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Experimental research on reinforced concrete slabs with loads from column placed on the slab

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KEYWORDS

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Crack

ABSTRACT

Slabs made of reinforced concrete often get subjected to loads that are distributed uniformly across the whole surface of the slab. On the other hand, there are situations in which the slab is subjected to concentrated loads by columns that are put directly on the slab surface and located at the free edge of the slab. This can easily cause damage to the slab. The authors of this paper conducted an experimental investigation to examine the behavior of a reinforced concrete slab with dimensions of 1200×1600×120 mm. The slab was subjected to direct column loads at the free edge of the slab. When the diameter of the primary load-bearing steel bars in the slab was changed, the findings of the research made it possible to establish the relationships between load-vertical displacement, load-tensile (compressive) deformation, and crack formation and propagation on the top and lower surfaces of the slab. Changing the steel bars resulted in a twenty percent decrease in load-bearing capacity for the S6 slab in comparison to the S1 slab, as demonstrated by the findings of the respective investigation.

1. Introduction

The research [1] focuses on the shear strength of both normal and high strength slabs. The results indicated that the parameters examined significantly affect the increase in shear strength, while the impact of tensile reinforcement is considerable. Various studies have examined the factors influencing the bearing capacity of slabs, focusing on aspects such as shape, size, and the number of columns, as explored by several groups of authors including [2-5].

Flat slabs and columns positioned directly on the slab were reinforced using glass fiber reinforced concrete (GFRP), shown in Figure 1 [6]. The GFRP flat slabs featuring symmetrical openings, with a test specimen size of (1100×1100×90) mm, were subjected to centric load testing until failure occurred. The findings indicated that the existence of openings diminished the shear capacity and heightened the deflection [7].

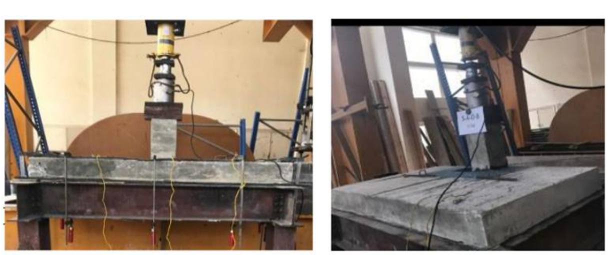

Fig.1. Column placed directly on slab reinforced with GFRP [6].

The authors Nasr Z. Hassan et. al., carried out an experiment involving seven column specimens positioned on a square flat slab measuring 1700×1700×160 mm [8]. Hanaa G. Mohammed et. al., examined a case of a flat slab subjected to direct loads from the columns. The authors conducted an experimental study on this model to determine the maximum load, bending, and stiffness, subsequently employing ANSYS software to verify the experimental findings and explore various larger-scale models [9].

Several authors continued with carrying out experimental research on flat slab specimens featuring square openings, focusing on the number of openings as the key parameter under investigation. Following the experimental research, the authors validated the experimental results through the use of ANSYS simulation software for computational analysis. The comparison demonstrated that the results from ANSYS aligned well with the experimental findings [10].

There were also studies done on the slab thickness factor. Nadia Nassif et al. did an experiment to test the bending strength of fiber-reinforced concrete flat floors [11]. Ngekpe, B. E. et al. investigated the use of a crack model in finite element analysis to investigate shear problems at edge connections [12]. D. Mahmood et. al. conducted a study on the shear strength of high strength fiber reinforced concrete in eccentrically loaded flat slabs. This study examines the shear strength of high strength concrete slabs, taking on the experimental program conducted. It explores the impact of various parameters, including concrete compressive strength, steel fiber reinforcement, and load eccentricity, on the stresses experienced in slab-column connections [13].

This paper presents an experimental survey based on the analyzed research results of the authors, focusing on the behavior of a reinforced concrete slab measuring 1200×1600×120 mm. The slab bears the direct load from a column positioned at its free edge, with variations in the diameter of the steel bars incorporated into the slab.

