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Research Article

Investigate the Effect of Replacing the Traditional Reinforcing With Steel Stirps in Two-Way Concrete Slabs

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ABSTRACT

This study analyzes the effect of employing steel strips as a new reinforcing method in two-way concrete slabs rather than the traditional approach of steel bar reinforcements. The study includes the casting of two slabs with self-compacting concrete and evaluating them under uniform load. The proposed reinforcing technique is used for first slab, and the traditional reinforcing method is used for the second slab. Both styles of reinforcing method used the same equivalent amount of steel. Significant observations in behavior were recorded throughout the research process in ultimate load, first crack load and important computation was done about stiffness and energy absorption. Furthermore, new analytical equations proposed to compute the amount of steel strips that required for design the suggested method of reinforcement. The ultimate load of the panel with steel strips was 106 kN while the panel with bar reinforcements was 144.5 kN. In spite of lower ultimate load but proposed style of reinforcement shows more absorb energy 1399 joule than traditional style which was 610 joules at service load.

In projects focused on sustainability, steel strips could be a preferred option despite the lower load resistance, especially when green building standards or environmental certifications are important.

The outlook of the proposed reinforcing technique refers to open the way for the huge questions that may eventually – with more improvements – lead to change the reinforcing method of two-way concrete slabs.

Keywords: Two-way slabs, Flexure behavior, Steel strips, Uniform load, Self-compacting concrete, Sustainable engineering, Green building.

1. INTRODUCTION

This study attempts to contribute to the structural field by introducing a proposed technique for strengthening two-way slabs using steel strip plates. It is obvious that using steel strips plate rather than conventional bar reinforcing will offer significant environmental and economic benefits. Using scrap steel for the strips helps reduce waste and improves sustainability by decreasing the need for new steel production, which in turn lowers emissions. However, the main question is whether or not using this technique will enhance the performance of two-way slabs. This technique originally came to light following the success of employing the plate as a reinforcing mechanism in two-way concrete slabs. Lu et al. (2001) [1] employed various sizes of exterior steel plates fastened to the lower side of the slabs by an appropriate epoxy resin, whereas Ebead and Marzouk (2002) [2] varied the manner of fastening the plates by using steel bolts in different arrangement patterns. Elbakry and Allam (2015) [3] used the previous two procedures, then a modified methodology that included steel anchor bolts and epoxy glue was suggested to prevent any expected debonding. Al-Zahid and Alwash (2022) introduced an experimental study about using the perforated steel plate with a circular form as a reinforcement instead steel bar [4]. The behavior tested under concentrated load. They repeat their study with other adopted shapes which was octagonal openings [5]. They presented (2023) research about using the shape of opening with rectangular and octagonal but under uniform loading [6].

Instead of traditional reinforcements or perforated plates, the current study will propose a steel strips plate implanted in a tension zone of the slab as a proposed reinforcing approach. The study will include casting two slabs with overall dimensions of (1000*1000*60) mm using a special type of concrete and assessing them under uniform load. One of these slabs will be as a control slab and reinforced by a traditional deformed bar. The remaining slab will be reinforced by steel strips plates, taking into consideration that each specimen has the same equivalent amount of steel. The

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judgement criteria will be based on the load deflection curve and ultimate load. In addition, the initial crack load and crack pattern were analyzed.

2. MATERIAL AND METHOD

The current section listed all of the items were used to complete the experimental portion of this research, as well as the test technique was included.

2.1. Type of concrete

In traditional reinforcements, there is no separative plane between the concrete over the reinforcements and the concrete under the reinforcements, While the proposed technique is not, so the self-compacting concrete is a significant key that will be used to succeed with the suggested reinforcing method. In addition to the ordinary cement, fine and coarse aggregate, minerals (silica fume) and chemical admixture (Glenium 54) were used. The size of the fine aggregate particles was equal to (4.75 to 0.15) mm, whereas the maximum size of the mix according to coarse aggregate was 14 mm. The mineral admixture is used to improve the mix cohesiveness and minimize the segregation risk, while enhancing the consistency and workability of the mix are the action of chemical admixture [7, 8]. The percentage of materials should fulfill three essential roles: flow ability, passing ability, and stability. There were several trial mixes conducted in order to discover the optimal ratio. Table 1 displays the percentage ratio to achieve the optimal trial mix established and utilized in the current study, which gave a compressive strength equal to 42.8 MPa.

