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CONCEALED BEAM IN REINFORCED CONCRETE STRUCTURES: A PERFORMANCE-BASED ANALYSIS

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ABSTRACT

The use of hidden beam in reinforced concrete construction is seen as an effective method in reducing excessive deflection in large spans. However, despite its presumed advantages and growing usage, no mention of it in standard civil engineering literature, codes and standards. In this paper, performance-based analysis is

Introduction

Beams are structural elements whose primary function is to transfer the loads from adjoining slabs to the supporting members. Where a concrete slab is very wide, beams are usually provided in-between to convert them into smaller panels. The dimensions of the beam required will depend on factors which vary between the span and the estimated load transferred to the beams from the slab.

Hidden beam also known as concealed beam, secret beam, wide-shallow beam, or wide-band beam is a beam whose width -to- depth ratio is

carried out on three different cases of slab arrangement involving hidden beams using SAP2000. The process is performed under dead and live load combination and based on the design guidelines in BS8110. The result of the performance-based analysis shows a 4%, 2% and 11% decrease in deflection, stress distribution and area of bending steel reinforcement required for the case with hidden beam in comparison with the case without beam. This indicates that the presence of hidden beam in slab is significant. Thus, it is recommended that for reducing excessive deflection in large spans, hidden beams can be introduced. However, further studies should be conducted to determine the optimum width of the hidden beam for most effective utilization.

greater than 2, though, in most cases it is usually constructed having the same depth as the slab, in other words, it is provided within the depth of the supporting slabs. These hidden beams are constructed by placing additional longitudinal reinforcing bars in the slab along the line where the actual beam should have been present or in the middle of large span slabs where excessive deflection is feared and may involve stirrups or not (Shuraim, 2012; Serna-Ros, et al., 2002; Lubell et al., 2009; Conforti et al., 2015; Conforti et al., 2017). However, despite its growing popularity and usage, no mention of this type of beam in standard civil engineering literature, codes and standards. The idea of hidden beam is to help disperse loads imposed on the slab thereby relieving the slab of excessive stresses and thus accommodating even larger spans.

Adequate information and documentations on hidden beams especially with regards to its performance only started in the late 2000, thus, research on the performance of these beams is still scanty and need further investigations especially with the growing popularity and usage in reinforced concrete constructions.

Ozbek et al., (2020) experimentally investigated the drawbacks of hidden beams. A total of fourteen half-scale specimens, including conventional T-beams and hidden beams were tested to failure under four-point loading. Reinforcement ratio and slab thickness were adopted as test parameters. The results indicated that hidden beams were able to achieve reference strengths after excessive deformations or they occasionally could never achieve these capacities.

Helou & Awad (2014); Helou and Diab (2014) investigated the structural influence of hidden beams in RC slabs. Numerical results from the investigations show that hidden beams are never adequate and are thus generally unnecessary.

Mahmad and Raviz (2017) **studied the flexural behavior of RC slabs with concealed beams using ANSYS. They** reported that the deflection of slabs supported with concealed beams was significantly more.

Arakere and Doshi (2015) also studied the performance of slabs with concealed beams due to seismic loading. They reported that the displacement of slab with concealed beam was greater compared to that with normal beam. The researchers recommended normal beams for building under seismic loading.

On the contrary to previous researchers, Chetan and Hemant (2017) in their research on the performance of concealed concrete beams recommended the use of concealed beams ahead of normal beams for buildings during earthquake excitation. The authors reported that although the stiffness of the slab with concealed beams was less, the base shear was significantly lesser, since the lesser the mass, the lesser will be the seismic force. The authors also posit in their conclusion, that in multi-storey structures, if long span slabs are present, they tend to deflect more. Thus, concealed beams can be provided in order to decrease the deflection and increase the stiffness of the slab.

While the few available literature focused on the performance of hidden beams under seismic loading, present study intends to investigate the performance of hidden beams under dead and live loads based on the design guidelines in BS 8110 (1997).

Methodology

Modelling of Slab with Hidden Beams

To investigate the performance of hidden beam under dead and live loads and based on the design guidelines in BS8110 (1997), a 150mm thick slab as shown in Figure 1 is modeled and designed in SAP2000 (2021) considering three cases.

