Analysis and design of cantilever falsework for high rise building

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Abstract: The supporting system for formwork called as falsework is an essential component for every construction work. Supporting of such formwork becomes more challenging when it is to support a cantilever projection to be casted in concrete. The difficulty increases when such supporting is to be provided at higher level of a multistoried building where support cannot be provided from ground. Hence a practical method of supporting such formwork is presented. A typical example of a cantilever structure to be casted for a span of 2.5 meters is presented for which the falsework is to be designed. This paper includes analysis of falsework structure for all possible loads and its design for the same. The selection and designing of structural members is done as per Indian standard guidelines. Emphasis has been laid on the fact that only structural members and materials readily available in market are used in falsework erection. Erection techniques involve use of rolled steel beams, acrow props and fillet welding which is easily executable on every construction site.

Keywords: Falsework, rolled steel beams, acrow props, formwork

INTRODUCTION

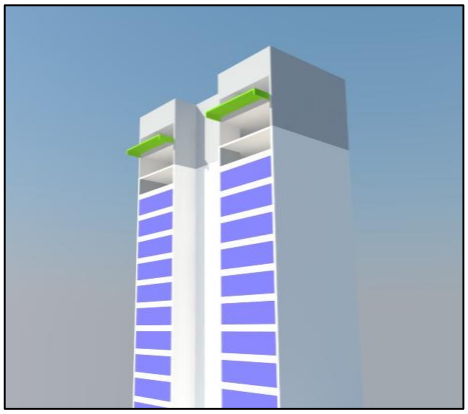
Modern high rise building designs incorporate many cantilever projections which are both for aesthetic purpose and increasing built-up area. In high rise buildings it becomes more difficult to execute such designs because of many factors, one major factor being not able to support the formwork from ground. Cantilever projections can be casted in concrete without any hassle if they span up to 1 meter. But supporting formwork for long span cantilever structures ranging more than 2 meters in length needs some special techniques. Before implementation of such temporary structure, load analysis and its respective design needs to be performed. It is however noticed that such falsework erection tasks are handed over to contractors without considering any analysis and safe design which may pose threat to safety of execution. It may also happen that they end up with an heavier design which is more expensive than what is required. This paper presents the practical approach by basic analysis to give optimum design maintaining balance between safety and economy during construction.

MATERIALS AND ITS TYPICAL ARRANGEMENT

The falsework being a temporary structure, has to be detached once the concrete gains strength, thus the materials used should be such that they are readily available in market and be sold back easily. The basic required materials and services are:-

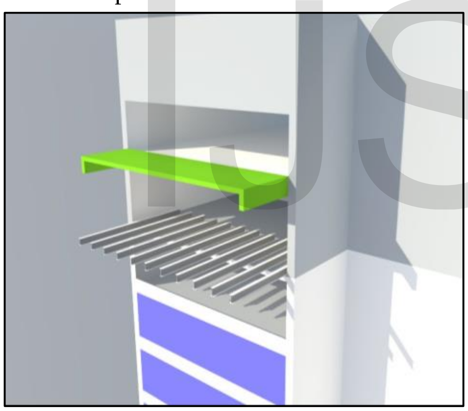
1) Rolled Steel I-beams (cross section depending upon design).
2) Acrow props (complying with AS3610-95).
3) Fillet weld (5mm weld).

The technique includes use of rolled steel beams which are counterbalanced by tightening those using acrow props. Following figures represent the step by step arrangement of steel beams and acrow props for erecting the system which will support the formwork.



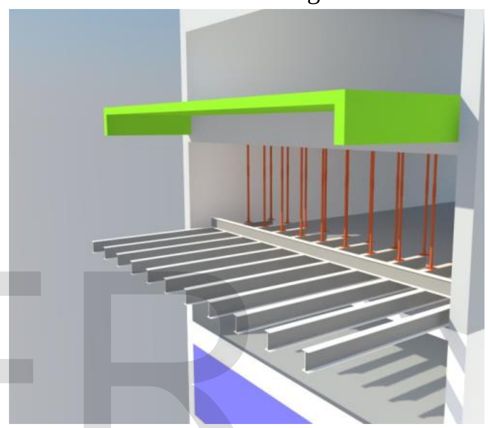
(Figure 1.a)

A typical example of a cantilever structure to be casted in concrete in higher floors of a multi-storey building is shown in figure 1.a. The green colored projection represents reinforced concrete structure yet to be casted. It spans 2.5 meters outwards.



