International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-3, February 2020

Rheodynamic Concrete as a Progressive Viability in the field of Concrete Technology

Yaman Hooda, Haobam Derit Singh

Abstract: ***The most important material which is used for the construction of any concrete structure is concrete itself. It is considered to be as a versatile construction material as its properties can be changed by various means, with the help of different elements and as and when required. Rheodynamic Concrete or Self-Compacting Concrete is a special form of concrete which can easily flow into any kind of formwork uniformly, without facing the problem of bleeding and segregation, gives a better finish, has a great characteristic of placement, requires no vibration, and thus gives a safe working environment. Due to a number of merits, this type of concrete had becoming popular in the construction work. Simultaneously, the big industries across the world are producing the by products such as fly ash, rice husk ash, etc. Thus, this paper represents a review, which is done to incorporate these wastes by – products in Self-Compacting Concrete and observe, how the different properties of the same has been modified effectively and efficiently.***

Index Terms**:** ***Fibres, Fly Ash, Rice Husk Ash, Self – Compacting Concrete.***

I. INTRODUCTION

For most manmade constructions, concrete is widely used. By mixing cement, fine aggregates, coarse aggregates and sometimes admixtures, in some required proportions, it is made into use. This mixture of cement aggregates and water is placed in different types of form and allows curing so as to get a hard – rock like substance, known as **concrete.** This hardening is due to the chemical reaction occurred between the cement & the water, which continues for a longer span of time, resulting the stronger of the concrete with age. But, there arises a limitation on the fluid behaviour of freshly prepared concrete. To achieve its workability and the strength required for the concrete, thorough compaction is essential using vibrators or by the process of vibration. Insufficient compaction of concrete gives rise to formation of numerous voids which affects the long-term durability and performance of structures. **Rheodynamic Concrete or Self - Compacting Concrete (SCC)** gives an alternative for all such problems. SCC is the concrete which offers the ability to compact itself without any additional compaction or vibration. The development of Self – Compacting Concrete began in the late 20th century. In late 1900's, the scientists at the University of Tokyo, Japan developed SSC and it took them almost 10 years to use this special type of concrete, which doesn't require any method of compaction or vibration to achieve its full compaction. On the onset of 21st century, this special concrete has been widely used in Japan for ready mixed concrete and pre - fabricated works. In 1989, European countries founded European Federation of Natural trade associations representing producers and applicators of specialist building products (EFNARC). SSC is generally made up of OPC of grade 43 or 53 and aggregates were of even quality with respect to size, grading and shape. The water used for making this form of concrete should be same used for a Reinforced Cement Concrete or Pre – stressed Concrete. The chemical admixtures used in making of SCC are Superplasticizers, such as Viscosity Modifying Agents (VMA). The mineral admixtures which can be used in making of SCC include Fly Ash, Fibres (Steel Fibres, Polymer Fibres), Silica Fumes, Stone and Marble Powder, Ground Granulated Blast Furnace Slag (GGBFS) and many more, which can enhance the properties of SCC.

There are three different methods through which Self – Compacting Concrete can be made: 1. Powder Method, 2. VMA Method and 3. Combined Method. In Powder Method, SCC is made by increasing the proportion of powder content. VMA method includes the use of Viscosity Modifying Admixtures. Combined methods include both increasing the proportion of powder content and using Viscosity Modifying Admixtures. Usually, Viscosity Modifying Admixtures are mixed in a little dosage of 0.3 to 0.55 percent by wt. of the binding agent content. The application of these methods depends upon various factors such as availability of materials, constructional conditions, etc. From the various researches and studies that has been conducted in the past, it was found that it is always better to use poly - carboxylate based Superplasticizers (PC). The Hyper plasticizers are having efficiency than melamine or naphthalene-based Superplasticizers with respect to the slump retention property. Such plasticizers cause dispersion of the finer particles by the process of steric hindrance of many side line chains of PC other than only by the property of Zeta Potential of naphthalene or melamine-based plasticizers. In India, commonly used VMAs are Multi carboxylatethers (MCE) and carboxylic acrylic ester (CAE). The main difference between other types of concrete and SCC is its level of workability.

Revised Manuscript Received on February 05, 2020.
* Correspondence Author
Yaman Hooda*, Department of Civil Engineering, SGT University, Gurugram, Haryana, India. E-mail: yamanhooda@gmail.com
Haobam Derit Singh, Department of Civil Engineering, Amity University, Noida, India. E-mail: haobamderit38@yahoo.com

The workability of SCC is higher than "very high" Degree of Workability as per IS 456:2000. To characterize the workability property of SCC, several tests are conducted as per EFNARC specifications and guidelines are:
Slump flow given by :Abrams Cone ;$T_{50\ cm}$ Slump Flow, V – Funnel, J – ring, U – Box, L – Box, Orimet ,Fill – Box and GTM Screen Stability Test. The belief that SCC cost is so higher than cost of corresponding normal strength/high strength concrete is incorrect. It was observed that the materials cost of SCC is approximately 10 – 15 percentage higher than the cost of the materials of other types of concrete. If one take care of other cost components such that the cost of compaction, then one can easily conclude that for comparable strength, SCC is evidently not costly. However, the applications of SCC in present world is limited because of inadequate standard mix-design procedure and methods of testing. Self - compacting (or – Consolidating) Concrete proved itself as a revolutionary step put forward in field of concrete technology. With conjunction with other building materials, SCC can be used on a greater scale and may find applications in every constructional department.

