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Study of the Influence of Recycled Aggregate (Class-I Brick Bats) and Corrugated Steel Fibers in Self Compacting Concrete Beams

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Abstract

This study presents the performance of Self compacting concrete (SCC). Ordinary Portland cement was replaced with fly ash(FA), and coarse aggregate(CA) was partially replaced with class I bricks (BB). In addition to this steel fibers (SF) were added in proper proportion. Suitable dosage of super plasticizers and viscosity modifying agents were also added for achieving increased workability and to maintain a low w/p ratio. By conducting fresh and hardened tests on the specimens an attempt has been made to study the workability, compressive strength, split tensile strength, flexural strength and shrinkage characteristics of SCC. Though the replacement of CA with BB showed a considerable decrease in the strength when compared to the control specimen (CA), the addition of steel fibers increased the same. But there was no major decrease in the split tensile strength and flexural strength. The addition of steel fibres had minimal influence on the workability of SCC. The test results reveal that the BB along with steel fibers could be effectively used in SCC which may be applied for instances which require normal strength of the order of 20N/mm^2.Also usage of BB in SCC can serve as an effective way of disposal of construction wastes from building construction and demolition.

Keywords:*Self compacting concrete, steel fibres, recycled aggregate, Brick bats*

1. Introduction

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with low water-cement ratio providing the potential for high early strength, earlier demoulding and faster use of elements and structures. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

The introduction of SCC can positively change the construction process and eliminate the necessity for mechanical vibration improving the working environment and the health and safety of workers. Vibrators used for the compaction of concrete are a major source of noise on construction site and in concrete precast factories.

There is also an increasing awareness of *'hand-arm vibration syndrome'* also known as *'white finger syndrome'* caused by regular or prolonged use of vibrators. Self-compacting concrete technology eliminates the use of vibrating equipment and so minimizes the risk of injuriesor harm caused by exposure to continuous high frequency noises and mechanical vibration.

2. Scope of the Work

In this study an attempt has been made to evaluate the strength characteristics of SCC produced using recycled aggregates. The recycled aggregate considered for the study was class I brick which was used as partial replacement of CA. If only cement is used in SCC the cost will be high. Also, it is susceptible to be attacked and will produce much thermal cracks. Therefore it is necessary to replace cement also with additions. Fly ash was added as pozallanic admixture in addition to super plasticizer (SP) and viscosity modifying agent(VMA).

various mix proportion alternatives, simple testing methods to study the deformability, stability, and filling capacity of SCC were tried. Also various SCC mixes were prepared with different contents of cementitious materials, w/p ratio, VMA, SF etc., are discussed in this paper. Here an effort has been taken to compare the characteristic properties of SCC using normal aggregates and SCC using recycled aggregates. The materials were tested for their suitability of use.With the results obtained a detailed study of the strength of SCC has been made.

3. Test Methods for Assessment of Properties of Fresh SCC

The test methods used for assessment of fresh properties of SCC were slump flow, L-box, Orimet, V-funnel test, U-tube test, Orimet/ J Ring combined GTM green stability test and Orimet test.

3.1 Slump Flow Test

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan (1) for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

3.1.1 Assessment of Test

This is a simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test can be profitably be used to assess the consistency of supply of ready-mixed concrete to a site from load to load.

3.1.2 Interpretation of Result

The higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight. A value of *at least* 650mm is required for SCC. There is no generally accepted advice on what are reasonable tolerances about a specified value, though ± 50mm, as with the related flow table test, might be appropriate.

The T50 time is a secondary indication of flow. A lower time indicates greater flow ability. The Brite EuRam research suggested that a time of 3-7 seconds is acceptable for civil engineering applications, and 2-5 seconds for housing applications. In case of severe segregation most coarse aggregate will remain in the centre of the pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will not occur since this is a time related aspect that can occur after a longer period.

