International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

Workability, Strength and Durability Properties of Concrete with Blended Cement and Different Types of Fine Aggregates

Gab Suresh
AGM, Concrete Technologist
Ramco Research and Development Centre (RRDC)
A Division of The Ramco Cements Limited
Chennai-India

Abstract:- The use of Manufactured Sand (M-Sand) and Crushed Stone Sand (CSS) is steadily growing due to scarcity of natural River Sand. Now-a- days the sand available in the river bed contains high percentage of silt and clay. Generally CSS and a few source of M-Sand samples contain higher percentage of Fine, Flaky, Elongated and rough texture particles and negligible clay content when compared to the River Sand. At the same mix proportions, concrete workability with river sand will be higher when compared to that with M-Sand or CSS concretes due to the spherical shape and smooth texture of river sand particles. The purpose of this research is to achieve the same workability, strength and durability properties of concrete by using appropriate proportion of River Sand, M Sand and CSS without changing cement content and free water cement ratio. From the test results it was ascertained that the concrete workability, strength and durability properties show more or less equal values which could be possible by designing the concrete mix proportions based on the gradation, fines content and other physical properties of fine aggregate.

Keywords—River Sand, Crushed Stone Sand, Manufactured Sand, Vertical Shaft Impact

INTRODUCTION

River sand is a product of natural weathering of rocks over a period of millions of years. Natural rocks are disintegrated by weathered process. The disintegrated particles are worn out by streams or glacial agencies and finally get deposited on the banks of the rivers and are called River Sand also called Uncrushed Sand. Now-a-days River sand is becoming a scarce product and hence exploring alternatives to it becomes imminent. Crushed Stone Sand (CSS) or Crushed Rock Fines (CRF) is produced by crushing hard granite stones and Crushed Gravel Sand(CGS) is produced by crushing natural gravel.

IS 383-2016 code stated that Manufactured Sand is manufactured from other than natural sources. Copper Slag, Iron Slag and Steel Slag materials are considered as Manufactured Aggregates. Recycled Concrete Aggregates also considered as Manufactured Aggregates. As per IS 383-2016 code, the utilization of Manufactured Aggregates in different concretes are given in Table 1. The limits of deleterious materials in the fine aggregate are given in Table 2 as specified in the same code.

Crusher Stone Sand / Crushed Rock Fines / Crusher Dust / Quarry Dust are the fine particles obtained as a by-product during the crushing of rocks to produce coarse aggregates. Jaw crusher or Cone crusher is used for crushing large size rocks to small size rocks. This material contains more fine particles, dust, flaky, and elongated particles. It shows high water demand for required workability and this may lead to develop more shrinkage cracks in concrete. Thus Crushed Stone Sand should be used only after proper testing and designing the concrete mix accordingly.

PRODUCTION TECHNOLOGY OF M-SAND / ROBO SAND / ECO SAND

To resolve the Crushed Stone Sand quality problems, the technology of processing to improve the particle shape and reduce the fines content has been developed. Rock crushed to the required grain size distribution is colloquially termed as manufactured sand (M-Sand). Generally M-Sand production involves crushing, screening and washing. M-Sand particles are cubical in shape and also some extent smooth texture. M-Sand is manufactured using technology like “Rock-on-Metal and Rock-on-Rock” process which is synonymous to that of natural process undergoing in river sand formation.

M-Sand is produced by feeding hard stones of varying sizes to primary and secondary crushers (Jaw crusher and Cone crusher), for size reduction and these crushed stones are further crushed in Vertical Shaft Impact (VSI) crusher to attain the required grain size distribution and shape to that of River Sand. The VSI crusher by its unique design and action of attrition produces well shaped fine aggregate particles that are cubical angular particles. Generally the real M-Sand or Robo Sand quality is better than the River Sand. The comparisons between River Sand and M-Sand are given in Table 4.

