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Composite Beam Under Different Monotonic and Dynamic Loading: A Review

Ayad Hasan Jawad*, Hesham A. Numan

Civil Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

*Email: *ayaidhasan@uomustansiriyah.edu.iq*

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Abstract

In the modern world, composite construction is widely used due to its exceptional properties in reducing the structure's weight and carrying load. This paper reviews some researchers' earlier investigations in the past two decades. To understand the behavior of composite beams, the effect of various load applications, and the beam behavior's response to changes of shear connector type and some types of concrete and materials such as Glass Fiber Reinforced Polymer (GFRP) and display some methods for strengthening the beam. Monotonic and dynamic loads were considered based on experimental, numerical in addition to experimental and numerical studies together carried out by the researchers, as well as statistical data collected and analyzed. The results obtained based on the reviewed articles are that the use of an angle shear connector reduces the ultimate strength by 4.12% for single angle connectors compared to headed stud connectors, pultrude Glass Fiber Reinforced Polymer GFRP composite beam has approximately 50% higher ultimate capacity and less weight compared to an equivalent RC beam, stiffeners are an effective method to strengthen the composite beam against different load circumstances. Statistics revealed that the interconnection ratio is an important factor for the composite beam behavior.

Keywords: Composite beam; monotonic load; Dynamic Load; Statistical Analysis; Shear Connectors

1. Introduction

Composite constructions are widely used in various applications in different countries ,such as bridges, and buildings. The basic idea of using composite structures or materials is that each material has its unique properties or usage, so combining two or more materials is necessary to get the full benefits of all the materials used. For example, concrete has good compressive strength, but it is weak in tension, so steel is used to improve the tensile strength, forming reinforced concrete; later, in the early 1900s, the use of steel sections such as I-section or H-section along with concrete to form composite sections in its known form shown in Fig. 1 has become popular [1]-[3]. Fig. 1 shows that the composite section consists of a concrete deck on a steel section connected by shear connectors. The composite beam concept combines different materials, but the steel-concrete composite is the most commonly used [4],[5].

1.1 Advantages and disadvantages of composite beam

The composite section primarily aims to get a higher span-to-depth ratio and other advantages, including greater stiffness, load capacity, and collapse capacity. It is generally smaller than other designs that may be considered for the same load intensity. This leads to less material usage, weight, and depth of the member than non-composite members.

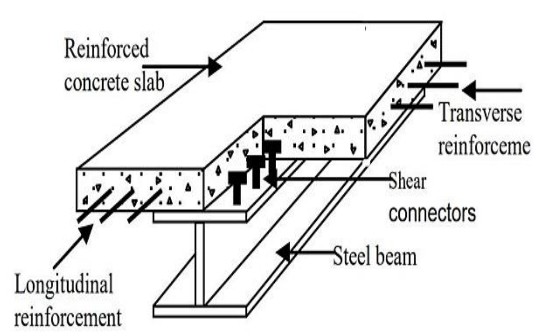

Figure 1. Typical Composite beam section [4]

Composite sections also have disadvantages; one obvious disadvantage is the need to provide shear connectors, the necessary effort involved, and the slightly difficult design of individual elements [5]-[10].

12 Composite beam interconnections

The steel section may be linked to the concrete slab using shear connectors. As illustrated in Fig. 2, many types of shear connectors are used in different composite constructions. The shear connectors facilitate the interaction between steel and concrete by preventing slip and uplift. The slip is the horizontal shear in this link between steel and concrete and may be either full or partial. Full and partial shear connections refer to the strength of the longitudinal shear connection. On the other hand, if the shear connectors successfully avert the slide, then the steel and concrete connection is said to interact fully; otherwise, the connection is said to interact partially. Fig. 3 shows the behavior of a composite beam with different degrees of interconnection and their stress distribution. However, even for full interaction and when there is a large number of connectors in the composite structures, a significant slip occurs between the layers; this can be attributed to the flexibility of the connectors and the fact that most shear connectors have to undergo some deformation before they can sustain any load. [6], [11]-[15]. This article represents the previous works on composite beams with some types of shear connectors subjected to different loading conditions; it is divided into two main parts (monotonic load and dynamic load), and each part is divided into (experimental investigations, numerical investigations, and numerical and experimental investigations together). The primary objective of this article is to answer common questions addressed in the subject about the real behavior of composite beams under different types of loading and open the field for future studies.

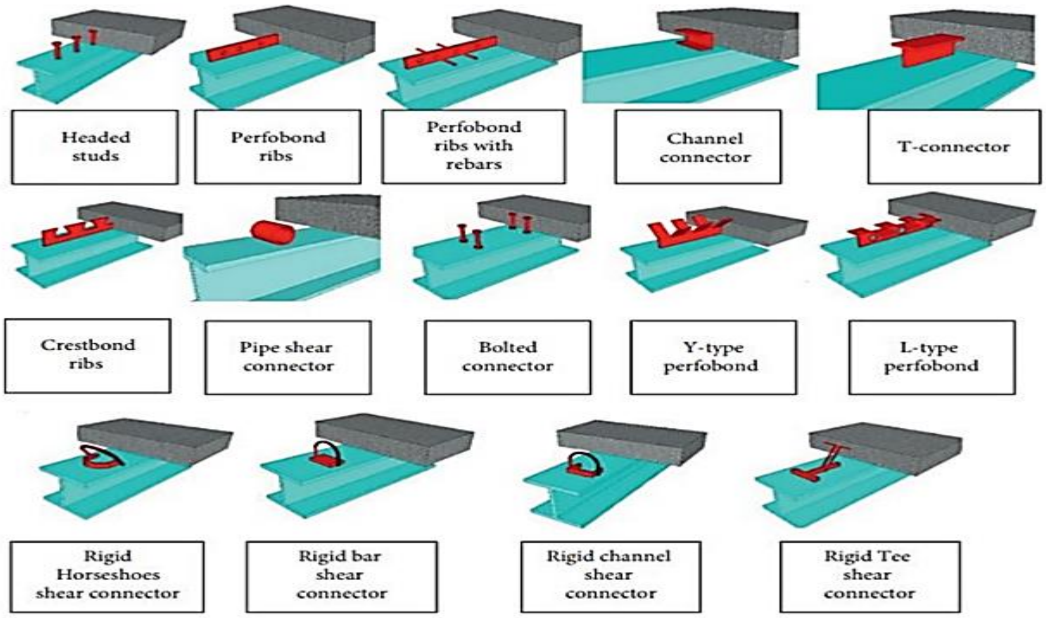

Figure 2. Types of shear connectors [11]

