Paper No. 539

MEASUREMENT OF INELASTIC DEFLECTION BY LASER SPECKLE TECHNIQUE

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ABSTRACT

Laser speckle technique, which is generally applied to locate the crack propagation in fracture mechanics, is first time utilized to measure the deflections in a flexure test. Moment deflection curves are plotted for a number of beam tests both for laser and gage measured deflections. The comparison given by deflections obtained from laser speckle technique and conventional deflection gages indicated that the technique may be applied in measuring the deflections in a flexure text.

INTRODUCTION

Measurement techniques or devices for deformation generally employ either a regular geometric pattern or a constant as a base transducer. The change of the regularity of the pattern or the base response is converted into the measured quality. Rulers, pressure and strain gages, moire and interferometries methods are all this type of devices or techniques. Since the 1970s a series of new techniques have been developed that employ random pattern as transducers. Measurement is made not by knowing the deviation from regularity but by determining the correlation between two random signals. This has opened a new field of activity wherein new measurement instruments are being developed.

LASER SPECKLE TECHNIQUE

Laser speckle technique is to measure the surface displacement of a body using laser interferometry. A laser beam is expanded by a lens and a pin hole, and the uniform light is applied on the specimen. Thee reflected light produces a random shaped speckle pattern of unusually high contrast on the image formed by a lens. Each speckle is random shaped but is almost of the same size. When the specimen moves, the speckle moves with the specimen.

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We expose the speckle pattern twice on the same film before and after the deformation. By the double exposure, sets of two speckles, which are slightly apart corresponding to the magnitude of displacement at each point, are recorded on the film. After developing the negative film, we apply a laser beam at a point of the film. Then fringes appear on the screen. The direction of the fringe is prependicular to the direction of the displacement, and the distance between the fringes is inversely proportional to the magnitude of the displacement at the point where the laser beam is applied. Measuring the spacing and the direction of the fringe, the magnitude and direction of the displacement at the point are obtained. The fringe pattern may be recorded using a video camera and transformed into the digitized image which is taken into a personal computer. Using an image analysis technique and the Fast Furrier Transform, the spacing and thee direction of the fringes are calculated. [1]

APPLICATION OF LASER SPECKLE TECHNIQUE TO FLEXURE TEST

A number of beam specimen were tested at Fracture Mechanics Laboratories of SEC Division at AIT, Bangkok. The deformation was measured using the deflection gages and the laser speckle technique. The images were scanned by video camera and brought into a personnel computer. Later on these were applied to image analysis to get deflections. In the following the detail of the tests is given.

CASTING OF THE SPECIMEN

The following mix proportion by weight for casting the beams was adopted.

Cement	Sand	Gravel	Water
1.00	2.00	4.00	0.50

The cement used was high early strength cement. The river sand and crushed gravel were obtained locally. Six cylinders were also cast for each beam from the same mix. The beam specimens were cured in a fog room for 14 days, after which these were tested under four point bending. The average compressive strength obtained from the 36 cylinders was 20 MPa. The steel of 276 MPa yield strength was used. The details of the beam section are shown in Figure 1.

TESTING OF THE SPECIMEN

Before the test, 6 mm spacing grid was drawn on the central 20 cm portion of each specimen. The grid was used to identify the point at which displacement were to be measured by laser speckle technique. A slot was cut on the bottom side of the beam at

center to force the crack to appear at the mid span. However, this technique was dropped in the subsequent tests so that cracks may appear naturally. The test was performed on a rigid machine, using a deflection control, in a dark room. Th displacements at the center and the two ends of the beam were monitored on a computer screen through automatic data loggers. Displacement transducers were fixed at the mid span as well as at the supports. A transducer was also applied on one end of the beam to measure rigid body movement in the horizontal direction if any (See Figure 2).

