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Behaviour of SCC designed using Sugarcane Baggase Ash and Marble Powder under Cyclic loading

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Abstract:- In this study, the effects of the two additives, marble powder (MP) and sugarcane bagasse ash (SBA), on the properties of freshly-poured and fully-cured self-compacting concrete are investigated. One of the major conclusions from more research is that, when used at the recommended dosage, marble powder works best with soybean husk ash. It shows good workability and strength. The best mineral admixtures to use and their recommended dose range will be determined using the findings of this investigation. Sugarcane bagasse ash (SBA), which contains silica, should be a great alternative to cement. The binder setting time is extended when SBA and OPC are mixed. Direct addition of sugarcane bagasse ash affects the workability of the new concrete mix and shows great impact on unit weight. A small amount of marble powder added to fresh concrete improves its workability and boosts the mix's unit weight, compaction, and strength. Combinations of marble powder and Sugarcane bagasse ash increase the compressive strength of concrete more than using just Sugarcane bagasse ash alone. The maximal compressive strength on varies dosages of marble powder (MP) and sugarcane bagasse ash (SBA) was 10% and 15%, respectively, after 7 days and 28 days of curing. At optimal dosage, split tensile strength was significantly higher than that of conventional self-compacting concrete. After seven and 28 days of cure, it grows by 1.2% and 2.4%, respectively. L-box, V-box, and slump testing on novel SCC has been performed in this experimental research to show the rheology of concrete mixes of various grades under monotonic loading, cyclic loading, stability and fatigue loading.. The properties of hardened concrete are studied using several grades at various optimum dosages. The results of the cyclic load clearly demonstrate the high plastic strain range, which promotes toughness and decreases brittleness

Keywords*: Compressive strength, Cyclic Loading, Marble powder, Self Compacting Concrete, Split tensile strength Sugarcane bagasse ash.*

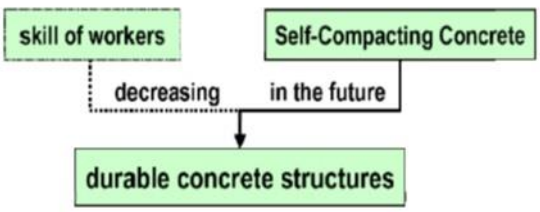
1. Introduction

SCC typically provides good early-phase resistance. A few of its many benefits are production with low water-cement percentages, early mold removal, and quicker building use countless studies and the most recent statutory provisions aid in the creation of self-compacting concrete, and countless experiments were carried out using a variety of testing techniques.

Understanding the way self-compacting concrete (SCC), an emerging concept, responds to cyclic loads is essential. In this study, the behavior of SCC under various compressive cycle loads was investigated. For the purpose of examining SCC behavior, various cyclic loading types were applied. The specimens under study contained the following characteristics: compressive strength of 300 MPa, 50 MPa, and 704 MPa; medium slump of 550–650 mm; and SF1 (Slump Flow Class).

Plastic strain increases and crack patterns develop as a result of successive cyclic loading, as shown. the amount of energy absorbed while loading and when conducting studies, as well as the amount of energy absorbed by concrete in hysteresis loops. Being the main reason for failure, fatigue is a crucial concern. When repeatedly subjected to stress or strain at a level lower than the material's ultimate static strength, materials have a propensity to crack and eventually break.

Maximum compaction performed by trained laborers and high-quality mechanical equipment/machines are critical requirements for making durable concrete buildings. The production of self-compacting concrete that can reach every corner of the formwork and is compacted without the need of external vibration is the best way to assure the long-term viability and quality of building. To create enduring concrete constructions, Prof. Okamura from Kochi University in Japan invented self-compacting concrete for the first time in 1986. Ozawa and Maekawa conducted studies on SCC manufacture and its workability and characteristics at the University of Tokyo. The necessity for self-compacting concrete is shown in Fig 1.1 Flow Chart.



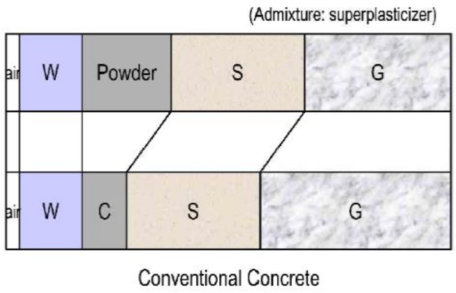


Fig.1.1 Flow Chart shows the SCC need **Fig.1.2 Comparison among SCC and CC**

Characteristics of SCC

Self-compacting concrete" is a flowing concrete that does not require vibration because it uses super plasticizers and stabilizers to significantly increase the ease and rate of flow while also achieving compaction into each component by way of self-weight without any segregation.

