Review On Behaviour Of Steel Concrete Composite Slabs By Varying Different Parameters

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Abstract. Steel-concrete composite slabs have gained widespread popularity in construction industry due to their superior structural performance and cost-effectiveness. The study encompasses a wide range of research findings and methodologies to evaluate the effects of varying parameters, such as material properties, design configurations, and construction techniques, on the overall behavior of these slabs. The fundamental principles of composite slab systems, emphasizing synergy between steel and concrete components that contributes their enhanced load-carrying capacity, durability, and resistance to various loads, environmental conditions are discussed. Some key parameters explored in this review include the type and properties of concrete and steel, shear connectors, deck profile, and construction methods. The influence of these parameters on important performance indicators like strength, stiffness, and serviceability is thoroughly examined. The insights provided in this review paper aim to assist engineers, researchers, and practitioners in making informed decisions regarding the design and construction of steel-concrete composite slab.

Keywords: Composite slabs, Deck Profile, Steel fiber, Shear connectors, Load carrying capacity.

1 Introduction

Concrete composite slabs have emerged as a prominent structural solution in modern construction, offering a versatile and efficient system that combines the strengths of steel and concrete to meet the complex demands of contemporary architecture[1]. These slabs represent an essential component of building infrastructure, providing a robust and cost-effective solution for both residential and commercial structures. As the construction industry continues to evolve, the role of concrete composite slabs in ensuring structural integrity and performance becomes increasingly vital. The fundamental principle underlying concrete composite slabs involves the collaboration of two essential materials: steel and concrete. Steel serves as the primary load-bearing element, offering high tensile strength and flexibility, while concrete contributes to the compression resistance, providing stability and durability. Through embossments in the composite slab reinforced with profiled steel decking sheet, the system

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offers a feature for strong mechanical interlock between the concrete and steel deck interface. This system employs the steel deck as permanent formwork to support the concrete and also as a tensile reinforcement[2]. The profiled decking sheet must offer resistance to both vertical separation and horizontal slippage between the concrete's contact surface and the decking sheet [3, 4]. The amalgamation of these materials results in a structural system that capitalizes on their complementary properties, resulting in enhanced load-carrying capacity, improved fire resistance, and overall structural efficiency.

Profile deck sheets often include reinforcement details to enhance their structural strength and load-bearing capacity. These reinforcements typically come in the form of embossments, ribs, or corrugations strategically designed along the length and width of the sheet. The reinforcements in profile deck sheets serve multiple purposes like Increased Load Bearing Capacity, Enhanced Rigidity, Improved Bonding with Concrete, Better Resistance to Lateral Forces. Reinforcement details vary based on the specific design and intended application of the profile deck sheet. The choice of materials, depth, spacing, and shape of the reinforcements is determined by the engineering requirements, the expected loads, and the environmental conditions the structure will face. The thickness of the steel sheeting was found to significantly impact the longitudinal shear strength of a composite slab.[5]. The longitudinal shear bond between steel sheeting and concrete affects bearing capacity due to stress-slip behavior. [6, 7]. Two methods for designing composite slabs are using m-k and partial shear.[8, 9]. Numerous researchers tested longitudinal shear resistance under flexural loading using empirical methods and indirectly evaluating the m-k method [10-12]. Embossed sheeting's shear bond characteristic rating uses empirical factors "m" and "k", which represent mechanical interlocking and friction between steel and concrete. The failure load at the end slip of 0.1 mm must surpass the specified criterion for ductile failure of composite floors by more than 10% in order to avoid being categorized as brittle failure [5]. Over the past few decades, broad studies have been carried out on the structural performance of one and two span composite slabs using various concretes and steel sheets (with or without embossments/mechanical connectors) [13-17]. Preliminary cycling loading can cause chemical bonds to fail at the interface between concrete and steel, according to their findings [18].

Composite decks, composed of a combination of materials such as wood fibers, plastics, and additives, have gained popularity for their durability and versatility. Profile sheeting, on the other hand, is recognized for its efficient spanning capability and aesthetic appeal. The composite nature of the deck augments load-bearing capacities, while the profile sheeting adds rigidity and spans efficiently across structural supports. The profiled sheets act as a strong foundation, supporting the weight of the composite decking and any additional loads. The combination of these two materials results in a robust and lightweight structure, making it an attractive option for a wide range of construction applications. Both composite decking and profile sheeting are known for their weather-resistant properties. This makes the composite deck with profile sheeting suitable for various climates, as it can withstand exposure to sunlight, rain, and temperature fluctuations without significant deterioration.

