

The Impact of Prevailing Structural Design Trends on the Cost of Building Construction

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Abstract

High rental rates, especially in urban areas, has lead to a big mismatch between the demand and supply in the housing market in the country. Building owners cite the high lending rates on housing loans by the banks for pegging rents that is beyond the affordability of most average seekers of accommodation.

This unfortunate scenario of owners not getting the right tenants and tenants not finding affordable houses begs a much deeper question beyond the lending rates from the banks and into the factors affecting the actual cost of construction in the first place. Of the various factors affecting the cost of construction, the structural component is a major cost contributor, amounting to as high as 40% of the building cost in certain cases.

The vagaries of market forces such as inflation and labour wages is not within the control of any single individual and outside the scope of this paper. Structural components being a major cost driver, this paper examines the optimality of the prevailing structural design trends in the country.

1- The Housing Market Paradox

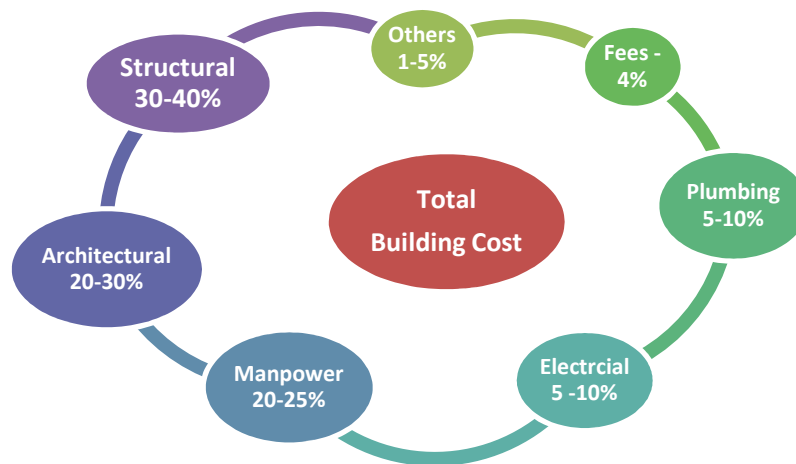
The irony in the rise in supply not resulting in the fall in the rental charges of the houses/apartments in Thimphu has recently headlined in the national newspaper titled *"Is Thimphu only for the Rich"*. Despite the urban sprawl and the proliferation of new buildings, people are facing difficulty finding "affordable" accommodation. This has led to a big mismatch between the demand and supply in the housing market. Incidentally housing loan is among the major non performing loans in most of the banks.

The newspaper however, bought into the house owner's diagnosis of high lending rates from the banks as the cause for this mismatch and conveniently purported *"it Starts with the Banks"*. While higher lending rates does compel the owners to peg rents to cover the commensurately higher monthly EMI's, this peculiar scenario of owners not getting right tenants and tenants not finding affordable houses begs a much deeper examination on the factors affecting the cost of construction.

Of the various factors affecting the cost of building construction, the structural component is a major cost driver amounting to as high as 40% of the final cost in some cases. Given this high stake, how optimally a building is designed will have a huge bearing on its final cost and in this sense *"it all Starts with the Designer"*. The optimality of the structural components of buildings build in a major urban area is examined and presented in this paper.

2- The Cost Break -Up of a Building

The morphology of the building has a huge impact on the cost of the building. The plan shape and size of the building, the framing grid alignment and spacing, wall to floor ratio, degree of circulation space, storey height and total height are some of the key morphological aspects which impacts the cost. The choice of the architect and designer is therefore a key decision in the process related to the quality and cost of the building project. In so far as the key functional components of the building is concerned, the major contributor of cost and their general cost factor by percentage of the total building cost for a typical reinforced concrete building is depicted below.



3- What are Buildings Designed for - Structurally?