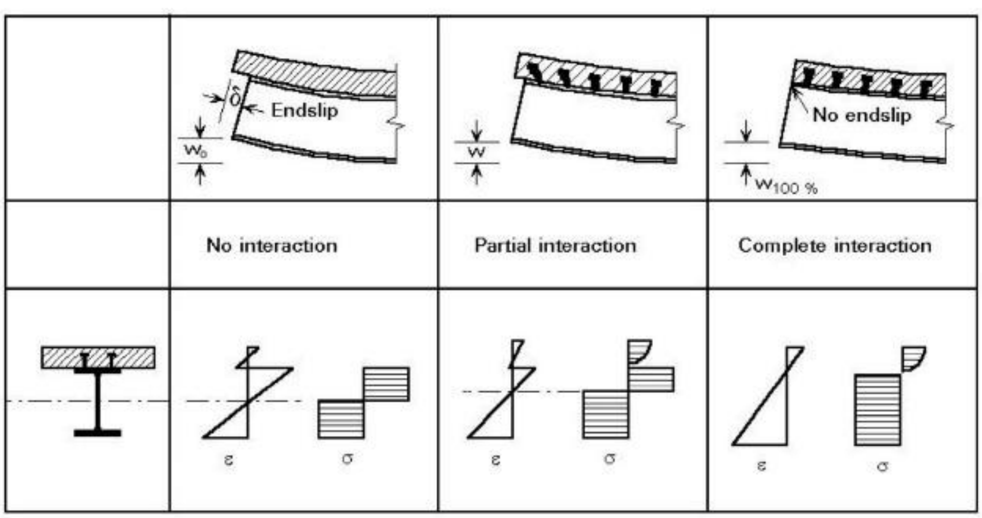

Figure 3. Different degrees of interactions and stress distribution [16]

2. Monotonic load

A monotonic load is a loading that does not change with time and has no movement. It can be exerted slowly on a member or structure during specimen testing [17].

2.1 Experimental investigations

The long-term behavior of supported composite beams was studied by Fan et al. [18] under the effect of positive and negative bending moments (over three years). The research yielded that under the positive bending moment action, the mid-span deflection was 2.5 times greater than its initial value, plus concrete cracks due to concrete shrinkage in the negative bending moment were propagated, causing a huge increase in deflection. Hsu et al. [19] proposed and examined a new composite beam and floor system under flexural bending. Fig. 4 shows the geometry of some specimens and that the system consisted of three components. A corrugated cold-formed metal deck supports a concrete slab; steel joists run back-to-back, and a continuous cold-formed furring shear connection. The authors found that the ductility and ultimate strength of the proposed composite section can be increased by fifty-six to eighty percent and fourteen to thirty-eight percent, respectively, compared to a built-up or non-composite section during the test. Neagoe et al. [20] investigated the structural behavior of a pultruded Glass Fiber fiber-reinforced polymer (GFRP) composite beam under a joyous bending moment in a bending test configuration. They considered the effect of partial interaction. Three failure modes shown in Fig.5 were noticed during the tests. This research concluded that the GFRP composite beam is structurally active with high flexural potential to the self-weight ratio and approximately 50% higher ultimate capacity and less weight than an equivalent Reinforced Concrete (RC) beam. Also, due to the web-flange junction forming a transition area where the internal microstructure of the composite shape changes, rupture at this point was the most common cause of failure for GFRP profiles. The behavior of two tilted angle shear connectors under monotonic loading investigated by Khorramian et al. [21], 112.5 and 135 degrees on inclining between the leg of angle and the steel beam was considered. They disclosed that the inclined angle connector with 112.5 degrees has less strength and stiffness than the inclined angle with 135 degrees. Nine concrete-cellular steel beams were analyzed for their structural behavior and studied by Oukaili and Abdullah [22]. The beams were examined under the effect of combined flexural and torsion up to failure. Both strengthening by external prestressing and intermediate stiffeners and strengthening only via intermediate stiffeners were offered as potential strategies. The authors found that adding vertical stiffeners at all web posts raises the ultimate capacity by 4.44%, 33.3%, and 21.8% for specimens under pure torsion, specimens subjected to combined flexure and torsion, and specimens exposed to pure bending, respectively.

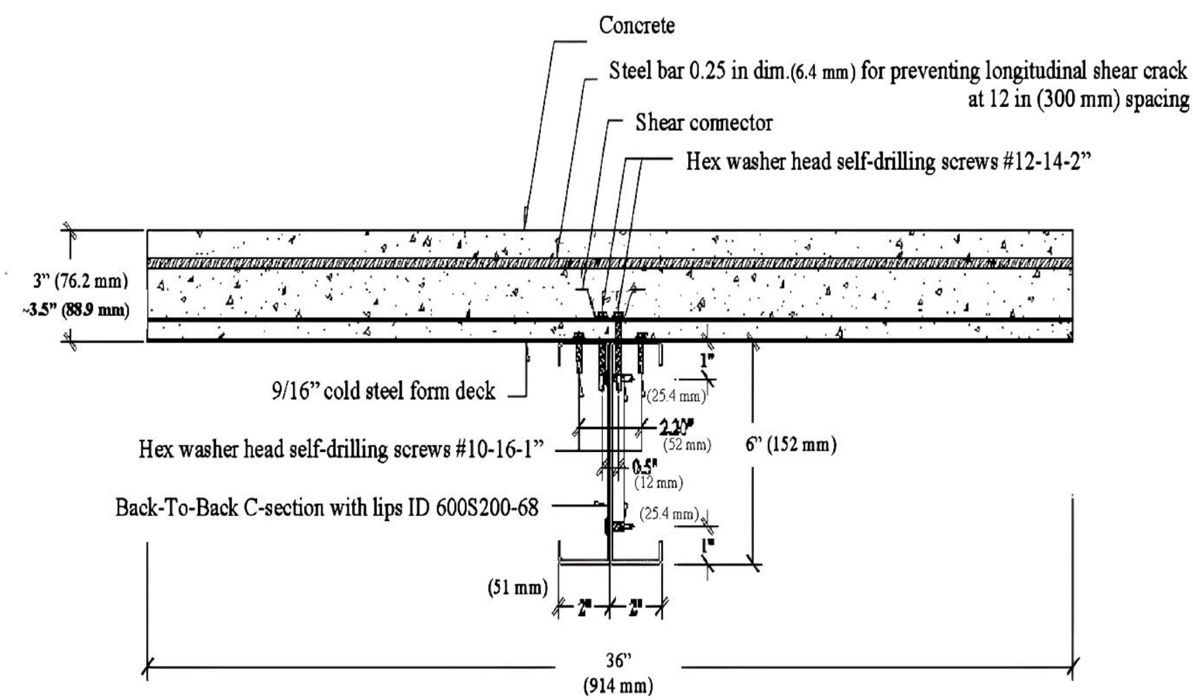

Figure 4. Details of the composite section used [19]

