Excess Capacity in Historic American Reinforced Concrete Floors

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ABSTRACT

The introduction of reinforced concrete as a structural material into American structural practice circa 1900 created unique challenges in design and analysis. Engineers and builders had to simultaneously determine the proper constituent materials for the concrete, the relation between materials proportions and strength, and formulas for sharing load between steel and concrete. Early on there were only local building codes, which often treated concrete as masonry. This was followed, starting in 1909, by the reports of the "Joint Committee" which served as a de facto national code for concrete; the first version of the American Concrete Institute code was published in 1941 and has been updated regularly since.

All of the early codes, and specifically including the Joint Committee report and the ACI code, used allowable-stress design with a linear-elastic model of flexure. Load and resistance factor design using an ultimate-strength model was first introduced in the US as an alternate method in the 1956 ACI code, was elevated to equal status with the 1963 code, and made the standard method with the 1971 code with the linear-elastic allowable-stress model left as an alternate. Given that the ultimate-strength model is generally accepted to provide more accurate representation of flexure in reinforced-concrete, the allowable-stress alternate received little use after the transition period.

Many details have changed minimally since the 1910s, including provisions for T beams that take advantage of the slab for additional compression flange area. The provisions for calculating shear capacity in both concrete and web reinforcing changed minimally except for the transition from allowable-stress to load-and-resistance-factor design.

Re-analysis of extant concrete structures designed before the 1956 code changes generally shows a pattern of significant excess capacity in flexure and limited excess capacity in shear. For members that are generally not controlled by one-way (beam) shear (two-way slabs and one-way slabs) the increase in flexure capacity governs; for members where one-way shear is a controlling factor, the small increase, no change, or decrease in shear capacity governs.

Much of the current literature on evaluating the capacity of extant concrete structures focusses on strength degradation from material changes such as rusting rebar and from overall material changes such as carbonation. The presence of excess capacity should also be considered, and it is possible based on review of the governing codes and design methods to determine general patterns as to how much excess capacity may be expected.