3.2 J - Ring Test

The principle of the J Ring test may be Japanese, but no references are known. The J Ring test itself has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals: in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The diameter of the ring of vertical bars is 300mm, and the height 100 mm. The J Ring can be used in conjunction with the Slump flow, the Orimet test, or eventually even the V funnel. These combinations test the flowing ability and(the contribution of the J Ring) the passing ability of the concrete. The Orimet time and/or slump flow spread are measured as usual to assess flow characteristics. The J Ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

3.2.1 Assessment of Test

These combinations of tests are considered to have great potential, though there is no general view on exactly how results should be interpreted. There are a number of options – for instance it may be instructive to compare the slump-flow/J Ring spread with the unrestricted slump-flow: to what extent is it reduced? Like the slump-flow test, these combinations have the disadvantage of being unconfined, and therefore do not reflect the way concrete is placed and moves in practice. The Orimet option has the advantage of being a dynamic test, also reflecting placement in practice, though it suffers from requiring two operators.

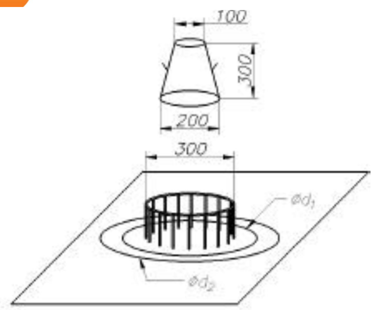

Fig .1 (J – Ring Test Apparatus)

3.2.2 Interpretation of Result

It should be appreciated that although these combinations of tests measure flow andpassing ability, the results are not independent. The measured flow is certainly affected by the degree to which the concrete movement is blocked by the reinforcing bars. The extent of blocking is much less affected by the flow characteristics, and we can say that clearly, the greater the difference in height, the *less* the passing ability of the concrete. Blocking and/or segregation can also be detected visually, often more reliably than by calculation.

Note: The results of the J Ring are influenced by the combination method selected and results obtained with different combinations will not be comparable.

3.3 V - Funnel Test

The test was developed in Japan and used by Ozawa et al. The equipment consists of a V-shaped funnel, an alternative type of V-funnel, the O funnel, with a circular section is also used in Japan. The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

3.3.1 Assessment of Test

Though the test is designed to measure flowability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result – if, for example there is too much coarse aggregate, high flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete is not clear.

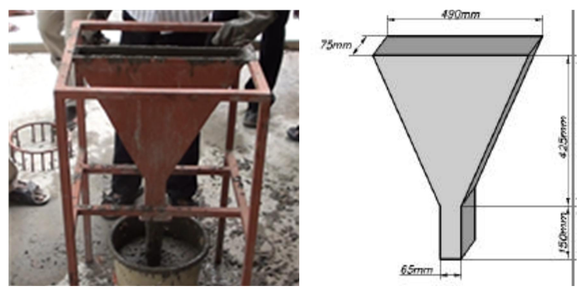

Fig .2 (V-Funnal Test apparatus)

3.3.2 Interpretation of Result

This test measures the ease of flow of the concrete; shorter flow times indicate greater flowability. For SCC a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow, and prolonged flow times may give some indication of the susceptibility of the mix to blocking. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

3.4 L- Box Test

This test, based on a Japanese design for underwater concrete, has been described by

Peterson (2).The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus is shown in figure D.6.1.The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1in the diagram). It indicates the *slope* of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The sections of bar can be of different diameters and spaced at different intervals: in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete.

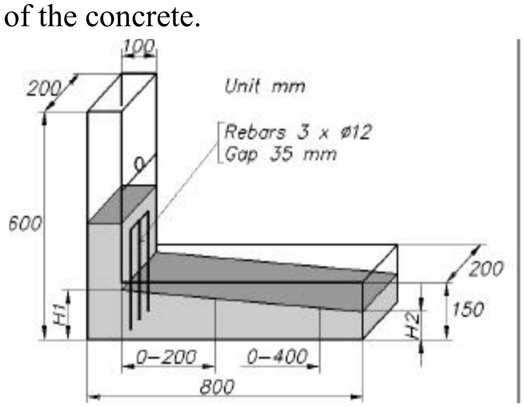

Fig. 3 L- Box Test Apparatus

3.4.1 Assessment of Test

This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

3.4.2 Interpretation of Result

If the concrete flows as freely as water, at rest it will be horizontal, soH2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 times can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

4.**Test Methods Assessment for Properties of Hardened SCC**

4.1Structural Properties

The basic ingredients used in SCC mixes are practically the same as those used in the conventional HPC vibrated concrete, except they

