كلية الهندسة بشبرا
FACULTY OF ENGINEERING AT SHOUBRA
ERJ
PRINT ISSN 3009-6049
ONLINE ISSN 3009-6022

ENGINEERING RESEARCH JOURNAL (ERJ)
Volume (54),Issue (3)
July 2025, pp:66-75
https://erjsh.journals.ekb.eg

Behavior of Lightweight One-Way R.C Solid Slabs Containing Polyolefin Macro-Fibers-Parametric study

Mohamed Hussam El-Din Mohamed Moukhtar [1,*], Maher Adam [1], Ahmed Mahmoud [1], Amgad Mahmoud [2], Sayed S. Hussein [1]

[1] *Department of Civil Engineering, Faculty of Engineering at Shoubra, Benha University, Cairo, Egypt.*
[2] *Faculty of Engineering, Modern university for technology and information (MTI), Egypt.*
**Corresponding author*

E-mail address: mohamed.mokhtar19@feng.bu.edu.eg, maher.adam@feng.bu.edu.eg, ahmed.ahmed@feng.bu.edu.eg, amgadm696@gmail.com, sayed.abdelwahab@feng.bu.edu.eg

Abstract: This study aims to investigate the flexural behavior of lightweight foamed reinforced concrete one-way solid slabs incorporating polyolefin macro-fibers and reinforced with steel or GFRP bars under monotonic static loading. One simply supported slab was experimentally tested to validate the numerical model, while eleven slabs were analyzed using ANSYS 15 to evaluate the influence of key parameters including reinforcement type (steel and GFRP bars), reinforcement ratio, GFRP elastic modulus, fiber content, fiber aspect ratio, and steel yield strength. All slabs have an overall depth of 100 mm, a width of 500 mm, and a total length of 1300 mm with a clear span of 1200 mm. The load was applied at one-third points of the span to simulate realistic bending conditions. The results revealed that increasing the GFRP bar diameter to 12 mm and the polyolefin fiber content to 0.2% produced the highest ultimate load increases of 66.5% and 49.6%, respectively, and reduced slab deflection by 24.6% and 5.3%, respectively. These findings demonstrate the effectiveness of combining GFRP reinforcement with polyolefin fibers in enhancing flexural performance and provide a validated numerical framework for optimizing the design of lightweight foamed concrete slabs.

Keywords: Lightweight foamed concrete; One-Way R.C Solid Slabs; Polyolefin Macro-Fibers; Glass fibers bars (GFRP); Numerical analysis.

1. Introduction

The high self-weight of conventional concrete often presents a challenge in construction projects due to increased material and handling costs. Using lightweight concrete (LWC) helps overcome this limitation by reducing the concrete density to below 2000 kg/m³. [1] Among LWC variants, foamed concrete stands out for its wide use in construction [2]. Foamed concrete not only reduces structural weight but also improves overall performance. Lightweight foamed concrete (LWFC) provides multiple benefits, such as: (1) excellent thermal and sound insulation; (2) high flowability and ease of placement; (3) self-compacting properties; (4) lower dead loads, which reduce foundation costs; (5) enhanced fire resistance; and (6) faster and more economical construction [3]

Diab et al.[4] investigated lightweight foamed concrete slabs reinforced with corrosion-resistant GFRP bars and polypropylene fibers (PPF) to enhance flexural strength and reduce self-weight, to avoid the high density and low tensile capacity of conventional concrete. Numerical analysis using ABAQUS and code-based calculations confirmed that combining GFRP bars with fibers improved overall structural performance and crack control.

Klak and Jomaa'h.[5] assessed the structural behavior of one-way lightweight concrete slabs using lightweight expanded clay aggregate (LECA) under cyclic loading and high temperatures. Nine slabs with 0%, 20%, and 40% LECA replacement were tested at ambient, 400 °C, and 700 °C. Results showed that higher LECA content lowered flexural strength, stiffness, and fire resistance, with load capacity decreasing by 35.1% and deflection increasing by 37.2%. Stiffness loss reached up to 50% under repeated loading.

Adding polyolefin fibers to lightweight foamed concrete (LWFC) improves flexural and tensile strength, enhances crack control and cohesion, increases resistance to impact, and minimizes segregation [6]. Polyolefin fibers also reduce wear on equipment such as mixers, pumps, and pipelines during concrete production and placement [7]. Unlike steel fibers, polyolefin fibers have low electrical conductivity, making them ideal for structures where minimal conductivity and electromagnetic interference are required [8]. They are non-corrosive, chemically inert, non-alkaline, and help eliminate rust issues associated with exposed fibers [9].

Karamloo et al.[10] used polyolefin macro fibers to investigate their influence on the mechanical and fracture behavior of self-compacting lightweight concrete. Their results showed that adding fibers up to 0.5% by volume slightly affected the compressive strength and elastic modulus, both reached maximum values at 0.1% fiber content. However, the inclusion of polyolefin fibers significantly enhanced tensile strength (by ~15%), fracture toughness, and post-cracking ductility, which indicated improved crack-bridging and energy absorption capacity. The researchers also observed that fiber addition increased the cracking deflection capacity, demonstrating that even at low contents, polyolefin fibers effectively improved the flexural performance and toughness of lightweight concrete without compromising its strength characteristics.

Doostmohamadi et al.[11] used polyolefin-based macro fibers and handmade GFRP anchorage systems to examine their combined effect on improving the bond behavior between GFRP bars and self-compacting lightweight concrete. Sixty direct pull-out tests were conducted considering different concrete strengths (21–40 MPa), anchorage configurations, and fiber volume ratios of 0.3% and 0.5%. The results demonstrated that the addition of polyolefin fibers eliminated concrete splitting and significantly enhanced the maximum bond stress developed in the GFRP bars. Moreover, fiber reinforcement promoted a crack-arresting mechanism along the bar, leading to improved bond strength and ductile post-failure behavior. The study also confirmed that specimens containing fibers exhibited no splitting failure, unlike mixes without fibers.

