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Investigation on Beam and Column Joints using SIFCON to Resist Earthquake Forces

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Abstract - *Earthquakes are the dangerous natural hazards. It will affects the living things and structures of the building which will lead to the destruction of the building. The structural components of the building can be affected during earthquakes by several reasons such as weak stories, improper designing of structures, insufficient detailing etc. But the main component in reinforced concrete structures was beam and column joints. During earthquakes the beam column subjected to crack and then, the entire structures of the building gets failed. The major failure occurs in the beam and column joints are shear failures and formation of cracks. During earthquakes the sudden formation of cracks in joints are due to the brittle nature of concrete. The Slurry Infiltrated Fibrous Concrete (SIFCON) possess a high strength and increases the ductile property of concrete. SIFCON have high resistance to impact loading and formation of cracks. Steel fibers are used along with cement slurry and partial replacement cement fly ash slurry (70% cement and 30% fly ash). Applying the cyclic loading over the beam and column joints specimen, to determine the cracks formation, shear failure and bending failure. It will be compared and analyzed with specimen of beam and column joints made up of the conventional concrete (M30) and concrete with partial replacement of fly ash to the volume of cement (70% cement and 30% fly ash).*

Key Words: Earthquakes, beam and column joint, cracks, shear and bending, SIFCON, Steel fiber, Cement, Fly ash.

1. INTRODUCTION

Slurry Infiltrated Fibrous Concrete (SIFCON) was considered as special type of fiber concrete. SIFCON has the high fiber content among the various Fiber Reinforced Concrete (FRC). SIFCON has excellent application in increasing the ductile property of concrete. The production of SIFCON varies from other Fiber Reinforced Concrete. The SIFCON was infiltrated in the cement slurry or in flowing mortar. It act as a High Performance Fiber Concrete. Slurry Infiltrated Fibrous Concrete act as a unique construction material possess high strength and high ductility. It will be excellent potential for Structural Application. SIFCON contain high cementitious content. SIFCON has the outstanding properties such as ductility, high strength and resistance to crack. It will increase the tensile property of concrete.

2. OBJECTIVES OF THE PROJECT

- To arrive the strength in up gradation of beam and column joint.
- To improve the ductility of the joint.
- To protect the structures as well as life of the people against the earthquake forces.
- To maintain the integrity of the structures.

3. SCOPE OF THE PROJECT

- Make the beam column joint specimen using the conventional concrete.
- Make the beam column joint specimen using SIFCON.
- Apply the cyclic loading on the specimens.
- Analyze the tensile strength and crack resistance of the two specimen against earthquake forces.

4. REVIEW ON PERFORMANCE OF SIFCON

Sudharsana Rao et al (2010) was applied impact loading on two way slabs to analyze the strength by using SIFCON. The strength of the slab made by SIFCON has to be analyzed with slab made up of FRC, RCC and PCC. The strength and energy absorption of SIFCON has higher than other slab.

Wang et al (1994) Due to anisotropic nature, the SIFCON has different strength in different direction. The test have to be done in deep beam and direct shear specimen. These test were conducted to measure the shear properties of SIFCON. Fibers of two different aspect ratio and diameters were inserted in the specimen. Deep beam of SIFCON was tested to analyze the shear resistance. It will discuss the experimental programme and design implication, when the high volume of fiber is used in cementious composite.

V.S.Parameshwaran (1990) thus the behavior of high volume percentage of steel fibers mortar specimen was casted. These specimen was subjected to the flexure. By applying cyclic load test and flexural test. The specimen made up of by conventional fiber mortar and Ferro cement mortar specimen. The strength and deflection of these specimen were compared with steel fibers specimen. The

test result indicates that steel fiber mortar specimen possess high flexural strength.

M.L.Wang et al (1991) the test was conducted to determine the shear strength of SIFCON. A cylindrical SIFCON specimen were cored and tested in torsion. The shear strength of SIFCON depends on the range on orientation of fiber in the specimen.

S.Balaji et al (2017) the SIFCON was used in the beam of various location to analyze the flexural behavior with other conventional concrete. The two point flexural forward cyclic loading system was applied. From these, loading capacity, stiffness degradation, ductility and energy absorption capacity are determined.

