Modification of SCC using Particle Packing Density Technique Through Partially Changing Cement Material with Limestone Powder and Quarry Dust

Shivam Verma
M.Tech, 2ND Year
Babu Banarasi Das University
Lucknow, India

Mr. Bilal Siddiqui
Assistant Professor
Babu Banarasi Das
University Lucknow, India

Prof. (Dr.) Surendra Roy
Professor & H.O.D
Department Of Civil Engineering
Babu Banarasi Das University
Lucknow, India

Abstract:- **Self Compacting Concrete (SCC) is positively one of the foremost Advanced materials used today by the Construction Industry thank's to its incredible workability and low porousness, a couple of properties being confirmed by the great amounts of fine aggregates, the superior additives, and consequently the fillers, that defined SCC's mix compared to usually vibrated concrete (VC). The foremost challenging problem with Self-Compacting Concrete (SCC) is that they require extra binders material even for medium as well as for low resistance concrete (20 mpa to 35 mpa) to maintain the rheological or physical properties and biochemical properties, which ends up in high impacts on the environment and reasonable cost. Self-compacting concrete is tremendously popular within the field of concrete technology and it act a significant part while placing the concrete within the congested and heavy-dense reinforcements. Self-compacting concrete can be produced with high fluidity and good cohesion, and it gets compacted by its gravity. this current research is meant to save binding contents without compromising the rheology of concrete mix having high volumes of coarse aggregates and partially replacing cementitious materials with limestone powder and replacing the sand material with Quarry dust use of the particle packing density technique.**

Self-compacting concrete was produced by partially replacing the cementitious material with 10%, 20% 30% of Limestone powder and quarry dirt, and their influence on the fresh properties like passing and filling ability and also the flowability is inspected as per European Federation of the National Associations Representing for Concrete (EFNAR) procedures. Results of fresh and hardened properties revealed replacement of up to 10% of limestone and quarry dust is that the optimal level and other replacement levels produced a reasonable result for brand new particle packing density technique of SCC. Compression strength, water absorption factor, and density values are slightly stricken by the addition of 20% and 30% replacement of those fillers materials. In the current research we use mix design method for SCC to supported particle packing density method to saves a lot of binder during concrete production, aggregates have to be optimally packed. The existing particle packing model is either complex or still needs development. So, here we formed to develop a new packing model for an aggregates that are exclusive and easy to use and save extensive laboratory test and trial's. Using the planned particle packing model for analytical packing density of coarse aggregate (20 mm and 10 mm) and fine aggregate is found, and also the results are validate through an experiment.

Keywords: Particle packing density, limestone powder, quarry dust, binding properties, blended coarse aggregate.

INTRODUCTION

Cementitious based materials are the widely used among all produced materials in view of their several applications within construction manufacturing. Traditional construction and engineering materials are needed to satisfy new and challenging demands. One of the existing advances in concrete technology was the development of Self-Compacted Concrete (SCC). Self-compacting concrete may be a new category of concrete mix that doesn't want any type of external vibration for putting and compaction. It can flow under its own weight to fill any type of congested reinforcement. Hardened SCC is compressed and homogeneous with mechanical and durable properties comparable to that of conventional concrete. Self-compacting concrete gives big amount of concrete settlement, with faster construction time and can flow around heavy dense reinforcement places. The flexibility of SCC affirms an elevated degree of similarity, minor concrete voids, and uniform concrete strength, giving the possibility to give a good finish and durability to the structure. SCC is usually produced with an irregular water-cement ratio for prime early strength, high durability, and fast use of elements and structures.

The use of SCC is smaller in overall structures in nation like India because of its higher in cost, and unavailability of proper mix design methods for SCC production. Due to the high use of Cementitious material compared to standard concrete, SCC isn't economical, particularly for a medium grade of concrete like (Compressive strength up to 40 N/mm2), that are majorly utilized in country like India. So it's needed to develop an SCC for a normal use so it's essential to make it economical in cost by which everyone can afford it by using basic mix design technique .

Concrete may be a primary construction material and industry incorporates a greater demand for achieving a powerful and durable concrete. Cement, aggregates, water, mineral and chemical admixture are the raw materials employed in the manufacture of traditional concrete. According to the Cement Industry 2019 report, India is the second-largest cement manufacturer within the world and also the per capita cement consumption is predicted to be 239kg. Cement production industries are the crucial resources of carbon-di-oxide emission which they produce 310 million tonnes of cement clinkers and that they are the huge pollutants to the environment . Statement records says about 12% -15% of total industrial energy emission is subsidized by the cement manufacturing industry. It reasons a primary hazard to dwelling hood and endangers the human respiratory systems by way of generating huge quantity of particulate matters within the production stage. Hence it's far essential to go looking for another material to exchange the cement within the production of concrete so as to avoid wasting the energy furthermore because the environment. Nowadays cement is partially replaced with wide variety of supplementary cementitious materials (SCM) and top quality SCM produces strong and durable concrete.

Lime stone and Granite quarries are appreciably increasing in number and that they produces big quantity of Lime stone and Quarry dirt in powder form during their crushing procedure. Handling becomes a assignment for these quarries, because of the actual fact the land filling and disposal of this powder creates critical environmental problems like water, land pollutions and cause determinantal results to the human healthiness. Both powdered materials are very pleasant in nature and that they contaminate the air during summer and spring seasons . However these finer materials could also be successfully utilized as a binder medium to reinforce the flowability and viscosity within the manufacturing of special concrete like self-compacting concrete (SCC). Mineral admixtures and plasticizers are accustomed achieve the fluidity of concrete and also the particle size spreading is that the best idea to optimize the fluidity of self-compacting concrete. Inter particle separation combined with particles packing density is that the main rheological parameter governing the layout of self-compacting concrete. The addition of mineral additives or powders additionally to the cement content is employed to realize the acceptance viscosity of self-compacting characteristics. Hence this paper mainly specialised in characterizing the self-compacting concrete produced with the integration of quarry dirt and limestone powder as a partial replacement of cementitious material. Their affects on fresh properties and few hardened properties were determined and described.

HISTORY OF SCC

Japan was the first country to introduce self-compacting concrete (SCC) prototype in 1980's and led to the development of the first practicable SCC by researchers Okamura & Ouchi at the University of Tokyo and After that SCC was researched by European countries. Self-compacting concrete have many applications for the construction industry, due to its excellent properties such as self consolidation and flow under its own weight and fill up in very congested reinforcement section areas and complex structures area without any external compacting applied on it like vibrators . Thus, it is used in constructing multistorey reinforced concrete structures, long vertical columns and beams and slabs in buildings etc. Self-Compacting Concrete has fantastic item properties, for example, remarkable stream rate, more modest measure of labor force necessities, limited water use, and less cover materials use, and so on. However, even after long existence of booming applications and despite its many benefits, the acceptance and application of SCC technology in huge range of construction for supplying it all over the india have been slow. In India, demand for the self-compacting concrete is increasing day by day for construction by replacing it with normal concrete, due to a shortage of skilled labours in the construction workplaces as well as due to the quality of finished concrete SCC possesses. SCC is better than normal concrete in terms of fresh properties, mechanical and durability properties of concrete because air voids presented in concrete mix due to lack of compaction are eliminated. As per research done by Global market vision, the SCC market will be worth 30.3 Billion USD by 2024 worldwide.

The ongoing Indian situation in development shows expanded development of enormous and complex designs, which frequently prompt troublesome cementing conditions. Vibrant concrete in congested areas may cause some risk to labour in addition to sound tension. There are dependably questions about the strength and durability set in such areas. So it is beneficial to take out vibration practically speaking, if conceivable. In nations like Japan, Sweden, Thailand, the UK, and so forth, the information on SCC has moved from the space of examination to application. In any circumstance, in India, this information is to be endless.