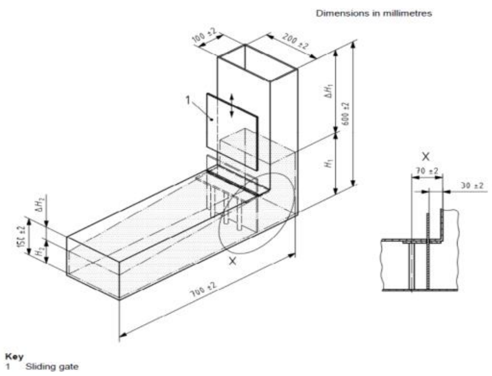
Only concrete that satisfies the requirements for Passing Ability, Filling Ability, Segregation resistance, and Viscosity lay as per as per IS 1199 (Part 6) can be referred to as self-compacting concrete.

Properties of Fresh SCC:

Passing Ability (free from blocking at reinforcement)

Ratio of passing ability $P_L = H_2/H_1$

Where H_1 is the average depth of concrete in the vertical part (in millimeters) and H_2 is the average depth of concrete at the end of a horizontal L-box section (in millimeters)



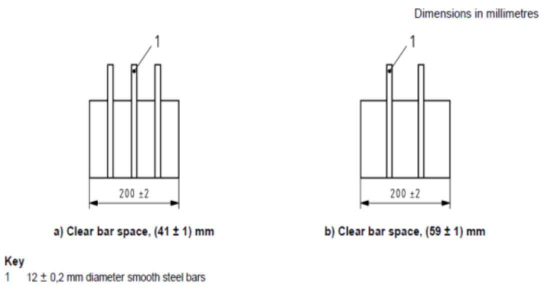


Fig.1.3 Typical general assembly **Fig.1.4 Bar Position in L-Box**

Filling Ability (flowability)

Using a Slump-flow test, flowability is assessed. The slump-flow number describes a fresh mix's capacity to flow in open spaces.

The following are examples of slump-flow classes for various applications:

(a) SF1 (slump flow 550 mm - 650 mm).

1) This type of SCC is appropriate for unreinforced or minimally reinforced concrete constructions cast from the top with free displacement from the delivery point (as an example, dwelling slabs).

2) Casting with a pump injection method (as an example, tunnel linings).

3) Sections those are sufficiently small to preclude prolonged horizontal flow (such as piles and some deep foundations).

b) SF2 (slump flow 660 mm - 750 mm) is suitable for everyday applications (such as walls and columns).

c) SF3 (slump flow 760 mm–850 mm) is appropriate for filling beneath formwork, vertical applications in heavily reinforced buildings, and complex geometries-based constructions. While SF3 offers a better surface polish than SF2 for common vertical applications, segregation resistance is more challenging to control.

Dimensions in millimetres

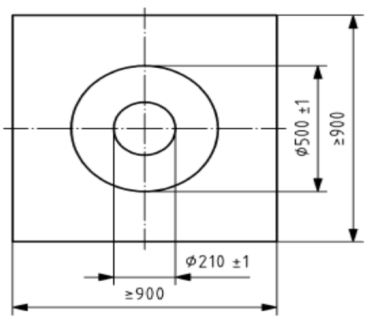
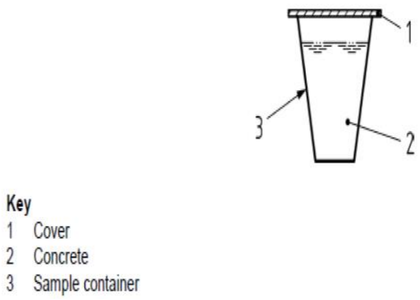


Fig.1.5 Base Plate **Fig.1.6 Base Plate With The Slump**

Segregation Resistance (Stability)

A segregation resistance (sieve) test is used to examine this quality of newly laid concrete. After sampling, the freshly laid concrete is allowed to sit for 15 minutes to check for the separation of any bleed water. The sample's top portion is then put into a sieve with square holes measuring 4.75 mm. After two minutes, the weight of the material that has passed through the sieve is noted. The segregation ratio (SR) is then calculated as the percentage of the sample that makes it through the sieve. There are two types of segregation resistance: SR1 and SR2.

