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Critical Analysis on R. C. Voided Slab and Conventional R.C.C. Slab Parametric Study

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Abstract: ***The examiner and design of slabs are interactive area of research work. In the earliest of 20th century Reinforced Concrete slab and floors was built on regular basis. But due to demand of economy and fast construction Voided slab Slabs have proven to be more desirable as compared to RCC slab. As we know if the construction time of any project increases it also increases the cost of construction. There might be an accountable difference in cost within a year of construction of same square feet of area. For this we really need to minimize the time without compromising the quality.***

Keywords: Voided Slabs (HCS), Reinforced Cement Concrete, voids, Pre-stressed, Shear, Moment, Deflection, and force, Storey shear and Displacement.

1. Introduction

Present study involves a RC framed structure (G+21) each for HCS and RCC slab located in Seismic Zone II, III, IV and V. The main objective of the study is based on analysis of two structure i.e. one having Voided slab as flooring and other having RCC slab as flooring. Structural parameters included for comparison are deflection, shear moment axial force, storey shear and displacement. Separate models were generated for HCS and RCC slab for each Seismic Zones II, III, IV and V and were compared Zone wise. Study was carried to show how HCS are economical over RCC slab by comparing the structural behavior of building element which are columns, floor and footings.

There is wide range of structural element available in market with enhanced structural properties compared to conventional one. One of the elements which is widely used are the precast structural elements which are produced in factories with great accuracy and skilled supervision. Among this we have Voided slab Slabs which are quick to setup and are generally cost effective. HCS units have good sound and thermal properties and long spans which is easy to achieve economically. Voided slab slabs are precast, prestressed elements generally used as flooring. They usually consist of continuous voids which run along the length to reduce the self-weight. The reduction in dead load of element reduces the depth of other structural elements. HCS are constructed in precast factories using low slump high strength prestressed strands.

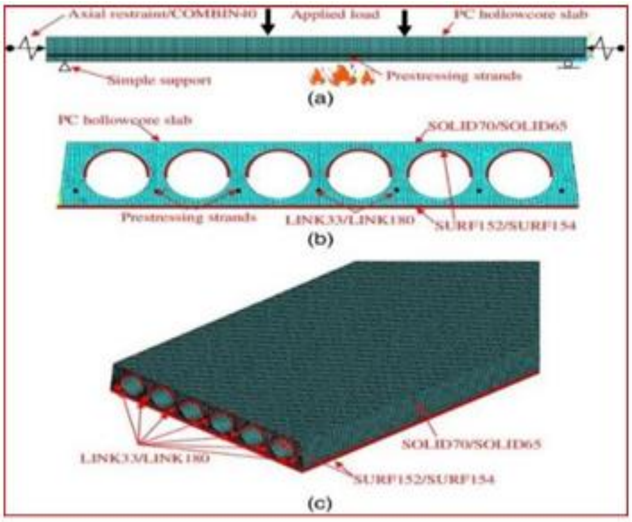


Fig 1.1:Voided slab BarPlacement

Fig 1.2 :Voided slab ConnectionwithConcreteBeam

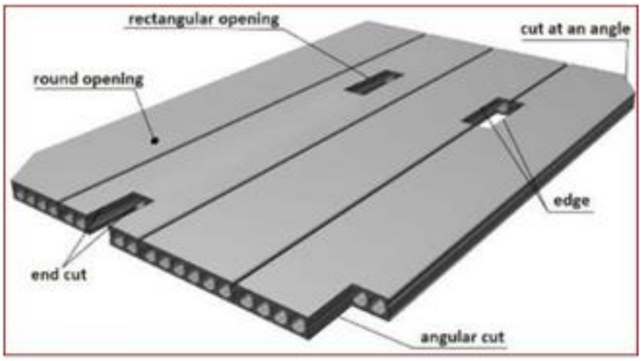


Fig1.3:Voided slabwithOpenings

2. Brief History of Past Work Done

Ihsan A. Al-Shaarbaf 1, Adel A. Al- Azzawi 2& Radhwan Abdulsattar 3, 2018, this paper is based on literature reviews related to previous research and studies on HCS. Based on the past researches this paper suggests it is feasible to use HCS one way slab as a roofing member for buildings. The NSM-CFRP strengthening method majorly supports the bending and shear load capacity of prestress HCS. The reduction in shear span to depth ratio for solid slab causes larger flexural strength by about 29.06% and ultimate deflection by about 17.79%. There is a reduction in cross sectional area extends between 29% to 35% for block slabs, which ultimately leads to reduction in weight of the HCS compared to conventional slabs i.e. RCC slab. In this paper the authors have discussed on various advantages of Voided slab slab and process to design the Voided slabslab.