The structural system of a building much like the skeleton system in a human body, is what keeps the building upright and stable. The system has to withstand and defy gravity so that the fifth floor and its occupants does not come crumbling down on top of the ground floor. The self weight of the building and the weight of all the occupants and "their stuffs" are what constitutes the gravity load. The systems has to also withstand and remain stable under the impact of lateral loads. Two major source of lateral loads are the wind and earthquakes.

Lying on one of the seismically active regions in the world does warrant the need to consider earthquake loads in the design. For the want of our country specific seismic hazard data/parameter, an Indian code for earthquake loading is imprudently adopted. The consequence being, we are either over preparing or under preparing our buildings for a major seismic event that may or may not befall our cities. Either of the scenarios is not ideal as under preparing would spell disaster and over preparing means all the extra cost and effort for nothing. Anyhow, until such time a country specific seismic hazard data becomes available, the current "better safe than sorry" approach by adopting the most relevant Indian codes does seem like a wise option given the proximity of our territory and the similarities in the construction and material standards and practices. The effect of wind on low and mid rise structures, like the ones permitted in our country by due to the building height restriction, is not very critical and as such not taken into account. And in any case, once the earthquake loads are considered it is not necessary to

also consider the wind loads. This relaxation seems to have been however wrongly applied as evidenced by the repeated failure of roofing systems of buildings all over the country during windstorm season.

4 - Optimality of the Structural Components

The assessment of the design of the various structural component of a case study sample reinforced concrete structure building in a major town is presented in the table below.

Structural Element	Component	Provided	Required	Optimality Factor	Cost Implication factor
Roof Truss	Tubular Steel Section	6.21kg/sqm	3.1kg/sqm	0.49	2.04
Slabs	Rebar	14.11kg/sqm	6.15kg/sqm	0.43	2.32
Beams	Rebar	17.2kg/rm	14.43kg/rm	0.83	1.20
Columns	Rebar	46kg/rm	20kg/rm	0.43	2.34
Footings	Rebar	17.6kg/sqm	14.04kg/sqm	0.79	1.25

On average, a cost implication factor of 1.83 is "surcharged" onto the steel rebar used in the case study building analyzed. Study on a couple more sample buildings also revealed a cost implication factor in and around the same range. Anomaly in the volume of concrete consumed based on the section dimensions provided and what is optimally required for the design loading regime considered are also observed. And likewise the instances of incorrect detailing and positioning of rebar. Such erroneous detailing not only entail unnecessary cost implication but could also undermine the overall structural integrity and safety of the members.

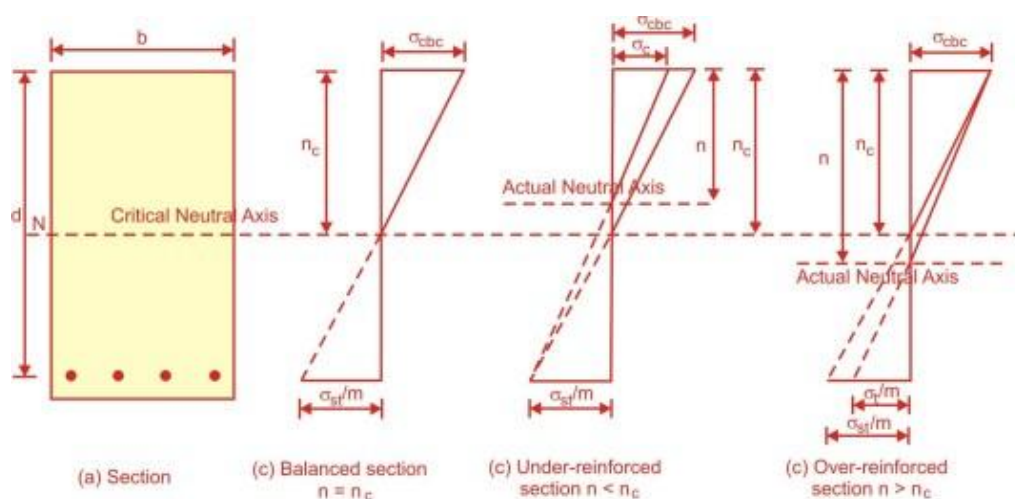
The findings here are based on a study of three sample buildings and as such a mere indicative of a trend rather than a definitive conclusion. More such analysis is of course warranted to come to a statistically credible conclusion on an underlying oversight in the design practice trend of "overdesigning" structures in the country.