II. MATERIALS AND ITS PROPERTIES

A. Fly Ash

It is one of the major residues, which is formed in the process of combustion that comprised of very fine particles which rises with the flue gases. Bottom Ash are those ashes which doesn't rise. Generally fly ash is captured with the use of Electrostatic Precipitators or other particle-filtration equipment in which it is captured before the flue-gases reaches the coal-fired power plant chimneys and in accordance with the bottom-ash removed from furnace bottom is jointly known as Coal Ash. Fly ash consists of various constituents which are toxic, that includes Beryllium, Arsenic, Boron, Cadmium, Chromium VI, Lead, Thallium, Cadmium, Chromium, Lead, Manganese, Mercury, Molybdenum, Selenium, Molybdenum, Strontium, and Vanadium. The Compositions of Fly Ash varies depending upon type of the product of combustion process, i.e., either Bituminous, Sub – Bituminous or Lignite. It is observed that in either of the process, the content of SiO_2 is maximum. The chemical content of fly ash used in various studies is listed in Table 1.

Table 1: Physical Properties of Fly Ash

Properties	G	F	IST	FST	LOI
B. Mahalingam et al. [1]	2.12	9.027	57.27	117	0.68
Subhan et. al. [2]	2.14	-	-	-	4.15
H.H. Alghazali et. al. [3]	2.68	-	90	195	0.12
N. Puthipad et al. [4]	3.15	3.49	-	-	-
H.-A. Nguyen et al. [5]	2.9	-	-	-	2.76
B.M. Vinay Kumar et al. [6]	2.17	-	160	360	0.7

G = Specific Gravity F = Fineness (m^2/kg)
IST = Initial Setting Time (minutes)
FST = Final Setting Time (minutes)
LOI = Loss of Ignition (%)

Table 2: Chemical Properties of Fly Ash

Chemical Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
H.H. Alghazali et. al. [3]	35.17	21.07	6.58	26.46	6.22
Subhan et. al. [2]	58.57	28.18	3.46	2.22	0.33
O. Almuwbber et al. [7]	53.6	27.7	3.56	7.25	1.6
N. Puthipad et al. [4]	20.26	5.7	2.92	64.84	0.91
H.-A. Nguyen et al. [5]	58.33	26.23	3.49	5.72	1.26
B.M. Vinay Kumar et al. [6]	90.7	0.14	4.1	2.1	1.03

Thus, from the past work, it may be said that the average specific gravity of fly ash used in the studies is 2.52. Also, the average fineness was found to be 6.25. The initial and final setting time was 102.7 and 224 minutes respectively. The loss of ignition was found to be 1.4%. In this present world, fly ash is widely being used as a supplementary cementitious material for the production of concrete. In SCC, the utilization of raw fly ash is necessary to enhance the performance of concrete mixed with raw fly ash compared to ordinary Portland concrete. Also, as a supplementary cementations material, fly ash in the concrete helps in achieving the maximum utilization of raw fly ash rather than to be considered as a waste disposal, which will eventually leads to numerous environmental-issues. In the production of SCC, raw Fly Ash is collected and is used directly. The chemical composition of fly ash observed in several studies are listed in Table 2. Fly Ash Reuse includes being used as a supplementary material for Portland cement and Sand,in concrete production, embankments and other structural fills (typically for road construction), Cement clinkers production, flow able fill and grout production, waste solidification and stabilisation, Mine reclamation, road sub -base construction, stabilization of soft-soils, as aggregate materialsubstitution (as in used for production bricks), soil amendment, in asphaltic concrete as a mineral filler, fertiliser, soil stabilisation in stock feed yards, loose application on rivers and roads to melt ice and parking lots for ice control respectively.

Fig. 1 proves that the class 1 fly ash particles are of spherical shape. The superplasticizer is blended with a VMA to enhance SCC stability.

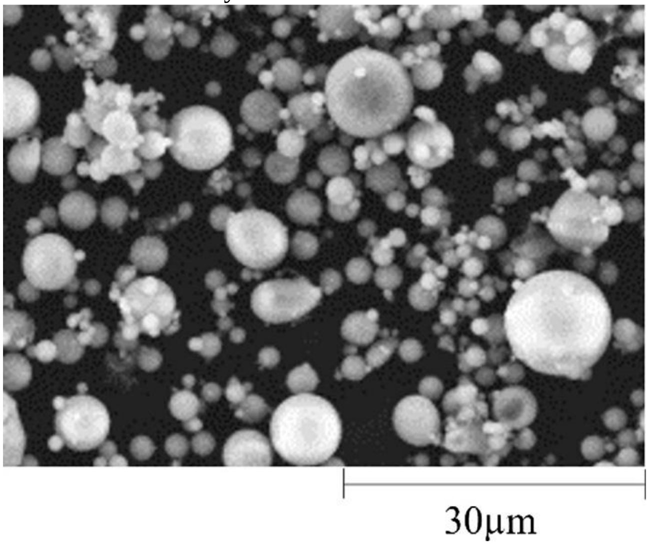

Fig. 1:- SEM Image of Fly Ash particles at 2500_magnification. [4]

B. Rice Husk Ash:

Rice Husk Ash (RHA) is an agricultural waste product that is being produced in large quantities globally every year and there is a difficulty involved in its disposal. Rice husk ash creates great environment threat causing severe damage to land and atmosphere. Many methods are being thought for disposing them, the best method to dispose them; is use of RNA as cement replacement material. Rice husks are the coatings of grains or seeds of rice. During growing season, in order to protect the seed, the husk is comprises of a hard material, including lignin and opaline silica. Rice husk ash gives many advantages due to its various properties.

The Properties of RHA in physical sate can be given in Table 3.

Table 3: Properties of RHA in Physical State

Properties	G	F	MPS	SSA
Kannan & Ganesan [8]	2.08	91	5.27	36.47
Le et. al. [9]	-	-	5.7	22.36
Sua-iam et. al. [10]	2.24	-	39.34	0.37
Safiuddin et al. [11]	2.1	-	6	2.33
Habeeb and Mahmud et al. [12]	-	-	11.5 – 63.8	25.3-30.4
Ganesan et al. [13]	2.06	99	3.8	36.47

G = Specific Gravity
F = Fineness (m^2/kg)
MPS = Mean Particle Size (µm)
SSA = Specific Surface Area (m^2/gm)

It is found that the mean particle size of Indian RHA is 71.61µm. The specific gravity is found to be in the range of 2.06 – 2.24. Also, fineness percentage passing is found to be 98%. Below is the RHA chemical composition as informed by few researchers.