The VSI machine is shown in Fig. 1. In the production process of M-Sand it is a challenge to avoid generating of a high percentage of fines. Very fine particles will be removed by washing. However, the latest development of equipment combined dry screening

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

with air classification to govern the grading curve very precisely, including the finest part. The River Sand, CSS and M-Sand fine aggregates colour and coarse particles properties are shown in Fig.2. The quality of M-Sand samples which were collected from different suppliers in Tamil Nadu are shown in Table 3

LITERATURE

Prof.Venkatarama Reddy et. al. (2012)[7] investigated that the mortar workability, compressive strength, modulus of rupture, modulus of elasticity, bond strength properties are superior by using M-Sand when compared to those of natural River Sand. Saeed Ahmad et al. (2008)[11] found that concrete compressive strength increased and workability decreased with increasing proportion of M-Sand. Balamurugan et.al.(2013)[8] ascertained that quarry dust can be utilized in concrete mixtures as a good substitute for river sand with higher strength at 50% replacement. Adams et.al.(2013)[9] found that the replacement of 50% fine aggregate by M-Sand induced higher compressive strength, split tensile strength, flexural strength and durability. Priyanka et.al. (2013)[10] determined that the compressive strength of cement mortar with 50% replacement of river sand by M-Sand reveals higher strengths as compared to 100% River sand mix.

EXPERIMENTS

In this research physical properties such as sieve analysis, particle shape, specific gravity, water absorption, fines and silt content, bulk density etc of different types of fine aggregates were studied and the effect of using these materials on the performance of concrete are investigated. From the sieve analysis results it was observed that River Sand and M-Sand are coarse sand and Crusher Stone Sand is fine sand. The sieve analyses and other physical properties of aggregates are presented in Table 5 and Table 6 respectively.

The main objective of this research is to establish the data to achieve more or less equal concrete workability, strength and durability properties by fixing appropriate fine aggregate proportion in the total aggregate. Nominal and Design mix concrete trials were carried out by using Ramco Super Grade cement (PPC) and different types of fine aggregates i.e. River sand, M-Sand and CSS. Basically the percentage of fine aggregate in the total aggregate was fixed based on the fine aggregate gradation, fines content (<75microns) and other physical properties. Concrete trials were also carried out with blending of coarser and finer fine aggregates. The River sand & CSS and M-Sand & CSS were blended 50:50 and 55:45 ratios by volume respectively and these blending gradation curves are shown in Fig.3. The test results of workability, strength and durability obtained for the nominal mix and design concretes are presented in Table 7 and Table 8 respectively.

From the test results of nominal and design mix concretes it was ascertained that at the same cement content and free water cement ratio, all concretes were attained relatively equal slump, flow, compressive strength and durability properties by fixing appropriate proportion of River Sand, CSS and M-Sand in total aggregate based on the gradation, fines content and other physical properties of fine aggregate. This methodology is not only helpful to obtain relatively equal rheological, strength and durability properties of concrete with different quality of River Sand, CSS and M-Sand, it will be also useful to minimise the plastic shrinkage and plastic settlement cracks in the structures. The nominal mix concretes slump tests photographs are shown in Fig. 4 .

Concrete trials were also carried out at different percentages of replacing River Sand with Crushed Stone Sand considering relatively same workability, strength and durability of all concretes. Crushed Stone Sand was added for replacement of River Sand from 0% to 100% in the increment of 10% and the percentage of total fine aggregate proportion by volume gradually decreased from 45 % to 36% in the total aggregate volume. The River Sand and CSS blend concretes design mix proportions are given in Table 9. For all these mixes were also maintained constant cement content and free water cement ratio. The fine particles (150, 300 and 600 microns) content per one cubic meter concrete for different proportions of River Sand, CSS and blended River Sand & CSS fine aggregates are presented in Fig.5. From the graph it was observed that 300 to 600 microns particles content is gradually decreased, below 150 microns particles content gradually increased and 150 to 300 microns particles content slightly increased by gradually replacing River Sand with Crushed Stone Sand. Due to this phenomenon all concretes have attained more or less equal slump, flow, compressive strength and durability properties. The photographs of flow tests of the concretes containing the blends of River Sand and CSS are shown in Fig.6, and Fig. 7shows the results of their workability, strength and durability.

