Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.IV)

6-4-22

DATA PROCESSING AND SIMULATION BY COMPUTERS FOR CRACKS OF REINFORCED CONCRETE STRUCTURES

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SUMMARY

In future seismic design of reinforced concrete structures, damage evaluation, which is conducted on the basis of the extent of cracks on structural members, should be adopted more actively as a criterion for structural design. The easiest and the most effective approach to establish damage evaluation system is to construct and use a data base for cracks. In this paper, some methods for the processing of crack data observed at failure tests are discussed for purposes of construction of a crack data base in the future.

INTRODUCTION

In the present seismic design approach for buildings, safety of structures is mainly discussed on the basis of their response displacement caused by an earthquake motion. Almost all present seismic design codes allow that inelastic deformation may develop on many structural members of a building during a severe earthquake, and also allow that many cracks may occur in reinforced concrete buildings. Such understanding as following seismic design criteria is a kind of common consensus for structural designers ; 1) in medium size earthquakes which may occur several times for the period of building use, few structural members should yield, and 2) in very severe earthquake which may occur once for the period of building use, or may not, collapse of the building should be prevented, even if many structural members might suffer damages.

How do architectural designers understand the above criteria, and how do they predict the extent of damages on a building in the design process? Users of the buildings will raise the same questions about the above criteria explained by structural designers, as clients (and users) must be expecting design without damage by earthquakes. Even structural designers may be surprised confronting cracked buildings, even if they had designed the buildings understanding the above criteria.

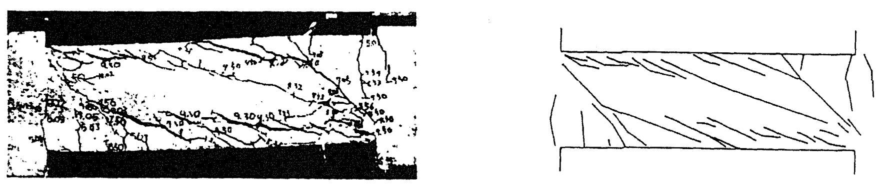
It causes such problems that expression of the criteria is very abstract and does not have a prediction capability for degree of physical damage. In future seismic design approaches, we should present the damage degree predicted on buildings using more plain descriptors. The crack patterns predicted are particularly appropriate as one such descriptor in reinforced concrete buildings. The easiest and the most effective approach in order to establish the prediction system of crack patterns is to use the crack data obtained from laboratory tests for various kinds of structural members. Some methods for data processing of cracks which have been tried by the author and others (Ref.1 - 3) are presented in this paper, and the method for construction of a crack data base is discussed.

METHODS OF DATA PROCESSING FOR CRACKS

Use of computer systems is appropriate for data processing of cracks. The data processing mainly consists of three steps, i.e., input, store and output (simulation). The author and others have tried three kinds of processing methods for data input.

The Method Processed by Digitizer (Ref.1) Photographed cracks are processed by this method. The hardware used for data processing are a personal computer and a digitizer. A photograph is put on the digitizer. Each crack on the photograph is recognized as a bi-linear broken line connecting both end-points with the midpoint. If there is an area where concrete spalled off, it is recognized as an approximate polygon. The values of the X-Y plane coordinate for each crack and polygon recognized are input to computer disk memory with rectangular frame which is identified with the periphery of the structural member. The operation is conducted by a human.

Fig.1 is an example processed by this method. Figure (a) presents the original cracks on a photograph, and Figure (b) presents the crack pattern replayed by the X-Y plotter. The merits in this method are ; 1) easy and inexpensive and 2) such kinds of cracks as bending, shearing, bond-splitting, etc., are input on the basis of the operator's evaluation.



(a) Original Photograph (b) Recognized Cracks

Fig.1 An Example Processed by Digitizer

The Method Processed by Mouse Device (Ref.2) In a case where the original photographs are small, the cracks are sketched directly on the computer display with a mouse device. Each crack is also identified by a bi-linear broken line, and the values of X-Y plane coordinate for three points are input to the computer disk memory. Fig.2 shows an example processed by this method. Although the data processed are not strict in comparison with the method using the digitizer, this method has merit in that the correction for old cracks processed previously and the supplement of new data are very easy.

