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Analyitical Investigation of Exterior Beam-Column Joint Using Fiber Reinforced Concrete

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Abstract—*Beam and column where bisect is called as joint or link. The act of beam-column joints have long been recognized as a significant factor that affects the overall behaviour of Reinforced Concrete framed structures subjected to large lateral loads. The reversal of forces in beam-column joints during earthquakes may cause distress and often failure, when not designed and detailed properly. One of the methods of bracing the reinforced concrete structural members is different fibre additives can be combined with concrete to design for specific applications and optimize mechanical properties which will result in large energy absorption capacity of structural members. Fiber reinforced concrete are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear, and axial load carrying capacity of elements. Beam-column joints, being the lateral and vertical load resisting members in reinforced concrete structures are particularly vulnerable to failures during earthquakes. Hence this paper discusses structural behaviour of Beam and column Joint using normal concrete and recron fiber concrete under Static loading. begin the main text.*

Keywords: *beam-column joints, flexural, shear, recron, fiber, crack, load-displacement*

1. INTRODUCTION

During some of the past shocking earthquakes, it was established beyond doubt that beam-column joint acts as one of the weakest links in moment resisting framed RC structures. The behavior of reinforced concrete frame structures as observed during earthquakes all over the world highlighted the consequences of poor performance of beam-column joints. Further, it was observed that during earthquakes, the exterior joints had suffered more in comparison to the interior ones. The failure of beam-column joints during past earthquakes opened a new research direction in the field of strengthening of beam-column joints for enhancing seismic safety.

2. BEAM-COLUMN JOINT

Beam-column joint may be defined as the portion of the column within the depth of the deepest beam [ACI 352R-02, 2002]. In a moment resisting frame, three types of joints can be identified viz. interior joint, exterior joint and corner joint, which is shown in Fig. 1. The severity of forces and demands during earthquake on the performance of these joints needs a better understanding of their behavior. These forces develop complex mechanisms involving bond and shear within the joint. The joint region is subjected to horizontal and vertical shear forces whose magnitude is typically many times higher than in the adjacent beams and columns.

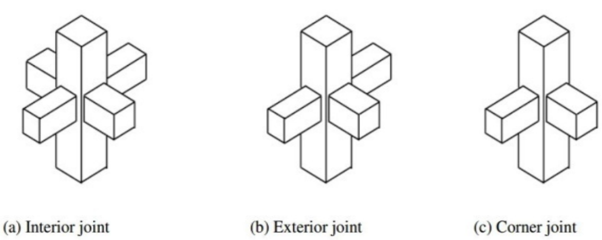

Fig. 1: Types of beam-column joints [Uma and Prasad, 2006]

3. FIBER REINFORCED CONCRETE

Concrete is well known as a brittle material when subjected to normal stresses and impact loading, especially, with its tensile strength being just one tenth of its compressive strength. It is only common knowledge that, concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses, to compensate for the lack of ductility and is also adopted to overcome high potential tensile stresses and shear stresses at critical location in a concrete member .Even though the addition of steel reinforcement significantly increases the strength of the concrete, the development of micro-cracks must be controlled to produce concrete with homogenous tensile properties. The introduction of fibers was brought into consideration, as a solution to develop concrete with enhanced flexural and tensile strength, which is a new form of binder that could combine Portland cement in bonding with cement matrices.

Fibers are generally discontinuous, randomly distributed throughout the cement matrices. Referring to the American

Concrete Institute (ACI) committee 544 , in fiber reinforced concrete there are four categories namely

1. SFRC - Steel Fiber Reinforced Concrete
2. GFRC - Glass Fiber Reinforced Concrete
3. SNFRC - Synthetic Fiber Reinforced Concrete
4. NFRC - Natural Fiber Reinforced Concrete

3.1. Recron fiber

Recron fiber is of polyester type which belongs to SNFRC group. Recron fiber was used as a secondary reinforcement material. It arrests shrinkage cracks and increases resistance to water penetration, abrasion and impact. It makes concrete homogenous and also improves the compressive strength, ductility and flexural strength together with improving the ability to absorb more energy. Use of uniformly dispersed Recron fibres reduces segregation and bleeding, resulting in a more homogeneous mix. This leads to better strength and reduced permeability which improves the durability.