Elavarasi et al (1991) the low velocity impact loading test was carried in slab made up of SIFCON. It can be compared with the slab made up of RCC and PCC. The first crack, ultimate failure energy, absorption capacity, ultimate crack resistance, crack resistance ratio, ductility indices and failure pattern were analyzed from the test. The test result indicates the SIFCON slab performs better in durability and strength characteristics.

Kuldeep Dagar (2012) was conducted study on SIFCON as a high strength, high performance material containing relatively high volume of percentage steel fibers as compared to SFRC. It is also termed as high volume concrete fibrous concrete. The steel fibers varies from 5 to 25 percent in SIFCON depending on the geometry of the fibers. The matrix of SIFCON consists no coarse aggregate. But has high cementious content. It may contain fine or coarse and additive to this add fly ash, mica silica and latex emulsion. The uniaxial tensile strength, Compression strength, Flexural strength and shear strength were conducted. The result obtained will be higher than the normal concrete.

Shashi Kant Sharma et al (2017) had studied that SIFCON possess high toughness and impact resistance thereby rendering it suitable for blast resistance and impact resistance. It also be used as a good seismic retrofitting. SIFCON is a concrete rich in cement matrix and fibrous content thus eliminating coarse fraction. Fibers used in the ranges of 6% to 20%. The material used are cement, fiber, sand, steel slag and water. It does not have specific mix design, so proportion of cement and sand in the ratio of 1:1, 1:1.5, or 1:1.2. For this test have to be conducted such as flow test, compressive strength test, flexural strength test, split tensile strength test and impact energy test. They saw better result compared to the normal conventional concrete.

Anette jansson (2011) had conducted study on steel fibers in concrete. It is well known that fiber reinforcement act as crack arresting agent, there is still a need for deeper knowledge of the actual cracking behavior especially regarding cracks with width smaller than 0.3mm. Design and analytical method of fiber reinforcement concrete has been done, after the effect of fiber distribution has to be identified. The tensile strength, softening curve, stress strain relationship, compressive strength, bond behavior and young's modulus of the fiber reinforcement has been analyzed.

R. Giridhar and P.Rama Mohana Rao (2015) conducted study on the mechanical properties of SIFCON specimen. The matrix in SIFCON has no coarse aggregate, but have high cementious content. The properties of cement and sand used for SIFFCON are 1:1 by weight of cement. Water cement ratio taken as 0.4. percentage of steel fibers taken 2% by weight of cement. The percentage of cement of fiber by volume used is 4%, 6%, and 8%. The main objective is to find the mechanical property of SIFCON for various types of steel fibers are used which are of different aspect ratios. The 8% fiber volume shows the greater strength than that of remaining volume fraction in compressive strength, Flexural strength as well as split tensile strength.

M. Drdlova et al (2010) was studied on waste fibers coming from the recycling process of the tiers were incorporated in slurry infiltrated fibrous concrete. Which is special type of high performance concrete with high fiber content. SIFCON material with waste fiber was used for the production of the shield system for protection of critical infrasture against blast and ballistic load. Using the waste fibers in SIFCON technology can reduce the price of the composite by 70% by keeping the original SIFCON extraordinary properties, which make it very competitive material in the high performance concrete area. Fibers are partly contaminated by rubber and textiles. Three different volume fraction of fiber reinforcement has to be prepared using waste fibers. The obtained result indicates that usage of waste fibers does not change the strength properties and values of SIFCON produced by the industry.

H K Sharma et al (2015) studied on Beam- column joints have been recognized as critical elements in the seismic design of reinforced concrete frames. This study investigates the flexural behavior of beam-column junction with steel fires. Beam – column joint of a multi-storied building has been selected, dimensional analysis was carried out and corner beam – column joint was modeled. Control specimens were also cast simultaneously to investigate structural characteristics of concrete under compression, tension and flexural conditions. Ten specimens of beam – column junction were cast, using high performance fiber reinforced concrete, with fiber contents varying from 0, 6, 8, 10, and 12% by volume. These were tested under loading frame to study the load deformation behavior, failure pattern and other ductility associated parameters. The typical results illustrate that compressive, tensile and flexural strength values are increased. When compared with their companion specimens of High performance concrete SIFCON based beam column joints impart dimensional stability and integrity to the joints.