The way of loading was to give a small displacement at the center of the span. We mad the former one of the double exposure before the start of loading. All the recordings were computerized to eliminate the time dependent effects. The latter exposure on the same film was taken when the central gage reading reached 150 to 200 micrometer. Before taking the latter exposure rigid body movement was eliminated by moving the camera in vertical and horizontal directions equal to the respective amount of movement along those directions, in the very first test. Further the camera was moved by 150 micrometers. That was done to have a good fringe spacing which could bee measured easily. Then the process was repeated with the increment of 100 to 200 micrometer displacement at the central gage. In subsequent tests rigid body motion was eliminated using extremely rigid supports.

The doubly exposed films were developed and were taken into dark room to study the fringe pattern. The laser beam was applied to the developed films and fringes resulting on screen were photographed by a video cameras. That was repeated for different slits. The distance between slit and screen was measured precisely. each image recorded by video camera was scanned into a personnel computer having a video graphic array monitor. A computer programme was developed to analyze these images. The deflections obtained from here were used to compute rotations and curvatures.

EXPERIMENTAL RESULTS

The relation between the moment and displacement at the mid span is shown in Figure 3. The theoretical deflection by Branson's method is also plotted on the same figure. The displacement computed from the experimental results is in a good agreement with gage reading whereas it shows a little difference with Branson's method.

In Figure 4, the moment curvature relationship obtained from experiment is plotted with the one obtained from Branson's method. This comparison is made on the basis of predicted crack spacing. There is a difference of almost 100% between the experimental and Branson's curve. The most obvious reason is that the results derived from the experiment are based upon predicted crack spacing. On the same diagram, the relationship

is plotted from subsequent tests, whilst no slot was cut at the center bottom fiber. This shows a close agreement with theoretical one. As there was only one crack in the first beam test, due to which the basis of calculation was not precise. Has the crack spacing been according to the prediction, the two curves should have been in an excellent agreement, the fact is confirmed by subsequent tests. However there is not that much difference between deflections obtained from the two types of tests.

DISCUSSION

The comparison given in Figure 3 shows a good agreement between the experimental laser and experimental gage deflections which is a good indication that the laser speckle technique may be successfully applied to flexure tests. There was an appreciable rigid body movement during the first test. Although it was eliminated during the test but still it should had have been much better if there were either no rigid body movement at all or a minimum of it, so that the test may be performed without much adjustments being made and with a minimum manual error involved. The assumption made in the development of the proposed method in an earlier publication [2] that "Inelastic rotation is lumped at the cracks only" is well justified from the Figures 5 & 6.

The deflected configuration on an exaggerated scale shows how precisely this technique can measure the deflections. The inelastic component of deflection is shown in a separate figure. The inelastic rotation is computed as given in the following.

The difference of measured deflection and theoretical elastic deflection at a point is computed. The same is repeated for adjacent points on a regular interval. To compute inelastic rotation, the difference at the two point is divided by distance between those points. The inelastic rotation is plotted vs moment in Figure 7. The inelastic deflections almost give a good indication that inelastic rotation is lumped at crack only. (See Figures 5 & 6).

CONCLUSIONS

The laser speckle technique can be successfully applied to record the load deflection relationships for a flexure text. It can give excellent results if rigid body motion is eliminated to a minimum. For that purpose rigid supports may be used to support the beam. Tests on slender beams give better results because the relative displacement at adjacent close points may be appreciable in that case as compared to stocky beams. Use of automatic data loggers is recommended to eliminate the ill effects of creep.

ACKNOWLEDGEMENTS

This research funded by DAAD, was carried out partially at SEC-AIT. The authors are much indebted to DAAD for providing the grant and to SEC authorities for providing the laboratory facilities. Many thanks are also due to Dr. Tamon Ueda and Dr. H. Hori, for the supervision and for the encouragement given throughout this research work. Thanks are also extended to the authorities of Deptt. of Civil Engineering, UET, Lahore, for allowing the use of their computer facilities.

