Performance Evaluation of Self-Compacting Concrete using Brick Dust and Marble Powder

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Abstract— Concrete being the most important constituent of construction has gone a mile change in recent years either by replacing its ingredients by some other or by adding some essential ingredients to improve the quality and endurance of concrete. An attempt has been made to replace natural fine aggregate (sand) by brick dust and addition of marble powder to the mix generating a new additive concrete which can more or less results to a self-compacting concrete (SCC). In this experimental work, attempt has been made to substitute natural sand (Fine Aggregate) by a mixture of brick kiln dust and marble powder (0%, 25%, 50%) to produce M30 grade of concrete with adding proper dosage of Super Plasticizer (SP-430) and Viscosity Modifying Admixture (VMA).

Keywords— *SCC, VMA, Super Plasticizer, WCR, Mix Design*

I. INTRODUCTION

Marble is a metamorphic rock resulting from the transformation of pure lime stone. The rock is also one of the most important materials used in buildings since ancient times, especially for decorative purposes. Marble is industrially processed by being cut, polished, and used for decorative purposes, and thus, economically valuable. In marble quarries, stones are cut as blocks through different methods. During the cutting process, 20-30% of a marble block becomes waste marble powder. Marble powder is a waste material generated in considerable amounts in the world. Marble waste leads to a serious environmental problem as well. Therefore, the use of waste marble in the concrete production as an admixture material or aggregate has increasingly become an important issue. Valeria et al (2005) in their study observed that marble powder had very high Blaine fineness value of about1.5 m2/g, with 90% of particles passing through 50 μm-sieves and 50% through 7 μm. Brick kiln dust in form of brick dust, broken small pieces, flakes of bricks, brunt coal ashes gives large amount of waste which is utilized for filling the low lying areas or dumped as the waste in India (Sharma et. al). In developing countries bricks are still one of the most popular construction materials. India is estimated to have more than 100,000 brick kilns, producing about 150-200 billion bricks annually, employing about 10 million workers and consuming about 25 million tons of coal annually (Maithel, 2012). For brick making availability of good soil is crucial. Recently number of additives is added or is replaced with clay to increase the performance of bricks including fly ash, bagasse ash, rice husk ash etc. (Gulden, 2015). The waste from the brick production units is also a cause of concern as the brick sector of India is unmanaged and has unskilled workers which causes high waste generation. The waste generated from the brick production can be broadly classified as; brick dust or Surkhi, deformed bricks, over burnt bricks and broken bricks. A Self-Compacting Concrete (SCC) is a high performance concrete, designed to flow into formwork and consolidate under its own weight without mechanical vibration. The fluid consistency and high flow ability are achieved through changing mix proportions by increasing cementious material, increasing paste content, careful selection of aggregate volume and gradation with lower water -cement ratio and by using admixtures and super plasticizers which gives the advantages of rapid placement at the area of reinforcement congestion, reduced labor cost and improved aesthetic surface. Aggregates, cement, water are the principal materials of SCC where as SP-430, VMA and other chemical admixtures can be used as additional materials to enhance the quality of concrete.

II. MATERIALS

A. Aggregate

The coarse aggregate chosen for SCC is typically round in shape, well graded and smaller in comparison to typical conventional concrete whose maximum size is 40 mm or more. In general, rounded and smaller aggregate particles not only aid in the flowability and deformability of the concrete but also prevent segregation. Gradation is an important factor in choosing a coarse aggregate for SCC where reinforcement may be highly congested or the formwork has small dimensions. Gap-graded coarse aggregate promotes segregation to a greater degree than well-graded coarse aggregate. Maximum size of coarse aggregate used in SCC ranges from 10 mm to 20 mm. Aggregates occupy 70% to 80% of the volume of concrete and normally provide concrete with better dimensional stability and wear resistance.

B. Sand

All normal concreting sands (less than 0.125 mm) are suitable for SCC and are very important for the rheology of SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

C. Cement

The most common cement currently used in construction is type I/II Portland cement. This cement conforms to the strength requirement of a Type I and the C_3A content restriction of a Type II. The Blaine fineness is used to quantify the surface area of cement. The surface area provides a direct indication of the cement fineness ranging from 350 to 500 m^2/Kg for Type I and Type II cements respectively.

