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"Experimental Study in RC Deep Beam by Using Hooked End Steel Fiber" A Review Paper

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ABSTRACT- According to Indian Standard provisions, deep beam is a beam having clear span to overall depth ratio less than 2.0 for simply supported beam and 2.5 for continuous beam. The effective span is defined as the Centre-to-Centre distance between the supports or 1.15 times the clear span whichever is less. Reinforced concrete deep beams have many applications in building structures such as transfer girders, wall footings, foundation wall caps, floor diaphragms, and shear walls. Continuous deep beams occur as transfer girders in multi-story frames. The Deep beams are structural elements loaded as simple beams in which a significant amount of the load is carried to the supports by a compression force combining the load and the reaction. A deep beam is a beam having a depth comparable to the span length.

Keywords –Steel fiber, deep beam, shear strength, deflection, shear span to depth ratio.

I. INTRODUCTION

The behaviour of deep beams is significantly different from that of beams of more normal proportions, requiring special consideration in analysis, design and detailing of reinforcement. Because of their proportions, they are likely to have strength controlled by shear. On the other hand, their strength is likely to be significantly greater than predicted by usual equations. Shear strength of deep beams may be as much as 2 to 3 times greater than that predicted using conventional equations developed for members of normal proportions. For deep beams, however a significant part of the load is transferred directly from the point of application to the supports by diagonal compression strut Diagonal cracks that form roughly in a direction parallel to a line from the load to support isolate a compression strut, which acts with the horizontal compression in the concrete and the tension in the main reinforcement to equilibrate the loads. The geometry of this mechanism and the relative importance of each contribution to shear strength clearly depend on the properties of the member as well as the placement of the loads and reactions. The reinforcement of deep beams differs from that of normal beams. The main flexural steel is placed near the tension edge, as usual, although because of the greater depth of the tension zone it may advisable to distribute such steel over, the bottom third of the member. As per IS 456-2000, flexural steel is placed within a zone depth equal to 0.25D-0.05L adjacent to the bottom face of the beam where D is the overall depth and L is the effective span.

II. THE FACTORS THAT AFFECT THE STRENGTH OF DEEP BEAMS.

A number of variables influence a deep beam's shear strength. Handful of most significant ones comprise compressive strength of concrete, Shear span to depth ratio, vertical and horizontal shear reinforcement, flexural reinforcement. Affection of every constituent of deep beams regarding shear capacity is discussed.

2.1 The Impact of Compressive Strength on Deep Beam Concrete.

Compressive strength of concrete owns primary factor in the structural strength of deep beams. The value of the compressive strength of concrete raises the nominal shear stress.

2.2 The Ratio of Shear Span-to depth (a/d)

A deep beam's shear resistance is basically dependent on it's a / d. It has been shown by numerous experimental studies that the a/ d is the most important parameter that impacts a deep beam's shear

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resistance, as the shear strength increases with a reduction in the amount of a / d. This is because the load is directly transferred to the supports by concrete struts, created as a consequence of diagonal cracks, as the a / d ratio decreases. This process is known as the tied-arch or strut-and-tie effectin deep beams.

2.3 Effective Size (Beam Depth)

As the beam depth increases, the shear strength of a reinforced concrete beam decreases. The influence of the size is prominently known as this phenomenon. The size effect occurrence was reaffirmed by many researchs tries on slender beams-beams with $a/d \geq$ 2.0. For the purpose of evaluation of the size-dependent shear strength of such beams, several analytical models have been suggested. It was established the concrete beam's critical strength reduced plus rise in beam depth, with a recognized

2.4 Beam Span To Depth Ratio (l_n/d)

Deep beams with various ratios of span to depth and concluded that the ratio of (l_n/d)also plays a major effect on the shear strength of a deep beam, similar to a/d ratio, with shear strength beinginversely related to the ratio of (l_n/d). Due to a longer arch is shaped to hold the load to the support as the l_n/d ratio increases and the mid span deflection increases at the same time, creating more flexural cracking than shear failure.

2.5 Longitudinal Reinforcement

The shear strength of a deep beam increased dramatically with the increase in longitudinal reinforcement. Similar studies have shown that longitudinal reinforcement has a linear association with shear strength for deep beams with no shear reinforcement up to a certain limit and has zero impact beyond that. Longitudinal reinforcement improves the shear potential of a deep beam by diminishing the crack width, enhancing the interface shear transfer mechanism and developing the dowel action.