CONCLUSIONS

1. By fixing appropriate weight of fine aggregate in total aggregate weight, **Nominal Mix Concretes** attained more or less equal slump, flow, strength and durability properties with River Sand (44%), M-Sand (39%) and Crushed Stone Sand (36%) without changing the cement content and free water cement ratio.
2. With fixing proper volume of fine aggregate in total aggregate volume, **Design Mix Concretes** attained more or less equal slump, flow, strength and durability properties with River Sand (45%), M-Sand (40%) and Crushed Stone Sand (36%) without changing cement content and free water cement ratio.
3. As a result of blending suitable ratios of different type of fine aggregates River sand & CSS (50:50) and M-Sand & CSS (55:45) concretes also achieved good rheological, strength and durability properties.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

4. With the higher percentage of CSS (43%) in the total aggregate (Table 8), the water demand is increased for getting required workability and it decreased the strength and durability.

5. By gradually increasing of CSS and proportionally decreasing the River Sand in total volume of fine aggregate and gradually decreasing the volume of total Fine aggregate in the total aggregate volume, concretes achieved almost equal slump, flow, strength and durability properties.

The above conclusions indicate that by fixing appropriate Fine and Coarse Aggregate Proportions based on Fine Aggregate Gradation, Fines content and coarser particles properties, one can make the concrete by using River Sand, M-Sand and Crushed Stone Sand or with the combination of these fine aggregates and get the almost same workability, strength and durability properties without changing the cement content and free water cement ratio.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the initiative of The Ramco Cements Limited for providing the state-of-the-art research facilities at Ramco Research and Development Centre (RRDC), Chennai. The author is extremely grateful to The Ramco Cements Limited and Technical and non-Technical Staff of the RRDC.

REFERENCES:

[1] IS 383 : 2016 "*Coarse and Fine Aggregate for Concrete – Specification*
[2] IS 516 "*Methods of tests for strength of concrete*"
[3] IS 2386 (Part I - VIII) " *Methods of test for aggregate for concrete*"
[4] IS 10262 – 2009 " *Concrete Mix Proportioning – Guidelines*"
[5] IS 456 – 2000 " *Plain and Reinforced Concrete – Code of Practice*"
[6] ASTM C 1202- 19 " Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
[7] Prof. Venkatarama Reddy (2012) "Suitability *of Manufactured sand (M-Sand) as fine aggregate in Mortars and Concrete*" Project Review Article, Dept. of Civil Engg., Indian Institute of Science, Bangalore.
[8] Balamurugan G and Perumal P (2013) " Use of quarry dust to replace sand in concrete-An experimental study" Int. Journal of Scientific and Research Publications, Vol. 3, Issue 12, Dec. 2013.
[9] .Adams A Joe, Maria A Rajesh, Brightson P, PremAnand M (2013) " Experimental Investigation on the effect of M-Sand in high performance concrete" American Journal of Engineering Research, Vol.02, Issue-12, pp-46-51
[10] Priyanka A. Jadhav and Dilip K. Kulkarni (2013) " Effect of replacement of natural sand by manufactured sand on the properties of cement mortar" Int. J. of Civil and Structural Engineering, Vol. 3, No.3, 2013
[11] Saeed Ahmad and ShahidMahmood (2008) " Effects of Crushed and Natural Sand on the properties of Fresh and Hardened Concrete" 33rd Conference on our World in Concrete &Structures, Singapore, pp. 25-27
[12]

Table 1: As per IS 383:2016 Utilization of Manufactured Aggregates in Different Concretes