Figure 5. Failure modes of hybrid beams: (a) profile web-flange shear preceded by crushing of the concrete slab; (b) crushing of the profile's web; (c) profile web-flange shear [20]

Vertical stiffeners and external prestressing increased the ultimate load capacity by 134.3% for pure bending, 116.6% for combined torsion and bending, and 4.88% for specimens under pure torsion. The flexural behavior of the composite beam encased in concrete pultruded I-beam and GFRP bars reinforcement was investigated by Hadi and Yuan [23], placement of the I-beam was also taken into account (in the middle, and a shift of 30 mm into the tension zone). The author concluded that the use of GFRP bars leads to an increase in the slip between the I-section and concrete, and the change in the location of the I-section has a negligible effect on the flexural response. Some researchers, such as Majeed [24], investigated the behavior of composite beams with lightweight concrete slabs and different degrees of interaction under monotonic load. The results showed no crucial difference in failure modes when lightweight concrete is compared to normal concrete, in addition to initial stiffness and ultimate strength decreasing when lightweight concrete is used for different degrees of shear connection. Composite beams exposed to hostile bending forces with corroded shear connections were tested for their monotonic and fatigue behavior by Chen et al. [25]. As shown in Fig. 6, shear connectors accelerated corrosion by sinking the beam in sodium chloride solution with a concentration of 5% and electric current with an approximate density of 200 $\mu A/cm^2$. The researcher concluded monotonic loading caused local buckling failure in the specimens, while fatigue loading caused stud shear fracture and crack initiation and propagation in the steel beam; shear connectors have an important role in beam stiffness and load-carrying capacity. Also, fatigue life decreased by 9.69% as the corrosion rate increased.

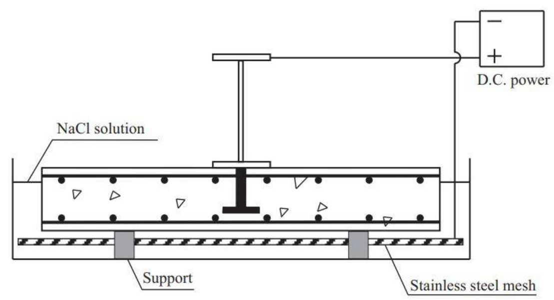

Figure 6. Accelerated corrosion setup [25]

The behavior of C and L-shaped connectors was investigated by Shariati et al. [26]. The authors concluded that C-shaped shear connectors have more shear strength than L-shaped connectors. In addition, the shear strength increases in C-shaped connectors as the angle leg size is decreased, but decreasing the leg size in L-shaped connectors reduces the strength and ductility. Other researchers, such as Lin [27], studied the mechanical behavior of the composite beam when subjected to a negative bending moment and torsional forces of varying ratios. The research was conducted to determine the connection between load and deflection, the strain development on shear studs and the leading steel girder, and the amount of slip at the interface. The researcher predicted that the yield and ultimate loads would drop and bending moment capacities would decrease due to torsion. Fig.7 shows the results of the interface slip for two specimens under applied loading and side elevation of specimens, in addition to the slip measuring location. According to the author, the numberace slide close to the 1/4 span was much larger than at either end.

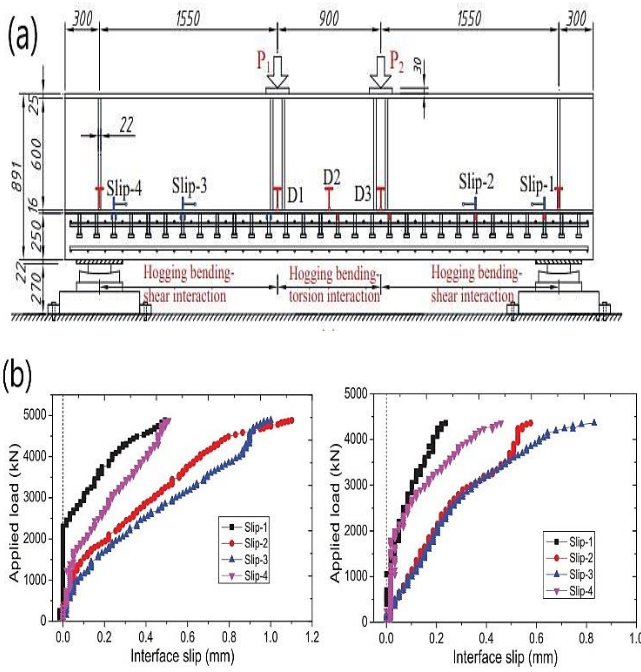

Figure 7. (a) specimen side elevation (b)Applied load-slip relationships on the steel-concrete interface [27]

2.2 Numerical investigations

The numerical investigation is the work that depends on the finite element (FE) method and is generally used to obtain or predict specific results or behaviors. Analysis of the mechanical performance and failure mechanism of a steel-concrete composite beam was performed by Zhao and Li [28] using the FE approach and software ABAQUS to create a comprehensive three-dimensional (3D) model. Numerical predictions were compared with earlier experimental data to determine the correctness of the numerical model in Fig. 8. The author concluded that there are three major causes for composite beam failure. The failure modes include concrete cracking under tension, concrete crushing under compression, and severe yielding of the steel beam under bending.

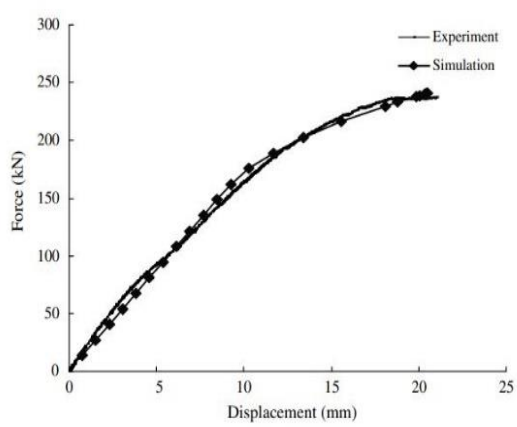

Figure 8. Numerical data calibration with previous experimental data [23]

Chen and Jia [29] researched the inelastic buckling of external tendons prestressed composite beams under negative bending moment based on (FE) analysis using the software ABAQUS. In light of the original geometric constraints and the resulting residual stress patterns, as shown in Fig .9(a) geometric imperfections in the steel bottom flange used in the study have an amplitude of no more than 1/1000 of the length of the steel beam, or no more than 5 mm, respectively; residual stress patterns for the rolled steel and the welded plated steel sections, as shown in Fig. 9(b) and Fig. 9(c), are also introduced in the nonlinear buckling analysis of the composite beams; as shown in Fig. 9. The author disclosed that as the force ratio increased the beam fracture moments are also increased and the buckling moment the imperfection reduces strength.

