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(Research Article)

Flexural behavior of 3D Panel slabs under uniformly distributed gravity loads

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Abstract

After each major earthquake light weight structures that can be constructed in a short time period are needed to accommodate homeless people affect by the earthquake. 3D panel structures are one type of theses structures. The 3D panel is made of a 3 mm diameter steel wire space truss integrated with a polystyrene core sheet and it is converted to a structural wall after shotcreting it with concrete or cement mortar. In practice the 3D panels are used to construct one or two storey houses. In construction practice additional steel reinforcements are added to the 3D panels to construct roof or floor slabs. In this paper 3D panel slabs with steel reinforcements are tested under distributed gravity loads. Test results show that the steel reinforced 3D panels are able to withstand safely gravity loads specified by international codes, and mid span deflection values were less than the limits specified by international standards. Furthermore the 3D panel slabs show almost full composite behavior under flexural moment effects.

Keywords :3D panels; Earthquake loads; Concrete; Buildings; Slabs; Flexural behavior

1. Introduction

Using lightweight materials such as wood, cold formed steel and 3D panels in construction of new buildings will reduce earthquake loads on these buildings. In 2023 two major earthquakes of 7.7 and 7.6 magnitudes hit east south of Turkey causing collapse of thousands of buildings and thousands of life losses and injuries [1]. The main reasons of building's collapses were low construction quality of the existing reinforced concrete buildings and also the soft soil conditions which led to amplification of the earthquakes ground acceleration and in some places liquefaction. Hence in design and construction of new buildings engineers should use better materials and calculate future earthquake loads taking into account soft soil conditions (i.e if exists) [2,5,7] . After the earthquakes construction of new buildings in a short time period was needed to provide accommodation to homeless people. Compared with reinforced concrete due to their low cost and fast construction 3D panels are used in practice to construct one or two story buildings as shown in Fig1.The 3D panel is made of a 3 mm diameter steel wire space truss integrated with a polystyrene core sheet and at construction site it is converted to a structural wall after shotcreting it with concrete or cement mortar. A general view and cross-sectional details of the 3D panel is given in Fig 2. In literature some research were conducted to understand the structural behavior of these panel buildings under earthquake loads. ½ scale one storey 3D panel building was constructed and tested in the laboratory under lateral loads up to failure [3]. Test results show that the building was able to reset lateral loads more than two times of design earthquake loads, and only minor local reparable damages were observed.

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Figure 1 Use of 3D panel in construction of one or two storey buildings

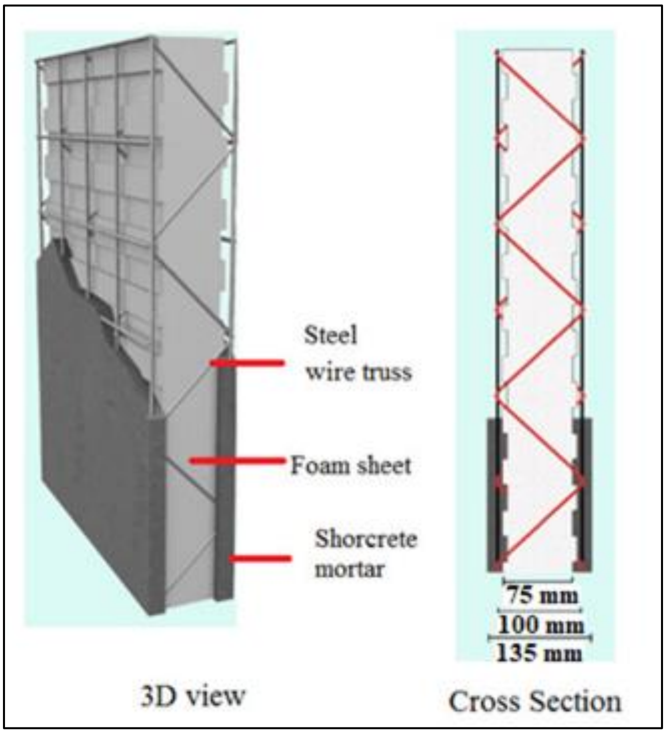


Figure 2 3D view and cross sectional details of a 3D Panel

Furthermore the 3D panel buildings due to their good heat insulation are energy efficient buildings [4,6]. In construction practice additional steel reinforcements are added to the 3D panels to construct roof or floor slabs. In this paper 3D panel slabs with steel reinforcements are tested under distributed gravity loads. Test specimens, test setup and test results are presented in the following paragraphs.

