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A state of the art review of " verification the shear reinforcement distribution across the web of "reinforced concrete deep beams

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ABSTRACT

As transfer girders in bridges and high buildings, RC deep beams are important structural systems carrying enormous loads over small spans that must be safe. The shear strength of deep beams is not reliably and properly predicted by recent design standards in practice codes, and in some situations, they are dangerous. To improve current design methodologies and more precisely anticipate the shear capacity of such members, it is the goal of this effort to understand the behavior of deep beams and their controlling factors. This study examines the impact of vertical reinforcement and shear span ratios on failure modes and strengths. This study summarizes earlier research on strengthening deep beams by perpendicular reinforcement ratio and adding SFRC technology. It also illustrates the impact of several strengthening materials (NSC, HSC, and RPC) on the flexural strength of RC beams.

Keywords: Deep Beam, Shear Reinforcement, Strut-tie method, Finite element

1. Introduction

Shear deformation dominates the behavior of the deep bundle, a structural element. The deep beam requires careful investigation, which is complicated by the presence of additives and structural variations as well as a change in the concrete's quality [1]. This work presents numerical calculations carried out to determine the precise prediction of shear strength, which is essential as shear failure is disastrous and can happen suddenly.

Like in Figure, deep reinforced concrete (2). A significant percentage of the load is transferred directly to the support by arching action for RC deep beams since it is applied at a distance from the support [2]. Deep beams are frequently utilized for transversal girders in offshore projects, buildings, and bridges.

ACI 318-14 [3] says, "Deep beams are elements which are loading on one side and directly supported on the opposite face as such compressive elements like struts may appear between both supports and the load, and that fulfill (a) or (b):

(a) The effective span is no more than 4 times the depth of member(h); (b) Combined loads are available within such a 2-h radius of the face of support. In contrast, Euro code 2 (EC2) [4] specifies that any beams with a span-to-depth ratio of less than 3 are deep beams.

Shear, as opposed to flexure, often governs the strength of deep beams [5]. Existing design models rely on empirical equations since the shear behavior of RC components is still poorly understood and is affected by a variety of influences. Even so, these methods are typically very they can result in harmful design solutions while simultaneously being cautious [6][7][8]. Therefore, it is necessary to examine and enhance the requirements of the current practice codes to take into account the factors that influence the shear behavior and strength of deep beams.

Numerous research projects, both theoretical and experimental, have looked at the shear behavior of beams in recent decades.

Figure .1. Some applications of deep beams

In comparison to the shear span, which is categorized as deep beams that are susceptible to strong loads, like transfer girders in high structures, have a significant amount of depth. Deep beams are specified as those with a shear span to effective depth ratio of no greater than two.

While narrow beams are defined as those with a ratio greater than two. While narrow beams shear mostly by beam-action, deep beams shear primarily by compression strut and tension tie. Transverse external post-tension is an effective way to improve the deep reinforced concrete beam's inadequate shear strength.

They discovered that all shear strengthened specimens greatly outperform the reference specimen in terms of ultimate load carrying capability, and the failure mechanism switches from increased ductility and stiffness, and closer to ductile flexural failure. The experiment is constrained by time and money, but the numerical model simulates the behavior of deep beams evaluated in the experiment using a finite element technique (FEM). The finite element method is used by the effective and user-friendly computer application ABAQUS to examine the behavior of concrete structures.

In this study, a finite element model developed using ABAQUS is used to analyze deep beams enhanced by transverse exterior post-tension.

2. Shear behavior

The shear behavior of deep beams is extremely complicated, and owing to a lack of data, there is currently no consensus on the function of size influence in the shear shown in Fig. (2). Deep beams are no flexural elements because their plane portions not maintain parallel during bending. thus, the stress study principles established for slender beams are neither suitable nor sufficient for determining the strength of deep beams.

