineering, Evanston, IL, Contract No.: ENG77-23534, Federal Research in Progress

774.0
Sih, G.C. and A. DiTommaso (Eds.), Fracture Mechanics of Concrete, Martinus Nijhoff Publishers, Dordrecht, The Netherlands, 1985

775.0
Spence, D. A. and D. L. Turcotte, Magma-driven Propagation of Cracks, Journal of Geophysical Research, Vol. 90, No. B1, 1985, pp. 575-580

776.0
Suaris, Wimal and Surendra P. Shah, Constitutive Model for Dynamic Loading of Concrete, Journal of Structural Engineering, ASCE, Vol. 111, No. 3, 1985, pp. 563-576

777.0
Swartz, S.E. and S.M. Rood, Fracture Toughness Testing of Concrete Beams in Three-point Bending: Phase I, Small Beams, in Proceedings, 1985 Society for Experimental Mechanics Spring Conference on Experimental Mechanics, Las Vegas, Nevada, June 9-14, 1985, pp. 119-126

778.0
Walder, Joseph and Bernard Hallet, Theoretical Model of the Fracture of Rock During Freezing, Geological Society of America Bulletin, Vol. 96, No. 3, 1985, pp. 336-346

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