International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 10 Ver V || Oct 2018 || PP 56-61

Current State Of Fibre Rein forced Self-Compacting Concrete

Elizabeth George[1], A K Verma[2], Shalini R George[3]
Associate Prof., Structural Engg dept., B.V.M. Engg College, V.V.Nagar, Anand, Gujarat, India-388120,
Prof. & Head of Structural Engg Dept, B.V.M. Engg College, V.V.Nagar, Anand, Gujarat, India-388120,
UG Student, Civil Engg dept., ADIT Engg College, New V.V.Nagar, Anand, Gujarat, India-388120
Corresponding Author: Elizabeth George

Abstract:*The relative compressive strength of concrete is high and tensile strength is low is a well-known fact, which provoked a host of investigations to circumvent the problems created by the low tensile strength. The presence of micro cracks hastened the relatively faster failure of concrete and researchers have been relentlessly working on this issue and came up with solutions like putting in fibers along with main reinforcement, whether natural or manufactured. The distributed fibres act as a bridge between micro-cracks leading to the improved mechanical properties such as ductility, impact strength, toughness, tensile strength and fatigue resistance. Moreover, the development of self-compacting concreter has enhanced the flowablity of concrete at all nukes and corners. A combination of FRC and SCC has created a composite known as FRSCC to annihilate the negativities of both.*

Key words: *FRC, SCC, FRSCC, micro-cracks, fibres, flowability*

Date of Submission: 12-11-2018 Date of acceptance: 26-11-2018

I. Introduction

Fibre reinforced concrete (FRC), though capable of having better flexural properties, lacks in fillablity which is taken cares of by the self-compacting concrete (SCC). So, the development of Fibre Reinforced Self Compacting Concrete (FRSCC) is a boon to construction industries struggling with the problems like fillability, higher flexural strength, durability, etc. this works brings out what has been investigated so far. Hybradization of fibres would be advantageous for improving the overall properties of concrete, wherein one type of fibre which is smaller for bridge the micro-cracks and the larger second type of fibre which is longer can arrest propagation of macro-cracks leading to enhanced toughness [1]

II. Published Work

Malhotra, et al [2] showed that polypropylene fiber reinforced, high-volume fly ash concrete has satisfactory workability, strength characteristics, very low permeability, low drying shrinkage, adequate ductility, and toughness characteristics.

Rossi [3] had shown that the minimum percentage of steel fibers needed is around 1 percent by volume and as the quantity of the cement paste and water-cement ratio (w/c) increases the compressive and uniaxial tensile strengths decrease compared to those of a normal concrete

Shin, et al [4], found that steel fiber reinforced high-strength concrete beams effectively resist abrupt shear failure. Tan, et al [5] had found that inclusion of fibers enhanced cracking load and the beam stiffness, as well as the creep and shrinkage restraints.

Coconut fibres provide excellent reinforcement for polymer concrete, increasing the fracture and flexural results [6]. Beneficial effects have been observed in reinforced engineered cementitious Composite members compared to conventional reinforced concrete [7]. External reinforcement of concrete beams without stirrups using epoxy bonded carbon fibre-reinforced-polymer sheets and strips could effectively be used as external torsional reinforcement [8]. Use of fibre-reinforced polymers as re-bars in reinforced concrete elements prevents corrosion effects that reduce the service life of members that use steel reinforcement [9].

The properties of SCC like flowability and high resistance to segregation can be effectively used to ensure filling of the heavily reinforced areas apart from elimination the need for vibration along with reduced resource and maintenance requirements [10, 11].

Okamura et al [12], has proposed that SCC can be prepared by fixing the coarse aggregate 50% of the concrete volume and sand 40% of the mortar volume and then manipulate the water/powder ratio and super plasticizer dosage so that self-compactability can be achieved easily.

Khayat et al [13] investigated the workability requirements needed to secure self- consolidation along with field-oriented tests that can be used to evaluate deformability, filling capacity, and stability of SCC.