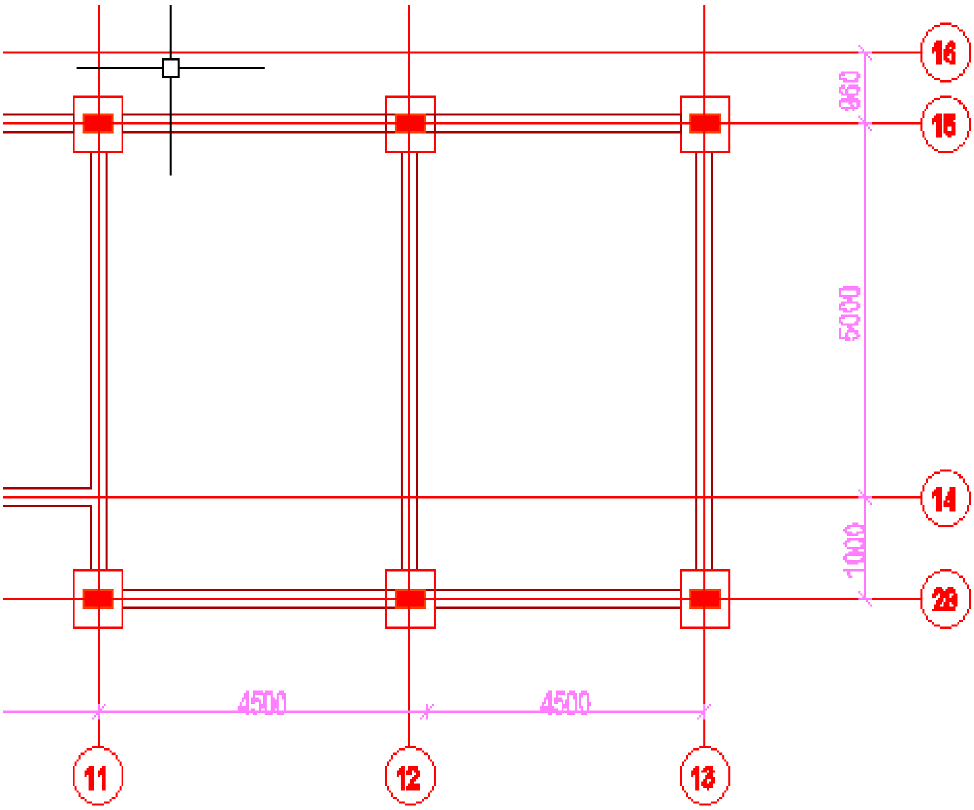

Figure 1: Slab and Beam arrangement for the Model

Case 1:

Slab with a 600x230mm dropdown beam (along gridline 12)

Case 2

Slab with a 150 x 450 mm hidden beam at the middle of the slab (along gridline 12)

Case 3
Slab without any intermediary beam

The system is acted upon by a live load of 2.0 kN/m^2 and dead load of 5 kN/m^2 in addition to its own self weight. The slab thickness in all the cases is set to 150mm, the periphery ledger beams have 600x230mm cross section while that of the supporting columns is 450x300mm, dead and live loads combination as recommended in BS8110(1997) is considered. Other design details are the compressive strength of 25N/mm^2 and tensile strength of 460N/mm^2 for concrete and rebar respectively.

Analysis and Results

Deflection

The deflection of the slab under dead and live loads action is shown in Figure 2 for the three cases considered. It is obvious from the nature and patterns of the figures that the deflection of the slab for case 1 (Fig. 2a) is less compared to cases 2 and 3 (Figs 2b and 2c) which show similar pattern. However, it is observed that the deflection for case 2, especially at the edges, is quite lesser than that of case 3. Generally, a 4% decrease in deflection for case 2 in relation to case 3 is observed. This indicates that the hidden beam has effect on the deflection of slab which is in agreement with the outcome of Chetan and Hemant (2017).