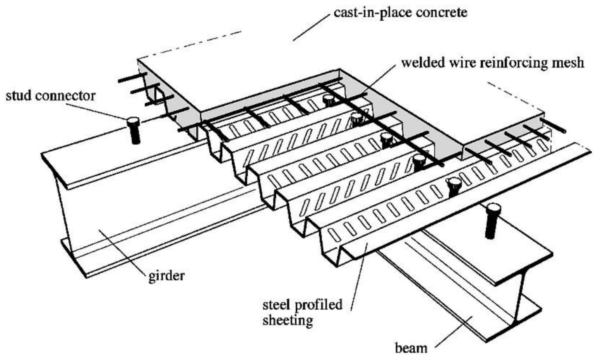

Fig. 1. Composite slab with Profile deck [19]

The composite material allows for a wide range of design options, and the profile sheeting adds an architectural element to the deck. This combination creates a visually appealing outdoor space that can complement various architectural styles. From residential and commercial buildings to bridges and infrastructure projects, the integrated system demonstrates adaptability and versatility. Life cycle assessments and comparisons with traditional construction materials provide insights into the sustainable aspects of the integrated system, contributing to the growing discourse on eco-friendly building practices. The structural advancements, coupled with its sustainable attributes, position this integrated solution as a viable alternative in modern construction practices. In the following sections, we will delve into the construction techniques, material considerations, design principles, and the various parameters which influence behavior and performance of composite slabs[20]. By gaining a comprehensive understanding of these factors, engineers, architects, and construction professionals can make informed decisions regarding the use of concrete composite slabs in their projects, ultimately contributing to safer, more efficient, and sustainable building structures in the contemporary construction landscape.

2 Scope of review

However, aforementioned research projects, nothing is known about how steel concrete composite slabs behave. Specifically, the impact of many factors such as the quantity and inclusion of steel fibers in composite slabs, the surface condition of the steel decking, the presence of mesh or reinforcing bars, the embossed or un-embossed sheets, and the requirement for shear connectors. Further research is necessary to determine the continuous composite slabs ability to support a given load, whether or not they have negative reinforcement over the supports. These are the some basic parameters along with the design codes that have been studied.

3 Structural Components

Composite slabs are made up of two components: a concrete slab and a steel deck that provides support. These components work together to create a structurally efficient and economical flooring system. Here's a breakdown of the key structural components used in composite slabs: Profiled Steel Deck, Stud Connectors, Edge Trim, Permanent Formwork, and Construction Adhesive. These components work together to create a structural system that efficiently utilizes the strength and stiffness of both steel and concrete. Compared to non-composite construction, the composite action between concrete and steel enables greater spans and better load-carrying capability. An innovative design strategy for composite slab behavior prediction has introduced [19]. The "New Simplified Method" combines traditional materials analysis with small-scale testing to create a simple mathematical model that is used to find the moment-curvature connection at a composite slab's critical cross-section. When analyzing critical cross-sections of composite slabs, this method breaks down the observed behavior into three separate stages. This simplifies the calculation of the slabs' ability to bear weight. Knowledge of the geometric dimensions, material properties (concrete and steel), and behavior of the steel-concrete connection are required, derived from experiments on smaller specimens.

3.1 Profile metal sheet

Steel decking serves as the formwork during the construction of the slab and provides support for the wet concrete[21]. The profiled design of the decking enhances the bond between the concrete and steel, creating a composite action [6, 22, 23]. The profiled steel deck may be either trapezoidal or re-entrant, depending on design requirements. The steel used in the deck is usually galvanized to protect against corrosion. Galvanizing enhances the durability of the steel and reduces the need for maintenance. The thickness and depth of the steel deck are important considerations in determining the overall strength and stiffness of the composite slab. These parameters are selected based on structural requirements and construction constraints. There are three major interlocking system in sheets 1) Mechanical interlocking (embossments), frictional interlocking (Dovetail) 2) End anchorage method 3) Types of profile sheets (rectangular, Trapezoidal, re-entrant) [24, 25]. The composite slab incorporates profiled steel decking sheets, which create a strong mechanical bond between steel deck and concretevia an embossed interface. This design aims to prevent both vertical separation and horizontal slippage between the concrete surface and the decking sheet, ensuring secure connectivity and stability between the two materials [3]. The composite system of a steel deck and concrete slab allows for the effective transmission of shear forces from the concrete slab to the steel deck. Vertical detachment between concrete topping and the profiled sheet results from the flexural and horizontal shear stresses generated within the concrete slab. This mechanism allows for efficient load distribution and ensures the structural integrity of the system [26]. Several variables, like the type of decking sheet, the mechanical shear connection type, the height and depth of the embossment constructed on the profiled deck sheet, and many others, influence the shear bond [27]. At the point of maximum strength, shear connectors cause a horizontal slippage between them as a result of the longitudinal shear stress. Accurately predicting the longitudinal shear stress ($\tau u,Rd$) during flexural loading can be difficult, prompting the use of an empirical method to indirectly assess the longitudinal shear resistance of composite slabs under such conditions [28].

Tested 200+ composite slab specimens with intermediate stiffeners, trapezoidal deck, shear studs, and embossment. The results have been compared with design procedures outlined in BS 5950: Part 4, taking into account the composite slab action and composite beam action.