Type of Aggregate	Plain Concrete (%)	Reinforced Concrete (%)	Lean Concrete (<M15) (%)
Coarse aggregate			
(a) Iron Slag Aggregate	50	25	100
(b) Steel Slag Aggregate	25	Nil	100
(c) Recycled Concrete Aggregate	25	20 (<M25)	100
(d) Recycled Aggregate	Nil	Nil	100
(e) Bottom Ash from thermal power plant	Nil	Nil	25
Fine Aggregate			
(a) Iron Slag Aggregate	50	25	100
(b) Steel Slag Aggregate	25	Nil	100
(c) Copper Slag Aggregate	40	35	50
(d) Recycled Concrete Aggregate	25	20 (<M25)	100

Table 2: As per IS 383: 2016 Limits of Deleterious Materials in the Fine Aggregate

Sl. No	Deleterious Substance	Uncrushed Sand (River Sand)	Crushed Sand (CSS)	Manufactured Sand
1	Coal and lignite, Max (%)	1.0	1.0	1.0
2	Clay lumps, Max. %	1.0	1.0	1.0
3	Material finer than 75 µm IS sieve, Max %	**3.0**	**15**	**10**
4	Mica, Max (%)	1.0	1.0	1.0
5	Deleterious materials (Max. %)	5.0	2.0	2.0

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

Table 3: The quality of M-Sand samples which were collected from different suppliers in Tamil Nadu

IS Sieve (mm)	**Cumulative Percentage Pass**					
	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
10.0	100	100	100	100	100	100
4.75	99.9	98.1	99.8	100	99.4	100
2.36	75.0	82.9	68.6	71.3	79.5	87.7
1.18	44.7	62.7	41.6	45.8	58.1	64.7
0.60	**29.5**	**50.1**	**29.8**	**34.7**	**46.4**	**51.7**
0.30	**17.4**	**36.1**	**22.2**	**24.8**	**35.6**	**38.4**
0.15	**5.7**	**15.3**	**14.0**	**13.3**	**19.9**	**22.6**
<75 µm	**3.5**	**9.3**	**12.0**	**13.5**	**16.7**	**18.5**
Zone	Zone-I	Zone-II	Zone-I	Zone-I	Zone-II	Zone-II
Fineness Modulus	3.28	2.55	3.24	3.10	2.61	2.35
Type of Sand	Coarse Sand	Fine Sand	Coarse Sand	Coarse Sand	Medium Sand	Fine Sand
Particle Shape	**Cubical Angular**	**Flaky & Elongated**	**More Cubical Angular**	**Cubical Angular**	**Medium Cubical**	**More Flaky & Elongated**

Table 4: Comparison between River Sand and M- Sand

Sl.No	**Description**	**River Sand**	**M- Sand**
1	Process	Naturally available on river banks	Manufactured in factory
2	Quality	No control over quality since it is naturally occurring.	Consistent quality since manufactured in a controlled environment (VSI)
3	Shape	Mostly sphere particles	Mostly cubical and angular particle (≈rounded angular)
4	Below 75 microns	< 3 %	≈ 10 %
5	Surface texture	Smooth	≈ Smooth
6	Clay and Organic impurities	Higher	≈ Zero
7	Over Sized materials	May contains oversized materials (like pebbles)	≈ Zero
8	Marine Products	It contains shells etc	≈ Zero
9	Workability	Better	≈ River sand mix (If adjust mix proportions based on fines and particle shapes)
10	Strength	Good	≈ River sand or slightly higher
11	Eco friendly	Harmful to environment. ECO imbalance, reduce ground water level and rivers water gets dried up.	Less damage to environment as compared to river sand
12	Gradation	It may vary load to load	Maintain good gradation
13	Applications	Recommended for RCC, Masonry and Plastering	Recommended for RCC, Masonry and Plastering (M-Sand with low fines and less flaky& elongated particles and smooth texture is suitable for plastering works).
14	Adulteration	Probability of adulteration is more (filtered sand). As a rule, supply shortage always brings adulterer products to the market.	Probability of adulteration is less
15	Availability	In monsoon more scarcity. Diminishing of Natural Rivers or River beds, not available for future generations	Uninterrupted supply (since plenty of hills/rocks available)
16	Price	High	Low when compared to River sand