Some of the advantages of Voided slab discussed in this paper are:

- It decreases the total dead load of the building
- It reduces construction cost and time.
- Immediate un-propped working platform.
- Extra-long spans.
- Factory produced to rigorous quality standards The process of designing VoidedSlab:

The design method for a Voided Slab floor system would naturally contain the subsequent conditions:

Prateek Ghosh, 2016, in this study comparison has been done between RCC and steel framed structures using Voided slab concrete slabs as utility. The study concludes that precast concrete constructions are very common in low earthquake regions as they are cost effective, quick to assemble and build. Have lower self weight, use fewer raw materials. Widely used in India, Europe, USA and Canada.

This paper is based on a case study of project "Shankaracharya Medical College and Hospital Building" situated at Junwani, Chhattisgarh. The project consists of a G+5 building to be used as hospital and a G+4 building for medical college. In this the author has discussed about the specification of voided slab slabs used in the mentioned project. The target for the completion of the project was estimated to be 24 months but if it was to constructed using the conventional method i.e., RCC then it was estimated to be 36 months. Due to the time limitation it was decided to construct a steel framed structure along with pre-cast pre-stressed hollow-core concrete slabs for roofs and floor. All the Voided slab slabs were 150 mm thick, 1.20m wide, and 6.00 m long. The slabs was prestress using 9 mm diameter, 1770 MPa low relaxation, seven-wire strands.

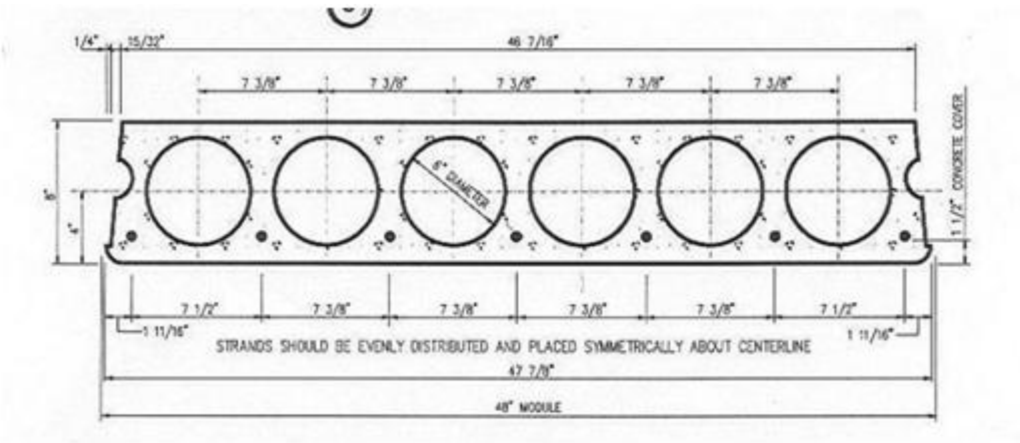


Figure 2.1: Voided slab Slab Detail

L.J. Woods[1], D.K. Bull[2] and R.C. Fenwick[3], 2008, this paper is based on performance of HCS under gravity loads. Paper includes the importance of negative bending moments in HCS and conditions how it is exposed to the (-) bending moments. Paper gives what should be included in HCS slab design to avoid failures due to shear and flexure in negative bending moment regions.

Negative Bending Moment in Voided slab Floors:
Negative moments can be formed in Voided slab floors by number of mechanisms such as when continuity has been established by using reinforced concrete topping. Some of the important actions are:

- Sway of the tall building, due to wind or seismic actions, which creates relative rotation between the support and voided units;
- Vertical earthquake ground motion, which induces upward and downward seismic forces on the floor;
- Lenthing of beams parallel to the voided units, which

pushes the supporting beams apart. This induces tension in the starter bars connecting the topping concrete and voided units to the supports. This action induces axial tension or negative moments in the floor.