4. DETAILS OF TEST SPECIMENS

In this paper, two RC beam- column connection are considered using normal concrete and recron fiber concrete under Static loading. All the specimens are identical in size and the beam sizes are 110 mm×110 mm and cross-section of the column are 130 mm×110 mm as shown in Fig.5. The length of the beam is 600 mm from the column face and the height of the column is 1100 mm.

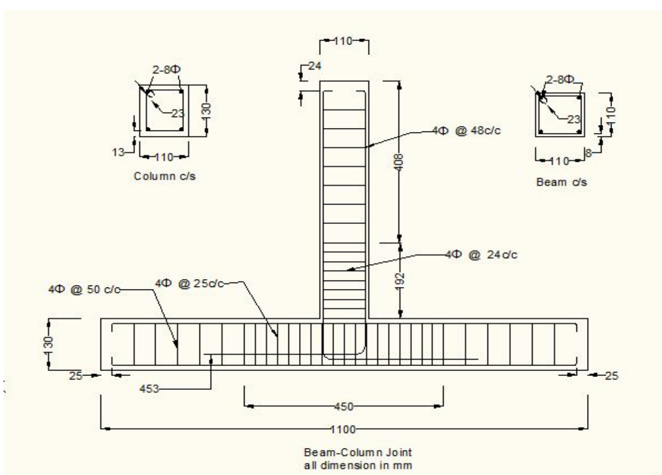

Fig. 2: Detailing of Beam-Column joint

5. NUMERICAL STUDIES

The numerical analyses on RC beam column joints with normal M30 concrete and M30 fiber reinforced concrete using the general purpose finite element software ANSYS 14.5. The study was carried out to simulate the behavior of these joints under static loading. Nonlinear static analysis was carried out for getting prior information about the load at first crack, crack pattern, load and deflection at yielding, ultimate load etc. for all the specimens in order to appropriately plan the arrangement of experimental investigation.

5.1. NONLINEAR ANALYSIS

Linear structural analysis is based on the assumption that structures undergo small deformations and the material remains elastic with linear load-displacement relationship. The analysis is performed on the initial undeformed shape of the structure. As the applied load increases raising the stress beyond elastic limit, this assumption remains no longer valid since the deformation may cause significant changes in the structural shape. This causes a change in the stiffness matrix leading to nonlinearity in structures. The nonlinearity in an RC element is mainly of two types, viz. geometric nonlinearity and material nonlinearity. Geometric nonlinearity refers to the nonlinearity in structure or component due to the changing geometry. Geometric nonlinearity may arise due to large strain, large rotation and stress stiffening. Material nonlinearities are due to the nonlinear relationship between stress and strain implying that the stress is a nonlinear function of strain. Concrete and steel are two constituents of R.C. structures. Out of these two, concrete is much stronger in compression than in tension (tensile strength is of the order of about one tenth of the compressive strength). The tensile stress–strain relationship of concrete is almost linear up to failure, while the stress-strain relationship in compression is nonlinear from the very beginning itself. Since the concrete and steel are both highly nonlinear materials, the material nonlinearity of R.C. structure is understandably complex. The nonlinear analysis of reinforced concrete structures has become very important in recent years. It is advisable to carry out a complete progressive failure analysis of the structure up to collapse to assess all safety aspects of a structure and for finding its deformational characteristics. The development of material models for uncracked and cracked concrete for all stages of loading is particularly a challenging field in nonlinear analysis of reinforced concrete structures. Since the stiffness matrix continuously changes during application of successive loads, the analysis needs to be performed by iterative methods, like direct iteration or the Newton-Raphson method.

5.2. ELEMENT TYPES

In the present FE analysis, all the structural elements were modeled using appropriate finite element from the available element library of ANSYS. Concrete was modeled by 3-D solid element. Reinforcing steel was modeled by a 3-D truss element. The next subsections discuss about all the elements used for modeling of beam-column joint.

5.2.1. SOLID65. SOLID65 is used for the 3-D modeling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete while the rebar capability is available for modeling reinforcement behavior. Other cases for which the element is also applicable would be reinforced composites (such as fiberglass), and geological materials (such as rock). The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. Up to three different rebar specifications may be defined.

The concrete element is similar to a 3-D structural solid but with the addition of special cracking and crushing capabilities. The most important aspect of this element is the treatment of nonlinear material properties. The concrete is capable of cracking (in three orthogonal directions), crushing, plastic deformation, and creep. The rebar are capable of tension and compression, but not shear. They are also capable of plastic deformation and creep.