The use of glass fiber-reinforced polymer (GFRP) bars in concrete has increased due to their high strength-to-weight ratio, corrosion resistance, and low thermal conductivity, making them a viable alternative to steel in durability-critical structures. Using GFRP rebars in lightweight foamed concrete (LWFC) provides advantages over traditional steel reinforcement, including lower weight, corrosion resistance, non-magnetic properties, and higher tensile strength. [12]. Additionally, GFRP rebars are non-conductive, making them suitable for structures where electrical insulation is needed. They also resist corrosion and do not rust like steel rebars, providing better durability in harsh conditions. [13].

Lu et al.[14] assessed the impact resistance of GFRP-reinforced concrete slabs under high temperatures using validated numerical and experimental methods. Results showed that heat exposure significantly reduced impact performance, increased displacement and failure severity, and made slabs more sensitive to deformation than conventional RC slabs.

A study by [15] highlights that despite the advantages of using GFRP bars as reinforcement in concrete, GFRP manufacturing still poses notable environmental impacts compared to steel, which must be considered in sustainable design.

ANSYS 15 has been used to model the slabs and replicate the experimental conditions, including material properties and loading configuration. Numerical results for deflection, stress, and strain were compared with experimental data to validate the model's accuracy and assess slab performance under different scenarios. Several studies [16-22] have shown that ANSYS is a reliable tool for analyzing the nonlinear behavior of concrete slabs, providing accurate predictions of deflection, stress distribution, and failure patterns in agreement with experimental observations.

The primary aim of this study is to investigate the flexural behavior of lightweight foamed concrete slabs reinforced with GFRP bars and polyolefin fibers under different parameters. One slab was tested experimentally to provide validation data, while additional variables were examined through finite element modeling using ANSYS 15. This approach allowed for a comprehensive evaluation of the effects of fiber content, fiber geometry, and steel yield strength on the ultimate load capacity, deflection, and cracking performance. The integrated experimental–numerical methodology aims to provide a reliable analytical tool for predicting slab behavior and to contribute to the development of lightweight, durable, and sustainable slab systems for modern construction applications.

2. EXPERIMENTAL PROGRAM

2.1 Description of tested specimen

A lightweight one-way reinforced concrete (RC) solid slab with an overall thickness of 100 mm and a concrete cover of 20 mm, providing an effective depth of 80 mm, was reinforced with 8 mm diameter GFRP bars. The slab had standard width and length suitable for laboratory testing. Monotonic static line loads were applied at points located at one-third spans from each support to simulate two-point bending. Deflection and strain were measured using a Linear Variable Differential Transformer (LVDT) and a strain gauge, respectively, to monitor displacement and verify stress distribution in the reinforcement during loading. as shown in Fig. 1.

2.2 Concrete mix

The materials used in this study included fine and coarse aggregates, cement (42.5N), solid foam, silica fume, and GFRP reinforcement bars as solid materials, while Sika Air and the superplasticizer (Sikament N.N.) were used as liquid admixtures in addition to water. The dry materials were first homogenized, after which the liquid admixtures were dissolved in water and added to the mix to ensure proper dispersion. The solid foam, consisting of chemically treated expanded polystyrene beads supplied by Chema Foam Group, was incorporated into the concrete mix as a partial replacement for coarse aggregate. This corrosion-resistant preformed polystyrene foam has a density of 80 kg/m³ (approximately 95% air content) and provides excellent resistance to moisture and corrosion. In addition to reducing the overall density of the concrete, it enhanced thermal and acoustic insulation, improved workability, and facilitated easy molding. Fig. 2 shows the appearance of the solid foam. The macro polyolefin fibers used were synthetic fibers with an embossed surface to improve bonding with the concrete matrix. These fibers were added to control cracking, enhance ductility, and improve impact resistance and durability of the concrete. Fig. 3 shows the shape of the macro polyolefin fibers. Table (1) summarizes the weight-based proportions for one cubic meter of control concrete, designed to achieve a target compressive strength of 245 kg/cm² (24.5 MPa) at 28 days, which corresponded to the testing day for the slab. The average concrete density was approximately 1900 kg/m³. For each mix, six standard cubes (150 × 150 × 150 mm) were prepared and tested at 28 days to validate the target strength and to provide input parameters for the ANSYS finite element analysis model. Table (2) present the mix variables of the additional batches and the corresponding average compressive strength for each mix, while Fig. 4 illustrates the casting and testing process.

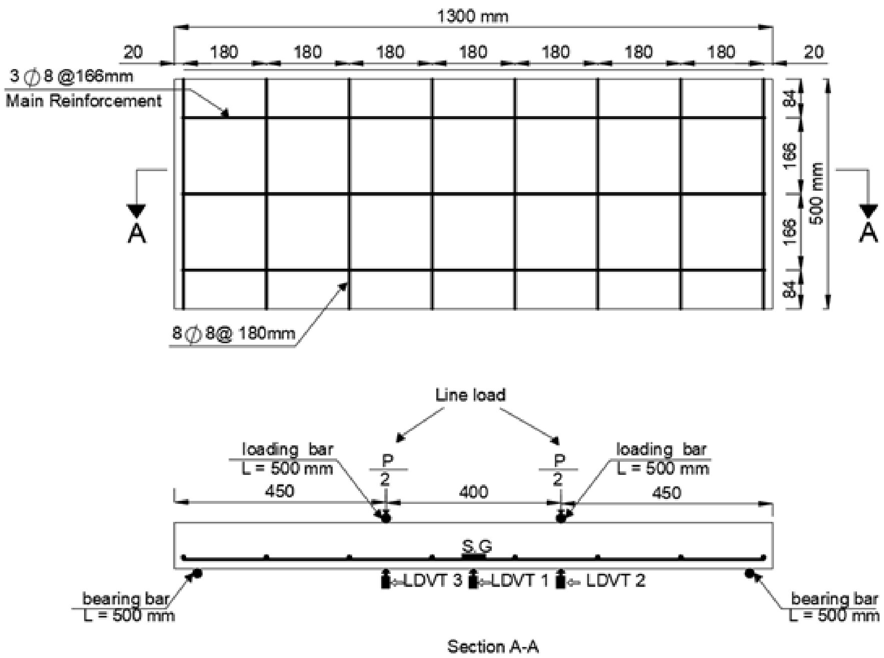


FIGURE 1. The experimental specimen: dimensions, reinforcement details and test setup.

