Beam-Column Connection with Core Reinforcement and Recycled Concrete Aggregate: An Overview

Muhammed Muneer E K, Gokul Raveendran K

Abstract— This paper presents the literature review on beam-column connection with core reinforcement and recycled concrete aggregate (RCA).The presence of core reinforcement improves the load carrying capacity, the energy dissipation capacity of the joint, stiffness and the ductility factor. Using RCA in concrete preserves the environment by reducing the need for opening new aggregate quarries and decreases the amount of construction waste that goes into landfill. The properties of RCA such as specific gravity, absorption, and the amount of contaminant present in it contribute to the strength and durability of concrete. The quality of RCA depends on the features of the original aggregate and the condition of the demolished concrete. Silica fume can be used to improve the strength of RCA and to make RCA par with natural aggregate.

Index Terms—Beam-column connections, core reinforcement, ductility, stiffness, recycled concrete aggregate (RCA)

1 Introduction

Design and detailing of beam column joints in reinforced concrete frames are critical in assuring the safety of these structures in earthquakes. Such joints should be designed and detailed to preserve the integrity of the joints sufficiently to develop the ultimate strength and deformation capacities of the connecting beams and columns, preventing excessive degradation of joint stiffness under seismic loading by minimizing cracking of the joint concrete and by preventing the loss of bond between the concrete and longitudinal beam and column reinforcement and prevent brittle shear failure of the joint.

It is recognized that beam column joints can be the critical reason in RC frame design for inelastic response to severe seismic attack. As a consequence, seismic moments of opposite signs are developed in columns above and below the joints and at the same time beam moment reversal across the joints. A horizontal and vertical shear force whose magnitude is many times higher than in the adjacent beams and columns developed at the joint region.

One of the major challenges faced by civil engineering industry is to execute the work eco-friendly. In this recent era, the construction industry has grown tremendously and together producing huge amount of waste. These wastes constitute a major portion of total solid waste production in the world. Most of these are used as landfill. Due to the shortage of dumping sites and increased cost of transportation, majority of countries are facing problems in handling and disposal of such wastes. The cement concrete has been very important and best building material for all types of industrial and civil works. The materials of demolished structure have to dump somewhere and for that the freeland must be required. This procedure is very difficult and time consuming process and for that process we need to pay. To avoid this problem, we have to use that material for some useful works. If we are able to use these materials in concrete as a substitute for constituent materials, it will be a sustainable solution. Studies are carried out regarding the suitability of using RCA rather using natural coarse aggregate.

2 Beam Column Joints

In a moment resisting frame, beam-column joints are generally classified with respect to geometrical configuration and identified as interior, exterior and corner joints (Fig.1). The basic requirement of design is that the joint must be stronger than the adjoining beam or column member. It is important to see that the joint size is adequate in the early design phase; otherwise the column or beam size will have to be suitably modified to satisfy the joint shear strength or anchorage requirements. The design of beam – column joint is predominantly focused on providing joint shear strength and adequate anchorage within the joint.

The joint is defined as the portion of the column within the depth of the deepest beam that frames into the column. When four beams frame into the vertical faces of a column, the joint is called as an interior joint. When one beam frames into a vertical face of the column and two other beams frame from perpendicular directions into the joint, then the joint is called as an exterior joint. When a beam each frames into two adjacent vertical faces of a column, then the joint is called as a corner joint. The severity of forces and demands on the performance of these joints calls for greater understanding of their

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seismic behaviour. These forces develop complex mechanisms involving bond and shear within the joint.

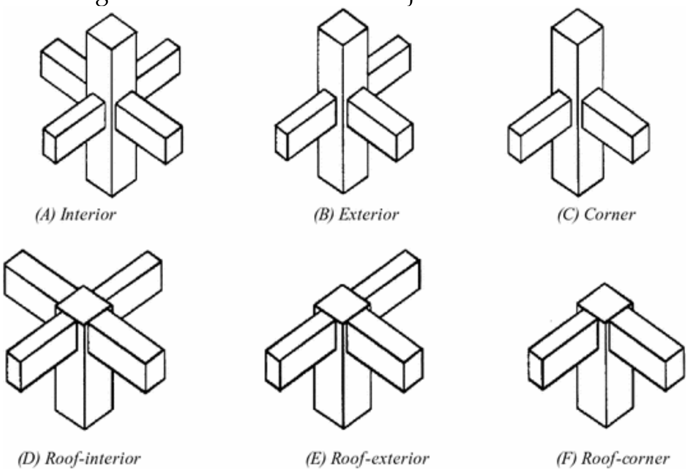

Fig 1: Types of joints

The pattern of forces acting on a joint depends upon the configuration of the joint and the type of loads acting on it. The effects of loads on the three types of joints are discussed with reference to stresses and the associated crack patterns developed in them.

