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Research Article

PERFORMANCE OF SHALE POWDER IN CEMENT CONCRETE

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A B S T R A C T

This article presents the performance of shale powder in cement concrete. The shale powder is used as additive for the concrete in the proportion of 0, 10, 20 and 30% by weight of cement. The concrete was tested under compression, split and flexural strengths. In all mixes manufacture sand used as fine aggregate and the mix was designed for M30 grade concrete. In addition to those mixes, with same grade of concrete, cubes, cylinder and beam specimens were prepared with natural sand and without shale powder. The test results of them consider for comparison purpose and also consider this as conventional or reference mix. From all the test results it is observed that, the mix with 10% of shale powder showed remarkable performance in compression, split and flexural strengths than conventional mix.

INTRODUCTION

Concrete is one of the world's most widely used material and it consists of binding material (cement), coarse aggregate, fine aggregate and water. The present work aimed to use supplementary cementtitious material (SCM) for the cement concrete to enhance the mechanical strengths. In this regard past works appeared on cement concrete has been discussed briefly. Mirzahosseini *et al*. (2015) focused on the combination of glass types and particle sizes affects the microstructure and performance properties of cementitious systems containing glass cullet as a SCM. Results showed that combined glass can increase reaction rate and exhibit pozzolanic properties, especially when particles of clear and green glass below 25 μm were used at a curing teperature of 50°C. The simultaneous effect of sizes and types of glass cullet (surface area) on reaction rate of glass powder also can be accounted for through a linear addition, reflecting that the surface area would significantly affect glass cullet reactivity. However, performance properties of cementitious systems containing combined glass types and sizes behaved differently. Taha *et al*. (2009) studied on the potential use of waste recycled glass in concrete as recycled glass sand (RGS) and pozzolanic glass powder (PGP). No major difference was found in compressive strength of concrete with the presence of RGS as sand replacement. The compressive strength of concrete reduced by 16 and 10.6% at 28 and 364 days respectively when 20% of Portland cement was replaced by PGP. All the used ASR suppressors in this study (GGBS, MK, PGP, and LiNO3) were proven to be very effective to reduce and eliminate the potential ASR risk. Amudhavalli and Mathew (2012) investigated on M35 grade concrete with partial replacement of cement by silica fume by 0 – 20%. They concluded that consistency increases with increase in silica fume percentage because silica fume have greater surface area than cement. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 10-15 % silica fume replacement level. Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength. When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of Silica fume. Kumar *et al*. (2012) studied on the properties of low/medium strength concrete. They observed that silica fume provide strong bonding amongst particle. Compressive strength was higher than normal concrete at 10% replacement of cement by silica fume. Split tensile strength and flexural strength were also increased at 10% cement replacement with silica fume. Silica fume concrete can be used in places of construction where there is a chance of chemical attack, frost action etc. Vidhyanagar and Strength (1989) studied on the feasibility of using the thermal industry waste of fly ash in concrete production as partial replacement of cement. Replacement proportion was 0- 40% and study was conducted on M25 & m40 mix. They concluded that the compressive strength and split tensile strength decreases as the percentage of fly ash increases and also cost of production of concrete decreases. Praveen and Janagan (2015) investigated on the usage of nano fly ash and nano GGBS in partial replacement of cement in different proportion. The percentage of fly ash

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and GGBS used in this study varied from 0-50% and 0-5% respectively. They concluded that 30 to 40 percentage cement replacement with Nano material gives better results. Fly ash gets higher strength in the longer duration. The partial replacement of OPC in concrete by Nano fly ash and GGBS not only reduce the environmental problem, it will also provide the economy of constructions. Olivia *et al*. (2015) Studied on ground cockle seashell as a partial cement replacement. Based on the trial mixes using the ground seashell with proportion of 2, 4, 6 and 8% by weight of cement, the optimum compressive strength was achieved for the mix that replaced cement by 4%. The seashell concrete yielded less compressive strength and modulus elasticity compared to the OPC concrete. It is noted that the tensile strength and flexural strength were higher than those of the OPC concrete, which is advantageous to increase concrete tension properties. Lertwattanaruk *et al*. (2012) investigated on four types of waste seashells, including short-necked clam, green mussel, oyster, and cockle to develop a cement product for masonry and plastering. Incorporation of ground seashells resulted in reduced water demand and extended setting times of the mortars, which are advantages for rendering and plastering in hot climates. All mortars containing ground seashells yielded adequate strength, less shrinkage with drying and lower thermal conductivity compared to the conventional cement. The results indicate that ground seashells can be applied as a cement replacement in mortar mixes and may improve the workability of rendering and plastering mortar. Kashyap *et al*. (2015) studied on the properties of concrete in which cement was partially replaced with rise husk ash (RHA) by 5-20%. Study was conducted on M30 mix concrete. The optimum strength is obtained at the level of 10 % of OPC replaced by RHA. OPC replacement by RHA results in reduction of cost of production of concrete in the range of 7 to 10%. Polytechnic (2014) studied on the use of RHA as a partial replacement of cement by 0-25%. From the investigation they concluded that the optimum percentage of RHA is in the range of 0-20%. The compacting factor values, bulk densities and compressive strengths of concrete were reduced as the percentage RHA replacement increased.

