International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Analysis and Design of Steel Building and its Comparative Study with Conventional RCC Building

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Abstract: ***This study reviews the analysis and design of steel members or sections to use in construction of apartment buildings, and its comparative study with conventional RCC structure. Nowadays the construction sector is exploring rapidly and it also involves new structural systems for fast and precise work on the field. During the recent decades, our society has been continuously experimenting with newer techniques and alternative materials. In a study it is found that the two major aspects for which all these alternatives get researched are Speed of Execution and Economy of Project. So we want to have a comparative study of steel apartment buildings with conventional RC structures. In the present work a G+5 story apartment building whose ground floor is considered as parking, which is situated in earthquake zone-II. The provisions of IS: 1893 (Part1)-2016 is considered using commercial software for the analysis of models. The design works will be carried out using IS: 800-2007 and IS: 456-2000 for steel structural system and RCC respectively. As the building considered for the design is a G+5 storied building, it is more an earthquake load dominating rather than a wind load. So keeping the wind analysis deprived the building is analysed for various combinations considering earthquake load. As earthquake forces are associated with inertia, they are related to the mass of the structure and so reducing the mass inevitably leads to lower seismic design forces. Indeed some steel structures are sufficiently light that seismic design is not critical. Equivalent Static Method of Analysis and Response spectrum analysis method are used for the analysis of both Steel and RCC structures.***

Keywords: Steel, reinforced concrete, precise work, speed, economy, commercial, residential, earthquake, development, strength, consumption, proficiency

1. Introduction

Traditional building materials like concrete raise environmental concerns due to high embodied carbon. In contrast, steel offers a sustainable alternative. This study explores the potential of steel construction for apartment building in India, a nation experiencing rapid development. While steel dominates industrial construction, its use in residencial and commercial sectors remains limited. This research aims to bridge this gap by analyzing the viability of steel for apartment buildings, focusing on its environmental benefits like recyclability and lower CO2 emissions.

Rapid urbanization necessitates faster construction methods for residential buildings. This study compares the construction speed of steel and reinforced concrete (RC) for G+5Apaertment buildings in a mid sized city like Jalna. While RC Construction is the traditional method, steel structures offer the potential for significant time saving. This research investigates the time difference between these two methods, considering a typical building layout with parking on the ground floor and identical upper floor.

Building projects often face pressure to minimize costs. Construction speed plays a crucial role in achieving this goal, as faster completion translates to lower indirect costs. This study compares the construction timelines for G+5 apartment building in Jalna using two methods conventional reinforced concrete (RC) and steel structure. While offers significant potential for time savings. This research investigates the impact of construction speed on indirect costs, focusing on the difference between the typical 14month timeframe for RC construction and the potential 5month timeframe achievable with steel structures. By analyzing this disparity, the study aims to highlight the economic advantages of steel construction for multi-story residencial building.

2. Cost Details

This research compare the overall building cost, which includes both direct and indirect cost.

a) Direct Cost

This study analyzes the direct costs associated with both stell and RC structural systems for the building. Direct costs encompass the materials used for the core structural elements. When these materials are excluded all other materials for both the systems are nearly equal e.g., wall material, flooring material, paints and other finishing items. The rates of the core material are assumed from the practical approach.

We estimate the total quantity of each core material for both systems. Established unit rates are then applied to these quantities to determine the individual material costs. Finally, The summation of these costs provides the total direct cost for each structural system. A separate table will be presented outlining the unit rates for each core material, facilitating a clear cost comparision between RC and Steel construction.

Table 1: Basic Rates of Core Materials

Basic Rates			
S. No.	Particulars	Rates	Unit
1	Deck Sheet	400	Cum.
2	Structutal Steel + Fabrication+ Erection	65000	Tonnes
3	Concreting	7000	Cum.
4	Steel Reinforcement	60000	Tonnes

1) Direct Cost of Conventional RC Building:
For this type of building only two core materials are considered i.e. concrete and reinforced steel. Firstly the quantity of concrete is worked out for all structural members. And the quantity of reinforced steel is calculated by assuming 80 kg/cum (80 kg of reinforced steel for every cum of concrete). Table below will show the total core material cost for conventional rc building.

Table 2: Estimate of RCC Building

ABSTRACT SHEET					
Name Of Work : Apartment Building (RCC) for Mtech Project					
RCC Work					
Sr No	Particulars	Quantity	Rate	Unit	Amount
1	Concreting	1029	7000	cum	7200579
2	Reinforced Steel	82	60000	Tonnes	4937540
Total Amount					12138118

When we refer above table we see the total core material cost for rc building is ₹ 1.21 cr (rounded up to ₹ 1.2 cr to simplify the calculation of indirect cost). But as mentioned above this are only core material cost we need to assume some cost for all other excluded materials. We will consider the approximate cost of ₹ 1 cr for other excluded materials. Hence the total direct cost for the rc building is approximately ₹ 1.5 cr.