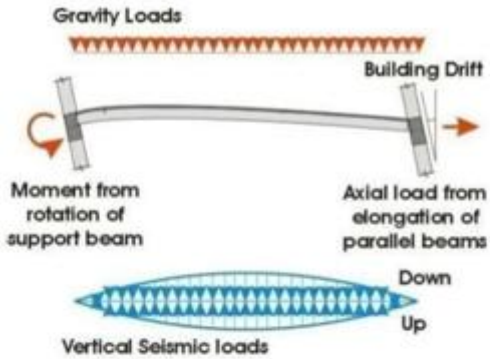


Figure 2.2: Loads contributing to bending potential loads acting

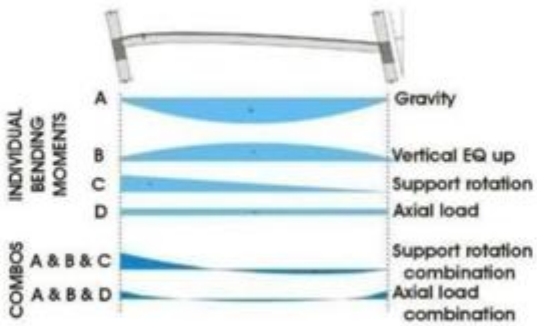


Figure 2.3: Bending moments from negative moment

Failure modes possible when Voided slab Floors are subjected to Negative Bending Moments:

Figure 2.4 : Hollow-core floor subjected to earthquake drift under upward vertical earthquake motion

Figure 2.5: Hollow-core floor subjected to earthquake drift under downward vertical earthquake motion

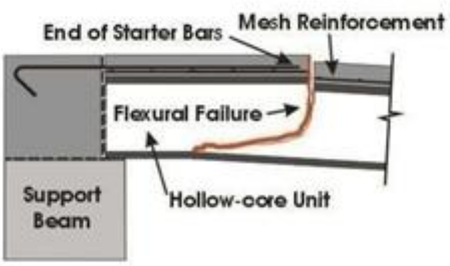


Figure 2.6: Flexural failure when mesh reinforcement ruptures at the end of starter bars

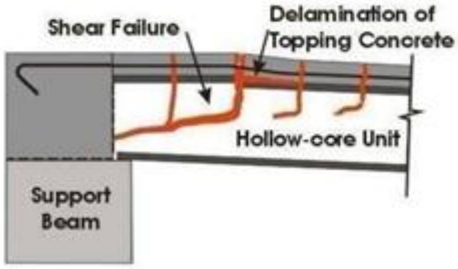


Figure 2.7: Flexure-shear failure induced by change in tension force in steel between flexural cracks

K. Soundhirarajan[1], M. Raghupathi[2], R. Ragupathi[3], K. Sathish kumar[4], V. Suresh kumar[5], 2018, this paper is based on study of structural behavior of HCS. The study concludes that Hollow core slab is most widely known for providing economical, efficient floor and roof system. HCS provides the efficiency of a precast member for load capacity, span range and deflection control. It also suggests that the top surface of HCS can be prepared by installing non-structural fill concretes ranging from 15-50mm thick depending on type of material used or by casting a composite structural concrete topping.

K.M. Monisha[1], G. Srinivasan[2], 2017, this paper is based on comparative investigation on structural behavior of HCS and RC slabs. Study suggests that cost efficiency of pre-stress Voided slab is high. Load carrying capacity of RCC slab is 20% less when compared to prestress Voided slab.

Prasad Bhamare[1], Sagar Bhosale[2], Akshay Ghanwat[3], Shubham Gore[4], Sheetal Jadhv[5], Sachin Patil[6], 2017, this paper concludes the design of precast members is economical if proper care is taken while designing. The cost and time duration of traditional construction is high when compared to precast construction. Better concrete quality can be achieved with lighter concrete units.

3. Methodology

The proposed work is planned to be carried out in the following manner

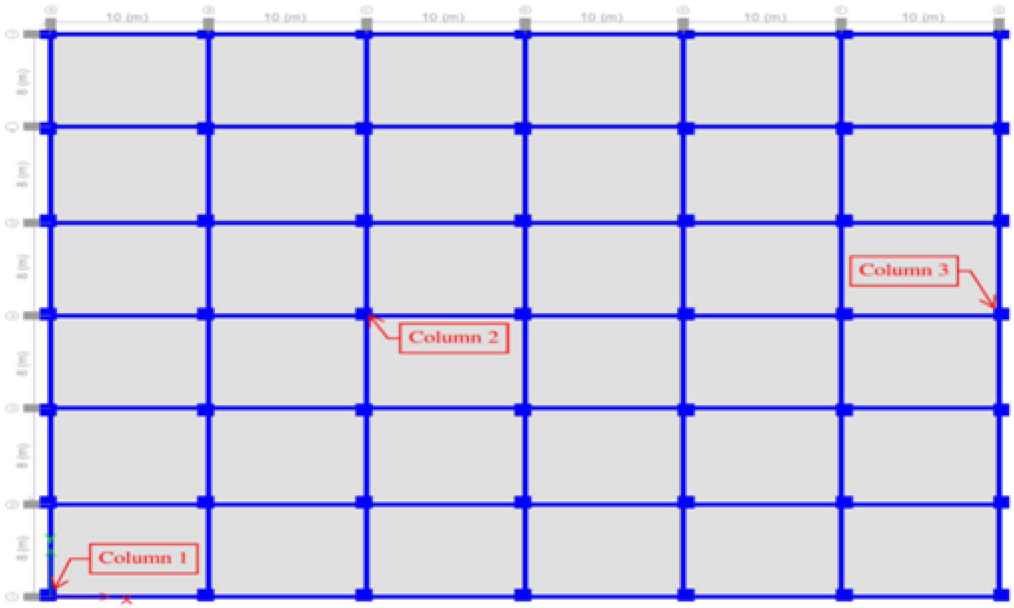
Study of seismic analysis method. Study of clauses related to design of RC structure from following codes:

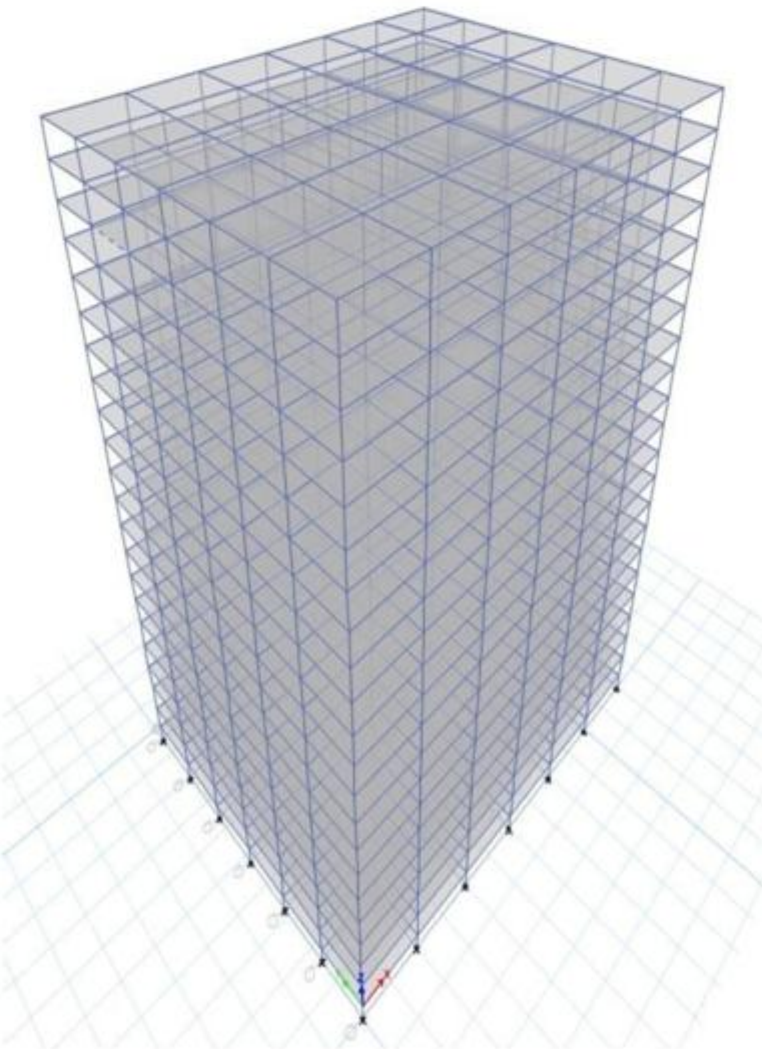
a) IS456:2000
b) IS1893:2016
c) IS13920:2016
d) IS 875 Part 1, 2 and 3.
   - Selection of buildingG+21
   - Analysis of columns, beams, floor and footing using ETABS.
   - Comparing the RC structural behavior of column, beams, floor and footing on following parameters:

Column: Shear, Moment, Axial forces.