III. STRENGTH OF RC DEEP BEAMS

A tied-arch action or truss (beam) action is considered by deep beams to transfer shear (Figure 3.1) The ratio of(a/d) and the amount of transverse reinforcement are the two most influential parameters affecting the type of load transfer mechanism. It has been demonstrated that a higher load fraction is transferred as a/d decreases through tied-arch action, which shows higher beam's shear strength as a consequence of immediate transport of the load through compressive struts from the loading point to the support(Figure3.a).In comparison ,higher a/d ratios transfer beams a large portion of loads by beam or truss action (Figure3.1b).Similarly, higher levels of transverse reinforcement contribute to a greater fraction of the load being transferred by truss action, although the effect of transverse reinforcement decreases at very low a /d ratios. On the other hand, to avoid splitting diagonal struts that form amidst loads and supports of deep beams that give them increased shear strength, a certain minimum amountof web reinforcement (vertical and horizontal) is required.

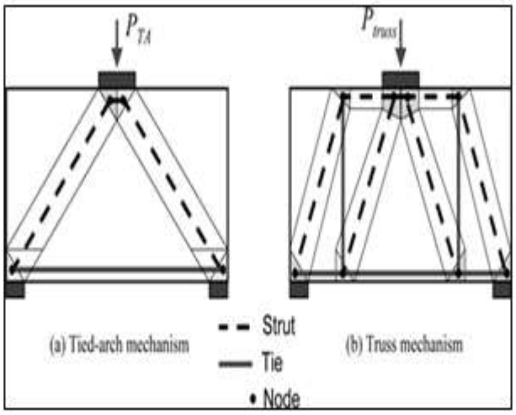

Figure 3.1 The act of the loading transfer mechanisms

Deep beam failure is normally due to concrete crushing in either the reduced compression zone area at the tip of the inclined cracks, known as shear compression failure, or by concrete fracturing along the crack, known as diagonal splitting failure. In the post-cracking zone, reserved energy occurs in deep beam that have a shear span to depth ratio of lower than 2.5, resulting in less brittle failure. There are four modes of failure for deep beams known as shear-compression failure, diagonal splitting shear failure and shear-flexure and flexure failure. The diagonal-splitting failure is brittle, sudden and for this reason treacherous, defined as shear failure. A critical diagonal crack develops from which failure occurs, joining the loading point at the top and the support point at the bottom of the beam. In the shear-compression failure mode, the concrete part between the load point and the support experiences high compression after the inclined crack appears and eventually fails. This mode of failure is an equally brittle mode of failure. A shear and flexure combination is the shear-flexure failure mode. First, flexural cracks, followed by partially diagonal cracks form. This is a ductile failure mode in which the beam deflects at the middle and at the time of failure, no explosive sound is heard.

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IV. FIBRE REINFORCED CONCRETE

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is only approximately one tenth of its compressive strength. As a result for these characteristics, concrete member could not support such loads and stresses that usually take place, majority on concrete beams and slabs. Historically, concrete member reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. Furthermore, steel reinforcement adopted to overcome high potentially tensile stresses and shear stresses at critical location in concrete member. The additional of steel reinforcement significantly increase the strength of concrete, but to produce concrete with homogeneous tensile properties, the development of micro cracks is must to suppress. The introduction of fibres was brought in as a solution to develop concrete in view of enhancing its flexural and tensile strength, which are a new form of binder that could combine Portland Cement in the bonding with cement matrices. Fibres are most generally discontinuous, randomly distributed throughout the cement matrices. The term of ‘Fibre Reinforced Concrete’ (FRC) is made up with cement, various sizes of aggregates, which incorporate with discrete, discontinuous fibres.

V. LITERATURE REVIEW

5.1 A.K. Sachan, C.V.S. Kameswara Rao studied “behavior of fibre reinforced concrete deep beams”. This paper describes an experimental investigation to study the strength and behavior of steel fibre reinforced concrete deep beams. In total 14 beams were tested. The effects of fibre content, percentage reinforcement and type of loading were studied. The ultimate load-carrying capacities, mode of failure and load-deflection behavior are reported. A simple model is proposed to predict the load-carrying capacity of the beams.

5.2 T.M. Roberts, N.L. Ho** studied “shear failure of deep fibre reinforced concrete beams”. The results of a number of tests on deep fibre reinforced concrete beams are presented. The beams contained conventional tensile steel reinforcement but different percentages of steel fibre in place of conventional shear reinforcement. All beams were simply supported and loaded to failure by a central load distributed through two bearing plates. The results confirm that steel fibres can prevent shear failure in deep beams, and indicate the various modes of fibre of deep beams.