S.No	Mix ID	% Fly ash	Cement (kg/m^3)	Fly ash (kg/m^3)	Water (l/m^3)	w/b-ratio	F.A (kg/m^3)	C.A (kg/m^3)	SP (l/m^3)	VMA (kg/m^3)	Brick Bats (kg/m^3)
1	BB-30	30	315	135	256.5	0.57	918.75	454.13	8	2	194.63
2	BB-40	30	315	135	256.5	0.57	918.75	389.25	8.5	2	259.50
3	BB-50	30	315	135	256.5	0.57	918.75	324.36	9.5	2	324.36

are mixed in different proportions and the addition of special admixtures to meet the project specifications for SCC. The hardened properties are expected to be similar to those obtainable with HPC concrete. Laboratory and field tests have demonstrated that the SCC hardened properties are indeed similar to those of HPC.Table1 shows some of the structural properties of SCC.

Table .1

ITEMS	SCC
Water-binder ratio (%)	25 to 40
Air content (%)	4.5-6.0
Compressive strength (age: 28 days) (MPa)	40 to 80
Compressive strength (age: 91 days) (MPa)	55 to 100
Splitting tensile strength (age:28 days) (MPa)	2.4 to 4.8 30 to 36
Elastic modulus (GPa)	600 to 800
Shrinkage strain (x 10-6)	

W/B – Water binder ; F.A – Fine Aggregates C.A – Coarse aggregates ; SP-Super plasticizer

4.2 Compressive Strength

SCC compressive strengths are comparable to those of conventional vibrated concrete made with similar mix proportions and water/cement ratio. There is no difficulty in producing SCC with compressive strengths up to 60MPa.

4.3 Tensile Strength

Tensile strengths are based on the indirect splitting test on cylinders. For SCC, the tensile strengths and the ratios of tensile and compressive strengths are in the same order of magnitude as the conventional vibrated concrete.

4.4 Bond Strength

Pull-out tests have been performed to determine the strength of the bond between concrete and reinforcement of different diameters. In general, the SCC bond strengths expressed in terms of the compressive strengths are higher than those of conventional concrete.

4.5 Modulus Of Elasticity

SCC and conventional concrete bear a similar relationship between modulus of elasticity and compressive strength expressed in the form E/(fc)0.5, where E=modulus of elasticity, fc =compressive strength. This is similar to the one recommended by ACI for conventional normal weight concrete.

5. Experimental Program

5.1 Casting of beam

Beam has been designed as an under reinforced section having dimensions 100x150x1200 mm. Total of four beams were cast including control specimen. Two 10mm dia bars were used as bottom reinforcement and two 8mm dia bars were used as top reinforcement. Stirrups of 8mm dia bars were spaced at 130mm spacing.mix proportion of 1:2.04:1.45 were adopted with water cement ratio 0.57 for casting, according mix design.

5.2 Number and Size of Specimen Prepared

Beam size = 100x150x1200 mm

Control beam = 3 nos

Mix with brickbat and without steel fibre = 3 nos

Mix with brick bat and steel fibre = 3 nos

Total no of beam = 9 nos

5.3 Test Setup

The beam specimen was setup as shown in figure 7.1. The beams were subjected to two point loading at 0.33m from each end. Deflection in the test specimen under loading points & at mid span were measured using deflectometers during testing. The load cell.

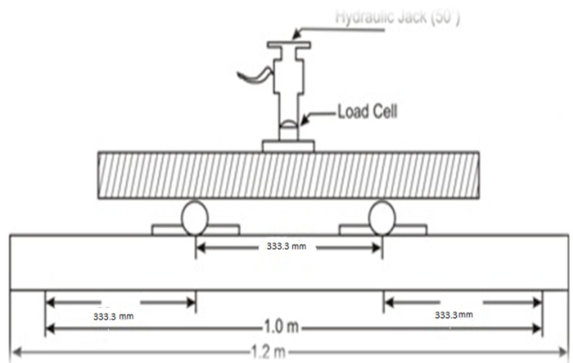

Fig . 4 (Deflection test)

6. Experimental Results

The experimental readings of deflection, Strain and stiffness are shown in table

Table 2 Deflection, stiffness, strain, characteristics of ordinary SCC concrete Beam