Table 5: Coarse and Fine Aggregates Sieve Analysis

Coarse Aggregate (single sized aggregate)					**Fine Aggregate**				
IS Sieve Size (mm)	**Percentage Pass**				**IS Sieve Size (mm)**	**Percentage Pass**			**IS 383 Limits for Zone - II**
	12.5 mm Agg.	**IS 383 Limits**	**20mm Agg.**	**IS 383 Limits**		**River Sand**	**M-Sand**	**CSS**	
40	100	-	100	100	10	100	100	100	100
20	100	-	**96.8**	**85 -100**	4.75	99.9	100	100	90 - 100
16	100	100	55.2	-	2.36	93	91.7	87.6	75 – 100
12.5	**98.7**	**85 - 100**	17.8	-	1.18	66.3	60.2	70.9	55 - 90
10	58.4	0 - 45	2.17	0 - 20	**0.60**	**35.1**	**29.5**	**52.3**	**35 – 59**
4.75	0.27	0 - 10	0.07	0 - 5	0.30	11.2	16.0	39.2	8 - 30
-	-	-	-	-	0.15	1.9	8.6	21.1	0 – 10*

** Crushed stone sand, the permissible limit on 150 µm IS Sieve is increased to 20 percent.*

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

Table 6: Coarse and Fine Aggregates Physical Properties

Sl. No	Description		12mmAgg.	20mmAgg.	River Sand	CSS	M-Sand
1	Specific Gravity	SSD	2.78	2.75	2.64	2.67	2.67
		True	2.77	2.74	2.61	2.60	2.62
2	Water Absorption (%)		0.51	0.46	0.94	2.43	1.73
3	Loose Bulk Density (kg/m^3)		1404	1462	1528	1660	1619
4	Compacted Bulk Density (kg/m^3)		1549	1623	1694	1924	1781
5	Flakiness Index (%)		22.7	11.4	-	-	-
6	Elongation Index (%)		20.3	14.4	-	-	-
7	Impact Value (%)		21.9	16.6	-	-	-
8	Crushing Value (%)		23.4	20.2	-	-	-
10	Angularity Number		8.11	5.06	-	-	-
11	< 75 microns (%) (by wet sieve analysis)		-	-	0.90	20.2	6.0
12	Fine Aggregate Zone		-	-	I	II	I
13	Type of sand		-	-	Coarse	Fine	Coarse

Table 7: Nominal Mix Concrete proportions and its workability, Strength and Durability Properties with different type of Fine Aggregates

Description		Fine Aggregate % by weight in total aggregate: River Sand (44) (MIX-NR)	M-Sand (39) (Mix-NM)	Crushed Stone Sand (36) (Mix-NC)
Mix Proportions in **Dry** condition (kgs)	Ramco Super Grade (PPC)	350	350	350
	Fine Agg.	790	700	638
	20mm Agg.	1014	1098	1144
	Total water (including water absorption)	205	210	214
	Free W/C	0.55	0.55	0.55
Initial Slump (mm)		98	90	73
Compressive Strength , MPa	1 -Day	9.2	9.4	10.6
	3 - Days	14.0	14.6	15.0
	7 - Days	19.1	19.7	19.1
	28 - Days	31.6	31.2	30.0
RCPT (Coulombs)	28 - Days	1177	1013	1182

Table 8: Design Mix Concrete proportions and its Workability, Strength and Durability Properties with different type of Fine Aggregates

Description		Fine Aggregate % by Volume in total aggregate: River Sand (45)	M-Sand (40)	CSS (36)	RS+CSS (50+50)	M-Sand + CSS (50+50)	CSS (43)
Mix Proportions per1m^3 concrete in **SSD** (kgs)	Ramco Super Grade (PPC)	340	340	340	340	340	340
	Fine Agg.	812	741	667	352+361	387+317	783
	12.5mm Agg.	446	486	519	494	502	454
	20mm Agg.	609	664	709	675	686	620
	Water (Free W/C)	187 (0.55)	187	187	187	187	199 (0.585)
Initial Slump (mm)		64	60	59	75	72	78
Initial Flow Diameter (mm)		455	448	425	453	428	440

