Non-Destructive Testing, Sensing and Imaging for Construction Materials and Structures

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ABSTRACT

This issue was proposed and organized as a means to present recent developments in the field of non-destructive testing of materials in civil engineering. For this reason, the articles highlighted in this editorial relate to different aspects of non-destructive testing of different materials in civil engineering, from building materials to building structures. The current trend in the development of non-destructive testing of materials in civil engineering is mainly concerned with the detection of flaws and defects in concrete elements and structures, and acoustic methods predominate in this field. As in medicine, the trend is towards designing test equipment that allows one to obtain a picture of the inside of the tested element and materials. Interesting results with significance for building practices were obtained.

Keywords: non-destructive testing, diagnostic, acoustic methods, ultrasound, building materials, defects.

I. INTRODUCTION

Engineering structures are gradually destroyed over time due to the influence of atmospheric conditions, excessive loads, and processes of natural aging. Since damage in a structural element may lead to improper operation of the whole object, various damage detection and structural health monitoring (SHM) methods have thus been investigated and developed to improve reliability and safety and to solve the maintenance problems of infrastructural and mechanical structures. The term non-destructive testing (NDT) covers a wide group of measurement and analysis techniques used in the process of assessing the current state of structural materials or elements. It is a quick and effective approach, the main advantage of which is the ability to examine the material in a non-invasive manner, without damaging or changing the composition or shape of the inspected object. In recent years, there has been growing interest in the development of non-invasive methods, including in the field of civil and mechanical engineering. The Special Issue "Non- Destructive Testing of Structures" has been proposed to gather the experience of civil and mechanical research communities in relation to the latest advances and trends in the field of diagnostics of structures and their components. A total of 22 papers were published in the Special Issue to touch different aspects connected with novel NDT approaches, with particular emphasis on the development of single and integrated measurement techniques, damage imaging procedures, advanced signal processing as well as modeling and numerical analyses for supporting SHM systems. A brief description of the Special Issue papers is presented below. A wide range of experimental and numerical studies is reported in the papers in this Special Issue [1–8]. Nazarko and Ziemia´nski [1] monitored the axial bolt forces by means of elastic wave propagation signals. A series of laboratory tests were carried out on flange connections with six bolts, subjected to static tensile tests. Some bolts were equipped with washer load cells for the precise measurement of axial force.

Civil infrastructures are integral to people's lives and are used in everyday life in the form of buildings, bridges, roads, tunnels, dams or power plants. These interdependent networks of infrastructures are an important asset as they ensure the smooth functioning of society, enabling economic vitality, the efficient flow and conservation of natural resources, and the comfort and safety of residents. These structures are inherently large in dimension, geometrically complex with different elements and joints, and composed of different materials [1]. These materials may be conventional such as concrete, steel and wood or composite materials including fibre-reinforced composites [2]. The failure of these structures can have catastrophic public safety and economic consequences. Early detection of damage and appropriate retrofitting will aid in preventing this failure, save expenditure on maintenance and replacement. This ensures that the structures operate safely and efficiently over its intended lifespan [3]. Hence, reliable techniques that are capable of assessing the structural health of these civil infrastructures are needed.

II. CONVENTIONAL CONCRETE

Normal conventional concrete can withstand a strength of 10 to 40 MPa. It consists of cement, coarse and fine aggregate with suitable water cement ratio. Mineral and chemical admixtures are rarely used. The water and cement paste fills the voids between the aggregates and binds them together. It possesses desired workability for a limited time. Strength and durability increases with proper curing with time. IS-10262- 2009 is the standard code book by Bureau of Indian Standards (BIS) which deals with the mix design procedures for concrete.

III. SPECIAL CONCRETES

Special concretes are designed to overcome a specific problem or to enhance the properties of conventional concrete. They are designed for reducing the self-weight (Light Weight Concrete), increase the strength (High Strength Concrete), increase the workability (self-flowing, Compacting concrete, SCC) , improve the impact, fracture, toughness and crack resistance of concrete (Fibre Reinforced Concrete), to make the concrete impermeable (Polymer Concrete) or permeable (No Fine Concrete) etc. The constituents of concrete are suitably varied to achieve the desired property. Mineral admixtures such as fly ash, GGBS, silica fume, slag are used to improve strength and plasticizers and super plasticizers are administered to improve the workability and reduce the water cement ratio. Light weight aggregates and air entraining is adopted to achieve light weight concrete. Various types of fibres are introduced into concrete to get fibre reinforced concrete.