PROBLEMS FOUND IN SCC

On Comparing to normal concrete SCC requires more amounts of cementitious substances particularly for medium resistance concrete (20-35 Mpa) to obtain required rheological properties so that compaction can be completed with none outside effort. In country like India such concrete is broadly used in rural as well as urban area. To make SCC in your price range and environment friendly , binder content material desires to be reduced. **Shi et.Al.** has reviewed different mix design method followed via numerous researcher and concluded that particle packing method maximum suitable and easier to reduce the binders without compromising rheological property. Therefore in present research attempt is made to develope mix design technique for medium resistance SCC mix (20-35 Mpa) the usage of particle packing method technique and also partially replaced the cementious materials subtitutes and blended coarse aggregates of different criteria (10mm and 20mm).

In the concrete industry, the aggregates used are of dissimilar size and shapes. So it's far very hard to predict the packing density of blended aggregates of various size and volume. Consequently in present research an attempt is made to increase new particle packing model which less complicated to apply and has good accuracy in predicting quantitative packing density of blended multi-component aggregate and also partially replaced cement materials with limestone powder and quarry dirt.

So the problem of prediction of packing density for the distinct mixing of exceptional and coarse aggregate is solved with the aid of developing a new particle packing model, and to clear up the problem of production of good value SCC mix for medium resistance concrete, with less cementitious material, a simplified mix design using particle packing method is specified. Also, many limitation influences the mix design of SCC like water-cement ratio, sand fines, length and extent of aggregate, admixture dosage,the extent of binders and so forth., as a way to discover the impact of numerous parameters and courting among various parameters multiple regression model is evolved in the present study.

OBJECTIVE AND SCOPE OF THE RESEARCH WORK

The goals of the research work are listed under.

- To advance a particle packing model, that could be expectant filling density for a different combination of coarse and fine aggregate and simple to apply in the concrete industry.
- To develop a cost-effective and simple mix design method for Self Compacting Concrete, the usage of the proposed particle packing model.
- To develop relations using a multiple linear regression investigation for the estimate of compressive strength, slump flow, and admixture dosage.

The Scope of the existing look is as beneath.

- To gain a particle packing model using locally existing material.
- To find ultimate packing density by experimentation and its authentication with the proposed particle packing mdel .
- To study the impact of aggregate parameters like the maximum quantity of aggregate, fines in the sand and packing density on properties of SCC.
- To study the impact of SCC using in part replacement of cementitious material with the aid of limestone powder and Quarry dirt.
- To locate the assets of cement materials the usage of ordinary Portland cement via limestone powder and quarry dirt and evaluation of particle packing density method.
- To locate compressive, tension , durability strength of SCC.
- To examine the effect of paste parameters like paste volume and its composition on the properties of SCC.
- To evaluate fresh properties of SCC mix the use of slump flow, T500 time test, and, hardened properties of SCC mix via cube compressive strength test.

RESEARCH METHODOLOGY

Figure 1.20 suggests the methodology followed for current research work to attain the objectives of the studies for new economical SCC. As shown in the figure the whole work of the current mix. is divided into two level i.e. aggregate segments and the Paste section. Inside the aggregate section, the particle packing density method is advanced to are awaiting the packing density of blended coarse and fine aggregate. As coarse and fine aggregate have different sizes of aggregates, the amount of volume of each size of aggregate should be determined in such a way that it outcomes result in highest quality packing. In current revisions as well in current research the packing model is innovative on an equivalent thought by means of perusing selective current packing density theories of solid physical science and current packing models. For estimation of the packing density of blended aggregates the use of proposed model worksheet is created manually. In aggregate phase, impact of size of aggregates, packing density and sand fines are evaluated for the best results of economical SCC. By Exceptional size of coarse aggregates while mixed with fine aggregates bring about distinct packing density and has different outcomes results comes at the properties of SCC. Consequently, the results come for packing density is check for SCC mix having the distinct size of aggregate which can be regional to be had in India. After the phase 1, it will likely be possible to decide the first-rate mixture of fine and coarse aggregate and their gradation for a new type of self compacting concrete.

The Paste made out from cementitious material, water and admixture for new SCC mixes. As one of the needs is to develop new linear regression form and mix design technique, large experiments covering effect of cement contents like (limestone powder , Quarry dirt and PPC), water-cement ratio, paste extent, and composition properties of mix concrete is studied in the paste segment. Inside the pasted segment, the fine aggregate is a part updated with Quarry dust as well as cementitious material is also replaced with limestone powder, and a coarse aggregate mixture keeping popular packing density is taken. So, in this phase segment, fine and coarse aggregate proportions inside the general combination are kept identical for all mixes. Paste volumes and aggregates composition is varied. Paste volume taken is in the variety from 300 litres to 365 litres in step with per cubic meter of concrete. SCC mixes are casted the use of 400 kg, 380 kg, 360 kg and 340 kg cementitious material in step with per cubic meter of concrete. Water cement ratio and admixture dosage also are varied for every cementitious material used for the new Economical self compacting concrete.

Primarily based on the results of each the phases a guideline is prepared for new design mix for self- compacting concrete. Also, regression models are prepared to are expecting compressive strength, slump flow and admixture dosage primarily based on parameters affecting them.

SIGNIFICANCE OF RESEARCH

In the current research, today's progression-primarily based totally particle packing version is progressive that's quite simple and smooth to practice. Using this version it is simple to count on the packing density analysis for the extraordinary blending of coarse and fine aggregate. In the proposed particle packing model, the packing phenomenon of the multi-component mix are clearly very easy. The model can

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

universally be followed for any size of the aggregate because it works on the size and quantity of air voids found in blended aggregate. The current version does not contain any complicated mathematical equations for the mix design, Spreadsheet is developed to perform calculations to find out the new packing density for the developemnet of newly economical SCC which can afford by everyone to use it normally.

- The usage of particle packing technique for low-payment SCC mixes are produced with least trial mixes. SCC mixes are produced the utilization of just about the same cementitious substances which is probably required for conventional concrete mixes. These consequences in Sustainable SCC make more construction of the building with economical cost.

