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Why do designs by different structural engineers vary so greatly?

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Structural design is a science as well as an art. So, designs by different structural engineers are expected to be different in terms of planning of structural systems, steel consumption in reinforced concrete (RC) members and in their detailing aspects. But, as structural analysis is based on the mathematics of the theory of structures and the structural design in IS 456 : 2000, the results of a given structural design must not vary greatly[1]. But, in practice, it is observed that vast differences exist in designs of similar buildings by different engineers. This aspect is quite disturbing to all concerned, particularly to a client. This is not a happy situation, from a professional standpoint. There are many problems in the planning, analysis and design of buildings, some of which are discussed below.

Problems

Planning

For houses and small buildings (say upto four storeys), load-bearing brick walls with RC floors give an economical and efficient structural system. For taller buildings, RC frames in both the principal directions need to be provided, with brick walls acting as filler walls. It is not easy to decide in a given case, whether load-bearing brick walls or frames will be appropriate. This is one of the reasons for differences in design results. Further, frames have to be provided in the two principal directions to resist horizontal loads due to wind or earthquake, which may act in any random direction. But the author has come across an existing building with frames in one direction supporting one-way slab system with no beams in the longitudinal direction. This building is vulnerable when wind or earthquake acts in the longitudinal direction. Likewise, for still taller buildings, shear walls are required to be provided which will interact with frames in resisting vertical and horizontal loads. However, some designers may consider only shear walls to resist horizontal loads, neglecting the interaction of shear walls with frames. Buildings under horizontal loads behave as one unit, so 3-D analysis must be employed for correct results. Some engineers may adopt 2-D analysis in each principal direction or may even consider only one frame under horizontal loads and superimpose this analysis on other frames too, thereby giving scope to considerable error in the results.

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Analysis

In small buildings with load-bearing brick walls, it is fair to assume that wind or earthquake forces will be resisted by brick walls by way of box-action in plan. In other words, brick walls act as shear walls in resisting wind or earthquake loads. In small buildings upto four storeys, a twin-system of frames with filler walls can also be considered, wherein vertical load is resisted by frames and horizontal load by filler walls acting as shear walls. This system will lead to a good reduction in steel consumption in buildings. In framed buildings, the effect of floor slab on the moment of inertia of beams should be considered by which moments in columns work out correct and reasonable, leading to an efficient column design. In practice, many engineers do not consider this aspect even in computer analysis, thereby leading to incorrect and expensive column design.

Design

Footings are designed as inverted floors loaded with uniform soil pressure from below. For reducing steel in footings, concrete depth is kept on the high side. Raft foundations may profitably be designed by the method of modulus of sub-grade reaction which gives a variable loading of soil pressure from below.

Column reinforcement is very sensitive to moments acting on a column section about the two principal axes. Some designers may design columns only for axial load, neglecting moments altogether. This approach gives minimum steel in columns but it leads to unsafe design. The code requires all columns to be designed with the minimum eccentricity moments or moments due to continuity with floor beams, whichever is more[1]. Some designers consider only one moment with axial load. The correct position is to consider axial load combined with biaxial bending. Further, slenderness effects in columns must not be neglected. Slender columns consume more steel and these should be carefully designed. Hollow columns should be checked for both the global and the local buckling effects. Some designers use a method of equivalent axial load[2]. But this is an approximate and crude method and it cannot replace the exact methods available to designers[3,4,5]. Moments in column design should be reduced in order to achieve reduction in column reinforcement. In beam design, support moments should also be reduced to get some reduction in steel over beam supports. In computer programs currently in use, centre-line moments are used for design, leading to more steel over support sections, The depth of beams is kept on the high side, to reduce steel consumption in beams and its width is kept on the low side, to reduce dead load of beams, but it should be adequate for shear and placement of bars in one or two layers for efficiency.

In slab design, slab thickness should work out less in order to save on the dead load which ensures economy in the design of beams, columns and footings. More steel should be provided at midspan, in order to satisfy deflection requirements of thin slab panels[6]. Engineers, unaware of the above fine points of design, may produce costly or unsafe designs.

Columns loads

Column loads can be computed by the following three methods.

(*i*) 3-D analysis by a computer program

(*ii*) tributary area method[7]

(*iii*) method of beam reactions.

These methods lead to reasonably correct values. These column loads are then used for design of columns and footings. Some designers, under pressure of time, use thumb rules for calculating column loads, for example 1.5 t/m^2 of covered area for an interior column, 2.0 t/m^2 of covered area for an exterior column and 2.5 t/m^2 of covered area for a corner column. These column loads are then used for column and footing design. This is not a correct procedure. It is similar to a mason's design. It is not fair to the client and it is against professional ethics.

Conclusion

Structural engineers are paid to produce safe and economical design of buildings. However, safety is the paramount requirement of good structural design and it must not be compromised with, in order to achieve economy. A structural engineer must bestow equal attention to all structures in hand, whether small or large. His approach should be strictly professional and he should exert his utmost to produce a satisfactory design in all respects. With professional commitment, the results of structural design by different engineers will not vary significantly in analysis and design aspects. In respect of planning and detailing aspects, some new concepts are expected from inspired and gifted engineers.

References

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