Zoran et al [14], investigated the properties of SCC with additives like fly ash, silica fumes, hydraulic lime and a mixture of fly ash and hydraulic lime and found that the addition of fly ash to the mixture containing hydraulic lime is brings in substantial improvement in the behaviour of SCC.

Sri Ravindrarajah R. [15] investigated the effect of varying dosage of high-performance super-plasticizer on the properties of flowing concrete (465 kg/m^3) as well as self-compacting concrete (350 and 135 kg/m^3 of cement and fly ash) mixes namely workability, bleeding capacity, segregation potential, compressive and tensile strengths, and drying shrinkage. The mix compositions and superplasticizer dosage influenced drying shrinkage significantly.

Pai BHV et al [16] investigated the possibility of using Ground Granulated Blast furnace Slag (GGBS) and Silica fumes (SF) in preparation of SCC and is evaluated in terms of self- compactability, compressive strength, split tensile strength and flexural strength.

Hazrina Ahmad et al [17], suggested circumventing the lacunas of placing of reinforcement as well as compaction of normally vibrated concrete through the use of Steel Fibre Reinforced Self-compacting Concrete (SFRSC) and found steel fibres enhances the hardened properties of self-compacting concrete

Steffen Grunewald et al [18] compared the workability of plain SCC and SCC with steel fibres. Tests used to evaluate fresh characteristics were slump flow, fiber funnel and the J-ring.

The effect of steel fibres on the strength and behaviour of self-compacting concrete on flexural elements as well as durability aspects of fibre reinforced SCC was studied by Ganesan, et al [19,20] and found that the optimum volume fraction of fibres for better performance is 0.5% for aspect ratios 15 and 35.

Linerato Ferrara, et al [21] worked on the influence of fibres on grading of solid skeleton minimum content and rheological properties of paste required to achieve the required self-compactability and rheological stability by conducting test on plane and fibre reinforced concrete for various mix compositions.

A study by Mustafa et al [22], concluded that high-volume coarse fly ash can be used to produce fibre reinforced self-compacting concrete, though high fly ash compromised the strength slightly. The fly ash used did not meet the fineness requirements of ASTM C 618.

Mustafa et al [23], investigated the workability of hybrid fibre reinforced self-compacting concrete (HFR-SCC) as a function of fibre volume, length, and aspect ratios of the fibres, using two different types of steel fibres.

Osman General, et al [24] discussed how steel fibres enhance the toughness of hardened concrete significantly apart from arresting the crack propagation. Fibre reduces flowability but proportionately enhances toughness.

Chih-Ta Tsai, et al [25] worked on steel fibre reinforced self-compacting concrete (SFRSCC). The conclusions drawn are: (i) the SFRSCC designed by the densified mixture design algorithm (DMDA) method reduces the entanglement or balling problem of fibres. In order to have high flowing capability, the content of steel fibre should not be greater than 0.5% for normal weight SFRSCC made with crushed coarse aggregate. (ii) Higher fibre content increased compressive strength, flexural strength, abrasion resistance, and fibre crack-control effect. (3) Combination of steel fibre and pozzolanic material improves the bonding strength. (4) The range of electrical resistivity as well as the level of chloride ion permeability has remained in the passive range.

Cunha VMCF, et al [26] examined the complex behaviour of a self-compacting concrete reinforced with two hooked ends steel fibre contents both numerically as well as experimentally. They found that a linear trend exists between the number of effective fibres and both the stress and energy dissipation. The interface behaviour of steel fibres was obtained from single fibre pull-out tests.

Pereira, et al [27] investigated the tensile behaviour of self-compacting concrete (SCC) reinforced with two distinct hooked ends steel fibre contents (30 and 45 kg/m^3) was characterized by performing displacement controlled tensile tests and found that a linear relationship exists between the post-cracking parameters and the number of effective fibres. Predominant failure mode of the fibres was fibre pull out. They developed a stress-crack opening relationships from the stress- displacement curves.