5.3 V.K.M Selvam, Lecturer in Civil Engineering, Regional Engineering College, Calicut, India studied “shear strength of reinforced concrete deep beams”. A hypothesis is made for the shear mechanism of concrete deep beams based on the failure mode observed during testing. Using the hypothesis an equation is developed for predicting the ultimate strength of the beam. The equation is found to give reasonable values for the ultimate loads for beams with depth with depth to span ratio as low as 1/3.

5.4 Vengata chalapathy, V. llangovan, R studied “study on steel fibre reinforced concrete deep beams with and without openings”. This experimental study deals with the behavior and ultimate strength of steel fibre reinforced concrete (SFRC) deep beams with and without openings in web subjected to two point loading, nine concrete deep beams of dimensions 750mm x 350mm x 75mm thickness were tested to destruction by applying gradually increased load. Simply supported conditions were maintained for all the concrete deep beams. The percentage of steel fibre was varied from 0 to 0.1. The influence of fibre content in the concrete deep beams has been studied by applying the modified Kong and Sharp’s formula of deep beams are compared with the experimental values. The above study indicates that the location of openings and the amount of web reinforcement, either in the form of discrete fibres or as continuous reinforcement are the principal parameters that affect the behavior and strength of deep beams.

5.5 E. Fehling & T. Bullo studied “ultimate load capacity of reinforced steel fibre concrete deep beams subjected to shear”. A numerical model based on the concept of smeared cracking to predict the structural behavior of reinforced steel fibre concrete deep beams is developed. Material parameters, which are necessary to formulate a constitutive relation for randomly oriented short steel fibre under biaxial states of stress are systematically quantified and implemented in the DIANA finite element program. The developed material model is utilized to simulate the structural behavior of the experimentally investigated reinforced steel fibre concrete deep beams found in the literature.

5.6 Aref Abadel Husain Abbasa TarekAlmusallam studied “Experimental study of shear behavior of CFRP strengthened ultra-high-performance fiber-reinforced concrete deep beams”. This experimental study aims to examine the effectiveness of shear stirrups and carbon fiber-reinforced polymer (CFRP) strengthening scheme in enhancing the deep beams’ shear strength. For this purpose, a total of six deep beam specimens of 150 mm × 300 mm (depth) × 1000 mm with an effective span of 750 mm, classified into three groups of two specimens each, were prepared. The beams of the first group were of normal concrete (NC). The beams of the second group were prepared using ultra-high-performance fiber-reinforced concrete (UHPFRC). In the third group, the UHPFRC deep beams were strengthened using CFRP strips. Each group had two beams – one with no shear stirrups and another with shear stirrups. All deep beams were tested under four-point loading until failure. According to the experimental results, shear stirrups effectively contributed to enhancing shear strength, ultimate load, and deformation capacity for NC deep beam. By utilizing the UHPFRC mix, the deep beams' shear strength was upgraded significantly compared with the NC deep beams, but the deformation capacity was reduced. The implemented strengthening scheme was effective in the enhancement of deep beams' shear strength and deformation capacity. The improvement in the shear strength of strengthened UHPFRC deep beams was moderate (16%); however, a considerable increase was observed in the deformation capacity as the displacement and energy ductility indices were enhanced by 49% and 185%, respectively.

5.7 Eissa Fathalla R.M.C.M.Rajapakse Boyan I.Mihaylova studied "Modeling the shear behavior of deep beams strengthened with FRP sheets". While external FRP sheets are a viable solution for the strengthening of concrete members, there is a lack of mechanical models that can capture their effect on the shear strength of deep beams. This is in part due to the complex de bonding and rupture behavior of FRP, which occurs in parallel with the activation and failure of the other shear mechanisms in deep beams. To address this gap, the current paper proposes a kinematics-based model for the behavior of shear-critical deep beams with externally bonded FRP sheets, including side and U-shape sheets, full wraps and inclined strips. The FRP contribution is modeled as a function of the displacements in the shear cracks by using appropriate constitutive relationships. The model is validated with 20 tests from the literature showing adequate shear strength predictions. Parametric analyses are used to show that the effectiveness of FRP sheets decreases with decreasing shear-span-to-depth ratio and increasing member size. The predictions of the ACI and CNR design equations are also evaluated with the help of the proposed model. While design codes do not account for initial cracks at the time of strengthening, the kinematics-based model is used to simulate this effect by later activation of the FRP.