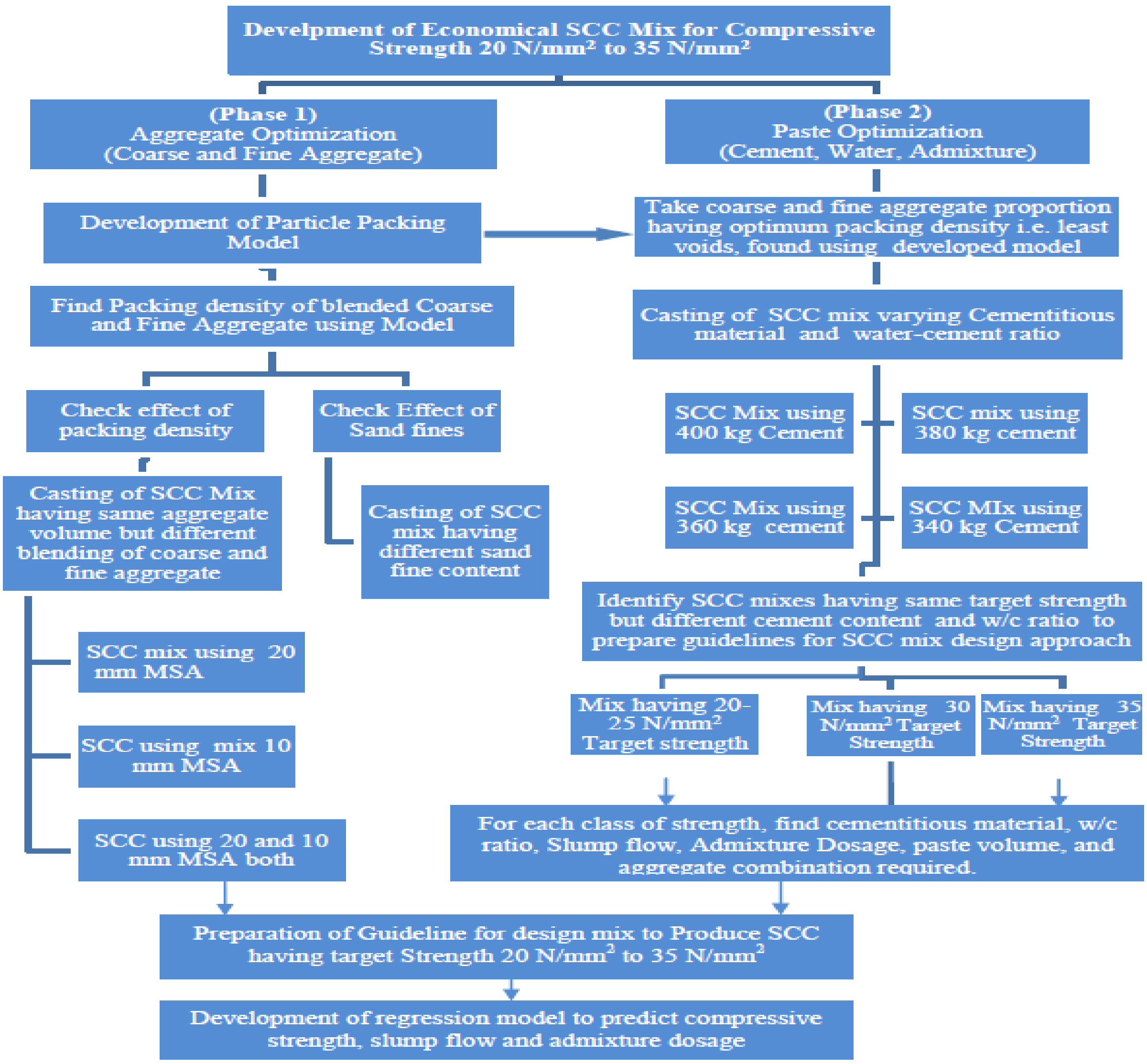
- If SCC replaces normal concrete, durability troubles produced due to loss of compaction can be removed and thereby maintenance value of concrete structures can also be reduced and the age of structures may be improved by this.

- Parameters affecting the compressive strength, slump flow and Superplasticizer dosage are discovered and the connection is established the use of multiple linear regression analysis to expect them.

- Strength properties of cement Increased by partially replaced with lime stone powder which makes cement material Economically low .

- A simple mix design technique primarily based on particle packing method is advanced through studying the various parameters affecting the self-compacting concrete mix.
- Gradation diversity of mixed high-quality and coarse aggregate suitable for making self- compacting concrete is specified.

FIGURE 1.20 Research Methodology Flow Chart



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

LITERATURE REVIEW

The main consciousness for writing assessment changed into to have a look at literature associated with diverse styles of to be had particle packing version and cementitious material is in part changed with limestone power and Quarry dust, application of various particle packing models for producing self-compacting concrete, to have a look at to be had guidelines, test and acceptance values for mix proportioning of SCC and other important authors related to mix proportioning of SCC.

Literature on Particle Packing Model and Theory

On particle, packing work is completed for a long and still, researchers are dealing with it to develop the current model or to find a new technique. The particle packing model is divided into two categories, the continuous and discrete model.

Fuller et al. [3] have announced the thought of 'composing an ideal particle size distribution (PSD) curvature for aggregates. Fuller known 'an experiential gradation curve termed as Fuller curve, which displays the particle grading having optimal density'. The idea behind the ideal PSD curve was to reduce the void present in the packed aggregate. As shown in equation 1.1 Fuller has used a distribution modulus (q) value equal to 0.6. This observationally advanced degree bend accepts particles of limitless finesses (i.e. Dmin = 0). This assumption of the Fuller curve with q = 0.5 can in no way be satisfied in real practice. In the Fuller curve gradation of aggregate is the coarser side and therefore Fuller curve is less suitable for SCC.

$$P(D) = \left(\frac{d}{dmax}\right)^{0.5} \quad (1.1)$$

P(D): Cumulative particles passing from the sieve size D .
d: Diameter of the particle being considered
d'max : big size of the particles

Anderson's et al.[4] reported that the air voids between the particles depend on the value of q and can be expressed as a percentage with this distribution modulus q as shown in equation (1.2). Andersen and Anderson recommended the value of q in the series of 0.34 – 0.51.

$$P(D) = \left(\frac{d}{dmax}\right)^{q} \quad (1.2)$$

q : Characterizes a control , which sets the movement of the degree bend towards fineness or coarseness.

"Brouwer's et al." [6] 'innovative a mix. design technique for SCC mainly based totally on advanced A&A model. The writer has studied Japanese System and Chinese system and stretched their use for Dutch process'. The Japanese technique used the individual packing densities of gravel and sand which leads to SCC that includes a better quantity of paste. Due to this SCC made using the Japanese method gives a higher strength than really targeted. The Chinese Technique considers the collective packing density of sand and gravel and adopts that the voids between the aggregates will be filled by paste. Brouwers must well-organized the packing of all aggregates, fillers, and cement fundamentally in this knowledge. Total 3 kinds of sand coarse, medium and fine, and coarse aggregate of size having MSA 16 mm are taken for the design mixture. Through an experiment results show that sand and gravel ratio of 60:40 in compressed conditions results in maximum packing density. A modified A&A model with q=0.25 is followed for optimal PSD. SCC mixes are casted using 480 kg/m3 powder content and results in concrete grade with compressive strength 35-45 Mpa. It is shown that more water is available for providing lubrication between the aggregates when aggregates are optimally packed. Brouwers planned that fines are very much important for growing cohesive SCC with out isolation and bleeding.

"Wang's et al." [7] had improved the Brouwer's particle packing based mix design procedure and useful it to produce SCC. He used q value ranging between 0.24 and 0.30 in improved A&A model depending on the application of mix and material nominated. It was testified that the distribution module from 0.24-0.30 is good for SCC and the optimum value is 0.28. He showed that due to the particle packing approach, 20% binder is reduced. Various mix design methods were compared and it was shown that most of the methods are prescriptive and to finalize constituent materials no specific method is available.

J. D. Dewar's [15] considered packing density in loose condition of aggregates. Instead of packing density the void ratio is calculated in this method. The voids ratio and the log mean size of each individual material are utilized to calculate the voids ratio for given combination of aggregates. For multi-component mixtures, an analogous process, as discussed above is used. The Dewar method requires that initially two most fine materials should be combined and later the next coarser material is added. Finding experimental void ratio for each material to be combined makes this method time consuming and difficult to use .

Azar Hamid Mir [1] said that The suitability of quarry dust as a sand replacement material shows that the mechanical properties are enhanced and also elastic modulus. The compressive strength tested optimal by replacing fine with quarry dirt in ratio of 60:40 .

Burak Felekoglu [2], recognized that the integration of quarry waste and the equal amount of cement content usually reduced the super plasticizer requirement and improved the 28 days compressive strength of SCC.
Normally the strength mixture of SCC contains nearly 300 to 310 kg of cement by inducing the quarry dust it can be increased a lot per cubic meter.

Mahendra R. et al. [9] , It is clearly observed that there is reliable increase in the strength of plain concrete when natural sand is fully replaced by quarry dust.

R. IIangovana [12], the study gives attention towards physical and chemical properties of quarry dust are satisfied in respect of requirements of codal provision. The complete replacement of sand with quarry dust gives the better results in terms of compressive strength studies.

RESEARCH GAPS FROM LITERATURES

Literature shows that still researchers are trying to develop new particle packing models and theories and still fundamental model needs to be developed . For continuous models various researchers have given different distribution modulus (q) values ranging from 0.22-0.29 for optimum packing of coarse aggregate. So, one should need to find the q value that suits their aggregates performing experimental iterations to find the best combination of fine and coarse aggregates for new economical SCC.

