ISSN: 2633-4828 Vol. 6 No.1, January, 2024

International Journal of Applied Engineering & Technology

STRUCTURAL BEHAVIOR OF FIBROUS REINFORCED ONE WAY COMPOSITE VOIDED DECK SLAB

Nawal S. Fadil,* Ahmed A. Mansor and Amer M. Ibrahim
Department of Civil Engineering, University of Diyala, Iraq

ABSTRACT

Utilising voids in concrete slab structures has been employed as a means to reduce the overall weight of the concrete. The problem lies in determining whether composite slabs can effectively withstand considerable compressive and shear pressures. This study focuses on the development of cavities in a voided deck slab, specifically in relation to plastic pipes and polypropylene fibre. The research involved determining the strength properties of slabs combined with a corrugated sheet and steel support elements, followed by the incorporation of plastic pipes and polypropylene fibre. The work experimentally explores the structural performance of composite reinforced concrete voided one-way slabs. Ten composite deck slabs were supported by steel sheets, with slab dimensions of 1850mm x 500mm x 110mm. Furthermore, several cavity geometries are utilised.

The reference specimen consists of a reinforced concrete slab that is supported by a trapezoidal steel sheet. The nine examples are grouped into three groups. The first group comprises three specimens with varying cavity geometry. The chosen materials for the cavities were plastic, mild steel, and stainless steel. These materials were shaped into truncated pyramids and truncated cones, respectively. The plastic pipes were introduced into the samples of the slab in the second group, using the identical cavity types as those in the first group. Lastly, the third group incorporates the inclusion of polypropylene fibre as a novel addition to the conditions of the second group.

The specimens that were manufactured underwent testing under two-point loading conditions. An analysis was conducted to assess the longitudinal shear capacity and crack behaviour of composite slabs using shear connectors. The study contributions resulted in a notable enhancement in the shear force capacity and flexural strength of voided deck slabs.

Using Polypropylene Fiber observed, a unique enhancement in flexural strength (9.2%), compressive strength (11.2%), and splitting strength (1.4%) of the slab compared with a single slab was selected as a control specimen and the first group.

The experiments provide a significant increase in the ultimate load's capacity of composite slabs for the plastic, plate, and stainless-steel specimens compared with a single slab was selected as a control specimen due to its homogeneous and type of geometries of steel sheet trapezoidal shape (34.6%, 23.1%, 26.92%, 48.46%, 25.38%, 29.23%, 51.92%, 40.38%, 50.77%), respectively.

The observations of concrete cracks were found to be 0.02 mm to 0.32 mm at a range of (7 to 10 KN), (6 to 10 KN) and (9 to 13 KN), respectively, compared with a single slab was selected as a control specimen, which represents the best choice to enhance the slabs performance. It has been found that the ultimate load capacity of the composite slabs containing plastic voids was more than an ultimate load of all other specimens. While deflection shows the highest value in the composite slabs containing stainless steel voids as a result of increasing strength.

Keywords: Composite slabs, PFRC, Profile steel sheet, Slab deformation, and Voided slabs.

1. INTRODUCTION

Concrete is often utilized in construction due to its adaptability. The cost of a floor system is higher due to the increased amount of concrete required. Bubble deck slabs frequently employ hollow plastic components manufactured from recycled plastic as a substitute for concrete, so diminishing the structural burden. The plastic sphere, when compared to a solid slab of similar thickness, decreases the dead load of the deck by two units while maintaining the same deflection and bending strength. A bubble deck slab minimises the amount of concrete used in its central area, where there is less stress on the structure. Utilising spaces inside solid slabs decreases their overall volume. The implementation of voided slab technology allows for cost reduction and minimises environmental effects while maintaining structural integrity. When the porous cores of standard slabs are extracted, they experience a reduction in mass ranging from 30% to 50%. The slab exerts less weight and has a lower hardness on the building's columns, walls, and foundations. The bubble deck technology has the potential to reduce the amount of structural concrete required by 35%. Building cost reductions of 10% can be achieved by the implementation of alternatives such as thinner floors and facades, smaller foundations, and shorter columns. Hollow core concrete is a prevalent feature in contemporary architectural designs. Utilising a variety of materials to investigate the behaviour of HCS. These structures often exhibit high resistance to bending moments when subjected to uniformly distributed loads. Shear failure may happen in the HCS when subjected to concentrated or distributed loads. This occurrence is not consistent. Conventional techniques such as thickening and filling hollow core slabs (HCSs) can potentially enhance their shear capability. According to ACI 318-08 (ACI Committee 318, 2014), increasing the thickness of HCS above a specific limit decreases its shear capability. However, filling in the holes would diminish the advantages of affordability and lightweight design.[1]. Abdel-Rahman et al., in [2] They, found that steel fibers in concrete increased all hollow beam mechanical properties. Steel fibers transmitted tensile stress over concrete fracture surfaces, improving load-bearing capability. Al-Yassri et al., in [3], They tested how hybrid reinforcement affects hollow core HCS cast with NSC. Several investigations showed that hybrid reinforcement—including CFRP and steel bars—improves ductility in HCS. However, hollow core HCS with CFRP bars as internal reinforcement has little effect on shear strength. CFRP reinforcement reduced the stiffness of the HCS after cracking, increasing deflection at a given weight.

2. FIBER REINFORCED CONCRETE

Fiber-reinforced concrete refers to the combination of concrete and fibrous material. These components enhance the building's structural stability [4]. Microfractures might result in tiny openings, so steel fibre is included. These additives mitigate fracture termination stress by transmitting tensile stresses across steel fibres. Despite the occurrence of visible fractures, the additives enhance the load-bearing capacity of the concrete and reduce the spread of cracks. Concrete is strengthened with the addition of fibres to enhance its durability [5]. Fibers can be manufactured from many materials. FRC mortar volumes are usually higher than those of normal concrete. Longer threads "ball" in concrete and make it hard to work with, so only 100–200 aspect ratio fibers can be utilized. Concrete fibers are usually unevenly distributed. Laying concrete in the opposite direction of applied stress increases flexural and tensile strength. Compaction is needed to properly disperse PP fibers and let fresh concrete flow well [6][7][8]. Polypropylene fiber can improve or decrease concrete compressive strength, depending on its effect. Experimental mistakes may mask the little polypropylene fiber's effect on concrete's compressive strength [9]. Concrete data requires a robust fiber-matrix link. Multiple cracking can occur if the concrete has reached the strengthening fiber volume. This is ideal because a brittle material can transition from one fracture surface to another, allowing it to withstand minor overload and shocks with noticeable damage Because it can break. Concrete enhancement involves making many cracks with as close a spacing as possible. Crack widths should be minute, almost unnoticeable. Hostile chemicals will penetrate the matrix less [10][11]. Concrete has unusual features because fibers' geometrical and mechanical properties change when hit. Fiber-reinforced concrete reliability depends on fiber orientation, kind, and %. The combination became harder to work with as particle size and amount exceeded 5 millimeters. Another important issue is the aspect ratio (l/d). Fiber workability is substantially affected by it. Increased aspect ratio reduces fiber workability [12].

3. RELATED STUDIES

In 2019, Al-Gasham et al. published the results of an experiment that aimed to investigate the impact of void size on the structural performance of one-way slabs. Self-compacting concrete was utilised in the construction of four distinct surfaces. Four specimens were fabricated to simulate a unidirectional slab. For the purpose of studying the effect of void dimensions on the behaviour of the slab, spherical objects with diameters equal to 50%, 58.3%, and 75% of the depth of the slab (D/H) were used. [13]

In 2018, In-Kwan Paik et al. introduced a novel type of voided slab system that combines voided slabs with deck plates, known as the void deck slab (VDS) system. Within the VDS cross-section, low-density void former materials are positioned between the ridges of the T-shaped steel deck plates. The installation technique is inserting the void formers and rotating them by 90 degrees, thereby firmly fastening them to the deck plates using the same materials. Consequently, individuals with modest expertise in the sector can proficiently install and secure the void formers with a significant degree of accuracy and enhanced user-friendliness.[14]

In 2017, Ahamed et al. manually analysed the voided slabs, taking into account both the longitudinal and transverse orientations. The STAAD Pro software utilises an idealisation technique to enable a thorough analysis of the bridge in the transverse direction. In industrial environments, the act of cutting can be expedited by utilising a heated wire, whereas on building sites, a manual saw can be employed for this task [15].