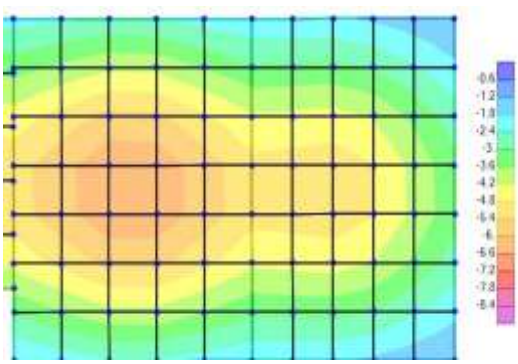

Fig. 2a: With Drop Down Beam

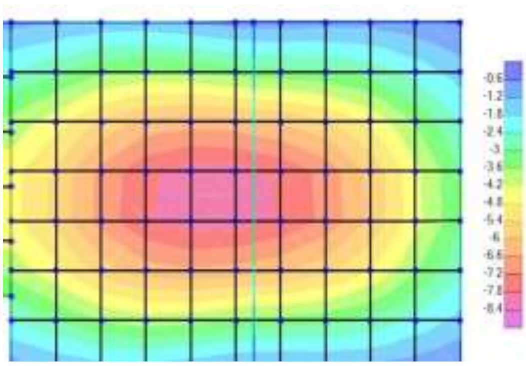

Fig. 2b: With Hidden Beam

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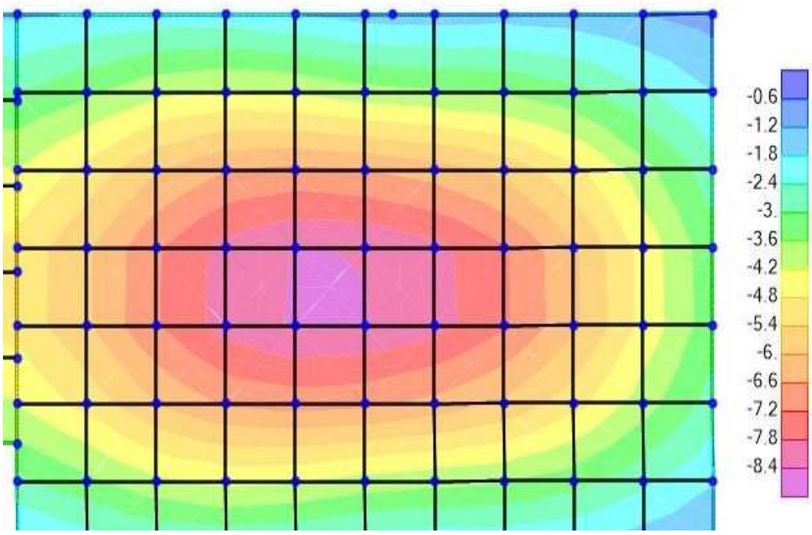

Fig. 2c: Without Beam

Stress Distribution

The stress distribution in the slab due to dead and live loads is shown in Figure 3 for all cases. The nature and pattern of stress distribution for cases 2 and 3 are very much similar, having maximum values along the edges of the slab. A 2% difference in the values of maximum stress is observed, thus indicating that the hidden beam has very little effect on the stress distribution of the slab. However, a significant stress distribution and pattern is observed in case 1. In this case, the stresses are maximum along the edges and along the dropdown beam with maximum value far less compared to cases 2 and 3.