For the SR1 class, segregation resistance should be between 15 and 20 percent, and for the SR2 class, it should be under 15 percent.[40]



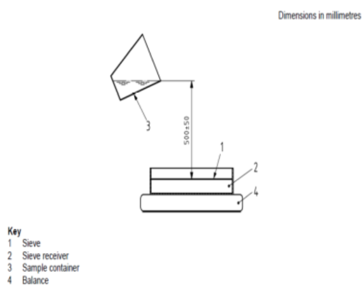


Fig.1.7 Sample Container and Cover **Fig.1.8 Measurement of Segregated Portion**

Viscosity

The viscosity can be calculated using the V-funnel flow time as specified by IS 1199 [31].Low viscosity concrete will first flow fast before coming to a stop. A concrete with a high viscosity may advance slowly over time. Fresh concrete is poured into a V-shaped funnel, and the time it takes for the concrete to flow out of the funnel is used to calculate the V-funnel flow time. There are two categories for viscosity: V1 and V2. For the V1 class, it must take less than 8 seconds to pass the concrete out of the V-funnel, and for the V2 class, it must take between 8 and 25 seconds.

Deformability (flow and filling ability)

The "Excess Paste Theory (EPT)" describes the mechanism governing the workability of concrete. According to this theory, enough paste is needed to cover the aggregates' surface area, and that extra paste works to lessen friction between the aggregates and improve flow-ability. Without the extra paste layer, the mixture would develop excessive friction between the particles and have very little workability.

The size of particles, forms, and volume percent influence the self-compacting concrete's capacity to pass, which increases as the volume fraction of large aggregates increases.

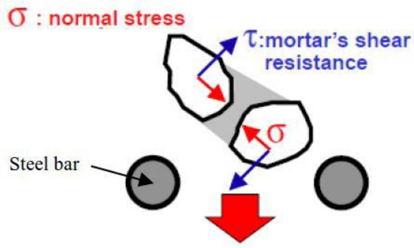


Figure 1.9 Stresses between the aggregates

• Segregation resistance is largely controlled by viscosity

Maintaining a high viscosity that will stop the concrete mix from bleeding and segregating. Water separates from the mixture and rises upward through capillary action during bleeding, a unique case of segregation. For concrete, some bleeding is typical, but excessive bleeding can result in a loss of strength, increased porosity, and poor durability, especially at the surface.

•Two basic methods can ensure adequate stability:

− A super-plasticizer (SP), a low water/cement ratio, a high powder content, mineral admixtures, and a low aggregate content are used in the first method. The second strategy is based on adding a super-plasticizer, low to moderate amounts of powder, and a viscosity-modifying adjuvant (VMA).

Mechanism for achieving Self compact ability

The following steps can be taken to achieve self compactability:

1. Lowering the water-to-cement ratio

2. Aggregate size restriction.

3. The addition of a mineral mix.

4. The use of VMA and super plasticizer.

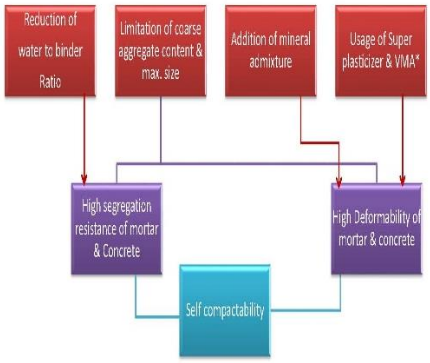


Figure 1.10 SCC Compability

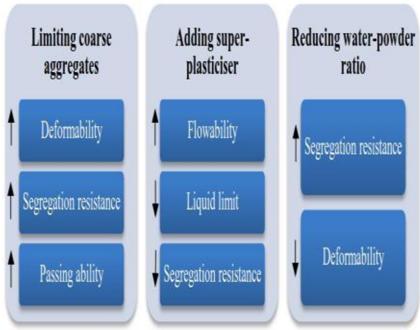


Figure 1.11 Mechanism of achieving SCC

The graph above clearly shows that self-compacting concrete's deformability, segregation resistance, and passing ability increase when coarse aggregate size is restricted.

While the liquid limit and segregation resistance of self-compacting concrete are reduced when super plasticizer is added, and the segregation resistance is increased and the deformability of self-compacting concrete is increased when the water-powder ratio is reduced.