In 2012, Hedaoo et al. conducted a study on the structural performance of composite concrete slabs employing CRIL DECKSPANTM. The results produced using the m-k procedure demonstrate a substantially weaker level of significance compared to those obtained by the experimental approach, with a little variation of 43%. The user's text is "[16]."

In 2013, Lakshmikandhan et al. conducted a study on a composite slab that utilised shear connectors. The study found that the slab experienced failure when subjected to lesser levels of loading. This study aims to objectively examine three distinct types of mechanical connecting systems. The study discovered a complete shear interaction with little slides in all three shear connector designs [17].

In 2014, Abbas et al. created an innovative composite slab test scale that was successfully implemented, leading to positive results. The investigation centred on assessing the concrete slab's ability to bond with the steel deck after the completion of the welding process. This technique comprised attaching two rows of shear connectors to the lateral beam using a steel sheet. The number 18 is enclosed in square brackets. Salman, in 2012, study the structural behavior of bubbled reinforced concrete slabs. The investigation of the composite slab based on different bubble shapes found the failure under the lower loading condition. The preferred solution is to utilize an ASB beam or an RHS with a welded bottom plate. In order to offer specific support for the decking in regions where T or RHS members are embedded in the slab, it is recommended to weld a shelf plate to the column web [19]. Concrete undergoes cracking due to several factors, with mechanical stresses and environmental variables being the primary contributors to this phenomenon. The occurrence of concrete cracking can be attributed to a range of stress processes, including those that exert their influence during the material's fluid state, as well as those that manifest once it has solidified and acquired increased brittleness. The stress systems can be differentiated based on both internal and environmental factors that serve as triggers. Several instances that can be considered are chemical reactions, thermal expansion, limitations, and overloads. Cracks can exhibit a wide variety of magnitudes, encompassing microscopic fissures within the material to substantial fissures visible on the surface. These cracks are formed as a result of external influence. [20]. Fibers Reinforced Concrete (FRC) is a concrete composite that has been developed over a span of more than fifty years, drawing upon extensive experience in the random distribution of steel fibers inside a concrete matrix. In recent years, various different forms of fiber have demonstrated their effectiveness and appropriateness for utilization in structural concrete elements [21][22]. There exist two primary categories of steel fibres, namely smooth fibres and deformed fibres. Various geometries, including round, rectangular, and hook-shaped, among others, can also be considered as viable options. The higher efficiency of deformed steel fibres can be attributed to the surface area effect, which leads to a reinforcement of the connection between the cement matrix and the fibres. Consequently, this improvement in interaction results in an enhanced resistance to pull-out forces [23]. The malleability of this material confers several advantages over metals due to its ability to be easily moulded into various forms. Glass was the initial and remains the predominant kind of performance fibre [24].

Pshtiwan et al., in 2011, the researchers investigated the flexural and compressive strengths of concrete samples with and without the inclusion of glass fibre. The objective of the study was to ascertain whether there was a noticeable disparity between the two types of concrete. The findings of the study, along with the results of experimental tests, a techno-economic comparison with other types of construction materials, and financial calculations, collectively demonstrate the significant potential of GFRC as a viable option in the field of construction [25].

Chaitanya Kuma, in 2016, put out a proposition to elevate the standards for various qualities of concrete, including compressive strength, tensile strength, and split tensile strength. The objective of this experiment was to investigate the effects of incorporating glass fibre into concrete at various concentrations, specifically at 0.5%, 1%, 2%, and 3% of the cement content [26].

Arunakanthi et al. in 2016 to compare the characteristics of glass fibre and steel fibre. Following the implementation of the FRC at various levels of 0.5%, 1%, 2%, and 3%, subsequent studies were conducted to assess its effectiveness. It was discovered that the incorporation of SF resulted in a linear increase in strength across all three dimensions, namely flexural, compressive, and split tensile. Nevertheless, it was observed that the incorporation of glass fibre resulted in a marginal increase of merely 1 percent in strength, after which the strength exhibited a subsequent decline.

In 2018, Alex Tharun and colleagues examined the impact of glass fibre reinforcement on the structural integrity of the concrete. The researchers discovered that an increase in the fibre content of reinforced concrete resulted in a decrease in its workability, whereas the conventional mix exhibited a higher compression factor. The incorporation of glass fibre also resulted in enhancements to the flexural strength, compressive strength, and split tensile strength of the material. The utilisation of natural fibres has the potential to enhance the resilience and robustness of delicate fabrics [27].

Kavitha et al. in 2017 aim to examine the potential influence of several parameters on the mechanical properties and long-term performance of natural fibre composites (NFCs). Artificial fibres have been specifically designed to serve as reinforcing agents in various materials such as carbon, aramid, polyethylene, polypropylene, acrylic, polyamide, poly (vinyl alcohol), polyester, and carbon. Various synthetic polymers, including as nylon, polyethylene, and polypropylene, are employed in the production of these fibres.[28,29,30]

4. EXPERIMENTAL WORK

4.1. Research Methodology

The study concerns with conducting an analysis of the experimental program, which encompassed the fabrication and examination of ten composite slab specimens. This analysis encompasses several other subjects, namely the differentiation between concrete and plate, the reaction of load deflection, the capacity of ultimate load, and the response of load deflection.

4.2. Description of the specimens

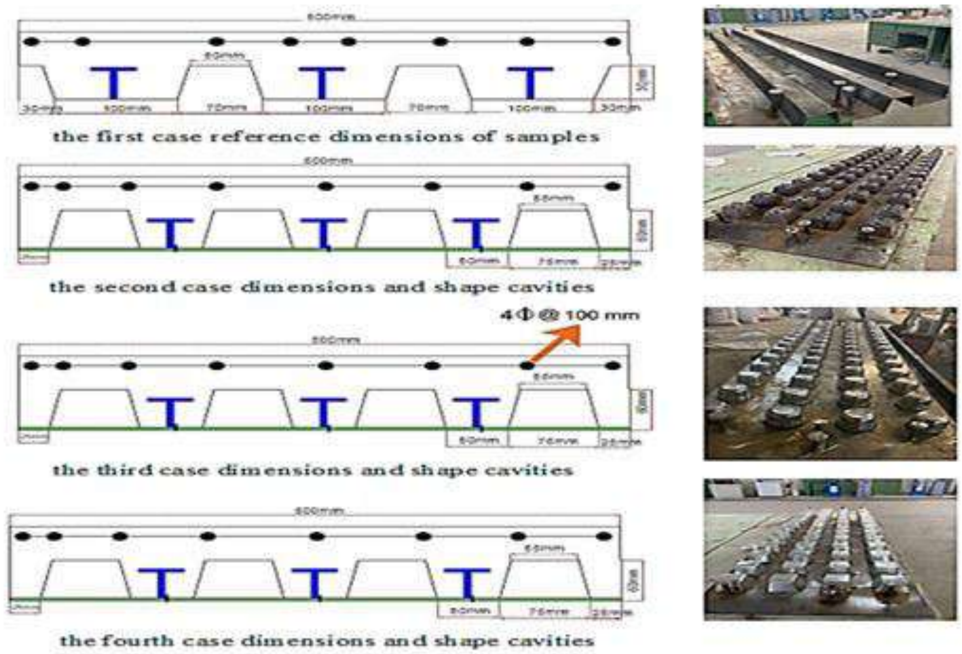

Figure 1: displays the specific characteristics and form of the specimen. The diagram

Depicts the cross-sectional arrangement of every sample of the composite deck slab. A total of ten composite slabs measuring 1850 x 500 x 110 mm were manufactured for this investigation. These slabs were then tested using a two-point loading setup to assess their performance. The control specimen was chosen based on its uniformity and the distinctive trapezoidal shape of the steel sheet it had. The three other specimens used as references show no signs of respiratory alterations after fusion. Three different steel sheet arrangements were employed in the fabrication of these tubs: one consisted of a flat plate, another was made from plastic, and the third had a truncated cone shape and was constructed using stainless steel. The tubs' cross-sectional areas displayed a variance ranging from around 3% to 3.5%. The last three composite slab specimens consist of both tubes and PFRC. Every support of each specimen is furnished with four shear connectors, generally known as headed studs. Figure 1 displays a table of the features related to the samples utilised in building the empty spaces within the remaining items.

4.3. Material and Method

- **Cement**

The project involved the utilization of Ordinary Portland cement (type I) produced at the Bazinia factory in Iraq. The mechanical qualities and chemical composition of the material adhere to the specifications outlined in the Iraqi Portland Cement Standard Specification.

