ANALYSIS AND DESIGN OF COMPOSITE STRUCTURE USING STAAD.Pro

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ABSTRACT

The project involves Planning, Analysis and Design of an Institutional Building with steel-concrete composite construction. The proposed structure is a G+5 building, with 3.658m as the height of each floor. The overall plan dimension of the building is 56.3m x 31.94m.The analysis and design involves the structural planning load calculation, analyzing it by 2D modeling using STAAD-Pro v8i, design of composite floors and columns, design of steel beams and design of foundation. Analysis has been done for various load combinations including seismic load, wind load, etc, as per Euro Code of Practice.The project also involves analysis and design of an equivalent R.C.C. structure so that a cost comparison can be made between a steel-concrete composite structure and an equivalent R.C.C. structure.

Keywords : Auditorium, STAAD Pro,Design, RCC, Steel.

1. INTRODUCTION:

The use of steel-concrete composite construction began around 1926. During recent years, composite design has been widely applied in building construction.The use of Steel in construction industry is very low in India compared to many developing countries. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially in the current development needs in India. Abroad, the use of structural steel has been growing, and has now become one of the important input materials of construction. In India, until nineties, availability of structural steel was in less and weather resistant and/or strength grades were not readily available. Thus, steel did not make much in-roads in building construction and highways, and its share in bridge construction also started decreasing. This coupled with many other reasons led to stagnation of steel demand, while large-scale production capacity has been created in the country during initial liberalization period of our country. Hence, proper development of steel application sectors has become an important issue and the steel framed composite construction is considered to be a cost effective solution for multi-storied buildings due to optimum use of materials.

Composite design provides the following advantages as compared with non composite design:

1. Efficient use of material. As a result of composite design, the size and weight of steel beams can be reduced by as much as 15 to 30%. The cost of fireproofing can be reduced in addition to the cost reduction of steel beams.
2. Greater stiffness. The stiffness of the composite section can be increased. This reduces the deflection of the member as compared with the non composite beam.
3. Extra usable space. The use of shallow beams can reduce building heights. It is also possible to increase column spacing’s to provide larger usable space within a structure.
4. Saving in labor and other construction material. Savings in labor, facing material, piping, and wiring can be realized.

1.1 Problem statement

Not exploring Steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. Also, it is evident that now-a-days, the composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges and high rise buildings. Composite Steel-Concrete Structures are used widely in modern bridge and building construction. A composite member is formed when a steel component ,such as an I beam ,is attached to a concrete component, such as a floor slab or bridge deck. In such a composite T-beam the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. The fact that each material is used to the fullest advantage makes composite Steel-Concrete construction very efficient and economical. However, the real attraction of such construction is based on having an efficient connection of the Steel to the Concrete, and it is this connection that allows a transfer of forces and gives composite members their unique behavior.

In due consideration of the above fact, this project has been envisaged which consists of analysis and design of a high rise building using Steel-Concrete composites. The project also involves analysis and design of an equivalent R.C.C structure so that a cost comparison can be made between a Steel-Concrete composite structure and an equivalent R.C.C. structure.

1.2 Objectives

- Analysis and design of a high rise building using Euro Code of Steel-Concrete composites.
- Analysis and design of an equivalent R.C.C structure.
- Cost comparison can be made between a Steel-Concrete composite structure and an equivalent R.C.C. structure.
- To Analysis and Design of Profiled Deck slab and it’s behavior.
- Analysis and Design of shear connection between slab and girder, girder and column.
- To study the Euro Codes for composite structure design and analysis
- Also study the Indian Standard codes required for composite structure design.

1.2.1 Need of steel in construction

In building construction, role of steel is same as that of bones in a living being. Steel is very advantageous because it:

- Offers considerable flexibility in design and is easy for fabrication.
- Facilities faster construction scheduling of projects.
- Enables easy construction scheduling even in congested sites.
- Permits large span construction repair/modification.
- Is an ideal material in earthquake prone locations due to high strength, stiffness, ductility.
- Is environment friendly and fully recyclable on replacement.

1.3 Limitation

In comparison with conventional methods the operation of advanced instrumentation requires a higher level of training and additional certification, which incurs more costs. However, as discussed above, the deployment of composite structure delivers a superior and therefore higher value service. Once advanced training is completed, as with any skill, it is important to practice what was learned on the training course. This can only be done if high-value advanced instrumentation is available. Again, purchase costs may be preclusive, so renting can be a preferable option. In addition, instrument purchase ties the user to a specific technology, whereas a rental fleet offers users the ability to deploy the most appropriate kit for each job, or to hire equipment from different manufacturers depending on the users' training, experience and preference. Purchase of a particular technology may also reduce or preclude access to other methods that may be developed at a later date.