2. Test Specimens and Test setup

To investigate the behavior of 3D panel slabs with additional reinforcement, two specimens were prepared in the laboratory. The width of each specimen was 1 m and the span was 4m.The first specimen was reinforced with 6 Φ 8 bottom steel reinforcements and the second specimen was reinforced with 6 Φ 8 top steel reinforcements. Then 80 mm concrete layer was casted on each specimen making the total thickness of the slab panel equal to 185 mm. Concrete compressive strength was 30 MPa .The 3D panel 3 mm diameter steel wire yield strength was 500 MPa , and the yield strength of the added steel reinforcements was 420 MPa. The 30 mm mortar layer compressive strength was about 10 MPa. Table 1 shows test specimen details. After 28 days of concrete casting test specimens were tested under increasing distributed loads .Fig 3.Shows the test setup and test specimens during preparation. Test specimen cross sectional details are shown in Fig4.

Table 1 Test Specimens details

Test Specimen No	Span (m)	Reinforcement	Top concrete thickness (mm)
1	4	with 6 Φ 8 bottom reinforcement	80
2	4	with 6 Φ 8 top reinforcement	80

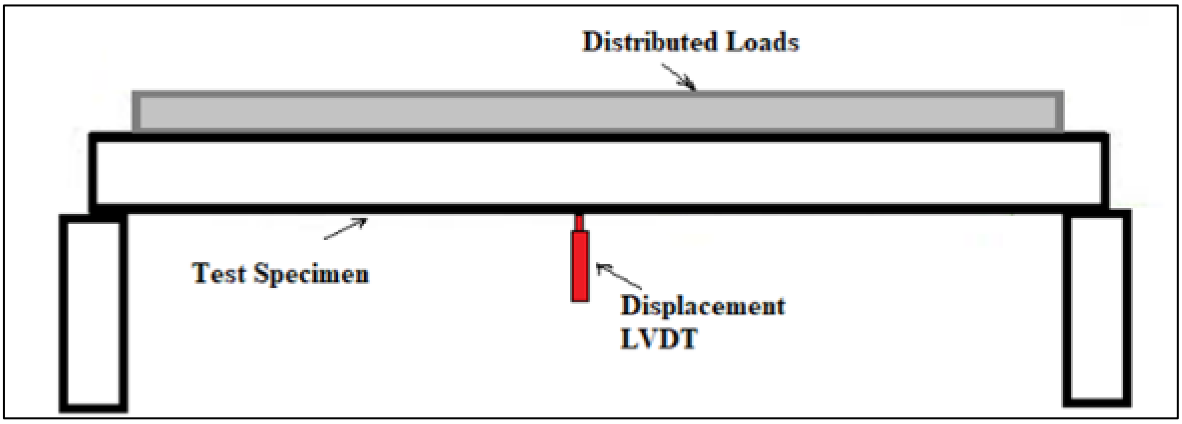
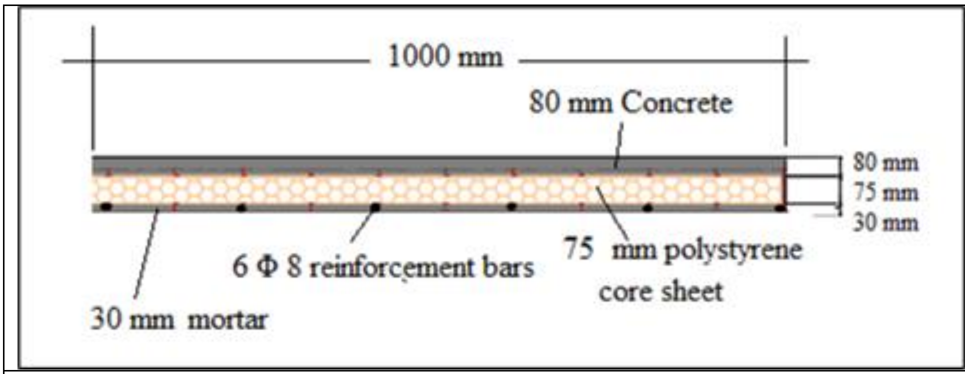
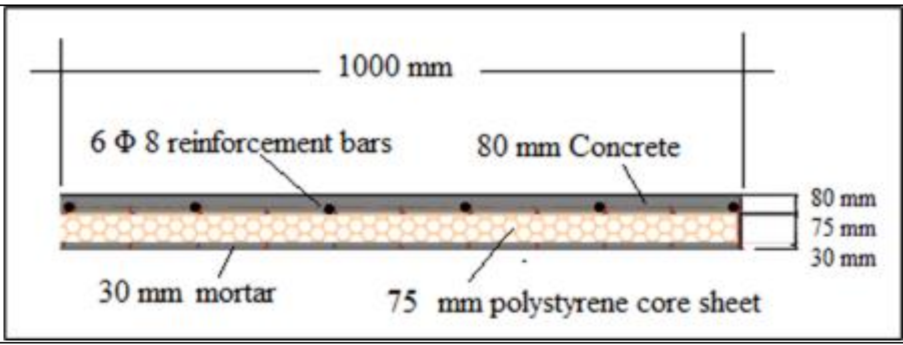