FIGURE 2. Solid foam

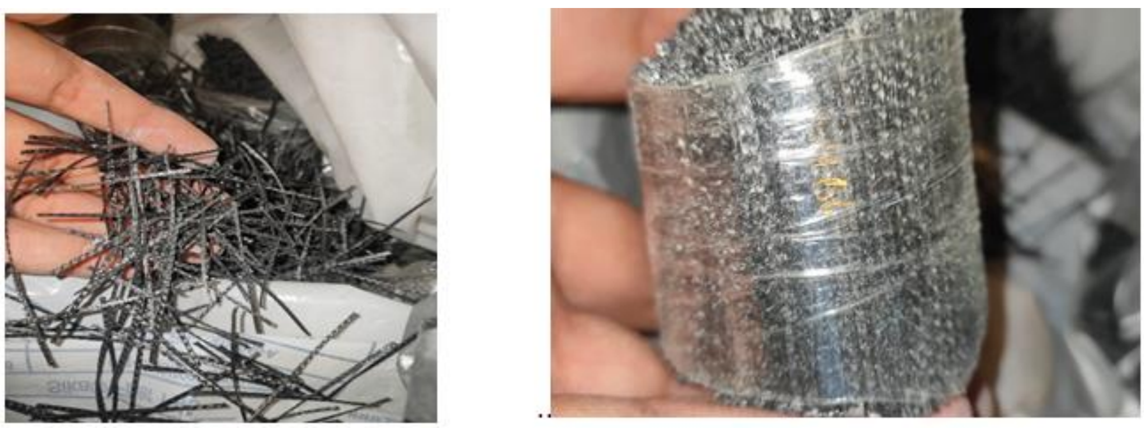


FIGURE 3. Macro Polyolefin Fibers

2.3 Experimental results

2.3.1 Failure modes and cracks pattern

The cracking behavior of specimen S1 was investigated through direct experimental testing. Vertical flexural cracks appeared near the tension zone within and around the constant moment region, initially forming at a load of 6.83 kN. With continued loading, new cracks developed and existing cracks propagated vertically towards the compression zone, with small branches forming near the lower tension face. At later loading stages, crack propagation slowed while existing cracks widened and inclined along compression stress paths. Final failure occurred at 26.94 kN. Fig. 5 illustrates the final crack pattern for S1.

2.3.2 Load deflection curves

Fig. 6 shows the load–deflection relation for specimen S1. Initially, the slab exhibited a linear elastic response up to the cracking load, when the concrete cracked at the tension face. Beyond this point, the stiffness decreased rapidly, resulting in larger deflection due to the low elastic modulus of the GFRP bars.

TABLE 1. Concrete mix design for one cubic meter.

Type	Cement	Sand	Coarse Aggregate	Silica Fume	Foam	Sika Air	Super-Plasticizer	Water
Weight (kg)	500	460	635	75	21	0.75	5	203
Specific gravity (kN/m^3)	31.5	25.9	27.2	22	0.7	10.1	11.5	10

TABLE 2. Mix variables of the additional batches

- Concrete mix	Fiber Content (%)	Aspect Ratio of Fibers	Fcu (MPa)
1	-	-	25
2	0.1	50	32
3	0.2	50	35
4	0.1	25	33