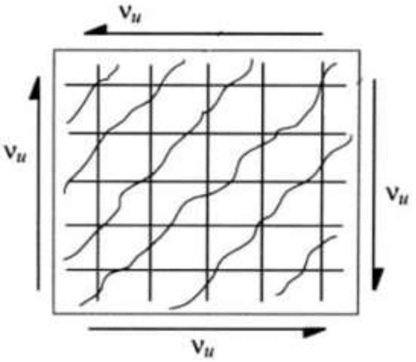

Figure .2. Shear behavior

2.1. Types of Failure Patterns of Deep Beams

Shear and flexural failures are the two primary forms of failure that deep beams experience. The three patterns of shear failure are as follows:

1. Shear tension failure; tensile crack growth in the compressive zone is a result of the flexural stress in this type of failure. Fig. (3a) illustrates how the beam failure by flexural in the compressive zone.
2. Shear compression failure, also known as concrete crushing owing to compressive stresses exceeding, happens when the compressive zone decreases because of the existence of diagonal ruptures and their

enlargement in the compressive zone, as illustrated in Fig. (3 b).

3. compression Struts or shear appropriate failure; arc generation is seen. This failure frequently affects deep beams with a small of (a/h). According to Fig.(3c), the deep beams fail either by an unexpected tensile crack matching to the strut axis or by a compressive crush in the direction of the strut axis.

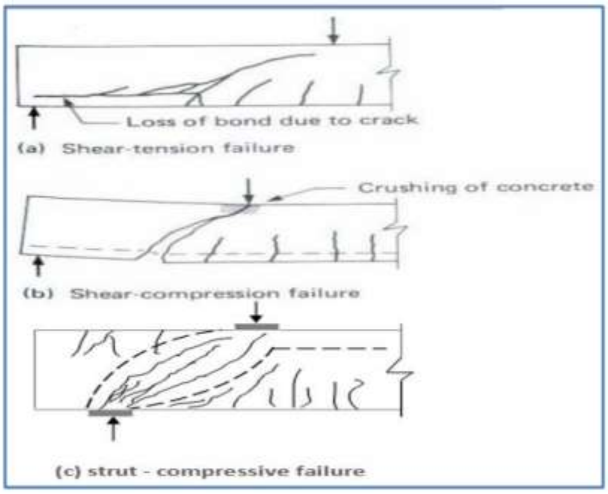

Figure .3. Patterns of failure of deep beams

2.2. Simple and Deep Beams: A comparison

The following are the distinctions between simple and deep beams, according to the design proposition:

1- Simple beams have a one-dimensional effect, but deep beams have a two-dimensional activity because of their dimensions.
2- The deep beam design does not still include a plane section.
3- Deformations of shear are disregarded in simple beams but not in deep beams. Even at the elastic stage, the stress distribution is nonlinear, and the shear stress distribution at the final maximum state is not parabolic.

2.3. Distribution of Stirrups across Web of Deep Beams

A stirrup is a closed loop of reinforcement bars that serves to keep the main reinforcement (RFT) bars in a reinforced concrete element together. Stirrups can take on a variety of shapes depending on the design and shape of the parts as shown in Figure (4). Stirrups are used to keep things in the same direction. It is our responsibility to ensure that the concrete foundations, beams, and columns, among other things... The greater the shear capacity, the deeper the beam. Steel stirrups must be inserted to increase the shear capacity of the beam when the depth is insufficient. Stirrups are usually made of a single piece of steel bent into a rectangular shape.

No stirrup is required if the concrete shear design strength is greater than the shear force. The ACI code, on the other hand, requires that minimum reinforcement (i.e. maximum spacing) be given for such an area.

ACI 318 specifies the spacing of distributed reinforcement shall not be greater
than d/5 or 12 in.