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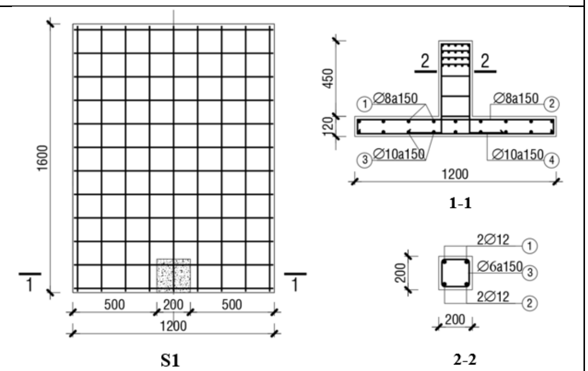
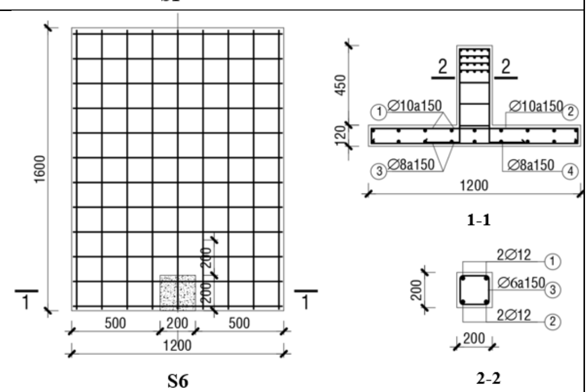
2. Materials and Methods

2.1. Design of experimental specimens

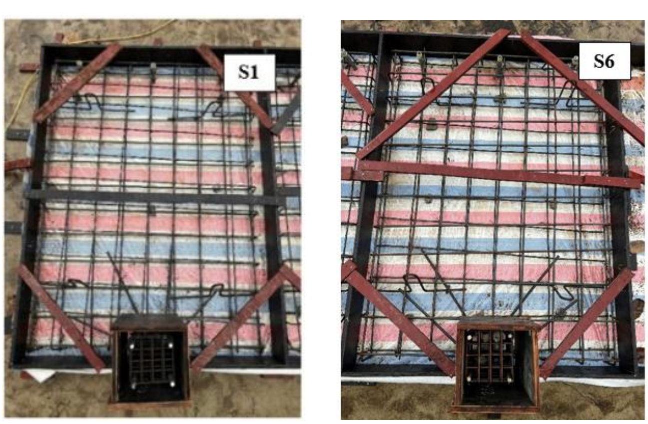
The test specimens exhibit shapes, parameters, and dimensions that are detailed in Table 1 below:

Table 1. Specimen parameters.

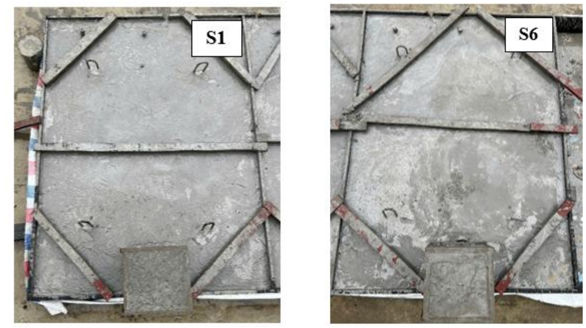
No.	Specimen parameters
S1	
S6	

2.2. Manufacturing of experimental specimens

The processing of formwork, reinforcement, and the pouring of concrete for the slab specimens are shown in Figure 2 as follows:



a) formwork, reinforcement (S1) b) formwork, reinforcement (S6)



c) pouring of concrete (S1) d) pouring of concrete (S6)

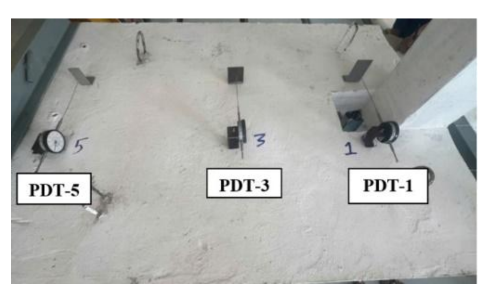
Figure 2. Formwork, steel reinforcement, and concrete pouring of specimens.

2.3. Experimental equipment layout diagram

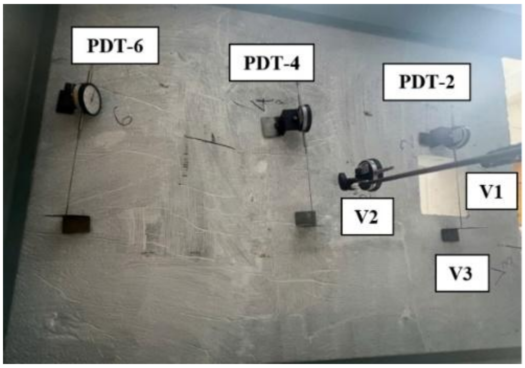
This study examines a slab that is supported on three edges, with the remaining edge left free. A column is positioned on this free edge, as shown in Figure 3:

Figure 3. Slab positioned on the test platform with the column at the free edge.