FIGURE 4. Casting and testing of the concrete cubes

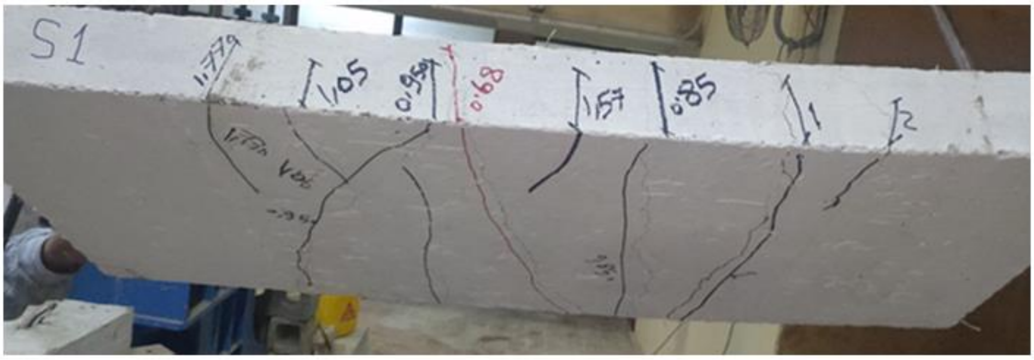


FIGURE 5. The crack pattern observed in specimen S1 at failure

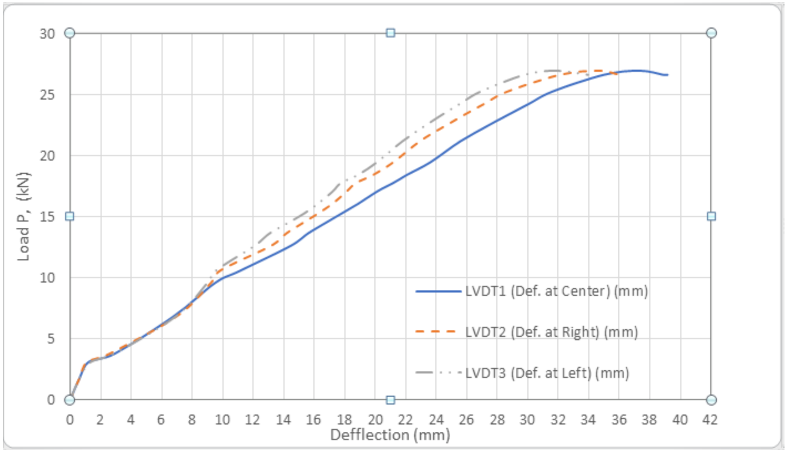
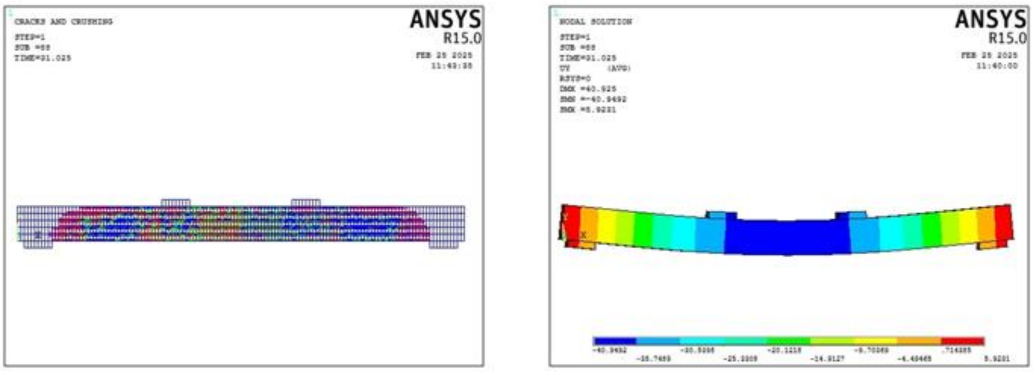


FIGURE 6. The load deflection relation for the specimen S1

3. VERIFICATION STUDY

One reinforced concrete slab specimen was tested experimentally and subsequently numerically analyzed using ANSYS finite element software to validate the accuracy of the developed model and examine its detailed behavior. Fig. 7 illustrates the crack pattern and deformed shape obtained from the numerical simulation, while Fig. 8 presents the comparison between the experimental and numerical load–deflection curves. The results showed a close agreement, with less than 15% difference in ultimate load and 3% in deflection, confirming the reliability of the numerical model in predicting the structural response under the applied loading conditions. This validated model was then employed to extend the parametric study and investigate additional factors beyond the experimental program.



a) Crack pattern of slabs 1 **b)** Deformed shape of slabs 1

FIGURE 7. shows the deformed shape and the crack pattern for slab 1

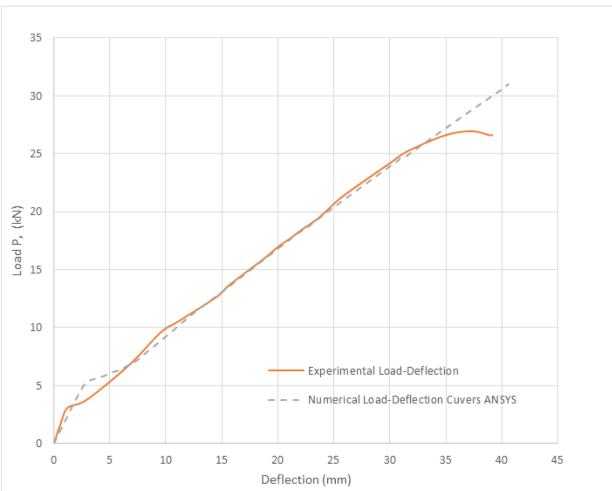


FIGURE 8. Comparison between the experimental and numerical load-deflection curves

4. NUMERICAL ANALYSIS

In the ANSYS 15.0 program, the SOLID65 element was used to model concrete, the LINK180 element for reinforcing bars, and the SOLID185 element for supports and loading plates. Nonlinear material properties were defined for all components. Flexural strains and mid-span deflections were calculated numerically, and the crack patterns at failure were obtained. Variations in flexural strain were plotted at the slab mid-section. All slabs were designed in accordance with the Egyptian Code (ECP 203-2020) [23]. The element properties were defined based on real constants and material models, as appropriate for each element type. The linear material properties and element types used in the model are summarized in Table (3).

4.1 Finite Element Model of Slabs

A total of eleven reinforced concrete slabs were numerically analyzed under different parameters. All slabs had identical dimensions of 1300 mm × 500 mm × 100 mm, and a finite element mesh size of 10 × 10 × 20 mm, as shown in Fig. 9. The bottom longitudinal reinforcement was modeled using the Link180 element, as illustrated in Fig. 10.

TABLE 3. Properties of Elements Used in the Study

Element Type	Application	Real Constant	Area of Bars	Modulus of Elasticity	Material
Solid 65	Concrete Elements	Set 25	------------	21000 to 25000	1
Link 180	Steel Bars	Set 8240	Ø 8 (f_y 240)	200000	2
	Steel Bars	Set 8360	Ø 8 (f_y 360)	200000	3
	Steel Bars	Set 8420	Ø 8 (f_y 420)	200000	4
	GFRP Bars	Set 850	Ø 8	50000	5
	GFRP Bars	Set 1050	Ø 10	50000	6
	GFRP Bars	Set 1250	Ø 12	50000	7
	GFRP Bars	Set 840	Ø 8	40000	8
	GFRP Bars	Set 830	Ø 8	30000	9
Solid 185	Plates	-------	------------	2000000	10