Based on the above introduction, it came to know that, it was not noticed any work on usage of shale powder for cement concrete works, in this regard herein an experimental investigation has been planned with shale powder to know the basic mechanical properties of cube compressive, split and flexural strengths. For cement concrete, the shale powder used as additive for the cement in various proportions of 10, 20 and 30%. Due to scarcity of river sand in the present scenario, herein manufacture same used as fine aggregate for the shale powder mixes. For comparison of strength results conventional mix (without shale powder and natural sand in place of manufacture sand) was planned and results are tested to ascertain the mechanical strength behaviours of shale powder concrete mixes. For all mixes the M30 grade concrete was taken and the mix was designed as per IS 10262(2009) guidelines. The next section describes the material properties of used materials in the present investigation.

MATERIALS AND MIX DESIGN

The following materials used in the present experimental investigation.

Cement: Ordinary Portland cement 53 grade Maha Brand confirming to B.I.S standards is used in the present investigations and its specific gravity is 3.15

Fine Aggregate (FA): For shale powder mixes manufacture sand was used and for reference mix natural sand was used. Both types of fine aggregates are conforming to zone II.

Coarse Aggregate (CA): Machine crushed angular granite obtained from quarry near Anantapur town was used as coarse aggregate. The coarse aggregate was free from clayey matter and organic impurities. Fineness modulus was 4.20. Aggregate passing through 12.5mm and retained from 4.75mm was used in the experimental work, which is acceptable according to IS 383-1970.

Water: Potable water used for the investigation and noticed that, it has been free from organic substances and acid concentration.

Shale Powder: Shale powder is a fine-grained powder, it is originated from sedimentary rock, formed from mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. Shale is characterized by its tendency to split into thin layers (laminate) less than one centimetre in thickness. This property is called fissility. Shale is the most common sedimentary rock. Shale powder is obtained from Rayalcheruvu village, Tadipatri Mandal, Anantapur district in Andhra Pradesh (State), India. The used shale powder can be viewed in figure 1and the chemical composition presented Table 1.

Table 1 Compound Analysis of Shale Powder

Sl.No	Compound	Percentage
1	Calcite	68.70
2	Montmorillonite	18.20
3	Fluorite	5.10
4	Quartz	4.0
5	Pyrite	4.0

Shale Powder

Coarse aggregate

Figure 1 Materials

Mix Design: M30 mix design has been made for slump of 50mm according to IS: 10262(2009) and the mix proportion obtained as 1: 1.40: 2.70 along with water cement ratio of 0.43 (The quantities of materials for different mixes per cubic meter presented in Table 2). Four shale powders mixes were manufactured, and the shale powder used in the proportion of 0, 10, 20, 30% by weight of cement and which has been a additive material for the cement. Coarse-aggregate has been Manufactured Crushed Stone and fine-aggregate has been as Crushed Sand. This concrete has been made by using Pan Mixer in lab and all the mixes are mixed until they have uniformity in the mix. The specimens of cube with 150×150×150mm size have been casted for Compressive Strength (CS). The specimen in cylindrical shape has diameter of 150mm and height of 300mm for Split Tensile Strength (STS) and 500×100×100mm dimensions of prisms, which has been used for evaluation of Flexural Strength (FS). The concerned cast specimens have been tested for Cube is 3, 7, 14 and 28 days of curing age and Cylinder and Beam is for 28 days of curing age. For experimental work total 48 cubes, 12 cylinders and 12 beams are cast and tested in the laboratory to obtain pre planned mechanical strengths.