- **Fine Aggregate**

The fine aggregate utilized in this project was sourced from the Al-Sidor region. The fineness modulus of the material is 2.38. The fine aggregate's grading and physical attributes must adhere to the guidelines outlined in the Iraqi Specification (I.Q.S. No.45, 1984).

- **Coarse Aggregate**

The coarse aggregates utilized in this investigation consist of naturally occurring gravel, possessing a maximum particle size of 10mm. Following the rinsing process, the gravel was further subjected to air-drying. The physical qualities and grading of the aggregates met the requirements outlined in Irrigation Standard No. 45 (1984).

- **Polypropylene Fiber**

This study used polypropylene fiber with a length of (12cm), diameter (18microns) and aspect ratio (600), tensile strength equal to (300-400MPa), and a specific gravity of 0.091 g/cm3 to improve concrete properties.

- **Superplasticizer**

A superplasticizer enhances the workability of concrete without creating segregation, hence making it simpler to handle. "Sika Viscocrete 5930" is the brand name for the material used in this investigation.

- **Plastic Pipes**

The recycled plastic material was used to create plastic pipes with a diameter of (25 mm) and (20 g) in weight, creating gaps inside the slabs in this investigation. Employing plastic material is to preserve energy since reprocessing recycled resources into new material requires far less energy than processing virgin materials. Additionally, recycling reduces global warming and air pollution by lowering the quantity of industrial labor required to manufacture a new product.

- **Steel Reinforcement**

Deformed steel bars are employed as steel reinforcement at the top of all slabs. The reinforcement measures (4mm) were used for control shrinkage and temperature and used in the ribs, the yield stress (Fy=442MPa) and ultimate stress (fu=620MPa).

- **Headed Stud**

The typical dimensions of a skull stud were determined to be a diameter of 10 mm and a total height of 75 mm, with the head having a diameter of 19 mm and a height of 7 mm.

- **Steel Sheets**

The cold-rolled steel sheets utilized in this study were sourced from Ukraine. This method was utilized to produce three distinct steel sheet geometries that possess approximately equivalent cross-sectional areas.

In order to increase strength and decrease the water-to-cement ratio, it is preferable to decrease water content as opposed to increasing cement utilization.

4.4 Mixing design

Table 1: Mixing design

	Type of fiber	Fiber percentage	Cement (kg)	Sand (kg)	Gravel (kg)	Additives	Water (kg)
1	none	0	460	704	901	3.5%	216
2	PP Fiber	0.5%	460	704	901	3.5%	216

The Chemical Admixture is used to Improve the Concrete Workability as in the following Processes:

1- The coarse and fine aggregate will be washed and dried to remove clay particles.

2- Adding Sika Vsco Crete 5930-L.

3- The first test that will be done is the slump test.

4- The first stage of tests was to cast three cylinders with the dimensions of (150mm x300mm) three cubes of size (150mmx150mmx150mm) and prisms specimens with the dimensions (100mmx10mmx500mm).

In order to compare the textures of various concretes, the slump test can be utilized. A poorly mixed quantity can be identified with a slump test, and the test itself exposes the workability and fluidity of the concrete.

mix code	slump test results (mm)
CSs	97
CS1s	69
CS1s – D25	65
CS1s-D25-pp	62

Figure 2: slump test

The slabs will stay 28 days in the water for curing and two days for drying. The components were combined until they formed a homogenous mass. Adding water gently to the mixture, followed by the fibers, which are also added gingerly, produces a slurry suitable for casting.

Figure 3: Developing and casting the mold.

After preparing the mélange, a vibrator was used to convey it to the mold, where it was formed into a panel. Normal concrete was cast in three layers, and each layer was meticulously leveled with a rod; the steel fiber cylinder was also a standard cylinder, measuring 100 mm in diameter and 200 mm in length. The air bubble was able to penetrate the surface of the specimen because the vibrating process continued until it did. Three cylinders must be cast for accurate measurements of the material's compressive strength, modulus of elasticity, and tensile strength. After vibrating the timbers from the exterior with a vibrator, concrete is poured into the mold. Shapes such as pyramids and cylinders.

5. RESULTS AND DISCUSSION

A comprehensive dataset was gathered for each slab, including measurements such as the degree of bending, the level of concrete tension at the compressed side, and the progression of cracks in response to gradual increases in loads. This chapter provides a comprehensive analysis of the test findings and assesses the regions of insufficiency. The outcomes of each experiment are contrasted with the initial hypotheses. An investigation was conducted to analyse the mechanical characteristics of traditional concrete and lightweight void slabs. The study also aimed to assess the impact of three different types of cavities and varying proportions. The topic also includes the impact of reinforcing the slabs with fibre and plastic tubes. The main objective of the experimental study was to examine the influence of void size, slab thickness, and the proportion of propylene fiber-reinforced concrete (PFRC) on the samples.

Furthermore, a thorough battery of tests was performed to assess the self-weight, load-carrying capacity, deflection, stiffness, ductility, and toughness of voided slabs in comparison to a solid control slab. This study investigated the influence of several parameters on the compressive, tensile, and flexural strengths of concrete. The examination encompassed an analysis of not only the concrete compressive strain and steel tensile strain but also the ultimate load capacity and load-deflection curve. In order to obtain accurate data for the analysis of the slab specimens, three samples were collected for each test, and the results are displayed in the table below.

Table 2: Results of Concrete mechanical properties

Specimen Symbols	F'C Mpa 28 days	Fr Mpa 28 days	Fct Mpa 28 days
reference	35	6.61	3.51

Table 2 shows the results of experimental standard cylinders of the specimens that was tested to calculate the compressive strength (f'_c), according to ASTM C39, splitting tensile strength (f_{sp}) according to ASTM C496 and static Young's modulus according to ASTM C469. The first step to obtain a reference slab case study is to investigate the slab deflection, crack patterns, and strain response. The results of the reference case are to be used to understand the various cases' results and other cases' behavior and responses. Figure 4 presents the reference specimen result. The amplification of deflections can be notable when fissures occur in reinforced concrete components. Concrete that undergoes cracking below the neutral axis undergoes a reduction in flexural stiffness and moment of inertia at the specific areas where the cracks manifest. The measuring of crack width is a crucial necessity in guaranteeing the operational effectiveness of structural components. The investigation of the specific case demonstrated that the breadth of the crack, when subjected to a force of 10kN, was found to be a minimal 0.02 mm. The presence of cracks can have detrimental impacts on various aspects, such as the transmission of forces, physical aesthetics, functional performance, and overall durability. In the context of designing fragile buildings, it is imperative to do precise calculations of fracture width and make accurate predictions.

Figure 4: Specimen result of reference slab case study

5.1.1 Test Results of Group A (slab without Pipes and without PFRC)

In order to achieve the objective of this study, the researcher developed a three case study groups. Where the first group contains three conditions: the first condition was with the plastic cavities (CS-1s), the second condition was the slab with mild steel cavities (CS-2s), and the third condition was the steel cavities (CS-3s).) which are approximately equal in the cross-section area in order to study the effect of the geometry of profile steel sheets on the structural behavior of composite slabs. In all first-group tests, the researcher did not used plastic pies or PFRC. All tests were to investigate the slab deflection, crack patterns, and strain response. All of the samples tested were found to be unsuccessful in the shear test. The test results, depicted in Figures 4.4-4.6, illustrate the failure modes of the slabs in this set.

Table (4-2) Details of Group A

Group	Code	Details
second group		
	CS-s	Reference
	CS-1s	The sample contains plastic voids slab without pipes and without fibers.
	CS-2s	The sample contains an iron metal void slab without pipes and without fibers.
	CS-3s	The sample contains steel voids slab without pipes and without fibers.

5.1.2 Ultimate Load Capacity of the Tested Composite Slabs in Group A

The ultimate load capacity and other results tested in group A are listed in Table 3. The results show an increase in the ultimate load capacity of composite slabs in four specimens with (truncated cone shape made from plastic, Truncated pyramid shape made from plate, and truncated cone shape made from stainless steel) compared with a single slab was selected as a control specimen due to its homogeneous and type of geometries of steel sheet trapezoidal shape (34.6%,25.38% and 26.9%), respectively. The cause of this act is to increase interlock between concrete and profile steel sheet. As well as distribution of gaps in both directions in composite slab specimens acts to increase ultimate load capacity. The characteristics of bubbles significantly influence the elasticity of a slab. The compressive strength of bubble plastic deck slabs exhibits superior performance in comparison to conventional slabs with equal volume. The spatial configuration of voides significantly affects the structural capacity of the slab. The load-bearing capability of the bubbles exceeds that of a conventional slab as a result of their unique form and composition.

