

# DESIGN OF BENT CAPS FOR CONCRETE BOX-GIRDER BRIDGES

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## ABRIDGMENT

Design recommendations for integral bent caps in straight, continuously reinforced concrete box-girder bridges were developed from the results of an experimental and analytical investigation. The results indicate that, in design, flexural reinforcement reductions of up to 40 percent can be made without reducing safety or adequate serviceability.

•DESIGN recommendations for integral bent caps in straight, continuously reinforced concrete box-girder bridges were developed from the results of an experimental and analytical investigation. The investigation was to determine whether certain assumptions and working-stress design methods in use in 1970 required more flexural reinforcement than necessary. This paper briefly summarizes the investigation and design recommendations. Further details are available elsewhere (1, 2, 3).

The results of the investigation indicate that, in design, flexural reinforcement reductions of up to 40 percent can be made without reducing safety or adequate serviceability. Even greater reductions in the amount of reinforcement can be made for bent caps with flared columns. Most of this improved economy results from changing from the working-stress to the load-factor method of design.

## INVESTIGATION

Studies were conducted on distribution of loads on the bent cap, effect of flaring the column in the plane of the bent, effective flange width of the bent cap in tension and compression, effect of spreading main tensile reinforcement into the adjacent superstructure, and location of critical design sections.

Experimental tests were conducted on two  $\frac{1}{5}$ -scale models of complete box-girder bridges, four  $\frac{2}{5}$ -scale models of single-column bent-cap portions of the bridges, and one  $\frac{1}{5}$ -scale model of a double-column bent-cap portion of a bridge. The model of a complete bridge with a single-column bent is shown in Figure 1.

Analytical studies included development of 2 computer programs. One used the elastic folded-plate method to predict the load-carrying mechanism of the complete bridges. The other used the finite element method to simulate in detail the behavior of the bent cap. Details included simulation of cracking of concrete and yielding of reinforcement.

## TEST RESULTS

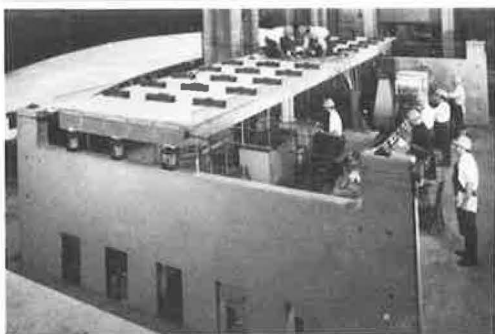
Results from tests of the 2 complete model bridges indicated that, at loads approaching

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Figure 1. Model single-column bridge ready for test.



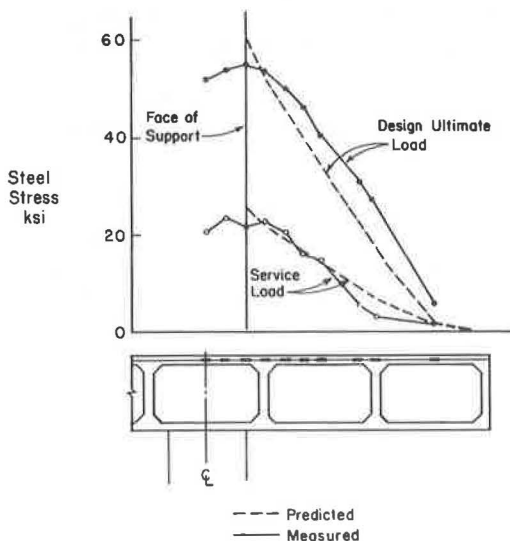
effective as supports. Stresses induced in the concrete of the flare itself were not excessive. Reinforcement stresses in the bent cap were comparable with those at corresponding locations in a specimen with a cylindrical column. On the basis of these results, we recommend that all flares up to 45 deg be considered effective supports. Similar provisions already exist in building codes.

Existing provisions for compressive flange widths in box girders, restated for overhanging flanges, were found to apply to bent caps. For tension flanges, we recommend effective widths similar to those for compression flanges if the effective overhanging flange width is limited to a fourth of the box web spacing. This width ensures that reinforcement will not be overstressed by secondary effects.

The effectiveness of flexural reinforcement was found to diminish rapidly with increasing distance from the bent-cap web. However, we recommend that reinforcement that is spread only to the limits of the effective flange width in tension be considered completely effective.

The critical design section for negative moment in the bent caps was found to be at the face of the support. This section is the intersection of the extremity of the effective support with the bottom of the bent cap. The critical design section for positive moment was found to be at mid-span of the double-column bent.

Figure 2. Measured and predicted stresses in bent cap.



1 ksi =  $6.89 \times 10^6$  N/m<sup>2</sup>

ultimate, little load was transferred laterally from girder to girder. Analytical results, based on elastic material properties, predicted a somewhat greater lateral distribution of load. However, with or without this distribution, moments in the bent cap were found to be essentially the same. On the basis of these results, we recommend that the current design assumption of no lateral distribution of load be used.

Two bent caps with flared columns were tested; one had a flared support surface forming a 45-deg angle with the vertical, and the other had an intermediate flare forming a 27-deg angle with the vertical.

Both flared columns were found to be fully

For each of the bent-cap specimens, steel stresses predicted according to the recommendations in the report were compared with those measured. Representative results are shown in Figure 2 for the specimen with a single cylindrical column.

Comparisons were made at service and design ultimate load levels. At design ultimate load, measured stresses near the end of the bent cap exceeded predicted stresses. This is a familiar effect of diagonal cracking, which traditionally is accommodated by extending reinforcement beyond theoretical cutoff points. Near the face of support, measured stresses were lower than those predicted.

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The opinions and conclusions expressed or implied in this report are those of the authors. They are not necessarily those of the Transportation Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, or the individual states participating in the National Cooperative Highway Research Program.

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