SELF-COMPACTING CONCRETE

Self-compacting Concrete (SCC) is a new concrete technology that offers very powerful benefits. Self-Compacting Concrete was developed in Japan in the late 1980s to reduce the labour required to properly place concrete. The researchers are Okamura, Ozawa and Japanese contractors Kajima, Maeda, Taisei [1, 2]. This technology allows significant improvements compared to conventional slump concrete, in terms of workability or slump flow ability. No vibration is necessary, and better quality concrete can be produced. Some of the benefits for designers and clients are more innovative designs, more complex shapes, faster construction, improved durability, and better appearance [3, 4]. Self-compacting concrete is not affected by the skill of workers, shape and reinforcing bar arrangement of a structure. Due to high fluidity and resisting pavers of segregation of SCC, it can be pumped to longer distances. The use of SCC not only shortens the construction period, but also ensures quality and durability. Concrete has excellent deformation in the fresh state and high resistance to segregation and, can be placed and compacted under its selfweight without applying vibration. Self-compacting concrete is also known as Self-Consolidating or Self-Leveling Concrete [5, 6].

The concept of self-compacting concrete (SCC) was proposed in 1986 by Hajime Okamura [1], but the prototype was first developed in Japan in 1988 by Ozawa [2]. This new concrete was deliberately designed to be able to fill every corner of the form and encapsulate all reinforcements only under the influence of gravitational forces, without segregation or bleeding. These advantages make SCC, particularly useful wherever placing is difficult as in heavily reinforced concrete members or in complicated work forms. Through extensive research, it has been established that the addition of fibers to concrete considerably improves its structural properties such as compressive strength, static flexural strength, impact strength, tensile strength, ductility and toughness [3–10].

IV. BASIC PRINCIPLE

The SCC is that which gets compacted due to its self weight and is de-aerated (no entrapped air) almost completely while flowing in the form work. In densely reinforced structural members, it fills completely all the voids and gaps and maintains nearly horizontal concrete level after it is placed. With regard to its composition, SCC consists of the same components as conventionally vibrated normal concrete, i.e., cement, aggregates, water, additives or admixtures [2, 6]. However, the high dosage of superplasticizer used for reduction of the liquid limit and for better workability, the high powder content as „lubricant" for the coarse aggregates, as well as the use of viscosity-agents to increase the viscosity of the concrete have to be taken into account[2, 9].Super plasticizer enhances deformability and with the reduction of water/powder segregation resistance is increased. High deformability and high segregation resistance is obtained by limiting the amount of coarse aggregate. These two properties of mortar and concrete in turn lead to self compact ability limitation of coarse aggregate content [2, 7].The use of fibers might extend the possible fields of application of SCC. The addition of discrete fibres with adequate mechanical properties, in to concrete matrix improves several properties such as toughness, increase resistance to fatigue, impact and blast loading, reduce spalling of the reinforcement cover and improve abrasion resistance and flexural and shear strength[3,4]. The extent to which fibres contribute to each mechanical and durability characteristics depend on many factors including fibre type, configuration, length and volume, water-powder material ratio and other mixture parameters. Types of fibres like plastic or polymeric fibres, glass fibres, steel fibres, carbon fibres and natural fibres like bast or stem, leaf fibres, fruit fibres and wood fibres can be used in SCC [10].Plastic which is a non-biodegradable material neither decays nor degenerates completely in water or in soil. Plastic when burnt releases many toxic gases which is not only dangerous to health of living beings but also results in environmental pollution [8]. The disposal of such waste plastics is a major challenge to the municipalities especially in the metropolitan cities and such waste plastics can be used in the form of fibres to impart some additional desirable qualities to the concrete [8]. In this experimental investigation an attempt has been made to study the flow and strength characteristics of SCC with the addition of various percentages of waste plastic fibres into it.