Table 3: Results of the Tested Composite Slabs in Group A

Slab symbol	Ultimate load P_u (kN)	Ultimate Deflection Δ_u (mm)	Failure Mode
CS-s	26	13.08	Brittle
CS-1s	35	14.7	Brittle
CS-2s	32	27.67	Brittle
CS-3s	33	44.66	Brittle

The primary focus of this composition pertains to the compartmental alterations exhibited by the specimens. The relationship between slab deflection and load is established in all three scenarios investigated in this set of studies. In comparison to the deflection observed in the reference slab

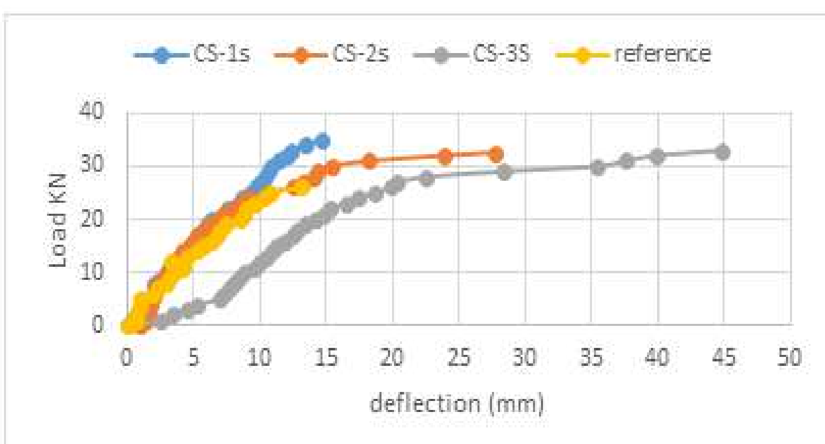

Figure 5: Deflection response of the first case study

The specimen labeled as CS-3s exhibited a greater degree of deflection when compared to the other slabs, namely CS-1s and CS-2s. The enhancement of deflection performance was observed with the incorporation of plastic and mild steel cavities.

5.1.3 Compressive Strain Development in Concrete Surface and Tensile Strain Development at Profile Steel Sheet in Group A

The concrete experienced an initial fracture, which was accompanied by rather minor compressive forces in both the steel and concrete materials. Nevertheless, when the magnitude of the load intensified, the stresses exhibited a gradual escalation until they reached their utmost value shortly before the ultimate load was attained. The strain observed in the specimen can be attributed to the overall deformation of the monolith. Figures 6 and 7 show the strain results of steel bars and slab concrete.

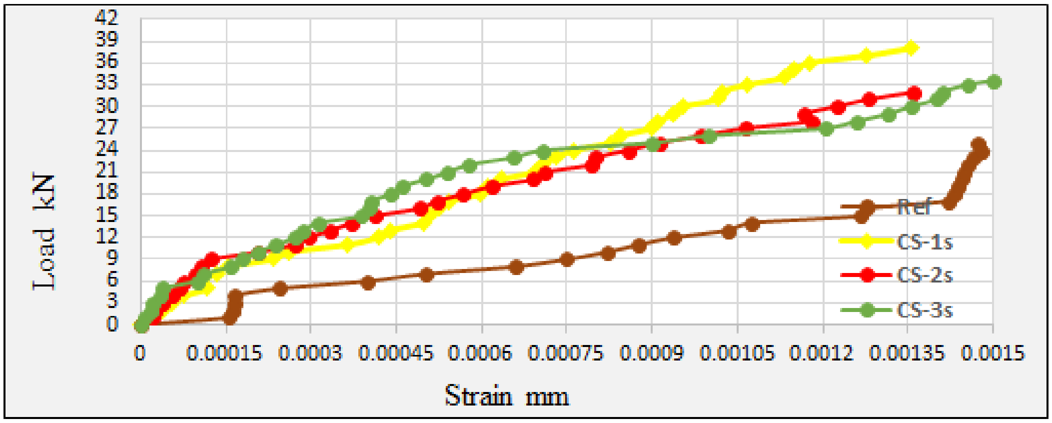

Figure 6: Steel strain results of the first case study

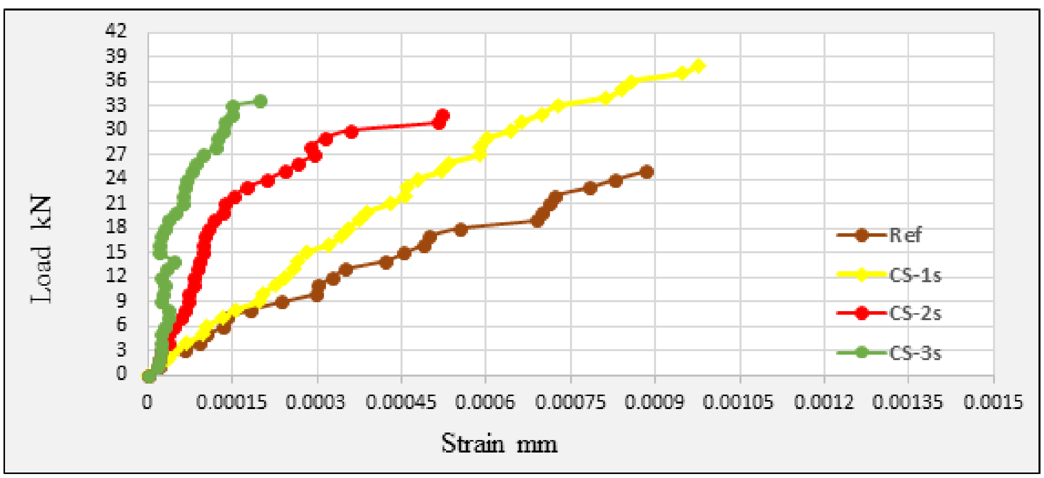

Figure 7: Concrete strain results of the first case study

The numerical results of the strain response are shown in Table 4.

Table 4: Numerical strain results of the first group of experiments

Case study	Concrete Strain	Steel strain
reference	0.000911	0.001486
CS-1s	0.000989	0.001513
CS-2s	0.000567	0.001388
CS-3s	0.000199	0.001499

The results observe a reduction in concrete strain in all cases while an increment in steel strain of CS-1s case study. This result is due to the different behavior of slab displacement, which is caused by different properties of cavity materials.

5.1.4 Mode of Failure and Crack Pattern of Composite slabs in Group A

The investigation of the specific case demonstrated that the breadth of the crack, when subjected to load, was found to be 0.02 mm to 0.32 mm for the CS-1s case study. The crack appearance was at 9Kn in CS-1s and 10Kn in CS-2s, while it appears in CS-3s case study under 7Kn. The presence of cracks can have detrimental impacts on various aspects, such as the transmission of forces, physical aesthetics, functional performance, and overall durability. In the context of designing fragile buildings, it is imperative to do precise calculations of fracture width and make accurate predictions. The observed specimen (CS-3s) exhibited fractures on both the tensile and compressive surfaces, indicating a more severe failure mode compared to the remaining slabs. There is a potential for mild steel and plastic cavities to enhance the failure shape and process on the tension face. Initially, fractures manifested exclusively on the tensile surfaces of the slabs in proximity to the periphery of the high-density region. Subsequently, the fissures propagated over the entirety of the slab. As the force approached the shear limit of the slab, the crack widths exhibited an increase in magnitude. The presence of additional voids in slabs was found to be positively correlated with an increased occurrence of cracks. Conversely, slabs constructed using CS-1 and CS-2 concrete exhibited a reduced incidence of fractures. External loads cause cracks in the form of flexural, bond, and diagonal tension due to direct and bending strains, respectively. Internal microcracks occur when the tensile stress exerted on the concrete surpasses its tensile strength. Over time, these cracks widen into larger cracks, which spread to the surrounding areas of the fiber element. Once the initial crack has fully formed in a piece of reinforced concrete, the tension within the concrete at the crack position is promptly alleviated and absorbed by the reinforcement. Cracking occurs in the area of reinforced concrete surfaces that experience bending stress. The temporal constraint on the extent of flexural cracks, originating from the steel and reaching the surface, may endure in reinforced concrete slabs. Over time, the widths of fractures may increase and become more consistent across the component when subjected to continuous pressure.

