International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 05 | May-2016 www.irjet.net p-ISSN: 2395-0072

Review on Shearing Resistance of Reinforced Concrete Beams without Shear Reinforcement

M.Sheik Mohamed[1], V.Kalpana[2]

[1]Assistant Engineer, Nabard & Rural Roads, Tamil Nadu Highways Department, Tirunelveli-627002, Tamil Nadu, India

[2]Assistant Professor Civil Engineering, Aalim Muhammed Salegh College of Engineering, Muthapudupet, Avadi-IAF, Chennai-600055, TamilNadu, India

---

Abstract-Shearing resistance or shear transfer mechanism in flexural members is a very complex phenomenon and it was the major problem in early 1940s.Major structural elements such as flexural members were failed in shear. For suppressing this shear problem extensive research is required. This paper explains about the behavior of shear strength of reinforced concrete beams made without web or shear reinforcement. The theoretical background behind in the shear failure has been discussed and thoroughly explained. The experimental setup procedures have been clearly illustrated. The shear transfer mechanisms namely beam action and arch action has been discussed in detail. The various failure modes are also presented.

Key Words: *Shear transfer, beam action, arch action, failure mode, span to effective depth ratio*

1. INTRODUCTION

The extensive study on flexural members subjected to bending gave a clear picture about its failure mechanisms and led to the development of design of flexural members with higher safety. These concepts were fully understood by the researchers and now fully incorporated in the design codes of many countries. Of course everyone knows that flexural failure is a ductile failure. After that the focus of many researchers transferred on the topic of behavior of members subjected to flexure and shear especially for flexural members. Even before 20^{th} century, lot of publications appeared and spoke about the complexity of the problem. Many structural elements are subjected to shearing forces. The forces act in the structural members either as seldom or in combination with other forces like flexure, shear and torsion. In addition to identifying the effect of shear forces acting alone, therefore it is necessary to examine the possible interaction with the other structural actions. In bending members, shear transfer mechanisms interact with bond between the concrete and embedded rebar and also the anchorage mechanism. Shear strength in steel reinforced concrete beams has been the subject of many controversies and debates since the beginning of 20th century. Due to the complexity, shear transfer mechanism is quite hard to understand. When compared with the bending failures, shear failures are very sudden and dangerous. It is a brittle failure in nature. Normally the beams subjected to vertical loading, may fail in shear before attaining their flexural capacity. So, considering the importance of shear phenomenon, the studies on the shear strength of concrete beams made without web reinforcement started from 1948 to till date. The main obstacle behind in this shear transfer mechanism is the number of parameters involved and these parameters are yet to be known. Extent knowledge of the different modes of shear failures and the mechanisms involved is necessary to suppress them. Existing codes and specifications of different countries for reinforced concrete design with regard to shear differ considerably .This only reflects the fact that we know very little about the behavior and strength of reinforced concrete subjected to shearing force in spite of the considerable number of tests and theoretical investigations made during more than half a century. Despite the ultimate research work, still we don't have a simple and analytically derived formula to predict the shear strength of reinforced concrete beams. As discussed earlier, every country followed the shear design of flexural members by their own design provisions. For example, Indian code formula for predicting the shear strength based on empirical equation and also in touch with the British Code. The current provisions for shear in standard codes such as American code, Indian code and British code are still based on empirical or semi empirical considerations. These failures show less or no prior warning before failure proceeding to the collapse of structures. So, researchers have concentrated on the internal mechanism of shear failure.

2. SHEAR CONCEPT

As we all know that, shear force is nothing net vertical force acting either to the left or right of the section of element. Shearing force exists in beams due to change in bending moment along the span.i.e; this force is equal to the rate of change of bending moment. Normally shear forces are classified into two types i.e. vertical shear force and horizontal shear force. The horizontal shear force occurs in beams when they are subjected to bending stresses. The vertical shear force present in beams when they are subjected to zero bending stresses. From the principle of complementary shear, vertical shear forces are always accompanied with the horizontal shear forces. These forces are very much predominant in beams as they cause severe deformation and lead to cause failure of structures.

3. EXPERIMENTAL SETUP FOR VERTICAL SHEAR FORCE

The vertical shear force is calculated as described below. From the principle of complementary shear, vertical shear force always accompanied with the horizontal shear force. If the vertical shear force is calculated then the horizontal shear force also has the same magnitude. Shear strength of concrete is nothing but resistance of vertical shear force. The shear strength contributed by the concrete can be found out by the beams cast with or without shear reinforcement. If shear reinforcement is provided, then the shear strength of concrete will be reduced. The situations arise where the nominal shear stress is less than shear strength of concrete, the minimum vertical bars should be provided in the form of stirrups in beams. The conventional test setup for finding shearing resistance of reinforced concrete beams cast without web or shear reinforcement is two point loading system and center point loading system. Out of this two, two point loading system is superior in which flexure-shear interaction can be created with three spans. In this arrangement, beam is subjected to symmetrically place two equal concentrated loads 'P' at distance say x (shear span) from the supports. It has the advantage of combining two different test conditions i.e., pure bending, that is, no shear force is present between the two loads P, and constant shear force in the two end regions or shear spans. The failure of the beam is caused by the crack developed in the shear region. This crack is known as web shear crack or diagonal crack. These cracks formed at 45 degrees to the longitudinal axis of beam. The shear stresses combined with bending stresses led to formation of principal tensile stresses near supports of beams section equal to the shear stresses. The principal tensile stresses nothing but diagonal tension which is responsible for the formation of web shear cracks. The cracks are formed in the concrete when the principal tensile stress exceeds the tensile strength of concrete. That's why shear strength of concrete is directly proportional to tensile strength of concrete and this tensile strength can be expressed by $\sqrt{f_{ck}}$. Shear strength of concrete normally varied from 10 to 20 percent of its compressive strength. The shear at which the inclined crack in beam without shear reinforcement is formed first is taken as shear strength of concrete.