In the discrete method, compression packing version advised with the aid of using De llaraad's is additional valuable for predicting packing density, but the difficulty of the version and the variety of enter information makes it extra tough to practice.

Therefore, research is needed to develop a new logical and simple method to find a packing density for blended aggregate, which overcomes the ambiguity of existing models to make SCC in low cost for production . The analytical procedure should be without any complex calculations and can be easily used at a construction site to find optimum packing density.

To make cement more economically we have to replace cementious material with same binding properties materials which can give the same reological possessions as well as compressive and tensile strength to self compacting concrete .

EXPERIMENTAL PROGRAM

The experimental program is prepared to develop the new economical SCC mix having compressive strength up to 20-40 N/mm2 using locally available material. In present research, coarse aggregate (20 mm and 10 mm), fine aggregate, partially replaced Portland pozzolona cement (PPC) with lime stone powder and quarry dust as a filler to fill the air void present during concrete mix , PCE based admixture (BASF 8549) are used to manufacture new SCC mix.

To make SCC mix layout as simple as traditional concrete mix, domestically to be had materials are used which could without problems be procured. As a chemical admixture, only PCE primarily based totally superplasticizer is used. As on this reseach we've changed PCC with lime stone and quarry dirt simultaneously 10% to 30% that is considered necessary for the manufacturing of SCC to make it economical, because of its curved particle shape, which gains the possessions of Portland pozzolanas cement is used with 10% to 30% of limestone and quarry dirt substantial. No different chemical or mineral admixture like air-entraining agent (AEA), silica fume, GGBFS , viscosity modifying agents and so on are used to hold mix design as easy as traditional concrete mix layout.

To confirm the rheological properties of SCC like flowability, passing ability, and segregation resistance, the test like Slump flow, T500 time, V funnel, L Box and Sieve segregation are completly following the EFNARC guidelines. As per IS code:456-2000, tensile and flexure strength has constant connection with compressive strength for conventional concrete. In current study similar substances are used like normal concrete, as a result only cube compressive strength take a look at is finished to discover the mechanical properties of the harden concrete as consistent with the guiding principles given in IS code: 516.

The experimental program is prepared to find out the effect of various parameters on the new mix designs of self-compacting concrete. An investigational program for new SCC mix designs is divided into two-phases (1) Aggregate Phase and (2) Paste Phase.

1. **Aggregate Phase :** In aggregate phase investigational application is ready to test the effect of problems just like the most size of aggregate and aggregate packing density property i.e. packing density, fines in sand and impact of paste composition for indistinguishable coarse aggregate volume. To test the aggregate effects, only aggregate proportions are transformed, at the same time as all different material percentage reserved constant .
2. **Paste Phase :** Paste includes Cement, water, admixture and air voids. So, in the paste phase new SCC mixes are casted by varying cement content like lime stone powder and quarry dust as a filler for air voids in concrete, water-cement ratio, and admixture dosage to verify their effect on concrete mix for target compressive strength of 20-40 Mpa.

TABLE 2.6 Requirements of SCC mix in Fresh State [25]

Test	Classes	Range (mm)	Application	Purpose	Remarks
Slump Flow	SF-1	550-650	Unreinorced	To check segregation, filling ability, viscosity	If paste extend several millimetres from the C.A. and if C.A. segregated at central area
	SF-2	660-750	Normal		
	SF-3	760-850	Very Congested Stru.		
T 500 time	VS-1	<=2	Good Filling,Surace finish	Viscosity	Prone to bleeding and segregation
	VS-2	>2	High segregation Resistance		Lake in Surface finish
V Funnel	VF-1	<=8	Same as T500	Viscosity	Same as T500
	VF-2	9 to 25			
L-Box	PA-1	>=0.80 with 2 rebars	Housing/Vertical Structures (Gap 80 mm to 100 mm)	Passing Ability-Flow without blocking	No need when gap is more than 100 mm
	PA-2	>=0.80 with 3 rebars	Civil Engineering Stru (Gap 60 mm to 80 mm)		
Sieve Segregation Test	SR-1	<=20%	For thin slabs & Vertical Application	Segregation resistance for higher slump flow	Flow Distance<5m Confinement Gap >80mm
	SR-2	<=15%	Tall Vertical Application		Flow Distance>5m Confinement Gap <80mm

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

Design Mixes for Aggregate Phase

It is already mentioned that current research is aimed to study low to medium resistance concrete (20-40 Mpa). Such concrete contains excessive volume of coarse aggregates; accordingly Granular structure has huge effect on fresh properties of SCC. Therefore, on this phase, effect of various fine and coarse aggregates associated properties like maximum size of aggregate, packing density and sand fines are studied. For this purpose in all mixes of paste volume and aggregate composition is kept same. The aggregate volume is likewise kept equal however their size and blending ratio are changed.

Calculation and test matrix of design mixes for Aggregate phase

For medium strength of concrete, aggregate volume in conventional concrete is around 60% to 70%. So, paste volume is in the range of 30-40%. Therefore, in aggregate phase to keep paste volume between 30-40%, for initial casting SCC mixes are prepared using 401 kg/m3 of cement. Once the guidelines of mix design will be prepared, the cementitious material can be chosen based on target strength and targeted fresh properties for the production of economical SCC. Now, for all combinations, water to the cementitious material proportion (w/c) is kept constant and is takes 0.51. Also, PPC cement 401 kg/m3 is taken for all mixes and therefore water is taken 201 litre/m3. SP dosage is kept constant at 0.8% of cement weight, so it comes 3.21 kg/m3. In view of 2% air content, the total volume of paste for these mixes in aggregate phase comes 361.84 litre/m3 of concrete. Later, the volume of aggregate will be 639.14 litre/m3 of the concrete.

If the volume of aggregates and aggregate proportion in total aggregate is known, their weights can be worked out as below given tables and figures.

Let assume that in a given volume of total aggregates, the volume of fine aggregates is VFA, Volume of Coarse aggregate taking size of 10 mm and 20 mm is V10mm and V20mm respectively and volume of filler material if any is VF.

Then total volume of aggregate is given by

VFA + V10mm + V20mm + VF = V

$$\frac{W_{FA}}{G_{FA}} + \frac{W_{10mm}}{G_{10mm}} + \frac{W_{20mm}}{G_{20mm}} + \frac{W_F}{G_F} = V$$

$$\frac{P_{FA}.W}{G_{FA}} + \frac{P_{10mm}.W}{G_{10mm}} + \frac{P_{20mm}.W}{G_{20mm}} + \frac{P_F.W}{G_F} = V$$

Where V= Total Volume of blended coarse aggregate
W= Total weight of blended coarse aggregate
G= Specific gravity of the given material
P= Percentage ratio of the aggregate in total aggregate

$$W = \frac{V}{\frac{P_{FA}}{G_{FA}} + \frac{P_{10mm}}{G_{10mm}} + \frac{P_{20mm}}{G_{20mm}} + \frac{P_F}{G_F}}$$

For example in a blended aggregate, if Fine aggregate is 64% and 20 mm aggregate is 36% and the total capacity of blended aggregate is 639.15 litre then the total weight of coarse aggregate .

$$W = (639.15)/\big((0.64/2.56) + (0/2.86) + (0.34/2.85) + (0/2.71)\big) = 1702.24 \text{ kg}$$

WFA=0.65X1702.24 = 1106.456 kg and
W20mm=0.35X1702.24 = 595.784 kg
Proportions finalized for SCC mix per cubic meter of concrete:

	Paste (360.84 liter)				Aggregates (639.16 liter)			
	Water	Cement	Admixture	Air	Sand	10 mm	20 mm	Filler
Volume (liter)	200	137.93	2.91	20	639.16			
Weight (Kg)	200	400	3.2	0	1107	0	596.08	0
	Paste Volume and Composition (fix)				Aggregate volume is fixed but proportion of			