When compared to static loading, specimens with different concrete strengths that are exposed to ten thousand cyclic loading have minimal impact on their ultimate strength. Further, they created three concrete blocks to represent the supports in order to study the behaviour of the deck under drooping and hogging bending moments [29]. They then compared their findings with those of similarly constructed decks that were merely supported by hogging bending alone[12]. Load-carrying capacity dropped by 50% with an embossment height reduction of roughly 30% [2]. Shear behavior of composite slab is complex and depends on shape and thickness [30] of the sheet, type of embossment, shear stiffener, load type, shear span, and thickness of concrete layer. FEM is carried out using ABAQUS 6.13, considering different shear spans and sheet thicknesses. The simulation models are subjected to static loading with a 20 mm mesh size. The thickness of the cold-formed deck profiled sheet enhances the composite slab's shear bond capacity and also helps in reduction of stress by 4-7% and deflection by 2-5% [31]. The de-bonding issue is one of the key problems that frequently arise when concrete and steel are utilized in structural elements.

Several techniques are used to solve this issue, including the use of various stud types, stud arrangement, various embossments, and surface treatments like adhesive and sanding. A study was conducted on the behaviours of a composite deck made of steel and concrete, with profiled sheeting and perfobondrib shear connections, It was figured out that, in comparison to traditional RC deck slabs, the composite deck slabs can support a load that is around 2.5 times greater [12]. Previous studies on composite slabs have highlighted the pivotal role of interfacial shear interaction in determining the ultimate bearing capacity. Strategies such as increasing sheet stiffness and incorporating shear screws can enhance shear bond strength of a composite slab. However, it's worth noting that producing profiled sheets with embossment incurs a higher production cost typically 30–50 percent more compared to sheets without embossment. This investigation presented two innovative types of profiled sheets that incorporate rectangular and V-shaped stiffeners. The impact of sheet thickness on load-carrying capacity was investigated in this study. The study also examined the effect of employing a staggered pattern of shear screws on load capacity, contrasting the outcomes with the effectiveness of end studs that are typically utilized.

Embossments are used in the steel decking of a concrete slab to provide mechanical interlocking between the outer skin of the plate and the concrete core [5, 32]. In reinforced concrete structures, embossments are often used to upturn the bond between the steel reinforcement and the concrete. These embossments can take the form of pressed or rolled indentations that extend into the concrete. Their primary function is to prevent the steel from separating from the concrete and to improve the shear connection between the two materials. The research contrasted decks utilizing horizontal web embossments against those employing vertical ones, revealing a notable 50% rise in shear strength with the vertical embossments. Particularly, the horizontal embossments exhibited limited resistance to shear slip load after the chemical bond between the steel deck and concrete was compromised [15, 28, 33]. Some inferred from this finding that alternating the direction of embossments (outer / inner) could result in a notable improvement in slip resistance. However, a separate study indicated that there wasn't a significant improvement in the bond shear resistance between embossments of different directions compared to unidirectional ones [34].They help to improve the bond strength and composite action of the slab. In deck profile the embossment and wedge effect prevent vertical separation [16, 35]. In the case of a sheet without embossment, a chemical adhesive is used to generate bond between the concrete and the slab. The adhesive chemicals, Araldite-GY257 IN and Aradur-140, are mixed in a 2:1 ratio and applied over the sheet before casting. These chemicals take 24 hours to create a bond between materials [36]. Extensive research has been conducted to analyze how different factors of embossments, including their direction, angle, depth, length, width, and inclination, impact slip resistance. Among these factors, embossment height significantly influences the ultimate load capacity.

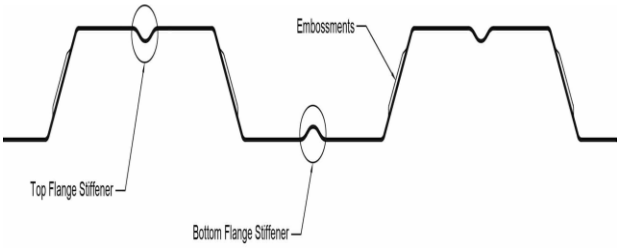

Fig. 2. Deck sheet profile

Stiffeners in profile sheets play a vital role in ensuring structural stability, preventing localized buckling, increasing load-carrying capacity, enhancing lateral stability, reducing deflection, improving composite action, preventing oil canning, and promoting overall durability. These make stiffeners an essential component in the design and construction of profile sheets, especially in applications where structural performance and stability are critical. The load-carrying capacity of composite floor with end stud anchorage has been found to increase by 8% to 33% [37]. They used mechanical shear connectors to improve the strength, stiffness, flexural capacity, and load-carrying ability of composite deck slabs [38-41]. Because of their huge width-to-thickness ratios, the deck slab may collapse, decks collapse mostly due to local buckling so required an complicated stiffeners[18, 42].

3.2 Shear connectors

Shear connectors are devices used to transfer shear forces between two different materials in a composite structure, such as a composite floor[43, 44]. They provide a mechanical connection between layer of and sheets, ensuring that they act together as a single unit to resist loads[45, 46]. Stud shear connectors have three important static behaviors: strength, stiffness, and ductility. Past research has indicated that a number of factors affect shear connections. Principal variables include shank diameter, stud height and tensile strength, compressive strength and elasticity modulus of concrete, and casting orientation of the concrete [47-51]. Shear connectors can be classified into three types: 1) chemical interlocking, which caused by chemical reaction between concrete and sheets, 2) mechanical interlocking, through shear transfer devices like screws, studs[52], and re-entrant edges of sheets, 3) frictional interlocking, achieved by providing embossments and intermediate stiffeners[53]. The examination of the structural performance of stud shear connections in precast deck bridges also requires consideration of the bedding height and the material qualities of the infill material [54, 55].