Table 4: Chemical Composition of Rice Husk Ash

Chemical Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Rego et. al. [14]	87.08	<0.1	0.11	0.7	0.7
Kannan & Ganesan [8]	87.89	0.19	0.28	0.73	0.43
Chopra et al. [15]	94	1.2	0.37	2.93	0.60
Sua-iam et. al. [10]	93.44	0.21	0.18	0.76	0.43
Memon et al. [16]	77.19	6.19	3.65	2.88	1.45
Della et al. [6]	94.95	0.39	0.26	0.54	0.90

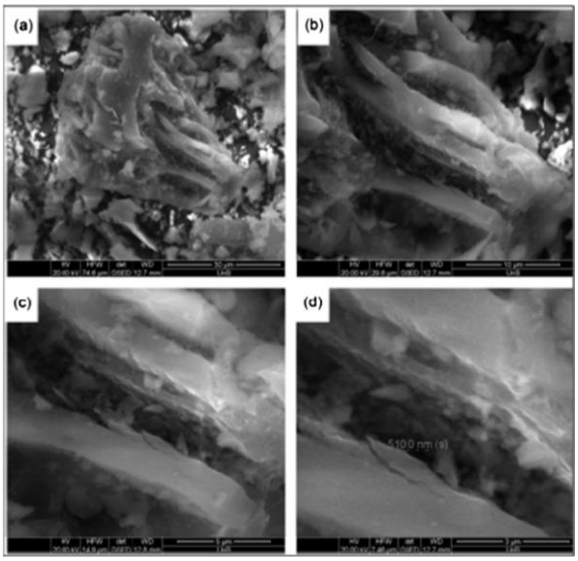

Fig. 2:- Morphology and Surface structure of the RHA: (a) Particle at lower magnification (2000X), (b) Particle at (5000X), (c) Particle with magnification (10,000X), (d) Particle with magnification (20,000X) [18].

Fig. 2 represents morphology and surface of RHA at different magnification levels which shows the interstitial and macro pores, occupied with Grounded Particles in fine state. At a higher magnification level of (20,000_), interstitial-pores can be observed, within of Macro pores. XRD analysis carried out by Ranjbar et al. [18] showed that after the addition of nano-TiO2 (NT), a fresh peak of portlandite is achieved, with the decrease in intensity of the materials (Alite and Belite).

The micrographs of SEM shows the extensive spreading of mortars that contains packed-pore structures of NT, resulting in strength and durability of specimens. Diffraction analysis by X-ray indicates RHA contains amorphous materials, with little quantities of phase of crystal – state materials such as cristobalite and sylvite.

C. Marble Fillers and Tile Wastes:

Marbles has been used commonly as a building material since the medieval times. To dispose the waste materials of the marble industry that consists of very fine-powders is known to be one of the worldwide environmental problems today. However, economically utilization of these waste materials are successfully done to improve some properties of fresh and hardened SCC. It is been observed that due to the very high fineness, marble powders proved to be very effective in obtaining good cohesiveness of Mortar and Concrete. These are used for other Ultra-Fine mineral additions [ike silica fume] that have the ability to give high to the concrete mixture a very high cohesiveness. In addition, its filler ability is proud to be a positive effect from early ages. The use of fillers is intended in reducing inter-particle friction and to ensure a higher packing density. A lot of researches were performed to study the properties of SCC with the incorporation of marble fillers and how it effects in the overall. These observations concluded that the using filler materials results in reduced cement content and workability improvement. Thus, decreased in Thermal and Shrinkage Cracking, Low Heat of Hydration can be achieved. Belaidi et al. [19] observed that by using both marble powder and natural pozzolana as a replacement to cement on SCC, had no adverse effect, which help in providing economic benefits and also, play a vital role in reducing the environmental pollution.

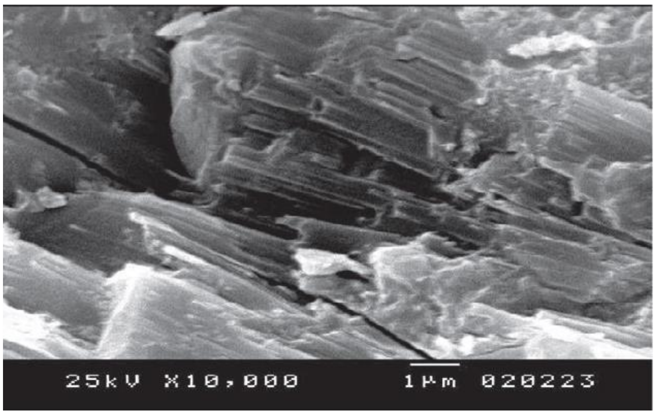

Fig 3:- Results of SEM Analysis of marble fillers incorporated cement pastes [19]

Fig 3 depicts the results of SEM analysis of the cement pastes, which is been modified by the addition of the marble fillers, conducted by Belaidi et al [19]. The chemical Properties of marble fillers and tile wastes used in various studies are listed in Table 5.

It's found that there is maximum of content of CaO is observed of approx. 48%. And least is K_2O of approximately 0.10%.