e) Floor: Displacement, StoreyShear.
f) Footing: BaseShear

ETAB Model





Building Specifications

S.No	Case I	Case II
1.	Slab type: RCC slab	Slab type: Hollow core slab
2.	Storey: G+21	Storey: G+21
3.	Plan Dimension: 60m x 48m	Plan Dimension: 60m x 48m
4.	Height of each storey: 3.5m	Height of each storey: 3.5m
5.	Column Size: 750mm x 750mm	Column Size: 750mm x 750mm
6.	Beam Size: 300mm x 700mm	Beam Size: 300mm x 700mm
7.	4 model each for Zone II, III, IV and V.	4 model each for Zone II, III, IV and V.
8.	Building is fairly symmetric in plan and elevation.	Building is fairly symmetric in plan and elevation.
9.	Soil Condition: Medium Soil	Soil Condition: Medium Soil
10.	Importance Factor: 1	Importance Factor: 1
11.	Response Reduction: 5	Response Reduction: 5
12.	Assume Slab Thickness: 300mm Calculation (d) = (L/35) Slab Dead Load = 7.5 kN/ m^2	Assume Slab Thickness: 300mm Calculation (d) = (L/35) Slab Dead Load = Reduced by 33% = 5.025 kN/m^2
13.	Live Load: a) On Roof: 1.5 kN/m^2 b) On Floor: 3 kN/m^2	Live Load: a) On Roof: 1.5 kN/m^2 b) On Floor: 3 kN/m^2
14.	Floor Finish: 1 kN/m^2	Floor Finish: 1 kN/m^2
15.	Material: M 40 Grade concrete & Fe 500 Reinforcement	Material: M 40 Grade concrete & Fe 500 Reinforcement
16.	Unit Weight: Concrete- 25 kN/cum	Unit Weight: Concrete- 25 kN/cum

4. Analysis and Comparison of Results

Axial Force (Column)
The maximum axial force in the 3 columns in longitudinal and transverse direction is considered for examine in seismic zone II, III, IV and V for case I and case II:

Graph: Axial force.xlsx

1) Axial force on all the three columns is longitudinal and transverse direction is less for case II compared to case I for every storey.
2) On comparing Axial force reduction in % wise following points can be observed:
3) For column 1 the reduction in axial force in case II is between 14% to 18.5% compared to case I and can be seen in all 4 Seismic zones.
4) For column 2 the reduction in axial force in case II is between 17% to 22% compare to case I in all four Seismic zones.
5) For column 3 the reduction in axial force in case II is between 14% to 20% compared to case I for zone II, III and IV and for zone V the reduction is between 12% to20%.

Shear Force (Column)
The maximum shear forces in the three columns in longitudinal and transverse direction is considered for examine in seismic zone II, III, IV and V for case I and case II :

Graph: Shear Force V2.xlsx Shear Force V3.xlsx

1) On observing the data shear force in X and Y direction for case II is less than case I, valid for all seismic zones.
2) There will be reduction in Area of steel (Ast) for case II as shear force is directly proportional to Area of Steel hence the structure will be economic.
3) It can be observed that the reduction of shear force percentage wise is between 18% to 22% for case II compared to case I.

Bending Moment (Column)

The maximum Bending Moment in the 3 columns in longitudinal and transverse direction is considered for examine in seismic zone II, III, IV and V for case I and case II:

Graph: Bending moment M2.xlsx Bending moment M3.xlsx
1) On observing the data bending moment in X and Y direction for case II is less than case I, valid for all seismiczones.
2) There will be reduction in Area of steel (Ast) for case II as bending moment is directly proportional to Area of steel (Ast) and hence the structure will be economic
3) It can be observed that the reduction of bending moment percentage wise is between 17% to 21% for case II compared to case I.

Displacement (Floor)
Plots of storey level displacement in longitudinal or transverse versus height are made for the two cases, all imposed on same graph: Graph: Displacement-floor from the graph it is observed that for case II displacement of

storey in X& Y direction is less compared to case I, zone wise.

1) As the zone changes from II to V, the value of displacement increases for both cases, but Case II displacement remains less from case I in every earthquake zone.
2) Storey level in X & Y direction, displacement of case II is around 20% less for every floor when compared to case I in each zone.

Storey Shear (Floor)

Plots of shear in story in longitudinal or transverse versus height are made for the two cases, all imposed on same graph.

Graph: Storey shear-Floor.xlsx

1) From the graph it is observed that for case II Storey shear in X & Y direction is less compared to case I, zone wise.
2) As the height of building increases the reduction value of storey shear in case II goes on increasing compared to case I.
3) Considering each zone the reduction in storey shear percentage wise for case II is from 19% (ground floor) to 23% (terrace) compared to case I.
4) The reduction of storey shear percentage wise for case II compared to case I is constant if we compare zone wise.

5. Conclusion

Based on analysis it can be concluded that loading on columns, beams and Footings for Voided slab model is less compared to RCC Slab model, hence the size and reinforcement of the members will be less for Voided slab structural members. It can be concluded that Voided slab buildings will take less time for erection than RCC buildings as Voided slab is precast and manufactured in factory with quality control. Thus reducing the cost of project and hence economical.

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