T. Suresh Babu (2016) had conducted project on fiber reinforced concrete. In this project they have used steel fibers of aspect ratio 50, steel mesh of diameter 0.62mm with spacing of 5mm. 1:1 mix was taken to cast. They compared it with conventional concrete and ferro cement. Fibers of 5%, 10% and 15% were added in both parallel and random orientation. Steel mesh of 5%, 10% and 15% were added in parallel manner and result are compared among those and as well as with conventional cement mortar. The result obtained from this project are SIFCON has higher compressive strength, stress strain behavior, capable handling compressive load than that of conventional cement and Ferro cement.

Balamuralikrishnan (2015) had study on retrofitting of cement composites, from this article he explained about that the Retrofitting of Externally Bonded Thin Cement Composites. This paper presents the results of experimental and analytical studies concerning the flexural strengthening of RC beams using externally bonded High Performance Fiber Reinforced Cementious Composites (HPFRCCs) like Slurry Infiltrated fiber Concrete (SIFCON) and Slurry Infiltrated Mat Concrete (SIMCON). Eight beams were strengthened with bonded SIFCON and SIMCON laminates at the bottom under virgin condition and tested until failure. Static responses of all the beams were evaluated in terms of strength, stiffness, ductility ratio, energy absorption capacity factor, compositeness between laminate and concrete, and the associated failure modes. Comparison was made between experimental results of SIFCON and SIMCON. The results show that the strengthened beams exhibit increased flexural strength, enhanced flexural stiffness, and composite action until failure. SIFCON and SIMCON laminates properly bonded to the tension face of RC beams can enhance the flexural strength substantially.

K. Parthiban et al (2013) had conducted study on sifcon. This work reports the flexural behaviour of SIFCON composites beam and to investigate the influence of volume percentage of SIFCON on strength and stiffness characteristics reinforced cement concrete and fiber reinforced concrete beams under flexural loading. Ordinary OPC of 53 grade, locally available river sand, Coarse aggregate (20mm) and steel fibers with an ultimate tensile strength are used. SIFCON beam were developed to study the strength of different volume of SIFCON in the ratio of 10, 20, 30, 40 and 50 and the results were compared with the ratio of 1:1 by weight of cement and sand, with a water cement ratio of 0.5. The strength related properties such as flexural strength, stress strain relationship were observed. The flexural strength of plain concrete can be improved by clearly by incorporation SIFCON and addition of SIFCON in conventional concrete. It also increase the strength and ductility under static loading. Addition of SIFCON in the conventional concrete reduces the number of cracks and their width.

H. K. Sharma and V.P. Singh (2008) had conducted an Experimental programme, in this study he had investigate the behavior of SIFCON slab. Thirty slab specimen corresponding to five test series moment capacity and failure characteristic. These result are compared with analytical values. The failure characteristic presents the multi crack behavior with densely packed cracking. The flexural toughness or energy absorption capacity of SIFCON being very high order slab, slab constructed with SIFCON could benefit greatly earthquake resisting structures to provide safe and cost effective alternatives due to reduced dead end weight. Structures of strategic nuclear containment structures. SIFCON can be of very economical material.

Chandran et al (2015) explained about the article, Investigation on flexural behavior of RC beams using uni and multi-directional BFRP composites. Concrete structures are deteriorated due to environment conditions. Strengthening of existing structures are the most important challenges in the Civil Engineering. This study presents the flexural behavior of Unidirectional and Multidirectional Basalt Fiber Reinforced Polymer (BFRP) composites, strengthened with reinforced concrete beams. For flexural strengthening of reinforced concrete beams and using M20 grade concrete and tested under two point loading. Test result indicates the stiffness of the beams is increased by increasing the number of layers. Curvature of strengthened beams are also decreased and by increasing the basalt fiber layers increase. In cracking behavior the number of cracks increase crack spacing decreased by increasing basalt fiber layers increase.