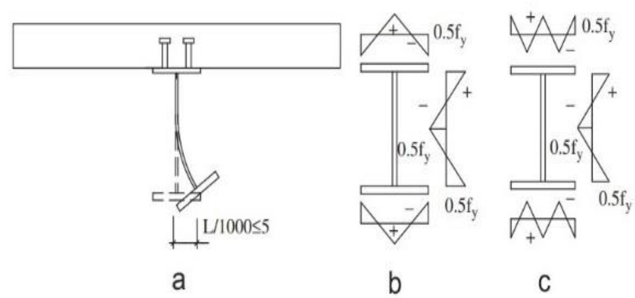

Figure 9. Initial imperfection and residual stress patterns of steel cross-section: (a) initial imperfection; (b) residual stress: rolled section; and (c) residual stress: welded plate section [24]

Lin and Yoda studied the combined hooping and torsional moment on curved composite beams and the influence of curvature on the elastic and inelastic response of the beams [30]. The geometry of the beam is illustrated in Fig. 10. Based on the author's prior experimental findings of the straight composite beam, the author used the FE approach and found that the initial cracking load, the yield load, and the ultimate load under negative moment all drop linearly with increasing curvature. As the curvature increases, it is discovered that the failure modes shift from bending failure to torsional failure. Yan et al. [31] investigated the strength behavior of steel-elastic concrete composite, and the nonlinear mechanical properties were considered. Deflection behavior and failure mode were studied to investigate the rubber content effect. Steel-elastic concrete composite beams' ultimate resistances and load-deflection behavior were unaffected by the addition of rubber at concentrations up to 15%. Also, increasing the yield strength leads to increments in the ultimate resistances. Therefore, strengthening steel-elastic concrete composite I-beams with high-strength steel may be cost-effective and efficient for increasing their ultimate strength.

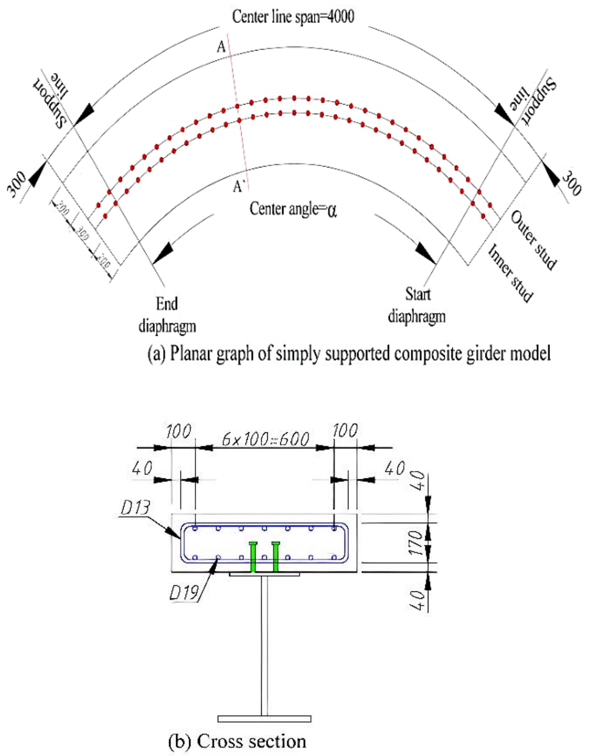

Figure 10. details of curved steel-concrete composite beam's shape [30]

A comparative study between available numerical and analytical models was presented by Kalibhat and Upadhyay [14]. The main objective was to obtain the significance of the partial interaction concerning the full composite action. The scholars concluded that the deflection increased by approximately 8% for the 0.6 degrees of interaction compared with the full composite action. As illustrated in Fig.11(a), the deflection is more significant with a larger span, while Fig. 11(b) shows that the rise in deflection diminishes with increasing span length. Although Bradford's and Girhammer's conclusions are conservative, the numerical model's results agree with Nie's.

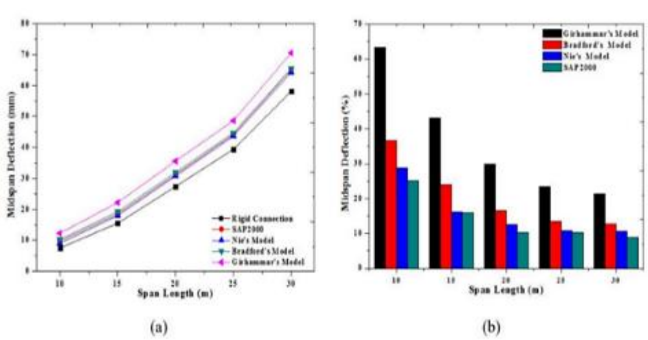

Figure11. impact of span length on deflection [12]

Silva and Dias [32] Employed numerical (FE) analysis to study the influence of partial interaction on the concrete slab's practical width evaluation. They disclosed that less connection stiffness leads to decreased shear lag, consequently making the effective width closer to the actual width. The lateral distortional buckling under negative bending was investigated by Rossi et al. [33]. Physical and geometrically nonlinear analysis was performed by the ABAQUS program, considering I-beam cross-section, negative moment distribution, web stiffeners, unrestrained length, and longitudinal reinforcement rate in the concrete slab. The authors concluded that the dimensions of the I-beam have the largest influence on lateral distortional buckling. Lacki et al. [8] used the ADINA System to perform parametric analysis to examine the steel-concrete composite beam with composite dowel. The influence of mechanical load on stress and strain distribution was characterized using the (FE) Method. The beams with composite dowels were compared to beams with studs. The author disclosed the composite beam with dowels is 12% lighter than the beam with headed studs. In addition, the steel percent in the composite dowels affects the dowel's performance, and the beam dimension affects the overall bending stress. As shown in Fig.12. It can be seen that compression occurs only at the supports. The rest of the beam is mostly under tension, and the stress doesn't exceed 144 Mpa.