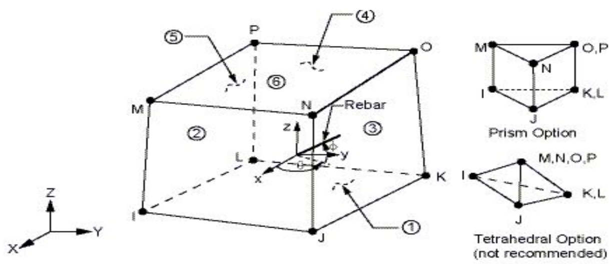

Fig. 3: SOLID65 Geometry

5.2.2. LINK180. LINK180 is a 3-D spar that is useful in a variety of engineering applications. The element can be used to model trusses, sagging cables, links, springs, and so on. The element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Tension-only (cable) and compression-only (gap) options are supported. As in a pin-jointed structure, no bending of the element is considered. Plasticity, creep, rotation, large deflection, and large strain capabilities are included.

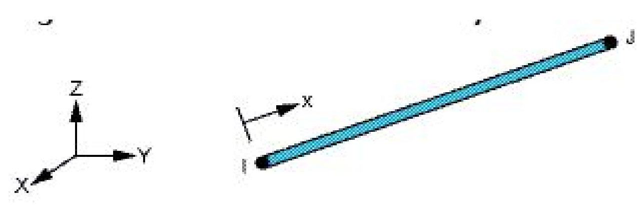

Fig. 4: LINK180 Geometry

By default, LINK180 includes stress-stiffness terms in any analysis that includes large-deflection effects. Elasticity, isotropic hardening plasticity, kinematic hardening plasticity, Hill anisotropic plasticity, Chaboche nonlinear hardening plasticity, and creep are supported. To simulate the tension-/compression-only options, a nonlinear iterative solution approach is necessary; therefore, large-deflection effects must be activated (NLGEOM,ON) prior to the solution phase of the analysis.

6. RESULTS AND DISCUSSIONS

The following comparisons are made: first cracking loads; loads at failure; crack patterns at failure; Ultimate failure load and ultimate stresses; load-deflection plots ; shown in Fig.6-Fig.12.The nonlinear analysis was carried out in ANSYS 14.5 for the same specimens with different material data is shown in Fig.5.

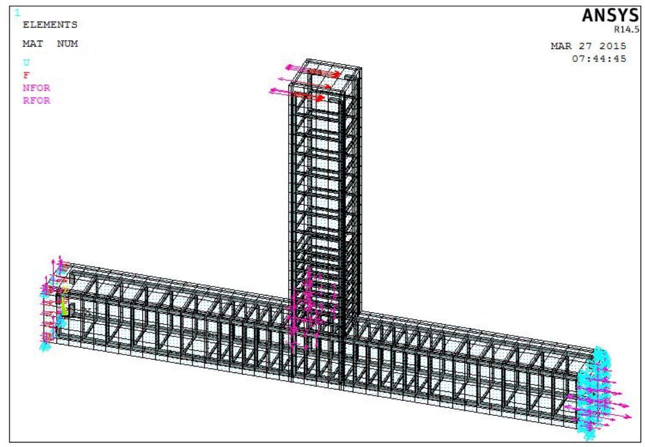

Fig. 5: Finite element model of Normal Concrete and Fiber Reinforce Concrete

Some of the representative results obtained from the analysis is presented in Fig. 6- 11. Fig. 6 shows the appearance of first flexural crack, which occurs in the beam near the beam-column joint at a load of 1543 N and displacement of about 0.55 mm at the beam tip for normal concrete. Fig. 7. shows the ultimate cracks at failure, which occurs in the beam as well as in the joint at a load of 8261 N for normal concrete. Fig.8. shows the stress contour for the same specimen. As shown in the window, "TIME" stands for the failure tip load, "DMX" for maximum deflection and "SMN" maximum bending stress at failure. The maximum deflection for the specimen normal concrete is 7.22 mm and maximum normal stress due to bending at failure is 136.303N/mm .