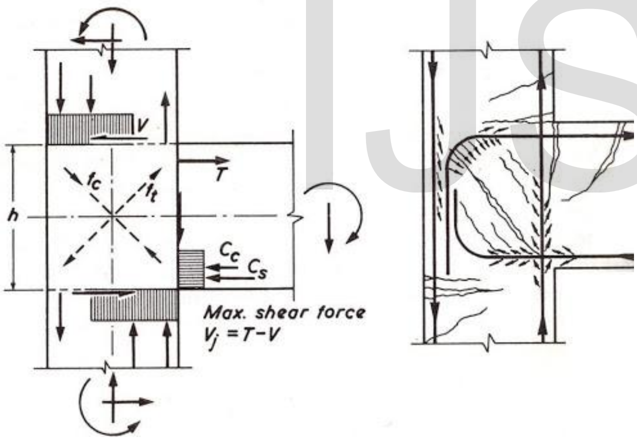

Fig 2: Forces acting on a Joint

The forces acting on an exterior joint can be idealized as shown in Fig.2. The shear force in the joint gives rise to diagonal cracks thus requiring reinforcement of the joint. The detailing patterns of longitudinal reinforcements significantly affect joint efficiency. The bars bent away from the joint core result in efficiencies of 25-40 % while those passing through and anchored in the joint core show 85- 100% efficiency. However, the stirrups have to be provided to confine the concrete core within the joint.

3 Joint Mechanisms

In the strong column-weak beam design, beams are expected to form plastic hinges at their ends and develop flexural over strength beyond the design strength. The high internal forces developed at plastic hinges cause critical bond conditions in the longitudinal reinforcing bars passing through the joint and also impose high shear demand in the joint core. The joint behavior exhibits a complex interaction between bond and shear. The bond performance of the bars anchored in a joint affects the shear resisting mechanism to a significant extent.

4 Core Reinforcement

It is a method of providing reinforcement in the core region. Based on the previous studies and guidelines of IS 456 : 2000 on lateral reinforcement, the following guidelines are used.

(a) The reinforcement shall consist of atleast 4 bars.
(b) The diameter of reinforcing bars shall not be smaller than 8 mm nor larger than 12 mm.
(c) The width and depth of core reinforcement shall preferably 0.6 to 0.8 times of B and 0.7 to 0.8 times of D respectively, where B and D are overall width and depth of beam in beam region and of column in column region.
(d) The length of core reinforcement shall preferably be 0.2 to 0.25 times of L, where L is the clear span of beam.
(e) The length of core reinforcement shall preferably be extended either sides of the column from the centre of the joint about 0.15 to 0.2 times of L1 or L2, where L1 and L2 are the clear height of column in subsequent floors.
(f) The diameter of lateral ties shall not be less than 6 mm and not greater than 8 mm.
(g) The pitch of the transverse reinforcement shall not be more than the least of the following.
  (1) The least lateral dimension of the core size
  (2) 0.5 times the pitch of column ties
  (3) 100 mm