Table 1: Proportion of materials used for self-compacting concrete

Ingredient	Cement	Water	Fine aggregate	Coarse aggregate	Glenium 54	Silica fume
Ratio	1	0.36	1.76	2	0.017	0.06

2.2. Details of Reinforcing Specimens

The main structural principle in reinforcing two-way slabs is the providing steel in tension zone. The difference between classical reinforcing method and proposed method is type of providing steel. The classical method used steel bar and suggested method used perforated steel plate. The used bar has a diameter of 6 mm. with spacing of 250 mm [9]. The thickness of steel was 1 mm and the width was 60 mm. Because of the edges of steel strips should be smooth without any distortion to avoid stress concentration points, the FLC Machine model (XQL-1330) was utilized to fabricate them. It is a very efficient machine with a position accuracy of less than 0.1 mm/m. Figure (1) illustrates the steel strips plate applied in currently research.

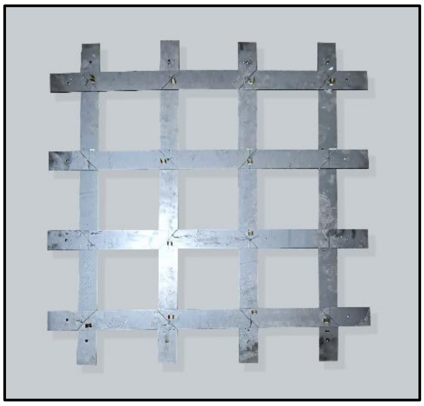

Fig. 1. steel strips plate mesh

Because the tensile strength of the steel bar was 591 MPa and the yield strength of the steel strips plate was 278 MPa, an equivalent quantity was regarded between them according to principle:

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$$As * fy_{steel\ strips} = As * fy_{bar\ rienforcements} \quad (1)$$

2.3. Supporting and Loading Condition

A rigid steel frame was used in the universal machine to test the specimens, providing simple support. The load condition was uniformly achieved by using a rigid piston comprised of a layer of sand over the tested slabs. A steel container opened from top and bottom is used over the specimens to put the sand inside, then a 6 mm thick base plate with dimensions of 91*91 mm, based on the sand layer. At last, a rigid frame over the base plate to provide uniform pressure on the plate [6]. Figure (2) illustrates the loading condition.

Fig. 2. Steps of achieving a uniform load

3. EXPERIMENTAL TEST RESULTS

This part is categorized to three sections, it is explained subsequently:

3.1. Load-Deflection curve

Figure (3) demonstrates how the load deflection curve behaved in comparison to a control load deflection curve reinforced with steel bars.