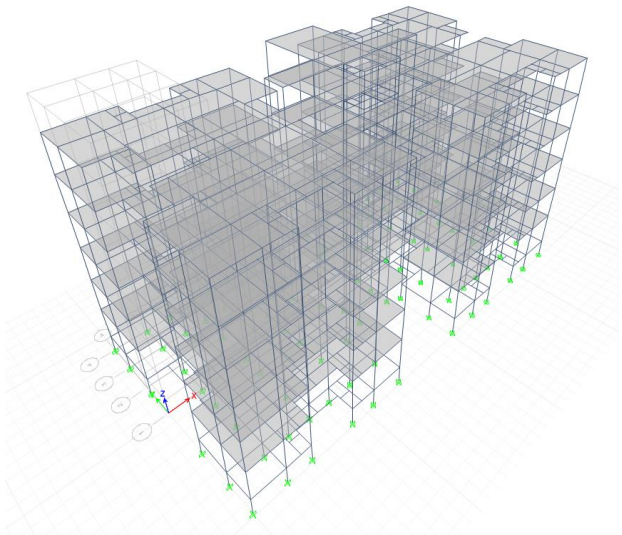

Image 1: RCC building frame

2) Direct Cost of Steel Building
For this building two new core materials are added to the two core materials which are in rc building that are deck sheet and structural steel. Structural steel is the most consumed material in steel building. Structural steel is estimated as of required for different structural members. Concrete quantity is worked out which is required for foundation and deck slabs in standard unit of cum. From the quantity of concrete quantity of reinforced steel is calculated considering 80 kg/cum (80 kg of reinforced steel for every cum of concrete). Quantity of deck sheet is assesses by calculating total floor area so it gets the unit of sqm. The table below shows the direct cost required for steel building.

ABSTRACT SHEET					
Name Of Work : Apartment Building (Steel)					
For : M.Tech Project Work					
Civil Work					
Sr No	Perticulars	Quantity	Rate	Unit	Amount
1	Structural Steel + Fabrication + Erection	110	55,000	MT	6,050,000
2	Reinforcement Steel	30	50,000	MT	1,500,000
3	Deck Sheet	2,400	400	SQM	960,000
4	Concreting	375	7,000	CUM	2,625,000
	Total Qty				**11,135,000**

Table 3: Direct Cost for Steel Building

This direct cost of core materials for steel building comes out to be ₹ 1.1135 cr (108% of rc core material cost). Hence, rounding up the steel core material cost to ₹ 1.2 cr (to simplify calculation). But as seen in the case of rc building excluded material cost needs to be add up in this cost i.e., ₹ 1 cr. The total direct cost of steel building comes out to be ₹ 2.2 cr, which is ₹ 20 lac higher as compared to rc building.

3) Land Cost: This cost is purely based on the assumption. As the overall plan dimension of this building is 34.55m x 18m, considering the margin required according to bye-laws, we will consider a plot of about 8500 sq.ft. (38m x 21m). As the city is second tier city we will assume the land price of ₹ 3500/sq.ft. Hence the overall land cost goes upto **₹** 3 cr. This assumed land cost will be used for the calculation of indirect cost.

4) Miscellaneous Cost: Miscellaneous cost is categorized for the uncertain and unavoidable expenses which happens during initial stages of building planning. This many can also be used for additional expenses in either of the above cost i.e., core material or land. This cost is about **₹** 50 lac. which will cover all expenses.

The total cost for rc building comes out to be ₹ 6.5 cr. and that of steel building is ₹ 7.0 cr. The consideration is made that builder funds the project by taking a bank loan at 10% interest rate in both the cases. To simplify the calculations it is assumed that the constant amount of loan value is drawn every month. So in case of rc building the loan value is spread across 12 months to get constant value to be drawn every month. And in case of steel building the loan value is spread across 4 months to get equal loan disbursement every month. Table below enlists the assumptions of indirect cost calculations.

Table 4: Assumptions for Indirect Cost Calculation

Assumptions		
1	Total units of construction are 32 i.e 32 flats	
2	All flats are sold after construction of building	
3	All values are in ₹ '000	
4	Price per Flat	2,063
5	Flats rate are same in both systems	

Table 5: Total Cost of RCC Building

RCC building	All values in ₹ '000
Land Cost	30,0000
Construction Cost	20,000
Miscellaneous	5,000
Total Costs	55,000

Table 6: Total Cost of Steel Building

Steel Structure	All values in ₹ '000
Land Cost	30,0000
Construction Cost	22,000
Miscellaneous	5,000
Total Costs	57,000

b) Indirect Cost:

Indirect cost is majorly related time. This cost is assessed considered for a common time period of 24 months. The costs include net sum of loan value and interest rate. Revenue includes income from sale of flats and interest income on FD.

The selling price of a flat is assumed to be same in both the cases at ₹ 21.000lac. This works out to total revenue of ₹ 6.90 cr (₹ 23.000 lac * 30 flats) in both the cases. Therefore, the profit margin would be 20% in case of rc building and 15% in case of steel building. To calculate this, another assumption was made that the sale of flats started after the construction of buildings was completed, and 3 flats were sold every month henceforth. So, in total period of 24 months, flats of rc building were started to get sold from 13th month as construction time was 12 months. All flats of rc building were sold out upto 23rd month. In steel building scenario sale of flats was started soon in 5th month as construction period to complete the building was 4 months, and all flats were sold out in 15th month.