To determine the deformations on both the upper and lower surfaces of the slab, it is necessary to position 3 strain gauges on the upper surface and 3 strain gauges on the lower surface, specifically at the beginning, middle, and end of the slab. Additionally, 3 vertical displacement gauges should be installed in the middle of the slab and at the base of the column, as shown in Figure 4:



a) upper surface



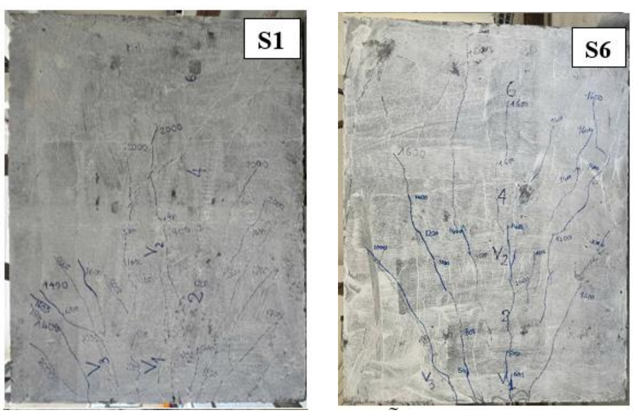
b) lower surface

Figure 4. Arrangement of experimental equipments on surfaces of the slab.

3. Results and discussions

3.1. Crack formation and propagation in slabs

Figure 5 shows the progression of cracks from initiation to complete slab failure as follows:



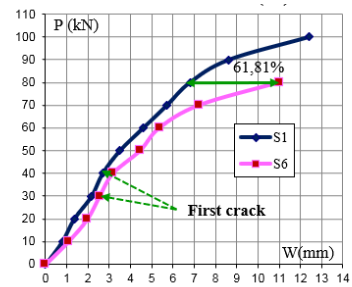
a) S1 slab b) S6 slab

Figure 5. Crack formation and propagation in slabs.

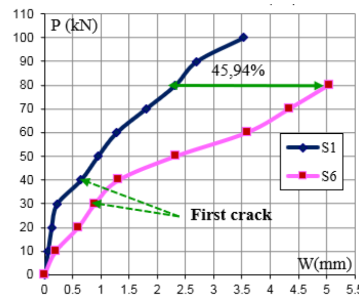
The first cracks in the S1 slab appear at a load level of 40 kN. At the 30 kN load level, cracks have developed in the S6 slab. The initial cracks in the S1 and S6 slabs exhibit similarities, with the cracks being concentrated at the base of the column, close to the point of force application and the free edge of the slab. As we increase the load on the slab, in S1 slab, cracks tend to develop gradually and spread throughout the slab. In S6, the cracks that emerge later evolve slowly and extend nearly throughout the entire slab.

3.2. Relationship between load and vertical displacement in slabs

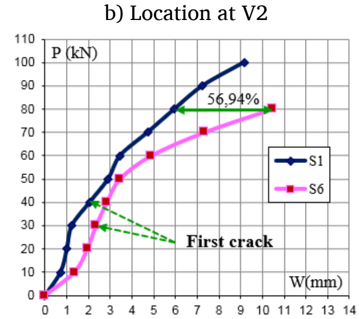
The author employs Psi as the unit of measurement for the experimental data (1 Psi = 0.05 kN). The author employs kiloNewtons as the unit of measurement for calculating data. Figure 6 shows the relationships between load and vertical displacement for slabs S1 and S6:



a) Location at V1



b) Location at V2



c) Location at V3

Figure 6. Relationship between load and vertical displacement of the slab.

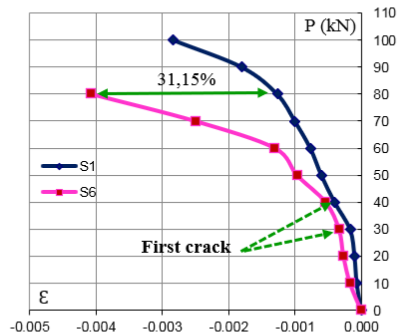
Analysis of the relationship diagrams between load and vertical displacement presented in Figure 6 reveals that at points V1, V2, and V3, when the load reaches P = 80 kN, the vertical displacement of slab S1 is less than that of slab S6 by 61.81 %, 45.94 %, and 56.94 %, respectively. S1 slab: At point V1, the maximum vertical displacement recorded is 12.4 mm, while the vertical displacements at points V2 and V3 are 28.47 % and 73.79 % lower than that of V1, respectively. S6 slab: At point V1, the maximum vertical displacement measures 11 mm, while the vertical displacements at points V2 and V3 are 45.91 % and 95 % lower than that of V1, respectively.