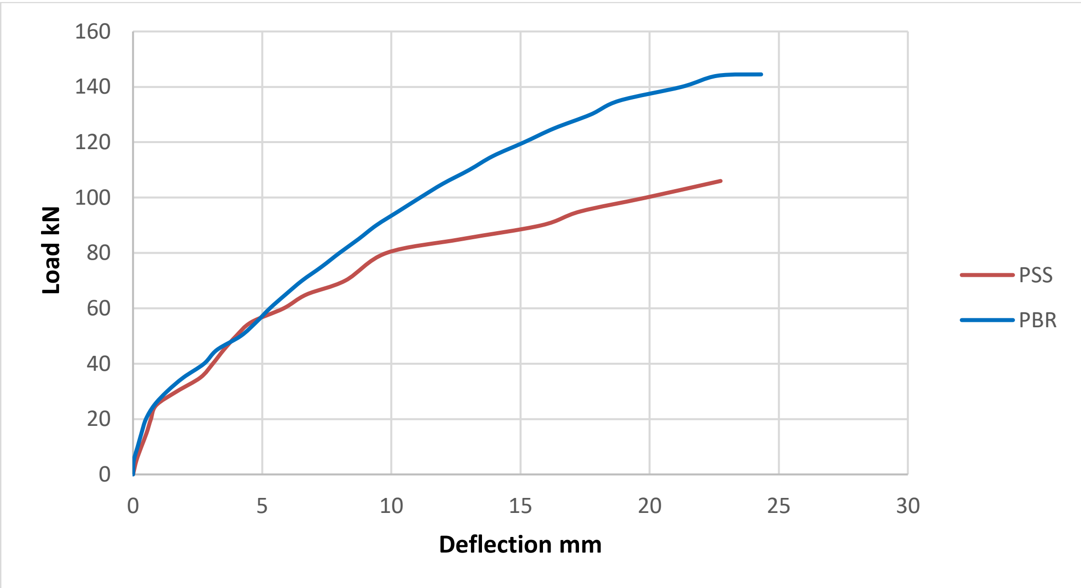

Fig. 3. Load-deflection curve for adopted models

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3.2. Tracking the Crack Generation and Details

The models were loaded uniformly and accurately observed to identify the first cracks, after which the load was increased until failure occurred. The crack width was measured at each level. Furthermore, another crack width measurement was done between these two levels (level at first visible crack load and level at failure load). The collected data are shown in Table (3).

Table (3): loads with associated crack width

No.	Model's identifier	Model's description	Load kN	Crack's width mm
1	PBR	Reinforced by steel bar	30	0.12
			70	0.73
			144.5	2.52
2	PSS	Reinforced by steel strips	31	0.15
			70	0.94
			106	2.85

3.3. Crack pattern

Because of the proposed technique of reinforcing two-way concrete slabs is now being investigated, an approach was taken to trace the process of crack development. The green-colored cracks appeared at the load that caused the initial crack, while they are indicated in red at the ultimate load. The cracks between these loads were colored blue. There is also a computer mapping for each level. The final forms of cracks in the specimens are depicted in Figures (4) and (5), respectively.