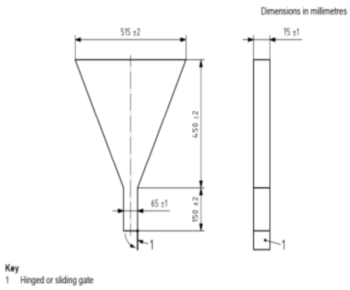


Fig.1.12 V-Funnel

Merits And Limitation Of SCC

Merits

Self-compacting concrete has a number of benefits over conventional concrete. Some of the benefits are as follows:

• The ability to build has enhanced.

• The workforce shrinks.

• Solidly connect to the reinforcing steel.

• Improvements in structural integrity.

• Project timelines are expedited.

• Less skilled labor is employed.

• Flows into several complex shapes.

• Reduces the equipment's wear and tear.

• Lessens the amount of voids in areas that have been severely reinforced.

• Produces superior surface finishes.

• Exceptionally durable and powerful.

• Facilitates the process of pumping.

• Reducing the noise that mechanical vibrators make.

• Produces an even, smooth surface.

- Rapid installation without mechanical consolidation or vibration
- Applications with deep sections or wide spans are suited for it.

Limitations

More precise measurements and monitoring are needed, as well as more trial batches and lab testing, for the intended combination.

Material Testing

Cement

This study uses OPC 43 and 53, which validate IS 8112:2013, to create SCC that is supplied by Ultratech. Every physical test is conducted in accordance with Indian standard specifications. present the collected results.

Table 1.1 Physical Properties of OPC 43

Physical properties		Result
Specific gravity		3.15
Consistency	Initial	100
	Final	450
Compressive strength	7 days	33
	28 days	48

Table 1.2 Physical Properties of OPC 53

Physical properties		**Result**
Specific gravity		3.14
Consistency	Initial	110
	Final	500
Compressive strength	7 days	40
	28 days	55.6

Fine Aggregate

The gradation of fine aggregate as specified in IS383:2016. Locally available Natural sand is used in this study. The physical properties of fine aggregate are shown in table 5.3.And Sieve analysis result is shown in table 5.4 and the graph plotted between cumulative percentage passing and sieve no. is shown in fig.4.1. As per Sieve analysis found that sand is of Zone II.

Table 1.3 Physical Properties of Fine Aggregate

Physical properties	**Result**
Specific gravity	2.67
Fineness modulus	3.6
Water absorption %	1

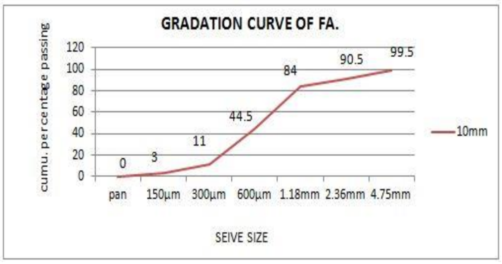


Fig 1.12 Gradation Curve Of Fine Aggregate

Coarse Aggregate

The grading was performed in accordance with IS 383:2016. In this present research work natural aggregate that is readily and locally available were used. Numerous test carried out for various percentage combination of 20 mm and 10 mm aggregate to reach the maximum density. Experimentally,, maximum density is reached on 40% and 60% of 10 mm and 20 mm aggregate size respectively. Table 4.5 lists the aggregate's physical characteristics. Additionally, the results of the sieve analysis are displayed in Table 5.6, and Figure 5.2 displays the graph that plots the cumulative percentage of passes against the sieve number.

Table 1.4 Physical Properties of Coarse Aggregate

Physical properties	Result
Specific gravity	2.75
Fineness modulus 20 mm	3.08
Fineness modulus 10 mm	3.057
Water absorption %	0.6

Fig 1.13 Gradation Curve of Coarse Aggregate

Sugarcane Baggase Ash

Table 1.5 Physical Properties of ScBA

Physical properties	Result
Specific gravity	2.106
Fineness modulus	0.7
Water absorption %	16.7 %

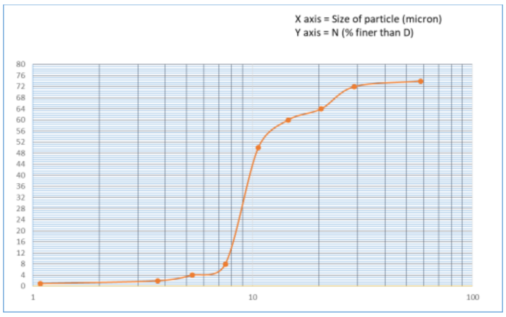


Fig 1.14 Particle Size Distribution Curve of ScBA

Experimental Obversvation Compressive Strength and Density

Compressive strength tests are conducted on cubes under CTM, and their weights are noted to find out the densities at 7days and 28days.