Design mixes to find the effect of aggregate size and packing density

According to EFNARC guidelines suggestions to produce SCC, fine aggregate material can be taken up to 47% to 56% of the total aggregate. As per particle packing model, for the aggregates used in this research, the packing density is maximum for 60% to 65% of Fine Aggregate blended with 35% to 40% Coarse Aggregate, also for FA: CA proportion 60:40, 55:45 , 53:47 and 52:48 packing density are good for strength. Therefore, to check the effect of packing density and the effect of volume of coarse and fine aggregate, total 13 mixes using above FA:CA ratios are designed to keeping paste volume and paste composition same. Three types of aggregate variation are taken for this concrete mix. Four mixes are prepared using 20 mm size aggregate, five mixes are prepared using 10 mm size aggregate and in 4 mixes are prepared by using a combination of both 20 mm and 10 mm size of coarse aggregates in the ratio of 75% 20mm and 25% 10mm. As shown in TABLE 3.80 , the mixture of 75% 20mm and 25% 10mm coarse aggregate gives optimal packing density when they blended together. For 20 mm Size Aggregates, fine and coarse aggregate proportions of 65:35, 60:40, 55:45 , 53:47 and 52:48 were taken. For10 mm MSA, fine and coarse aggregate proportions of 65:35, 60:40, 55:45, 52:48 and 48:52 were taken. For a combination of 20 mm and 10 mm CA with FA, FA: CA (10mm): CA(20mm) proportions of 60:10:30, 55:12:33 and 52:12:36 were taken. Mix proportions of all these mixes are presented in TABLE 5.20, TABLE 5.30 and TABLE 5.40.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

TABLE 5.20 Data for Mix Proportion per m3 using Maximum Size of aggregate 20 mm

Mix Designation	Combination of Aggregate			20 mm	10 mm	Sand	Cement	Water	SP
	FA	10 mm	20 mm	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
Mix A1	65:00:35			596.08	0.00	1107.00	400.00	200.00	3.2
Mix A2	60:00:40			684.83	0.00	1027.25	400.00	200.00	3.2
Mix A3	55:00:45			774.53	0.00	946.65	400.00	200.00	3.2
Mix A4	52:00:48			828.81	0.00	897.87	400.00	200.00	3.2

TABLE 5.30 Data for Mix Proportion per m3 using Maximum Size of aggregate 10 mm

Mix Designation	Combination of Aggregate			20 mm	10 mm	Sand	Cement	Water	SP
	FA	10 mm	20 mm	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
Mix A5	65:35:00			0.00	596.08	1107.00	400.00	200.00	3.2
Mix A6	60:40:00			0.00	684.83	1027.25	400.00	200.00	3.2
Mix A7	55:45:00			0.00	774.53	946.65	400.00	200.00	3.2
Mix A8	52:48:00			0.00	828.81	897.87	400.00	200.00	3.2
Mix A9	48:52:00			0.00	901.72	832.36	400.00	200.00	3.2

TABLE 5.40 Data for Mix Proportion per m3 using blending of 20 mm and 10 mm MSA

Mix Designation	Combination of Aggregate			20 mm	10 mm	Sand	Cement	Water	SP
	FA	10 mm	20 mm	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
Mix A10	60:10:30			513.62	171.21	1027.25	400.00	200.00	3.200
Mix A11	55:11:34			585.20	189.33	946.65	400.00	200.00	3.200
Mix A12	52:12:36			621.61	207.20	897.87	400.00	200.00	3.200

Sieve Analysis

Sieve analysis is performed as per the requirement of IS: 383-2016 [40] and IS 2386-2002 (Part-1) [41]. Both coarse and fine aggregate satisfies the requirements of the codes.

TABLE 3.3 Sieve Analysis of 20 mm Aggregate

Sr. No.	IS. Sieve Size	Weight Retained		Passing Weight (%)		Required Passing weight as Per IS. Specifications (%)
		Weight %	Cumulative Weight (%)			
1	40	0	0	0	100	100%
2	20	150	7.51	7.50	92.50	85-100%
3	10	1570	78.54	86.00	14	0-20 %
4	4.75	280	14.30	100.00	0.00	0-5 %
5	Pan	0	0.00	100.00	0.00	NA



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

TABLE 3.4 Sieve Analysis of 10 mm Aggregate

Sr. No.	IS. Sieve Size	Weight Retained			Passing Weight (%)	Required Passing weight as Per IS. Specifications (%)
		Weight (g)	Weight (%).	Cumulative Weight (%)		
1	12.5	0	0	0	100	100%
2	10	190	9.50	9.50	90.50	85-100%
3	4.75	1680	84.00	93.50	6.50	0-20 %
4	2.36	110	5.50	99.00	1.	0-5 %
5	Pan	20	1.00	100.00	0.00	NA

TABLE 3.50 Data for Sieve Analysis of Fine Aggregate

Sr. No.	IS. Sieve Size	Weight Retained			Passing Weight (%)	Required Passing weight for Zone-II as per IS-383 (%)	Required Passing weight for Zone-III as per IS-383 (%)
		Weight (g)	Weight (%).	Cumulative Weight (%)			
1	10	0	0	0.00	100	100	100
2	4.75	116	5.8	5.80	94.2	90 to100	90 to100
3	2.36	193	9.65	15.45	84.55	75 to 100	85 to 100
4	1.18	355	17.75	33.20	66.80	55 to 90	55 to 90
5	0.6	195.0	9.75	42.95	57.05	**35 to 59**	**60 to 79**
6	0.3	621	31.05	74.00	26	8 to 30	12 to 40
7	0.15	409	20.45	94.45	5.55	0 to 10	0 to 10
8	0.075	95.0	4.75	99.20	0.8	0 to 3	0 to 3
9	Pan	16.0	0.8	100.00			

Bulk Density, Void Volume and Packing Density of concrete

Bulk density is calculated with the procedure which is given in IS: 2386-2002 (Part-3). Bulk density, voids and packing density is calculated for fine aggregate, 10 mm coarse aggregate and 20 mm coarse aggregate and presented in TABLE 3.70. Also, to finding the best mixtures of 10 mm and 20 mm coarse aggregate, which results in finest packing density, packing density of different mixture is explored and presented in Table 3.80. Combination of 76% 20 mm coarse aggregate with 24% 10 mm coarse aggregate results in optimal packing density.

TABLE 3.70 Bulk Density, Volume of Voids and Packing Density of Coarse and fine Aggregate

Sr. No	Weight	Fine Aggregate (Sand)	Coarse Aggregate (10 mm)	Coarse Aggregate (20 mm)
	Specific Gravity	**2.57**	**2.86**	**2.86**
1	Wt. of container (w1) kg	6.8	6.8	6.8
2	Volume of container in m3 (v)	0.010474	0.010474	0.010474
3	Wt. of Container + Wt. of Compacted Aggr. (w3) (kg)	26.55	24.8	23.95
4	Dry Compacted Bulk density =(w3-w1)/v (kg/m^3)	1885.62	1718.54	1637.39
5	Voids as per SPGR based on DCBD=[(Gs-DCBD)/Gs]*100	26.63	39.91	42.75
6	Packing Density for DCBD	0.734	0.601	0.573


FIGURE 3.40 Bulk and Packing Density of Aggregate

TABLE 3.80 Data of Bulk Density, Volume of Voids and Packing Density of Graded Coarse Aggregate