5.2 Test Results of Group B (slab with pipes)

The second group included three conditions: the first condition involved plastic cavities with plastic pipes (CS-1s-D25), the second condition involved slabs with mild steel cavities and plastic pipes (CS-2s-D25), and the third condition involved steel cavities with plastic pipes (CS-3s-D25). The purpose is to examine the impact of adding plastic pipes on the structural behavior of composite slabs by using profile steel sheets with similar cross-sectional areas. The purpose of all tests also was to examine the deflection of the slab, the patterns of cracks, and the response of strain. Every sample that was examined failed to meet the requirements of the shear test. The test results demonstrate the several ways in which the slabs in this set failed.

Table 5: Details of Group B

Group	Code	Details
second group		
	CS-s	Reference
	CS-1s -D25	The sample contains a plastic void slab with pipes.
	CS-2s -D25	The sample contains an iron metal void slab with pipes.
	CS-3s -D25	The sample contains a steel void slab with pipes.

5.2.1 Ultimate Load Capacity of the Tested Composite Slabs in Group B

The maximum load capacity and other test results obtained from group B are presented. The results indicate that the ultimate load capacity of composite slabs increased when using three different specimens and compared with reference: a truncated cone shape made from plastic, a truncated pyramid shape made from plate, and a truncated cone shape made from stainless steel. The increase in ultimate load capacity for the plastic, plate, and stainless-steel specimens was 48.46%, 25.38%, and 29.23%, respectively. The distribution of gaps in both directions in composite slab specimens serves to enhance the final load capacity. The properties of bubbles have a substantial impact on the elasticity of a slab. The compressive strength of bubble plastic deck slabs surpasses that of conventional slabs with the same volume. The arrangement of empty spaces has a considerable impact on the load-bearing capability of the slab. The bubbles' load-bearing capacity surpasses that of a typical slab due to their distinctive shape and composition.

Table 6: Results of the Tested Composite Slabs in Group B

Slab symbol	Ultimate load P_u (kN)	Ultimate Deflection Δ_u (mm)	Failure Mode
CS-s -D25	26	13.08	Brittle
CS-1s -D25	38.6	23.6	Brittle
CS-2s -D25	32.6	27.67	Brittle
CS-3s-D25	33.6	49.5	Brittle

The results demonstrate the association between the load applied to the slab and the resulting deflection. The specimen's behavior closely resembled that of the reinforced concrete reference slab. Before fracturing, the test component displayed a nearly linear correlation between the applied load and the resulting displacement when operating within the elastic regime. The central component of the slab had a concrete rupture when the evenly distributed stress reached a specific threshold of expansion. In this part, the composition examines the transformation of slab form when containing pipes and investigates the effect that takes place when the specimens are fractured, resembling the fracturing of reinforcing bars. The observable deflections in the structure are a direct result of the applied load. Concrete inevitably experiences fragmentation as a result of external influences. The load-displacement curves indicated that the reinforcement consistently underwent fracture along a narrow crack. Each time, this occurrence occurs with a rapid decrease in the load.

5.2.2 Load-Deflection Behavior of the Tested Composite Slabs Specimens in Group B.

In the second test group, the correlation between slab deflection and load is proven in all three scenarios examined in this series of research. Compared to the deflection found in the reference slab, the CS-3s-D25 specimen displayed a higher level of deflection in comparison to the other slabs, specifically CS-1s-D25 and CS-2s-D25. The addition of plastic and mild steel cavities resulted in an improvement in deflection performance. Figure 8 depicted the deflection outcomes of the initial set of slabs.

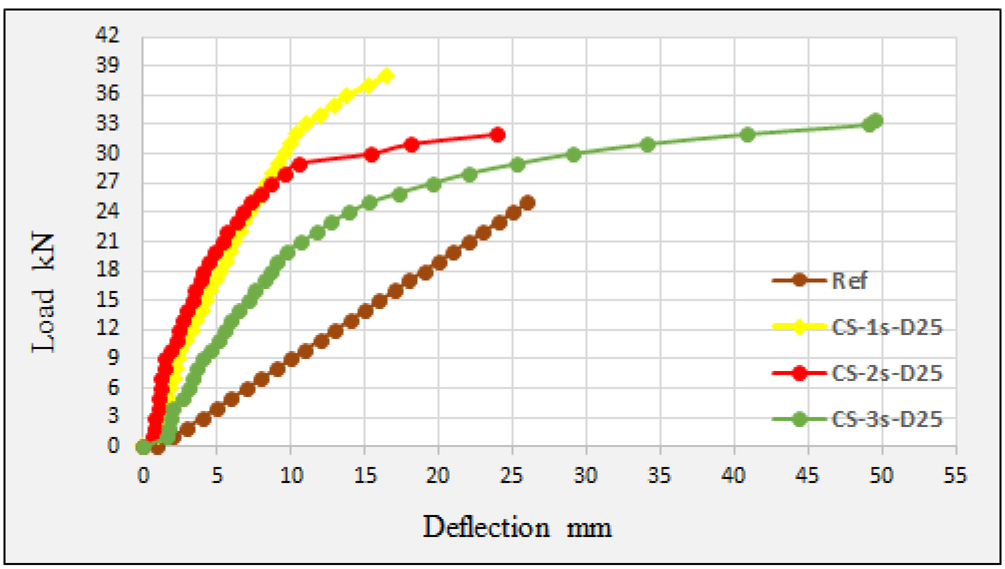

Figure 8: deflection response of the second case study

5.2.3 Compressive Strain Development in Concrete Surface and Tensile Strain Development at Profile Steel Sheet in Group B

The tests of the second group conducted on slabs with pipes also included the measurement of strains. The concrete underwent an initial fracture, accompanied by significant compressive stresses in both the steel and concrete elements. However, when the load increased in size, the stresses gradually increased until they reached their maximum amount just before reaching the ultimate load. The strain measured in the specimen is caused by the total deformation. Figures 9 and 10 display the strain measurements for steel bars and slab concrete. The amplitude of strains was significantly influenced by whether the wall surface of the slabs, where the measuring standards were positioned, was submerged in the samples**.**

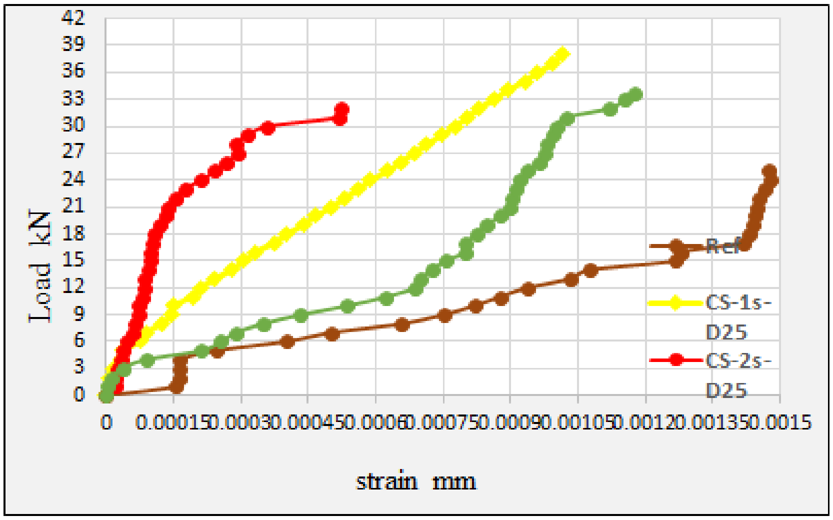

Figure 9: steel strain results of the second case study

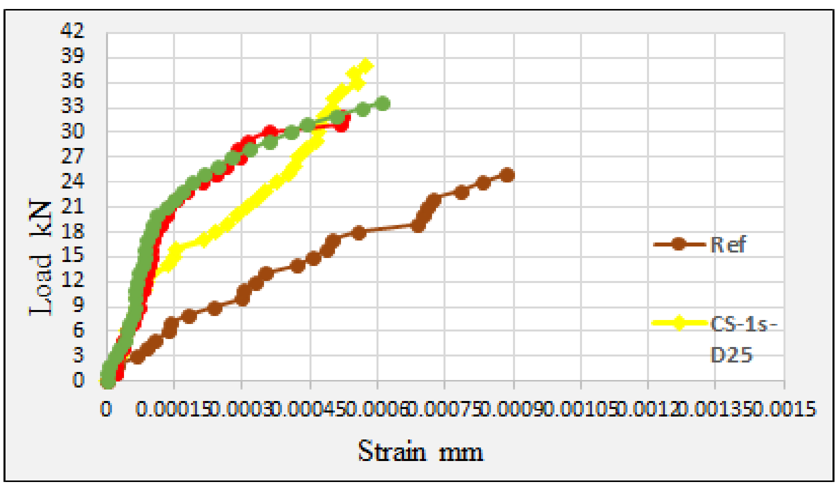

Figure 10: concrete strain results of the second case study

Table 7: numerical strain results of the second group of experiments

Case study	Concrete Strain	Steel strain
reference	0.000911	0.001486
CS-1s-D25	0.000989	0.001513
CS-2s-D25	0.000567	0.001388
CS-3s-D25	0.000199	0.001486