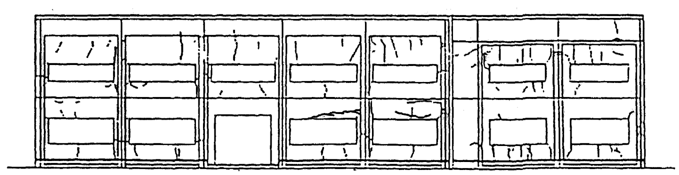


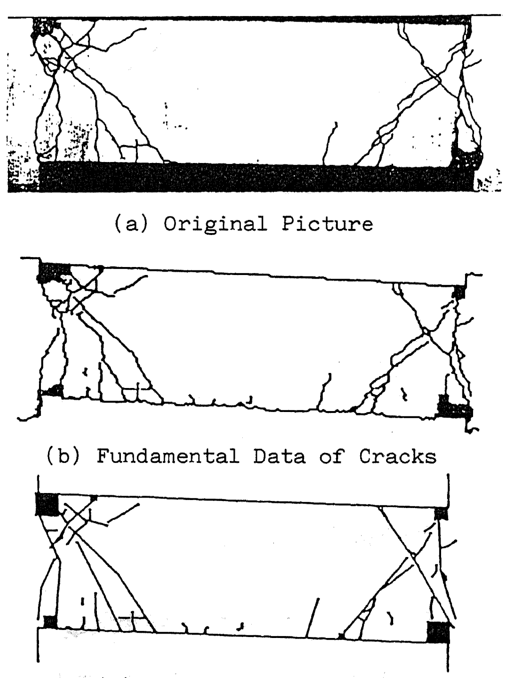
Fig.2 An Example Processed by Mouse Device

The Method Processed by Video-camera Computer Online System (Ref.3) This method is applied to data processing during tests. The outline of the system is shown in Fig.3. The video slicer in Fig.3 functions cutting the analogue signals less than a certain level of brightness set by manual operation. The A/D converter functions transforming the analogue to the digital, where the digit of 0 is given for the pixels of brightness higher than a slice-level set, and the digit of 1 is given for other pixels. The whole part of a picture photographed by the video camera is rearranged to a matrix of the pixels divided laterally and vertically. The digits which compose a matrix are transferred to the personal computer.

Fig.3 The Composition of Video Processor

Fig.4 shows an example processed by this method. Figure (a) presents the original picture. Figure (b) presents the picture replayed as only a matrix of the digits by the X-Y plotter. The spots which are not cracks in Figure (a) are removed by the control of the video-slicer. The matrix is called the Fundamental Data of Cracks, FDC, in the paper. The FDC in this stage is not suitable to be useful crack data, because each crack is not recognized as a complete crack. Figure (c) presents the crack pattern after each crack is recognized completely as a crack. Both end points and the midpoint of each crack are transformed to the values of X-Y plane coordinate. If there is an area where concrete spalled off, the area is transformed to an equivalent square with its central coordinate.

Crack recognition is conducted by the computer adopting the principle of pattern recognition. A comparatively intelligent technique is applied in this data processing. However, in this method, an issue to be improved is that a crack is recognized as plural cracks if there are discontinuous points in the original FDC. As for the hardware for this method, a large capacity of computer memory and high speed for data processing are required for image processing. Higher performance is also required for the video camera to resolve a picture as fine as possible. Such requirements for the equipment provided are the factors which make it expensive.



(a) Original Picture

(b) Fundamental Data of Cracks

(c) Recognized Cracks

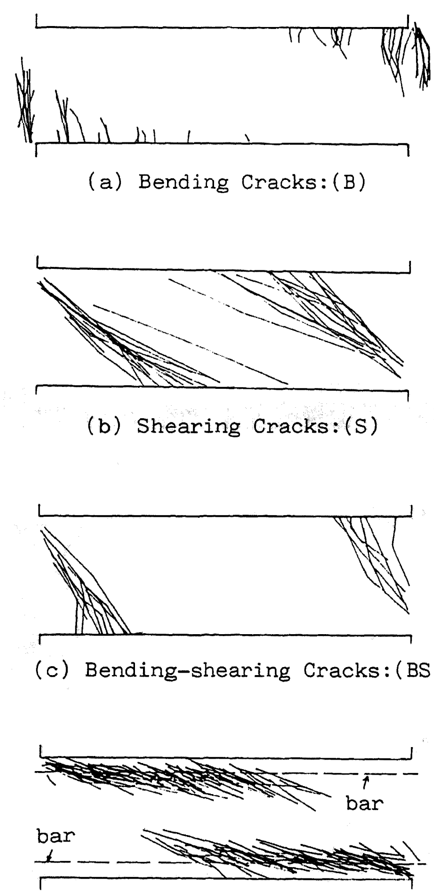
Fig.4 An Example Processed by Video Processor

SIMULATION OF CRACK PATTERN

If the crack data processed are accumulated on the computer disk memory enough, various analyses and simulation will be possible. The following is an example of some analyses for cracks input and simulation for crack pattern. The cracks obtained from the failure tests of eleven reinforced concrete columns which had the same dimensions were used for the analyses.