Oucief H, et al [28] discussed about hardened properties of hybrid fibre reinforced self-compacting concrete and found it to be promising. They found that hybridization can enhance overall properties of SCC as well as a performance synergy. Control, single, two fibres hybrid composites were cast using different fibre type steel and polypropylene with different sizes and tested for flexural toughness tests. They used fibres of 30mm and 20 mm long. Hybrids based on steel fibres (20 mm) long and polypropylene fibres demonstrated some synergy. More over found that the short fibre is clearly far more effective in producing synergy in hybrids than the length fibre.

Torrijos MC et al [29] analysed the mesostructural homogeneity of plain and SFRSCC to be used in slender elements of considerable height, avoiding the use of conventional reinforcement. They measured rheological properties and self-compactability through tests. In the hardened state studies at the mesostructural level include analysis of the distribution of the coarse aggregate and fibres along the height of the columns, measure of modulus of elasticity, compressive strength and ultrasonic pulse velocity.

Hemant B. Dhonde et al [30], worked on fresh and hardened properties of self-compacting fibre reinforced concrete (SCFRC), by adding steel fibres to enhance the tensile and shear resistance of the traditional fibre reinforced concrete, compromising the workability. The optimum fibre content to meet the workability requirements of the SCFRC mix was found to be suitable for application to the end regions of I-beams. Optimum fibre contents for SCFRC mixes used were: 1 % by volume of hooked short steel fibres (1.2 inch long) or 0.5 % by volume of hooked long steel fibres (2.4 inch long). Higher coarse aggregate / fine aggregate ratio reduces the filling ability and deformability of SCC, however, addition of VMA to concrete can ensure self- compacting capability. SCC with reasonable self-consolidation, without influencing the slump flow, could be possible using hooked short steel fibres (L= 30 mm), whereas, hooked long steel fibres (L= 60 mm) adversely influence filling.

Aly M. Said et al [31], investigated behaviour of beam-column joints cast using self-consolidating concrete under reversed cyclic loading wherein authors have cast full scale 3 m high beam-column joints as per the Canadian standards CSA A23.3-94 & ACI 352R-02. For comparison, specimen of theses joints was made with normal concrete as well as SCC and was tested under cyclic load applied at the beam tip. They found that the beam-column joint of SCC have similar load carrying capacity to that of normal concrete joints up to a certain ductility level. The lower aggregate content in SCC is attributed to a different behaviour at high ductility level.

Kabir Shakya, et al [32] examined the application of steel fibres in beam–column joints of rigid-framed railway bridges to reduce longitudinal and shear re-bars. Authors investigated the effect of reducing steel re-bars in beam-column joints and use of steel fibre reinforced concrete. A control specimen was prepared following the structural design of existing railway bridge in Japan and three more specimens with reduced longitudinal re-bars (27%) and hoops in column (29.2%) were prepared. Volume fractions of steel fibres used were 0%, 1% and 1.5%. They concluded that when 1.5% steel fibres were added to the concrete, the number of crack formation in beam-column joint was decreased to a great extent.

Ganesan N, et al [33] investigated the behaviour of hybrid fibre reinforced concrete beam–column joints under reverse cyclic loads. The grade of concrete was M-60 and designed using modified ACI method. In this study total 12 beam-column joints with reinforcement were casted. In this study crimped steel fibres and polypropylene fibres in hybrid form were used. Volume fractions of crimped steel fibres were 0.5% and 1% and that of polypropylene fibres were 0.1%, 0.15% and 0.2%. The beam-column joint made from Hybrid Fibre Reinforced High Performance Concrete (HFRHPC) showed a significant increase in ultimate strength and first crack strength. It is possible to reduce the congestion of steel reinforcement in beam-column joints by using HFRHPC. With 1% steel fibres and 0.15% polypropylene fibres energy absorption capacity and displacement ductility factor increased by 3.6 times and 3.1 times respectively.

Alireza Khaloo, et al [34] investigated the mechanical performance of self-compacting concrete reinforced with steel fibres. They studied the effect of steel fibres on rheological properties, compressive strength, splitting tensile strength, flexural strength and flexural toughness. Volume fractions of steel fibres used were 0.5%, 1%, 1.5% and 2%. M-40 and M-60 grade concrete were designed. They determined rheological properties by slump flow test, L-box test, V-funnel test. They concluded that workability of SCC is decreased by adding steel fibres as well as compressive strength of SCC is also decreased by adding steel fibres.