4. DEPENDENT VARIABLES

The shearing resistance of concrete depends upon shear span to depth ratio (a/d), tension steel ratio (ρ), compressive strength of Concrete (f_{ck}), size of coarse aggregate, density of concrete, use of fibers in concrete, size of beam, position and geometry of haunches, tensile strength of concrete, support conditions, clear span to depth ratio (L/d), number of layers of tension reinforcement, grade of tension reinforcement and end anchorage of tension reinforcement. The behavior of reinforced concrete beams in shear can be explained in two stages viz., pre-cracking stage and post cracking stage.

5. PRE-CRACKING STAGE

Before cracking, the reinforced concrete beam acts more or less like a homogeneous beam. The flexural stress (f) across any section are given by the classical formula

$$f = My/I \quad (1)$$

Where, M= bending moment (Nmm)

The shear stress (τ) across the same section is given by

$$\tau = Vay/Ib \quad (2)$$

Where, V = shear force (N), A = cross sectional area (mm^2)

y = the distance of centroid of an element from the neutral axis of the section (mm),

I = moment of inertia of the section (mm^4), b = width of the element (mm)

6. POST CRACKING STAGE

The total external shear force is resisted by the internal resisting mechanism of beam element. In other words, shear transfer mechanisms are of two actions. Namely, beam action and arch action. These two actions combined to resist the external shear force. It is believed that for slender beams (shear span/effective depth ratio>2.5) the resisting action is mainly due to beam action. For short beams (shear span/effective depth ratio<2.5) the resisting action is mainly due to arch action.

7. BEAM ACTION

Beam action of element generally comprises with three factors regarding, uncracked concrete in the flexural compression zone, aggregate interlock mechanism and dowel action of longitudinal bars. Out of the three major contributory sources, aggregate interlock mechanism resists larger amount of shear force. The approximate proportion of contribution of the above three forces are shear in compression zone - 20 to 40% ,shear from dowel action 15 to 25% ,shear from aggregate interlock 35 to 50% amount of shearing forces. The contribution resisting forces towards shear is illustrated by the following figure.

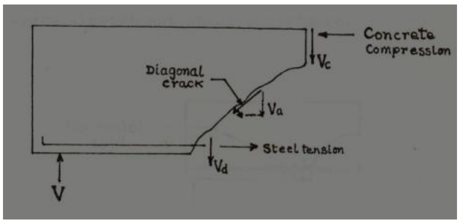

Fig-1: Shear resisting mechanism

8. ARCH ACTION

This happens when the beam is subjected to flexure-shear interaction. Flexure-shear interaction is nothing but the combination of bending moment and shear force act in a section. Due to the loading action on beam, it behaves as an arch with tie, in the flexural zone called as arch action in which the concrete acts as an arch and tension reinforcement acts as a tie able to resist more load even after diagonal cracking. This arch action generally takes more shear load in comparison with beam action.

9. FAILURE MODES

The following are the failure modes in shear of the reinforced concrete beams without transverse reinforcement. The beams may be failed in any of the following failure modes.

9.1. Splitting or compression or true shear failure

This type of failure occurs in deep beams when the shear span to effective depth of beams is less than 1.In this type, shear is transferred by a strut and tie mechanism in which tension reinforcement acts as tie and concrete acts as strut. After the formation of inclined cracking, shear is carried as an inclined thrust between the load and the reaction point and it behaves as a tied arch. The final failure becomes a splitting failure or it may fail in compression at the reaction. The analysis of such an end section is closely related to the analysis of a deep beam.

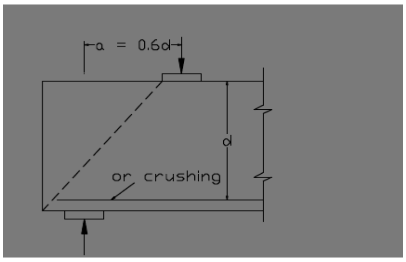

Fig-2: Splitting failure

9.2. Shear tension failure and shear compression failure

This type of failure occurs in short beams when the shear span to effective depth of beams is in the ratio of 1 to 2.5.This type failure takes place either by crushing of reduced concrete section above the tip of the crack under combined shear and compression is known as shear compression failure and secondary cracking along the tension reinforcement known as shear tension failure.