5.2.4 Mode of Failure and Crack Pattern of Composite Slabs in Group B

The investigation of the CS-1s-D25 case study determined that the crack's width, under load, varied between 0.02 mm and 1.0 mm. The case studies of CS-1s-D25 and CS-2s-D25 revealed cracks at 7 and 10 kilonewtons (KN), respectively. Conversely, the case studies of CS-3s demonstrated cracks occurring at forces below 6 KN. Cracks can have detrimental effects on various aspects, such as force transfer, aesthetics, functional performance, and overall durability. Accurate computation of fracture breadth and exact forecasting are crucial in the design of buildings prone to failure. The specimens (CS-3s-D25) that were found exhibited a more severe failure mechanism, as evidenced by the presence of cracks on both the tensile and compressive surfaces, in contrast to the other slabs. Enhancing the shape and progression of failure on the side of the material experiencing tension can be achieved by employing mild steel and plastic voids. The initial signs of damage appeared on the slabs' tensile surfaces along the border of the high-density area. Subsequently, the fissures propagated throughout the entire slab. The widths of the fractures exhibited a progressive rise in magnitude as the applied force approached the shear threshold of the slab. A direct relationship was seen between the quantity of voids in slabs and the occurrence rate of cracks. Conversely, there was a reduction in the frequency of cracks in slabs constructed using CS-1-D25 and CS-2-D25 concrete.

5.3 Test Results of Group C (slab with pipes and polypropylene)

The third group consisted of three conditions: the first condition comprised of plastic cavities with plastic pipes and polypropylene (CS-1s-D25-PP), the second condition comprised of slabs with mild steel cavities and plastic pipes and polypropylene (CS-2s-D25-PP), and the third condition comprised of steel cavities with plastic pipes and polypropylene (CS-3s-D25-PP). The objective is to analyze the influence of including plastic pipes on the structural performance of composite slabs utilizing profile steel sheets with comparable cross-sectional areas. The primary objective of all testing was to analyze the slab's deflection, crack patterns, and strain response. Each sample analyzed did not meet the specified criteria of the shear test.

Table 8: Details of Group C

group	code	details
third group		
	CS-s	Reference
	CS-1s -D25-PP	The sample contains a plastic void slab with pipes and polypropylene.
	CS-2s -D25-PP	The sample contains an iron metal void slab with pipes and polypropylene.
	CS-3s -D25-PP	The sample contains a steel void slab with pipes and polypropylene.

5.3.1 Ultimate Load Capacity of the Tested Composite Slabs in Group C

The test findings for group C, including their maximum load capacity, are presented in Table 9. Upon comparing three unique specimens, a plastic truncated cone, a plate truncated pyramid, and a stainless-steel truncated cone with a reference, the findings indicate an increase in the ultimate load capacity of composite slabs. The plastic cavities with PP and plastic pipes exhibited a 51.92% increase in its ultimate load capacity, whereas the plate with PP and plastic pipes showed a 40.38% increase, and the stainless-steel specimen with PP and plastic pipes showed a 50.77% increase. Polypropylene fibers hinder the growth and spread of cracks in concrete, so effectively stopping their progression and maintaining the integrity of the material. Furthermore, polypropylene fibers offer numerous benefits, such as affordability, exceptional flexural strength, and resistance to impurities and moisture, among others. Adding PP to composite slab specimens, including gaps spread in both horizontal and vertical directions, have a greater capacity to withstand ultimate loads. In this group of tests, the plastic deck slabs have much greater compressive strength as compared to conventional slabs of equivalent volume. The arrangement of voids has a significant impact on the load-bearing capability of the slab. Due to their distinct shape and composition, the load-bearing capacity of the bubbles surpasses that of a standard slab.

Table 9: Results of the Tested Composite Slabs in Group C

Slab symbol	Ultimate load P_u (kN)	Ultimate Deflection Δ_u (mm)	Failure Mode
CS-s -D25-PP	26	13.08	Brittle
CS-1s -D25-PP	39.5	21.4	Brittle
CS-2s -D25 -PP	36.5	22.3	Brittle
CS-3s-D25-PP	39.2	32.5	Brittle

As presented in previous sections, the results illustrate the correlation between the load exerted on the slab and the consequent deflection when containing plastic pipes and polypropylene. Adding polypropylene fibers to concrete enhances its flexural and split tensile strengths, as well as its overall toughness. The findings of this case study demonstrate that the incorporation of polypropylene fiber into concrete yields significant improvements in various beneficial characteristics. The test component exhibited an almost linear correlation between the applied load and the resulting displacement while operating within the elastic range. The core element of the slab experienced a concrete fracture when the uniformly applied force exceeded a particular limit of expansion**.**

5.3.2 Load-Deflection Behavior of the Tested Composite Slabs Specimens in Group C.

Across all three situations examined in this research series, the results of the third test group indicate a clear relationship between slab deflection and load. When analyzing the deflection levels of the reference slab, CS-1s-D25-PP, and CS-2s-D25-PP, it was observed that the CS-3s-D25-PP specimen exhibited a markedly greater deflection. The deflection performance was enhanced by including plastic and mild steel chambers. Figure 11 displayed the deflection data for the initial batch of slabs. The addition of polypropylene fibers causes the concrete mix to agglomerate. The addition of these fibers to concrete reduces its bleeding rate. A reduced occurrence of plastic shrinkage cracking in concrete is attributed to a decreased bleeding rate, which consequently signifies a slower drying rate. Moreover, after the solidification of concrete, the inclusion of polypropylene fibers can effectively inhibit the propagation of cracks. The fibers, acting as secondary reinforcement, effectively bind the concrete, thereby impeding the expansion of cracks and inhibiting their propagation.

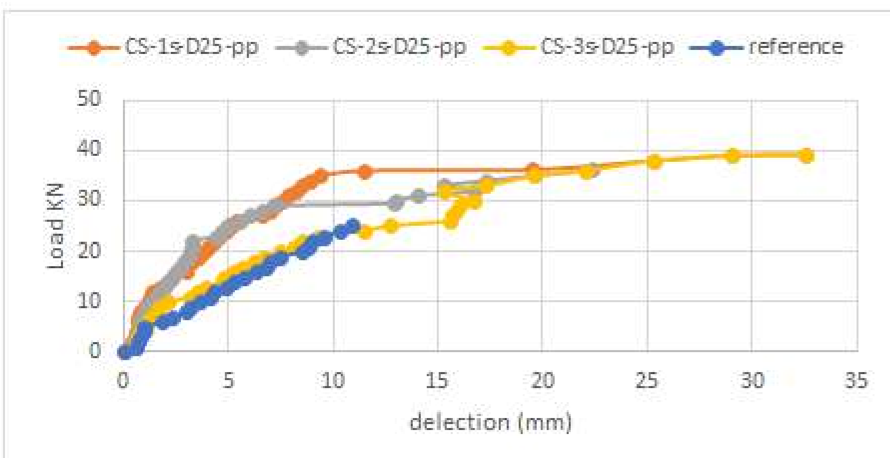

Figure 11: deflection response of the third case study

5.3.3 Compressive Strain Development in Concrete Surface and Tensile Strain Development at Profile Steel Sheet in Group C

The tests conducted on slabs with pipes and polypropylene fibers in the third group involved the measuring of stresses. The incorporation of polypropylene fibers in concrete results in the interconnection of pores, hence restricting the expansion into the concrete surface. The concrete experienced an initial fracture, accompanied by substantial compressive loads in both the steel and concrete components. Nevertheless, as the load grew larger, the strains progressively intensified until they reached their utmost level immediately prior to reaching the ultimate load. The strain observed in the specimen is a result of the overall deformation. Figures 12 and 13 illustrate the strain measurements obtained from steel bars and slab concrete. The magnitude of stresses was notably affected by whether the wall surface of the slabs, where the measuring standards were placed, was immersed in the samples.