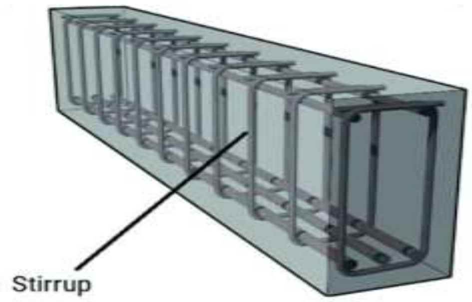

Figure .4. Stirrups in Deep Beams

3. Past Experience

3.1 The Shear Behavior in the Members of the Reinforced Concrete

Nineteen simply supported deep beams were investigated by de Paiva and Siess in 1965 [9]. Furthermore, all beams had the same span, despite the fact that the effective widths and depths of such beams vary. Shear span to depth ratio, the quantity of tension reinforcement, web reinforcement, and concrete strength were the primary variables in the study. According to the researchers, as the tension reinforcement % is raised, the beam load capacity increases, and the mode failure shifts from flexural to shear. They also stated that as the strength of concrete increases, the failure mode changes. The addition of vertical and inclined stirrups reduces beam deflection at ultimate load while having no effect on the formation of inclined fractures.

An experimental result of fifty-two deep reinforced concrete beams under two-point loads was reported by Smith and Vantasiotis, 1982[5]. The study's goal is to look at how horizontal and vertical web reinforcement, as well as the shear span-to-depth ratio, affect inclined cracking shear, crack width, midspan deflection, ultimate shear strength, and tension reinforcement strain. In addition, the test findings show that web reinforcement has an impact on inclined cracks, while vertical web reinforcement improves the ultimate shear strength of deep beams. The addition of horizontal web reinforcement, on the other hand, has no influence on the final shear strength. Increases in concrete compressive strength and a decrease in the ratio of shear span-to-depth imply a considerable gain in load-carrying capacity.

Birrcher et al. [10] did experimental research in 2009 to investigate the influence of member depth on the strength of reinforced concrete in deep beams. The experiments were performed on specimens with cross-sections of 525 575 mm, 525 1050 mm, and 525 1875 mm at the shear span to effective depth ratio values (a/d) of (1.20, 1.85, and 2.50). The researchers employed nine simply-supported specimens with a total span length of 6375 mm. The longitudinal tension reinforcement ratio was around 0.023. The experimental results of shear strength that have been normalized by the factor (fc bwd) for all testing specimens show that normalized shear strength has been significantly reduced with the increase in effective depth, except for specimens loaded with a 2.50 (a/d) ratio, where there has been a small reduction. This suggests that narrow beams with (a/d) > 2.0 have little impact. Furthermore, it is possible to discover that the regularized shear strength of deep beams (a/d) 2.0 has fallen considerably with the increase in the effective depth, implying that shear strength has decreased for slender beams (a/d > 2.0) as the depth has been increased to a lesser extent. The struts and tie model of the ACI 318-08 Code [11] were used to calculate the shear strength. When the analytical and experimental findings were compared, it was clear that this approach was conservative for all of the specimens, with only a few variations in the V test / V calc ratio. With the increase in the effective depth, for deep beam specimens (a/d 2.0).

The basic shear transmission mechanisms in beams are illustrated by the free-body diagrams in Fig .5.[12]. The applied shear (V) is transferred in beams without shear reinforcement through shear combination in the compressive zone (Vcz), dowel action (Vd), and the vertical aggregate interlock stress component (va) along the inclined crack's surface. These three elements make up the actual part of the shear resistance mechanism. For many years, researchers have studied and debated the proportions that are conveyed by each of these components. The depth of the compression zone, the ratio of the shear span to depth, the roughness of the crack, the strength of the concrete, and other factors influence how much shear is transferred by each component. In addition to these three shear-resistant mechanisms, residual tension across the crack also contributes to some shear transmission, but this contribution is rather limited, especially for large cracks. Due to the presence of stirrups, beams with shear reinforcement experience an extra vertical force (Vs), which is regarded as the steel's role in shear resistance.