Sr. No	Weight (kg)	50%(20 mm) + 50%(10 mm)	60%(20 mm) + 40%(10 mm)	75%(20 mm) + 25%(10 mm)
1	Wt. of container (w1) kg	8.69	8.69	8.69
2	Wt. of Container + Wt. of compacted Aggr.(w2) kg	34.46	34.79	36
3	Volume of container in m3 (v) m3	0.015	0.015	0.015
4	Compacted Bulk Density = (w2-w1)/v	1718.00	1740.00	1820.67
5	Volume of Voids in Compacted State of Aggregate (%) =	39.93	39.16	36.34
6	Packing Density(DCBD)= (Bulk Density/(Specific Gravity*1000)	0.601	0.608	0.637

MATERIAL TESTING DATA

General

In INDIA, the majority of the concrete mix, the coarse aggregates having a maximum size of aggregate i.e (MSA) 20 mm and 12 mm are used in combining with fine aggregate having MSA 4.75 mm. In current study material used are 20 mm and 10 mm down coarse aggregate, 4.75 mm down fine aggregate, Portland Pozzolona Cement (PPC) and PCE based superplasticizer Master Glenium Sky BASF 8549. All the materials taken are effectively accessible locally. All important properties of those materials like specific gravity, water absorption, gradation, etc. are determined and presented. Master Glenium SKY 8549 observe all of the necessities of IS: 9103:1999 [38]. PPC cement taken satisfies all of the necessities of IS: 1489-2015 [39]. The test declaration of the Portland pozzolona cement taken in this research is given through the manufacturer of SCC mix design.

1. **Materials**

This phase offers the information of the traits of the one of a kind materials used on this experimental investigation.

2. **Concrete**

Concrete is utilized as a limiting material. In this trial examination, Common Portland Concrete of Grade 53 is utilized. The concrete is determined to be conforming to various specifications of IS 12269-1987. The physical properties of cement are tested, and the outcomes are tabulated in Table I as in step with IS 4031-1998.

3. **Aggregates**

Aggregates are sluggish granular materials which includes fine aggregate, gravel, or crushed stone which might be mixed along with water and Portland cement to make concrete. They are significant elements in making concrete.

4. **Coarse aggregate**

In current experiment work coarse aggregate of 10 mm and 20 mm blended coarse aggregate are used which offers the higher partical packing density for concrete.

5. **Fine aggregate**

Fine aggregate used on this experimental work is regionally available river sand, care is taken to peer that the sand is free from impurities, waste stones and to stay clean. Sand used is confirming to the necessities of IS: 383-1970.

In this test we've extensively utilized a lime stone powder and quarry dirt as a filler material to remove the air voids from the concrete mix.

6. **Chemical Admixture**

In the current study, Master Glenium SKY 8549 is used. It is used to enhance the workability of the concrete and additionally especially formulated to offer excessive water

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

reductions up to 25% without loss of workability and reduce permeability to give outstanding concrete.

7. Water

Water is the most important ingredient of concrete which helps to bind the cement contented and aggregates. Clean & potable water is used for concrete mixes.

Test strategies on SCC (Self Compacting Concrete)

The strategies provided right here are devised especially for SCC. Existing rheological test procedure have not taken into thought right here, though the connection among the results of those tests & the rheological characteristics of the concrete is likely to figure highly in future work, together with standardization work .

A concrete mix can only be labeled as SCC if the necessities for all of the following 3 workability properties are fulfilled.

1. Filling ability
2. Passing ability
3. Segregation resistance.

Filling ability: It is the ability of SCC to circulate all areas inside the formwork under its own weight. Tests, which includes slump flow, V-funnel etc, are used to determine the filling ability of fresh concrete.

Passing ability: It is the facility of SCC to flow through close-fitting openings, which includes spaces among steel reinforcing bars, under its own weight. Passing ability may be determined with the aid of using the usage of U-box, L-box, Fill-box, and J-ring test strategies.

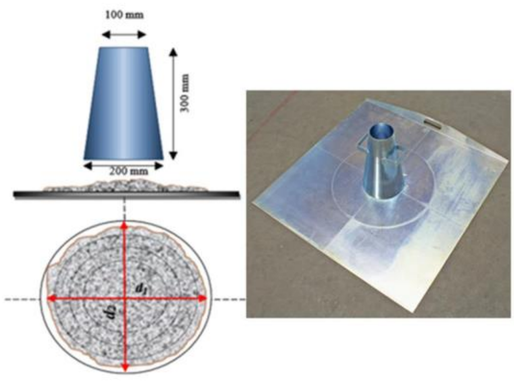
Segregation resistance: The SCC should meet the filling ability and passing ability with uniform composition at some point of the procedure of transport and placing.

Slump flow test and T_{50} cm test method

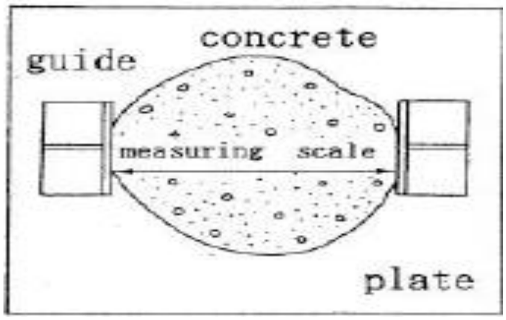
The slump flow is used to determines the straight free flow of SCC in the absence of any obstacles. It changed into first advanced in Japan for utilized in assessment of submerged concrete. The diameter of the concrete circle is a sizes of the filling volume of cement. Slump flow is certainly one of the most characteristically utilized SCC tests till now.

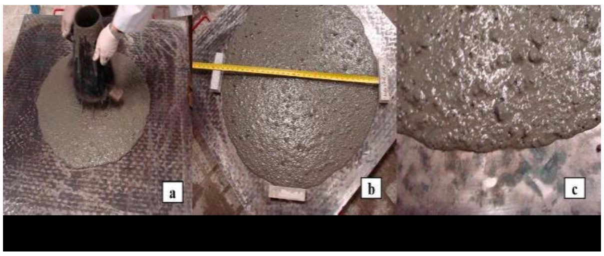
Slump flow device

The mould applied in the shape of a compact cone with internal dimensions of 200 mm diameter on the base, 100mm diameter at the top and the height of 300 mm. The base plate is completely of non-absorbing material of at least 700 mm square area, which is marked with center position for the slump cone, and further concentric circle of 500mm dia. The other device required are trowel, scoop, ruler, and stop watch.



$$SF = \frac{(d_1+d_2)}{2}$$





Procedure

Around 6 liter of cement is expected to play out the test. The base plate and the inside of the slump cone have been saturated. The base plate was put on level stable ground and the slump cone was put midway on the base plate and hold down solidly. The concrete was filled into the cone with the scoop without compressing. The overabundance material at the highest point of slump cone was removed and evened out with a trowel. The excess cement across the foundation of the cone was wiped out. The slump cone was raised vertically upwards allowing the concrete to flow out uninhibitedly. The time taken for cement to arrive at the 500 mm spread circle was recorded through the using of the stopwatch. This is the T50 period. After the flow of cement was stopped, the final diameter across of cement in perpendicular direction was estimated. The average of the two estimated diameters is alluded to as slump flow in mm.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

FRESH PROPERTIES RESULTS OF SCC

An effect on of limestone and quarry dust powder at the fresh properties of self-compacting concrete changed into studied and the outcomes of Slump flow, V funnel, L box and U box test are given in table 5. From the test results , it's far determined that the flow properties of 10% limestone powder was little excessive while in comparison to control concrete and its passing ability as well as the filling capability are expanded. The slump flow value is 741mm for CC series and while it is 748 mm for LS10 but LS20 and LS 30 shows lower workability than reference concrete. But they're in the EFNARC guiding principle stated in table 4 , and stated to be a self-compacting concrete. Excluding it's much found that for the same level of substitute with quarry dust powder, The flowability in all the 3-alternative was discovered decreased even as in compares to Lime stone sequence. Consequently the self-compacting concrete designed with lime stone powder is greater flowable than SCC produced with quarry dust powder. The proof of go with the flow of mortar and its bleeding characteristics in QD series are discovered with the aid of its slump flow T500 take a look at . Lime stone powders indicates better shape when compared to quarry dirt and the friction between the particles results in the high flowability characteristics . In V funnel test all the SCC composites satisfies the acceptance criteria of EFNARC specifications. But, in limestone sequence the 20% and 30% replacement levels compact the filling and passing ability which gets altered with the replacement of 30% quarry dirt in the fresh compound.