Table 5: Chemical Properties of Marble Filler and Tile Wastes

Chemical Constituents	M. Tennich et al. [20]	M. Tennich et al. [21]
CaO	49.49	47.09
Al_2O_3	0.46	0.58
Fe_2O_3	0.66	0.06
SiO_2	7.36	3.78
MgO	0.23	4.62
SO_3	0.08	0.41
K_2O	0.11	0.09

D. Fibres:

The most commonly used man - made fibres in the field of construction are steel and polymer. In the present scenario, different types of Steel-Fibre types can be found available as reinforcement in markets. The type of steel fibres that are used commonly is Round steel fibres because these are produced in which round wires are cut into short lengths. Typical diameter of such fibres lie in the range of 0.25 to 0.75 mm. Rectangular shaped Steel-fibres is produced by slitting the sheets about 0.25 mm thick. The different types of steel fibres that are used includes: crimped, indented, machined and hook-ended fibres (for improving the mechanical bond between the fibre matrixes). The aspect ratio of such fibres which are employed are made to vary abruptly from 30 to 250.

Fibres that are made available from Mild Steel drawn wire confirming to IS: 280-1976 with wire diameter varying from 0.3 to 0.5 mm have been used practically in India. Generally round steel fibres are produced by chopping or cutting the steel wire, flat sheet fibres that have a typical cross-section with ranges (0.15 to 0.41 mm thickness and width from 0.25 to 0.90 mm) are formed by slitting flat sheets. Since the individual fibres tends to cluster with one another, it is difficult in obtaining a uniform distribution in the matrix but this can be avoided if the fibre bundles are added which sepárates during the process of mixing. Another type of fibres which is commonly used is Polymer Fibres. Polypropylene is available abundantly and cheapest polymers. One of the most important advantages of Polypropylene fibres is that they are resistant to most chemicals. These fibres are the cementing-matrix that deteriorate first under aggressive Chemical Attack. The melting point of such fibres is 165 ºC. They have high melting point so that a working temperature as high as 100ºC may be sustained for short periods without causing any problems to the fibre properties.

Such fibres have low modulus of elasticity. There are two types in which Polypropylene fibres are available: monofilaments, which are produced from spinnarets, and film fibres, that are produced by extrusions. The commonly used fibres are film fibres. These fibres are obtained from fibrillated film twisted into twine and chopped, usually into 25-50 mm lengths for use in concrete.

Polypropylene fibres can be easily mixed due of its hydrophobic nature because they do not require longer contact during the mix-process and needed only to be uniformly and evenly dispersed in the mix itself. Prolonged mixing may lead to undesirable shredding of fibres. The most commonly used fibre in the concrete for civil engineering applications are Steel fibres. But, in today's world, with the development of technology and science, different types of fibres are being invented time to time, which leads to the development of concrete of better properties. These fibres include synthetic fibres. These Synthetic fibres include Polypropylene fibres, polyethylene fibres, polyvinyl fibres or polyolefin fibres. The low-modulus polypropylene fibres are used in small amount for the purpose of cracking control at the initial shrinkage as in the first hours of setting both concrete and fibres are having same Young's modulus. Among Synthetic Fibres, for the behaviour of Post-cracking of a PFRC to a SFRC with a lower fibre content in terms of weight, Polyolefin fibres are the one which have been designed. The Polyolefin fibres are having good tensile properties, provide excellent resistance to abrasion. These fibres are an alternative to the steel solutions when meshes are used as they have excellent endurance in chemically aggressive environments. This also leads to low cost and placing them safely. PFRC provides considerable residual strengths in tension [24] and are of lower weights in comparison with other types of fibres [25]. Both the construction industry and study oriented communities significantly advances in the plastic fibres applications incorporating in RCC [26, 27]. These fibres found application because of their cost of material and its lack of corrosion, when subjected to hazardous environments. [28].

Since these fibres which are having plastic properties, mixed rightly without any clustering problems, such fibres offer a condensed influence on workability. A major advantage of using such fibres is the handling becomes easy as such fibres are safer and lighter. Also, the fibres save time in preparation and the placing of wire mesh. This allows the continuous-production of concrete, which leads to labour cost reduction [30]. Moreover, current advances in the area of numerical models helped to present the fibres contribution in the FRC structural design elements [31 - 35]. The various properties of the fibres that influence the concrete mix are its mechanical properties, and physical properties such as fibre percentage used in the mix designing and alignments of the fibres of the concrete mix [35, 36].

The combination of PFRC and Rheodynamic Concrete may permit a change in the orientation of fibre and their distribution by ways of the flow properties of SCC, as had been already shown in PFRC-SCC [37, 38].

III. EFFECT ON PROPERTIES OF SCC BY USING DIFFERENT MATERIALS

A. Compressive Strength:

The study that is conducted by B. Mahalingam et al.[1] include class F Fly Ash conforming to IS: 3812-2003 and OPC of grade 53, conforming to IS 12269: 2008. In his study, SCC mixed was designed with 450 kg/m3 of binder content, with the two different level of replacements with cement {30% and 40%}. To examine raw FA influenced on the strength of the concrete mix in compression, the specimens of concrete were casted and put in laboratory for about 24 hours. It is then demoulded and put in water curing that is controlled until specified testing durations. As per the standards, after 91, 56, 28, 7 and 3 days of curing, the strength in compression was determined. It had been found that there is an increased with curing duration in the strength of concrete in compression. Also, after curing for 56 days, a considerable increased in its compressive strength was observed. On contrary, it was observed that compressive strength reduces for replacement-level 40% as compared to 30% for the same curing duration. Also, compressive strength of SCC was affected by using different percentage of VMA. It had been observed that by increasing the percentage of VMA upto certain limit increases the compressive strength and then, it starts reducing gradually [2]. As per F. Alhussainy et al. [39], if the strength in compression of SCC incorporated with FA was measured by considering 3 cylinders of 100 mm diameter and 200 mm height in accordance to AS 1012.9 [40], then its outcome of the test depicted that the average compressive strength comes out to be 57 MPa.
Also, if silica fumes were also incorporated with SCC, then the compressive strength is found to be increased more after 28 days. It was observed that in the SCC mix obtained by adopting 25% and 10%, the compressive strength was increased to about 74.55 MPa was obtained [41]. The concrete mixes strength in compression decreased with an increase in concentration of FA and there is no improvements found when the cements were extended in corporation with slag regardless of concentration considering both SPs. Not comparing segregated concrete mixes, cements having high silicate phase ratio was found to result in higher compressive strengths as compared to those with lower- ratio values was obtained [42].