D. Super Plasticizer

Super plasticizer is a chemical compound used to increase the workability without adding more water to form a uniform mix. This acts as a lubricant among the materials. In order to increase the workability, the water content is to be increased provided corresponding quantity of cement also added to keep the water cement ratio constant, so that the strength remains the same. The job of SP-430 is to impart a high degree of flow ability and deformability, however high dosages can lead to a high degree of segregation (Ramchandran, and Malhotra). Conplast SP 430 is utilized in this project, which is a product of FOSROC (Manufactured at Bangalore, India) having a specific gravity of 1.22.

E. Viscosity Modifying Admixture

VMA improves the viscosity and cohesion of fresh concrete and thus reduces the bleeding, surface settlement and aggregate sedimentation resulting in a more stable mix.

F. Water

Potable water is used for mixing and curing.

G. Brick Dust

Brick dust is a waste product obtained from different brick kilns and tile factories. There are numerous brick kilns which have grown over the decade in an unplanned way in different parts of India. Tons of waste products like brick dust or broken pieces or flakes of bricks (brickbat) come out from these kilns and factories. So far, such materials have been used just for filling low lying areas or are dumped as wasted material.

H. Marble Powder

Marble pieces are cut into smaller blocks in order to give them the desired smooth shape. During the cutting process about 25% of the original marble mass is lost in the form of dust. In India, marble powder is settled by sedimentation and then dumped away which causes environment pollution generating dust in summer and distressing agriculture and public health.

I. Cement

The physical properties of cement and compressive strength of Grade 43 concrete have been presented in Table 1 and 2.

Table 1: Physical Properties of Cement

Properties	**Value**
Standard Consistency	37%
Specific Gravity	3.15
Initial Setting time	125 min
Final setting time	215 min
Fineness	330kg/m^2

Table 2: Compressive Strength of Cement (Grade 43)

Duration (Days)	**Compressive Strength (N/mm^2)**
3	26.5
7	38.3
28	51.1

J. Fine Aggregate

Fine aggregate which is used in experiment is of grey colour with angular shape having specific gravity 2.65, water absorption capacity of coarse aggregate was 1.1%, having fineness modulus 2.2 (Table 3).

Table 3: Sieve Analysis of Fine Aggregates (IS: 383-1970)

IS: Sieve Designation	**Wt. Retained on sieve(g**	**% Wt. Retained**	**Cumulative % Wt Retained**	**% Passing**	**Zone - II**
4.75 mm	60	0.6	0.6	99.4	90-
2.36 mm	94	9.4	10	90	75-
1.18 mm	274	27.4	37.4	62.6	55-
600	234	23.4	60.8	39.2	35-
300	286	28.6	89.4	10.6	8-30
150	79	7.9	97.3	2.7	0-10
75 micron	18	1.8	99.1	0.9	0-5
Pan	9	0.9	100	0	-----

K. Coarse Aggregate

Coarse aggregate which is used in experiment is of grey color with angular shape having specific gravity 2.65, water absorption capacity of coarse aggregate was 1%and having fineness modulus 7.87 (Table 4).

Table 4: Sieve Analysis of Coarse Aggregates (IS: 383-1970)

IS: Sieve designation	**Wt retained on**	**% Wt. Retained**	**Cumulative % Wt.**	**% Passing**
40 mm	0	0.00	0.00	100
20mm	200	4.0	4.00	96
10mm	4200	84.0	88.0	12
4.75mm	355	7.1	95.1	4.9
Pan	245	4.9	100	-----

L. Methodology of design mix

a. Super plasticizer

The super plasticizer used in concrete mix makes it highly workable for more time with much lesser water quantity. It is observant that with the use of large quantities of finer material (fine aggregate + cement + fly ash) the concrete is much stiff and requires more water for required workability hence, in the present investigation SP-430 is used as water reducing admixture.

b. Dosage

The optimum dosage is best determined by site trails with the concrete mix, which enables the effect of workability as a guide, the rate of addition is in the range of 2.5% of power value.

c. Water

This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

d. Brick Dust and Marble Powder

Brick dust and marble powder collected from the dump area which were used for making concrete, should be cleaned and dried in room temperature. The partially dried brick dust and marble powder were passed through a 4.75 mm IS sieve and retained in 75 micron sieve.