Table 4. EFNARC guidelines for SCC

Method of testing	Unit	Typical range of values	
		min	max
L-Box Test	-	0.8	1.0
U-Box Test	mm	0	30
V-Funnel Test	sec	6	12
Slump flow test	mm	650	800
J-Ring test	mm	0	10

Table 5. Fresh properties of SCC

Series	Slump flow	T500mm (sec)	Vfunnel (sec)	L box (h2/h1)	U box (mm)
CC	741	1.08	6.83	0.986	8
10LS	748	1.02	6.78	0.994	5
20LS	716	1.24	7.10	0.917	12
30LS	695	1.43	8.64	0.849	18
10QD	720	1.41	7.38	0.884	17
20QD	698	1.67	7.65	0.852	22.5
30QD	672	1.86	11.41	0.811	27

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

TESTS ON HARDENED CONCRETE

Compressive Strength Test

The cube shape example is of the size 150 x 150 x 150 mm. On the off chance that the biggest aggregate size of the total doesn't surpass 20 mm. cylindrical shaped test have a length equivalent to two times the diameter. They are 15 cm in diameter across and 30 cm long. smaller test examples might be utilized yet a proportion of the measurement of the example to greatest size of aggregates, at least 3 to 1 is kept up with.

After making the concrete Cubes of size 150x150x150mm were cast and allowed for curing in curing chamber for 28 days and 56 days. And tested in Automatic compression testing machine of 2000KN-capacity.

TABLE 6.10. Data of Compressive strength test and fresh properties of design mix with MSA 20 mm

Mix Designations	Combinations of Aggregate			Slump Flow (mm)	T500 (Sec)	V Funnel (Sec)	L-Box (H2/H1)	Sieve Segregation Portion (%)	Compressive Strength		Remarks/Opinion
	FA	10 mm	20 mm						7 Days	28 Days	
Mix A1	65:00:35			700	1.72	4.8	1.0	5.82	22.29	38.18	Cohesive Mix
Mix A2	60:00:40			685	1.59	4.4	0.95	6.65	21.1	39.27	Cohesive Mix
Mix A3	55:00:45			656	3	2.4	0.95	10.35	23.26	39.92	Cohesive Mix
Mix A4	52:00:48			645	3.12	1.66	1.0	13.25	25.9	41.37	Bleeding

TABLE 6.20. Data of Compressive strength test and fresh properties of design mix with MSA 10 mm

Mix Designation	Combinations of Aggregate			Slump Flow (mm)	T500 (Sec)	V Funnel (Sec)	L-Box (H2/H1)	Sieve Segregation Portion (%)	Compressive Strength		Remarks/Opinion
	FA	10 mm	20 mm						7 Days	28 Days	
Mix A5	65:35:00			640	2.41	3.86	0.95	4.36	21.6	39.78	Cohesive Mix
Mix A6	60:40:00			630	2.56	4.84	0.95	5.25	22.21	39.18	Cohesive Mix
Mix A7	55:45:00			625	3.52	5.98	0.95	5.80	21.54	41.28	Cohesive Mix
Mix A8	52:48:00			610	2.62	9.47	0.95	6.95	20.62	38.48	Cohesive Mix
Mix A9	48:52:00			600	2.4	10.5	0.90	9.75	19.98	37.73	Bleeding

TABLE 6.30. Data ofCompressive strength test and fresh properties of design mix with MSA 20 mm+10 mm

Mix Designation	Combination of Aggregate			Slump Flow (mm)	T500 (Sec)	V Funnel (Sec)	L-Box (H2/H1)	Sieve Segregation Portion (%)	Compressive Strength		Remarks/Opinion
	FA	10 mm	20 mm						7 Days	28 Days	
Mix A5	65:35:00			640	2.4	3.86	0.95	4.36	22.76	39.65	Cohesive Mix
Mix A6	60:40:00			636	2.57	4.85	0.94	5.25	23.31	39.18	Cohesive Mix
Mix A7	55:45:00			628	3.61	5.99	0.95	5.80	22.52	41.58	Cohesive Mix
Mix A8	52:48:00			610	2.68	9.47	0.95	6.95	21.63	38.70	Cohesive Mix
Mix A9	48:52:00			600	2.42	10.5	0.90	9.75	20.96	39.93	Bleeding

The fresh and hardened properties of all the mixes are presented in TABLE 6.10, TABLE 6.20 and TABLE 6.30. In SCC mixtures, fine aggregate is slowly decreased till the bleeding is observed in the given concrete mix . Once bleeding is observed in concrete then after no further reduction of FA is made.

CONCLUSION

Conclusions based on experimental work

- Maximum slump flow for 10 mm MSA was 634 mm using 401 kg cementitious material, whereas 651 mm slump flow was observed using only 360 kg cementitious material for 20 mm MSA, due to the high amount of packing density. So, about 16-20% binders can be saved using the particle packing technique for manufacturing economical SCC.

- In the current study, for the same aggregate volume, paste volume and paste composition but different packing density, the increment of 12.88% was observed in slump flow test, while increment of 2.62% was observed in compressive strength test due to which the increase in packing density shown. So, it can be concluded that packing density has a primary effect on fresh properties while the strength of the concrete mix was not much affected and also if the size of aggregate will decreased then mix becomes more cohesive in nature.

- It is observed that, dosage of Super plasticizer cannot be decided only on the basis of the Marsh cone test in which the fine aggregate is very imp., it also depends on volume of fine aggregate. As the fine aggregate amount is decreased, the dosage of superplasticizer is also reduced. SP dosage decided by the Marsh cone test which can be modified based on fine aggregate volume in concrete mix.

- In paste composition, water volume impacts more fresh properties as compared to cement quantity. So, for a cost-effective SCC mix for medium resistance concrete, water volume have to be kept as maximum as viable in order that it does now no longer reason bleeding and segregation, on the equal time it have to be within the limits of structural concrete.

- In this studies we've got additionally observed that after we partially changed the cementitious material with limestone powder and quarry dirt as a filler material which gives the higher fresh properties and hardened properties results with particle packing technique . with the aid of using the use of this method with limestone powder and quarry dirt with proportion 10%, 20%, 30% gives the better results in binding of SCC in addition to saves extra binding material than traditional concrete mix.

- New mix design procedure proposed by using the particle packing model for SCC production, based on the target slump flow and compressive strength is simple and effective to produce good SCC mix with less amount binders.

- In countries like India, If SCC replaces normally used concrete, durability issues produced due to lack of compaction can be eliminated by replacing cement admixtures so the maintaining cost of concrete structures of the building can be reduced and the age of structures can be increased.

ACHIEVEMENTS REGARDING OBJECTIVES

All the main purposes of the researchs are skillful. So the developed particle packing model is more effective and very simple in guessing the compacted packing density of blended coarse and fine aggregate materials. The basic theory and limits which affect particle packing are researched and presented successfully in front of globally. Also using this model for preparing a mix design procedure for self-compacting concrete is given. The mix design procedure is very simple and it is possible to produce economical SCC using cementitious material almost equal to normal concrete with the minimum trials. which can easily used by the users to use SCC in general construction for there buildings in place of normally used concrete and thereby the quality of concrete and age as well as durability of concrete can be increased easily. Grading of blended coarse and fine aggregate is suggested which can be help to produce SCC in minimum trials and can produce it for large construction. The recommendation is given to adjust EFNARC guidelines to produce economical SCC. Also using the regression analysis, variables significantly affecting compressive strength, slump flow, and admixture dosage are determined and the relation between them is established to predict the future response.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

REFERENCES

[1] He. Okamura, M Ouchi, Self-compacting concrete, Journal of advanced concrete information, 1(1) (2003) 5-15.