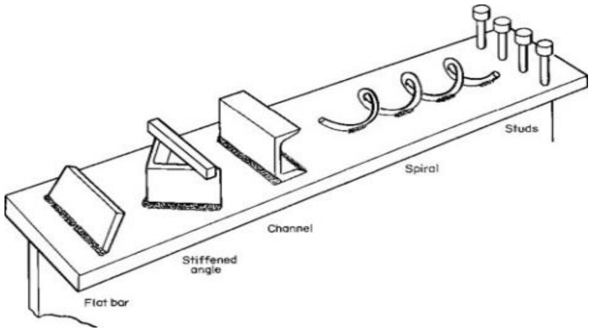

Fig. 3. Types of connectors [43]

These systems enhance the load-bearing capacity and overall performance of composite floors. Examples include flat bars, stiffened angles, channels, and studs (as shown in Figure 3. Shear studs are the most widely used type of connector [53, 56]. Headed stud shear connectors, often utilized in composite bridges at diameters of 19 or 22 mm, stand as the prevalent choice. In high shear zones, numerous studs are welded onto the top flanges to ensure robust shear connection for strength and fatigue resistance. Yet, the extensive use of studs can lead to prolonged welding durations and complicates the removal of concrete slabs, risking damage to both the studs and steel girders. Moreover, densely clustered shear connectors pose safety hazards for construction workers. Therefore, in the case of uniformly distributed shear pockets within precast decks, larger studs present a practical alternative. Research suggests that creating shear pockets with consistent distribution and minimal gaps in precast decks leads to enhanced performance. To ensure precast deck bridges meet strict design standards for strength and fatigue in areas with heightened horizontal shear, using shear connectors with increased capacity will guarantee an even distribution of shear pockets. This is exemplified through details included within each shear pocket. The connectors attach to steel beams that cannot be removed or recycled at the end of the structure's life [57]. The researcher concluded that using cold-formed sections and proper design codes can conservatively estimate the capacity of cold-formed shear connectors.[58].

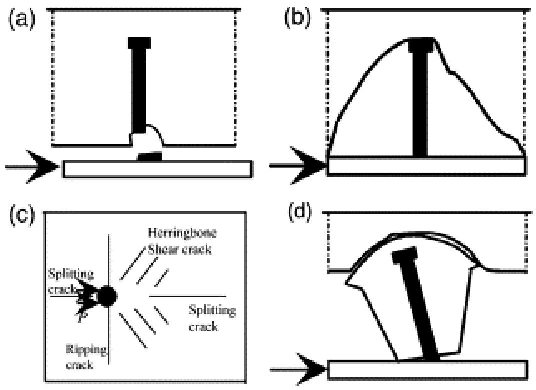

Fig. 4. Modes of failure in stud shear connection [59]

There are Four modes of failure in stud shear connection: 1) Shank failure, 2) embedment failure, 3) slab cracking, 4) shear failure of slab. Figure 2 outlines the various failure modes of stud shear connections, including stud shank failure, embedment failure, splitting failure, and concrete slab shear failure. When using larger studs, preventing concrete slab failure becomes crucial, necessitating adequate provision of transverse reinforcements. Newly conducted research involved static push-out tests on studs of varying sizes: 25mm, 27mm, and 30mm. After conducting these tests, we were able to assess the static strength, ductility, and shear stiffness of the material. This led to the creation of simplified tri-linear load-slip curves. These curves are instrumental in nonlinear analyses of composite beams, specifically addressing partial interaction. Furthermore, the ultimate strengths of the larger bolts were compared with the design equations specified in Eurocode 4, resulting in a comprehensive evaluation [59]. Anchorages at support ends significantly affect floor load capacity, and end anchoring [60, 61] to the successful reduction of the relative end slip of concrete in relation to a deck sheet. [42]. Numerous shear connector types that have been proposed thus far have proven to be expensive and given that there is minimal data regarding their capacity and performance in literature [58, 62]. They examined the impact of the shear connection's nonlinearity in composite beams using a finite element method and results demonstrated that the nonlinearity of the shear connection causes a notable increase in deformation of steel-concrete composite beams [63].

Bolted connections' mechanical performance is affected most by the diameter, bolt strength, and concrete compressive strength. This work compared the findings of practical tests with numerical modelling to offer many equations for calculating the shear resistance of bolted connections [64]. Shear failures at supports in deck slabs can occur due to various factors, leading to compromised structural integrity. Shear bond failure in a deck slab refers to the loss of adhesion or bond between different layers or materials within the slab, typically between the concrete slab and other materials like steel reinforcement or additional layers of concrete or composite materials. By using a nonlinear mixed FEM model to study the about continuous composite beams with discontinuous shear connections. The areas at hogging moment where crack occurs were of particular interest to the researchers [65]. They used 3D FEM to determine shear effect on composite floor systems by reducing ultimate strength and initial stiffness [66]. The literature lacks information on the interactions between steel profiled sheeting and the concrete slab, particularly in FEM studies[67]. Study showed bolted shear connectors for composite beams behaved like standard headed-stud shear connectors. In other places, bolted shear connections in composite beams with steel decks have been numerically modelled [68]. Also these connections were found to have a higher shear capacity and ductility than headed-stud shear connectors [69]. The research conducted an extensive experiment on anchor bolts that were exposed to tension and shear. The study specifically focused on anchor bolts that did not have a nut inserted. The study involved varying the anchor bolt diametre (19 and 25 mm), embedment length (76, 127, and 178 mm), and also the concrete strength (20.7 and 34.5 MPa) for the shear strength tests. The study revealed that these anchors provide 80% of the shear resistance found in welded headed studs, but only 15% of their shear stiffness [70].