Optimum dosage of ScBA

From table it is clear that compressive strength of 10% replacement is more than 7.50% and 12.50% in 7 days and in 28 days. So, the optimum percentage replacement is 10%.

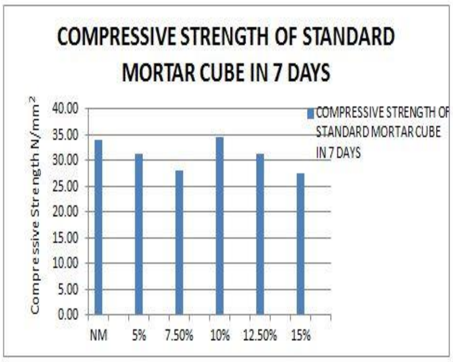


Fig 1.15 Compressive strength with replacement of ScBA in 7 days

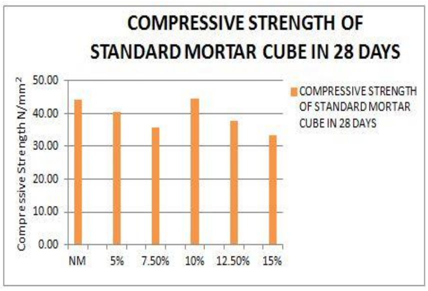


Fig 1.16 Compressive strength with replacement of ScBA in 28 days

Optimum dosage of MP

Compressive Strength of Standard Mortar cube for Different Percentages of MP

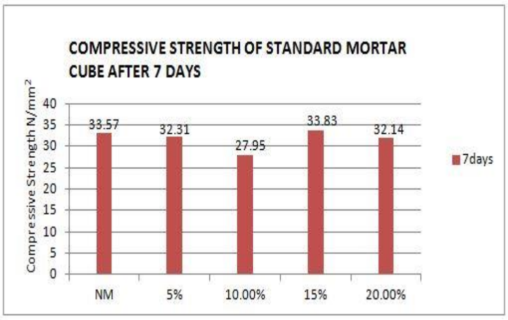


Fig 1.17 Compressive strength with replacement of Marble Powder for 7 days

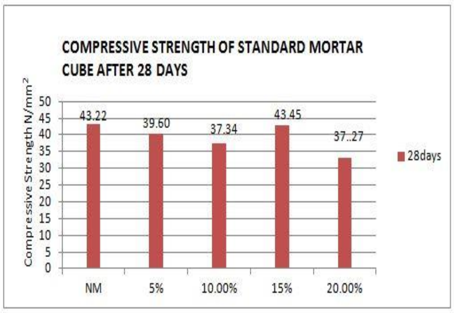


Fig 1.18 Compressive strength with replacement of Marble Powder for 28 days

After getting results for the compressive strength of standard mortar cubes with various percentages of partial replacement of cement. It is clear that Compressive strength is low for 10% and 20% than 15% in 7day as well as 28 days. Hence we get optimum dose of 15% for further studies.

Specification	Compressive strength in day (N/mm²)					Avg. Comp. strength
NM	7days	3No's	34.26	36.53	35.98	35.59
	28days	3No's	52.17	49.86	51.9	51.31
SHA5%+MP15%	7days	3No's	30.45	31.5	32.58	31.51
	28days	3No's	49.56	48.58	47.61	48.58
SHA7.5%+MP15%	7days	3No's	28.83	28.32	26.1	27.75
	28days	3No's	46.16	47.26	45.58	46.33
SHA10%+MP15%	7days	3No's	34.98	37.53	39.59	37.37
	28days	3No's	53.1	54.89	58.46	55.48
SHA12.5%+MP15 %	7days	3No's	28.68	26..79	30.52	29.60
	28days	3No's	35.2	31.63	37.89	34.91
SHA15%+MP15%	7days	3No's	21.36	24.71	25.9	23.99
	28days	3No's	24.96	21.32	24.65	23.64

Table 1.6 Compressive Strength of M45 Grade Concrete Cubes with Different Percentage of ScBA