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APPENDIX

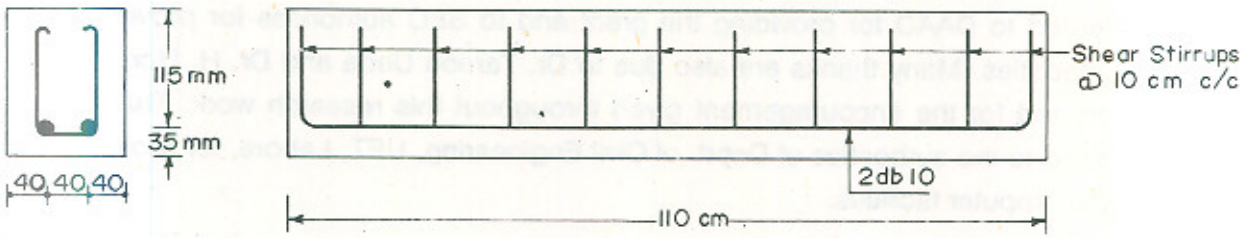


FIGURE. 1 Detail of the Beam Tested

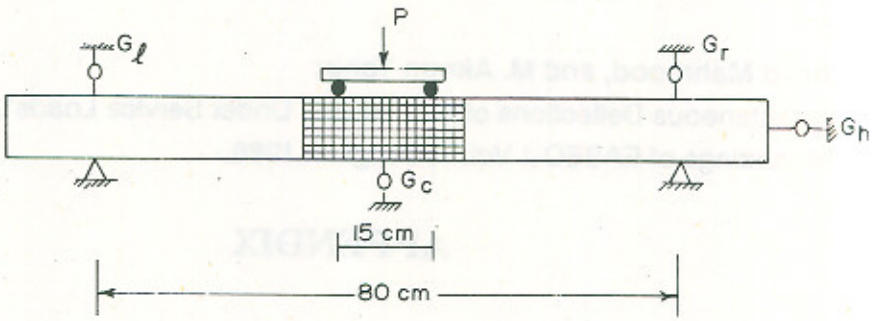


FIGURE. 2 Set up of the Test

FIGURE. 3.