Table 1. Summary of composite slabs

Author	Size of specimen (l x b x d) mm	Varying parameters	Result
Aarthi et al.,[45]	2200 x 900 x 150	Thickness of sheet = 1mm Embossments radius = 5mm	Bond between concrete and steel deck: 1) adhesive mortar bond 2) mechanical interlock - embossments. 3) localized connections - end anchorages.
Ahmed etal., [41]	1200 x 750 x 90	Thickness of sheet = 1mm Corrugated profiles = 60 x 45 mm Stud connectors (6mm dia) Mesh = 6mm@230mm c/c	Short shear span tests exhibited higher ductile behavior. The enhancement in ductility in the short shear span test estimated around 74%. Interestingly, long shear span specimens demonstrated less deterioration in bond slip compared to short shear span.
Cifuentes et al., [5]	2600 x 927 x 140	Thickness of sheet = 0.8, 1, 1.2 mm	Thickness of deck sheet is an important parameter for shear strength. Without crack inducers the longitudinal shear is more – long span slabs. The cyclic loading does not affect load carrying capacity of slabs.
Gilbert et al., [27]	3650 X 1200 X 150	Thickness of sheet = 0.75 mm Type of profiles = Re-entrant, trapezoidal	The ultimate shear stress is greater at L/6 span compared to L/4 span. The flexural capacity is controlled by slip at concrete.
Hedaoo et al., [18]	2700 x 830 x 102	Thickness of sheet = 0.8 mm Shear span = 300, 375, 450,525 600, 675 mm	An increase in shear span length led to a decrease in longitudinal shear stress within the slab. Design calculations for longitudinal shear stress in slabs using line loads and the m-k method yielded slightly higher values compared to those obtained using the PSC method.
Chen et al., [29]	2500 x 920 x 135	Thickness of sheet = 0.9 mm Shear studs = 19 mm dia	Shear bond failure – 1) bottom crack 2) shear bond slip 3) Deck fails. The shear bond stress of shear span supports the bond strength of deck slab
Manjunath et al., [36}	1500 x 1000 x 85 mm	Thickness of sheet = 1 mm	Totally 25% of concrete volume can be reduced by using steel deck. The

	Embossment – both with and without Mesh = 3mm @ 38.1 mm c/c	load carrying capacity is 14% more compared to slab with embossments. The stud provide extra strength and ductility.

3.3 Reinforcement / Mesh

Reinforcement in profile sheeting serves several crucial purposes. It provides structural support and strength to the sheets, enhancing their load-bearing capacity and resistance against various forces like wind, snow, and impact. This reinforcement helps prevent deformation or damage to the sheets, ensuring durability and longevity in their use. Additionally, reinforcement can also offer stability and rigidity, maintaining the integrity of the structure where these sheets are applied. Overall, reinforcement in profile sheeting is essential for maintaining structural integrity, increasing resilience, and extending the lifespan of the sheets in diverse environmental conditions. According to studies conducted for a single specified length, researchers [71, 72] show that reinforcing bars enhance the flexural capacity without interfering with the resistance to horizontal shear-bond. The most effective method to enhance a composite slab's flexural capacity is to add shear connections and reinforcing bar to the bottom of the concrete topping. The extra reinforcing bar may prolong the composite slab's sudden failure following the concrete topping's flexural cracking [71]. Profile deck sheet slabs can be reinforced or unreinforced, each with distinct advantages. Reinforced profile deck sheet slabs typically incorporate reinforcement bars or mesh within the concrete, enhancing their load-bearing capacity, durability, and resistance to various forces. These reinforcements help distribute loads, prevent cracking, and improve the structural integrity of the slab, making them suitable for heavier loads and harsher environments. On the other hand, unreinforced profile deck sheet slabs lack these added reinforcements, making them more suitable for lighter loads and less demanding applications. They might be cost-effective for projects where heavy loads aren't a concern, but they might be more prone to cracking and have limited durability compared to reinforced slabs. Choosing between reinforced and unreinforced profile deck sheet slabs depends on the specific requirements of the project, considering factors like load capacity, durability, and cost-effectiveness.