5.8 Mohammad AlHamaydeh George Markou Nikos Bakas studied "AI-based shear capacity of FRP-reinforced concrete deep beams without stirrups". The presented work utilizes Artificial Intelligence (AI) algorithms, to model and interpret the behavior of the fiber reinforced polymer (FRP)-reinforced concrete deep beams without stirrups. This is done by first running an extensive nonlinear finite element analysis (NLFEA) investigation, spanning across the practical ranges of the different input parameters. The FEA modeling is meticulously validated against published experimental results. A total of 93 different models representing a multitude of possible FRP-reinforced deep beam designs are rigorously analyzed. The results are then utilized in building an AI-model that describes the shear capacity for FRP-reinforced deep beams. The study investigates the effect of several factors on the shear capacity and identifies the vital parameters to be used for further model development. Additionally, the developed AI-model is benchmarked against several design standards for blind predictions on new unseen data and design codes, namely: the EC, ACI 440.1R-15, and the modified ACI 440.1R-15 (for size effect). The AI-model demonstrated superior generalization on the blind prediction dataset in comparison to the design codes.

5.9 Mohamed S.Manharawy Ahmed A.Mahmoud studied "Experimental and numerical investigation of lightweight foamed reinforced concrete deep beams with steel fibers". This paper aims to experimentally and numerically study the effect of steel fiber on the behavior of Lightweight Foamed Reinforced Concrete (LWFRC) deep beams and its mechanism to improve the mechanical properties and crack control of concrete. In addition to this, steel fibers compensate for the lack of resistance due to the use of lightweight foamed concrete (LWFC). This paper will also address the effect of some variable parameters on the structural behavior such as: (1) volume of fiber; (2) fiber aspect ratio; (3) longitudinal reinforcement ratio.

5.10 Shengxin Fan Yao Zhang Kang HaiTan studied "Fire behaviour of deep beams under unsymmetrical loading". This paper focuses on the condition where a reinforced concrete (RC) deep beam is subjected to two concentrated loads (P1 and P2), which are positioned at respective distances a and c from bottom supports. In general, equal shear spans ($a = c$) and equal point loads ($P1 = P2$) are commonly assumed in most experimental programmes. Nevertheless, such cases are rare in practice. In contrast, due to the fact that deep beam floor normally subjects to irregular layout of column grid, deep beams are usually subjected to unequal load magnitude (load inequality or $P1 \neq P2$) and unsymmetrical load positions (load asymmetry or $a \neq c$). Although previous research has demonstrated the significant influences of load asymmetry and inequality on the structural performance of deep beams at room temperature, no research programme has been performed to study their influences on the fire performance of deep beams. As a result, this study is proposed to investigate the shear behaviour of unsymmetrically-loaded deep beams at fire condition, analytically and experimentally. The current research first derives a strut-and-tie-model (STM) to predict the shear capacity of RC deep beams under unequal/unsymmetrical loading conditions and at elevated temperatures. The STM takes into account the effects of unsymmetrical loading configurations, contribution of steel reinforcement on strut capacity, and thermal-induced gradient. Additionally, a test programme on six RC deep beams under fire condition is conducted for verification of the proposed model.

5.11 Zherui Li Hiroshi Isoda Akihisa Kitamori studied "Analytical model for the capacities of traditional Japanese timber frames with deep beams". In this study, the lateral resistance of a deep beam with beam-column joints in a timber frame applied in traditional Japanese residential houses and their possible interactions are discussed through experimental and theoretical analysis. When the frame deforms under lateral force, the rotation of the deep beam is constrained by the columns on both sides, and an axial force is generated on the deep beam along the diagonal direction. Via integration with beam-column joints, an estimation method of the lateral resistance of a traditional timber frame with a deep beam is proposed and confirmed with comparative tests. The results indicate that the resistance of the deep beam is affected by both the magnitude of the moment of the beam-column joints and the difference between the joint moments on the left and right sides of the beam. Meanwhile, the axial force on the deep beam is conducive to delaying the occurrence of ultimate failure of the beam-column joints.

5.12 Marcos V.G.Silveira Bruno Paini Luís A.G. Bitencourt Jr studied "Design and experimental investigation of deep beams based on the Generative Tie Method". The high level of shear stress present in reinforced concrete deep beams has been the subject of interest for a considerable number of studies due to the uncertainties involved. Several structural codes and standards around the world have recommended using the strut-and-tie method (STM) to design such elements. The STM is proven efficient and accurate, however, the successful application of the method relies decisively on the skills of the designer to conceive truss-like models. In this paper, a framework named Generative Tie Method (GTM) is proposed as an alternative approach to overcome some limitations of the available methods for the design of deep beams. The GTM uses performance ratios obtained from finite element analysis (FEA) as decision-making criteria on the reinforcement layout design of structural concrete members. The FEA strategy used in this approach is based on the elastic–plastic stress fields.