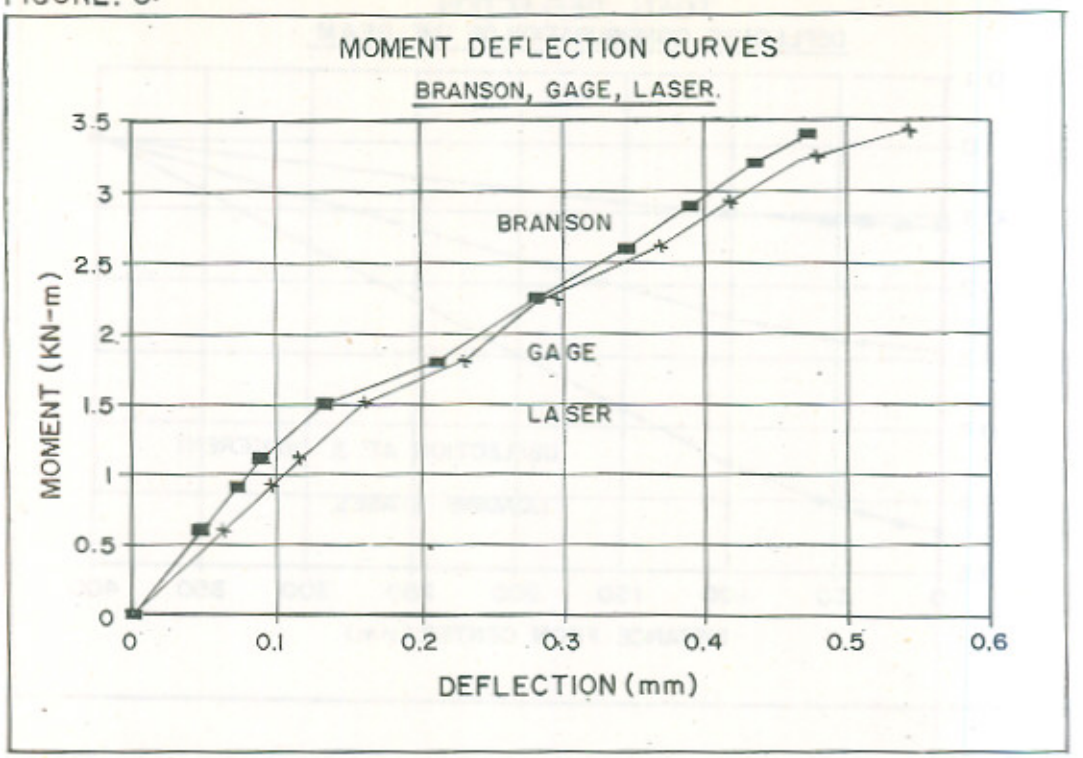


FIGURE. 4.