Table 2 Quantities of Materials

Sl. No	Cement (kg/m^3)	Mixture of Shale Powder (total %age of additive material)	Shale Powder (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	w/c-ratio
1	432.55	0	0	622	1194	0.43
2	432.55	10	43.255	622	1194	0.43
3	432.55	20	86.51	622	1194	0.43
4	432.55	30	129.67	622	1194	0.43

DISCUSSION OF TEST RESULTS

Conventional concrete mix

At initial stage the conventional or reference mix has been tested under compression, split and flexure. The conventional mix does not have shale powder and natural river sand was used as fine aggregate. The test results of these are presented in Table 3. In fact these test results are considered in the investigation for comparison of shale powder mixes. The compressive strengths are evaluated at 3,7,14 and 28 days and at these days the strengths are 15.16, 22.70, 31.04 and 36.17MPa respectively. In addition those compressive strengths split and flexural strengths are evaluated at 28 days and those were noticed as 3.32 and 7.84Mpa.

Table 3 Basic Strengths for M30 grade Conventional Concrete

Sl.No.	Age of Sample	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
1	3 days	15.16	_	_
2	7 days	22.70	_	_
3	14 days	31.04	_	_
4	28 days	36.17	3.32	7.84

Shale powder mixes in compression

Concrete cube specimens cast with different percentage of shale powders are tested at 3,7,14 and 28 days. For each mix three samples considered, an average of three samples result presented in Table 4 and figure 2. As the concrete age increases the strengths are increasing and this trend is quite matched with earlier observations and also with the conventional mixes behaviour. At 28 days the average cube compressive strength for 0% was noticed as 34.88MPa and for the 10% shale powder mix the strength is 36.19. For other mixes of 20 and 30% shale powder the strengths are decreasing. By observing the 28 day strengths for various mixes with respect 0% shale powder, the mixes with 10,20 and 30% shale powder showed strength in percentages is +3.75, -14.67 and -38.18% respectively. Similarly by keeping the conventional concrete mix as reference (36.17MPa), the strengths variations are -3.54,+0.069,-17.71 and -40.37% respectively. From this it is noticed as when the mix prepared with manufactured sand and 10% shale powder as additive and 28 days strength of results all most matching with conventional concrete mix. It infers the strength loss with usage of manufacture sand mix compared with conventional mix, can be compensated with 10% shale powder addition.

Table 4 Strengths of concrete with different combination of Shale Powder

Sl.No.	% of Shale Powder	Compressive Strength (N/mm^2)				% variation in compressive strength for 28 days aged specimens	
		3 days	7 days	14 days	28 days	% of change with respect 0% shale powder mix	% of change with respect conventional concrete (CC) mix
1	0%	14.58	23.06	28.67	34.88	_	-3.54
2	10%	16.60	24.87	32.04	36.19	+3.75	+0.069
3	20%	13.72	19.20	25.76	29.76	-14.67	-17.71
4	30%	13.20	14.71	19.86	21.56	-38.18	-40.37

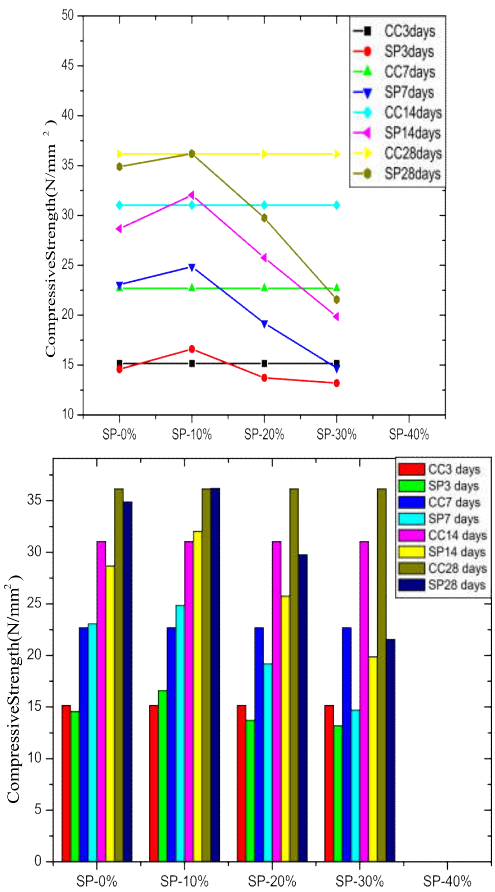

Figure 2 Compressive Strengths of shale powder mixes

Shale powder mixes in split tensile strength (STS)