5.13 Liu Jin Yushuang Lei WenxuanYu studied "Dynamic shear failure and size effect in BFRP-reinforced concrete deep beam". The purpose of this study is to investigate the size effect on dynamic shear failure of deep concrete beams with Basalt Fiber Reinforced Polymer (BFRP) bars. In order to accurately simulate dynamic shear failure behavior of BFRP-reinforced concrete deep beams, a three-dimensional meso-scale numerical model was established, which considered the heterogeneity of concrete, the interaction between concrete and BFRP bars, and the strain rate effect of meso-components. Firstly, the measured data of the existing experiments were input into the numerical model to obtain ideal numerical calculation results, which proved the rationality and accuracy of the simulation method. Then, the shear failures of geometrical-similar BFRP-reinforced concrete deep beams with different sizes under different strain rates were studied. The influence of beam depth, stirrup ratio and strain rate on the shear failure of BFRP-reinforced concrete deep beams and the corresponding size effect law were investigated. The results indicate that: 1) The failure modes of beams under dynamic loading are different from those under static loading; 2) Both the strain rate and the stirrup rate can effectively improve the bearing capacity of the beam and weaken the shear size effect, but the effect of strain rate is significantly greater than that of stirrup rate.

5.14 Ahmed Bediwy Karam Mahmoud studied "Structural behavior of FRCC layered deep beams reinforced with GFRP headed-end bars". In this study, seven concrete deep beams reinforced with glass fiber reinforced polymer (GFRP) headed-end bars were constructed and tested to failure. The beams had a rectangular section of 250 mm in width and 590 mm in depth with overall span of 1,390 mm and were tested under three-point bending loading. The main test variables were the longitudinal reinforcement ratio and the incorporation of fiber-reinforced cementitious composite material in the tie zone. The arch action mechanism developed in all specimens as substantiated by the measured strains along the tie length. In addition, analysis of test results showed that the incorporation of basalt fiber pellets or steel fibers in the tie zone of the beam improved the behavior including the ductility and the load carrying capacity. It was also found out that the provisions for strut-and-tie model in the Canadian codes for FRP-RC structures and the American code for steel-RC structures yielded reasonable predictions to the load capacity of deep beams.

5.15 Hui Chen Wei-Jian Yi studied "Shear size effect in simply supported RC deep beams". The shear size effect refers to the phenomenon that the shear strength of reinforced concrete (RC) beams decreases as the beam depth increases. The shear strength of RC deep beams is sensitive to boundary conditions (in this case, load- and support-bearing plate (or column) sizes), which in turn affect the shear size effect of deep beams. In this study, to separate and identify the influences of the bearing plate size on the shear size effect, existing deep beam tests on shear size effect are classified. It is verified that the shear size effect of deep beams with a fixed bearing plate size is stronger compared to deep beams with proportionally varied plate sizes. By using a non-linear analysis software ATENA based on concrete fracture and plasticity theory and a mechanical model called cracking strut-and-tie model (CSTM), the shear size effects of the classified test groups are accurately predicted, and the maximum height of each beam group is extrapolated to 4 m. Through in-depth analysis of the finite element model and CSTM results, it is inferred that the possible reasons that lead to the shear size effect of RC deep beams are: (1) bearing plate size effect, that is the reduced relative strut width caused by the disproportionately varied bearing plate size with the beam height; and (2) beam depth effect, which refers to the deterioration of the shear transfer strength by aggregate interlock of the critical shear crack due to the increase of the beam depth. In addition, based on the prediction results for the 4 m high beams and the existing test results, the STM in the ACI 318-14 is evaluated. The results show that the ACI STM cannot inherently consider the beam depth effect, resulting in the safety of large-size deep beams designed according to the ACI STM is lower than that of small-size deep beams. For this reason, proposals for considering the beam depth effect in STM design are put forward.

5.16 Dr.G.S.Suresh, Shreesh Kulkarni studied “Experimental study on behaviour of RC deep beams”. The present work is deals with experimental study of behaviour deep beam. Objective of the present work are to study the behaviour of deep beam for shear and bending strength by experimental and analytical study using ANSYS 14.5, to compare the experimental results with analytical results. This present work deals with study on deep beams with different percentage of tension reinforcement (0.43, 0.64, and 0.86) and different grades of concrete (M25 and M30). In ANSYS 14.5 software, SOLID 65 and LINK 180 element represent concrete and reinforcing steel bars.

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