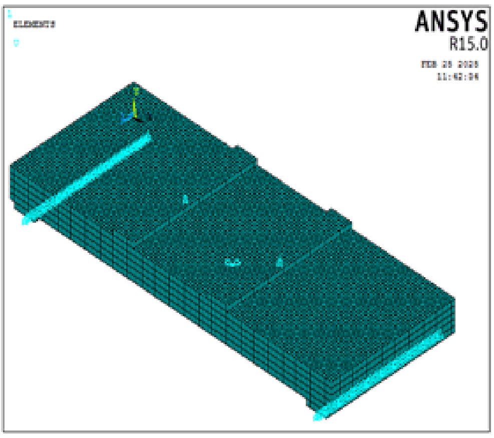


FIGURE 9. Concrete elements

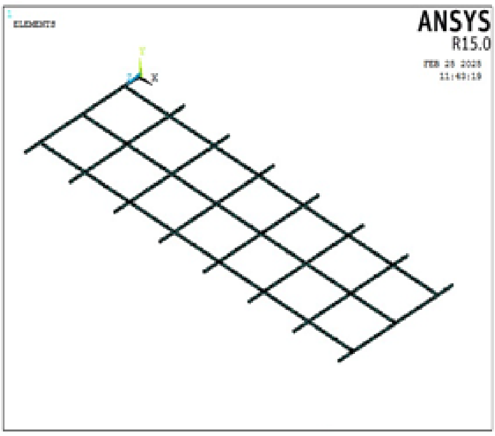


FIGURE 10. Reinforcement bar elements

4.2 Numerical Results of Slabs

The study involved the modeling of eleven simply supported slabs, which were categorized into six distinct groups for the examination of various structural parameters. One main control specimen (S1) was used. An additional reference specimen (S4), reinforced with steel bars (Fy = 240 MPa), was used as the control specimen for comparing reinforcement types (Group 2) and investigating the effect of steel yield strength (Group 6). The investigated parameters included the number of reinforcement bars, the type of reinforcement, the GFRP bar ratio, the GFRP elastic modulus, the yield strength of steel bars, the fiber volume ratio (Vf %), and the fiber aspect ratio (l_f/ϕ_f). Table 4 summarizes the key numerical modeling parameters for each slab specimen. Table 5 presents the detailed parameters for each group. A comparative analysis was conducted between the different slab groups, considering the relevant variable parameters. Table 6 summarizes the numerical results of the ultimate load (Pu) and ultimate deflection (Δu) for all slab specimens. The overall load–deflection response is shown in Fig. 11, while Fig. 12 presents the curves for all slab specimens.

4.3 Discussion

The results of the numerical parametric study provide a comprehensive understanding of the flexural behavior of lightweight foamed reinforced concrete one-way slabs containing polyolefin macro-fibers and reinforced with either GFRP or steel bars. The study examined the influence of various parameters such as reinforcement ratio, reinforcement type, GFRP elastic modulus, fiber volume ratio, fiber aspect ratio, and steel yield strength on the ultimate load capacity and mid-span deflection.

The results indicated that increasing the GFRP reinforcement ratio by using larger bar diameters (from 8 mm to 10 mm and 12 mm) led to a substantial improvement in the ultimate load capacity, which increased from 30.99 kN to 51.63 kN, while the mid-span deflection decreased from 40.59 mm to 30.58 mm. This enhancement is mainly attributed to the higher reinforcement area that provides greater stiffness and delays the formation and propagation of flexural cracks. These findings are in close agreement with the results reported by Tran et al[24] who confirmed that increasing the reinforcement ratio in FRP-reinforced concrete members enhances the load-carrying capacity, reduces mid-span deflection, and improves overall flexural performance.

When comparing GFRP to steel reinforcement, replacing the GFRP bars with steel (Fy = 240 MPa) caused a reduction in the ultimate load capacity from 30.99 kN to 26.89 kN but led to smaller deflection values (40.59 mm to 32.05 mm). Although steel reinforcement has a higher modulus of elasticity, its lower tensile strength causes earlier yielding, resulting in lower ultimate load but higher stiffness. This trend agrees with the observations made by Elkhouly et al. [12] who found that steel reinforcement generally provides lower load-carrying capacity but better control of deformation than GFRP.

A similar influence was observed when varying the elastic modulus of GFRP. Reducing the modulus of elasticity from 50 GPa to 40 GPa and 30 GPa led to a noticeable decrease in ultimate load (30.99 kN to 21.25 kN and 16.03 kN, respectively). Interestingly, the deflection slightly decreased rather than increased, which may be due to brittle failure occurring earlier in the loading process, preventing larger displacements. Lower elastic modulus values reduce stiffness and increase the likelihood of premature failure.

The inclusion of polyolefin fibers considerably improved the overall flexural response of the slabs. As the fiber volume ratio increased from 0.0% to 0.1% and 0.2%, the ultimate load capacity rose significantly from 30.99 kN to 46.38 kN, while the corresponding deflection remained nearly constant at around 38 mm. This enhancement can be mainly attributed to two factors. First, the addition of polyolefin fibers improved the post-cracking behavior of the lightweight foamed concrete. The fibers acted as bridges across microcracks, enhanced post-cracking ductility, and increased the overall toughness of the material, enabling higher load resistance without excessive deformation. These findings are consistent with those reported by Karamloo et al. [10] and Doostmohamadi et al. [11], who observed that the optimal performance of polyolefin fibers in lightweight concrete occurs at a fiber content of 0.1–0.2%. Second, part of the observed improvement can be attributed to the increase in the concrete compressive strength (fcu). A higher fcu enhances the load-carrying capacity of the slabs and allows the GFRP reinforcement to contribute more effectively to resisting the applied loads. Consequently, the flexural behavior becomes primarily governed by the reinforcement response rather than by premature cracking of the concrete. Based on comparative results, approximately one-third of the improvement in flexural capacity can be associated with the increase in fcu, while the remaining enhancement is mainly due to the fiber-bridging mechanism and improved post-cracking ductility.

Furthermore, the fiber geometry played an important role in the structural performance. For slabs reinforced with 0.1 % fiber content, reducing the aspect ratio from 50 to 25 improved the load capacity from 34.58 kN to 38.52 kN and reduced deflection from 38.14 mm to 30.38 mm. This behavior can be explained by the denser fiber distribution achieved with shorter fibers, which provides more effective crack control and higher stiffness. These findings are in agreement with Yoo et al. [25], who reported that decreasing the fiber length from 30 mm to a shorter length improved flexural performance due to the increase in the number of fibers bridging the crack surface and the enhancement of fiber dispersion within the matrix.

Regarding the influence of the steel yield strength, increasing fy from 240 MPa to 360 MPa and 420 MPa enhanced the ultimate load capacity from 26.89 kN to 36.04 kN. The deflection decreased at 360 MPa (23.6 mm) but slightly increased again at 420 MPa (28.47 mm). For the same load level, the specimen with fy = 240 MPa exhibited the largest deflection, followed by the specimen with fy = 360 MPa, while the specimen with fy = 420 MPa showed the smallest deflection. The initial reduction is attributed to the greater stiffness resulting from higher yield strength, while the subsequent increase corresponds to the improved ductility and energy absorption capacity of high-strength steel before failure. This explanation aligns with the findings of Charif et al. [26].