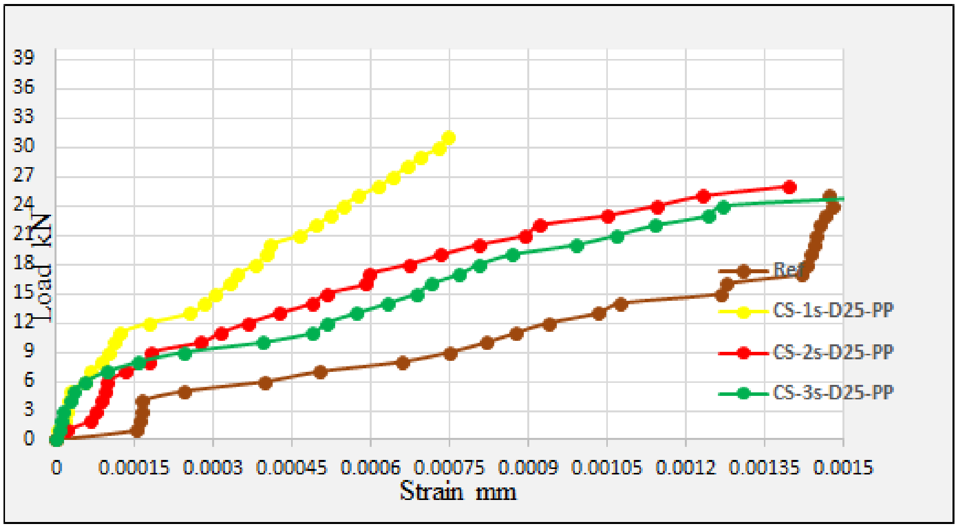

Figure 4.12: steel strain results of the third case study

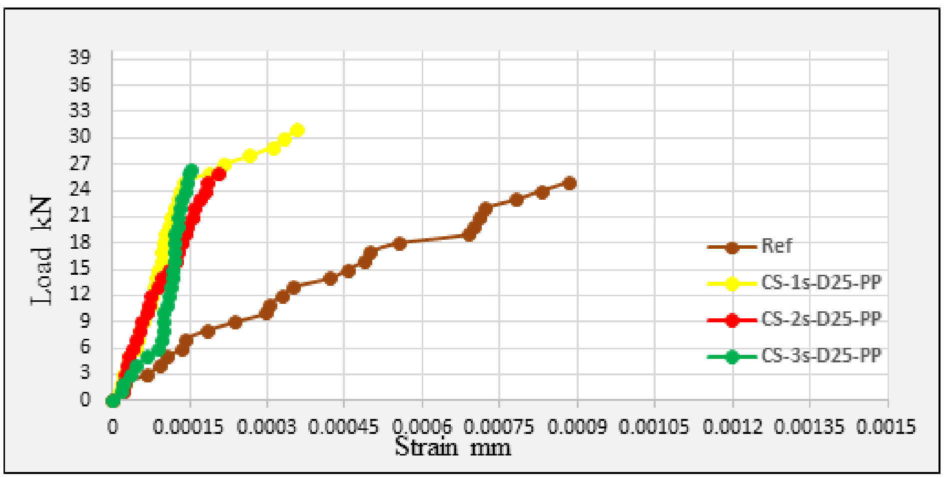

Figure 4.13: concrete strain results of third case study

Table 10: numerical strain results of the third group of experiments

Case study	Concrete Strain	Steel strain
reference	0.000911	0.001486
CS-1s-D25-PP	0.000682	0.001977
CS-2s-D25-PP	0.00048	0.00194
CS-3s-D25-PP	0.00015	0.000977

5.3.4 Mode of Failure and Crack Pattern of Composite Slabs in Group C

The analysis of the CS-1s-D25-PP case study revealed that the crack width ranged from 0.02 mm to 0.7 mm under the applied load. Inspections of CS-1s-D25-PP and CS-2s-D25-PP uncovered cracks at 13 and 13 kilonewtons (KN), respectively. However, examinations of CS-3s-PP showed cracks at values lower than 9 KN. Cracks can cause negative impacts on different areas, including the transfer of force, appearance, functional performance, and overall durability. Precise calculation of fracture width and accurate prediction are essential when constructing structures that are susceptible to collapse. The specimens (CS-3s-D25-PP) exhibited a more severe failure mechanism, characterised by the presence of cracks on both the tensile and compressive surfaces, in contrast to the other slabs. Employing mild steel and plastic cavities can enhance the shape and course of failure on the side under tension. The cracks first emerged on the tensile surfaces of the slabs situated at the periphery of the high-density region. Afterward, the cracks spread throughout the entire slab. The widths of the fractures increased significantly as the load approached the shear threshold of the slab. There was a clear correlation between the number of empty spaces in slabs and the frequency of cracks.

In contrast, slabs made using CS-1-D25-PP and CS-2-D25-PP concrete experienced a decrease in crack occurrence. Due to the incorporation of polypropylene and plastic pipes within the solid slab, the occurrence of vertical cracks, also known as flexural cracks, initiated and extended vertically until reaching the upper third of the slab, where they ceased. In other words, the slab's ability to support weight was not impaired because there was not enough space for the compressive block needed to counteract the applied forces. Modifying the shape of the cavity resulted in a noticeable impact on the ultimate strength, unlike the unchanged control slab. This process can be elucidated by the propagation of cracks within the material. External forces cause fractures to occur in the form of flexural, bond, and diagonal tension due to both direct and bending strains. Internal microcracks form in concrete when it experiences tensile stress that exceeds its tensile strength. Over time, these cracks widen and extend to the adjacent areas of the fibre component. Upon the complete development of the first crack in a piece of reinforced concrete, the stress at the fracture site is promptly alleviated and assimilated by the reinforcement. Cracks may develop in reinforced concrete surfaces when they are subjected to bending stress. Flexural fractures originating from the steel within reinforced concrete slabs may have a limited distance they can travel before reaching the surface. When subjected to continuous pressure, the widths of fractures may increase and eventually become more consistent across the component.

6. CONCLUSION

1. The results show an increase in the ultimate load capacity of composite slabs compared involves three specimens with different cavity geometries. The selected cavities materials were made from plastic, mild steel plate, and stainless-steel plate with a single slab by (34.6%,25.38%, and 26.9%), respectively. Also, the investigation of the specific case demonstrated that the breadth of the crack, when the subjected load was found to be 0.02 mm to 0.32 mm for the specimen, consists of cavities truncated pyramid shaped made of platic. The crack appearance was at 9Kn in it, and 10KN in the specimen consists of cavities truncated pyramid shaped made of mild plate, while it appears in the specimen consists of cavities truncated cone-shaped made of stainless steel under 7KN.

2. The results show an increase in ultimate load capacity for the plastic, plate, and stainless-steel specimens was 48.46%, 25.38%, and 29.23%, respectively. The analysis revealed that the crack's breadth, when subjected to load, ranged from 0.02 mm to 1.0 mm. Case studies of the specimen consist of cavities truncated pyramid shaped made of platic with plastic pipes and for the specimen consists of cavities truncated pyramid shaped made of the mild plate with plastic pipes showed cracks at 7 and 10 KN, respectively, while case studies of for the specimen consists of cavities truncated pyramid shaped made of stainless steel with plastic pipes show cracks at less than 6 KN.

3. The present plastic cavities with PP fibers and plastic pipes exhibited a 51.92% increase in its ultimate load capacity, whereas the plate with PP and plastic pipes showed a 40.38% increase, and the stainless-steel specimen with PP and plastic pipes shown a 50.77% increase. Polypropylene fibers revealed cracks at 13 KN, but investigations of the stainless-steel specimen with PP and plastic pipes shown demonstrated cracks at levels below 9 KN. The ultimate load capacity in the composite slabs for all specimens having are more than an ultimate load of a trapezoidal shape.