Specifications	Compressive strength in day (N/mm²)					Avg. com. strength
NM	7days	3No's	45.56	45.09	45.8	45.48
	28days	3No's	65.92	61.43	66.94	64.76
SHA5%+MP15%	7days	3No's	40.62	43.7	41.53	41.95
	28days	3No's	58.63	61.53	60.36	60.17
SHA7.5%+MP15 %	7days	3No's	40.2	39.16	41.67	40.34
	28days	3No's	55.26	57.81	56.49	56.52
SHA10%+MP15%	7days	3No's	44.38	49.58	47.94	47.30
	28days	3No's	61.53	66.75	64.2	64.16
SHA12.5%+MP15 %	7days	3No's	35.52	39.26	33.32	36.03
	28days	3No's	51.43	49.18	49.16	49.92
SHA15%+MP15%	7days	3No's	30.56	25.36	27.39	27.77
	28days	3No's	40.96	39.24	36.65	38.95

Table 1.7 Compressive Strength of M60 Grade Concrete Cubes with Different Percentage of ScBA

Specifications	Compressive strength in day (N/mm²)				
NM	7days	3No's	48.56	49.63	45.97
	28days	3No's	76.54	74.96	75.36
SHA5%+MP15%	7days	3No's	44.56	43.7	45.61
	28days	3No's	65.3	65.79	60.78
SHA7.5%+MP15%	7days	3No's	40.2	42.63	41.67
	28days	3No's	59.14	57.76	59.73
SHA10%+MP15%	7days	3No's	49.27	50.7	48.41
	28days	3No's	73.86	74.9	76.3
SHA12.5%+MP15%	7days	3No's	35.12	38.17	41.32
	28days	3No's	55.63	40.18	44.16
SHA15%+MP15%	7days	3No's	30.56	30.36	33.96
	28days	3No's	41.96	39.62	39.65

Table 1.8 Compressive Strength of M60 Grade Concrete Cubes with Different Percentage of ScBA

Comparison of Density in Nominal Mix and Design Mix.