Mohammed Alias Yusof, et al [35] investigated on the mechanical Properties of Hybrid Steel Fibre Reinforced Concrete with Different Aspect Ratio. They studied the mechanical properties of fresh and hardened state hybrid steel fibre reinforced concrete. The fibres were used of 30 mm (aspect ratio = 40) and 60 mm (aspect ratio = 80). Volume fractions of fibres were 0.5%, 1.0%, 1.5%, 2.0%. It has been found that at volume fraction 1.5% (70% long fibres and 30% short fibres) the hybrid steel reinforced concrete gave the highest flexural strength and split tensile strength. At volume fraction 1.5% (30% long fibres and 70% short fibres) the compressive strength attains maximum value. They have also observed that workability of concrete mix will reduced by increasing the percentage of fibre in the mix.

Ramadevi K et al [36] investigated the behaviour RC beam structurers strengthened by hybrid-fibre reinforced concrete. Fibres used are polypropylene and crimped steel up to 2% by volume of concrete. Compared to the controlled specimen, the ultimate deflection of HFRC beam was found to be more.

Liu, Cong [37] investigated the seismic behaviour failure modes of beam-column joint assemblies reinforced with steel fibres. He has developed a simplified procedure to evaluate the joint-shear contribution provided by different amount of steel fibres with and without the presence of stirrups. Moreover, it has been found that by using 1% by volume steel fibres significantly reduce the lateral reinforcement in the beam. Steel fibres in the joint enhance the capability of energy dissipation and can retain high level of moment carrying capacity even after high intensity cyclic loading.

Gustavo J Parra Montesano's et al [38] studied the feasibility of using high performance fibre reinforced composite as a means to eliminate need for confinement reinforcement in beam-column connections subjected to earth quake induced loading. They have concluded that the beam-column connections constructed with HPFRCC material containing 1.5% volume fraction of ultrahigh molecular weight polyethylene fibres exhibited excellent strength, deformation capacity and damage tolerance.

Ganesan N, et al [39] describes the experimental results of SFRHPC exterior beam-column joint subjected to cyclic loading for fibre volume fraction varying between 0 to 1%. They have concluded that these joints can undergo large displacements without developing wider cracks compared to HPC joints.

Perumal et al [40] investigated the effect of different proportions of hybrid fibre combinations (1.5% of steel fibre and 0 to 0.4% of polypropylene fibre) at beam-column joint. It has been observed that mix with 1.5% steel fibre and 0.2% of polypropylene fibre exhibited maximum strength deformation capacity, energy dissipation capacity and minimum damage.

Liberto Ferrara et al [41] tried to have correlation among fresh state performance, fibre dispersion and hardened state properties of SCC at the industry level. They found that superior mechanical performance of FRSCC in a cost effective way is possible through the dispersion and the orientation of fibres in concreter through a suitably balanced set of fresh state properties and a carefully designed casting procedure.

Mazaheripour H ET AL [42] investigated the effect of polypropylene fibres on LLSCC and found that when SCC was lightened to 75% of their normal weight, their fresh properties are affected immensely. Polypropylene fibre did not influence the compressive strength and elastic modulus. However, the tensile strength and flexural strength are enhanced.

Burcu Akcay et al [43] examined the effects of fibre dispersion on mechanical properties of SCC. They investigated the workability using three types of steel fibres in two volume fractions and found that mechanical properties of SCC can be enhanced with homogenous distribution of fibres.

Orbe A et al [44] worked on the structural application of SFRC. Various fibres were studied to find the suitable fibre. Steel fibre reinforced self-compacting concrete mix was designed for improved performance. A relationship between magnetic and mechanical properties were established in order to predict the softening and hardening in flexural behaviour of the composite.