4. When comparing composite slabs with plastic and iron metal gaps to trapezoidal geometries, it can be observed that the former demonstrates reduced deflection when subjected to equivalent loads.
5. Composite slabs, including steel gaps exhibit greater deflection under equivalent applied forces compared to slabs having a trapezoidal shape.
6. The behavior of the specimen that contains plastic voids in the all group is better than that of the single slab was selected as a control specimen.
7. The results observe a reduction in concrete strain in all cases while an increment in steel strain of for the plastic case study. This result is due to the different behavior of slab displacement, which is caused by different properties of cavity materials.
8. All the composite slab specimens filure as brittle.
9. The inclusion of polypropylene fibers in void slabs does not influence the shear failure mechanism.
10. The implementation of longitudinal plastic lines caused the enlargement of fissures, while narrower fissures demonstrated a diminution in dimensions.
11. Recycled plastic pipes replaced concrete in the core of the slab to reduce the amount of cement. So, no cement would be made, and CO2 emissions worldwide would decrease. So, this technology is good for the environment and will last.
12. Reducing the amount of materials used expedites the building process. Additionally, it decreases dead weight, which provides a smaller building foundation; the reduction was (14%).
13. As distribution of gaps in both directions in composite slab specimens acts to increase ultimate load capacity.
14. The separation between the concrete and the plate in the single slab was selected as a control specimen form begins lateral, and it changes into longitudinal, while in all specimens it occurred only lateral.

REFERENCES

[1] I. M. E. El-arab, “Web Shear Strengthening Technique of Deep Precast Prestressed Hollow Core Slabs under Truck Loads,” pp. 129–145, 2017, doi: 10.4236/jbcpr.2017.54010.

[2] A. M. Abdel-Rahman, N. Z. Hassan, and A. M. Soliman, “Punching shear behavior of reinforced concrete slabs using steel fibers in the mix,” *HBRC J.*, vol. 14, no. 3, pp. 272–281, 2018, doi: 10.1016/j.hbrcj.2016.11.001.

[3] L. S. Al-yassri, E. Labeebhuseinqueduiq, A. Y. Ali, and M. M. Al-khafaji, “EXPERIMENTAL INVESTIGATION FOR THE BEHAVIOR OF HOLLOW CORE CONCRETE SLAB REINFORCED WITH,” vol. 10, no. 3, pp. 308–317, 2017.

[4] “SHEAR BEHAVIOR OF POLYOLEFIN FIBRE REINFORCED CONCRETE,” pp. 37–38.

[5] “Document downloaded from : This paper must be cited as Cuenca Asensio, E .; Serna Ros, P . (2013). Failure modes and shear design of prestressed hollow core slabs made of fiber-reinforced concrete. Composites Part B : Engineering. The final publication is available at Copyright Elsevier,” vol. 45, pp. 952–964, 2013, doi: 10.1016/j.compositesb.2012.06.005>.The.

[6] A. K. Yadav, B. Prasad, V. Kumar, and M. Mohan, “Properties of Polypropylene Fiber Reinforced Concrete and Structural Behaviour of Beam,” *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 6, no. 6, pp. 10200–10210, 2017, doi: 10.15680/IJIRSET.2017.0606011.

[7] M. A. Chowdhury and S. Hossain, “A Review on Tensile and Flexural Properties of Fiber-Reinforced Polymer A Review on Tensile and Flexural Properties of Fiber-Reinforced Polymer Composites,” no. November 2020, doi 10.9790/019X-07051626.

[8] S. Khan, R. A. Khan, A. R. Khan, M. Islam, and S. Nayal, “Mechanical properties of Polypropylene Fibre reinforced concrete for M 25 & M 30 mixes : A Comparative Study,” no. 6, pp. 327–340, 2015.

[9] J. E. Shoenberger and J. G. Tom, “Polypropylene Fibers in Portland Cement Concrete, Report DOT/FAA/RD-92-9,” 1992.

[10] M. Rakhshanimehr, M. R. Esfahani, M. R. Kianoush, B. A. Mohammadzadeh, and S. R. Mousavi, “Flexural ductility of reinforced concrete beams with lap-spliced bars,” *Can. J. Civ. Eng.*, vol. 41, no. 7, pp. 594–604, 2014, doi: 10.1139/cycle-2013-0074.

[11] Z. I. Khayoun, H. M. Kamal, and Y. K. Ibrahim, “The Effect of Hybrid Fibers Reinforcement on the Mechanical and Physical Abstract :” pp. 207–216, 2020, doi: 10.2174/1874149502014010207.

[12] F. S. Dissertation, “Steel Fiber Reinforced Concrete Under Concentrated Load,” 2017.

[13] T. S. Al-Gasham, A. N. Hilo, and M. A. Alawsi, “Structural behavior of reinforced concrete one-way slabs voided by polystyrene balls,” *Case Stud. Constr. Mater.*, vol. 11, p. e00292, 2019, doi: 10.1016/j.cscm.2019.e00292.

[14] and S. N. In-Kwan Paik, “Evaluation of Noise Insulation Performance for Void Deck Slab System which Combines Deck Plates with a Voided Slab System,” *Int. J. Appl. Eng. Res.*, vol. 13, no. 10, pp. 7348–7359, 2018.

[15] N. I. Ahamed and A. Nair S, “Analysis and Design of Voided Slabbridge,” *Int. J. Res. Eng. Technol.*, vol. 06, no. 17, pp. 33–41, 2017, doi: 10.15623/ijret.2017.0617006.

[16] N. A. Hedaoo, L. M. Gupta, and G. N. Ronghe, “Design of composite slabs with profiled steel decking: a comparison between experimental and analytical studies,” *Int. J. Adv. Struct. Eng.*, vol. 4, no. 1, p. 1, 2012, doi: 10.1186/2008-6695-3-1.

[17] K. N. Lakshmikandhan, P. Sivakumar, R. Ravichandran, and S. A. Jayachandran, “Investigations on Efficiently Interfaced Steel Concrete Composite Deck Slabs,” *J. Struct.*, vol. 2013, pp. 1–10, 2013, doi: 10.1155/2013/628759.

[18] H. S. Abbas, S. A. Bakar, M. Ahmadi, and Z. Haron, “Experimental studies on a corrugated steel-concrete composite slab,” *Gradjevinar*, vol. 67, no. 3, pp. 225–233, 2015, doi: 10.14256/JCE.1112.2014.

[19] S. J. H. J W Rackham, G H Couchman, *Composite Slabs and Beams using Steel Decking: Best Practice for Design and Construction (Revised Edition)*, no. 13. 2014.

[20] A. A. A. B. U. Altemen, F. H. Arna’ot, A. A. Abbass, and M. Ozakca, “Punching Shear Behavior of Small SFRC Flat Plate,” *ICOCEE-Cappadocia2017*, no. May, pp. 891–901, 2017.

[21] R. Vasudev and B. G. Vishnuram, “Studies on Steel Fibre Reinforced Concrete - A Sustainable Approach,” vol. 4, no. 5, pp. 1941–1944, 2013.

[22] S. Engineering, *Fibre-reinforced Concrete for Industrial Construction*. 2005.

[23] K. Holschemacher, T. Müller, and A. Fischer, “Effect of fibre type on properties of steel fibre reinforced concrete,” *Mater. Exp. Maint. Rehabil. - Proc. 10th East Asia-Pacific Conf. Struct. Eng. Constr. EASEC 2010*, no. May 2007, pp. 383–388, 2006.

[24] J. D. Chaitanya, G. V. S. Abhilash, P. K. Khan, and G. Manikanta, "Experimental study on Steel Fiber Concrete American Journal of Engineering Research (AJER) Experimental Studies on Glass Fiber Concrete," no. October 2016, 2018.

[25] P. Shakor and S. S. Pimplikar, "Glass Fibre Reinforced Concrete Use in Construction," no. September, 2016.

[26] J. D. Chaitanya, G. V. S. Abhilash, P. K. Khan, G. Manikanta, and V. Taraka, "Experimental Studies on Glass Fiber Concrete American Journal of Engineering Research (AJER)," *Am. J. Eng. Res.*, vol. 5, no. 5, pp. 100–104, 2016.

[27] E. Kern and H. Schorn, "Steel Fiber Reinforced Concrete," *Beton- und Stahlbetonbau*, vol. 86, no. 9, pp. 205–208, 1991, doi: 10.1002/best.199100380.

[28] J. Bothma, "ISI2013-15. Literature Review on Macro Synthetic Fibres in Concrete," *Univ. Stellenbosch, Inst. Struct. Eng.*, p. 20, 2013.

[29] Ibrahim, A.M., Hamood, M.J. and Mansor, A.A., 2016. BEHAVIOUR OF WIDE REINFORCED CONCRETE BEAMS WITH DIFFERENT SHEAR STEEL PLATES SPACING. Journal of Engineering and Sustainable Development, 20(5), pp.120-135

[30] Mansor, Ahmed A., Wissam D. Salman, and Ahlam S. Mohammed. "The Effect of Steel Fiber Content on the Behavior of Reinforced Concrete Bubbled Slab: Experimental Investigation." *Diyala Journal of Engineering Sciences* (2022): 85-93.