TECHNICAL NOTE

CYCLIC TESTING OF A HAUNCHED REINFORCED CONCRETE BEAM

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INTRODUCTION

This is a summary report of recent testing of a haunched reinforced concrete beam at the Ministry of Works and Development Central Laboratories. The testing will shortly be reported in greater depth in Ministry of Works and Development Central Laboratories Report No. 5-79/2.

Seismic design philosophy of reinforced concrete frames generally assumes that critical components will experience large inelastic cyclic rotations without significant loss of strength. A full size model of the haunched beam/column joint proposed for the William Clayton Building in Wellington was tested under cyclic loading primarily to investigate:

1. the beam plastic hinge formation within the haunch,
2. the behaviour of the positive moment flexural steel at the haunch root, and
3. the performance of the stirrups, and in particular the ties at the haunch root.

As the object of the test was to investigate the effects of the haunches, the beam/column joint region was not investigated. This enabled a simple beam test to be done.

The haunched beams are typical of those in the second floor of the four-storey two-way reinforced concrete moment resisting frame building (Fig. 1). The beams were haunched to provide additional clearance for services.

TEST PROCEDURE

The test beam was a full size model of two half-bays of typical transverse interior beams and a column stub for the William Clayton Building. The prototype transverse beams span parallel to the one way precast floor system so the beam gravity shears and moments are negligible. Vertical jack loads were applied on the column stub of the simply supported model, (Fig. 2c) and measurements taken of applied load, beam deflections and rotations and reinforcement strains. The location of the supports on the test beam correspond to midspan of the prototype beams, and thus are at the points of contraflexure of the prototype beams under seismic loading. However, under seismic loading the beam moments are of opposite sense and resisted by equivalent column moments whereas the test arrangement allows only for continuity of beam moments, and no column moments

(Fig. 2d). Thus the test is adequate for testing beam strength and ductility under seismic load, but does not test the bond of either beam or column bars in the joint, the shear strength of the joint or check that the flexural strength of the column exceeds that of the beam. Although the investigation was limited by the test arrangement it was adequate for the specific purposes of this test, and gave a significant reduction in the test cost.

Previous testing had provided information on the joint and column behaviour^(2,3).

Load during the initial cycles on the beam was applied up to a level to induce a theoretical maximum of strain of $\frac{3}{4}$ the yield strain in the reinforcement at the most critical location, with the vertical deflection at the centre of the beam being measured. This enabled a deflection corresponding to a ductility factor (DF) of 0.75 to be obtained and, by proportion, a theoretical deflection at DF = 1.0. During subsequent cycles the beam was deformed up to predetermined central deflections depending on the ductility factor, DF, where :-

$$DF = \frac{\text{Maximum deflection}}{\text{Yield deflection}}$$

The location of the theoretical first yield of the longitudinal reinforcing was at the haunch notch with upward load, and the beam/column junction with downwards load.

TEST RESULTS

The maximum applied load exceeded the theoretical maximum based upon measured material properties, including strain hardening of the steel, by 2% for upwards load and was 5% less than the theoretical maximum for the downwards load.

Excellent behaviour was exhibited by the test unit with stable moment-deflection loops still being achieved at DFs as high as 18. Plastic hinging extended throughout the haunch region of the beam and for a distance of about the beam depth beyond the haunch notch.

At each increase in applied deflection the number of cracks, crack widths and crack propagation progressively increased, eventually forming a network pattern. No spalling occurred before DF 10 and most of the cover concrete was still intact at DF 18, at which stage the maximum crack width was 12 mm, recorded approximately in the middle of the haunch.

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of the unit at various stages in the test are shown in Fig. 3. A graph of the applied load against measured vertical deflection is shown in Fig. 4 and a graph of applied moment against measured curvature for a zone in the haunch region is shown in Fig. 5. The "fatness" of the hysteresis loops, total absence of any "pinching" effects, and small load reduction on repetitive cycles and the continuing increase in load at each increase in ductility factor indicate the excellent energy absorbing capacity and small amount of degradation of the beam. No buckling of the longitudinal bars occurred and stresses measured in the stirrups in the haunch did not exceed more than half the yield stress suggesting that less vertical reinforcing could be provided. During construction of the beam, the U-shaped stirrups at the haunch notch were pulled up and welded tight, but in general the remaining stirrups were a loose fit. Their adequacy in restraining the longitudinal reinforcing may be attributed to the cover remaining relatively intact due to the large spread of the plastic hinge zone which eliminated local regions of high strains.

DISCUSSION

The maximum ductility factor, $DF = 18$, is considerably greater than the typical maximum $DF = 8$ obtained from tests using uniform beams⁽²⁾. The detailing of the steel in the haunch root was also found to be adequate but future testing should investigate the performance of ill fitting stirrups in this area.

It is likely that the geometry of the haunch which enabled the section capacity to closely follow the seismic bending moment diagram, and the absence of gravity shears and moments had a major influence on the performance. Further research should investigate the effects of the haunch geometry and increased shear stress.

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REFERENCES

1. L. M. Megget, "Analysis and Design of a Base-Isolated Reinforced Concrete Frame Building". Bulletin of the N.Z. National Society for Earthquake Engineering, Vol. 11, No. 4, December 1978, pp 245-254.
2. Blakeley, R.W.G., Megget, L. M. and Priestley, M.J.N., "Seismic Performance of Two Full Size Reinforced Concrete Beam-Column Joint Units". Bulletin of the N.Z. National Society for Earthquake Engineering, Vol. 8, No. 1, March, 1975, pp. 38-47.
3. Beckingsale, C. W., "Post Elastic Behaviour of Reinforced Concrete Beam-Column Joints". PHD Thesis under preparation. University of Canterbury.

FIGURE 1: REINFORCING DETAILS OF TEST BEAM

FIGURE 2: LOADING ON PROTOTYPE AND TEST BEAM

(a) Test Unit at Maximum Downwards Deflection

(b) Test Unit at Maximum Upwards Deflection

(c) Crack Pattern in Haunch Zone at $DF = 4$

(d) Crack Pattern in Haunch Zone at $DF = 18$

FIG. 4 APPLIED LOAD VS VERTICAL DEFLECTION AT COLUMN STUB

MEASURED MOMENT-CURVATURE ZONE TWO

FIG. 5 MEASURED MOMENT CURVATURE RELATIONSHIP WITHIN HAUNCH ZONE