3.3. Relationship between load and deformation of slabs

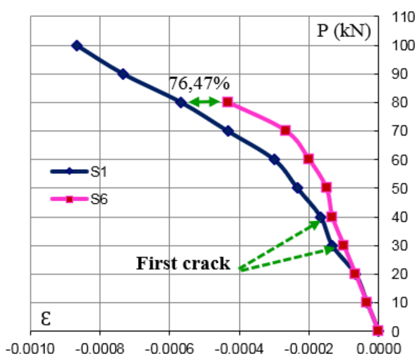
3.3.1. Compression zone deformation: shown in Figure 7

At point PDT-1, when the load reaches P = 80 kN, the deformation in the compression zone of slab S1 is 31.15 % less than that of S6. At this load level, S6 attains its maximum load capacity and starts to fail, whereas S1 continues to endure the force. S1 functions effectively up to the load level of P = 100 kN before it starts to fail. At points PDT-3 and

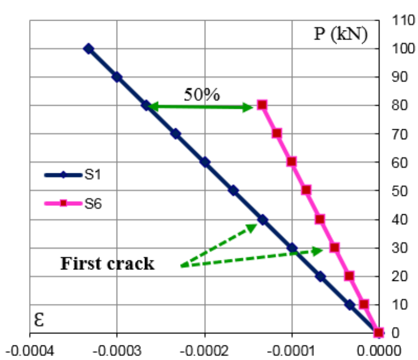
PDT-5, conversely, when the load reaches P = 80 kN, the deformation in the compression zone of slab S6 is 76.47 % and 50 % smaller than that of S1, respectively.



a) PDT-1



b) PDT-3

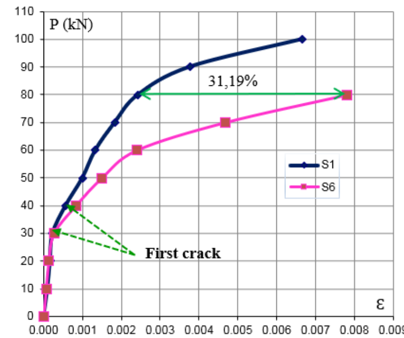


c) PDT-5

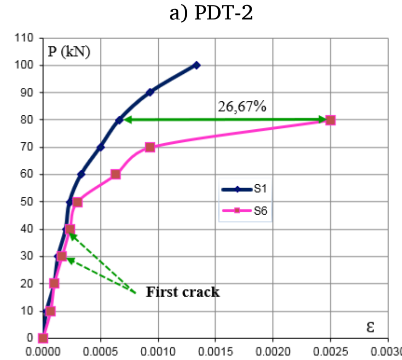
Figure 7. Load and compressive strain relationship.

3.3.2. Tensile zone deformation: shown in Figure 8

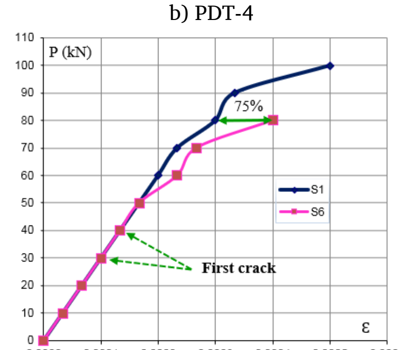
The diagram showing the relationship between load and tensile deformation, as presented in Figure 8, reveals that: At a load of P = 80 kN, at point PDT-2, the tensile strain of slab S1 is only 31.16 % in comparison to slab S6. At point PDT-4, the tensile strain of slab S1 is only 26.67 % in comparison to slab S6. At point PDT-6, the tensile strain of slab S1 is only 75 % in comparison to slab S6. At a load level of P = 80 kN, slab S6 attains its maximum load-bearing capacity and starts to fail, whereas slab S1 continues to support the load until it reaches P = 100 kN, at which point S1 begins to fail.



a) PDT-2



b) PDT-4



c) PDT-6

Figure 8. Relationship between load and tensile strain.