Morteza H Begi etal [45] investigated the combined effect of fibers and nanosilica on SCC. They had tested and compared the mechanical, rheological and durability properties. They found that nanosilica and fibres can improve the mechanical properties and durability of SCC. Microstructural properties were studied using AFM and XRD

Amin Abrishambaf et al [46] studied the influence of the fibre distribution and orientation on the post-cracking behaviour of steel fibre reinforced SCC. Post cracking behaviour was assessed by both splitting tensile tests and uniaxial tensile tests. They found that the splitting tensile test overestimated the post-cracking parameters.

Pajak M et al [47] studied the flexural behaviour of SCC reinforced with straight and hooked end steel fibres at levels of 0.5%, 1% and 1.5% and compared it with normally vibrated concrete. They proposed a deflection-CMOD (crack mouth opening displacement) relationship for SFRSCC.

Mazaheripour H, et al [48] investigated the GFRP-concrete bond behaviour to formulate sound design equations because the currently available bond laws of conventional steel bars cannot be used. Thirty six pull out bending tests were carried out to evaluate the bond performance between GFRP bars and steel fibre reinforced SCC. SFRSCC cover and bond length paid an important role on the bond strength.

Ponikiewski Tomasz et al [49] investigated the effect the method of forming of beam elements has on the distribution of steel fibres. They have experimented on beams cast with dimensions 120×15×15 cm^3 and 180×15×15 cm^3. The self-compacting mixture contained steel fibres of varying lengths (35 and 50 mm) and varying levels of their volume ratio in the mix (0.5% - 1.0% - 1.5%). They had used computed tomography for 2D and 3D images for distribution of fibres throughout the internal volume of the concrete.

Youok Setyo Hadiwidodo et al [50] applied Taguchi method in SCC freshened property studies. They found that Taguchi method is a promising approach to optimize mix proportions to meet the freshened properties of SCC.

Arabi NS Alqadi et al [51] examined the influence of cement content, water to powder ratio, fly ash content and superplasticizer on compressive strength of SCC using contrast constant factorial design and response surface methodology. They found that the above mentioned variables as well as their interactions influence compressive strength.

Wu-Jian Long et al [52] tried to model the effect of mixture parameters and material properties on the hardened properties of pre-stressed self-compacting concrete and to identify the relative significance of the primary parameters and their interactions in terms of the mechanical and visco-elastic properties of SCC

Wu-Jian Long, et al [53], investigated the effect of chloride penetration of hybrid fibre reinforced self-compacting concrete (SCC). They found that the chloride penetration resistance of concrete can be improved by single incorporation of either carbon or cellulose fibres. They used the orthogonal array for planning the experiment.

Athiyamaan V, et al [54] discussed the use of statistical approaches like DOE is used in optimizing the concrete performance. Statistical models could be developed to create predictive models to select optimal combination of various parameters to meet the objectives.

III. Conclusion

Literature survey conducted establishes that many researchers have developed SCC and evaluated various properties of it, attributing to its properties to ensure filling of the regions otherwise difficult to fill with normal concrete.

Further, investigators studied the effect of addition of various fibres on different properties of normal concrete, whereas few researchers have attempted the same with SCC. They found that addition of fibres in to SCC improves hardened properties of it.

However, the investigation of one of the most critical area of concrete structures, namely beam-column joint, especially using SCC with fibres is not much ventured into. This investigation is imperative looking into the susceptibility of RCC structurers, particularly joints to failure under seismic loading conditions. Such loading situation demands the structure to have high ductility ratios and able to absorb as much as energy as possible after the initiation of yielding. The structures ductility ratio as well as the ability to absorb energy is enhanced by the addition of short and long fibres into SCC, which in turn will prevent catastrophic failure of joints of the structurers.

Reference:

[1]. Alp Eren Yurtseven, Determination of Mechanical Properties of Hybrid Reinforced Concrete. Int. J. of Applied Research 2004; 13(2):12-36

[2]. Malhotra VM, Garette GG, and Bilodeau A. Mechanical Properties and Durability of Polypropylene Fiber Reinforced High-volume fly ash Concrete for Shotcrete Applications. ACI Materials Journal 1994; 91(Pt 5): 478-486.