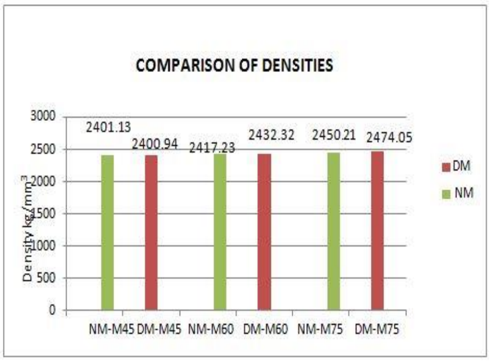


Fig 1.19 Comparison of Concrete Densities

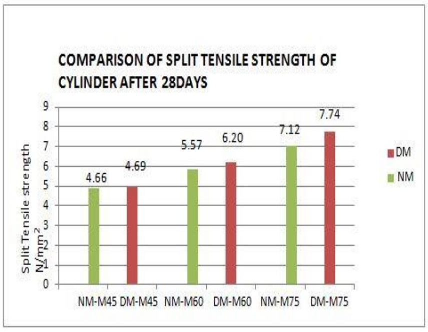


Fig 1.20 Split Tensile Strength of Cylinder After 28 days

Cyclic Loading Evaluation

Behavior of M45 Cylinders Under Cyclic Loading

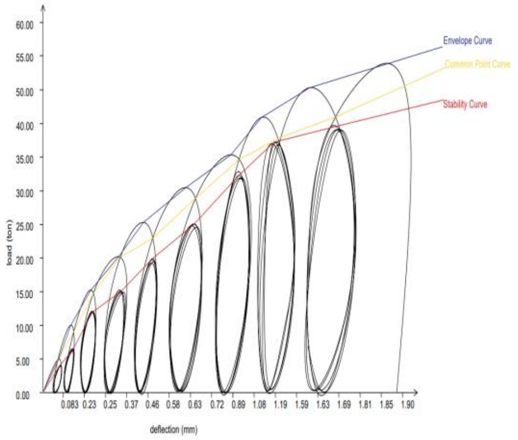


Fig 1.22 Cyclic loading on M60 Cylinder Specimens

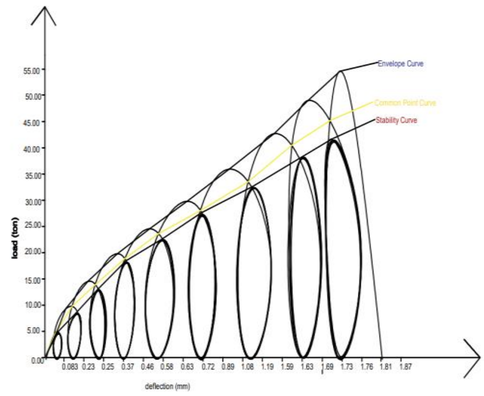


Fig 1.23 Cyclic loading on M75 Beam Specimen

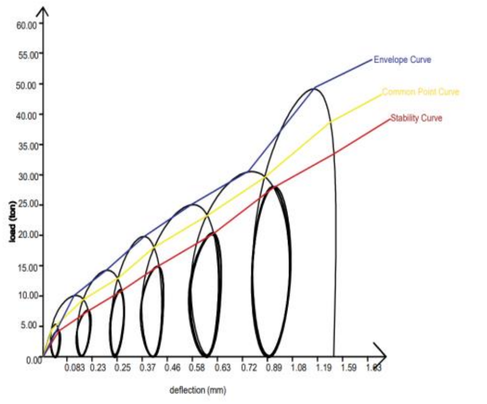


Fig 1.21 Cyclic loading on M45 Cylinder Specimens

Study of Crack Pattern

The behavior of SCC is similar to that of ordinary concrete. Once the paste matrix and aggregates meet at an interfacial transition zone, microcracks cause a more brittle mode of fracture. It was found that cracks began to propagate toward the center at roughly 70–80% of peak local. The failure was brought on by surface chipping and specimens splitting vertically in the direction of stress. The elastic qualities and strengths of mortar and coarse aggregate are comparable. When compared to regular concrete, there were comparatively few failure planes found due to the high strength of the concrete and the limited number of probable failure planes. The number of bond cracks was also decreased as a result of the strength and elastic qualities working together and the higher tensile bond strength. Hence, compared to normal-strength concrete, high-strength SCC has a more homogenous behavior, producing a smooth and vertical failure plane.

Failure Mode of Cube Specimens

Fig 1.24 Failure Mode of Cube Specimens

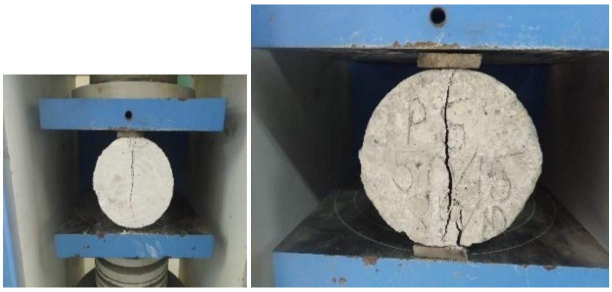


Fig 1.25 Failure Mode of Cylinder Specimens

Failure Mode of Beam Specimens

M45 Beam of Size 700x150x150

Fig 1.26 Failure Pattern Beam Specimen under Flexural loading (M45)

Fig 1.27 Failure Pattern of M45 Beam Specimen under Cyclic loading

Fig 1.28 Failure Pattern of M60 Beam Specimen under Flexural loading

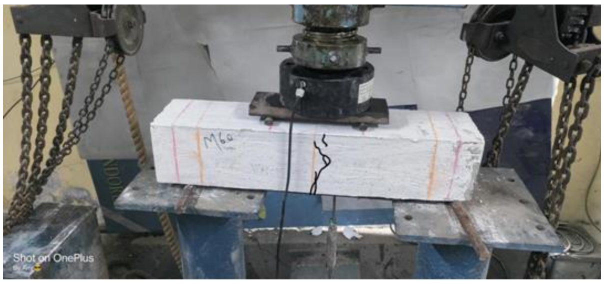


Fig 1.29 Failure Pattern of M60 Beam Specimen under Cyclic loading

Fig 1.30 Failure Pattern of M75 Beam Specimen Under flexural loading

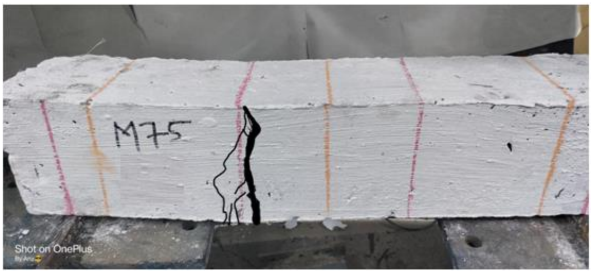


Fig 1.31 Failure Pattern of M75 Beam Specimen under Cyclic loadings

M75 Beam of Size 700x150x150

Failure Mode of Beam Specimens

Both M45 & M75 designed for under reinforced section hence clearly shows the ductile failure. The monotonic loading beams have cracks with small openings at the tension zone. In cyclic loading Observed Cracks are following the pattern of propagation from tension to compression zone to the compression zone. The same expected pattern is also found in instability loading.