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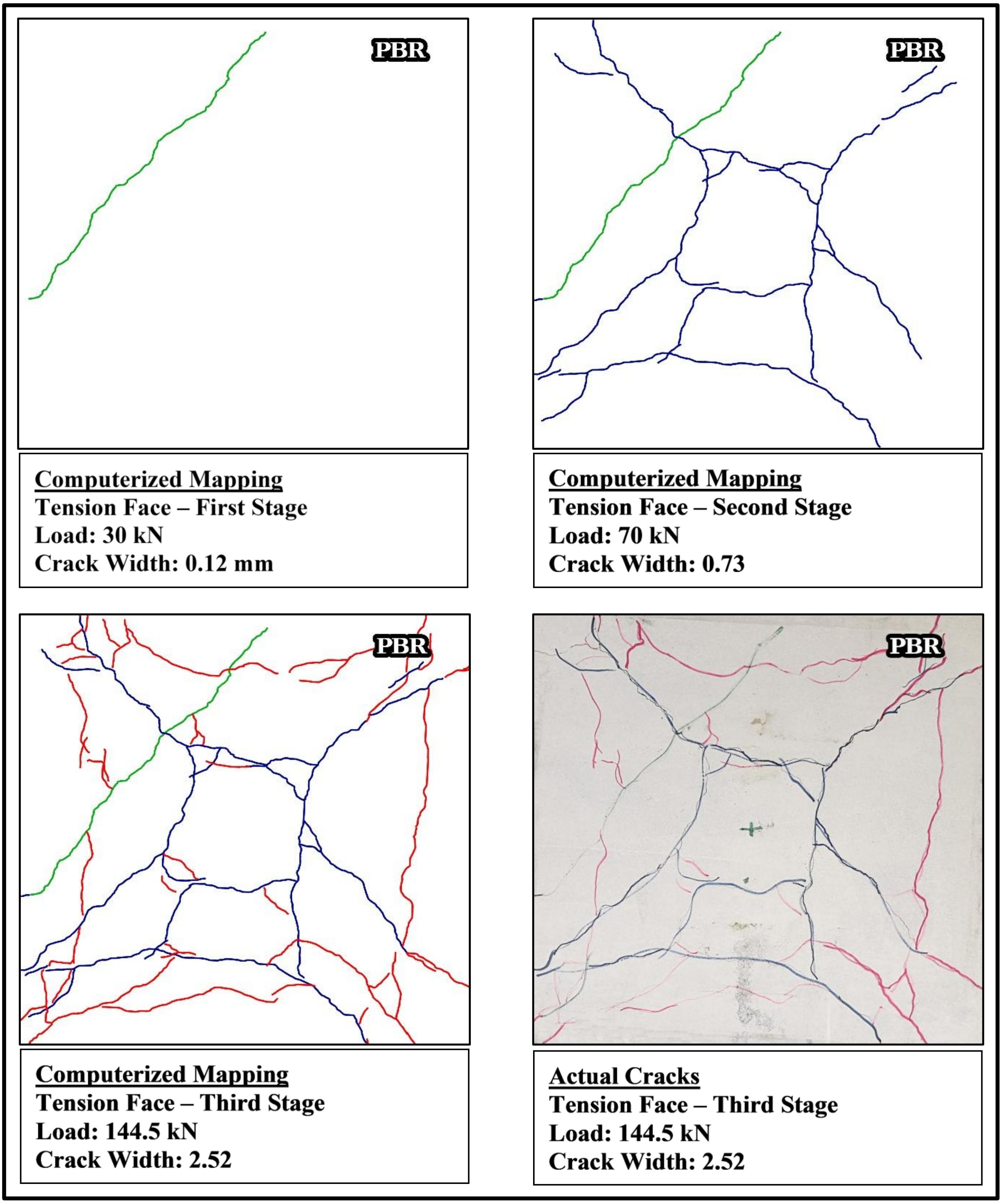

Fig. 4. Crack pattern for PRB (Tension Face)