Ahmadi et al. [43] obtained the strength in compression for the SSC mixture that is in corporation with RHA of varying proportions of 20% , 10%, as compared to a regular concrete at 2 different water cement ratios (i.e.,0.41 , 0.36) upto 180 days . It had been observed that the SCC mixes achieved 31% – 41% high compressive strength compared with normal concrete. Suaiam and Makul [10] interpreted that the SCC mixtures that were made with RHA of 20%, as partial replacement of OPC, resulted at 91 days , a similar compressive strength due to 2 reasons: Pozzolanic-reaction between the particles and the internal structure of denser particles [16]. Safiuddin et al. [11] intercedes the compressive strength of SCC mix upto 56 days is enhanced by the addition of RHA and then it started to decreased because of the pozzolanic activity resulted from the mixes and the RHA's micro filling ability. Compressive strength at 28 days was observed between 44 and 95 MPa, whereas it ranges between 46 and 97 MPa for different mixes. For RHA proportion of 30% with w / b ratio 0.36, the maximum compressive strength is noted. Chopra et al. [15] noted that at 28 days the mix compressive strength varies from 36.51 and 41.31 MPa, and at 56 days the compressive strength for SCC mixes varies from 39.81–46.6 MPa that contains varying proportions of “RHA” (11%–21%) of w / b ratio 0.41. It had been concluded that the maximum magnitude of compressive strength was found for RHA mix of proportion 15%. As observed by Zhang and Malhotra [44] and Bhanumathidas and Mehta [45], it had been concluded that upto RHA 30% proportion may be used in normal concrete for achieving higher compressive strength. The incorporation of steel fibres in the SCC mix exhibited that the strength in compression was observed to be in the range of 66.2 and 66.7 MPa when the proportion of the steel fibres were 20% and 30% respectively [46]. In other experiment, the normal compressive strength for SCC mix was obtained to be 53 MPa and when different proportions of the steel fibres were mixed in the SCC mix as a quantity of 90 kg/m^3, 60 kg/m^3 and 30 kg/m^3, 60 kg/m^3 and 90, the strength in compression was found to be 59.89 MPa, 61.78 MPa and 57.22 MPa respectively [47].

The SCC’s mechanical properties in corporation with marble fillers and tile waste studied by M. Tennich et al. [20], were obtained with the use of simple compressive and ultrasonic testing for the curing ages of 28; 21; 14 and 07 days. For the specified time and the concrete age, 3 test specimens were prepared and for 24 hours it was kept in the casting mould, and then these were unmoulded and water curing kept at 21 $\pm$ 3 °C till the time of testing. It had been observed that the strength of SCC combined with marble and tile waste in compression was found to be 1.472 % higher. It was also concluded that the resulting strength of SCC in compression with inclusion of both the tile and marble waste was more than the compressive strength of SCC if it was combined with each material separately.

The polymer fibers such as polypropene fibres and polyelfin shows an interesting change in the characteristics of SCC. As per the observation by A. Enfedaque et al [48], it was clearly seen that by changing the proportions of the polymer fibres, the properties of SCC changes. Even though the addition of Bond improving admixture causes the change in the properties of SCC, it was found that the if polyolefin fibres of 10 kg/m^3 added in SCC, the strength in compression was measured 37 MPa and, which decreased to 35.5 MPa for the concrete mix which was made up by adding bond improving admixture, which may be a result of high amount of fibres and thus, lesser compaction.

B. Split Tensile Strength

It was been noted that the strength obtained by conducting split tensile test of the Rheodynamic concrete mix was also affected by the different percentage of VMA. As observed in strength in compression, the split tensile strength also increases when the percentage of VMA increases upto certain limit and then, it started reducing gradually. When the test was conducted by testing 3 cylinders with diameter of 150 mm and 300 mm in height, as per AS 1012.10 [40], the split tensile strength in average was found to be 3.8 MPa. Thus, it had been found that the tensile strength after conducting split tensile test was nearly around 4MPa [1].

Rahman et al. [49] found that the SCC split tensile strength with mix having RHA of varying proportions of 40%, 30%, 20% and 0% as partial cement replacement, increased with decreased with RHA content. Addition of 21% RHA gives similar strength values as in the normal control mix. Chopra et al. [15] obtained the ranges of tensile strengths of 2–2.5, 2.4–3.8 and 2.7–4.0 MPa with 7, 28 and 56 days, respectively. Also, he observed that replacing the cement with RHA less than 15%, there is an increase in this considered strength. But, with20% RHA replacement, the strength was acceptable as the strength was found to be more than controlled SCC mix. Khadiry et al. [50] used SCC incorporated shell lime powder (SL) with SCC. The SL-SCC spilt tensile strength was observed to be 23.97 % and 5.20% more than in the case of RHA-SCC for curing of 7 and 14 days.

As the pattern observed in the determination of compressive strength, the same pattern had been observed in the determination of split tensile strength, though there was a little change was observed in this category. The strength in the tension was observed as 4.95 MPa and after the addition of bond improving admixtures, it was observed that 4.78 MPa [48]. The split tensile strength of SCC also increased when it was blended with the tile and marble wastes. By adding different composition of the waste materials, it had been commented that the strength of SCC in split tensile test per addition of different proportions of tile waste and marbles varies in the range of 5% - 16% [20].