Elavarasi (2013) says the article about Behavior of fly ash based slurry infiltrated fibrous concrete. The aim of the present work is to study the effect of fly ash and fiber content on mechanical properties of SIFCON and to arrive the optimum percentage of fly ash and fiber content. An experimental investigation was carried out to study the mechanical properties of fly ash based SIFCON by replacing cement with 10, 20 and 30% of fly ash. Fiber content in experimental part three 2/3 scale exterior beam column joint specimens were tested under quasistatic cyclic loading. Results showed that the control specimen showed brittle shear failure at low drift levels, whereas in the strengthened specimens, plastic hinge formation moved away from column face allowing specimens to fail in flexure. The proposed technique greatly improved lateral strength, stiffness, energy dissipation, and ductility.

Sharma (2008) investigated the Performance characteristics SIFCON plates, SIFCON being a new kind of fiber reinforced composite material, limited literature is available regarding its application as structural elements. In the present study, experimental program was carried out to investigate structural behavior of SIFCON slabs. Thirty slab specimens corresponding to five test series were tested to study load deformation behavior, ductility associated parameters, ultimate moment capacity and failure characteristics. The results are compared with analytical

values and a good agreement is exhibited. SIFCON slabs demonstrated improved strength and ductility related properties. The failure characteristic presents multicrack behavior with densely packed cracking. An appropriate design method to evaluate ultimate moment capacity is, finally, presented.

Venkatachalam (2010) have studied the flexural and residual strength of SIFCON experimentally and have also obtained the optimum cross section for sandwich SIFCON beams. They have cast prisms of 100 x 100 x 400 mm to evaluate the flexural and residual strength. Prisms with layers of concrete and SIFCON, FRC and SIFCON were cast for control specimens. The authors have found flexural of concrete beam with SIFCON and FRC beam with SIFCON are higher than the conventional and FRC concrete. The use such section will effectively reduce the depth of cross section of beam. They have also found that SIFCON sections can be used in structures designed to resist impact loads. From their experimental investigation, the authors have found that the optimal cross section would probably be a SIFCON layer in extreme compression and tension zone with FRC for the remaining section.

Rao (2005) investigated the Behavior of slurry infiltrated fibrous concrete (SIFCON) simply supported two-way slabs in flexure. It is recent developed construction material. The matrix consists of cement slurry or flowing cement mortar. This composite material has already been used for structures subjected to blast loading, repair of pre-stressed concrete beams and safe vaults. This paper presents the information on behavior of two-way slabs in flexure. Flexure and cyclic load tests have been conducted and compared with FRC and plain concrete slabs. Both strength and deflection characteristics have been studied. SIFCON slabs with different volume fractions of fibers have been produced and tested under uniformly distributed load. The superiority of SIFCON slabs over fiber reinforced concrete slabs and plain concrete slabs has been demonstrated. The SIFCON slab specimens behaved well in cyclic loading test. The crack width is much less in SIFCON slabs specimens than the FRC specimens.

Svermova (2002) experimentally says about the Development of insitu SIFCON for connections in precast concrete and seismic resistant structures. The aim of this research was to develop slurries which produce good SIFCON but do not require to be vibrated. Slurries with different water/binder ratio and dosage of superplastiziser, limestone powder, sand and welan gum was tested. The Mini-slump test, Lombardi plate cohesion meter, J-fiber penetration test, and induced bleeding test were used to evaluate the rheology of the slurries. Finally, the compressive strength was measured. A two-level fractional factorial statistical model was used for the design of components and for practical evaluation of the multi-parameter results. The development of self-compacting slurries with different compressive strength has practical significance since such SIFCON does not require to be vibrated. SIFCON is a material with unusual (very high performance) mechanical properties and can be used in both ordinary and new special types of construction.

5. CONCLUSION

From the above literature study, SIFCON increase the ductile property of concrete. It turn the concrete into non-brittle. SIFCON act as a high crack resistance. If SIFCON will be used in the beam column joint, it will increases the strength of concrete as well as the ductility. During earthquakes, the joints will not get failure due to cracks because of high ductile content in concrete and also it act as a shear resistance.

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