MOTIVATION AND RESEARCH OBJECTIVES

1. Motivation

Structures are composed of a variety of construction materials such as metals, alloys, concrete, masonries, polymers, fibre composites, timber and glasses [8]. The NDT technique for these diverse materials should be chosen on the basis of [9]:

a. The physical nature of the material property or the discontinuity
b. The underlying physical process that governs the NDT methods
c. The physical nature of the interaction of the sensor with the test material
d. The economic, environmental and other factors

The material properties can be differentiated into mechanical properties and electromagnetic properties. The mechanical properties are hardness, compressive strength, elasticity, ductility, tensile strength and elastic constants. The electromagnetic properties are conductivity, permittivity and magnetic permeability.

Further, several discontinuities/damages such as voids, cracks, debondings, delamination also affect the characteristic properties of materials. For instance, crack in metal has different property compared to crack in the concrete. The diversity of the structure is not only limited to the material property but also the geometrical shape which also influencesthe sensitivity of different sensors used in these NDT techniques. The diverse material properties, geometrical shapes and varied damages in the structures make the selection of NDT technique a challenging task. The potential and limitations of each NDT technique should be considered based on the material property. Also, it is impossible to use a single NDT technique for different construction materials in a structure. Based on this status quo, a combination of different NDT techniques or the development of an integrated NDT technique can overcome this current limitation. This study focuses on the use of such combination of NDT techniques and integrated NDT techniques for health monitoring of a variety of construction materials with a variety of damages. These construction materials include concrete, metals and polymers which are most abundantly used in civil infrastructures. The damages include both surface and hidden defects including cracks, cuts, blowholes, gaps and debondings.

2. Objectives

The general objectives of this research are as follows:

- To develop a sensing technique and methods for profiling and non-destructive evaluation of surface flaws in civil infrastructures;
- To develop a methodology for Testing tilted construction SCC materials and structures;
- To develop a fiber based non-destructive evaluation of gaps and debondings between external reinforcement and concrete.

V. RESULT AND ANALYSIS

NON-DESTRUCTIVE PLASTIC FIBER SLUMP FLOW TEST RESULTS

In the slump flow test the ability of SCC to flow is measured for each trial mix for different percentage of fibres. The slump flow values are tabulated in Table No 3.26 for the final control mix and three other mixes. It can be observed that flow spread decreases with increase in fibre content up to 1.0% up to which the fines quantity was kept at 472 kg/m3 and w/p ratio was kept at 0.35. Thereafter to get the required flow, fines content was 472 kg/m3 and w/p ratio to 0.35 and super plasticizer dosage was increased to 1.0% therefore the slump flow values also increased but were within the EFNARC limits. The slump flow of the mix without fibres is the largest. The effect of percentage of fibres on slump value is shown in Fig.No.5.1. The fibres are needle like structures which increase the resistance to flow. But the plastic fibres are flexible compared to stiff steel fibres, so the flow properties are better for plastic fibres. All the slump flow values are in the range of 760mm to 850mm which is the limit specified by EFNARC 2005 of SCC.

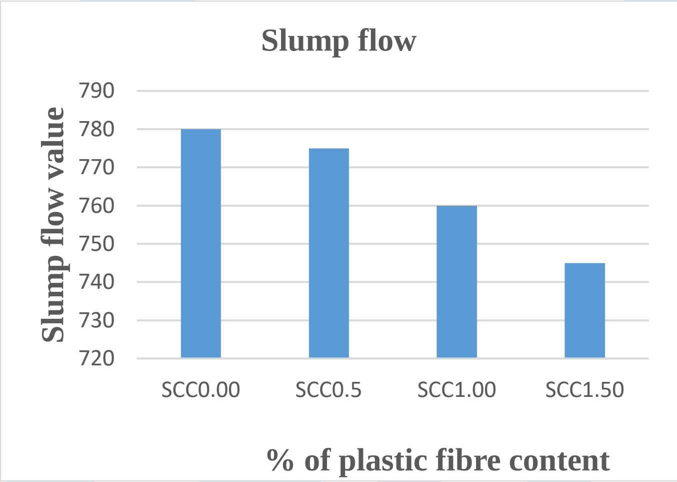

Fig. 5.1 Graph b/w % plastic fibre and Slump flow value

NON-DESTRUCTIVE PLASTIC FIBER T_{50}CM TIME RESULTS

The opposition to segregation is a calculated by T50cm time. The results of T50cm time are shown in Table 3.26. It gives free-range flow rate of concrete mix. If T50cm time is lower it shows that viscosity of mix is lesser and there is greater fluidity. The mixes with fibres from 0.0% to 1.0% are relatively low viscosity mixes, where flow happens quickly that is there is greater fluidity. As the fibre percentage is increased T50cm time has increased and is represented in the Fig.5.2. This is because of fibres which increases the viscosity and thus takes more time to flow. If T50cm time is more than 5 sec the mixes are generally considered as high viscosity mixes. As per the EFNARC 2005 necessities every mixes satisfy VS2 class of SCC.