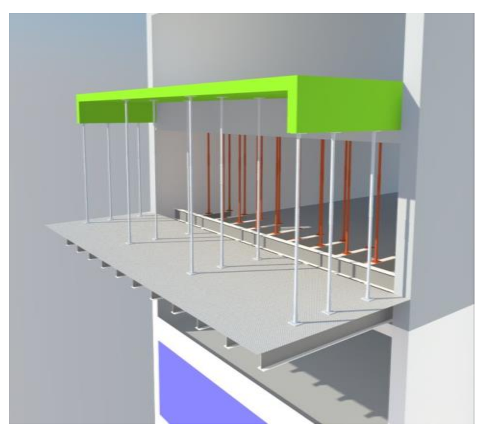
(Figure 1.b)

The next step involves placing of rolled steel beams (I-beams) of required cross-section and spacing as per design as shown in figure 1.b. The length of each beam should be twice the span of cantilever structure to be casted and 0.5 meter more on the overhanging part. Thus for this case 3 meters of length will be overhanging and remaining 3 meters will be inside. Steel beams of 6 meter span will be used. Figure 1.c shows the acrow props that have been tightened between steel beams and upper slab from inside. This will counteract the overturning of steel beams due to load acting on its overhanging part. A cross steel beam is to be joined by means of welding. It should be attached in a direction perpendicular to the longitudinal axis of main beams such that it holds all those beams together. It also prevents unwanted twisting and bending in other directions. In case one of the main beam or the props used to hold it fails, then the cross beam will hold the beam at its position and distribute its load on the other beams thus avoiding any accidents on the construction site. The cross beam attached can be of same cross section as main beam as shown in figure 1.c.



(Figure 1.c)

Steel plates can then be laid over the overhanging beams. The thickness of plate should not be less than 4 millimeters. It is to be properly welded to the beams beneath. After plates are being laid and joined, it serves as a platform ready for all the shuttering works to be performed as seen in figure 1.d.



(figure 1.d)

METHODOLOGY

Load assumptions

Following are the loads that the falsework will be subjected to. It should be noted that since this is a temporary structure, considering seismic loads is not appropriate.

1) Load of wet concrete to be casted is assumed 26 kilonewton/meter^3 as per IS 456-2000. For a slab thickness of 150mm it will form a load intensity of approximately 4 kilonewton/meter^2
2) Load of Steel base plate (5mm thick) – 0.4 kilonewton/meter^2
3) Working load which will include load of workers, small equipments etc is assumed to be 3 kilonewton/meter^2
4) Load of shuttering including weight of shuttering plywood, wooden supports and props is assumed to be 1 kilonewton/meter^2

An addition of all the above loads gives a load intensity of approximately 8.5 kilonewton/meter^2. Figure 2.a shows longitudinal section plane of the main beams. Since the load acting on beams is transmitted through plates we can assume that it is uniformly distributed on all the beams throughout its length.

Analysis of falsework structure

Assuming that the rolled steel beams are placed at 1 meter center to center spacing, a uniformly distributed load of 8.5 kilonewton/meter will act on each of the beam individually. Figure 2.b shows the load acting on a single beam and its corresponding shear force and bending moment diagrams. For safe design the corresponding shear force and bending moment are multiplied 1.5 times their own values respectively.

Hence the rolled steel beam is to be designed for a maximum factored bending moment(BM) of 57.37 kilonewton-meter and maximum factored shear force (SF) of 38.25 kilonewton.

