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Elastic Transverse Impact On Beams

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Abstract. Present investigation were carried out to study photoelastically the stress distributions in a simply supported beam with over- hangs subjected to a low velocity central- and quarter- span- impact loadings by light strikers keeping beam/ striker weight ratio constant (2.675), and then comparing the results so obtained with those in similar simply supported beams made of other materials subjected to central- impact loadings from an analysis of dynamic strain gauge data. Interesting new findings were obtained from the results of the present investigation and also from results reported in the literature in this respect.

Introduction.

In modern times dynamic stress analysis is becoming increasingly important for various engineering applications. Although significant amount of insight in these respects have been developed, the subject being rather intricate would continue to attract of more research workers in future.

A beam is a common structural element, and in several applications, simply supported beams with over- hang are employed in practice. Transverse and longitudinal bridge girders and chassis of rails- and road- wagons are some of the typical applications of the same. Here, photoelastic technique was employed to determine dynamic stress distributions in a model simply supported beam with over- hang.

Objective:

The present investigation was undertaken with the following objectives in view:

i) To record full-field fringe photographs using a Fastax framing camera for a simply supported urethane rubber beam model for different over- hang ratios subjected to low velocity, central- and quarter span -impact loadings employing light weight strikers. By introducing a suitable datum in the fringe photography it was proposed to determine photographically the deflection- histories for these beams.

ii) From the observations as mentioned above, it was proposed to identify the over- hang ratio which produces the most unfavourable boundary stress distributions.

iii) For achieving the objective mentioned in (ii) above, it was proposed to experimentally determine the contact force as a function of time employing a suitable transducer [14].

iv) To appreciate the material dependence of dynamic stress distributions, it was proposed to record contact force and boundary strain as a function of time in simply supported beam made of the following materials; Aluminium, PMMA and PMMA- Aluminium- PMMA composite, having geometrical similarity with urethane beam model, and subjected to central impact loadings.

v) Utilizing the data as obtained above, it was proposed to correlate contact forces and maximum tensile stress/ strain produced in simply supported beams with over- hang made of different materials and subjected to low -velocity -central -impact loadings.

The Fastax framing camera used with a framing rate of 12,000 f.p.s. (Frames per second). A goose control unit was used to synchronize the photographic recordings [12] with the event. The typical collision velocity of the striker was 1.6 m/s.

The overall dimensions of the urethane rubber beam model was 253mm x 24.3mm x 12.5mm thick. The study was conducted for three different simply supported spans, namely 90mm, 120mm and 150mm with over- hang ratios: 0.322, 0.263 and 0.204 respectively.

For the urethane rubber beam model the weight of the striker was varied between 10.5gm to 17.5gm keeping the beam/ striker weight ratio constant (2.675) and the shape of the striker cylindrical with a hemi-spherical tip made of araldite.

For determining the contact force as a function of time experimentally, two quartz- crystal-sensing elements were employed for fabricating the transducer. A suitable charge amplifier and a storage oscilloscope were used. For determining the collision velocities in these experiments a suitable photo- transistor and a light source were used for determining the contact velocity of the striker [14]. In some of these experiments the internal triggering mode of the oscilloscope was employed, where as in some of other experiments an external triggering mode was used.

The overall dimensions of the Aluminium, PMMA and PMMA- Aluminium- PMMA beams were essentially the same as that of urethane rubber beam model. The simply supported span of these beams selected for study was, however, kept at 120mm only. The collision velocities in these experiments were also essentially the same as in the case of urethane rubber beam model. The weight of the striker made of mild steel, however, was increased to 41.5gm.

Literature References

Determination of time- histories of stresses in beams subjected to impact loading is a problem of considerable, current, engineering interest. Employing the techniques of dynamic photoelasticity can make full- field analysis of such problems. Dally [1] in a paper provided a state- of- the art report on the subject. The techniques of high speed photography always associated with dynamic photoelasticity have gradually evolved through the contributions of many research workers, notably, Cranz et al. [2], Christie[3] and Tayor et al. [4].