Fig 1.32 Failure Pattern of M75 Beam Specimen under Monotonic loading

Fig.1.33 Failure Pattern of M75 Beam Specimen under

Cyclic loading

Fig 1.64 Shear Failure Pattern of M75 Beam Specimen under Stability loading

Fig 1.35 Failure Pattern of M75 Beam Specimen under Fatigue loading

Conclusions

In the present work, following conclusion were drawn

1. According to the chemical analysis, it is discovered that ScBA can function as a pozzolanic material and contains a sizable amount of silica, alumina, and other elements. ScBA can also be used in place of some of the cement, such as RHA, as required by IS Code 10262-2019. Therefore, it is advised that ScBA be updated in the IS code as a mineral additive for usage in the Design Mix of the states that have high ScBA content.
2. Powdered marble, whose compositions are already recognized in the past researches, as supplemental cementitious materials that function well in place of OPC and significantly lower the per cubic meter cost. The results unequivocally demonstrate, using SCBA & MP in concrete its lowers costs by 10% for various grade of concrete.
3. The study demonstrates that the need for Super plasticizer rises as the percentage of mineral additions increases.
4. The optimum dosage for replacing OPC has been determined to be 10% and 15% for ScBA and MP, respectively, demonstrated their greatest strength during a range of challenges.
5. The initial compressive strength and density of designed SCC over the nominal mix in the ScBA SCC mix is initially lower for seven days, and by twenty-eight days, it reaches its full strength.
6. When 10% ScBA and 15% MP are added to concrete, the tensile strength of the concrete enhance significantly.
7. In the ScBA SCC mix, the designed SCC's early age compressive strength and density above the nominal mix are initially lower for seven days before reaching full strength at age twenty-eight.
8. The cyclic load result demonstrates that the design mix including 15% MP and 10% ScBA accumulated a large plastic strain range, increasing the concrete's toughness and reducing its brittleness while also exhibiting high energy dissipation.
9. All cylinders and beams have a load-deflection curve that follows a parabolic path until failure.
10. All results fall within a good range with an efficacy of greater than 90%, according to best fit curves. Peak stresses corresponding to a common point is 80-90% of the envelope curve.
11. The repeated experimental results yielded an envelope strain and stress curve, a locus of common points, and a locus of stability points. The stability point curve defines the SCC permissible stress limits, which account for the loss of compressive strength due to repeated stresses.
12. The cyclic stress-strain curve establishes the location of common and stability points. This helps in

developing block shear diagram of SCC possessing 10%of ScBA and 15 % MP contribution in partial replacement of OPC.

13. The envelope stress-strain curve, a locus of stability points, and a locus of common points were the outcomes of the repeated experimental measures. The stability point curve is used for establishing the SCC tolerable stress limits, which must account for compressive strength depreciation from repeated loading.
14. The stress-strain envelope curve, common point curve and stability point curve all can be expressed mathematically using polynomial or logarithmic functions. This curve's correlation regression index ranges from 0.76 to 0.97, indicating strong test performance. Peak stresses corresponding to the common point is more than 75% of the envelope curve.
15. Over 75% of the envelope curve is made up of peak stresses that correspond to the stability point.
16. Plastic strain accumulates with load cycles with peak stresses of the stability point curve below which strain accumulate to stabilize and the sample was never found to collapse.
17. Cost analysis clearly shows that for optimum dosage, there is reduction of about 8-10 % in costing for concrete, design using ScBA & MP, which increases on raising grade of concrete and mixing with heavy machinery. This sustainable concrete also reduces carbon production which indirectly provides the carbon credit to the user.
18. Plastic strain accumulates with load cycles with peak stresses of the stability point curve, below which strain stabilizes and, thus, below which the model could not fail.

Conflict of Interest statement

This is submitted for publication as per academic requirement of Oriental University Indore.

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