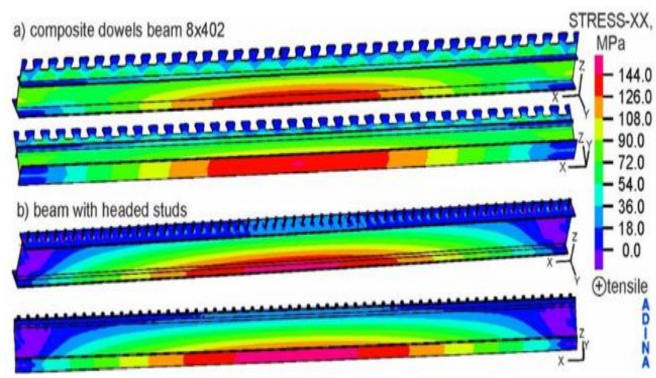

Figure 12. Stress distribution in steel parts [8]

2.3. Experimental and numerical investigations

Some researchers performed experimental and numerical investigations, such as Vasdravellis et al. [34], who studied composite beams loaded in both directions simultaneously (axial compression and negative bending moment). The (FE) model was constructed and calibrated based on results from the experimental work. The research yielded that the negative moment capacity was dramatically decreased with the simultaneous action of compressive action. Compressive loading also accelerates local buckling failure modes in the compression zones of a composite section and compromises its rotation capacity. Vasdravellis and Uy experimentally and numerically examined the shear strength and moment-shear interaction [35]. Combined bending and shear were applied on a composite beam considering the effect of partial shear connection. The author concluded that the partial shear connection reduced the shear strength but increased the ultimate deformation capacity under high shear force. Ban et al. [36] observed how composite beams with multi-spans responded to flexure and torsion forces. The partial and complete connections were considered. The study's results showed that such beams' stability depends on the span-to-depth ratio and the degree of shear connection. Both flexure and torsion failure modes were seen in multi-span steel-concrete composite beams, as in Fig.13, based on how much each activity is combined. The concrete cracked and crushed around the loading points. Fig. 13(a), and 45-degree diagonal fractures are shown in the most common torsion scenario, Fig .13(b).

Figure 13. Crushing and cracking behaviors are typical in this situation. Modes of failure that are dominated by flexure (a) and torsion (b) [36]

Muteb and Abdul Rasoul [37] performed a monotonic load test on a composite beam with an ultra-high-performance concrete slab with various numbers and distributions of shear connectors. The results showed that the increase in the number of shear connectors had a minor influence on maximum deflection. At the same time, there was a clear effect on the ultimate load, which increased to a maximum percentage of 8%. Lacki et al. [38] tested the connectors executed from sections of a non-weldable top hat with four shot nails to optimize the length of the connectors 60 and 100mm were used. They disclosed that the increase in length of the sheet fold increases the bearing capacity of the connector and reduces the slip. Shamass and Cashell investigated the effect of high-strength steel (HSS) on composite beam behavior [39]. Priorities were steel quality and shear connection strength. The author concluded that slip is greater for beams with S690 HSS than those with S460. Increases in both degrees of connection and deflection lead to greater ultimate loads. When the degree of shear connection is increased to a particular point, the bending ratio falls by the numerical bending strength data obtained (M_{FE}). Fig. 14 shows that as the degree of shear connection increases, the bending ratio decreases to a certain level.

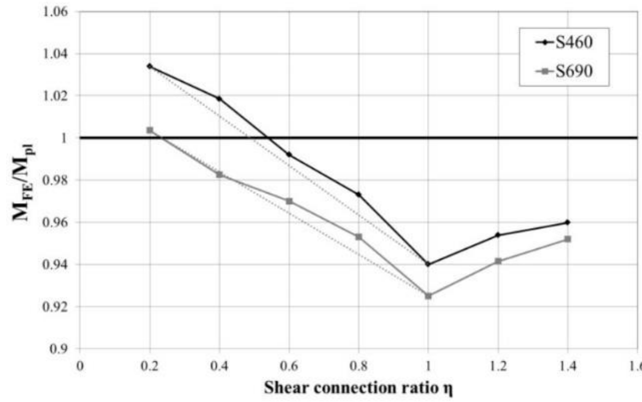

Figure 14. Degree of shear connection's influence on flexural strength [39]

Composite beams made of high-strength concrete and Carbon Fiber Reinforced Polymer (CFRP)-strengthened steel were tested for their flexural behavior by Ercan and Tuyan [40]. The author concluded that steel and concrete must be fully strengthened to use the composite beam, and experimental and numerical results have given the same flexural rigidities in the linear region. Fig. 15 shows the load vs deflection plot; the deflection value also increases as the load increases.

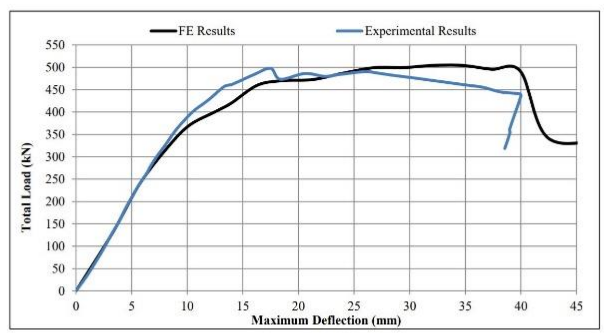

Figure 15. Experimental and FE results of the

the load-deflection curve of the composite beam [40]

Al-Khekany et al. [41] studied the effect of replacing headed studs with angle shear connectors using experimental and numerical methods on the composite beam performance subjected to negative bending moment; the author concluded that the final strength was decreased by 4.12% for single angle connector compared to headed studs. The data was gathered by analyzing the rigidity of a shallow floor composite beam, sometimes known as a "Δ-shape" for its unusual profile by Kyriakopoulos et al. [42]. Flexural behavior for positive moments was evaluated by applying a three-point load and introducing substantial displacements. Maximum deflections were close to (span length/16), much greater than the conventional figures of (span length/50 or 40) for composite beams. Some other researchers, such as Shi et al. [43], proposed an alternative composite beam and compared to the standard composite beam; it was made from two full-depth precast concrete slabs with extending rebars and reversed grooves, an H-shaped steel beam with welded shear studs, additional transverse rebars, and cast-in-situ ultra-high-performance concrete. It was concluded that the proposed beam developed excellent flexural performance, and the failure mode was steel beam yielding and concrete crushing. To observe the response of a prestressed steel-concrete composite beam to a positive bending moment, Almeida et al. [44] conducted four bending test configurations. They disclosed that the ultimate moment could increase to nineteen percent by adding prestressing and significantly reducing deflections under service loads.