2 MATERIAL AND METHODS :

2.1 Design Method for deck slab

As there is no Indian standard covering profile decking, Eurocode 4 (EC4) provisions are considered. The design method defined in EC4 requires that slab be checked firstly for bending capacity, assuming full bond between concrete and steel, secondly for shear bond capacity and, finally, for vertical shear. The analysis of the bending capacity of the slab may be carried out as though the slab was of reinforced concrete with the steel deck acting as reinforcement. However, no satisfactory analytical method has been developed as far for estimating the value shear bond capacity. Based on test data available, the loads at the construction stage often govern the allowable span rather at the composite slab stage.

Steps in the Design of Profiled Decking:

1. List the decking sheet data (Preferably from manufacturer's data)
2. List the loading
3. Design the profiled sheeting as shuttering
4. Calculate the effective length of the span
5. Compute factored moments and vertical shear
6. Check adequacy for moment
7. Check adequacy for vertical shear
8. Check deflections
9. Design the composite slab.
10. Calculate the effective of the span
11. Compute factored moments and vertical shear
12. Check adequacy for moment
13. Check adequacy for vertical shear
14. Check adequacy for longitudinal shear
15. Check for serviceability, i.e. cracking above supports and deflections

2.2 Basic Beam Design Considerations

The analysis of composite section is made using Limit State of collapse method. IS: 11384 – 1985 Code deals with the design and constructions of only simply supported composite beams. Therefore, the method of design suggested in EC 4 is also referred along with IS: 11384.

2.3 Composite Column Design

Design of composite column is based on limit state method. Euro code 4 is generally followed for composite column design, as there is no Indian Standard covering composite columns.

For structural adequacy, the internal forces and moments resulting from the most unfavorable load combination should not exceed the design resistance of the composite cross-sections. While local buckling of the steel sections may be eliminated, the reduction in the compression resistance of the composite column due to overall buckling should definitely be allowed for, together with the effects of residual stresses and initial imperfections. Moreover, the second order effects in

slender columns as well as the effect of creep and shrinkage of concrete under long-term loading must be considered, if they are significant. The reduction in flexural stiffness due to cracking of the concrete in the tension are should also be considered.
Isolated symmetric columns having uniform cross sections in braced or non-sway frames may be designed by the simplified design method, which adopts the European buckling curves for steel columns. However, this method cannot be applied to sway columns.
When a sufficiently stiff frame is subjected to in-plane horizontal forces, the additional internal forces and moments due to the consequent horizontal displacement of its nodes can be neglected, and the frame is classed as "non-sway".

2.4 Fire resistance

Composite columns were actually developed for their inherent high resistance. Composite columns are usually designed in the normal or `cool' state and then checked under fire conditions. Additional reinforcement is sometimes required to achieve the target fire resistance. Some general rules on the structural performance of composite columns in fire are summarized as follows.
The fire resistance of composite columns with fully concrete steel sections may be treated in the same way as reinforced concrete columns. An appropriate concrete cover insulates the steel and light reinforcement is also required in order to maintain the integrity of the concrete cover. In such cases, two-hour fire resistance can usually be achieved with the minimum concrete cover of 40mm.

- For composite columns with partially concrete encased steel sections, the structural performance of the columns is very different in fire, as the flanges of the steel sections are exposed and less concrete acts as a `heat shield'. In general, a fire resistance of up to one hour can be achieved if the strength of concrete is neglected in normal design. Additional reinforcement is often required to achieve more than one-hour
- Analysis was done assuming that the building is a concrete building.
- 2D analysis was done for two cases:-
- Frame along shorter direction
- Frame along longer direction
- Footing was idealized as fixed support.

For concrete filled tubular sections subjected to fire, the steel sections are exposed to direct heating while the concrete core behaves as `heal sink'. In general, sufficient redistribution of stress occurs between the hot steel sections and the relatively cool concrete core, so that a fire resistance of one hour can usually be achieved.
Steel fiber reinforcement is also effective in improving the fire resistance of a concrete filled column. It is also a practice in India to wrap the column with fibro-cement to increase the fire rating.

3. RESULTS AND ANALYSIS

- Analysis was done using STAAD-Pro V8i
- Dead load,live load, wind load and the seismic load are considered.