In case of rc building, lifting equal amount of loan value in twelve months owner had the loan book value of 5.5 cr. Then from 13th month he started selling 3 flats per month and amount received by selling 3 flats was used to repay the loan. Doing the same in each month, in 21st month the owner repaid his loan and started earning profits. In next three months including 21st month he sells his remaining flats and earns profits. The buffer period of these three is kept ideal without investing that money anywhere for any emergency cause. To complete total cycle it took 23 months so only single month was remained so no investments are done to earn interest revenue and to avoid complications.

On the other hand, in case of steel building receiving loan value in 4 equal parts owner draws total loan in 4 months. As the speed of steel construction was fast in steel, building was erected in 4 months. The sale of flats was started from 5th month of the cycle. Similarly selling 3 flats each month and money received by selling those flats were used to repay the loan. It was obvious as the sale of flats started early the repayment of loan also got finished early. Due to which in the case of steel owner saves the money in paying interest of loan. Constantly selling 3 flats per month in 13th month owner repays total loan, and in next three months including 13th month owner earns the profit. But as mentioned above to keep the balance between both the cases we have assumed both cycles of constant duration i.e. 24 months. In case of steel building 9 months are remaining ideal. So selecting simplest and safest option, owner decides to invest his money in Fixed Deposit (FD) at interest rate of 5%. His FD schemes runs for next 9 months and earns some interest revenue for him. So in case of steel building owner has additional source of income, i.e., interest on FD.

After calculating tricky indirect cost, to get the clear idea about the net profit earned in both the cases "Net Profit Margin" (NPM) is calculated. This NPM is nothing but the ratio value of net inflow divided by total amount invested.

Table 7: NPM Calculation for RCC Building

RCC building	All values in rupees
Loan Amount	55000000
Interest Cost	4790000
Income from sales of Flats	69000000
Net Inflow	9210000
Net Profit Margin	13.34%

Table 8: NPM Calculation for Steel Building

RCC building	All values in rupees
Loan Amount	57000000
Interest Cost	3283000
Income from sales of Flats	69000000
Net Inflow	8717000
Net Profit Margin	12.63%

NPM for conventional rc building is 13.34% and that for steel building it is 12.63%. The difference between NPM of both type of building is 0.71% which comes out to be ₹ 4.93 lac in absolute terms. The returns are slightly lesser than in case of s building, the time of construction is significantly less and scrap value is very high for steel building.

Note: Detail calculations are presented at the end of this paper.

c) Scrap Value:

Scrap value of the building is the cost which owner gets after demolishing the building at the end of its design life. This value is not merged in the calculation as the calculation is done till the end of 24 months period. The scrap value will be received after years. When scrap value is studied in both the cases scrap value return from conventional rc system will be much less as the core material of this system is concrete. The concrete forms pure waste at the end of its design life. On the other hand steel structure building is having structural steel as the core material. This material will give good return as a scrap. But the calculation of this value is bit tricky as building has the design life of about 50 years, estimating the rates of material of at end of that period and then calculating that value. As without considering scrap value the difference between NPM is very less, if the scrap value is considered there is chances of getting more profit from steel structure building than conventional rc building.

3. Conclusion

- In comparison of material cost steel building is comes out to be costly than rc building by 5-10%.
- Time required for construction of steel building is significantly less than that of rc building, during pandemic or any other emergency when erection needs to be quick steel building should be preferred.

- After the descriptive and detail calculation of the overall revenues and costs, we conclude that NPM in both the cases is not materially different.

Particulars	RCC building	Steel building
Loan Amount	55000000	57000000
Interest Cost	4790000	3283000
Income from sales of Flats	69000000	69000000
Net Inflow	9210000	8717000
Net Profit Margin	13.34%	12.63%

- Minor difference of 0.07% in NPM in steel building favor shows that owner/builder can prefer this new type of building.
- It is observed that the core material cost of steel structure is more than rc structure, but speedy erection may make steel structure economically viable.
- Speedy construction facilitates quicker return on the invested capital and benefits.
- In modern society in which speed and productivity in every context is deterministic, application of rapid and optimal methods such as steel structural systems is inevitable option.
- It must always be considered that the construction wastes should be minimized or even eliminated as much as possible. In conventional rc structural system, waste production is inevitable though. In this respect, application of steel structural system is possible due to possibility of reuse of used members in these structures and it must be taken into account more than before so that it can bring about a healthier environment.

Acknowledgements
It gives me great pleasure and a sense of utmost fulfillment to present this project for my M.Tech dissertation work. I express a deep sense of thoughtful and gratitude to all those who have helped directly or indirectly in different way the conduct of progress my respective work. First and foremost, I keep on record my deepest sense of gratitude and obligation to my guide R.S. Patil & HOD. G.R.Gandhe

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