Photoelastic Investigation on Stresses of I-Beam with a Hole under Tension*

By Heihachi SHIMADA** and Ichiro Tuzi***

The object of the work described was to obtain information about the stresses due to tension in an I-beam with a circular hole at the web, which were studied photoelastically.

Test pieces were made of epoxy resin with adhesive method. The stress concentration occurred on the hole boundary at the minimum section. The values of stress concentration of the I-beam were calculated from the values of the stress concentration with a circular hole of a beam having the equal sectional area without a flange.

Introduction

The stress distributions due to tension in the bar with a circular hole have been the subject of several studies\(^{(1)-(8)}\), but the stress distributions of an I-beam with a circular hole at the web have never been considered three-dimensionally. The two-dimensional theoretical solution of that problem was obtained by Isida\(^{(7)}\) who put the two-dimensional assumption that the ratio of the height of the flange to the width of the web was interchangeable with the ratio of Young’s modulus for flangeless beam.

If the hole of the I-beam becomes larger, it is seen that the two-dimensional assumption will not hold for the above-mentioned problem. Therefor, an I-beam with a circular hole under tension was studied photoelastically, and the stress of the boundary of the hole was obtained. The models used were made of epoxy resin with adhesive method. The observations were made by a simple polariscope.

Model construction and test procedure

The resin used for the beam was epoxy resin KT-102 (made in Japan). The flange parts were bonded to web parts by Araldite 121 which set at room temperature 20°C. Very small initial stresses were introduced by bonding. The shapes and dimensions of the models used are shown in Fig.1 and Table 1, where b’ includes the adhesive layer. To eliminate the error of each test piece, the first test was conducted on the I-beam with the smallest hole; after the first test, the hole of model was machined to a larger size. Thus, the model was tested first with the minimum radius of the hole and then with successively larger values of radius of the hole. Fig. 2 shows part of the isochromatic fringe patterns of the models in the dark and light fields, where the numbers indicate the fringe order.

Stresses on the boundary of the holes

The stresses \(\sigma_y\) on the boundary of the holes are shown in Figs. 3 and 4. In Fig. 3, \(d=6.04, H=18.00\) and in Fig. 4, \(d=2.03, H=17.92\), where \(\sigma_y\) is pure tension stress=\(P/(2b+2Hd)\), and dotted lines indicate the stresses on the boundary of the holes in the beams without flanges, \(r/b=0.4, 0.5\) respectively. From these curves, it is seen that \(\sigma_y\) of the I-beam and flangeless beam have a similar tendency.

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Fig. 1 The shape of the model
(a) Isochromatic fringe patterns. \( d = 2 \text{ mm}, \ H = 12 \text{ mm} \)

(b) Isochromatic fringe patterns. \( d = 2 \text{ mm}, \ H = 12 \text{ mm} \)

Fig. 2
To compare the maximum stresses of the I-beam with a hole and of the flangeless beam with a hole, an equivalent width is considered, where $b_p = b' + Hd/h$ as shown in Fig. 5, in which, area A equals to area B. Figs. 6 to 8 show the maximum stress $\sigma_m$ versus $\beta$, $d = 6, 4$ and 2 respectively, where $\beta = r/b_p$, $\alpha = \sigma_m/\sigma_a$. In these figures, the curves are values of $\alpha_\beta$ which can be calculated from the stress concentra-

---: the values of the flangeless beam, $r/b = 0.4$

Fig. 3 Stress distributions on the boundary of the hole, $d = 6.04, H = 18.00$

---: the values of the flangeless beam, $r/b = 0.5$

Fig. 4 Stress distributions on the boundary of the hole, $d = 2.03, H = 17.92$

Fig. 5 Sketch showing the equivalent width

Fig. 6 The maximum stress $\alpha$ versus the equivalent width, for $d = 6$

Fig. 7 The maximum stress $\alpha$ versus the equivalent width, for $d = 4$

Fig. 8 The maximum stress $\alpha$ versus the equivalent width, for $d = 2$
Fig. 9 shows the values of $\alpha/\alpha_0$ for $\beta$ and the values of $\alpha/\alpha_0$ distribute in the neighborhood of unity. From these results, it is seen that the maximum stress of the hole boundary of the I-beam under tension equals to the maximum stress with the same circular hole of the flangeless beam having equal sectional area. One of the authors formerly researched "stresses of the resin bar with metal reinforcement on both sides having a hole under tension" and the results showed that as the radius of hole becomes larger, the values of the maximum stress become smaller rapidly, but the results with I-beam show a different tendency, therefore the calculating method assuming that the ratio of the height of the flange to width of web is interchangeable with the ratio of Young's modulus, is not applicable to the I-beam problem except in the small range of the hole radius.

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References