C. Slump

The value of slump also changes as the constituents of the SCC mix changes. When the SCC mix was incorporated with fly ash, it had been observed that the average value of slump was found to be 655 mm [2]. In other study conducted by H.Y. Leung et al. [41], the value of slump was found to be 660 mm. Also, the value of slump may change when admixtures were also added in the SCC – Fly ash mix. The values obtained were ranged from 640 – 800 mm [42].

When the SCC mix was incorporated with polyolefin fibres, it had been observed that the result of slump test was quite same, i.e., SCC mix with and without polyolefin fibres. In both the cases, it had been noted that the slump value comes out to be nearly 570 mm [48].

Also, when steel fibres were added in SCC mixture, it had been observed that with different proportions of fibres indulged in the SCC mix, the value of the slump of the SCC mix changes. When the steel fibres were used as 90 kg/m^3, 30 kg/m^3, 60 kg/m^3 and 0 kg/m^3, it had been observed that the magnitude of the slump value comes out to be 551 mm, 731 mm, 715 mm and 752 mm respectively [47]. So, it had been concluded that the value of the slump decreases as the proportion of fibres in the SCC mix increases.

Chopra et. al. [15] concluded that when the RHA was added in the SCC mix, the slump value was found to be 730 mm – 600 mm by considering RHA replacement of 0% and 20% respectively. Another experimental study showed that the magnitude of slump was found to be 630 mm – 580 mm corresponding to 0% and 40% partial replacement [49]. Also, the partial replacement of 0% and 10% RHA gave the slump value of 770 mm and 535 mm respectively [16].

If Marble fillers and tile wastes were introduced into the SCC mix, the slump value of SCC was found to be in the range of 680 – 710 mm [20].

D. J – Ring Test

The value of the J – Ring test is observed to be 4 mm -10 mm when fly ash was added in the SCC mix in different proportions [2]. In the other study, it was concluded that the magnitude of J – Ring was nearly 6.35 mm [51]. The test when incorporated with RHA showed that the different proportions of RHA yielded different J- ring test value. The partial replacement of 0% and 40% RHA gave the slump value of 5.2 mm and 4.4 mm respectively [49]. When superplasticizer was added in the SCC mix with RHA, it had been noted that the value of the test comes out to be 730 mm and 765 mm with partial replacement of 0% and 20 % RHA respectively [11].

E. V – Funnel Test

Chopra et. al. [15] concluded that when the RHA was added in the SCC mix, the slump value was found to be 6 sec – 13 sec by considering RHA replacement of 0% and 20% respectively. Another experimental study showed that the magnitude of slump was found to be 5.9 sec – 7.0 sec corresponding to 0% and 40% partial replacement [49]. Also, when the superplasticizer was added in different proportions, the partial replacement of 0% and 10% RHA gave the slump value of 6 sec and 29.3 sec respectively [16]. When the SCC mix was incorporated with polyolefin fibres in the quantity of 10 kg/m^3, the results of the V – Funnel Test were found to be 15.5 seconds, which was 16.5 seconds when there was no addition of polymer fibre [48].
When the steel fibres added into the Rheodynamic concrete mix in the different quantities of 60 kg/m^3, 30 kg/m^3 and 0 kg/m^3, the V – funnel test value was found to be 9.06 seconds, 9.74 seconds and 15.33 seconds respectively [47]. The magnitude of the V - Funnel test was found to be 7 seconds -12 seconds when fly ash was added in the SCC mix in different proportions [2].

IV. RESULTS AND DISCUSSIONS

After having an intense review on different aspects of Rheodynamic Concrete, from table 6, one can easily note that how the different properties of Rheodynamic Concrete are hampered by the addition of different by – products.

Table 6: Comparative Effects of Waste Materials on Different Properties of Rheodynamic Concrete

	FA	RHA	Fibres	Marble Fillers and Tile Wastes
CS	It is increased till 30%*	It is increased till 30%*	It is increased till 25-30%*	It is increased till 2-3%*
STS	It is increased till 30%*	It is increased till 15%*	-	It is increased till 5-15%*
Slump Value	Ranges from 650–800 mm**	Ranges from 550–800 mm**	Ranges from 550–750 mm**	Ranges from 680–750 mm**
J – Ring Value	Ranges from 5-10 mm**	Ranges from 4-5 mm**	-	-
V – Funnel Value	Ranges from 7-12 sec**	Ranges from 6-10 sec**	Ranges from 9-15 sec**	Ranges from 9-15 sec**

CS = Compressive Strength
FA = Fly Ash
STS = Split Tensile Strength
*with partial replacement with cement.
**with different proportions.

V. CONCLUSION

It is no doubt that the SSC or Rheodynamic Concrete is proved to be an important type of concrete which can be used in construction fields as the properties of the same only reflects its advantages. These properties can be easily understood when they are compared with normal PCC or any other type of concrete. Also, it had been shown that most of the waste materials from the various industries such as rice husk ash, marble, fly ash, tiles or fibres, are proved to be beneficial to the concrete. And while considering the self-compacting concrete too, the properties are modified, merely enhanced by the addition of these waste products. Huge increment is observed in the properties of Rheodynamic Concrete like Compressive Strength, Split Tensile Strength, Slump value, V – Funnel Test and J - Ring Test after the addition of these waste materials.