4 Fiber Reniforced Concrete (FRC)

Reinforcement is essential for the widespread use of concrete in construction. Its limited strain capacity and low tensile strength make it inherently brittle. Typically, this reinforcement involves strategically integrating continuous steel bars within the concrete structure to withstand imposed tensile and shear stresses. However, an alternative approach involves the use of fibers. Fiber-reinforced concrete (FRC) is created by adding short, randomly dispersed fibers to concrete. They can be sourced from materials like steel, glass, polymers, or natural sources. Fiber-reinforced concrete differs from traditional reinforcing steel bars by offering enhanced crack control, especially when fibers are closely spaced within the mixture. It's essential to understand that using fibers as concrete reinforcement doesn't replace the role of conventional steel bars. Instead, both fibers and steel bars play distinct yet complementary roles in advancing concrete technology. Their combined use proves beneficial in various construction applications, showcasing their unique contributions in different scenarios.

4.1 Types Of Fiber Reniforced concrete

Fibers can be classified based on their modulus of elasticity or their source. When considering their modulus of elasticity, fibers are divided into two primary groups: hard intrusion (high modulus than concrete) and soft intrusion (low modulus than concrete). Materials like steel, carbon, and glass fall into the hard intrusion category due to their higher elastic modulus compared to the cement mortar matrix. Conversely, fibers like polypropylene and certain vegetable-based fibers have a lower elastic modulus than the concrete mix, placing them in the group of low elastic modulus fibers. High modulus fibers possess the ability to enhance both flexural and impact resistance concurrently, making them a valuable material option. On the other hand, low elastic modulus fibers primarily enhance the impact resistance of concrete and have less effect on its flexural strength. Fibers are categorized into three primary groups depending on their source: metallic fibers, mineral fibers, and organic fibers. Within organic fibers, there are two subcategories: natural and synthetic. Natural fibers encompass those derived from plants and animals. Synthetic fibers are further divided into natural polymer fibers and artificial fibers .

Among all the fibers, SF stands out as the predominant choice among fibers utilized for reinforcing concrete. Originally incorporated to mitigate plastic and drying shrinkage in concrete, SFs have evolved significantly through ongoing research and development. It has been discovered that the inclusion of SFs in concrete brings about substantial enhancements across various aspects. The addition of SFs to concrete yields remarkable improvements in several key areas. These include a notable increase in flexural toughness, a heightened capacity for energy absorption, the promotion of ductile behavior leading up to ultimate failure, a reduction in cracking, and an overall enhancement in durability [74]. This paper delves into a comprehensive review of the effects stemming from the introduction of SFs into concrete. Furthermore, it investigates the resulting mechanical properties and explores the various applications of Steel Fiber Reinforced Concrete.

4.2 Steel Fibers

In 1910, Porter introduced the concept of using Steel fibers in concrete [75]. Yet, the inaugural scientific research on Fiber Reinforced Concrete in the US dates back to 1963 [76]. SFRC is a vital building material made up of hydraulic cement, fine and coarse aggregates, water, and sand. As per the ACI 544.IR, 1996, SFs are defined as discrete, short steel lengths with an aspect ratio ranging from 20 to 100 [77, 78]. Typically measured in terms of length, diameter, and aspect ratio, these fibers are dispersed throughout the concrete mix to improve its tensile strength, toughness, and durability. The addition of steel fibers helps to control cracking, increase resistance to fire[79], impact and fatigue, and enhance the overall structural integrity of the material [80, 81]. This reinforcement method is commonly used in construction applications such as pavements, industrial floors, and precast elements, offering a cost-effective and efficient way to improve the performance of concrete structures [78]. These fibers come in various cross-sections small enough to be easily dispersed randomly within fresh concrete through standard mixing techniques. To improve the workability and stability of SFRC, chemical admixtures like superplasticizers can be added to the concrete mix. The engineering requirements of SFs, including their shape, material, length, diameter, and cross-sectional type, are specified in ACI 544.

The behavior of SFRC can be categorized based on its application, the percentage of fiber volume, and its effectiveness. Concerning the fiber volume percentage, three distinct categories are identified

- In the past, a small amount of SF, typically less than one percent per volume of concrete, was utilized to prevent plastic shrinkage and strengthen pavements.
- Moderate SF volume fraction (1-2% per concrete volume) improves MOR, flexural toughness, and impact resistance.
- Specialized applications like impact and blast-resistant structures may require a high volume fraction of SFs (>2% per volume of concrete) such as Slurry Infiltrated Fiber Concrete and Slurry Infiltrated Mat Concrete.

At times, steel fibers (SFs) function as supplementary reinforcement alongside traditional steel bars or pre-stressing strands, acting as primary reinforcement. Yet, within the high volume fraction group—where SFs exceed 2% of the concrete's volume—these fibers exhibit remarkable mechanical traits, potentially obviating the necessity for continuous reinforcement. Nonetheless, their application remains specialized due to processing constraints and elevated costs.