Compressive Strength , MPa	1 -Day	7.9	8.4	8.3	7.9	7.0	5.6
	3 - Days	15.9	15.9	15.7	15.3	14.5	11.3
	7 - Days	20.6	20.9	19.7	19.4	18.3	15.3
	28 - Days	29.5	31.1	28.7	29.7	28.7	22.5
RCPT (Coulombs)	28 – Days	1097	1285	1304	1174	1358	1613

Table 9 River Sand and CSS Blend Concretes Mix Proportions

Description		M-RC1	M-RC2	M-RC3	M-RC4	M-RC5	M-RC6	M-RC7	M-RC8	M-RC9	M-RC10	M-RC11
		Fine Aggregates proportions in percentage (by Volume)										
		(45)* 100 RS	(44) RS+CSS 90+10	(43) RS+CSS 80+20	(42) RS+CSS 70+30	(41) RS+CSS 60+40	(40) RS+CRS 50+50	(39) RS+CSS 40+60	(38) RS+CRS 30+70	(37) RS+CSS 20+80	(36.5) RS+CSS 10+90	(36) 100 CSS
Mix Proportions per 1m^3 concrete in SSD(kgs)	Ramco PPC	350	350	350	350	350	350	350	350	350	350	350
	River Sand	811	714	620	530	443	360	281	205	133	66	0
	CSS (CRF)	0	80	157	230	300	366	428	487	541	601	659
	12.5 mm	440	448	456	464	472	480	488	496	504	508	512
	20 mm	601	612	623	634	645	656	667	678	688	694	699
	Water	193	193	193	193	193	193	193	193	193	193	193

*The percentage of Total Fine Aggregate proportion by volume in total aggregate volume

Fig.1 Vertical Shaft Impactor (VSI) for producing M-Sand

River Sand (Mostly Spear particles)

Crushed Stone Sand (Mostly flaky and elongated particles)

M-Sand (Mostly rounded angular)

Fig. 2 Fine Aggregates coarsar partciles properties (after <0.60 mm particles)

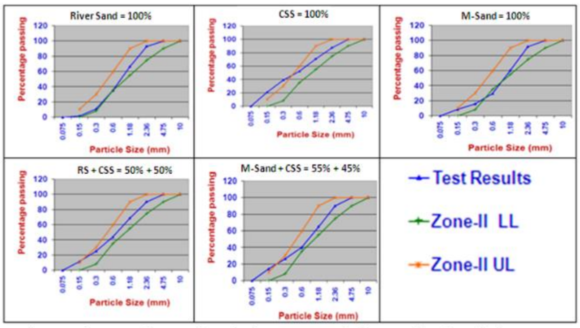

Fig.3 River Sand, CSS and M-Sand gradation curves and also combined gradation curves

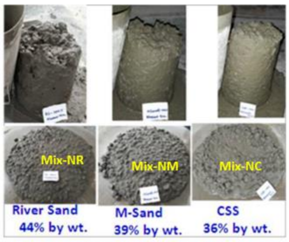

Fig. 4 : Photographs of Slump and Flow tests for Nominal Mix Concretes with River Sand, CSS and M-Sand

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 04, April-2021

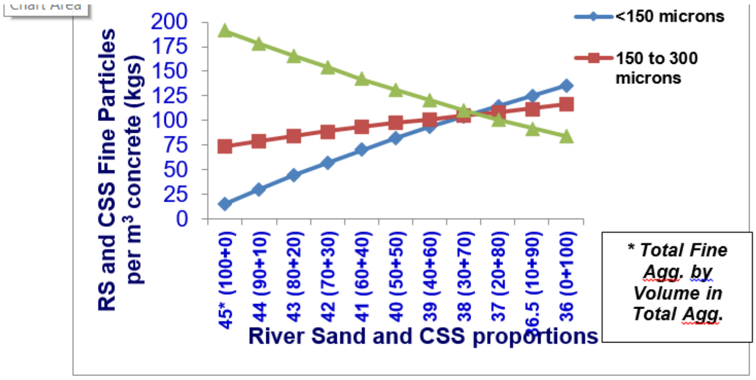

Fig. 5 : Fine particles content (150, 300 and 600 µm) per one cubic meter concrete for different River sand and CSS proportions