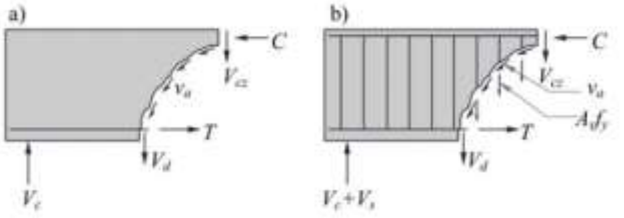

Figure .5. Shear transmission mechanisms in RC beams[12].
a) Beams without shear reinforcement
b) Beams with shear reinforcement

Given that RC deep beams with shear reinforcement exhibit a remarkably greater concrete role to shear resistance than do beams without shear reinforcement, the majority of present shear design measures make unadventurous estimates for the shear strength of deep beams with shear reinforcement. It is thought that stirrups assist constrain the longitudinal steel bars in place, avoiding shear cracks from increasing and so permitting a rise in dowel action, which improves the influence of longitudinal steel reinforcement on the shear resistance of beams with stirrups. Ashour, A. F.

2000 [13]. The shear capacity of RC deep beams is proposed using a numerical technique. Deep beams are thought to be under aircraft stress. It is supposed that concrete and steel reinforcement are rigidly plastic. Idealized shear failure mechanisms consist of moving stiff blocks that are separated by yield lines. The estimated shear capacity and the experimental findings show good agreement. Contrary to how deep beams are defined in most of the practice codes; the suggested model demonstrates that the shear span but not the beam span affects shear capacity. According to the model, the shear capacity improved when the shear span to depth ratio went from 2 to 0.5. When it comes to deep beams without web reinforcing, the shear capacity is seen to increase linearly as the main longitudinal bottom steel increases, but only up to a certain point beyond which no more gains in shear capacity could be made. The finite element of RC deep beams has been the subject of extensive research. Deep beams behave differently than typical flexural members; shear, rather than flexure, is primarily responsible for their strength. They are categorized as non-flexural members because their plane parts bend rather than stay flat. Before cracking, the elastic behavior is characterized by deep beams. The strength of the beams is evaluated using nonlinear analysis or finite element analysis after that significant rearrangement of stresses and strains results in substantial effects of stress and shear deformation. It is based on D-region behavior because failures result from crushing or splitting in diagonal compressive struts. The shear strength of deep beams is a consequence of numerous elements, including loading, horizontal and vertical web reinforcement, span-to-depth ratio, and concrete compression strength. Hassan et al. (2018) [14]. Lafth and Ye (2016) [15], and Ismail et al. (2017) [1]. For the purpose of strengthening reinforced concrete deep beams, a number of approaches, such as External Post-Tension and Fiber Reinforced Polymers (FRP), have been researched. In the ABAQUS program, Rai and Phuvaeavan (2019) [16]investigated the RC deep beam reinforced by external V-shaped rods employing concrete damaged plasticity in comparison to reference beams. They discovered that the theoretical approach's stress resulted in stress that was more closely related to Finite Element Analysis than their experimental finding. The damage plasticity model was created by Hafezolghorani and colleagues in 2017 [17]. For the unconfined pre-stressed concrete beam based on four concrete grades, this model integrated a strain-based damage mechanics component with a stress-based plasticity component. Experimental data or existing constitutive models, such as those proposed by Park (1975) [18] for unconfined concrete, are used in concrete damage plasticity models to describe uniaxial compressive behavior.

a. Homogeneous Section of RC Deep Beams

3.2.1. Normal Concrete and High-Strength Concrete

High-strength concrete beams have been found to have a substantial size effect on the shear. As a result, several changes to the ACI shear design provisions are suggested. Karim (1999) [19] provided a new shear strength prediction equation for an RC member without web reinforcing at both the ultimate and cracking stages. For both normal strength concrete (NSC) and high strength concrete (HSC) members, dimensional analysis, interpolation function, and multiple regression analysis were used to analyze 350 beam test outcomes from the existing RC beams literature in shear covering a range of beam possessions and test approaches. To account for the difference in behavior between the arch action of short beams and beam action of long beams, an interpolation function was utilized. Raghu and his colleagues. (2000) [20] have out a thorough investigational and technical study to determine the concrete component of shear resistance in HSC beams. The experimental program entails testing 24 beams, both with and without shear reinforcement, to investigate the role of concrete in shear strength. Compression strength is the most mutual material property used in the design of buildings. Its status lies in the fact that concrete is strong in compression but weak in tension. In the ASTM C 39 standard (1999b)[21], the compression strength is tested using 6x12 inch (150x300 mm) or 4x8 inch (l00x200mm) cylindrical specimens. Test samples may be made in the laboratory, cast in the field, or cored from an existing structure. The modulus of elasticity is one of the most significant possessions for pre-stressed concrete applications as a substantial measure of the predicted pre-stressing loss is owing to the elastic shortening of the concrete, which is contingent on these assets. The modulus of elasticity is typically specified from the slope of the stress-strain curve of concrete under uniaxial compression. There are several different definitions of modulus of elasticity, namely secant modulus, tangent modulus, and initial modulus.