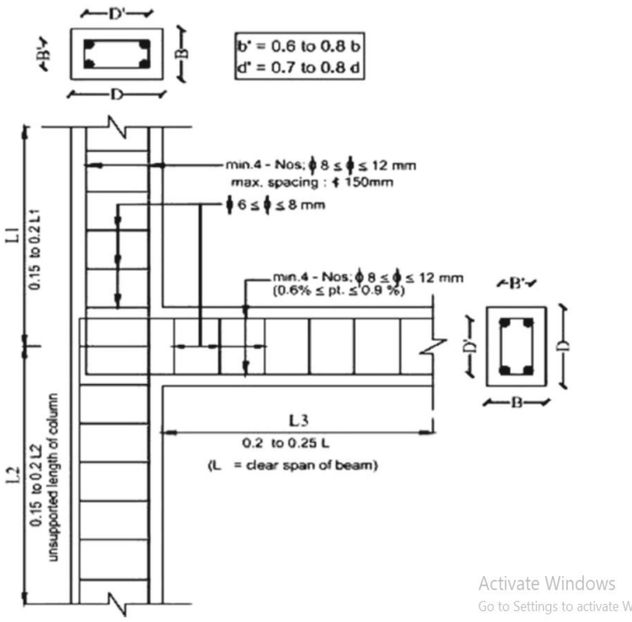

Figure 3: Beam column joint showing details of core reinforcement only

5 Recycled concrete aggregate

One of the problems associated with recycled aggregates is the adhered mortar at the surface of the RCA. This remnant of mortar responsible for the lower specific gravity, higher absorption, lower abrasion resistance of RCA as compared to natural aggregate. The removal of unwanted contaminants on RCA can be done by crushing with the appropriate type of crushers (impact crusher, cone crusher, etc.) which are effective at removing the adhered mortar on the surfaces of RCA. Washing RCA prior to the batching process is also recommended to minimize the amount of fine particles. The handling of RCA prior to the mixing process influences the quality of the batched concrete. Combined with proper mix design and batching process, the use of partially saturated to fully saturated RCA has shown to improve concrete performance relative to that of concrete batched with dry RCA.

6 Objective of the Study

This objective of this paper is to study published literatures related to the on beam-column connections with core reinforcement and effects of RCA in concrete.

7 Literature Reviews On Wide Beam Column Connections

Kaliluthin AK and S Kothandaraman [1] studied the performance of exterior beam column joint with core reinforcement technique subjected to reverse cyclic loading. In this experimental study, three sets of one-third scaled exterior beam column joint specimens using M30 grade concrete were cast and tested. The first set of specimens were detailed as ordinary moment resisting frame (IS:456 and SP:34) and designated as joint BCJ1. The second set of specimens were detailed as special moment resisting frame (IS:13920) and designated as BCJ2. In the third set, the reinforcement detailing followed in joint BCJ1 was integrated with a new type of reinforcement (called core reinforcement) proposed in this study and designated as BCJ3. Based on the experimental result, the joint BCJ3 gave the better performance considering the strength in terms of load carrying capacity, energy dissipation capacity, stiffness and ductility factor. The results of reverse cyclic loading tests performed in the exterior beam column joint models indicate that the additional core reinforcement in the beam column joint region did not undergo much reduction when compared to other types of joints.This combination of core reinforcement technique in the beam column joint region may contribute to reduction in destruction due to earthquakes.

Bo Hu and Tribikram Kundu [2] presented an experimental investigation of the seismic behaviour of various types of recycled aggregate concrete (RAC) beam column joint specimens, including three interior joints and two exterior joints, were tested under quasi-static cyclic loading and their behaviors were evaluated in terms of strength, stiffness, cumulative energy dissipation, damping ratio, and damage indexes at different load steps. The influence of joint type, column axial compression level, stirrup ratio in the joint panel, and longitudinal reinforcement ratio on the seismic performance of RAC joints was evaluated. The results indicated that strength of a RAC joint can be improved by increasing the longitudinal reinforcement ratio in its beams. Test results clearly indicated that a higher axial load on the column of a RAC joint improves its seismic performance in several aspects like cracking process. Stiffness degradation, and damage accumulation were delayed, and strength, initial stiffness, ductility, energy dissipation and viscous damping were increased.

Parekh D N and Dr. C D Modhera [3] has studied the percentage variation effect of silica fume and recycled aggregates on recycled aggregate concrete. It is well known fact that recycled aggregate is giving little lower strength than natural aggregate concrete. Hence it was necessary to improve strength of recycled aggregate concrete for higher recycled aggregate content. Silica fume was very popular material used for strength improvement. Hence popular mix of 1:1:2 was checked with different silica fume combination. 5%, 7% and 10% of silica fume were replaced with cement and 30%, 50% and 100% of recycled aggregates were replaced with natural aggregate and results were analyzed. It was found that 7% addition of silica fume to 100% RA concrete will give the same result as that of 100% NA concrete. It was observed that the presence of recycled aggregates seemed to produce lower performance levels in terms of sustained load. However, the addition of silica fume was also seen to have a beneficial effect on controlling this performance.

Kho Pin Verian et al [4] presented a review of the potential and challenge of using recycled concrete aggregate (RCA) as the substitute for natural aggregate (NA) in concrete mixtures. Multiple techniques to improve the performance of RCA concrete, reported cost savings in concrete production and recommendations regarding the application of RCA in concrete were also evaluated. The handling of RCA prior to the mixing process influences the quality of the batched concrete. Combined with proper mix design and batching process, the use of partially saturated to fully saturated RCA has shown to improve concrete performance relative to that of concrete batched with dry RCA. Also there are several ways to improve the quality of concrete containing RCA such as using saturated RCA, incorporating sufficient amounts of SCMs (i.e., FA, GGBFS, metakaolin and SF) in the mixture and performing other mixture-design modification (i.e. increasing the amount of cement, using superplasticizer to lower the w/b), coating RCA surfaces with PP, applying new ways of mixing concrete techniques (i.e., TSMA, TSMAS, TSMASC, MMA, SEMA), surface-modification technology, self-healed the RCA prior to its usage in the concrete mixture, reducing the amount of old mortar and other impurities in RCA particles, incorporating fiber into RCA concrete mixture.