Analysis was done for the load combinations given below:

1. Dead load + live load
2. Dead load + live load + wind load in (+ve) x – direction

3. Dead load + live load + wind load in (- ve) x – direction
4. Dead load + live load +earthquake load in (+ ve) x – direction
5. Dead load + live load +earthquake load in (- ve) x – direction

DESIGN OF BEAMS

The beams are designed using SP – 16

Beam 1-longer span

Maximum positive B.M M_u(+ve)= 1617.087 kN.m

Maximum negative B.M M_u(-ve)= 980.359 kN.m

Maximum S.F V_u= 547.085 kN.

Initially a beam of size 300 x 900 is selected

Here,b = 300mm

d = 850 mm

$$\frac{M_u}{bd^2} = \frac{1617.087\cdot10^6}{300\cdot\ 850^2} = 7.4$$

$p_t = 2.44\%$

$p_c = 1.32\%$

$$\text{Steel in tension} = \frac{2.44\cdot 300\cdot 850}{100} = 6222mm^2$$

$$\text{Steel in compression} = \frac{6222*1.32}{2.4} = 3366mm^2$$

Considering 60% of steel,

$$\text{Steel in compression} = 3366*0.6/100 = 2020mm^2$$

$$\text{Total amount of steel} = 6222 + 2020 = 8242mm^2$$

$$\text{Total volume of steel} = 8242\cdot 9412 = 77.57\cdot10^6\ mm^3$$

$$\text{Total weight of steel} = 77.57\ \cdot10^{-3}\ \cdot\ 7800 = 605.046kg$$

Providing steel reinforcement of 8mm diameter bars @200mmc/c.

Steel Reinforcement = $\frac{2400 \cdot 9142 \cdot 50 \cdot 7800 \cdot 10^{-9}}{200} = 42.78kg$

Total steel = 605.046 + 42.78 ≈ 650kg

Total volume of concrete = $9.142 \cdot 0.3 \cdot 0.9 = 2.46m^3$

DESIGN OF COLUMN

The design of the column was carried out as per SP-16 Design Axial Load, Fx = 6201.959 kN.m. Design Bending Moment about x-x axis, Mux = 1359.377 kN.m. Design Bending Moment about y-y axis, Muy = 416.74 kN.m.

Resultant Moment □ 1.15 □ $\sqrt{1359.382 \text{ x } 416.7422}$ □ =□ 1635.096kN.m

Considering a section of 500 x 900 mm,

Using 4% of reinforcement,

$\frac{Pu}{fck \; bd} = \frac{6201.96 \times 1000}{25 \times 900 \times 500} = 0.55$

$\frac{Mu}{fck \; bd^2} = \frac{1635.096 \times 10^6}{25 \times 900^2 \times 500} = 0.16$

$\frac{p}{f_{ck}} = 0.22$

Therefore p = 5.5%

Weight of steel = $\frac{5.5}{100} \cdot 900 \cdot 500 \cdot 3.66 \cdot 1000 \cdot 7800 \cdot 10^{-9}$