4. Conclusions

The research findings on the S6 slab indicated a 20 % reduction in bearing capacity, with an increase in the number of cracks that extended further compared to the S1 slab. Additionally, the cracks on the S6 slab reached the opposite edge of the column and appeared earlier than those on the S1 slab. Concerning vertical displacement in the slab: at the location below the column and at the failure load level of the S6 slab (80 kN), the variation in vertical displacement values between the two slabs is 88 %. Concerning the deformation in the compression (tension) zone: it indicates that the PDT-1 (PDT-2) position exhibits a significantly larger deformation value in comparison to other zones within the slab. Changing the steel bars in the floor from ϕ8 to ϕ10 (and vice versa) clearly demonstrates a significant impact on the load-bearing capacity of the slab.

References

[1]. I. M. Metwally, M. S. Issa, and S. A. El-Betar "*Punching Shear Resistance of Normal and High- Strength Reinforced Concrete Flat Slabs*". Civil Engineering Research Magazine, 30(3), Pp. 982-1004, 2008.

[2]. V. Filatov "*Evaluation of punching shear strength of flat slabs supported on rectangular columns*". E3S Web Conf., 33, 2018. DOI: 10.1051/e3sconf/20183302007

[3]. A. Elsayed, M. Elsayed, and D. M. Saad "*Punching Shear Behavior of RC Flat Plate with Openings Rested on Coupled Columns*". 114th Iastem International Conference, Stockholm, Sweden, At: Stockholm, Sweden, 2018, pp. 7-13.

[4]. F. Sheta, E. E.-D. Mostafa, and A. Khalil "*Non-linear Finite Element Analysis for the Behavior of Punching Shear in Flat Slabs with Openings*". International Journal of Scientific & Engineering Research, 11(10), Pp. 239-247, 2020.

[5]. A. H. Jasim and H. K. Ammash "*Effect of using column capital on the punching shear strength of flat slab-edge column connection under eccentric loading*". In Journal of Physics: Conference Series, 1895(1), 2021. DOI: 10.1088/1742-6596/1895/1/012060

[6]. W. A. Ali, E. S. Mohamed "*Behaviour of Strengthened Flat Slab with Opening at Edge Column under Punching Shear Strength*". International Journal of Engineering and Advanced Technology, 9(3), Pp. 1039–1045, 2020. DOI: 10.35940/ijeat.C5004.029320

[7]. M. T. Abduljaleel, A. S. Mahmoud, and A. R. Yousif "*Experiential investigation of two-way concrete slabs with openings reinforced with glass fiber reinforced polymer bars*". Journal of Engineering Science and Technology, 12(4), Pp. 898-912, 2017.

[8]. Nasr Z. Hassan, Mostafa A. Osman, Awad M. El- Hashimy, and Heba K. Tantawy "*Enhancement of punching shear strength of flat slabs using shear-band reinforcement*" HBRC Journal, 14(3), Pp. 393-399, 2018. DOI: 10.1016/j.hbrcj.2017.11.003

[9]. H. G. Mohammed, A. E. Y. A. Elezz, N. G. Fahmy, and L. M. A. el-Hafez "*Studying the effects of shear studs on the punching shear resistance of thin flat slabs with edge column connections and openings*" Asian J. Civ. Eng., 25(3), Pp. 2823–2841, 2024. DOI: 10.1007/s42107-023-00948-z

[10]. H. Mohammed, N. Fahmy, L. Soliman, and A. Abouelezz "*Experimentally, analytically, and numerically investigation of punching shear behaviour of edge-flat slab column connections with different opening numbers*" Int. J. Archit. Eng. Urban Res., 6(2), Pp. 248–266, 2023. DOI: 10.21608/ijaeur.2024.239696.1050

[11]. N. Nassif, W. Zeiada, G. Al-Khateeb, S. Haridy, and S. Altoubat, *Assessment of Punching Shear Strength of Fiber-reinforced Concrete Flat Slabs Using Factorial Design of Experiments*". Jordan Journal of Civil Engineering, 16(1), Pp. 139-154, 2022.

[12]. Ngekpe. B.E, Ode. T, and Eluozo S.N., "*Application of Total-Strain Crack Model in Finite Element Analysis for Punching Shear at Edge Connection*". International Journal of Research in Engineering and Social Sciences, 6(12). Pp. 1-9, 2016.

[13]. D. Mahmood and M. Zaki, "*Punching shear strength of fibrous high strength reinforced concrete flat plate slabs with eccentric loading*". Cesare'14 International Conference Civil Engineering for Sustainability and Resilience Amman, Jordan University of Science and Technology, 2023, pp.23-32.