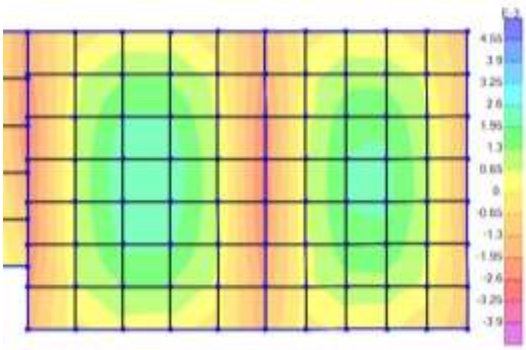

Fig. 3a: With Drop Down Beam

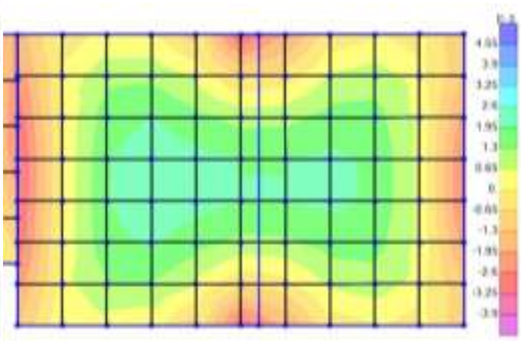

Fig. 3b: With Hidden Beam

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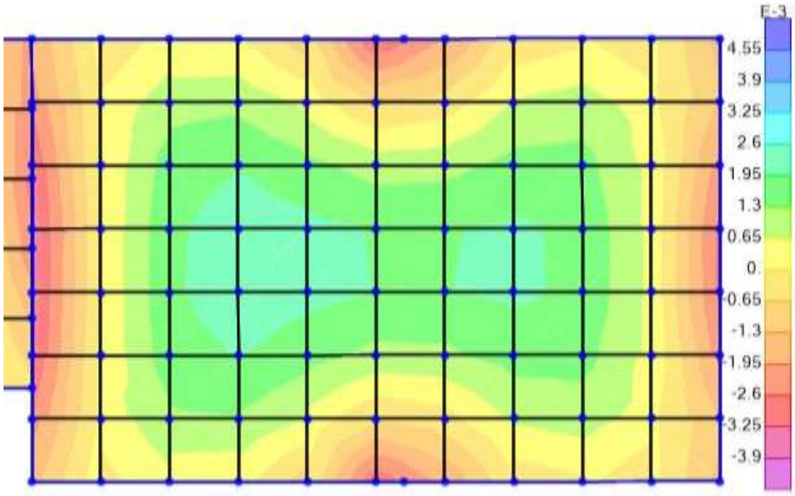

Fig. 3c: Without Beam

Area of Bending Steel Reinforcement Required

Area of bending steel reinforcement required to satisfy flexure and deflection is considered and presented in Figure 4 for all cases. Again similar pattern is observed for cases 2 and 3, maximum values are observed at the edges for top reinforcement and at the middle for bottom reinforcement as is expected. A significant difference in the area of steel reinforcement required of up to 11% is observed between cases 2 and 3. This further confirms the work of Chetan and Hemant (2017) who poised that the presence of hidden beam in slab has positive effect and is considerably significant.

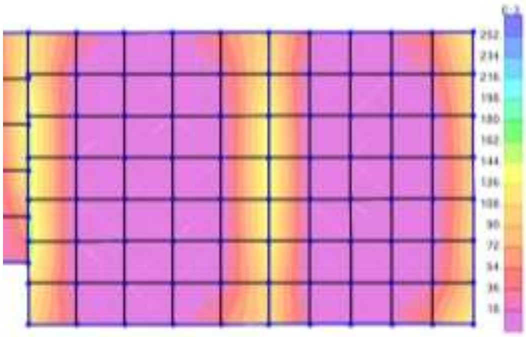

Fig. 4a: With Drop Down Beam

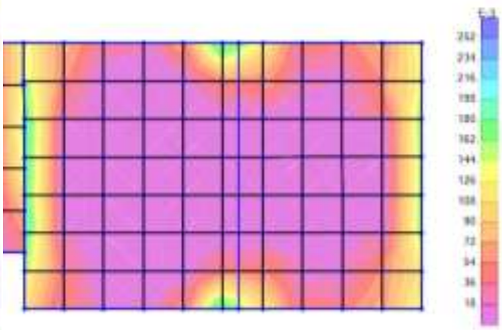

Fig. 4b: With Hidden Beam

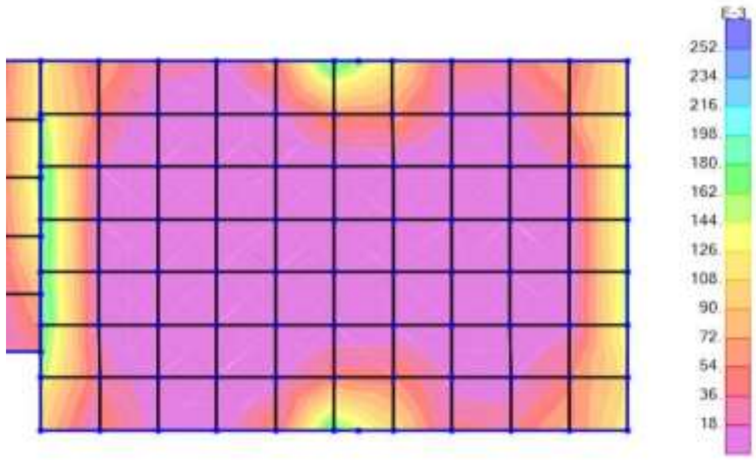

Fig. 4c: Without Beam

Conclusion

Performance-based analysis was performed on hidden beam in reinforced concrete slab, the result of the analysis shows a significant reduction in the stress distribution, deflection and area of bending steel required in the slab with respect to slabs with and without hidden a beam. Consequently, hidden beam can be used to achieve reductions in stress distribution, deflection and area of bending steel required in large spans. Further investigations should be conducted to determine the optimum width of the hidden beam in slab construction and also the cost analysis, this will provide a holistic investigation on the hidden beam for most effective utilization.

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