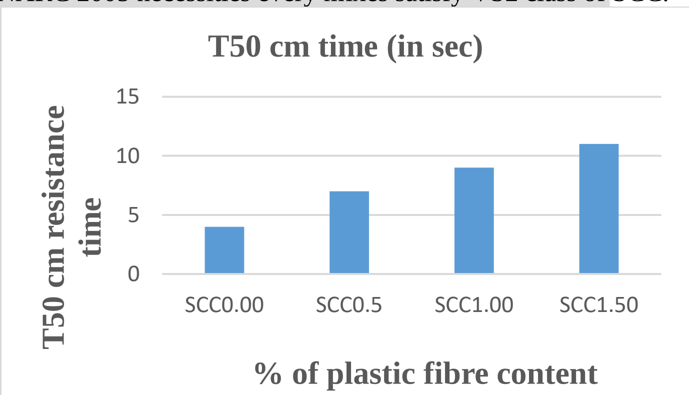

Fig. 5.2 Graph b/w % of plastic fibre and T50cm time values

NON-DESTRUCTIVE J –RING TEST RESULTS

The J-Ring test outcome point to passing capacity of improved WPFRSCC and control mix. J – Ring blocking values measured in mm, is taken as difference in height of concrete surface at central Position inside the ring and outside the ring. The evaluation is a suggestion of passing capacity, the degree to which passage of concrete is restricted. The values are given in Table 3.26. The values are gradually increasing as the percentage of fiber increases. The presence of more fibers causes blocking of flow between the obstacles, so more concrete is retained inside the ring. The values are within the particular limits as recommended by EFNARC 2005 up to 1% of fiber content. After 1% values are to some extentbigger than the particular limits. The effect of percentage of fibres with J-Ring values are represented in Fig5.3

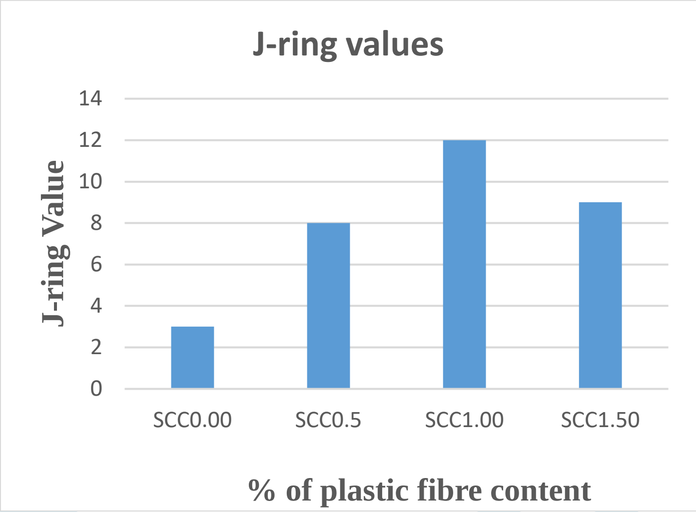

Fig. 5.3 Graph b/w % plastic fibre and J-ring values

NON-DESTRUCTIVE V – FUNNEL TEST RESULTS

In V-funnel test the SCC is made to change its way and go through choke zone to assess its ease. From V-channel test outcomes, arranged in Table 3.26 it tends to be seen that V-pipe time increments with increment in level of filaments. The variety is spoken to in Fig.No.5.4. This is on the grounds that when cement with more level of strands moves through limited area, filaments alongside coarse total start to isolate and brings about blockage of course through the opening of V-pipe. High stream time shows low deformability which may because of more fiber content. The estimations of V–pipe time for the majority of the blends are between 9 to 25.According to EFNARC 2005 prerequisites all the blends fulfill VF2 class of SCC.