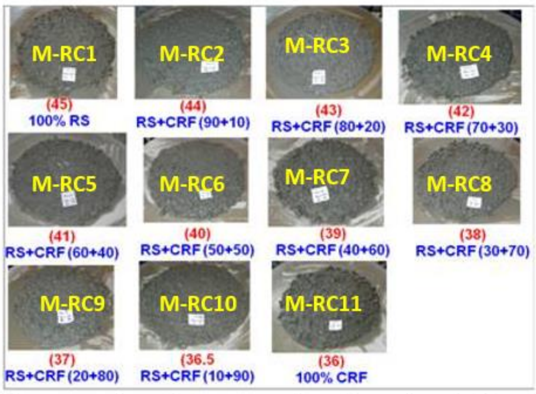

Fig. 6 : Photographs of River Sand and CSS(CRF) blend concrete Flow Tests

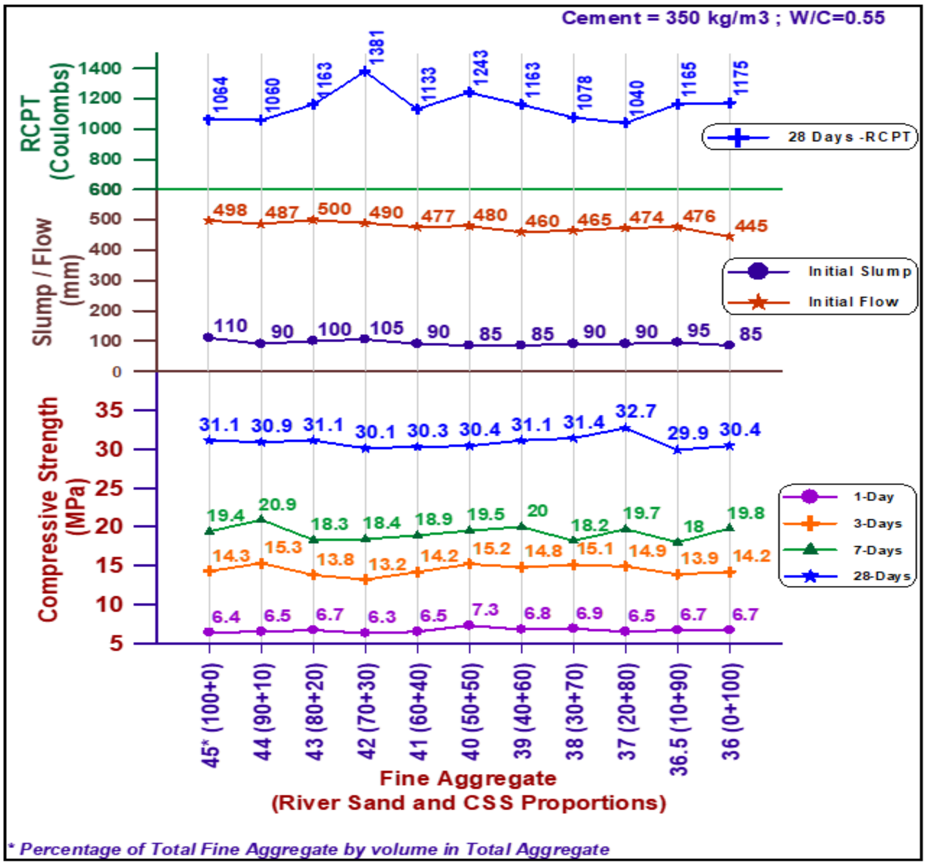

Fig. 7 River Sand and CSS blend concrete workability, strength and durability test