TESTS WITH CLAMPED BEAMS*

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A most frequent structure of buildings is clamped beam, nevertheless subject to a full uncertainty in design. In the following, a rather unique test, likely to throw light on this problem, will be presented, and some theoretical principles on the design of clamped beams will be established.

The Municipal Council of Public Works performed official load tests on a novel-system floor structure. Beams of this structure exposed to ultimate load differed from the usual joists by being clamped into a concrete or reinforced concrete cornice in the surrounding wall; accordingly, the steel or reinforced concrete beams can be considered as perfectly embedded and designed as such, that is, at the mid-span section, one third of the moment on the simply supported beam has to be reckoned with. At the same time, there are various means to provide for absorbing the two thirds of moments arising at the clamping. For the structure exposed to the load test, the excess tension in the beam top is absorbed by the reinforcement embedded in the concrete surrounding the beam, while the lower r.c. slab will act as a compressed flange.

Several questions arise in connection with the correctness of this arrangement:

1. Whether such an embedment may be assumed to be complete, and if not, then what degree of embedment may be reckoned with?
2. Is there an interaction between concrete and steel I-beam, that is, does the bond between concrete and steel beam hold?
3. Is it permissible to design the additional reinforcement for the excess moment arising at the beam edge (one third of the maximum moment of the simple beam), that is, is it permissible to assume a moment distribution half by half on the steel beam and on the r.c. beam?

Two r.c. beams have been tested, both embedded into coherent concrete beams of wall thickness at floor level. Deflection has been measured at five spots though of uneven distribution imposed by the scaffolds, arranged as seen in Fig. 1. Support rotations have also been measured by means of a level; for beam 1 it was placed on the cornice on the left-side support, and for beam 2 at 15 cm from the left-side wall. Since cracks have been encountered more than 15 cm away from the wall, also level on beam 1 may be assumed to have indicated the rotation at the support.

The loading process and the phenomena at failure were the following: to place a course of bricks lasted about 6 minutes; no pauses were left except at reading off.

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* Details from the article published in the journal Betonszemle, Vol. II, (1914) pp. 68—71, 83—87, 101—104 (in Hungarian).

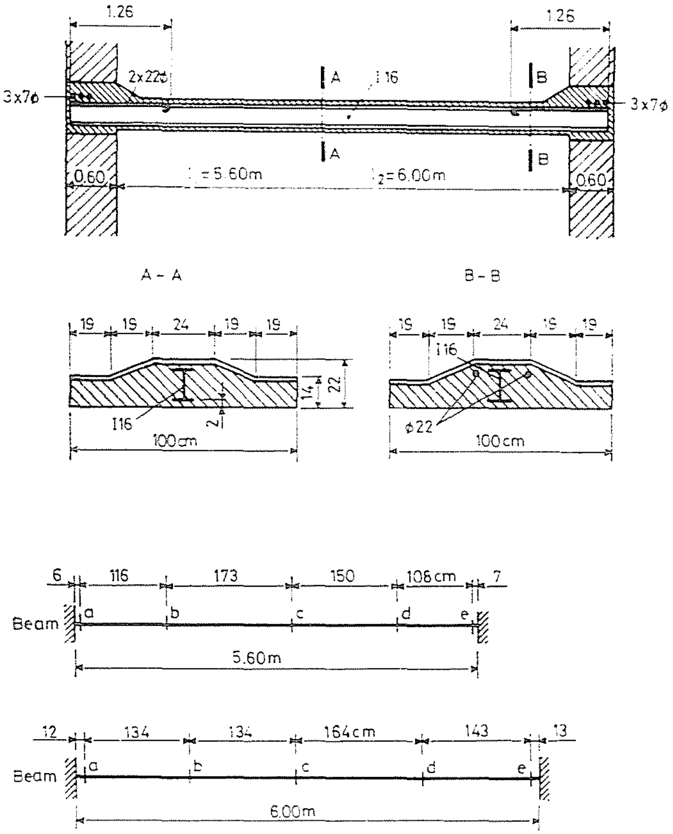

Fig. 1

With 18 courses of bricks on, beam 1 exhibited a fast growing crack in the tailing; after 20 courses, the first crack at mid-beam appeared, after 22 courses the level bubble took on moving; after 24 courses also deflection meters showed constant deflection, during a rest of 10 minutes the deflection rate did not decrease, at 28 courses the beam subsided on the scaffolding, meanwhile at one embedment the steel beam crushed the concrete cornice, and it even would destroy the underlying brick vault, were it not underpinned in advance.

Beam 2 cracked only at the tailing under 18 brick courses, while at mid-beam, no crack appeared before 20 courses.

After unloading, steel beams were unbedded; steel beam 2 had three curvatures: at both embedments, about 5 cm from the wall plane, and at 15 to 20 cm from the middle section of the beam. Beam 1 did not curve at the tailing where the vault ceded. Complementary reinforcement did not exhibit any sign hinting to the stress level, or slip inside the concrete.

It was interesting to see the failed beam to have also been curved at the tailing although here the calculated steel stress was lower than the yield point.

This fact shows that *a clamped steel beam cannot undergo increasing deflections else that with three spots at the yield point. These spots can be considered to contain hinges.* One or two hinges in a clamped beam still leave it load bearing, namely the part between the two hinges acts as a simple beam, and the parts outside it as simple cantilevers. But with three hinges increasing displacements occur. Actually, there is no real hinge. The steel tensile diagram is known to point out the yield point, a stress where the steel undergoes increasing strain under an about constant load. In bending, the beam may also be bent by a moment constant for a while, to increase only after a given deflection. (By the way, this is not perfectly true, the moment has to continuously but slightly increase.) This means that at a moment of the tailing or even at the middle of an embedded steel beam eliciting the yield point the beam could bend but because of the principle above increasing deflections cannot develop. What does happen at further load increase? The cross sections referred to could absorb a higher moment only after a deflection of a given value that, however, cannot take place. Thus, under further loads the beam will act as if it had hinges at the given cross sections, that is, at these cross sections the moment will remain as high as at the yield point (at a slight increase). The load can further be increased until the yield point has been reached at a third cross section, and then increasing displacements will develop.

This means, at the same time, that the degree of clamping is irrelevant.

If a steel beam has to be designed for a given load, then at mid-span a cross section can be assumed and its moment capacity should be calculated, leaving the rest of the moment determined on the simply supported beam to the tailings. If this latter moment cannot produce yield in the steel, the steel beam will not fail under the given load.

Thus, rather than for a moment $\frac{pl^2}{12}$, a clamped steel beam could be designed for a moment of $1/2\,\frac{pl^2}{8} = \frac{pl^2}{16}$ even if its ends are free to rotate to a certain degree.