Overall, the discussion confirms that each investigated parameter distinctly influenced the flexural performance of the slabs. The addition of polyolefin fibers and the use of GFRP bars proved to be the most effective strategies for enhancing load capacity and controlling deflection in lightweight foamed reinforced concrete slabs, consistent with the behavior reported in previous studies.

TABLE 4. Key numerical modeling parameters for all slab specimens

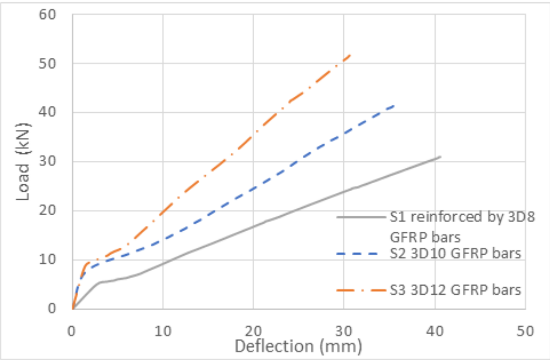
Specimen	Fcu (MPa)	Reinforcement type	Reinforcement bars	Fiber Volume Ratio %	Fiber aspect ratio	E (MPa)	Fy (GPa)
S1	24.5	GFRP	3 ∅ 8	-	-	50000	-
S2	24.5	GFRP	3 ∅ 10	-	-	50000	-
S3	24.5	GFRP	3 ∅ 12	-	-	50000	-
S4	24.5	Steel	3 ∅ 8	-	-	200000	240
S5	24.5	GFRP	3 ∅ 8	-	-	40000	-
S6	24.5	GFRP	3 ∅ 8	-	-	30000	-
S7	31.6	GFRP	3 ∅ 8	0.1	50	50000	-
S8	35.2	GFRP	3 ∅ 8	0.2	50	50000	-
S9	32.9	GFRP	3 ∅ 8	0.1	25	50000	-
S10	31.6	Steel	3 ∅ 8	0.1	50	200000	360
S11	31.6	Steel	3 ∅ 8	0.1	50	200000	420

TABLE 5. The studied parameters for each group.

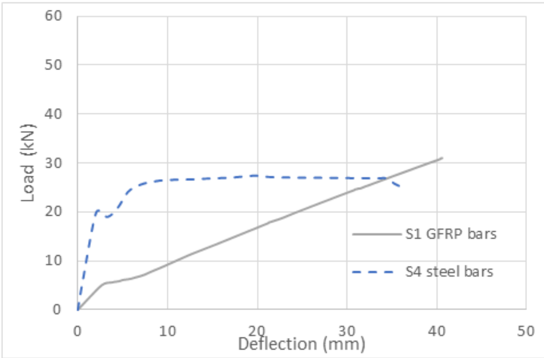
Groups	Specimens	Investigated Parameter
Group 1	S1, S2, S3	Effect of FRP bar ratio
Group 2	S1, S4	Effect of reinforcement type
Group 3	S1, S5, S6	Effect of GFRP elastic modulus (E)
Group 4	S1, S7, S8	Effect of fiber volume ratio
Group 5	S1, S7, S9	Effect of fiber aspect ratio
Group 6	S4, S10, S11	Effect of steel yield strength (Fy)

TABLE 6. Numerical results of ultimate load and ultimate deflection

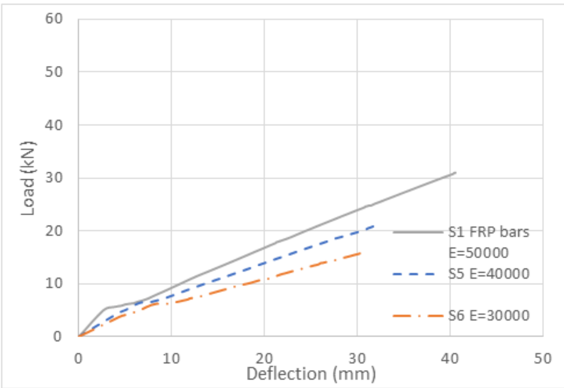
Specimen	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
P_u (kN)	30.99	41.54	51.63	26.89	21.25	16.03	34.58	46.38	38.52	31.9	36.04
Δ_u (mm)	40.59	35.57	30.58	32.05	32.56	30.64	38.14	38.44	30.38	23.6	28.47



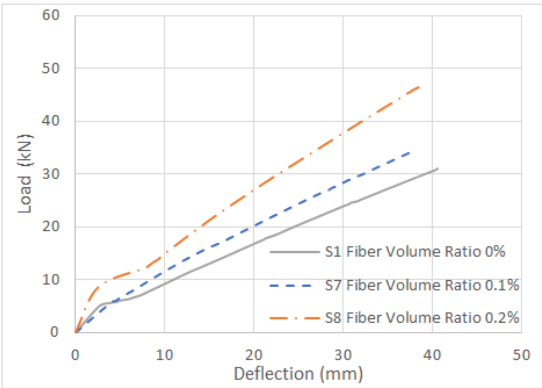
a) Group 1 study the Effect of GFRP bar ratio