[3]. Rossi P. Steel Fibre Reinforced Concretes (SFRC): an Example of French Research. ACI Materials Journal 1994; 91(Pt 3):273-279

[4]. Shin SW, Oh JG, Ghosh SK. Shear Behavior Of Laboratory-Sized High Strength Concrete Beams Reinforced With Bars And Steel Fibers in Fiber Reinforced Concrete: Developments and Innovations; Papers presented at the ACI Conventions in Boston, March 191, and in Dallas, November 1991; Ed. by James I. Daniel, Surendra P. Shah; American Concrete Institute, Detroit, MI, 1994 (ACI SP-142):181-200.

[5]. Tan KH, Paramasivam P, Tan KC. Instantaneous and Long-Term Deflections Of Steel Fiber Reinforced Concrete Beams. ACI Structural Journal, 1994; 91 (Pt4):384-393.

[6]. Reis JML. Fracture and flexural characteristics of natural fibre-reinforced concrete. Construction and Building Materials 2006; 20: 673-678.

[7]. Fischer G, Victor C. Li. Effect of fibre reinforcement on the response of structural members. Engineering Fracture Mechanics 2007; 74:258- 272.

[8]. Chalioris CE. Torsional Strengthening of Rectangular and Flanged Beams Using Carbon Fibre-reinforced-polymers – Experimental study. Construction and Building Materials 2008; 22(Pt 1):21-29.

[9]. Francesca Ceroni, Edoardo Cosenza, Manfredi Gateano. Durability issues of re-bars in reinforced concrete members, Marisa Pecce, Cement & Concrete Composites 2006; 28:857-868.

[10]. Ouchi, M. State-of-the-art report on self-compactability evaluation. Proceedings of the international workshop on self-compacting Concrete 1999, Kochi, Japan.

[11]. The European Guidelines for Self-Compacting Concrete Specification, Production and Use, SCC European Project Group 2005.

[12]. Okamura, H. Ozawa, K. Mix design for self-compacting concrete, Concrete Library of JSCE 1995; 25: 107-120.

[13]. Khayat KH. Workability, testing, and performance of self-consolidating concrete. ACI materials journal 1999; 96(3): 346-353

[14]. Zoran Grdic, Iva Despotovic, Gordana Toplicic Curcic. Properties of self- compacting concrete with different types of additives. Architecture and Civil Engineering 2008; 6(2):173-177.

[15]. Sri Ravindrarajah R. Development of high strength self-compacting concrete with reduced segregation potential. 3rd International RILEM Symposium, Reykjavik, Iceland, August 2003.

[16]. Pai BHV, Nandy M, Krishnamoorthy A, Pramukh Ganapathy C. Experimental Study on Self-compacting Concrete Containing Industrial By-Products. European Scientific Journal 2014; 10(12): 292-300.

[17]. Hazrina Ahmad, Mohd Hisbany Mohd Hashim, Siti Hawa Hamzah, Afidah Abu Baka, Steel Fibre Reinforced Self-Compacting Concrete (SFRSC) performance in slab application: A review. AIP Conference Proceedings 1774, 030024 (2016)

[18]. Steffen Grunewald, Joost C Walraven, Parameter-study on the influence of steel fibres and coarse aggregate content on the fresh properties of self-compacting concrete. Cement and Concrete Research 2001; 31(12):1793-1798.

[19]. Ganesan N, Indira PV, Santhoshkumar PT, Ultimate strength of steel fibre reinforced self-compacting concrete structural elements. The Indian Concrete Journal 2006; 8-15.

[20]. Ganesan N, Indira PV, Santhoshkumar PT, Durability aspect of steel fibre reinforced SCC, The Indian Concrete Journal 2006; 31-37.

[21]. Linerato Ferrara, Yon Dong Park, Surendra P Shah, A method for mix-design of fibre-reinforced self-compacting concrete. Cement and Concrete Reseearch 2007; 37(6): 957-971.

[22]. Mustafa Sahmaran I, Ozgur Yaman. Hybrid Fibre Reinforced Self-Compacting Concrete with a high-volume coarse fly ash, Construction and Building Materials 2007; 21: 150-156.