To determine whether steel fibers can be used in composite slab construction in place of wire mesh, concluded that additional study was still needed before using steel fibers instead of steel mesh in negative moment zones [82, 83]. The findings show that adding more than 20 kg/m3 of steel fibers offers notable benefits in terms of peak load and the load at which slide between the steel decking and concrete occurs. It also provides excellent crack control at service loads [84]. The use of steel fibers with a fiber volume of 30 to 60 kg/m3 increases the punching shear resistance of slabs by 9 to 39.8% [85]. Addition of steel fires increases the ductility, improve abrasion, flexural strength, impact resistance, high flexural and fatigue flexural with durability and also increases the strength and toughness as compared to plain concrete [86, 87]. This experiment revealed that the inclusion of steel fibers resulted in an enhancement of both compressive and tensile strength [88]. The mechanical characteristics of concrete were examined with and without 'hooked' steel fibers. As the fiber dosage rate increased, the concrete's workability considerably decreased [89].

4.3 Types of Steel fibres

Some various types of steel fibers used in concrete reinforcement, each with its own specific characteristics. The choice of steel fiber type depends on the intended application and the desired properties of the reinforced concrete. Here are some common types of steel fibers:

- Hooked-End Steel Fibers - These fibers have a hooked end, providing mechanical anchorage within the concrete, used in crack resistance and ductility.
- Straight Steel Fibers - Straight steel fibers are uniform in shape, used in rack control and tensile strength are the primary concerns.
- Deformed Steel Fibers - They have surface irregularities, enhancing bonding with the concrete matrix, used to improve bond strength and crack resistance.

- Crimped Steel Fibers - Crimped fibers have a wavy or zigzag shape, providing increased interlocking with the concrete, used to enhance the toughness and impact resistance.

The selection of the appropriate steel fiber type depends on factors such as the specific requirements of the project, the characteristics of the concrete mix, and the expected performance of the reinforced structure.

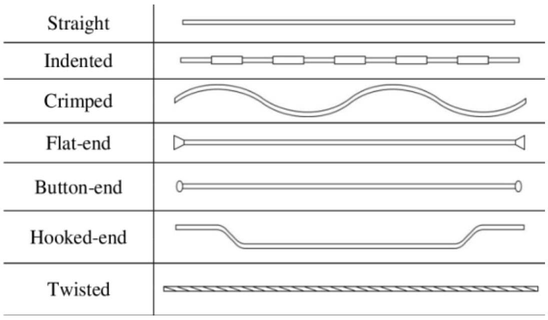

Fig. 5. Types of steel fibres

It's important to note that the specific benefits achieved by adding steel fibers depend on factors such as the type of fibers used, their length and aspect ratio, the concrete mix design, and the overall design and also construction of the composite slabs. The incorporation of steel fibers is a common practice in construction to optimize the performance of composite structures, particularly in applications where enhanced strength, crack control, and durability are essential.

5 Modes Of Failure

Deck slabs, commonly used in bridge construction or multi-story buildings, can experience various modes of failure: The three basic modes of failure in slabs are 1) Flexure 2) Shear at support 3) Shear bond mode [90, 91]. In terms of material, boundary conditions, and geometric shapes, the shear bond between concrete and deck sheet in composite slabs is a highly nonlinear issue. The composite slab's profiled sheet, end anchoring, embossments, and intermediate stiffeners all contribute to its resistance to shear bond. Cold formed deck profiled sheet in the right shape provides resistance against both horizontal slip and vertical separation[16, 27]. If the load placed on the composite slab is greater than its tensile strength, cracks will appear. The load is first transferred to the concrete [92]. Shear bond failure will occur if critical loading has been reached. Figures 6 (a) and (b) depict various composite slab failures [10, 15].

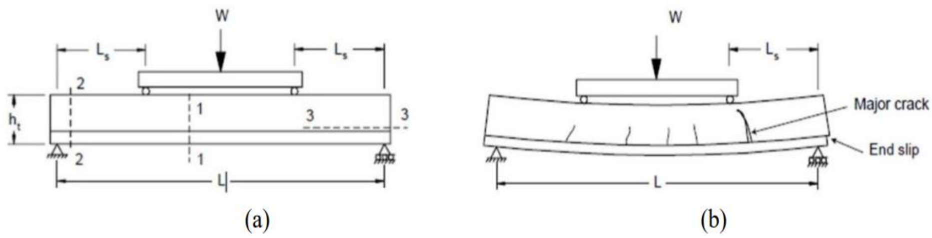

Fig. 6. Different failure modes in slabs [10]

Flexural strength quantifies a beam's or slab's capacity to withstand bending moments before failing, and it is a representation of concrete's tensile strength [93]. Examining the flexural load capacity of RC slabs, a straightforward technique for determining slab strength based on recognised in-plane forces was created [94]. Meanwhile, some discussed conventional methods, such as theoretical approaches and approximate deflection analyses, along with the development of a method termed frame analysis [95]. The Eurocode 4 standard utilizes the "partial connection" or "m-k" method to determine the flexural strength of composite slabs. Comparisons are drawn between three-point and four-point loading scenarios [96]. A three-point flexural test measures the slab's maximum strength, whereas a four-point loading test distributes this maximum strength among the loading points. Four-point loading tests are more favorable for non-uniform materials like composites and wood, while three-point tests are better suited for homogeneous materials like plastics. The loading concentration differs: in a 3-point test, the load is focused at the center of the loading point, while a 4-point test spreads the load over a larger area, reducing the likelihood of early failure [97]. To measure deflection, a digital encoder is employed in the 3-point test, whereas a deflectometer is commonly used in the 4-point test [98]. Eurocode 1994-1-1 recommends specific design procedures for new sheeting, including the partial connection method and the m and k approaches. It is anticipated that the latter will fail in longitudinal shear. Furthermore, partial connection technique design is recommended for slabs displaying ductile shear behaviour. Scaled-down specimen testing may be divided into two main groups. In the first, extra restricting pressures are needed to preserve specimen balance in settings similar to Daniels' and Patrick's push-out experiments. The second group includes configurations such as Porter's and Stark's tests, which do not require these extra forces to be applied during testing [99].