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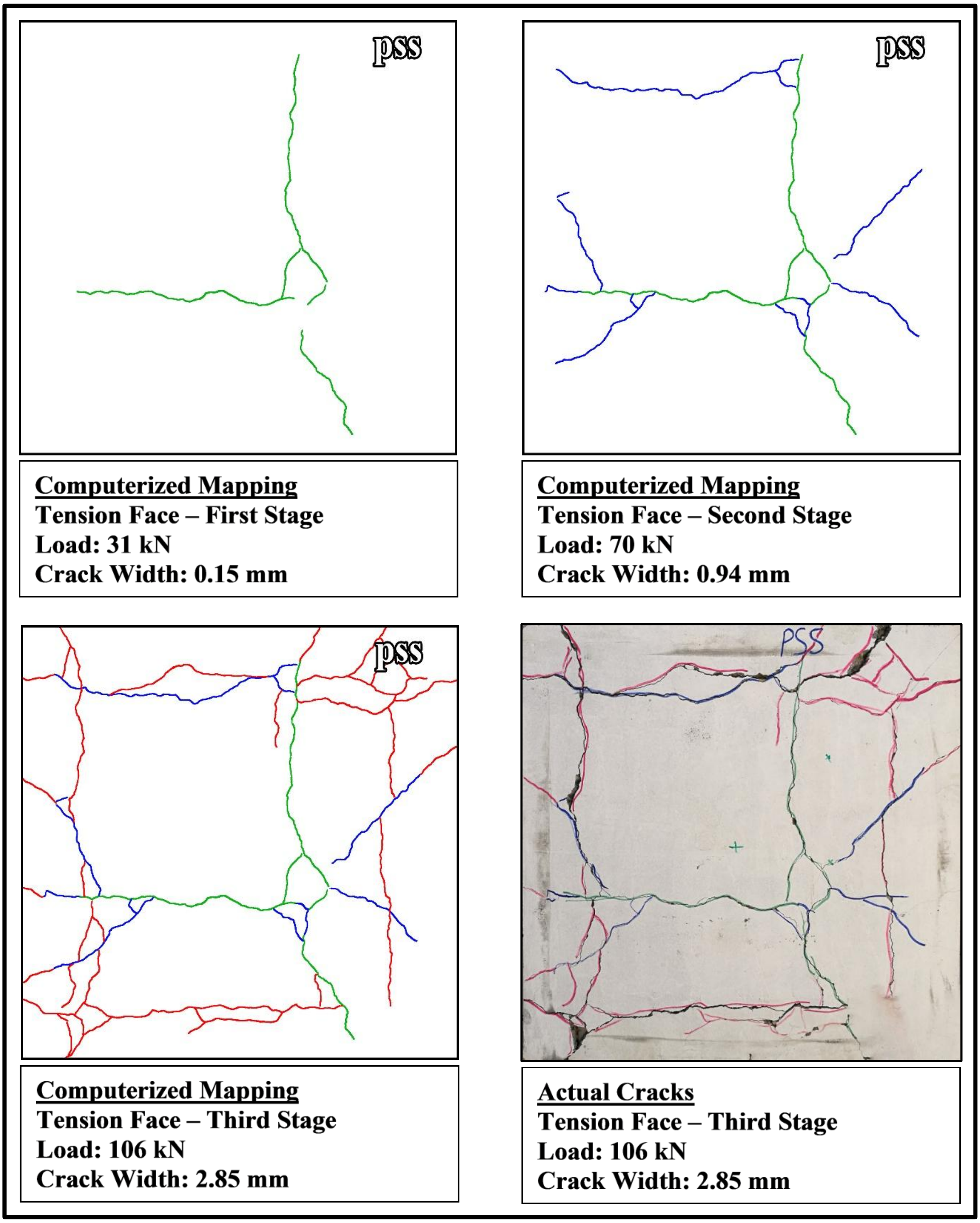

Fig. 5. Crack pattern for PSS (Tension Face)

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4. ENERGY ABSORPTION CAPACITY

Energy absorption was calculated by computing the area under the load-displacement curve [10]. A MATLAB program was developed for the purpose of these calculations. The results clarified in Figure (6).

The calculation of the absorbed energy at the service load is important because it represents the condition under which the structural element operates within the limits defined for its actual use.

The value of service load will compute according to:

Ultimate load = 1.4*dead load + 1.7*live load [9] (2)

Service load = dead load + live load (3)

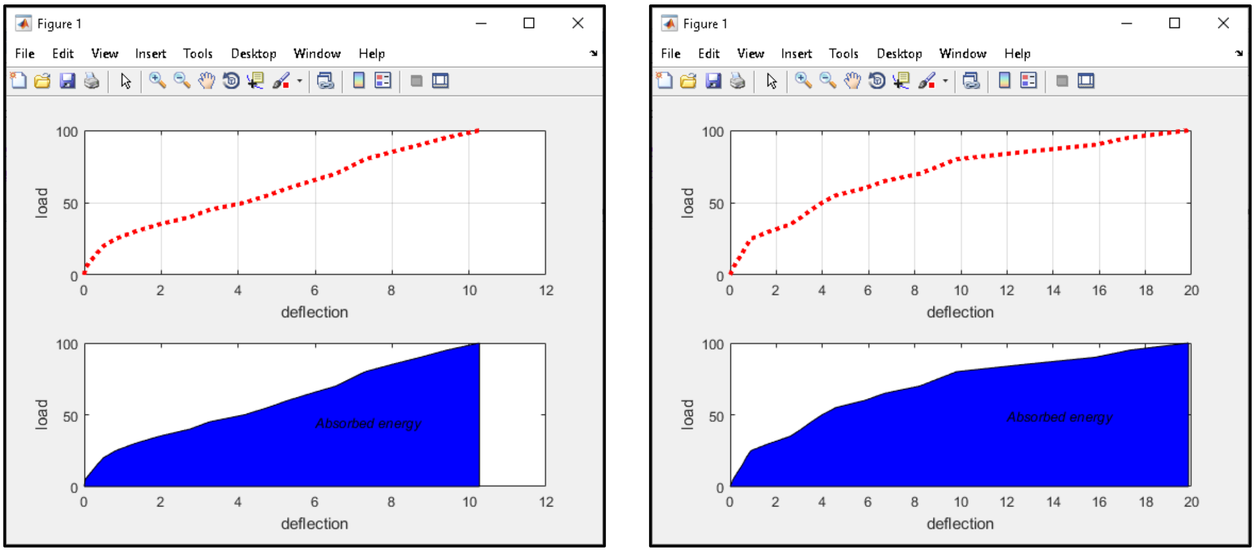
The factor that changes the service load to the ultimate load will be the average of the factor of dead load and the factor of live load, and that will equal to (1.4 + 1.7)/2.