Classification of Cracks The cracks input to the computer disk memory were classified to any of the following five kinds; i.e., bending crack (B), shearing crack (S), bending-shearing crack (BS), bond-splitting crack (BO) and the secondary small crack branched from a shearing crack (SBC). The classification was established by an operator at the time of data input.

Analysis Fig.5 shows each kind of crack pattern replayed by the X-Y plotter. It is observed from Fig.5 that each kind of crack classified is distributed in its proper zone. Fig.6 shows the relationships between the inclination and the length for each kind of cracks. It is also observed from Fig.6 that there is a proper relation between them in each kind of cracks. Fig.7 shows an example of the crack pattern simulated using characteristic properties shown in Fig.5 and Fig.6.



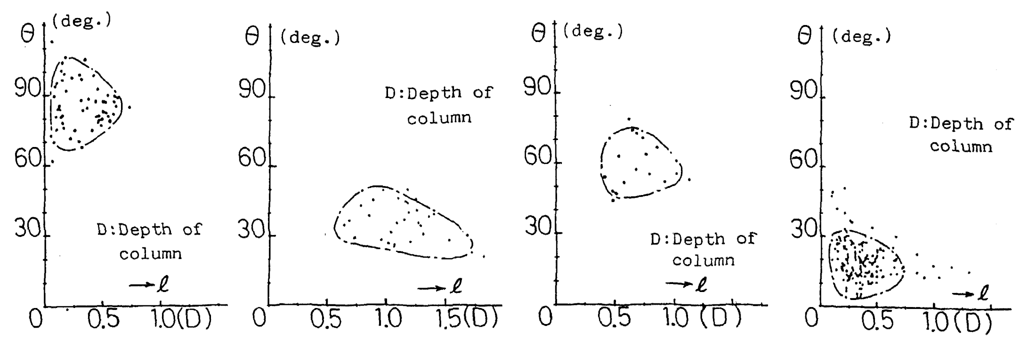
(a) Bending Cracks:(B)

(b) Shearing Cracks:(S)

(c) Bending-shearing Cracks:(BS)

(d) Bond-splitting Cracks:(BO)

Fig.5 An Example of Classification of Cracks



(a) Bending Cracks:(B) (b) Shearing Cracks:(S) (c) Bending-Shearing Cracks:(BS) (d) Bond-Splitting Cracks:(BO)

Fig.6 An Example of The Relationships between Inclination (θ) and Length (ℓ)

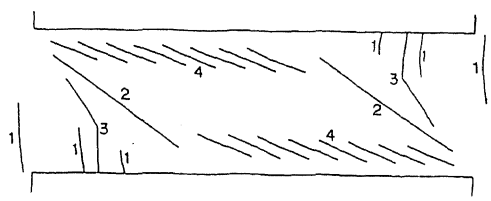


Fig.7 An Example of Crack Simulation

COMPOSITION AND FORMAT FOR CRACK DATA BASE

Consrtuction of a data base for cracks is required in order to make damage evaluation possible for a newly-built building. If the data base is complete, various analyses for the cracks and various simulations will become easy. Imformation required in the data base follows.

<u>Information on The Structural Members</u> The following information concerned with the structural members themselves should be input in addition to the crack data ; 1) name of the structural member, (column, beam, shear wall, etc.), 2) deformation angle of the structural member when the cracks had been photographed, 3) dimensions of the structural member, 4) reinforcement ratios for both bending and shearing, 5) value of axial force, 6) material strengths for both concrete and reinforcing bars, 7) others if necessary.

<u>Information on The Cracks</u> The following information should be input concerned with the cracks themselves 1) the values of X-Y coordinate corresponding to both end points and the midpoint of cracks, and each vertex of the polygon which represents an area where concrete spalled off, (the data are input automatically at data processing), 2) kind of cracks, (bending, shearing, bending-shearing, bond-splitting, concrete-spalling, etc.), 3) crack width, if it is known.

CONCLUSIONS

Some methods to transform cracks to digital data were discussed. The method processed by a personal computer with a digitizer is easy and effective to input photographed cracks to the computer disk memory, although the operation depends on human work. The method processed by a video camera computer online system is appropriate for data processing of cracks during tests in the future, although still it has some issues to improve in this stage.

A tentative concern with the composition and format for the crack data base was presented. If a common format for data base is completed, it would become useful for many researchers who have crack data. When many crack data will have been accumulated, a new seismic design approach with damage evaluation will develop by active use of the crack data base.

ACKNOWLEDGMENTS

The suggestions and cooperation for this paper by Prof. C.A. DeDeurwaerder is deeply acknowledged.

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