M. Mix Design (IS: 10262-2009)

a. Design stipulations

Characteristic compressive strength required in the field at 28-days: 30Mpa
Maximum size of aggregate: 12.5mm (rounded)
Degree of workability: 0.9 (compaction factor)
Degree of quality control: Good
Type of exposure: Severe

b. Test data of materials

Specific gravity of cement: 3.15
Compressive strength of cement at 7-days: Satisfies the

requirements of
IS: 269- 1989 (38.3N/mm^2)
Specific gravities of Coarse aggregate: 2.65
Fine aggregate: 2.65

c. Water absorption

Coarse aggregate: 0.5%; Fine aggregate: 1.0%; Brick dust: 1.2%; Marble powder: 0.4%

d. Free surface moisture

Coarse Aggregate: Nil; Fine aggregate: 2.0%; Brick dust: 2.3%; Marble powder: Nil

N. Fineness modulus

Coarse aggregate: 6.15; Fine aggregate: 2.72

a. Steps taken in the mix proportioning: Trial mix 1

1. Target mean strength for M30 grade concrete 0% replacement of fine aggregate with brick dust and marble powder
   fck* = fck + Ks
   fck* = 30 + 1.65 X 6.0 = 39.9N/mm^2
   Where,
   K= probability factor for various tolerances (5%) = 1.65
   S = Standard deviation for different degrees of control (Good) = 6.0
2. The water cement ratio required for the target mean strength of 39.9 Mpa is 0.38.
3. Selection of water and sand content for 12.5mm maximum size aggregate and the sand confirming to ZONE -II

   For W/C = 0.6, C.F-0.8, angular sand confirming to ZONE-II.
   (a) Water content per cubic meter of concrete = 208. l/m^3
   (b) Sand content as percentage of total aggregate by absolute volume = 62%
   (c) C.F = 0.9
   Corrections (Table 5)

Table 5: Conditional changes in water and sand

Change in condition	Water	Sand
W/C (0.6-0.38 = 0.22)	0	-4.4%
C.F = 0.1	+3%	0
Rounded	-15kg	-7%
Zone -2	0	0

The corrected water content per cubic meter of concrete 208 + ((3/100) X 208) -15 = 199.24 l/m^3
The corrected sand content as percentage of total aggregate by absolute volume 62 % - 11.4% = 50.6%

4. Determination of cement content
   Water/cement = 0.38; Water = 199.24 L/m^3, Cement content = 199.24Kg/m^3
5. Determination of coarse and fine aggregate contents for the specified maximum aggregate size of 12.5 mm, the amount of entrapped air in the wet concrete is 3%, taking this in to account and applying equations

$V = [W + (C/S_C) + 1/p \times (fa/S_{fa})] \times 1/1000$
$V = [W + (C/S_C) + 1/(1-p) \times Ca/S_{ca})] \times 1/1000$
0.97 = [199.24 + (524.31/3.01) fa/ (0.506 X 2.613)] X 1/1000.
Fa = 788.77kg/m^3

0.97 = [199.24+ (524.31/3.01) + Ca/ ((1-0.506) X 2.625)] X 1/1000.
Ca = 773.06kg/m^3.
The mix proportion then becomes (Table 6)

Table 6: Mix proportion ratio

Cement	F.A	C.A	Water
524.31kg	788.77kg	773.06kg	199.24
1	1.50	1.47	0.38

Further in the trial mix-1 cementation material is taken as 270Kg/m^3 of cement, the water/cementations material is 0.38 the fine aggregate/total aggregate is 62%.
The contents of cement, fine aggregate, coarse aggregate, water, SP 430, VMA is listed below.
Cement = 270kg/m^3,
Brick dust = 0 Kg/m^3
Marble powder = 0Kg/m^3
Fine aggregate = 788.77 kg/m^3
Coarse aggregate = 773.06 kg/m^3
Water = 200.98 l/m^3
SP430 dosage = 2.5% of cementation materials
VMA = 0.35% of cementation materials

b. Steps taken in the mix proportioning: Trial mix 2

Target mean strength for M30 grade concrete
25% replacement of fine aggregate with brick dust and marble powder
fck* = fck + Ks
fck* = 30+1.65X6.0 = 39.9N/mm^2
Where,
K= probability factor for various tolerances (5%) = 1.65 (IS: 10262-2009)
S = Standard deviation for different degrees of control (Good) = 6.0(IS: 10262-2009)
The water cement ratio required for the target mean strength of 39.9 Mpa is 0.38.
Selection of water and sand content for 12.5mm maximum size aggregate and the sand confirming to ZONE -II.
For W/C-0.6, C.F-0.8, Angular sand confirming to ZONE- II.
Water content per cubic meter of concrete = 208 L/m^3
F.A content as percentage of total aggregate by absolute volume = 62%
C.F = 0.9

Table 7: Corrected water content

Change in condition	Water	Sand
W/C(0.6-0.38 = 0.22)	0	-4.4%
C.F = 0.1	+3%	0
Rounded	-15kg	-7%
Zone -II	0	0