So

Ultimate load = 1.5* Service load (4)

Service load = 0.66* Ultimate load (5)

The ultimate load will be adopted at 144.5 kN because the control slab was reinforced by traditional deformed steel, and the value of the service load is 95.37 kN.



a. Energy absorption for PBR = 610 joule b. Energy absorption for PSS = 1399 joule

Fig. 6. Energy absorption

5. RESULTS DISCUSSIONS

The ultimate load of the specimen that was reinforced with steel strips (PSS) was 106 kN, whereas it was 144.5 for the specimen reinforced by a deformed steel bar (PBR). As a result, the specimen PBR had greater ultimate resistance loads than PSS by about 26 %.

The first visible crack was measured for both specimens, and no significant differences were observed. Additionally, the crack width was measured at the maximum load and at the load between the first crack appearance and ultimate load. Again, no significant differences were found in the results, especially considering that reinforced concrete is a heterogeneous material.

The panel with steel strips exhibits an increase in first crack load of about 3.3% greater than the specimens reinforced with deformed bar reinforcements. This slight advantage of the PSS specimen occurred due to the steel strips providing better distribution of the steel in the tension zone of the slab.

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At first glance, one might assume that the slab reinforced with conventional reinforcement performs better due to its higher load capacity. However, based on the energy absorbed by each specimen, it is found that the specimen reinforced with steel strips absorbs more energy within the service load range, up to 100 kN. Specifically, the energy absorbed up to the service load was 1399 Joules for the proposed model and 610 Joules for the specimen with deformed steel bar reinforcement. This results in an increase of approximately 129.5% in the energy absorbed by the steel strip-reinforced specimen compared to the deformed bar-reinforced specimen. This is due to the greater flexibility of steel strips, which allow for better energy dissipation, whereas rebar provides more rigidity and is less effective in energy absorption. Thus, steel strip reinforcement is more efficient in absorbing energy under service loads.

The key factor that must be considered is the interaction between the concrete and the steel strips, where the reliance was solely on the adhesion and friction between concrete and steel. If the comparison had been made with a specimen reinforced with plain steel bars, the results would likely have favored the proposed model. Therefore, it is recommended to introduce deformation on the edges of the steel strips to enhance mechanical interlocking, thereby improving the overall performance of the reinforcement.

6. CONCLUSION

The proposed reinforcement in this study represents the first step towards establishing a new method for slab reinforcement. Although the ultimate load capacity of the conventional model exceeds that of the proposed model, the latter demonstrates superior energy absorption within the service load range. In addition to these performance benefits, this approach offers significant advantages for sustainable engineering, particularly the potential for utilizing scrap steel strips, especially in areas where green building requirements are critical.

As a result of these considerations, the proposed approach may change the manner of concrete slab reinforcing in the future.

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