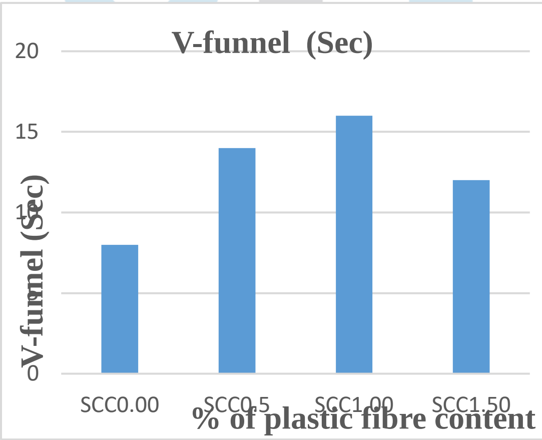

Fig. 5.4 Graph b/w % plastic fibre and V–Funnel test values

L- BOX TEST RESULTS

L-box is utilized to gauge the passing and filling capacity. At the point when SCC streams like water, it will be totally flat the proportion of stature in even area to vertical segment will be equalto1.0.AccordingtoEFNARC2005specificationiftheblockingratioisgreaterthan 0.8 the passing capacity is great. At the point when the proportion is underneath 0.8 there is danger of blockage of cement. From the L-Box test outcomes classified in Table 3.26 all the blends fulfill the prerequisites of PA2 class SCC. The variety of blocking proportion is appeared in Fig. 4.5. As the level of fiber builds, the blocking proportion esteem additionally expands this is again a result of blocking caused because of high fiber content alongside coarse total behind the strengthening bars which was watched outwardly.

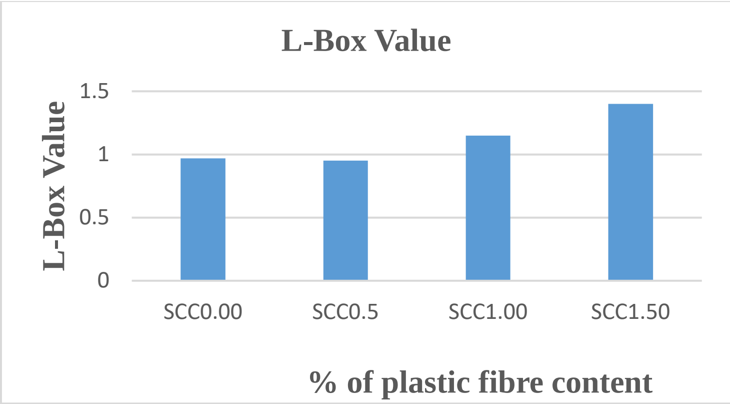

Fig. 5.5 Graph b/w % of plastic fibre and L- Box test values

TEST ON HARDENED CONCRETE

Fibers improve the performance of SCC in hardened state. The dissemination direction and the microstructure around the strands are very extraordinary in SCC and ordinary cement. In SCC filaments are completely inserted in the lattice. For each blend with changing level of fiber substance 3D shapes, chambers and bars examples were casted and relieved for 28 days. In order to evaluate the strength of SCC with waste plastic fibers the following tests were conducted.

- Test on Compressive Strength of cube in 28 Days
- Test on Split Tensile Strength of Cylinder in 28 Days
- Test on Flexural Strength of Beam in 28 Days

FABRICATION AND CASTING

For optimum workability a number of trials are done in the direction of turn up at the mixing sequence. At first cement, GGBS, finer & coarser aggregates are mixed in dry condition in a pan mixer for one minute. Then the fibers were added. After this 70% of determined measure of water was added to the dry blend and blended for one moment. The staying 30% of water, blended with the determined amount of super plasticizer was included the end and blended for five minutes.

After through blending of cement in skillet blender the solid was tried for functionality according to EFNARC rules. The crisp cement was filled blocks with no vibration, having an element of 150x150x150mm. So also chambers were thrown in steel molds having inward components of 150mm breadth and 300mm tallness for each blend. For flexure quality light emissions 150x150x700mm were thrown. In the wake of throwing examples were expelled from molds following 24 hours and drenched in clear water for relieving. The examples were relieved for 28days and expelled from the tank and permitted to dry. For each blend with shifting fiber content three 3D squares, three chambers, three shafts and three plates were thrown.