REFERANCES

1. B. Mahalingama, K. Nagamanib, L.S. Kannanc, K. Mohammed Haneefaa, A. Bahurudeen, Assessment of hardened characteristics of raw fly ash blended self-compacting concrete.
2. Subhan Ahmad, Arshad Umar, Characterization of Self – Compacting Concrete. Procedia Engineering 173 (2017) 814 – 821.
3. Hayder H. Alghazali, John J. Myers, Shear behavior of full-scale high volume fly ash-self consolidating concrete (HVFA-SCC) beams, Construction and Building Materials 157 (2017) 161–171.
4. Nipat Puthipad, Masahiro Ouchi, Sovannsathya Rath, Anuwat Attachaiyawuth, Enhanced entrainment of fine air bubbles in self-compacting concrete with high volume of fly ash using defoaming agent for improved entrained air stability and higher aggregate content, Construction and Building Materials 144 (2017) 1–12.
5. Hoang-Anh Nguyen, Ta-Peng Chang, Jeng-Ywan Shih, Herry Suryadi Djayaprabha, Enhancement of low-cement self-compacting concrete with dolomite powder, Construction and Building Materials 161 (2018) 539–546.
6. B.M. Vinay Kumara, H. Ananthana, K.V.A. Balaji, Experimental studies on utilization of coarse and finer fractions of recycled concrete aggregates in self compacting concrete mixes, Journal of Building Engineering 9 (2017) 100–108.

7. Omar Almuwbber, Rainer Haldenwang, Willy Mbasha , Irina Masalova. The influence of variation in cement characteristics on workability and strength of SCC with fly ash and slag additions. Construction and Building Materials 160 (2018) 258–267.
8. V. Kannan, K. Ganesan, Effect of tricalcium aluminate on durability properties of self-compacting concrete incorporating rice husk ash and metakaolin, ASCE J. Mater. Civil Eng. (2015), http://dx.doi.org/10.1061/(ASCE)MT.1943- 5533.0001330.
9. H.T. Le, K. Siewert, H.M. Ludwig, Alkali silica reaction in mortar formulated from self-compacting high performance concrete containing rice husk ash, Constr. Build. Mater. 88 (2015) 10–19.
10. G. Sua-Iam, N. Makul, Self-compacting concrete prepared using rice husk ash waste from electric power plants, Adv. Mater. Res. 488–489 (2012) 258–262.
11. M. Safiuddin, J.S. West, K.A. Soudki, Hardened properties of self-consolidating high performance concrete including rice husk ash, Cem. Concr. Compos. 32 (2010) 708–717.
12. G.A. Habeeb, H.B. Mahmud, Study on properties of rice husk ash and its use as
cement replacement material, Mater. Res. 13 (2010) 185–190.
13. K. Ganesan, K. Rajagopal, K. Tlangavel, Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete, Constr. Build. Mater. 22 (2008) 1675–1683.
14. J.H.S. Rego, A.A. Nepomuceno, E.P. Figueiredo, N.P. Hasparyk, L.D. Borges, Effect of particle size of residual rice-husk ash in consumption of Ca(OH)2, ASCE J. Mater. Civil Eng. 27 (04014178) (2015) 1–8.
15. D. Chopra, R. Siddique, Kunal, Strength, permeability and microstructure of self-compacting concrete containing rice husk ash, Biosyst. Eng. 130 (2015) 72–80.
16. S.A. Memon, M.A. Shaikh, H. Akbar, Utilization of rice husk ash as viscosity modifying agent in self-compacting concrete, Constr. Build. Mater. 25 (2011) 1044–1048.
17. V.P. Della, I. Kühn, D. Hotza, Rice husk ash as an alternate source for active silica production, Mater. Lett. 57 (4) (2002) 818–821.
18. E. Mohseni, F. Naseri, R. Amjadi, M.M. Khotbehsara, M.M. Ranjbar, Microstructure and durability properties of cement mortars containing nano-TiO2 and rice husk ash, Constr. Build. Mater. 114 (2016) 656–664.
19. Belaidi ASE, Azzouz L, Kadri E, Kenai S. Effect of natural pozzolana and marble powder on the properties of self-compacting concrete. Constr Build Mater 2012;31:251–7.
20. Mohsen Tennich, Mongi Ben Ouezdou, Abderrazek Kallel. Behavior of self-compacting concrete made with marble and tile wastes exposed to external sulphate attack. Construction and Building Materials 135 (2017) 335–342.
21. Mohsen Tennich, Abderrazek Kallel, Mongi Ben Ouezdou, Incorporation of fillers from marble and tile wastes in the composition of self-compacting concretes, Construction and Building Materials 91 (2015) 65–70.
22. J.H.S. Rego, A.A. Nepomuceno, E.P. Figueiredo, N.P. Hasparyk, L.D. Borges, Effect of particle size of residual rice-husk ash in consumption of Ca(OH)2, ASCE J. Mater. Civil Eng. 27 (04014178) (2015) 1–8.
23. M.G. Alberti, A. Enfedaque, J.C. Gálvez, Fracture mechanics of polyolefin fibre reinforced concrete: study of the influence of the concrete properties, casting procedures, the fibre length and specimen size, Eng. Fract. Mech. (2016).
24. M.G. Alberti, Polyolefin fibre-reinforced concrete: from material behaviour to numerical and design considerations, 2015.
25. K. Behfarnia, A. Behravan, Application of high performance polypropylene fibers in concrete lining of water tunnels, Mater. Des. 55 (2014) 274–279.
26. P. Pujadas, A. Blanco, S. Cavalaro, A. Aguado, Plastic fibres as the only reinforcement for flat suspended slabs: experimental investigation and numerical simulation, Constr. Build. Mater. 57 (2014) 92–104.
27. S. Yin, S.F.R. Tuladhar, M. Combe, T. Collister, N. Sivakugan, Use of macro plastic fibres in concrete: a review, Constr. Build. Mater. 93 (2015) 180–188.
28. C. Sorensen, E. Berge, E.B. Nikolaisen, Investigation of fiber distribution in concrete batches discharged from ready-mix truck, Int. J. Concr. Struct. Mater. 8 (4) (2014) 279–287.