$= 173.74kg \approx 200kg$

Volume of concrete = $0.9 \cdot 0.5 \cdot 3.66 = 1.647m^3$

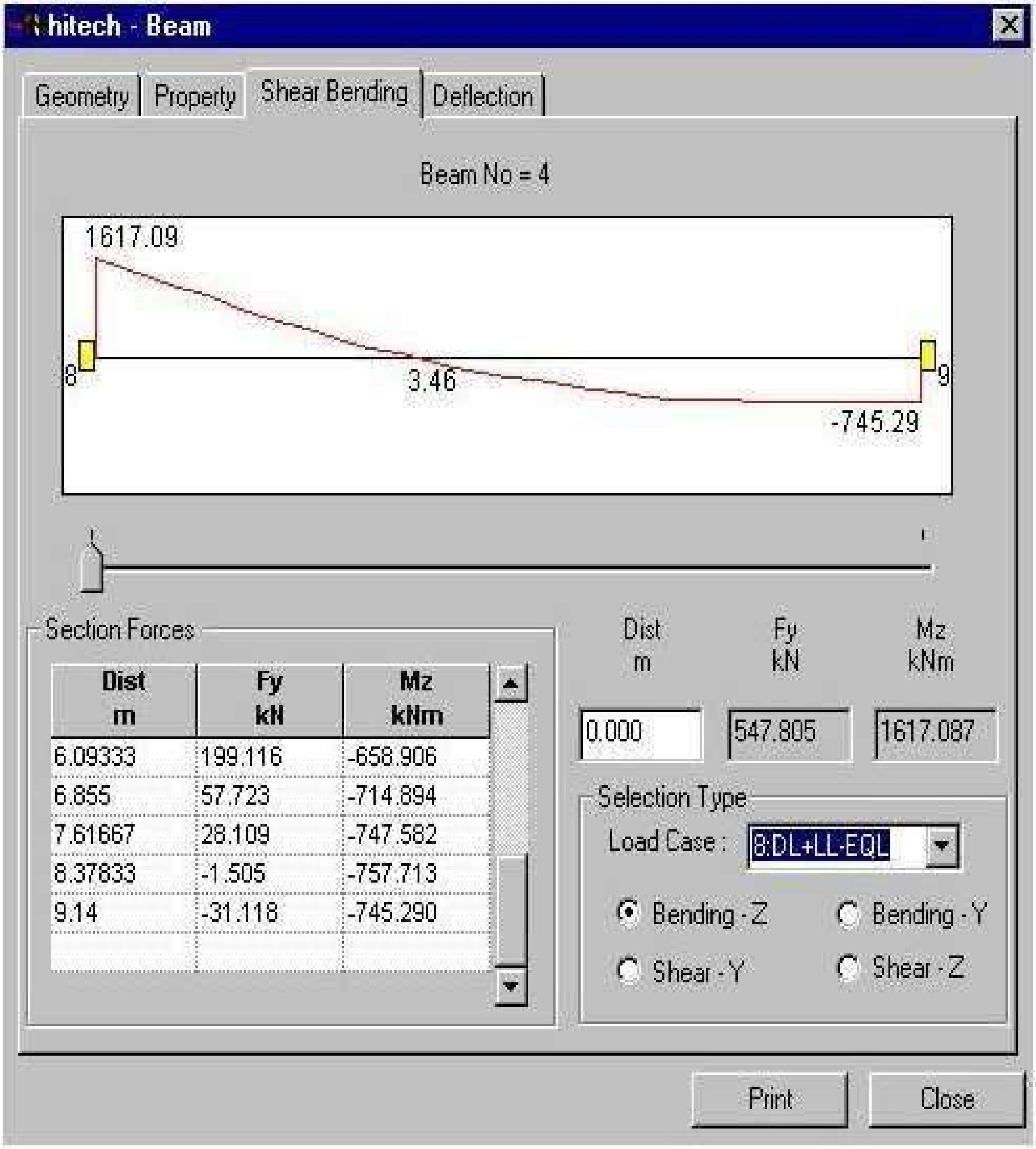

Figure 1 BMD for Beam

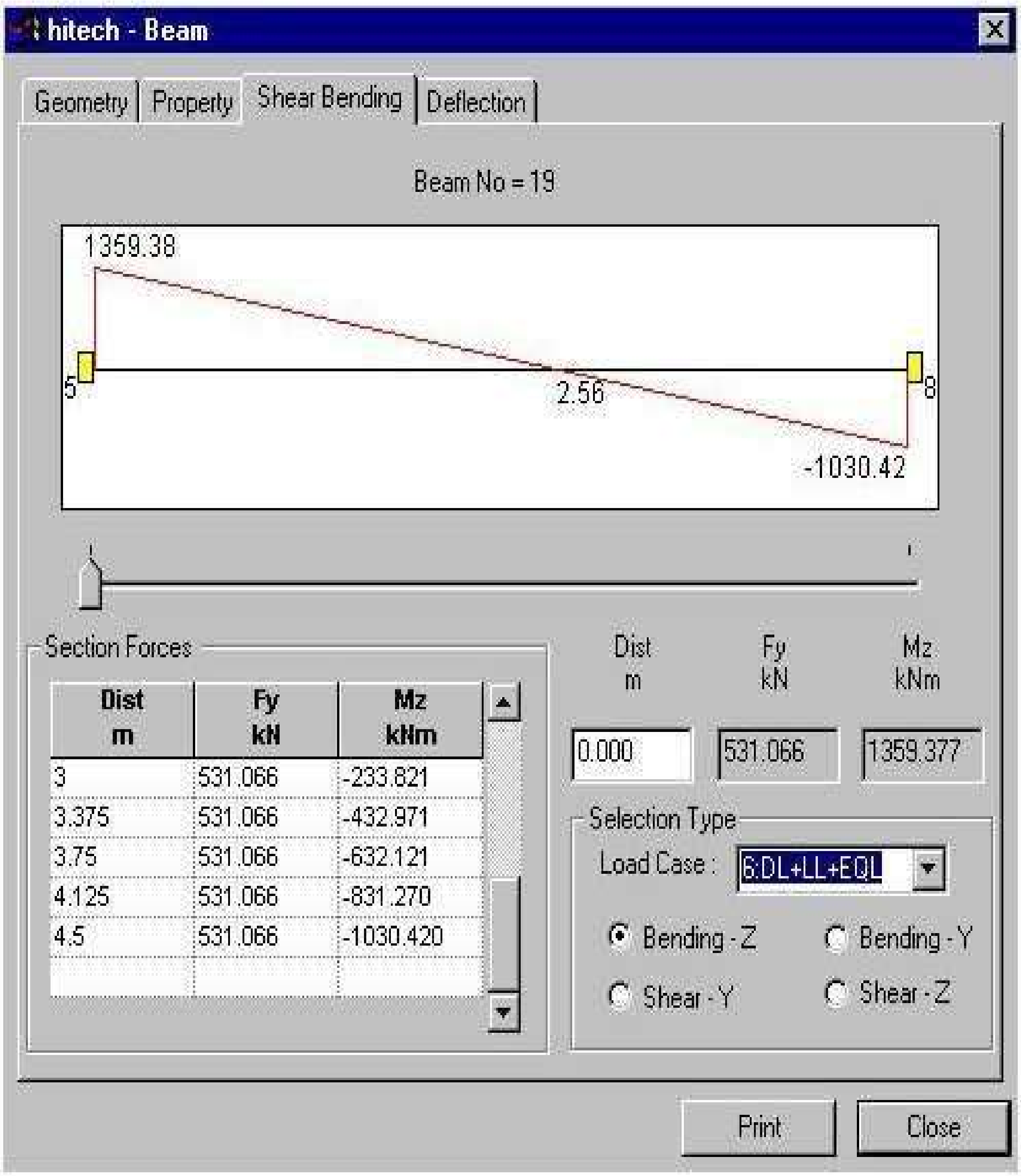

Figure 2 BMD for Column

3.1 COMPARISON OF COMPOSITE ELEMENTS WITH CONVENTIONAL RCC ELEMENTS

Table 3.1 Slabs

Material	Rate	Composite design	Amount	R.C.C.design	Amount
Steel	Rs.35/kg	9.36kg/sq.m	Rs.328	3.9kg/m	Rs.136.5
Concrete	Rs.2050/m^3	0.075 m^3/m	Rs.153.75	0.15 m^3/m	Rs.307.5
Formwork	Rs.80/sq.m	-	-	0.075sq.m/m	Rs.6
		Total	Rs.481.75	Total	Rs.447

Table 3.2 Beams

Material	Rate	Composite design	Amount	R.C.C.design	Amount
Steel	Rs.35/kg	1839kg	Rs.64365	650kg	Rs.22750
Concrete	Rs.2050/m^3	-	-	2.46 m^3	Rs.5060
Formwork	Rs.80/sq.m	-	-	19.194sq.m	Rs.1535.5
		Total	Rs.64365	Total	Rs.24792

Table 3.3 Columns

Material	Rate	Composite design	Amount	R.C.C.design	Amount
Steel	Rs.35/kg	798.3.9kg	Rs.27939	200kg	Rs.7000
Concrete	Rs.2050/m^3	1.21 m^3	Rs.2480.5	1.647 m^3	Rs.3376.35
Formwork	Rs.80/sq.m	2.4 sq.m	Rs.192	10.248sq.m	Rs.820
		Total	Rs.30611	Total	Rs.11197

4. CONCLUSIONS

1) A G + 5 structure of plan dimensions 56.3m x 31.94m has been analysed, designed and cost per unit quantities worked out.
2) An equivalent R.C.C. structure has also been analyzed, designed and cost per unit quantities worked out.
3) A comparative study of the quantity of material and cost has been worked out both for composite and concrete construction.
4) Though, the cost comparison reveals hat Steel-Concrete composite design structure is more costly, reduction in direct costs of steel-composite structure resulting from speedy erection will make Steel-Composite structure economically viable. Further, under earthquake considerations because of the inherent ductility characteristics, Steel-Concrete structure will perform better than a conventional R.C.C. structure.
5) For analysis,STAADPro-2003 software has been used.
6) Manual design has been carried out both for Steel-Concrete composite and R.C.C. structure.
7) Sufficient insight into the analysis and design of Steel-Concrete composite structure which is an emerging area has been gained.

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