COMPRESSIVE STRENGTH TEST

The procedure given in IS: 516-1959 was followed. The test was done on 150*150*150mm 3D squares, up to the times of testing the solid shapes were kept in water. The shapes were tried at 28days for quality attributes. In the wake of cleaning of the bearing surface of pressure testing machine, the pivot of the example was deliberately lined up with the focal point of push of the plate.

The necessities of the research are discussed in chapter 1. As the manufacture of SCC is enhanced because of exclusion of vibration here is a main impact in its introduction in the maturity of concrete construction over a decade. We have come to realize that expansion of waste plastic filaments is a need for the investigation as it improves a portion of the properties of cement and furthermore tackles transfer of waste plastic, which is an ecological issue. The subsequent waste plastic fiber fortified SCC invigorates better and strength. The requirement for assessment of new properties, solidified properties, solidness and its conduct under raised temperature has been distinguished.

In the wake of choosing the goals, tests were directed in the research center with GGBS based waste plastic fiber fortified cement. The crisp properties were assessed by leading droop stream, J ring, V pipe and L-box tests. To test the solidified properties 3D shapes, chambers, bars and plates for effect were cast and pressure, split rigidity; flexure and effect tests were done.

The impact of waste plastic strands on crisp properties and solidified properties like compressive, split tractable, flexure and effect quality have been assessed for various level of filaments like, 0.0, 0.5,1.0, and 1.5%. For a similar level of strands, solidness properties and its conduct under raised temperature was additionally examined. The examination did on WPFRSCC will clear path for increasingly number of utilizations in future and is useful for further examination too.

VI. CONCLUSIONS

From the results of experiments and analysis carried out the following conclusions were drawn:

- In the present examination WPFRSCC has been delivered without including thickness changing operator. In the new state, when the expansion of waste plastic filaments were expanded it caused lower flowability, passing capacity and isolation opposition. So the super plasticizer measurements were expanded from 0.7% to 1.0% as the fiber substance expanded from 0.0% to 1.5%. The super plasticizer dose for fiber content more noteworthy than 1.5%was over 1% which caused draining and isolation. So it tends to be reasoned that past 1.5% fiber content for an angle proportion of 50 it is hard to accomplish self-compacting concrete.

- As per the EFNARC 2005 rule for the approval criteria for SCC, slump-flow values are among 760-850 mm and therefore the WPFRSCC mixes go to class SF3. It might be used in very packed structures with compound shapes. It gives superior surface finish than SF2 for normal vertical applications.
- Every WPFRSCC mixes created go to VS2 class as T500 values are more than 2 As per the EFNARC 2005 rule. They assure viscosity and fluidity characteristics. It is satisfied for walls and piles and like tall structures.
- All the WPFRSCC blends delivered in this investigation have a place with VF2 class SCC as indicated by EFNARC 2005 rules as the V – pipe esteems are between 9 to 25. They fulfill consistency and stream capacity attributes. It is appropriate for dividers and heaps for example for tall and slim structures.
- All the WPFRSCC blends delivered in this work have a place with PA1 class SCC as indicated by EFNARC 2005 rules where the L-Box proportion esteems are more noteworthy than 0.8 with three bars in L-box. It is reasonable for support with dividing between 80-100mm accordingly all the blends are fulfilling the particular prerequisites for SCC in crisp state.
- Compressive quality estimations of WPFRSCC at 28days are expanding in the request for expanding level of strands upto 1.0% filaments. The most extreme compressive quality
- accomplished for 1.0% fiber substance is 44.30 N/mm2 for M40 structure. At 1.5% of fiber content, the quality reductions to 42.78 N/mm2.
- Split tensile estimations of WPFRSCC at 28days are expanding in the request for expanding level of filaments up to 1.0% strands. The greatest Split rigidity accomplished for 1.0% fiber substance is 4.59 N/mm2 for M40. At 1.5% of fiber content the rigidity diminishes to 4.24N/mm2.
- Flexural quality estimations of WPFRSCC at 28days are expanding in the request for expanding level of strands upto 1.0% filaments. The greatest Flexural quality accomplished for 1.0% fiber substance is 5.06N/mm2 for M40. At 1.5% of fiber content the quality declines to 4.49 N/mm2.
- From the solidified properties test outcomes it very well may be reasoned that most extreme compressive quality, split rigidity and flexural quality can be accomplished at 1.0% expansion of waste plastic filaments with an angle proportion of 50. Subsequently 1.0% of waste plastic fiber can be considered as ideal from quality contemplations for WPFRSCC.
- The cost examination of SCC per cum for various blends is contrasted and that of proportionate evaluation of NVC per cum. The proportional evaluation of NVC is chosen dependent on the compressive quality of SCC. From the table 8.4, it is seen that the expense of SCC (100% OPC) is 2.90% more than that of NVC.
- While looking at the expense of SCC and NVC, just the fundamental expense of cement is viewed as which incorporates the expense of material, transport charges and work charges? The expenses of steel and manufacture charges are rejected.