5- Over Designed Structures ?

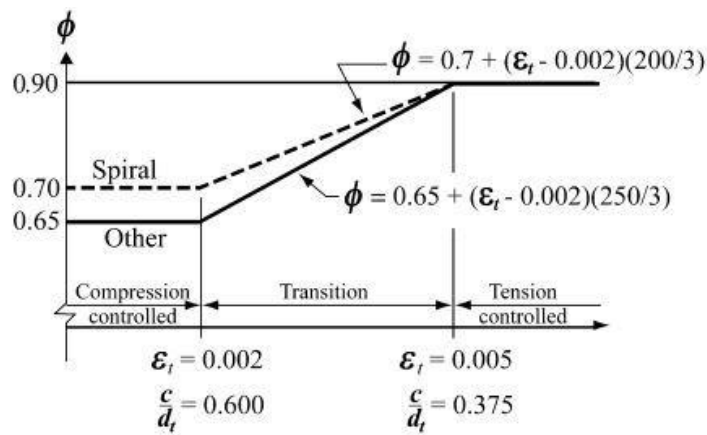
The proof of a good design is not only strength but also economy, besides so many other things. And given the burden of an ever rising cost of construction, it becomes all the more duty bound on the part of the designer to uphold the ethos of the profession and not forget the fundamental purpose of design. Behind the black lines and dots of a building drawing on a white paper is a design process that is largely a black box to the uninitiated building owners/client. Camouflaging our incompetence or irresponsibility under the veil of over designed structures without consideration on its ramification on the cost as well as the safety of the structure is not only a betrayal of the client's faith but is also a disservice to the honour and dignity of the profession.

"A note on over reinforced structure"

Incorrect detailing and placement of rebar and over designing of members, besides its needless cost implication, could lead to what is known as an "Over reinforced section (Compression Controlled)" - a cardinal sin in reinforced concrete design. If push comes to shove and the building must really meet the unfortunate state of its collapse limit state, like probable in an event of a major earthquake, the whole design approach is formulated so as to result in a gradual and extended damage of the members and not in an abrupt and sudden rupture. Designing and detailing members to be "under reinforced (Tension controlled)" is key to fulfilling this very important design objective.



As depicted in the sketch above and the figure below, over reinforced section would result in the concrete capacity being exceeded before that of the steel rebar, giving rise to the possibilities of a sudden and abrupt failure of the members as would be the case in the crumbling of the concrete, thereby endangering the lives of the occupants.



Interpolation on c/d_t :
 Spiral $\phi = 0.70 + 0.2[(1/c/d_t)-(5/3)]$
 Other $\phi = 0.65 + 0.25[(1/c/d_t)-(5/3)]$

Source - ACI 318

6- Recommendation and Conclusion.

As stated earlier the findings of the study is not a definitive conclusion on the state of prevailing design practices in the country but rather an indicative of a trend based on the cases being studied. It nonetheless does reveal that on the buildings that were studied, the owners did incur almost 80% more on the steel and rebar's than was actually required besides the possibilities of having violated a very fundamental tenet of reinforced concrete design principle.

Juxtaposing such trends to the housing market troubled by a mismatch in demand and supply due to house seeker not able to afford the high rents and loan defaults due to owners not being able to generate the EMI's, does call for a serious introspection on the role and responsibility of the "designer" in this larger schemes of things and also into the overall state of affairs in the profession.

The CDB's initiative to establish an Engineering Council to vet on the competency and inculcate professionalism in the engineering profession does seem very timely and necessary.

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