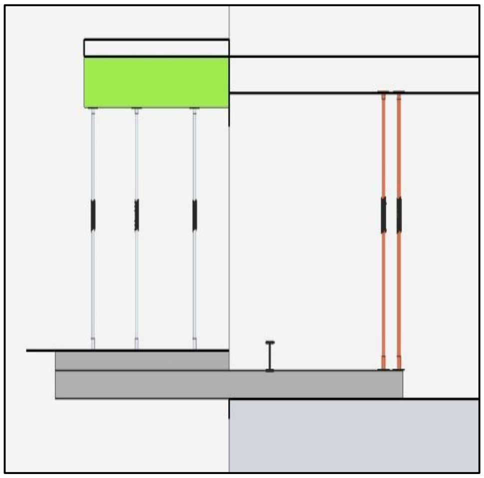


Figure 2.a

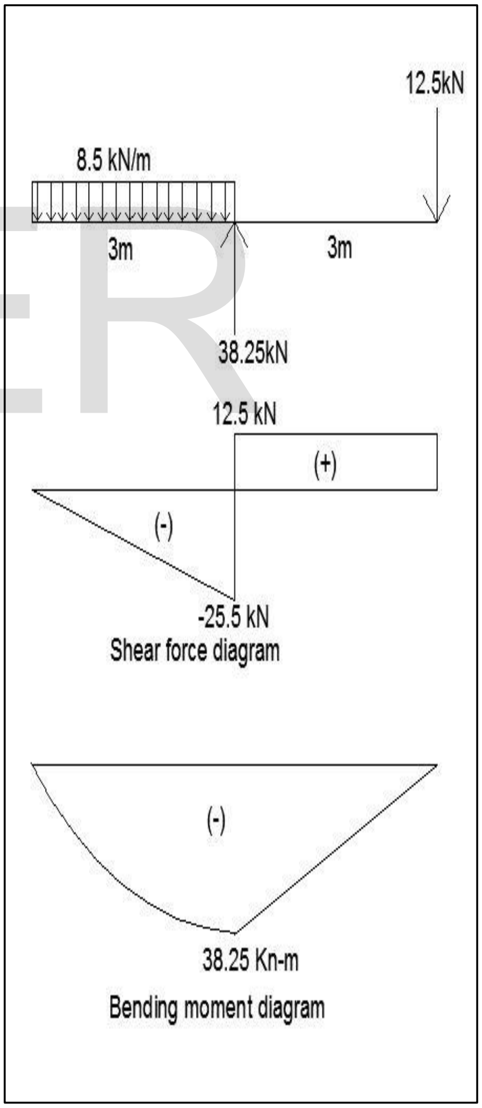


Figure 2.b

Designing of falsework structure

Design of rolled steel beam: The design is as per IS 800:2007 guidelines.

Design for resisting bending moment
For the factored BM the required Z_p is found out to be 252.45 X 10^3 mm^3
ISMB 200 provides an Z_p of 254.8 X 10^3 mm^3
Checks for bending
1) M_d = 57.9 kN-m >57.37 kN-m
(Max factored BM)
2) $M_d = 1.5\ Z_e\ f_y / r_{mo}$ for cantilever beam
Where M_d = 76.19 kN-m > 57.37 kN-m
(Max factored BM)
Hence the slected section ISMB 200 is safe in bending.

Check for shear
V_d = 149.58 kN
$0.6V_d$ = 89.75 kN > 38.25 kN
(Max factored SF)
Hence the selected section is safe in shear.

Check for deflection
For 3 meter overhang , $\partial_{permissible}$ =20mm
∂_{max} = 19.24 mm for selected section.
Hence selected section is safe in deflection.

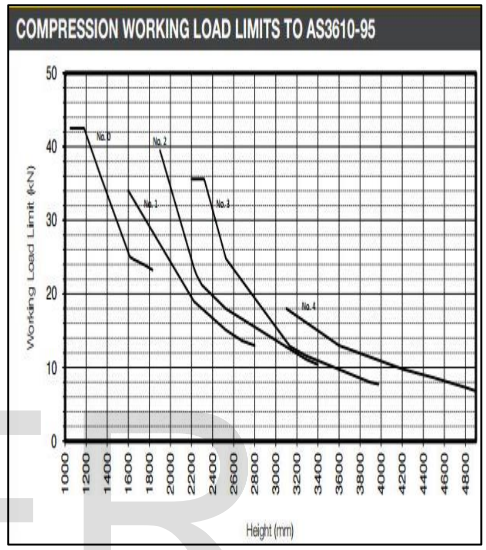
Check for web buckling
The buckling capacity of web is found to be 179.6 kN which is greater than reaction of 38.25 kN produced. Hence the selected section is safe against web buckling.

Check for web crippling
The crippling capacity of web is found to be 200.14 kN which is greater than reaction of 38.25 kN produced. Hence the selected section is safe against web crippling.

Selection of appropriate acrow prop :
Acrow prop is designed to take compressive load. Figure 3.a is a chart showing varying height ranges for which acrow props are available. Figure 3.b is a graph that represents the compressive load an acrow prop can bear for a given height.

ACROW PROP RANGE			
SIZE	CLOSED HEIGHT (mm)	OPEN HEIGHT (mm)	EST. WEIGHT (kg)
No.0	1050	1830	13.0
No.1	1600	2800	17.3
No.2	1900	3400	20.0
No.3	2170	3975	22.6
No.4	3100	4900	30.0

Table 3.a



Graph 3.b

Acrow prop no.3 is selected for this particular case which has closed height of 1900mm and can open up to 3400mm which is ideal for most of the floor to floor height. As per figure 3.b single prop can take compressive load of approximately 15 kN. It is greater than actually compressive force of 12.75 kN which will actually act on it as per fig 2.b. For safety purpose 2 props are used to counterbalance loads for every single beam at its inner end.

CONCLUSION
This method for erecting cantilever falsework can be adopted for spans more than 1 meter as shuttering work becomes difficult as span increases. The main advantage of this technique is simplicity in its design. The materials used are readily available in market and can be resold once its purpose is accomplished which makes this method very economical. Also the time

consumed is very less in assembling the falsework structure using this method which again contributes to economy. The basic Indian standard guidelines as per IS-800:2007 are met against failure in bending, shear ,buckling and crippling of web and serviceability in terms of deflection. The props are also selected as per AS3610-95. This ensures the safety of workers and structure during construction. Hence it can be concluded that the above way of erecting a cantilever falsework gives an optimum balance between safety and economy during construction.

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