3.2.2. Mechanical Properties of Reactive powder concrete

For the effective design and usage of RPC, the mechanical qualities must be characterized. The fundamental mechanical properties are covered in the sections that follow. RPC's great compressive strength is one of its most obvious advantages.

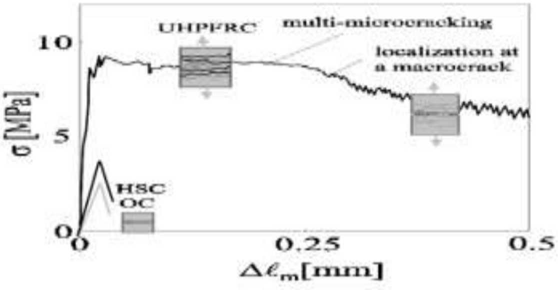

Figure.6. Mechanical Behavior of RPC in Tension.

RPC has been shown to be capable of achieving compressive strengths of 172-228 MPa by Perry and Zakariasen[21]. Kollmorgan[22] provided Studies demonstrating a compressive strength of about 193 MPa in support of this. The particle packing, the choice of particular ingredients, and the thermal curing of RPC are responsible for the improvement in compressive strength compared to NSC or HPC. Graybeal [23] showed an improvement of 53% when subjected to a 48-hour thermal treatment at 90 and 95% relative humidity compared to non-thermally cured specimens of the same age. A feature that depends on the material and is known as the modulus of elasticity is frequently explained as a mathematical relationship between stress and strain. Usually, when a number is given for concrete, it refers to the elastic region of the compressive stress-strain curve, which is defined in ASTMC 469 [24] and extends up to 40% of the ultimate compressive strength ($0.4f'_c$). The modulus of elasticity is the slope of the elastic region of the stress-strain curve. Due to the material's inherent fragility and low total tensile capacity, concrete's tensile strength is a characteristic that is sometimes overlooked. Both before and after breaking, the tensile strength of RPC is greatly enhanced. This tensile strength is made possible by the interaction of the steel fibers, which serve as micro-reinforcement to prevent cracks from forming. As seen in Figure (6), UHPFRC demonstrates a rise in tensile capacity after initial cracking, followed by a sizable plateau where the tensile strength remains constant with increasing body elongation. Ordinary concrete, on the other hand, practically immediately loses strength after the peak value. During this stage, a lot of tiny cracks known as micro-cracks form. In the last stage, known as the macro crack, the deformation localizes to a single crack, and the tensile strength declines gradually [25].

3.2.3. Reinforced Concrete with Steel Fiber (SFRC) .

It is not a novel idea to use steel fibers to enhance the performance of building materials [26]. Early SFRC studies were conducted in the 1950s and 1960s (1960). Most SFRC applications were made in bridge decks, slab areas, parking lots, airport pavements, connect decks, air terminal asphalts, halting zones, and erosion-prone places [30]. At first, just straight steel fibers were used, but since then, other varieties of steel fibers have been created, including enlarged-end steel fibers, crimped steel fibers, and hooked steel fibers. The primary goal of adding steel fibers to regular reinforced concrete is not to increase strength since this can be done more efficiently and affordably by reinforcing the bar that is positioned along the trend of the tension principle. Instead, it is used to address concrete issues that frequently cannot be resolved by bar reinforcing and manifest as micro cracks. Therefore, adding a significant amount of steel fibers to the concrete aids in tightening and strengthening fractures that develop in the concrete as a result of loads and pressures, as well as improving the ductility of the concrete [31]. Fig.7. curves illustrate the typical stress and strain relationship of the SFRC. The diagram shows that strain rises at maximum stress and that the slope of the descent is less steep than in control specimens devoid of fibers, indicating that the steel fibers add more hardness, which is responsible for absorbing energy throughout the deformations and can be calculated using the area under the curve or the load deformation curves.