REFERENCES

[1] Sholihin As‘ad, Purnawan Gunawan Fresh State Behavior Of Self Compacting Concrete Containing Waste Material Fibres‘ The Twelfth East Asia-Pacific Conference On Structural Engg. and Const. Procedia Engg 14 (2011) 797–804

[2] K.S. Johnsirani, Dr. A. Jagannathan _Experimental Study Of Fiber Reinforced Self Compacting Concrete‘ ISSN: 2348-4098 Volume 02 Issue 06 July 2014

[3] Ali Hussein Hameed _Effect Of Super plasticizer Dosage On Workability Of Self Compact Concrete‘ ISSN1999-8716,Vol.05,No. 02, Pp. 66-81,Dec. 2012.

[4] K.C.Denesh ―Experimental Study on Fiber Reinforced Self Compacting Concrete‖ (IJERT) ISSN: 2278-0181 Vol. 3 Issue 9, Sept.- 2014

[5] B.H.V. Pai, M. Nandy ―Experimental Study On Self compacting Concrete Containing Industrial By-Products‖ European Scientific Journal April 2014 Edition Vol.10, No.12 Issn: 1857 – 7881.

[6] Syal Tarun, Goel Sanjay, Bhutani Manish _Workability And Compressive Strength of Steel Polypropylene Hybrid Fibre Reinforced Self-Compacting Concrete‘ ―International Journal for Science and Emerging Technologies with Latest Trends‖ 6(1): 7-13 (2013)

[7] Wang Her Yung,Lin Chin Yung,Lee Hsien Hua _A study of the Durability properties of waste tire rubber applied to selfcompacting concrete‘ Construction &Building Materials41(2013) 665–672.

[8] 8.M.Seethapathi,S.R.R.Senthilkumar,K.Chinnaraju_Experimental Study on High Performance Self compacting Concrete Using Recycled Aggregate‘ Journal Of Theoretical And Applied Information Technology 10th Sept. 2014. Vol. 67 No.1.

[9] ―The European Guidelines for Self Compacting Concrete‖ Specification, Production and Use May-2005

[10] Shetty M. S., ―Concrete technology- Theory and Practice‖, S. Chand & company, New Delhi, 1982.

[11] Krishna Murthy.N, Narasimha Rao A.V, ―Mix Design Procedure for Self Compacting Concrete.‖ IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021,ISSN: 2278-8719, Volume 2, Issue 9 (September 2012), PP 33-41

[12] Oladipupo S. Olafusi, Adekunle P.Adewuyi,Abiodun I. Otunla ―Evaluation of Fresh and Hardened Properties of SelfCompacting Concrete‖ Open Journal of Civil Engineering, 2015, 5, 1-7 Published Online March 2015 in SciRes.

[13] O. R. Khaleel, s. A. Al-mishhadani, and h. Abdul razak ―The Effect of Coarse Aggregate on Fresh and Hardened Properties of Self-Compacting Concrete (SCC)‖ Procedia Engineering 14 (2011) 805–813 sciencedirect.Elsevier.

[14] Hajime Okamura, Masahiro Ouchi, “Effect of super plasticizer on self-compatibility of fresh concrete”, Journal of Transportation Research Board, (1997)37-40.

[15] Anant Patel, Prashant Bhuva, Elizabath Georgr, Darshana Bhatt, “Development of self- compacting concrete using different range of cement content, ”National Conference on Recent Trends in Engineering and Technology,(2011)1-5