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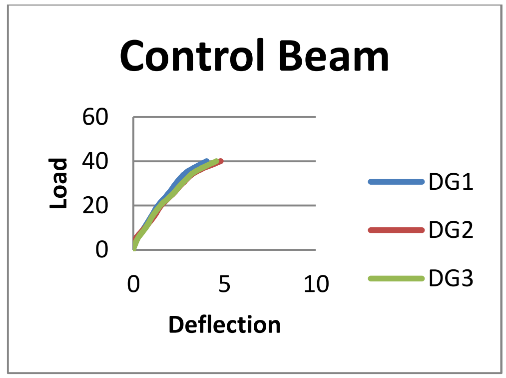
SI. N	LOAD (KN)	DEFLECTION IN mm			STIFFNESS
		DG 1	DG 2	DG 3	
1	0	0	0	0	0
2	5	0.22	0.25	0.15	20.00
3	10	0.62	0.70	0.66	14.28
4	15	0.99	1.15	1.05	13.04
5	20	1.37	1.55	1.50	12.90
6	25	1.90	2.16	2.15	11.57
7	30	2.36	2.72	2.70	11.02
8	35	2.93	3.40	3.35	10.29
9	40	4.02	4.80	4.55	8.33

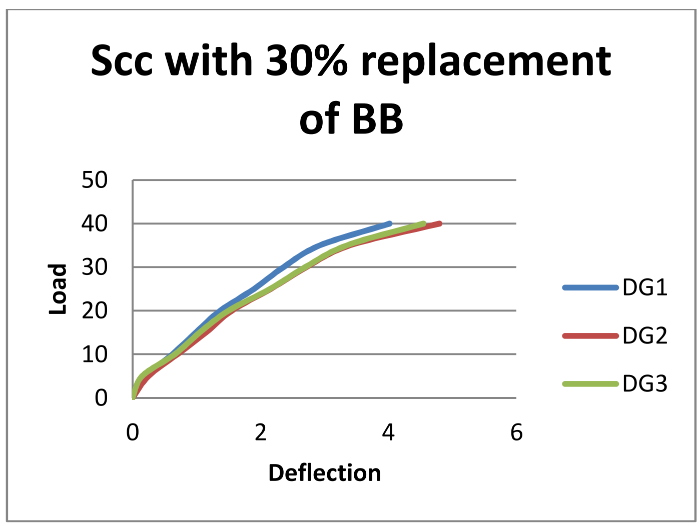
SI.NO	LOAD (KN)	DEFLECTION IN mm			STIFFNESS
		DG 1	DG 2	DG3	
1	0	0	0	0	0
2	5	0.36	0.37	0.17	13.51
3	10	0.78	0.80	0.53	12.50
4	15	1.32	1.34	1.01	11.19
5	20	1.84	1.85	1.46	19.04
6	25	2.33	2.34	1.90	10.81
7	30	2.80	2.83	2.32	10.60
8	35	3.60	3.67	2.95	9.53
9	40	5.06	5.11	4.65	7.83
10	45	6.88	7.25	6.30	6.20

ultimate load = 47 KNshear crack = 40 KN

Table.3 Deflection, stiffness, strain, characteristics of scc with 30% replacement of brick bat without steel fibre

7. Load Deflection Curve





7. ANALYTICAL INVESTIGATION

ANSYS is a finite element analysis (FEA) software package. It uses a preprocessor software engine to create geometry. Then it uses a solution routine to apply loads to the meshed geometry. Finally it outputs desired results in post-processing.