Shear failures at supports in deck slabs can occur due to various factors, leading to compromised structural integrity. These failures are often observed near columns or supports and can manifest in several ways: Punching Shear: Concentrated loads or high shear forces at the support regions can cause punching shear failures. This failure mode involves the slab failing around the column or support due to insufficient shear capacity. It leads to the formation of diagonal cracks originating from the support and propagating outward [100]. Insufficient Shear Reinforcement: Inadequate or poorly distributed shear reinforcement around the support regions can lead to shear failures [101]. Lack of proper reinforcement to resist the shear forces results in cracking and potential failure at these critical points. Improper Design: Flaws in the structural design, such as underestimating the shear forces or using inadequate concrete strength, can contribute to shear failures at supports. Excessive Loads: Applying loads that exceed the designed capacity of the deck slab at its supports can lead to shear failures. Increased loads or unexpected loads due to changes in use can result in shear stresses surpassing the slab's capacity. Deck slabs with size and shear span-depth ratios that are typical for bridge applications undergo vertical shear. Shear and flexure work together to cause this failure, which can occur brittle and without prior notice [4, 102].

Shear bond failure in a deck slab refers to the loss of adhesion or bond between different layers or materials within the slab, typically between the concrete slab and other materials like steel reinforcement or additional layers of concrete or composite materials. Several factors can contribute to shear bond failure: Poor Surface Preparation, Inadequate Bonding Agents or Adhesives, Improper Curing or Setting, environmental or thermal factors, and material incompatibilities. Bending test parameters are the basis for shear bond techniques including the PSC method and the m-k method [103]. Predicting shear bond between profiled steel sheet and concrete is challenging due to various factors, including the sheet's geometry and flexibility. This bond depends on multiple interconnected parameters, making theoretical prediction difficult [32]. Insufficient shear connection between the steel and concrete can result in brittle failures and decreased durability since traditional concrete is brittle and profiled steel is ductile. Consequently, there's a need for further research to develop advanced composite flooring systems using profiled sheets, ensuring higher performance and durability.

Table 2. Influencing Parameters and modes of failure

Mode of failure			Influencing Parameters
Composite slab	Shear strength of concrete	Diagonal crack due to tension Deck's corrugations parallel	Concrete thickness and compressive strength.
	Failure in stability		Concrete thickness
Shear transfer (Deck-concrete)	Corrugations Parallel Transverse	Interfacial slip	Edge member connections type, Embossments height and slope
		Shear in concrete, Rib	Compressive strength
Connections of Edge member	Spot welding	Weld	Welding procedure, Diameter , thickness ratio of plate to deck
		Sheet tearing and buckling Sheet shearing buckling the weld	Thickness of the deck and welding diameter, position in trough
	Shear studs	Stud failure Concrete cone failure	Diameter and height of stud Compressive strength
		Edge strip of carbel	Stud configuration, compressive strength of concrete

6 Conclusion

The comprehensive review on the behavior of steel-concrete composite slab by varying different parameters underscores the intricate interplay of factors influencing the structural performance of these composite systems. The examination of various parameters, including but not limited to steel types, concrete mix designs, fiber reinforcements, and construction methodologies, provides valuable insights into optimizing the behavior and functionality of composite slabs. The reviewed literature consistently highlights the positive impact of steel reinforcement, particularly steel fibers, on the composite slabs.

- Using profiled deck sheets results in a 25% volume reduction in concrete, the usage of embossed profiled sheet enhanced the connection between the sheet and concrete.
- The longitudinal shear strength of composite slabs was shown to be significantly influenced by the steel sheet's thickness.
- The headed shear connection performed better than the bolted shear connector. Consequently, headed shear connectors can be utilized in the production of composite slabs.
- The addition of steel fibers contributes to enhanced flexural strength, crack control, and overall durability. Furthermore, varying parameters such as fiber type, length, and aspect ratio showcase the nuanced effects on the structural response, allowing for a tailored approach to meet specific project requirements.
- It is discovered that the steel fibre reinforced concrete is equal to the steel reinforced concrete in the simply supported composite slabs.
- The m-k approach or the partial interaction method can be used to build composite slabs according to European code, while the British standard alone uses the m-k method, then codal measures are grounded on investigational research and involve finite element analysis of a composite deck slab with nonlinear interactions among the concrete, shear connectors, and profile deck.

Since in this paper we discussed various parameters that helps to increase the overall behavior of the slab by offering a roadmap for future research and innovation in the field, and also encouraging the development of more efficient and sustainable composite construction practices.

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