The corrected water content per cubic meter of concrete (Table 7)
208 + ((3/100) X 208) -15 = 199.24 L/m^3
The corrected sand content as percentage of total aggregate by absolute volume
62 % - 11.4% = 50.6%
Determination of cement content
Water/cement = 0.38
Water = 199.24 L/m^3
The cement content = 199.24 Kg/m^3
Determination of coarse and fine aggregate contents
For the specified maximum aggregate size of 12.5 mm, the amount of entrapped air in the wet concrete is 3%, taking this

in to account and applying equations

$V= [W + (C/S_C) + 1/p \ X \ (Fa/s_{fa})] \ X \ 1/1000$
$V= [W + (C/S_C) + 1/(1-p) \ X \ Ca/S_{ca})] \ X \ 1/1000$
0.97= [199.24 + (524.31/3.01) Fa/ (0.506 X 2.613)] X 1/1000.
Fa = 788.77 Kg/m^3
0.97 = [199.24 + (524.31/3.01) +Ca/ ((1-0.506) X 2.625)] X 1/1000.
Ca = 773.06 Kg/m^3.
The mix proportion then becomes (Table 8)

Table 8: Mix proportion ratio with cement 524.31kg

Cement	F.A	C.A	Water
524.31kg	788.77kg	773.06kg	199.24
1	1.50	1.47	0.38

The obtained contents of cement, sand, aggregate and water per cubic meter of concrete are listed below.

Cement = 524.31Kg
Sand = 788.77kg
Coarse aggregate = 773.06 Kg
Water = 199.24 Kg
Converting into SCC Proportions
The normal concrete mix proportions are modified as per EFNARC specifications and different trail mixes and caste. By considering the fresh properties and harden properties of the mixes we finally arrived at the SCC mixed proportions as
Cement = 524.31
Fine aggregate = 788.77
Coarse aggregate = 773.06
Total aggregate (T.A) = 788.77+773.06 = 1561.83
Taking 56% of T.A as F.A
F.A = 1561.830 X 0.56 = 874.62 Kg/m^3
C.A = 687.2 Kg/m^3
The modified proportion is presented in Table 9.

Table 9: Mix proportion

Cement	F.A	C.A	Water
524.31Kg	874.62 Kg	687.2 Kg	199.24 L
1	1.67	1.31	0.38

Further in the trail mix-1 cementation material is taken as 270 Kg/m^3 of cement, the water/cementations material is 0.38 the fine aggregate/total aggregate is 62%. The contents of cement, fine aggregate, coarse aggregate, water, SP 430 and VMA are listed below.

Cement = 270 Kg/m^3
Brick dust = 98.6 Kg/m^3
Marble powder = 98.6 Kg/m^3
Fine aggregate = 591.57 Kg/m^3
Coarse aggregate = 773.06 Kg/ m^3
Water = 200.98 L/m^3
SP 430 = 13.23 L/m^3 VMA = 1.85 L/m^3
SP430 dosage = 2.5% of cementation materials
VMA = 0.35% of cementation materials

c. Steps taken in the mix proportioning: Trial mix3

Target mean strength for M30 grade concrete
50%replacement of fine aggregate with brick dust and marble powder
fck* = fck + Ks
fck* = 30 + 1.65X6.0 = 39.9N/mm^2

Where,
K = probability factor for various tolerances (5%) = 1.65
S = Standard deviation for different degrees of control (Good) =6.0. The water cement ratio required for the target mean strength of 39.9 Mpa is 0.38.
Selection of water and sand content for 12.5mm maximum size aggregate and the sand confirming to ZONE -II.
For W/C-0.6,C.F-0.8, angular, sand confirming to ZONE-II.
(c) Water content per cubic meter of concrete = 208 l/m^3
(d) Sand content as percentage of total aggregate by absolute volume = 62% (c) X C.F. = 0.9
Corrections (Table 10)

Table 10: Water and Sand percentages in changing conditions

Change in condition	Water	Sand
W/C (0.6-0.38 = 0.22)	0	-4.4%
C.F = 0.1	+3%	0
Rounded	-15kg	-7%
Zone - II	0	0