Figure 3 Test Specimens and test setup



a)Cross section and reinforcement details of first specimen



b) Cross section and reinforcement details of second specimen

Figure 4 Specimens cross sectional details

3. Tests and Results

The two specimens were tested under increasing distributed loads. The distributed loads were applied using cement bags as shown in Fig 5. The total load –mid displacement values were measured and plotted as shown in Fig 6. From the results it is shown that the first specimen with bottom reinforcements has higher load carrying capacity and higher stiffness than the second specimen with top reinforcement. Furthermore the failure mode of the two specimens was different. By increasing loads flexural cracks starts at the bottom of the first specimen and the reinforcement steel yields , then by increasing loads the reinforcement steel reached its ultimate strength and ruptured , then the upper 80 mm concrete layer cracked and fail as it is shown in Fig7. However the second specimen with top reinforcements failed at lower loads compared to the first specimen and sudden concrete compression failure occurs at the 80 mm layer concrete.

Figure 5 Specimen during tests

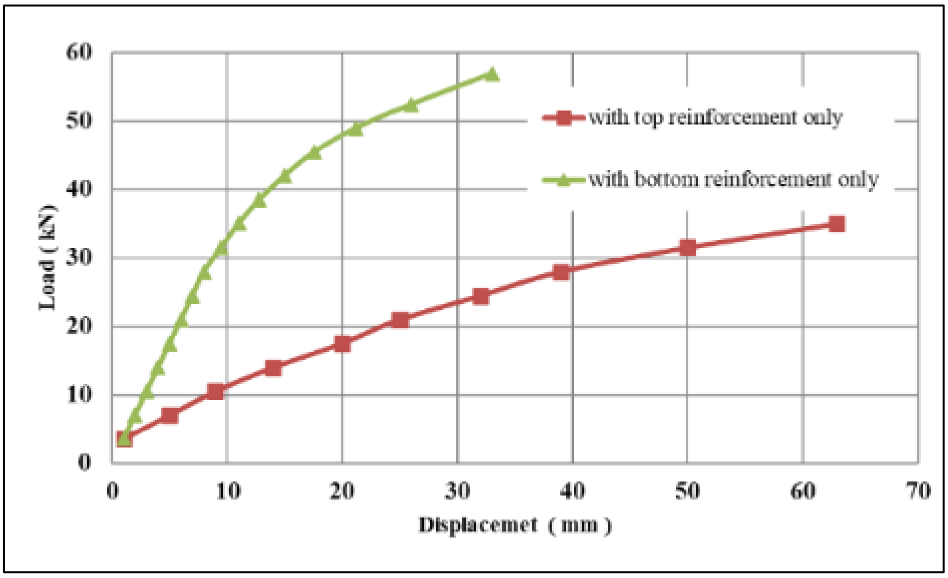


Figure 6 Total load-mid displacement curves of the two specimens

Figure 7 Failure mode of the first specimen with bottom reinforcement

4. Conclusions

In construction practice when the 3D panels are used as slab elements, 80 mm concrete layer is casted at the top of the panels and additional reinforcement is needed. The location of the additional steel reinforcements may be at the bottom side of the panel cross section or at the top side. In this research two 3D panel slab specimens with two different steel reinforcement positions were tested under gravity distributed loads. Test results show that the specimen with bottom reinforcements has almost twice higher stiffness and strength than the specimen with top reinforcements. Furthermore the failure mode of the two specimens was different. The first specimens (i.e with bottom reinforcement) failure mode was ductile by yielding of the steel reinforcements .However the second specimen (i.e with top reinforcements) failure mode was sudden by crushing of the 80 mm concrete layer.In both of the specimens, no separation occur between the 30 mm bottom mortar layer and the 80 mm top concrete layer . This shows good connection between the two layers because of the diagonal bars of the space truss . And the two specimens show almost full composite behavior under flexural moment effects. The deflection of the first and second specimens under service live load of 3 kN/m2 (total load of 12 kN , i.e 3 kN/m2 x 4 m span x 1 m width = 12 kN) are 6 mm and 11 mm respectively . This deflection value is less than the deflection value specified by international code of 16.7 mm (i.e L/240 = 4000/240 = 16.7 mm) . Test results show that the steel reinforced 3D panels are able to withstand safely gravity loads (i.e. dead and live loads) specified by international codes, and mid span deflection values were less than the limits specified by international standards. And it is better to locate the additional steel reinforcement at the bottom side of the panel cross section to get more load carrying capacity and also less deflections. In future research more tests are needed to get better understanding of the behavior of these panels under flexural moments and shear forces effects.

Compliance with ethical standards

Acknowledgments

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