Caijun Shi et al [5] conducted a review on the enhancement methods for recycled concrete aggregate and points out their advantages and disadvantages so as to facilitate the selection and further development of suitable enhancement methods for recycled concrete aggregate. It suggests that carbonation treatment is an efficient and feasible method for improving the mechanical properties and durability of recycled concrete aggregate. Carbonation treatment of recycled concrete aggregate is not only an efficient way for enhancing the properties of recycled concrete aggregate, but also an environmental friendly approach.

Huoth P et al [6] mentioned the ever increasing concrete usage and the concerns over its environmental impact because when reaching the end of the design life, concrete waste usually ends up as landfill. This creates a significant problem because of the difficulties associated with managing the increased volume of concrete waste. As a result, use of recycled concrete to replace the coarse aggregate has attracted attention as it can reduce the amount of landfill as well as requirement of virgin aggregate. Past studies have indicated some bonding issues of recycled concrete aggregate (RCA) at the interfacial transition zone (ITZ) preventing usage of material in structural concrete applications. The main objective of this investigation was to determine whether compression and flexural strength improvements could be gained with the addition of silica fume in the concrete mix. It was hypothesised that silica fume's fine particles reduced the porosity of the RCA which should result in an increased modulus of elasticity and improve the bond at the ITZ. This paper presents an experimental investigation into the effect of replacement of virgin aggregate with recycled concrete aggregate (RCA) with the addition of silica fume on the compressive and flexural strength of a blended cement concrete. Varying amounts of silica fume was used in addition to 100% coarse aggregate replacement. The investigation indicated that favourable strength results are achieved with the addition of 10% silica fume in RCA.

Ha G J and Cho C G [7] said lack of ductility in high-strength concrete members raises serious concerns for overall structural safety, especially for reinforced concrete beam column joints. In the current study, experimental research was performed to improve the seismic strength and performance of reinforced high strength concrete exterior beam column joints under cyclic load reversals. A new design approach for beam column joints was introduced using advanced reinforcement details. Specimens of reinforced high-strength concrete beam column joints were manufactured based on the new design method developed from the concept of a moving beam plastic hinge using anchor-type intermediate bars and advanced details of doubly confined closed stirrups in the beam near the joint, and tested for comparison with specimens designed using the conventional approach. The newly developed design approach minimized damage and considerably improved the structural performance of beam column joints under cyclic load reversals. The manufactured joints were expected to be effective in improving the weakness in induced by the brittleness of high-strength concrete in reinforced high-strength concrete beam column joints.

Prashant et al [8] had studied on use of recycle aggregate in SCC. In this study coarse recycled aggregate (RCA) are used in the production of selfcompacting concrete (SCC) in varying percentage replacements of natural coarse aggregate (NCA) from 0% to 100% with increment of 20%. This investigation is an attempt to examine the influence of recycled aggregate on strength, permeability, resistance to acid attack, chloride penetration, and alkalinity of self-compacting concrete. It is observed that recycled aggregate can be effectively used in the production of SCC without any significant reduction in strength and durability. This has encouraged the use of recycled aggregate in concrete which not only allows for a more efficient life cycle of natural resources but also contributes to environmental protection leading to sustainable development.

8 CONCLUSION

The literatures reveal the following conclusions.

1) There is a significant potential for growth of recycled aggregate as an appropriate and green solution for sustainable development in construction industry.
2) Concrete with 100 % RCA and 7% silica fume shows similar strength of concrete with NCA.
3) The quality of concrete with RCA can be improved by using saturated RCA, incorporating sufficient amounts of SCMs in the mixture and performing other mixture-design modification (i.e. increasing the amount of cement, using superplasticizer to lower the w/b), coating RCA surfaces with PP, applying new ways of mixing concrete techniques, etc.
4) The core reinforcement technique exhibits better performance compared to the normal ductile joint reinforcement.
5) The core reinforcement technique improves the ultimate load carrying capacity.
6) The addition of core reinforcement in the beam column joint region increases the ductility and energy dissipating capacity, the most important properties required for earthquake resistant structures.
7) The combination of core reinforcement technique in beam column joint region may contribute to reduction in destruction due to earthquakes.

ACKNOWLEDGMENT

The author wishes to thank the support given by Civil

Engineering Department of Vidya Academy of Science and Technology under A.P.J Abdul Kalam Technological University, Kerala, India.

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