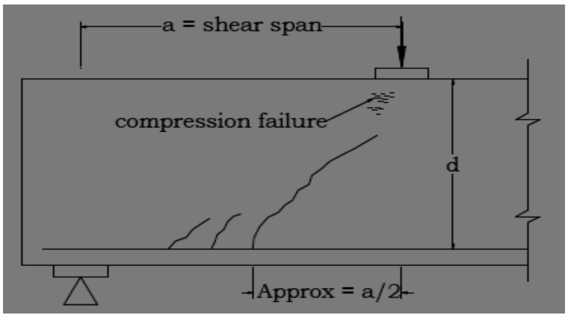

Fig-3: Shear compression failure

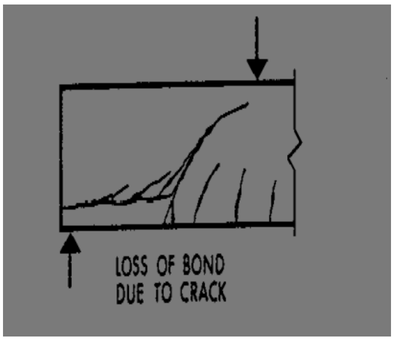

Fig- 4: Shear tension failure

9.3. Diagonal tension failure

This type of failure occurs in normal beams when the shear span to effective depth of beams is in the ratio of 2.5 to 6.Initially flexural cracks are appeared and then flexure shear cracks originates from the final flexural crack. Due to the increase in load this type of crack propagates gradually until it reaches the loading point. This type of failure crack pattern usually has greater crack width and originates either left or right end support of beam.

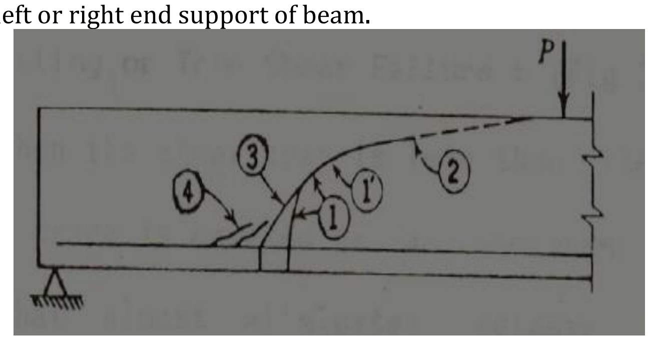

Fig-5: Diagonal tension failure

9.4. Flexural failure

This type of failure occurs in slender beams when the shear span to effective depth of beams is more than 6.In under reinforced beam the failure is started with the yielding of tension reinforcement and then crushing of concrete in the compression zone. This type of failure is termed as flexural tension failure and ductile in nature. In over reinforced beam failure occurs due to crushing of concrete in the compression zone and then yielding of tension reinforcement. This type of failure is termed as flexural compression failure and brittle in nature.

10. CONCLUSIONS

The shear force transfer mechanisms in flexural members play an important role in design of flexural members in geometrical aspect and structural aspect. The shear design provisions available in various countries still based on empirical approach. From the exhaustive study, it was clearly understood that brief research is still required in analyzing this shear phenomenon. Apart from this, the shear design provisions adopted in codes of various countries have to be formed and follow a deterministic approach. The safety should be fixed based on type of shear failures.

REFERENCES

[1] Abdul Ghaffar, Afzal Javed, Habibur Rehman, Kafeel Ahmed and Ilyas."Development of shear capacity equations for rectangular reinforced concrete beams,"PakJ.Engg& Appl.Sc., vol.6, Jan.2010,pp.1-8,

[2] ACI 318, "Building code requirements for structural concrete," ACI committee, Farmington Hills, Michigan, USA, 2007.

[3] Altaan SA, Alfeel JR. "Evaluation of shear strength of concrete beams,"Cement and Concrete composites,vol.12,pp.87-94,1990.

[4] Londhe R,"Shear strength analysis and prediction of reinforced concrete transfer beams in high-rise buildings," Structural Engineering & Mechanics, vol.37, pp.39-59,2011.

[5] Sudheer Reddy L,Ramana Rao NV, Gunneswara Rao TD,"Shear resistance of high strength concrete beams without shear reinforcement,"International Journal of Civil and Structural Engineering,vol.1,pp.101-113,2010.

[6] Vollum RL, Sagaseta J,"Influence of beam cross section, loading arrangement and aggregate type on shear strength,"Magazine of Concrete *Research*,vol.63,pp.139-155,2011.

BIOGRAPHIES

Mr.M.Sheik Mohamed is currently working as an Assistant Engineer in the Tamil Nadu Highways Department. He has totally Three and half years' experience in construction, design and teaching and his area of interest in the field Concrete Technology, Analysis of Structures and Design of Structures.

Ms.V.Kalpana is currently working as an Assistant Professor in Aalim Muhammed Salegh College of Engineering. She has totally one year experience in teaching field and her area of interest in the field of Analysis of Structures and Design of Structures.