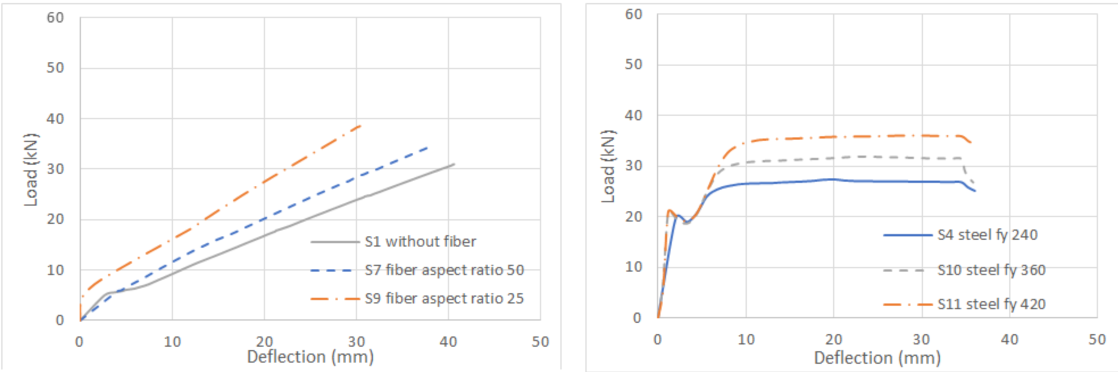
b) Group 2 study the Effect of reinforcement type



c) Group 3 study the Effect of GFRP modulus of elastic



d) Group 4 study the Effect of fiber volume ratio



e) Group 5 study the Effect of fiber aspect ratio **f)** Group 6 study the Effect of yield strength of steel bars

FIGURE 11. The load-deflection curves for all groups

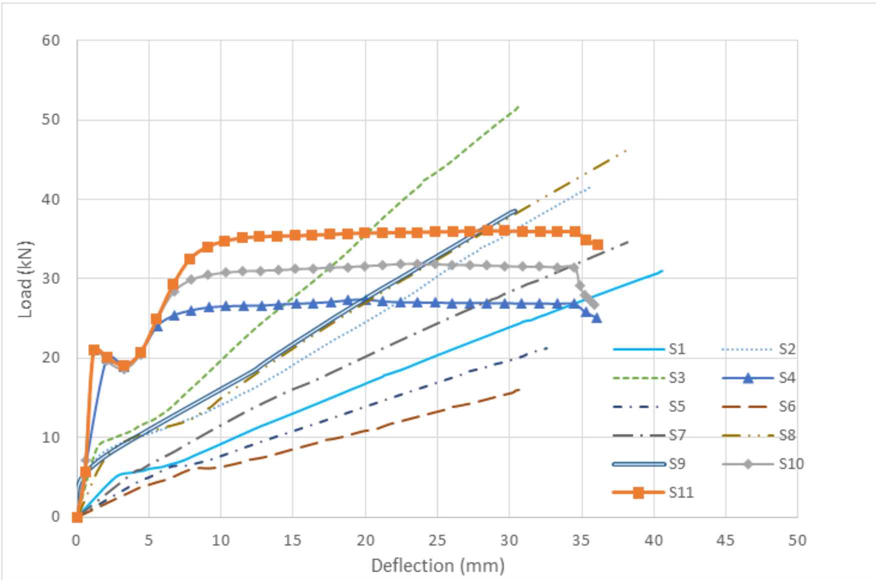


FIGURE 12. The load-deflection relations of all slabs

5. Conclusions

1. Increasing the number of GFRP bars from 8 mm diameter to 10 mm and then 12 mm increased the ultimate load of the LWFRC slab by 34% and 66.5%, while deflection decreased by 12.4% and 24.6%, respectively.
2. Using steel reinforcement instead of GFRP bars resulted in a 13.2% decrease in ultimate load and a 21.0% decrease in deflection.
3. Reducing the elastic modulus of GFRP bars from 50,000 MPa to 40,000 MPa and then 30,000 MPa caused the ultimate load to drop by 31.4% and 48.3%, with deflection reductions of 19.8% and 24.5%, respectively.
4. Adding 0.1% polyolefin fibers to the LWFRC increased the ultimate load by 11.6% and reduced the deflection by 6.0%. Raising the fiber content to 0.2% led to a 49.6% increase in ultimate load and a 5.3% decrease in deflection.
5. Reducing the fiber aspect ratio from 50 to 25 increased the ultimate load by 11.4% and decreased deflection by 20.4%.
6. Increasing the yield strength of steel reinforcement from 240 MPa to 360 MPa and then 420 MPa raised the ultimate load by 18.6% and 34.1%, while deflection first decreased by 26.3% and then slightly increased again by 20.6% compared to the 360 MPa case.
7. The experimental results and the nonlinear finite element analysis conducted using ANSYS 15 showed a high degree of consistency, with the predicted ultimate load and displacement differing by 14.8% and 3.3% from the experimental results, respectively.
8. The failure mode of all LWFRC slabs was flexure failure.

REFERENCES

[1] F. K. Alqahtani and I. Zafar, “Plastic-based sustainable synthetic aggregate in Green Lightweight concrete – A review,” Jul. 19, 2021, Elsevier Ltd. doi: 10.1016/j.conbuildmat.2021.123321.

[2] S. K. Adhikary et al., “Lightweight self-compacting concrete: A review,” Resour. Conserv. Recycl. Adv., vol. 15, Nov. 2022, doi: 10.1016/J.RCRADV.2022.200107.

[3] S. A. Yildizel, M. Uzun, M. A. Arslan, and T. Ozbakkaloglu, “The prediction and evaluation of recycled polypropylene fiber and aggregate incorporated foam concrete using Artificial Neural

Networks," Constr. Build. Mater., vol. 411, Jan. 2024, doi: 10.1016/j.conbuildmat.2023.134646.

[4] H. E. Diab, Y. A. Algash, A. N. Khater, and A. M. Ahmed, "Performance of Structural Lightweight Reinforced Concrete Solid Slabs with FRP Bars and Contain Polypropylene Fibers," Eng. Res. J. (ERJ, no. 54, pp. 304–316, 2025, Accessed: Apr. 19, 2025. doi:10.21608/erjsh.2025.327647.1368

[5] F. S. Klak and M. M. Jomaa'h, "Conventional and lightweight aggregate one-way reinforced concrete slabs subjected to fire and repeated loads: comparative experimental study," Aust. J. Struct. Eng., vol. 25, no. 1, pp. 106–123, Jan. 2024, doi: 10.1080/13287982.2023.2213504.