The study of stress- histories in beams by the method of dynamic photoelasticity was reported by many workers, notably Tuzi et al.[5], Durelli et al. [6], Betser et al. [7], Goldsmith et al. [8], Kuske [9], and Clark et al. [10] and Feder et al. [11] in an early paper employed dynamic photoelasticity for studying explosion loading on specimens.

Experimental Details:

In a paper (OS01W0028) entitled "Full- field Dynamic Photoelastic Studies of Transversely Impacted Beams" author reported the details of experiments in the Advanced Technology in Experimental Mechanics (ATEM'03) conference held in Nagoa, Japan during September, 2003 [12]. For the sake of brevity the same is not reproduced here.

Conclusions:

From the results of the present investigation and also from results reported in the literature in this respect interesting results were obtained and the following conclusions [13] can be drawn:

1. For a low velocity impact employing a light striker, the over- hang has a considerable influence on the maximum contact force generated and its duration, and also on the impact stress-generated at the lower and upper boundary boundaries of the beam, primarily due to the inertia of the over- hangs.

2. Under comparable situations, the 'dynamic load amplification factor' for a beam with over- hang can be greater than that of a beam without over- hang by a factor of more than two.

3. Under comparable situations, a beam with over- hang would develop a significantly lower maximum tensile stress as compared to beam without over- hang.

4. For a simply supported beam with over- hang, the initial transient is generally short- lived and then followed by a quasi-static situation for the rest of the duration, unlike that generally happens in a simply supported beam without over- hang. Also a simply supported beam with over- hang develops a significantly lower beam deflection per unit striker weight as compared in a simply supported beam without over- hang, the impact parameters being comparable.

5. For a low velocity impact employing a light striker, the maximum contact force under quarter-span impact loadings always increases and can increase by about 10% as compared to that of

central impact loadings. This would result in the generation of slightly larger local compressive stresses under quarter- span loadings as compared to those under central impact loadings.

6. The maximum tensile stresses at the lower boundary under the quarter- span loadings always decreases and can decrease by about 30% as compared to those under central- impact loadings.

7. Out of the three beam- spans studied without changing the overall dimensions of the beams, 120 mm beam- span produced the largest tensile stress per unit striker weight both under central- and quarter- span -impact loading situations. For 120 mm beam span the duration of maximum tensile stress was also the largest as compared to 90 and 150 mm beam- spans.

8. In spite of large variations in the Hertz's constant for the aluminium, PMMA and PMMA-aluminium- PMMA beams with that of urethane rubber beam, the 'dynamic load amplification factor' recorded an increase of 27% for aluminium beam and a increase of 24% for PMMA beam as compared to that of the urethane rubber beam. The increase for the PMMA- aluminium- PMMA beam was only 1.5%.

9. Although that 'dynamic load amplification factors' were of the same order, the local contact deformations for the beams of different materials varied widely, while for the urethane rubber beam, the local contact deformation was about 2.9 mm, for the aluminium, PMMA and PMMA-aluminium- PMMA beams the same varied between 0,019 and 0.087 mm.

10. The 'gross- impulse' per unit striker weight for the beams of different materials was surprisingly vary close to each other. This varied between 0.45 and 0.52 seconds, signifying that patterns of actual force- histories for the beams of different materials were not highly dissimilar.

11. For simply supported beams made of different materials and subjected to low velocity central impact loadings by light strikers, the 'normalised maximum tensile stress' was primarily the same for the PMMA and PMMA- aluminium- PMMA beam (21) and the same for aluminium beam was considerably more (42).

12. Since the variation in the modular ratios of the beams of different materials was much wider than that of the 'normalised maximum tensile stresses', a power law seems to be an appropriate choice for establishing a correlationship between them. The exponent values for the beams of different material studied in the present work ranged between 1.0 and 2.58.

13. For establishing a correlationship between peak tensile strains and 'normalised Hertz's constants' for the beams made of PMMA, PMMA- aluminium- PMMA and aluminium, a power law may not, however, be required. Similarly for establishing correlationship between peak tensile strains in the PMMA beam subjected to different central impact loadings with 'normalised Hertz's constant', a linear law may be adequate.

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