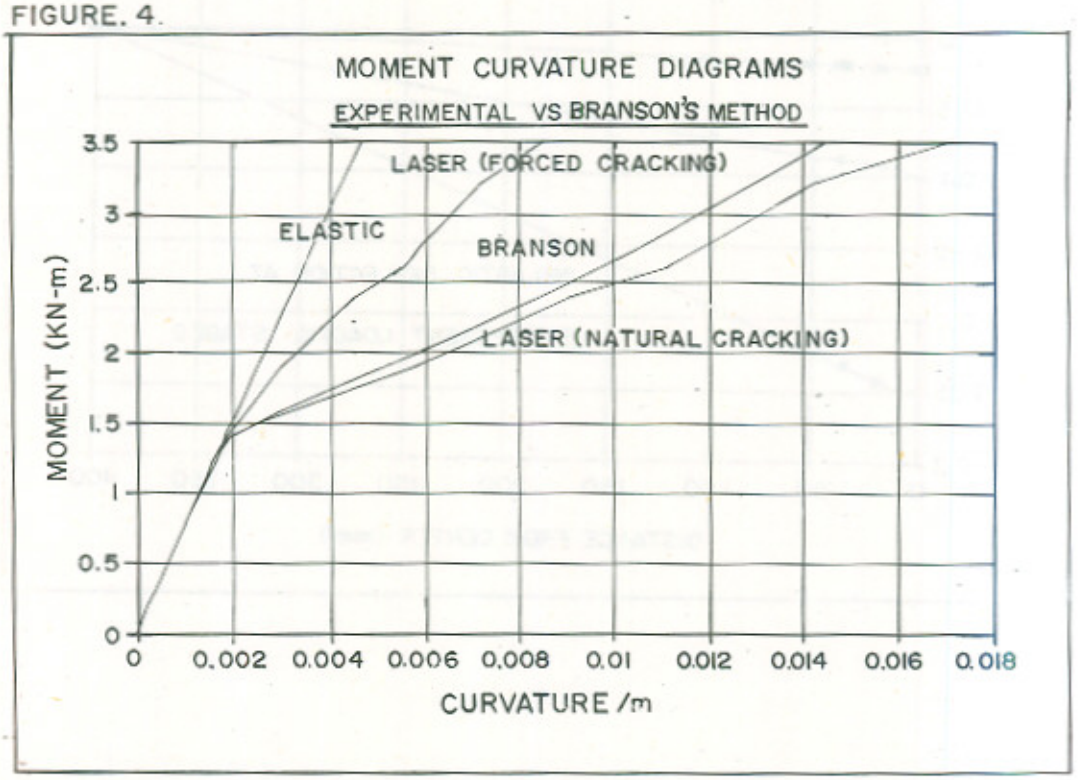


FIGURE. 5

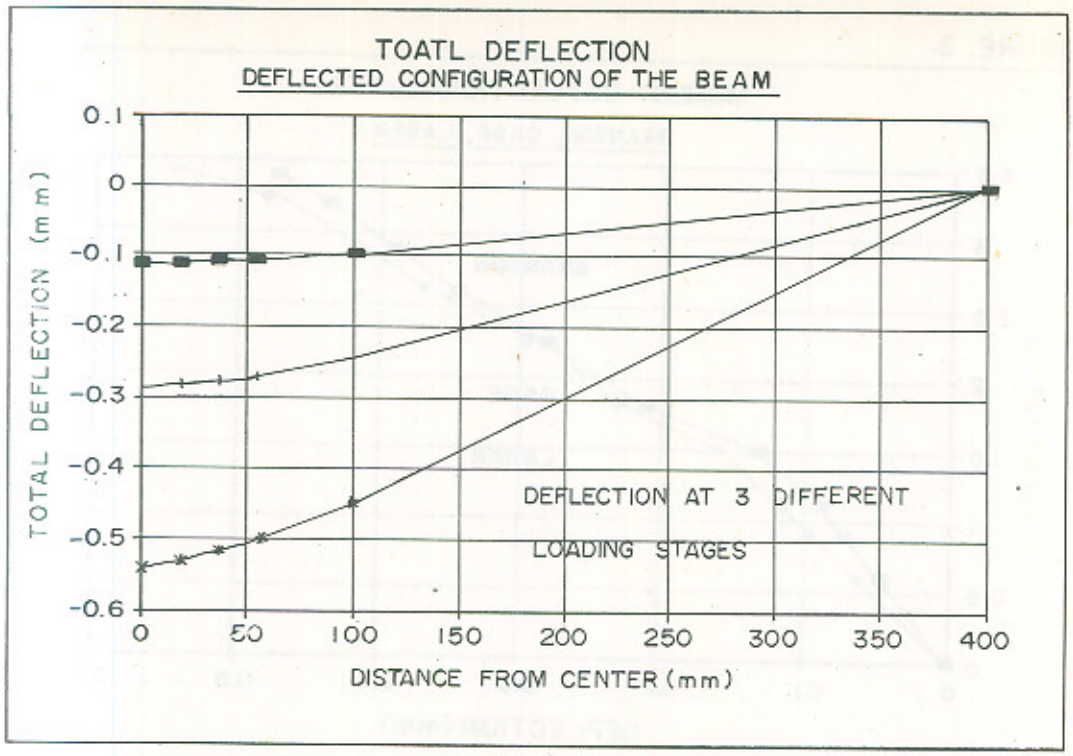


FIGURE. 6

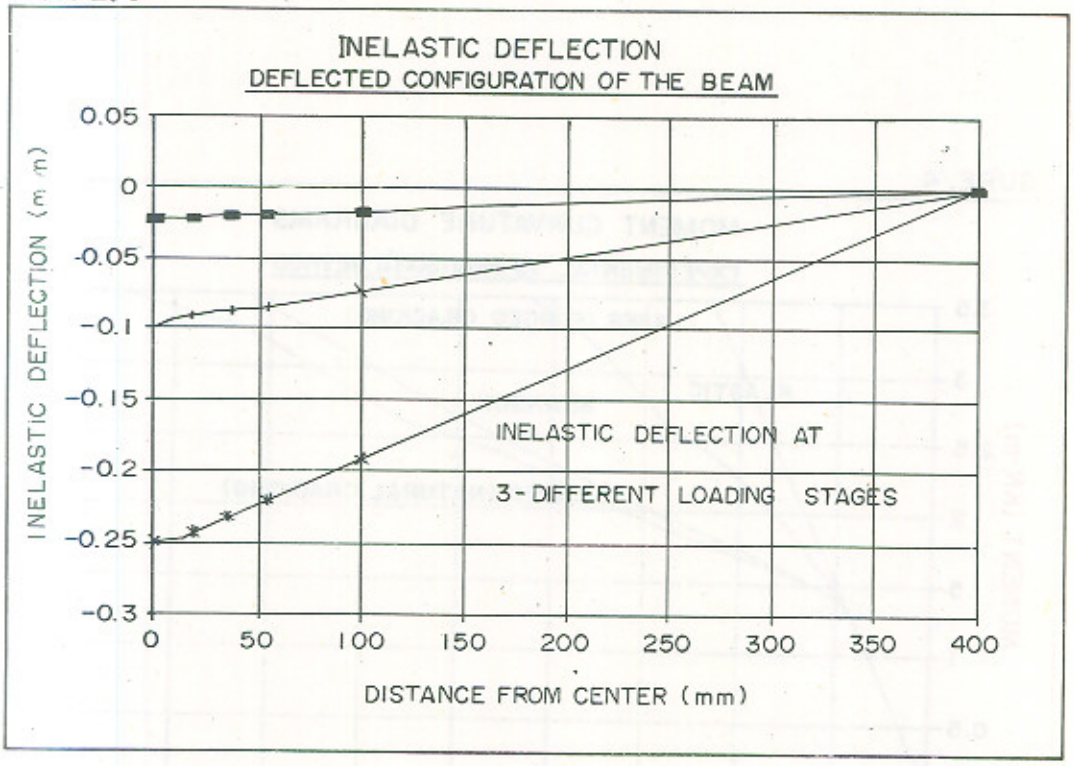
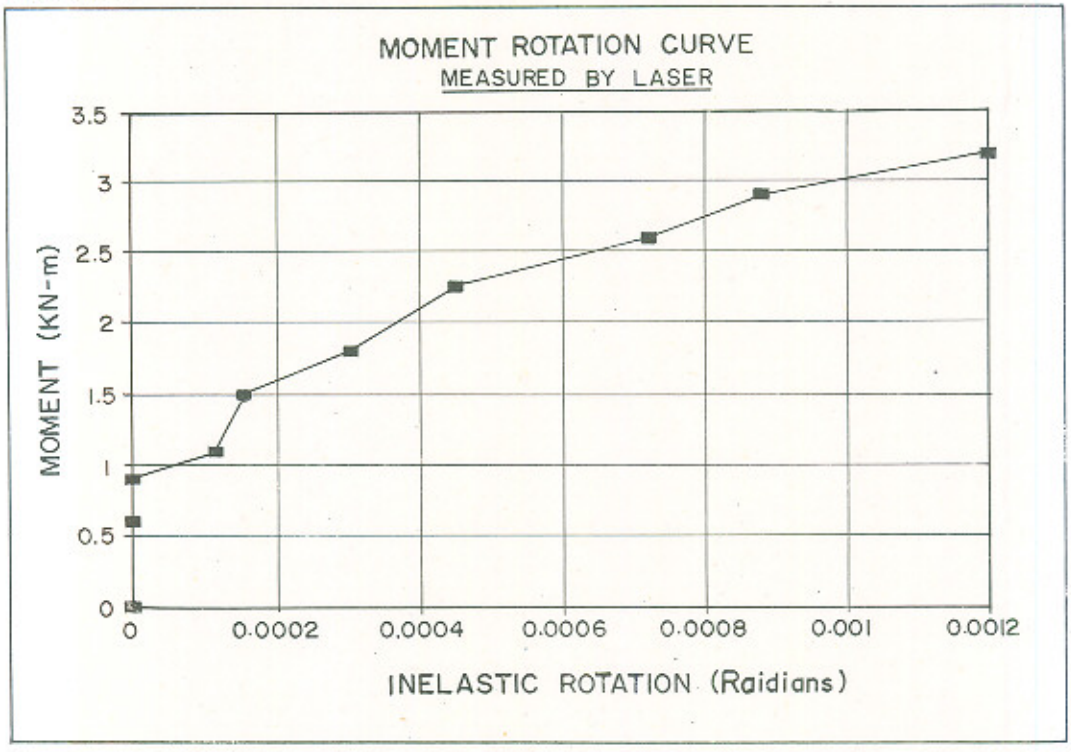


FIGURE. 7


MOMENT ROTATION CURVE
MEASURED BY LASER
MOMENT (KN-m)
3.5
3
2.5
2
1.5
1
0.5
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
INELASTIC ROTATION (Raidians)