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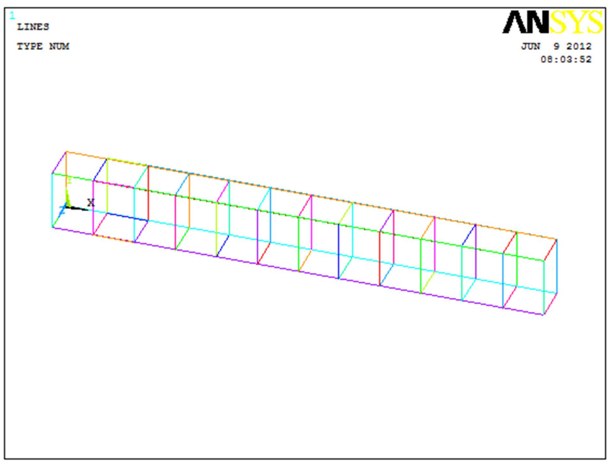
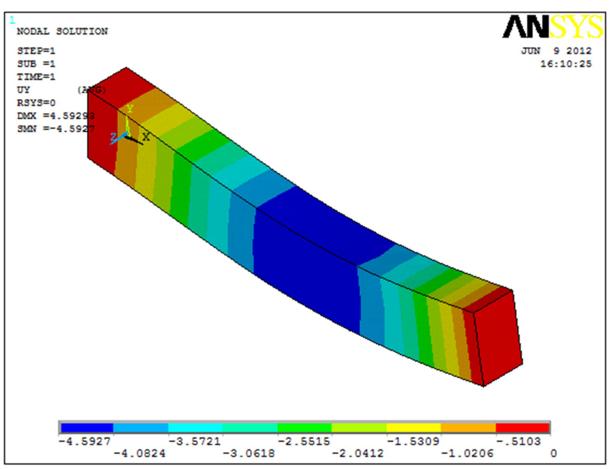
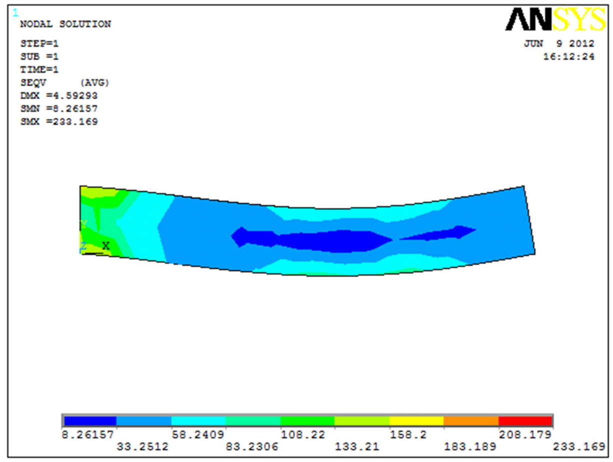
Finite element analysis was first developed by the airplane industry to predict the behavior of metals when formed for wings. Now FEA is used throughout almost all engineering design including mechanical systems and civil engineering structures.

ANSYS is used throughout industry in many engineering disciplines. This software package was even used by the engineers that investigated the World Trade Center collapse in 2010.







8.Summary and Conclusion

Summary:

Self-Compacting Concrete is a high-performance concrete which flows under its own weight and does not require any external vibration for compaction. It is easier in placing and has a high durability. A proper mix design for the normal self-compacting concrete was determined after several trials having w/p ratio 0.57. Three trial mixes were decided upon. Cubes, beams and cylinders were cast using these trial mixes with three samples in each case. They were left for curing after 24 hours and tested for compressive strength, tensile strength and flexure after 7 days, 14 days and 28 days.

Self-compacting concrete with partial replacement of coarse aggregate using brick bat was prepared with 30%, 40% and 50% replacement. Also self-compacting concrete reinforced with steel fibres and coarse aggregate partially replaced with brick bat were prepared with varying ratios with 20%, 25% and 30% steel fibre and 30%, 40% and 50% brick bat was prepared. The fresh state tests such as slump-flow, L-box, J-ring and V-funnel tests were conducted. The samples were then cast into cubes, cylinders and beams and later cured after

24 hours. Then the compressive, tensile and flexure strength tests were conducted.

The results of the fresh state and hardened state testing were then studied, tabulated, plotted and compared.

CONCLUSION:

As a result of this experimental study we have arrived at the following conclusion:

- The properties of SCC are changed considerably on addition of steel fibres and suitable proportions of SP and VMA on a trial and error basis
- There is a decrease in the compressive strength, flexural strength and split tensile strength of SCC with partial replacement of coarse aggregate with BB and steel fibre reinforced SCC with partial replacement of coarse aggregate with brick bats.
- There is a further decrease in the compressive strength, flexural strength and split tensile strength of steel fibre reinforced SCC with partial replacement of coarse aggregate with brick bats.
- These experimental investigations could be extended by casting structural components of higher scale and tested for different loading conditions.

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