Both energy absorption under a dynamic load and preventing unexpected failures under a static load have been successfully achieved by adding steel fibers to increase compression stiffness [27].

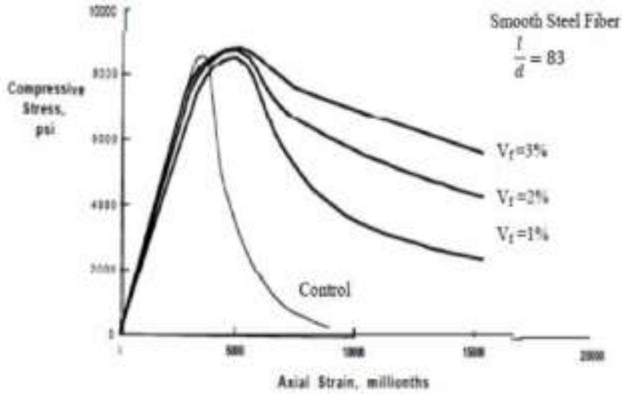

Figure .7. The Effect of the Compressive Stress-Strain Curve by Adding the Volume Fraction of Fibers.

Steel fibers in mortar and concrete have a greater impact on flexural strength than compressive strength and direct tension. Al-Taan and Swamy (1981) [28] simply supported beams were tested using specimens of rectangular beams (130 x 203 mm) with a cubic cross-section and a cubic compressive strength ranging from 36.97 MPa to 41.53 MPa under the influence of a single point load in the center in order to investigate the ultimate strength and deformation in the flexure of the SFRC beams. Three Vf steel fiber ratios were used using crimped steel fibers that were 50 mm long and had a 100:1 width to height ratio (0, 0.5, and 1.0 percent). Only the steel bars in the active stress zone are covered when SFRC is administered at maximum depth. We've come to the following conclusions:

More effectively than beams with fibers solely in the tension zone, beams with fibers along the entire length of the beam have resisted deformation.

- A 1% volume fraction of the steel fibers produced marginal improvements in the ultimate flexural strength.
- The addition of fibers decreased the strength of all fiber concrete beams at all loading stages. deformation and higher flexural stiffness, with cracks becoming more closely spaced.

The static flexural evaluation of beams with fiber and bars. A method (Doherty & Henager 1976) was devised to assess the strength of beams reinforced with bars and fibers. This method was comparable to the ACI ultimate strength design method, as shown in Figure. As depicted in Fig.8.

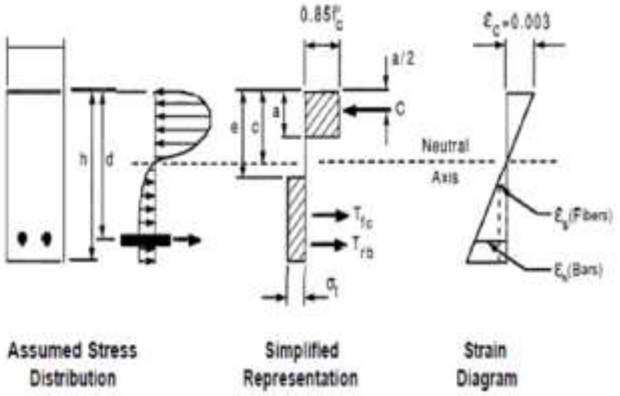

Figure .8. Design Assumptions for Analyzing the Single Reinforced Beams of Concrete, which Contain the Steel Fiber

In all failure modes, but especially those that result in high tensile stress levels, fibers have an impact on the mechanical characteristics of concrete. The behavior of the SFRC under stress is seen in Fig.9. The concrete model separates into two pieces when subjected to the maximum tensile force, rendering the specimen incapable of withstanding additional loading. The steel fiber concrete cracks under the highest tensile load. It doesn't split and can sustain more load at greater deformations since iron fibers are present. One may determine how much energy is absorbed by the specimen when it is subjected to a tensile tension by computing the area under the curve, which may be described as the post cracking SFRC response [29].