[23]. Mustafa Sahmaran, Alperen Yurtseven, Ozgur Yaman I. Workability of hybrid fiber reinforced self-compacting concrete. Building and Environment 2005; 40(12): 1672-1677.

[24]. Osman General, Witold Brostow, tea Dtashvili b and Michel Thedford, Workability and Mechanical Performance of Steel fibre-Reinforced Self-Compacting Concrete with Fly Ash, Composite Interfaces 2011; 18: 169-184, Tailor & Francis

[25]. Chih-Ta Tsai, Lung-Sheng Li, Chien-Chih Chang, Chao-lung Hwang.. Durability design and application of steel fibre reinforced concrete in Taiwan. Arabian Journal for Science and Engineering 2009: 34(1B).

[26]. Cunha VMCF, Barros JAO, Sena-Cruz JM. Tensile Behaviour of Steel Fibre Reinforced Self-compacting Concrete. SP-274-4 fibre Reinforced Self- Consolidating Concrete: Research and Applications, ACI Committees 544 & 237, 51-68.

[27]. Eduardo NB Pereira, Joaquim AO Barros, Aires Camoes. Steel Fibre Reinforced Self-Compacting Concrete – experimental research and numerical simulation. Journal of Structural Engineering 2008; 134(8)

[28]. Oucief H, Habita MF, Redjel B, Hybrid Fibre Reinforced self-compacting concrete: hardened properties. Int. National Journal of Civil Engineering 2006; 4(2): 77-85.

[29]. Torrijos MC, Barragan BE, Zerbino RL, Physical-mechanical properties and mesostructure of plain and fibre reinforced self-compacting concrete. Construction and Building Materials 2008; 22(8): 1780-1788.

[30]. Hemant B. Dhonde, Mo YL, Thomas TC, Hsu, John Vogel. " Fresh and Hardened Properties of Self-compacting fibre Reinforced Concrete. ACI Materials Journal 2007; 104 (5): 491 – 500.

[31]. Aly M. Said, Moncef L. Nehdi. Behaviour of beam-column joints cast using self-consolidating concrete under reversed cyclic loading. 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada Aug-2004.

[32]. Kabir Shakya, Ken Watanabe, Koji Matsumoto, Junichiro Niwa. Application of steel fibres in beam–column joints of rigid-framed railway bridges to reduce longitudinal and shear re-bars. Construction and Building Materials 2012; 482–489.

[33]. Ganesan N, Indira PV, Sabeena MV. Behaviour of hybrid fibre reinforced concrete beam–column joints under reverse cyclic loads. Materials and Design 2014; 686–693.

[34]. Alireza Khaloo, Elias Molaei Raisi, Payam Hosseini, Hamidreza Tahsiri. Mechanical performance of self-compacting concrete reinforced with steel fibres. Construction and Building Materials 2014; 179–186.

[35]. Mohammed Yusof, Norazman Mohamad Nor, Muhamad Fauzi Muhamad Zain, Ng Choy Peng, Ariffin Ismail, Risby Mohd Sohaimi, Ahmad Mujahid Ahmad Zaidi. Mechanical properties of hybrid steel fibre reinforced concrete with different aspect ratio. Australian journal of basic and applied sciences 2011; 5(Pt 7):159-166.

[36]. Ramadevi K, Ventesh Babu DL, Flexural behaviour of hybrid (steel-polypropylene) fibre reinforced concreter beams. Europian Journal of Scientific research 2012; 70: 81-87.

[37]. Liu, Cong, Seismic behaviour of beam column joint sub-assemblies reinforced with steel fibres; Department of Civil engineering, University of Canterbury, New Zealand 2006.

[38]. Gustavo J Parra Montesano's. Sean W Peterfrend, Shih-Ho Chao, Highly damage tolerant beam-column joint through use of high performance fibre reinforced cement composite. ACI Structural Journal 2005; 102(3): 487-490.

[39]. Ganesan N, Indira PV, Ruby Abraham. Steel fibre reinforced high performance concrete beam–column joints subjected to cyclic loading. ISET Journal of earth quake technology, Technical Note 2007; 44(3-4): 445–456.