The corrected water content per cubic meter of concrete 208 + ((3/100) X 208) -15 = 199.24 l/m^3
The corrected sand content as percentage of total aggregate by absolute volume 62 % - 11.4% = 50.6%
Determination of cement content
Water/cement = 0.38
Water = 199.24 l/m^3
The cement content = 199.24kg/m^3
Determination of coarse and fine aggregate contents for the specified maximum aggregate size of 12.5 mm, the amount of entrapped air in the wet concrete is 3%, taking this into account and applying equations
$V= [W+(C/S_C) + 1/p \ X \ (fa/s_{fa})] \ X \ 1/1000;$
$V= [W+(C/S_C) +1/(1-p)X \ Ca/S_{ca})]X1/1000;$
0.97 = [199.24 + (524.31/3.01) fa/ (0.506 X 2.613)] X 1/1000.
fa = 788.77kg/m^3
0.97 = [199.24 + (524.31/3.01) + Ca/ ((1-0.506) X 2.625)] X 1/1000.
Ca = 773.06kg/m^3.
The mix proportion presented in Table 11, 12 and 13. Table 14 represents the slump value of fresh concrete. The physical properties of SCC are presented in Table 15.

Table 11: FA and CA of mixed proportion with water content 157.29 L.

Cement	F.A	C.A	Water
524.31Kg	786.46 Kg	734.03 Kg	157.29
1	1.5	1.4	0.3

The obtained contents of cement, sand, aggregate and water per cubic meter of concrete are listed below.
Cement = 524.31Kg
Sand = 788.77 Kg
Coarse aggregate = 773.06 Kg
Water = 199.24 Kg
Converting into SCC Proportions
The normal concrete mix proportions are modified as per EFNARC specifications and different trial mixes and caste. By considering the fresh properties and harden properties of the mixes we finally arrived at the SCC mixed proportions as
Cement = 524.31
Fine aggregate = 788.77
Coarse aggregate = 773.06

Total aggregate (T.A) = 788.77+773.06 = 1561.83
Taking 56% of Total Aggregate as F.A
F.A= 1561.83X0.56 = 874.62 Kg/m^3 C.A =687.2 Kg/m^3
The modified proportion is (Table12)

Table 12: FA and CA of mixed proportion with water content 199.24 L.

Cement	F.A	C.A	Water
524.31 kg	875.59 kg	686.85 kg	199.24
1	1.67	1.31	0.38

Further in the trail mix-1 cementation material is taken as 270kg/m^3 of cement, the water/cementations material is 0.38 the fine aggregate/total aggregate is 62%.
The contents of cement, fine aggregate, coarse aggregate, water, SP 430, VMA are listed below.
Cement = 270 Kg/m^3
Brick Dust = 197.19 Kg/m^3
Marble Powder = 197.19 Kg/m^3
Fine Aggregate = 394.39 Kg/m^3
Coarse Aggregate = 773.06 Kg/m^3
Water = 200.98 L
Sp430 = 13.23 L/m^3
VMA = 1.85 L/m^3
SP430 dosage = 2.5% of cementation materials
VMA = 0.35% of cementation materials

Table 13: Ratios of mix proportions by weight

Mix	Grade of Cement Concrete	Trial	Cement	F.A	C.A	Brick dust	Marble powder	Sp-430 dosage	VMA Dosage
SC	M30	1	1.0	3.8	3.0	0	0	0.05	0.007
SC	M30	2	1.0	2.8	3.0	0.47	0.47	0.05	0.007
SC	M30	3	1.0	1.9	3.0	0.95	0.95	0.05	0.007

Table 14: Properties of Fresh concrete (SCC)

Trial Mix	Slump Flow
1	670
2	675
3	685
4	680

Table 15: Properties of Hardened concrete (SCC), (IS: 516-1959)

Trial Mix	Compressive Strength (N/mm^2)			Tensile strength(N/mm^2)	
	3 Days	7 Days	28	7 Days	28 Days
1	22.0	30.5	41.0	2.542	3.108
2	22.5	32.0	43.0	2.432	3.264
3	20.5	28.5	39.0	2.392	2.929

CONCLUSION

All concrete mixes using brick dust and marble powder fulfilled the performance criteria for fresh and hardened SCC. Good hardened properties were achieved for the concretes with 25% marble powder which can be considered as the optimum content for high compressive strength. The hardened properties of the SCCs were improved at 28 days due to greater hydration of cement Brick dust and marble powder can be efficiently used to produce good quality self-compacting concrete with satisfactory slump and setting times. Under certain conditions, replacement of fine aggregate by brick dust and marble powder appears to increase the strength of self-compacting concrete. In this study an effort has been made to evaluate the usefulness of brick kiln dust and marble powder both of which are waste material to produce cost effective self-compacting concrete.

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