29. T. Ochi, S. Okubo, K. Fukui, Development of recycled PET fiber and its application as concrete-reinforcing fiber, Cement Concr. Compos. 29 (6) (2007) 448–455.
30. R. Brighenti, D. Scorza, Numerical modelling of the fracture behaviour of brittle materials reinforced with unidirectional or randomly distributed fibres, Mech. Mater. 52 (2012) 12–27.
31. R. Brighenti, A. Carpinteri, D. Scorza, A computational approach to evaluate the mechanical influence of fibres on brittle-matrix composite materials, Comput. Mater. Sci. 64 (2012) 212–215.
32. R. Brighenti, A. Carpinteri, A. Spagnoli, D. Scorza, Cracking behaviour of fibre reinforced cementitious composites: a comparison between a continuous and a discrete computational approach, Eng. Fract. Mech. 103 (2013) 103–114.
33. R. Brighenti, A. Carpinteri, D. Scorza, Micromechanical crack growth-based fatigue damage in fibrous composites, Int. J. Fatigue 82 (2016) 98–109.
34. A. Carpinteri, G. Fortese, C. Ronchei, D. Scorza, S. Vantadori, Mode I fracture toughness of fibre reinforced concrete, Theor. Appl. Fract. Mech., 0167-8442 (2017),
35. M.G. Alberti, A. Enfedaque, J.C. Gálvez, On the prediction of the orientation factor and fibre distribution of steel and macro-synthetic fibres for fibre reinforced concrete, Cement Concr. Compos. (2016).
36. M.G. Alberti, A. Enfedaque, J.C. Gálvez, V. Agrawal, Fibre distribution and orientation of macro-synthetic polyolefin fibre reinforced concrete elements, Constr. Build. Mater. 122 (2016) 505–517.
37. M.G. Alberti, A. Enfedaque, J.C. Gálvez, Comparison between polyolefin fibre reinforced vibrated conventional concrete and self-compacting concrete, Constr. Build. Mater. 85 (15) (2015) 182–194.
38. M.G. Alberti, A. Enfedaque, J.C. Gálvez, V. Agrawal, Reliability of polyolefin fibre reinforced concrete beyond laboratory sizes and construction procedures, Compos. Struct. 140 (15) (2016) 506–524.
39. Faez Alhussainy, Hayder Alaa Hasan, Sime Rogic, M. Neaz Sheikh, Muhammad N.S. Hadi, Direct tensile testing of Self-Compacting Concrete, Construction and Building Materials 112 (2016) 903–906.
40. BS EN 12350-10:2010. Testing Fresh Self Compacting Concrete. L – Box Test.
41. H.Y. Leung, J. Kim, A. Nadeem, Jayaprakash Jaganathan, M.P. Anwar, Sorptivity of self-compacting concrete containing fly ash and silica fume, Construction and Building Materials 113 (2016) 369–375.
42. Omar Almuwbber, Rainer Haldenwang, Willy Mbasha , Irina Masalova. The influence of variation in cement characteristics on workability and strength of SCC with fly ash and slag additions. Construction and Building Materials 160 (2018) 258–267.
43. M.A. Ahmadi, O. Alidoust, I. Sadrinejad, M. Nayeri, Development of mechanical properties of self-compacting concrete contain rice husk ash, Int. J. Civil Struct. Constr. Archit. Eng. 1 (2007) 258–261.
44. M.H. Zhang, V.M. Malhotra, High-performance concrete incorporating rice husk ash as supplementary cementing materials, ACI Mater. J. 93 (1996) 629–636.
45. N. Bhanumathidas, P.K. Mehta, Concrete mixtures made with ternary blended cements containing fly ash and rice husk ash: fly ash, silica fume, slag and neutral pozzolans in concrete, ACI SP-199 1 (2004) 379–391.
46. Yining Ding, Dong Li, Yulin Zhang , Cecilia Azevedo, Experimental investigation on the composite effect of steel rebars and macro fibers on the impact behavior of high performance self-compacting concrete, Construction and Building Materials 136 (2017) 495–505.
47. Salem G. Nehmea, Roland Lászlób, Abdulkader El Mirc, Mechanical Performance of steel fiber reinforced self-compacting concrete in panels, Procedia Engineering 196 (2017) 90 – 96.
48. A. Enfedaque, M.G. Alberti, J.A. Paredes, J.C. Gálvez. Interface properties of polyolefin fibres embedded in self-compacting concrete with a bond improver admixture. Theoretical and Applied Fracture Mechanics 90 (2017) 287–293.
49. M.E. Rahman, A.S. Muntohar, V. Pakrashi, B.H. Nagaratnam, D. Sujan, Self compacting concrete from uncontrolled burning of rice husk and blended fine aggregate, Mater. Des. 55 (2014) 410–415.
50. S.M. Khadiry, G.P. Nayak, T. Aziz, S. Saurav, B.H.V. Pai, Evaluation of properties of self-compacting concrete specimens having rice husk ash and shell lime powder as fillers, Am. J. Eng. Res. 3 (2014) 207–211.
51. Hayder H. Alghazali, John J. Myers, Shear behavior of full-scale high volume fly ash-self consolidating concrete (HVFA-SCC) beams, Construction and Building Materials 157 (2017) 161–171.

AUTHORS PROFILE

Yaman Hooda – He is working as Assistant Professor at SGT University, Gurugram, Haryana. He completed the degree of Masters in Technology in Structural Engineering (Gold Medalist) and the degree of Bachelors of Technology in Civil Engineering (Gold Medalist). He has a good knowledge of the software tools used in the same above stative fields, such as Autodesk AutoCAD 2D and 3D Modelling, STAAD Pro and ETABS. The area of research work will include the topics in the area of Structural Engineering, Earthquake Engineering and Concrete Technology.

Haobam Derit Singh – Career in Structural Design. A Post graduate in Structural Engineering with Civil Engineering background. Proficient and a great command over ETABS, STAAD Pro and AutoCAD. Preferred research area includes that of Structural Engineering with main preference to "Earthquake Engineering" and "Concrete Technology"