[2] Shi Chi, Wu. Z, Lvi. K, Wu. Li, A review on combination design methods for self-compacting concrete, Constr. Figure. Mater., 84 (2015) 387-398.

[3] W.B. Fuller's, S.E. Thompson, The rules of proportioning concrete, Trans. ASCE. 33 (1907) 67–172.

[4] A.H.M. Andreasen, J. Andersen, Relation b/w grain size and interstitial space in products of unconsolidated granules, Kolloide. 50 (1930) 217–228.

[5] J.E. Funke, D.R. Dingeri, Particle-packing singularities and their application in materials processing, Mrs. Bulletini, 22(12) (1997) 19-23.

[6] H.J.H. Brouwers, H.J. Radixe, Self-compacting concrete: a theoretical and experimental study, Cem. Concr. Res. 35 (11) (2005) 2116–2136.

[7] Xia. Wang, K. Wang, P. Taylore, G. Morcous, Assessing particle packing based self-consolidating concrete mix design Method, Constr. Build. Material. 70 (2014) 439–452.

[8] I.Mehdipouri, K.H. Khayate, Understanding the role of the particle packing characteristics in the physical properties of cementitious suspensions: A literature analysis, Construction, and Building Materials, 1621 (2018) 340-353.

[9] Be.Esmaeilkhanian, K.H.Khayatey, O.H.Wallevike, Mix design method for low-powder self-consolidating concrete: Eco-SCC content optimal and performance. Materials and Structures 50(2) (2017) 124.

[10] F.V.Mueller, O.H.Wallevike, K.H.Khayate, Connecting solid particle packing of Eco-SCC to material performance, Cement and Concrete Composites, 54 (2014)117-125.

[11] W. Toufare, M. Borne, E. Klose, Involvement of optimization of components of different density in polydisperse particles systems, Freiberger Brochure A. 558 (1976) 29–44.

[12] De. Larrardo F, Concrete optimal about packing density and rheology, 3rd RILEM International Symposium on Rheology of Cement Holdups such as Fresh concrete. 2009.

[13] F. De Larrardo, Concrete Mixture Proportioning: A Scientific Approach, E&FN Spon, London, and New York, 1999.

[14] F. De Larrardo, Concrete mixture proportioning: a scientific method, CRC Press. 2014.

[15] J. Dewar, Computer modeling of concrete mixtures, CRC Press, 2002.

[16] R.K Mc.Geary, Mechanical packing of spherical particles, Journal of the American Ceramic Society. 44(10) (1961) 513-522.

[17] JA Elliotte, A Kelly, AH Windle, Recursive packing of dense particle mixtures, Journal of Materials Science Letters. 21(16) (2002) 1249-1251.

[18] KL Radhika, PR Kumar, Chand MS, Prasad B, Optimization of Mix Proportioning for Self Compacting Concrete using Particle Packing Concepts, in 8th RILEM International Symposium on Self-Compacting Concrete, Washington DC, USA. (2016) 53-64.

[19] A.K.H. Kwaan, V. Wong, W.W.S.Funga, A 3-parameter packing density model for angular rock aggregate particles, Powder Technol. 274 (2015) 154–162.

[20] W.J. Longey, Y. Gu, J. Liao, F. Xing, Sustainable design and ecological evaluation for low binder self-compacting concrete for normal contruction use, J. Clean. Prode. 167 (2017) 317–325.

[21] Rodrigueze S. G., Rodrigueze V.I., Aaguado A, Simple and rational methodology for the invention of SCC mixes, Journal of Materials in Civil Engineering, 28(2) (2015) 04015116-1-10.

[22] India Brand Equity Foundation Report on Cement Industry (June 2020) Science, https://www.ibef.org/download/Cement-June-2020.pd

[23] Worrell E, Price L, Martin N, Hendriks C, Ozawa Media L. CO2 emissions from the worldwide cement industry. Annual Review of Energy and Environment. 2001; 26:302-329. https://doi.org/10.1146/annurev.energy.26.1.303

[24] Yang R, Yu R, Shui Z, Gao X, Han J, Lin G, Qian D, Liu Z, Yongji H . Environmental and economical sociable ultra-high-performance concrete incorporating appropriate quarry-stone powders. Journal of Cleaner Production. 2020:121112. https://doi.org/10.1016/j.jclepro.2020.121112

[25] Felekoglu B. Utilization of high volumes of limestone quarry wastes in the concrete industry (Self-compacting concrete case).Resources Preservation Reprocessing. 2007; 51:4 770-791. https://doi.org/10.1016/j.resconrec.2006.12.004

[26] Sadek DM, El-Attar MM, Ali HA, Felekoglu B. Reusing of marble and granite powders in self-compacting concrete for sustainable development. Journal of Clean Production.2016; 121:10 19-32. https://doi.org/10.1016/j.jclepro.2016.02.044

[27] Medina G, Sáez del Bosque IF, Frías M, Sánchez de Rojas MI, Medina Granite quarry waste dirt as a upcoming eco-efficient additional cementitious material (SCM): scientific and technical thoughts. Journal of Cleaner Production. 2017; 148:1 467-476. https://doi.org/10.1016/j.jclepro.2017.02.048

[28] Ho DWS, Sheinne AMM, Ng CC, Tam CTe. The use of quarry dust for SCC applications. Cement Concrete Research. 2002; 32:4 505-511. https://doi.org/10.1016/S0008-8846(01)00726-8

[29] Felekoğlu Be, Türkel Se., Baradan B. Effect of w/c ratio on the fresh and hardened properties of SCC. Building and Environment. 2007; 242:4 1795 -1802. https://doi.org/10.1016/j.buildenv.2006.01.012

[30] Demone PL. Self-compacting Concrete: An analysis of 1.1 decade of case revision. Cement and Concrete Mixtures. 2006;197-208. https://doi.org/10.1016/j.cemconcomp.2005.10.003

[31] Dehwaha HAF. Mechanical propertie's of SCC which includs quarry dirt powder, silica fume, or fly ash. Construction and Building Materials. 2012; 26(1): 547-551. https://doi.org/10.1016/j.conbuildmat.2011.06.056

[32] Khaleell OR, Al-Mishhadan SA, Abdul Razaka H. The Result of Coarse Aggregate on Fresh and Hardened Properties of SCC. Procedia Engineering. 2011; 14: 805-813. https://doi.org/10.1016/j.proeng.2011.07.102

[33] Schankoski RA, Pilar R Ricardo de Matos P, Roberto Prudêncio L, Douglas Ferron R. Fresh and hardened properties of self-compacting concretes produced with diabase and gneiss quarry by product powders as alternative filler. Structure and Building Materials. 2019; 224:10 659-670. https://doi.org/10.1016/j.conbuildmat.2019.07.095

[34] Gupta. N., Siddique. R., Belarbi. R., Sustainable and Greener Self-Compacting Concrete incorporating Industrial By-Products: A Review, Journal of Cleaner Production(2020). https://doi.org/10.1016/j.jclepro.2020.124803

[35] IS code 12269 -2013, Indian Standard Ordinary Portland Cement 53 Grade specifications. BIS India.

[36] IS code 383 -2016, Indian Standard Coarse and Fine aggregate conditions. BIS India.

[37] NanSu, H'su. K'C, Chai HW. An easy mix design method for the self-compacting concrete. Examine,2001;1799-1807. https://doi.org/10.1016/S0008-8846(01)00566-X

[38] EFNARC Specification and Guiding principle for Self-Compacting Concrete, February 2002.

[39] IS 516 -1959, Indian Standard Procedures of Tests for strength of concrete, BIS India.