3. Dynamic load

Any load that varies over time is considered a dynamic load. The forces that these loads apply to buildings are often substantially higher than their monotonous counterparts. Compared to someone standing stationary, a person repeatedly leaping up and down exerts far more force on the ground. [17].

3.1 Experimental investigations

Xiao et al. [45] performed an impact load test on a composite beam with a sand layer on the concrete slab surface. The author concluded that the maximum displacement and strain on the lower beam layer increase with the increase in sand layer thickness and impactor height. Deflection at the bottom layer (w_0), concrete strain at the top layer (C), steel strain at the bottom layer (S), and acceleration at the bottom layer (a_0) are depicted as functions of time in Fig. 16. These factors quickly attain their maximum levels under impact loading. Afterward, they gradually fade over time (t), eventually coming to a stillness.

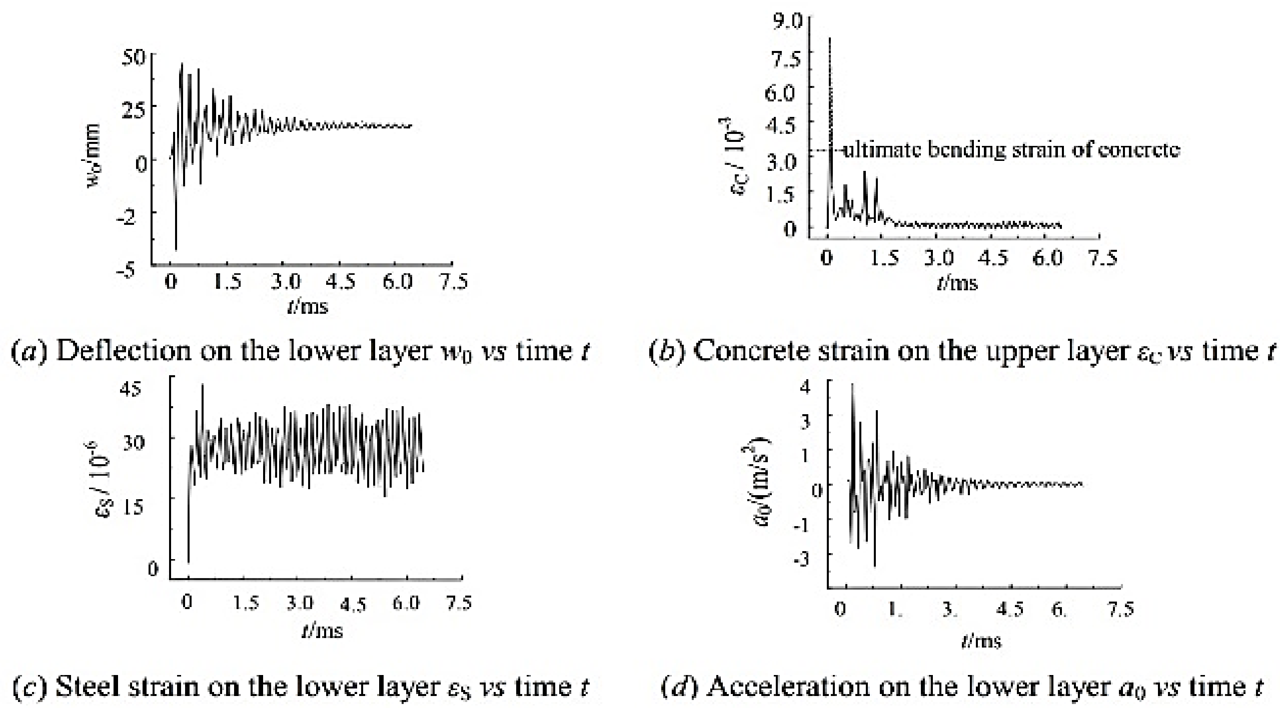

Figure 16. Impact transient response mid-span [45]

Henderson et al. [46] looked at the dynamic characteristics of steel-concrete composite beams with various types of shear connections. The scholar concluded that larger values of connector stiffness resulted in lower natural frequencies. Forcible vibration with varying degrees of shear connection was used to investigate the dynamic behavior of composite beams. Yanling et al. [47] results showed that when the shear connection degree decreased, slip, mid-span acceleration, and deflection all increased. Al-Darzi [48] examined the influence of high-strength concrete on the behavior of composite beams subjected to monotonic and repetitive loads. The author concluded that the beam resistance was lower under repeated load if compared with monotonic load by about 5 % to 28.53 %. Abdulridha et al. [49] studied the behavior of composite beams with two types of concrete (normal and self-compact concrete) subjected to impact load. A falling weight produced the impact in three sequence strikes. The research outcomes were that the max amplitude of deflection history increased by 23% between the third and first strike. The composite beam with self-compact concrete maximum impact force is more than the maximum impact force for the beam with normal concrete by percentages not exceeding 19.35%. A push-out test of the composite beam under cyclic load was conducted by Lowe et al. [50]. They concluded that when many cycles were applied, it led to increasing beam capacity against longitudinal splitting instead of premature failure of the composite beam.

3.2 Numerical investigations

Some researchers adopted numerical investigations, such as Moscoso et al. [51], which enlarged the composite beam's previous numerical 3D model to cover the external pre-stressed tendons. The new model can detect the complete nonlinear response of seven previous experimental external pre-stressed steel concrete composite beams up to ultimate loads. The misstep percentage between predicted numerical and experimental collapse loads ranges from five to eight percent. Researchers studied the influence of a harmonic load on the behavior of composite beams with varying degrees of shear connection. Hamood et al. [52], using ANSYS software, found that shear connection degrees to be a significant index related to the longitudinal shear capacity of the bonding at the interface of the concrete and steel section; the author concluded that a decrease in the degree of connections led to a reduction in the composite beam's overall bending stiffness. Tahmasebinia et al. [53] researched the floor system's dynamic performance of the composite beam when subjected to both forced and free vibration. The study found that longer beams in composite systems have a lower natural frequency, and the crucial frequency range for building composite beam floors is between 1.8 and 2.2 Hz, based on the calculated fundamental frequencies. Mohammed and Abebe [54] examined composite beams' structural response to impact and explosion loading. In addition to the failure of the composite beam owing to excessive concrete damage under combined blast-impact loading, the study indicated that increasing the flange and web thickness of an H-type structural steel beam significantly improves the displacement response, as shown in Fig. 17.