[6] S. K. Adhikary, Z. Rudzionis, A. Balakrishnan, and V. Jayakumar, "Investigation on the Mechanical Properties and Post-Cracking Behavior of Polyolefin Fiber Reinforced Concrete," Fibers 2019, Vol. 7, Page 8, vol. 7, no. 1, p. 8, Jan. 2019, doi: 10.3390/FIB7010008.

[7] A. Sedaghatdoost and M. Amini, "Mechanical Properties of Polyolefin Fiber-Reinforced Light Weight Concrete," Civ. Eng. J., vol. 3, no. 9, pp. 759–765, Oct. 2017, doi: 10.21859/CEJ-030912.

[8] M. G. Alberti, A. Enfedaque, and J. C. Gálvez, "Fibre reinforced concrete with a combination of polyolefin and steel-hooked fibres," Compos. Struct., vol. 171, pp. 317–325, Jul. 2017, doi: 10.1016/J.COMPSTRUCT.2017.03.033.

[9] M. Gorji Azandariani, M. Vajdian, M. Javadi, and A. Parvari, "Durability and compressive strength of composite polyolefin fiber-reinforced recycled aggregate concrete: An experimental study," Compos. Part C Open Access, vol. 15, p. 100533, Oct. 2024, doi: 10.1016/J.JCOMC.2024.100533.

[10] M. Karamloo, O. Afzali-Naniz, and A. Doostmohamadi, "Impact of using different amounts of polyolefin macro fibers on fracture behavior, size effect, and mechanical properties of self-compacting lightweight concrete," Constr. Build. Mater., vol. 250, p. 118856, 2020, doi: 10.1016/j.conbuildmat.2020.118856.

[11] [11] A. Doostmohamadi, M. Karamloo, and O. Afzali-Naniz, "Effect of polyolefin macro fibers and handmade GFRP anchorage system on improving the bonding behavior of GFRP bars embedded in self-compacting lightweight concrete," Constr. Build. Mater., vol. 253, p. 119230, 2020, doi: 10.1016/j.conbuildmat.2020.119230.

[12] A. Elkhouly, M. Tayel, and H. Sallam, "Comparative Study on Using Steel and Glass Fiber Reinforced Polymer Rebars as Reinforcement on Flexural Behavior of Concrete Beams.," ERJ. Eng. Res. J., vol. 47, no. 2, pp. 163–177, 2024, doi: 10.21608/erjm.2024.258544.1312.

[13] A. Manalo et al., "Comparative durability of GFRP composite reinforcing bars in concrete and in simulated concrete environments," Cem. Concr. Compos., vol. 109, p. 103564, May 2020, doi: 10.1016/J.CEMCONCOMP.2020.103564.

[14] C. Lu, Z. Qi, Y. Zheng, G. Xuan, and Y. Yan, "Long-term tensile performance of GFRP bars in loaded concrete and aggressive solutions," J. Build. Eng., vol. 64, p. 105587, Apr. 2023, doi: 10.1016/J.JOBE.2022.105587.

[15] G. Y. Işildar, S. Morsali, and Z. H. Zar Gari, "A comparison LCA of the common steel rebars and FRP," J. Build. Pathol. Rehabil., vol. 5, no. 1, Dec. 2020, doi: 10.1007/S41024-020-0074-4.

[16] M Abo Elyazed, "Numerical Investigation of Reinforced Concrete One-way R.C. Slabs Reinforced with Hybrid HFRP Bars," Int. J. Eng. Res., vol. V8, no. 06, pp. 793–799, 2019, doi: 10.17577/ijertv8is060470.

[17] A. H. Adheem, L. Rasheed, and I. M. Ali, "Flexural behavior of lightweight aggregate concrete one-way slabs," Int. J. Civ. Eng. Technol., vol. 9, no. 13, pp. 277–289, 2018.

[18] G. M. Werdina, "Finite Element Analysis of Fiber Reinforced Concrete Slabs under Torsion," Open Civ. Eng. J., vol. 18, no. 1, Oct. 2024, doi: 10.2174/0118741495354199241001110433.

[19] S. Wahab et al., "Comparative Analysis of Shear Strength Prediction Models for Reinforced Concrete Slab-Column Connections," Adv. Civ. Eng., vol. 2024, 2024, doi: 10.1155/2024/1784088.

[20] X. Chen, B. Luo, and X. Liu, "Experimental and Numerical Investigation of a New Type of Composite Slab with a Separate Joint," Buildings, vol. 14, no. 7, Jul. 2024, doi: 10.3390/BUILDINGS14071890.

[21] A. S. G. Qanber, M. H. Yas, and M. M. Kadhum, "Numerical and Experimental Behavior Analysis of Slabs Strengthened Using Steel Plates and Slurry-Infiltrated Mat Concrete (SIMCON) Laminates," Infrastructures, vol. 8, no. 5, May 2023, doi: 10.3390/INFRASTRUCTURES8050085.

[22] ANSYS. Release Version 15.0.0, A Finite Element Computer Software and User Manual for Nonlinear Structural Analysis, ANSYS Inc. Canonsburg, PA 2013.

[23] Egyptian Code of Practice for Design and Construction of Reinforced Concrete Structures (ECP 203-2020), Housing and Building Research Center, Ministry of Building and Construction, Giza, Egypt, 2020, Chapter 6, pp. 110–112.

[24] H. Tran, T. Nguyen-Thoi, and H. B. Dinh, "State-of-the-art review of studies on the flexural behavior and design of FRP-reinforced concrete beams," Mater., vol. 18, no. 14, p. 3295, Jul. 2025, doi: 10.3390/MA18143295.

[25] D. Y. Yoo, S. T. Kang, and Y. S. Yoon, "Effect of fiber length and placement method on flexural behavior, tension-softening curve, and fiber distribution characteristics of UHPFRC," Constr. Build. Mater., vol. 64, pp. 67–81, Aug. 2014, doi: 10.1016/J.CONBUILDMAT.2014.04.007.

[26] A. Charif, A. Khalil, and S. Mourad, "Flexural behavior of beams reinforced with steel bars," Lat. Am. J. Solids Struct., vol. 13, no. 13, pp. 2430–2448, 2016, doi: 10.1590/1679-78253135.