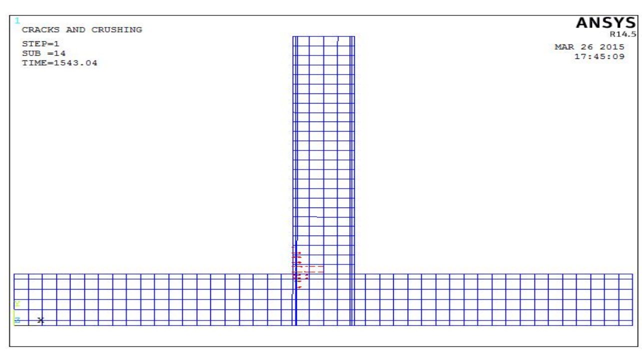

Fig. 6: First crack in Normal Concrete

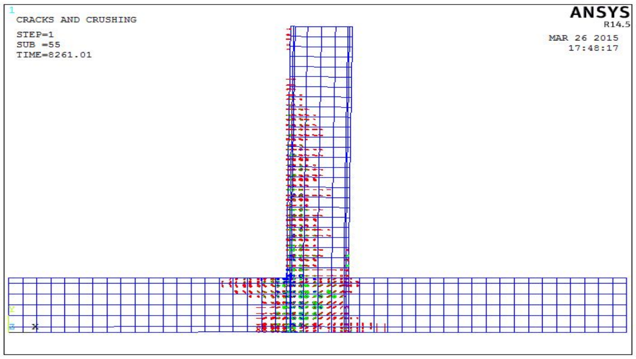

Fig. 7: Ultimate cracks for Normal Concrete

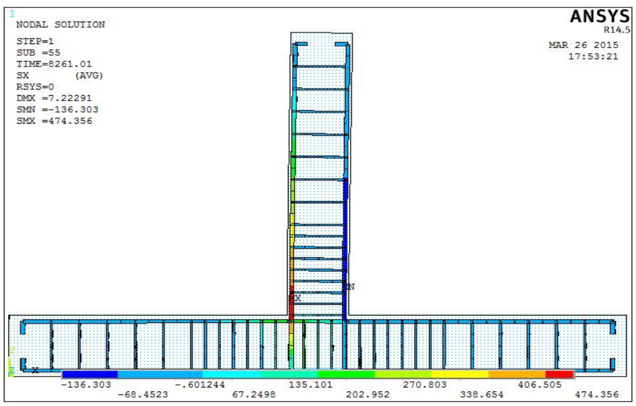

Fig. 8: Ultimate failure load and ultimate stresses for Normal Reinforced Concrete

Fig.9. shows the first flexural crack for fiber reinforced concrete, which occurs at a load of 1962.21 N and displacement of about 0.69 mm at the beam tip. Thus, due to fiber concrete, the development of first crack occurred at a higher load level in comparison to that in the corresponding normal concrete specimen. Fig.10. shows the ultimate cracks of fiber reinforcement concrete which occurs at the ultimate load of 9657.94 N. Fig. 11 shows the plot of stress contour for fiber reinforced concrete.