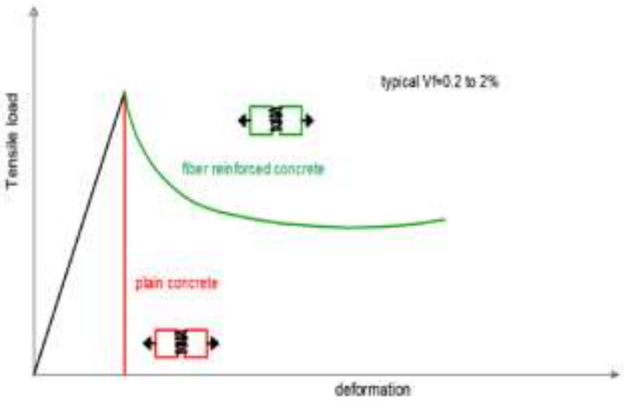

Figure .9. The Deformation for Steel Fiber and Plain Concrete Tensile Load.

4. Conclusions

This article provided a summary of the models that are now available for use in design and the current understanding of the shear behavior of RC beams;

1. A variety of factors, such as (a/h), (fc'), longitudinal reinforcement ratio, vertical and horizontal shear reinforcement ratios, and clear span to depth ratio, have an impact on how the RC deep beams behave.
2. One of the factors that significantly affected the behavior of concrete deep beams was the shear span to depth ratio, which had a bigger effect than the clear span to depth ratio.
3. When the ratio of the shear span to depth is low, the ultimate shear capacity of deep reinforced concrete beams increases with increasing concrete strength.
4. The insertion of fiber enhances the shearing and diagonal cracking capacity of deep beams, improving their behavior.
5. Web reinforcing decreases the fracture's breadth but has no impact on the shape of the crack.

More so than horizontal shear steel, vertical shear steel has an impact on the RC deep beam's shear capacity. Reviewing practical research and earlier theoretical works on the behavior of deep beams, it was discovered that there is a The findings demonstrate that the shear equations may reasonably forecast the shear capacity of thin beams (beams with a shear span to depth ratio larger than 2). However, the predictions made by these equations for RC deep beams (beams with a shear span to depth ratio smaller than two) are extremely dispersed, typically too conservative, and occasionally even dangerous. As a result, such equations cannot be utilized to accurately forecast the shear behavior of RC deep beams. The strut-and-tie model is another logical explanation for the shear design in RC members. For the design of shear in discontinuous areas like RC deep beams, this model is advised. This model is used and advised for the design of RC deep beams in the current codes of practice. Codes of practice do not, however, offer comprehensive instructions on how to choose a suitable model and specify the sizes of its components. Additionally, it is difficult to forecast the effective concrete strength in an inclined strut using the calculations provided by the codes of practice. A logical method of forecasting the shear behavior of RC elements appears to be the integration of (ABAQUS) into layer analysis software. For RC narrow beams, this model is capable of producing results that are satisfactory.

In conclusion, the behavior and capacity of RC narrow beams can be reasonably predicted using the shear design methodologies that are now available. More study is still required to fully comprehend the behavior of RC deep beams and to analyze the impact of many design factors, including the shear span to depth ratio, the compressive strength of the concrete, the shear reinforcement, and the member depth.

Acknowledgments

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Conflict of Interest

The authors reaffirm that there is no conflict of interest with the publishing of this article.

Abbreviations

FEM	Finite element method
SFCR	Steel Fiber reinforced concrete
NSC	Normal Strength concrete
HSC	High Strength Concrete
RPC	Reactive Powder Concrete
RC	Reinforced Concrete

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