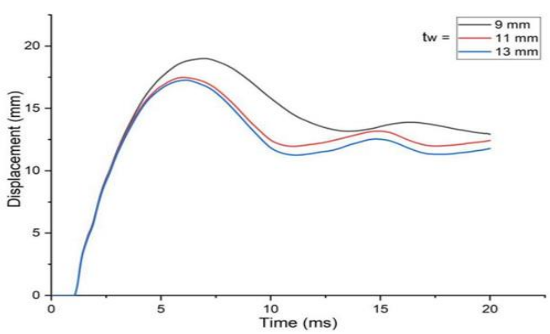

Figure 17. Impact loading displacement-time histories of a composite beam with varying web thicknesses [54]

3.3 Experimental and Numerical Investigations

Researchers adopted both experimental and numerical investigation, such as Hufenbach et al. [55], who investigated the carbon-reinforced composites subjected to low-velocity impact experimentally and its modeled three-dimensional (3D) orthotropic continuous damage-based material numerically using LS-DYNA software. They concluded that adding sheet metal would improve impact damage tolerance, but fundamentally for 0° reinforcement samples without significantly reducing structural strength. Under fixed boundary conditions at both ends, numerical and experimental works with drop-weight impact test rigs were done on recycled aggregate concrete-filled square steel tubular members by Yang et al. [56]. The researchers discovered that core concrete was cracked and crushed in the middle of the span and the area immediately adjacent to the supports. While steel tubes typically buckle between the mid-span and the supports, they break concave in the impact zone.

Allawi and Ali [57] investigated the effect of (GFRP) and different strengths of concrete slab on the composite beam behavior under impact and monotonic load effect. The research yielded that deflection for normal-strength concrete is 45% less for high-strength concrete. As shown in Fig. 18, the damping time for a specimen with high strength subjected to impact load (CHI) is 1.95s, 59% greater than that of a specimen with normal strength concrete (CNI), which is 1.23s.

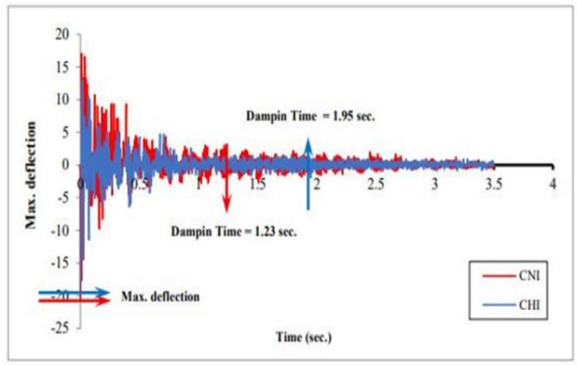

Figure 18. Deflection - time relationship and damping time [57]

Eleven composite steel-reinforced concrete specimens were tested experimentally and numerically by Zhu et al. [58] to see how they would react to drop hammer strikes. They disclosed that concrete dissipates energy more than reinforcement or structural steel. Additionally, the increase in energy dissipation percentage with increasing impact energy means that encasing steel in concrete components effectively enhances impact strength. Ali and Allawi [59] researched how impact loading altered the elastic behavior of (GFRP) hybrid composite beams with and without stiffeners. The authors concluded that using stiffeners was a useful method to enhance the composite beam impact force and damping time by (22 and 26.67%), respectively, and decrease deflection at mid-span and damping ratios by (10 and 16%). Under low-velocity impact, Nasery et al. [60] studied the influence of geometric shape and support of concrete-encased concrete-filled steel tubes. The scholars disclosed that a circular tube section exhibited less performance when subjected to an unexpected load such as impact than the beams with a square tube section. Additionally, the performance of the beam increases with length beyond support.

4. Statistics based on earlier research findings

This part statically discusses the influence of some parameters on the hybrid beam behavior and the link between them based on the data collected by the author based on the results obtained for both dynamic and monotonic load by Allawi and Ali [59] and Jaafer and Saba [61] respectively. Statistics were assembled using the statistical program (MINITAB version 18). To understand the relation between the maximum deflection of a specimen under different loading conditions, for the impact test adopted by (Allawi and Ali, 2021), the variables were (dropped high and max force) by activating regression fitted line plot. The corresponding maximum deflection to these variables and their formulas are shown in Fig. 19 to 21 in addition to the mean R-squared. The confidence level was 95%. It can be seen that the deflection increases and the curve goes up as the drop is high and the max force increases. By activating the matrix of plots interface with smoother in the Minitab package, Fig. 21 displays the relationship between the response and continuous predictors. It can be seen that a drop high has the most significant effect on deflection, and the maximum force grows as the drop high grows.