[40]. Perumal, Thankakumari. Seismic performance of hybrid fibre reinforced beam-column joint. International National Journal of Civil and Structural Engineering 2010; 1(4): 749-755.

[41]. Liberto Ferrara, Nilufer Ozyurt, Marco di Prisco. High mechanical performance of fibre reinforced cementitious composites: the role of "casting-flow induced" fibre orientation. Materials and Structures 2011; 44(1):109-128.

[42]. Mazaheripour H, Ghanpour, Mirmoradi S H, Hosseinpour I, the effect of polypropylene fibres on the properties of fresh and hardened lightweight self-compacting concrete. Construction and Building materials 2011; 25(1)351-358.

[43]. Burcu Akcay, Mehmet Ali Tasdemir. Mechanical behaviour and fibre dispersion of Hybrid-steel fibre reinforced self-compacting concrete. Construction and Building Materials 2012; 28(1): 187-293

[44]. Orbe A, Cuadrado J, Losada R, Roji E, Framework for the design and analysis of steel fibre reinforced self-compacting concrete structurers. Construction and Building Materials 2012;35:676-686

[45]. Morteza H Begi, Javad Berenjian, Omid Lofti Omran, Aref Sadeghti Nik, Iman M Nikbin. An experimental survey on combined effects of fibres and nanosilica on the mechanical, rheological and durability properties of self-compacting concrete. Materials & Design 2013; 50: 1019-1029.

[46]. Amin Abrishambaf, Joaquim A O Barros, Victor MCF Cunha,Relation between fibre distribution and post-cracking behaviour in steel fibre reinforced self-compacting concrete panels. Cement and Concrete Research 2013; 51: 57-66.

[47]. Pajak M, Ponikiewski T, Flexural behaviour of self-compacting concrete reinforced with different types of steel fibres. Construction and Building Materils 2013; 47:397-408

[48]. Mazaheripour H, Barros J A O, Sena-Cruz J M, Pepe M, Martinelli E. Experimental study on bond performance of GFRP bars in self-compacting fibre reinforced concrete. Composite Structurers 2013; 95:202-212.

[49]. Ponikiewski Tomasz, Jacek Gołaszewski, X-Ray Investigation And Strength Measurement Of Steel Fibre Reinforced Self-Compacting Concrete Beams. Transactions of the VŠB – Technical University of Ostrava Civil Engineering Series 2016;16(2).

[50]. Youok Setyo Hadiwidodo, Sabarudin Bin Mohd, Taguchi experiment Design for Investigation of Freshened Properties of Self-Compacting Concrete. American J. of Engineeering and Applied Sciences 2010; 3(2): 300-306

[51]. Arabi NS Alqadi, Kamal Nasharuddin Bin Mustapha, Sivkumar Naganathan, Aahit NS Al-Kadi, Development of Self-compacting Concrete using contrast constant factorial design. Journal of King Saud University – Engineering Science 2013; 25: 105-112.

[52]. Wu-Jian Long Kamal Henri Khayat, Guillaume Lemieux, Feng Xing, Wei-Lun Wang. Factorial Design Approach in Proportioning Pre-stressed Self-Compacting Concrete. Materials 2015; 8: 1089-1107.

[53]. Wu-Jian Long, Zhe-Ming Mai, Jin-Guang Shi, Tian-Tian Zhao, and Wu-Lei Peng. Research on Chloride Penetration Resistance of Hybrid Fiber Reinforced Self-Compacting Concrete. 5th International Conference on Durability of Concrete Structures Jun 30–Jul 1, 2016 Shenzhen University, Shenzhen, Guangdong Province, P.R. China.

[54]. Athiyamaan V, Mohan Ganesh G. Statistical and Detailed Analysis on fibre Reinforced Self-Compacting Concrete Containing Admixturers – A State of Art of Review. IOP Conf. Series: Materials Science and Engineering 2017; 263

Elizabeth George "Current State Of Fibre Rein forced Self-Compacting Concrete "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 10, 2018, pp 56-61