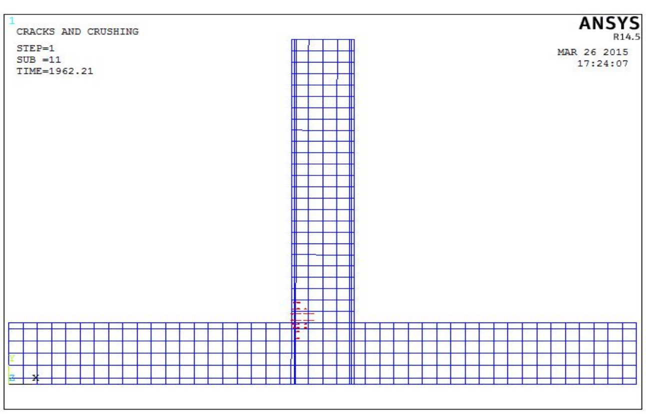

Fig. 9: First crack in Fiber Reinforced Concrete

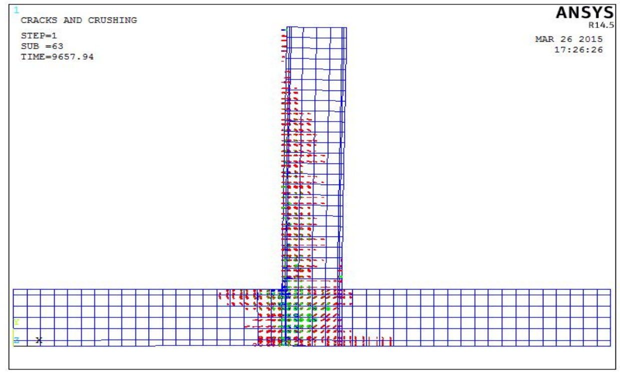

Fig. 10: Ultimate cracks for Fiber Reinforced Concrete

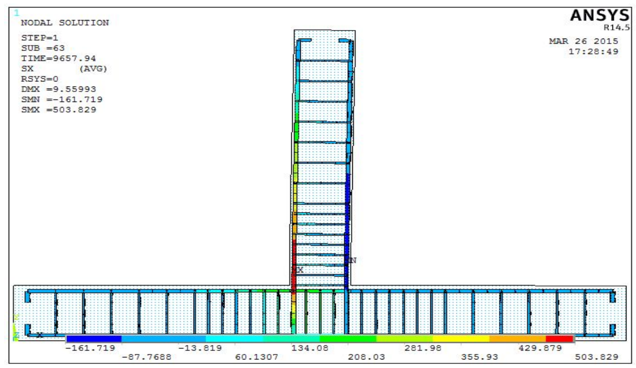

Fig. 11: Ultimate failure load and ultimate stresses for Fiber Reinforced Concrete

A typical load-displacement curve involving both normal and fiber reinforced concrete specimens is shown in Fig. 12.. It can be observed that for normal concrete at a load of 1543 N, the slope of the curve changes indicating the development of first crack. After the first crack, further increase in load leads to stiffness reduction due to the development of subsequent cracks. A substantial stiffness reduction has been observed to have taken place after the load at beam tip exceeded the load corresponding to the yielding of steel. The failure for the control specimen occurs at the load of 8261 N and at a displacement of 7.22 mm. Further, the load-displacement plot indicates that at a load of 1962.21 N, the slope of the curve changes indicating the development of first crack for fiber reinforce concrete specimen.. The failure of the Reinforce Concrete specimen occurs at a load of 9657.94 N and at a displacement of 9.559 mm. Thus, it is clear that there is substantial gain in ultimate load carrying capacity due to using fiber in concrete. The curves shown in Fig. 12 has been marked showing the first crack and ultimate load. The failure load obtained from numerical analysis for both Normal Concrete and Fiber Reinforce Concrete specimens are shown in Fig.12. The beam-column joints with beam weak in flexure and beam weak in shear were designed as strong column-weak beam. The beam was idealized as a cantilever beam for arriving at the failure tip load of the beam.

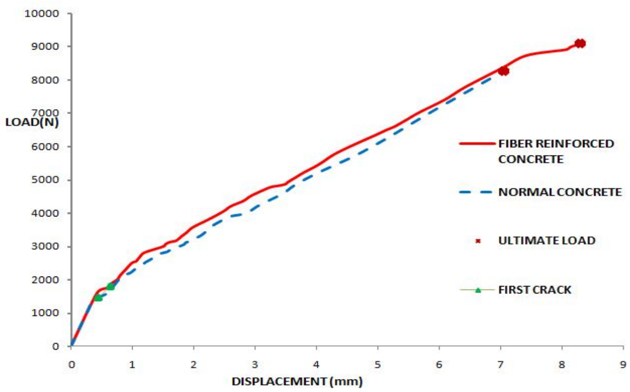

Fig. 12: Typical Load-Displacement Graph.

7. CONCLUSION

The numerical simulations were carried out for all the specimens using the general purpose finite element software ANSYS 14.5. All the elements were simulated with appropriate elements from the ANSYS 14.5 library. The results obtained for ultimate failure through numerical simulation are in agreement with those obtained by theoretical calculation based on strength criteria. The results of numerical analysis on reinforced concrete beam-column subassemblies designed for gravity load only have been presented. In addition, it can be noted that first crack and ultimate failure coming much earlier in normal concrete than fiber reinforced concrete. Fiber reinforced concrete maximum deflection and maximum bending stress at failure is much higher than the normal concrete.

Based on the interpretation of result the following major conclusion are drawn.-column joints, the following conclusions were drawn.

- The addition of fibres plays an important role for arresting, delaying and propagating of cracks.
- There was remarkable increase in load carrying capacity due to addition of fibre
- The initial stiffness for fibres specimen increased tremendously
- The energy dissipation increased considerably for fibres specimens
- The ductility increased tremendous for fibres specimens

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