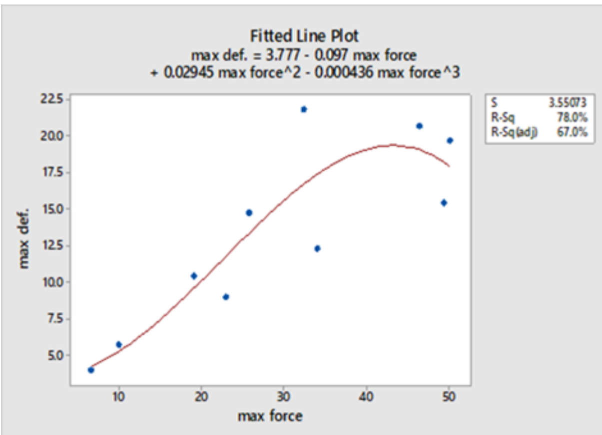

Figure 19. Max deflection vs. max force

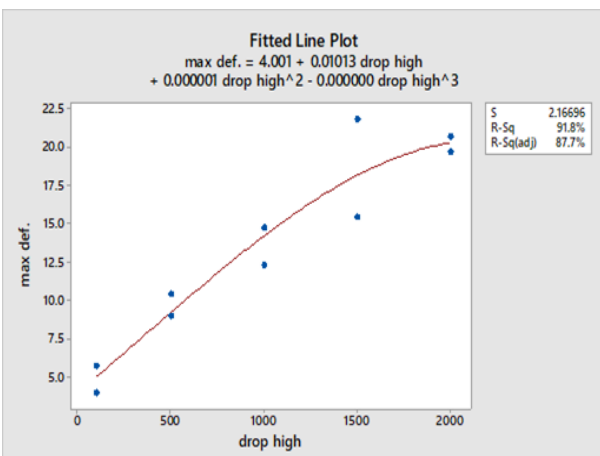

Figure 20. Max deflection vs. drop high

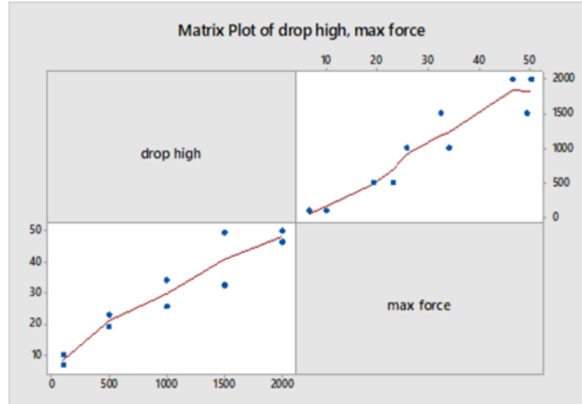

Figure 21. Drop high with max force

The results of monotonic load test results were obtained by Jaafer and Kareem [61], who studied the performance of a curved in-plan composite beam based on the data extracted for a beam with a central angle of 16.85 degrees the response of max deflection to the variables (ultimate load and the number of shear connectors and the degree of shear connection). Fig. 22 to 24 shows the formulas and the mean R-squared. Fig. 25 demonstrates that the interconnection ratio influenced by the number of shear connectors has the most crucial effect on the deflection value. As these variables increase, the maximum deflection also increases.

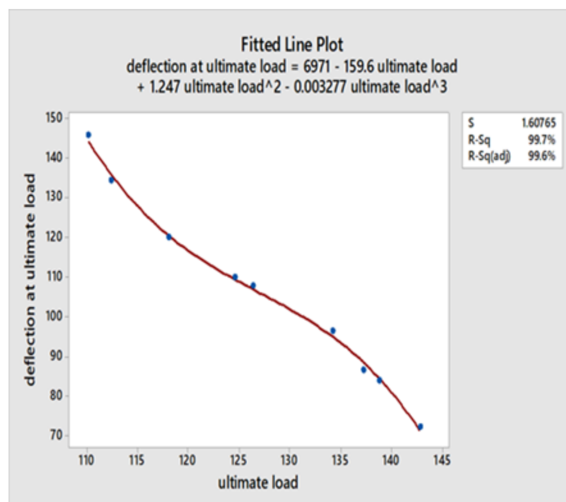

Figure 22. deflection vs. ultimate load

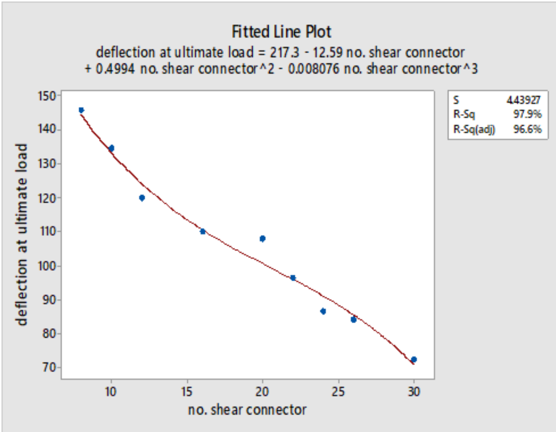

Figure 23. deflection vs. number of shear connectors

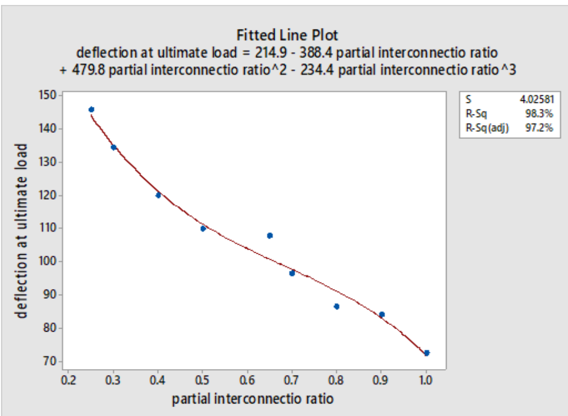

Figure 24. deflection vs. partial interconnection ratio

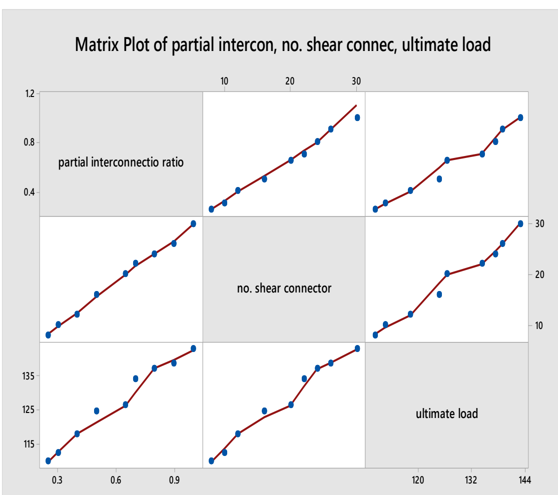

Figure 25. partial interconnection ratio with the number of shear connectors and ultimate

5. Conclusion

This paper reviews the previous researcher's composite beam investigations to understand the behavior of composite beams under various conditions and applications of monotonic and dynamic loading. Compared to an equal RC beam, a pultruded (GFRP) composite beam is more structurally active, with a greater flexural capacity to self-weight ratio, a higher ultimate capacity by around 50%, and a lower weight. Using stiffeners with pultruded (GFRP) composite beam is a useful method to enhance the composite beam impact force and Damping time by (22 and 26.67%) respectively, and decrease deflection at middle-span and damping ratios by (10 and 16%). Bending moment capabilities, yield, and ultimate loads are diminished when torsion is present. The initial cracking load, yield load, and ultimate load under negative moments for a circular composite beam are all shown to drop linearly with increasing curvature, and the failure modes are found to switch from bending failure to torsional failure. Shear connector type has an important role in beam behavior; for example, replacing the headed stud connector with an angle share connector reduces the ultimate strength by 4.12%. Studies in the field of impact for the hybrid beam with a concrete slab are limited, and more studies are needed to understand the beam behavior and the difference between various material responses to dynamic load. There is no crucial difference in failure modes when lightweight concrete is compared to standard concrete. The statistics clarified that the interaction ratio is an important factor affecting the deflection of the composite beam.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Both authors conducted this work

Hesham A. Numan suggested the article title and structure. Ayad Hasan Jawad did the research, performed the statistics, and presented it in its final form. Both authors discussed the results and contributed to the final manuscript.

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