28 days aged Cylinder concrete samples were tested under compressive testing machine (capacity 2000kN) for its tensile

strength having different percentages of mixture of shale powder as an additive material of cement. The different levels of shale powder as additive material for cement are 0%, 10%, 20% and 30%. Three cylinders were tested for blended and control mix. Three samples of each material were tested and the average strength of these three cylinders is taken as the final result. It has been mentioned that, maximal STS has been reached at the 10% shale powder and beging reducing more than 10%. The behaviour of other mixes can be viewed in figure 3. When compared with 0% shale powder mix and also conventional mix, the 10% shale powder mix showed an increment of split tensile strength in percentage about 6.23 and 9.84% respectively. For higher dosage of shale powder mixes the STS are decreasing and these variations can be viewed in Table 5.

Table 5 Split tensile strength

Sl.No	% of Shale Powder	Split Tensile Strength (N/mm^2) 28 days	% of change with respect 0% shale powder mix	% of change with respect conventional concrete (CC) mix
1	0%	3.432	_	+3.373
2	10%	3.646	+6.235	+9.840
3	20%	2.876	-16.200	-13.373
4	30%	2.532	-26.223	-23.734

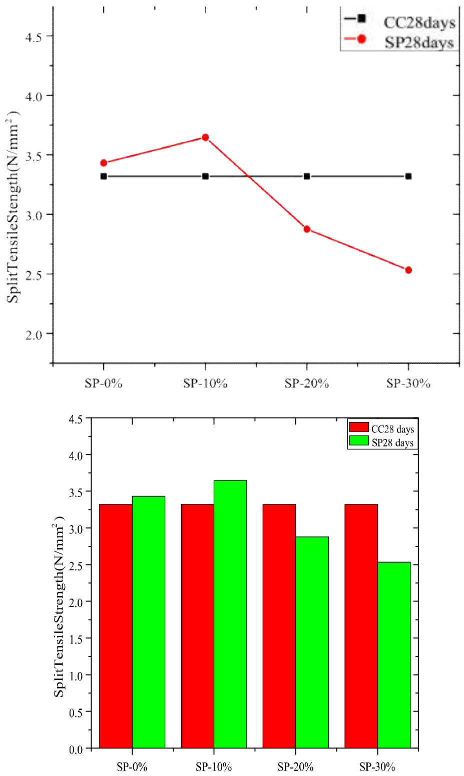

Figure 3 Split Tensile Strength

Shale powder mixes in flexural tensile strength

28 days concrete beam or prism samples (500x100x100mm) were tested for its flexural strength under two point loading. Three samples of beams were tested for blended and control mix and three samples of each material were tested, the average strength of these three beams is taken as the final result. The final results for various mixes are presented in Table 6 and the results are plotted in bar and line chart and are presented in figure 4. From the results it is noticed that, the 10% shale powder mix shown higher strength than the other mixes. 10% shale powder mix provided an increment of flexure strength in percentage is 7.23 and 11.35% compared with 0% shale powder and conventional mix respectively. For 20 and 30% shale powder mixes the strengths are decreasing, this type of observations also noticed in compressive and split tensile strengths.

For 10% shale powder mixes the compressive, split and flexural strengths are increasing, it may be due to, during the hydration process of cement matrix, $Ca(OH)_2$ [calcium hydroxide] might noticed as residual product. Whenever the supplementary material existing in the mix the, it may react with calcium hydroxide and provides secondary CSH [calcium-silicate-hydrated] gel. In our case the shale powder react with calcium hydroxide and provided as secondary CSH gel for the mix. As the dosage of shale powder increases, the availability of $Ca(OH)_2$ is not proportionate with shale powder levels. At higher levels of shale powder this may act as filler materials without proper bond between the matrixes, hence at higher dosages of shale powder the mixes are shown down fall trends in strengths.

Table 6 Flexural tensile strength

Sl.No	% of Shale Powder	Split Tensile Strength (N/mm^2) 28 days	% of change with respect 0% shale powder mix	% of change with respect conventional concrete (CC) mix
1	0%	8.141	_	+3.839
2	10%	8.730	+7.234	+11.352
3	20%	7.886	-3.132	+0.586
4	30%	6.677	-17.983	-14.961

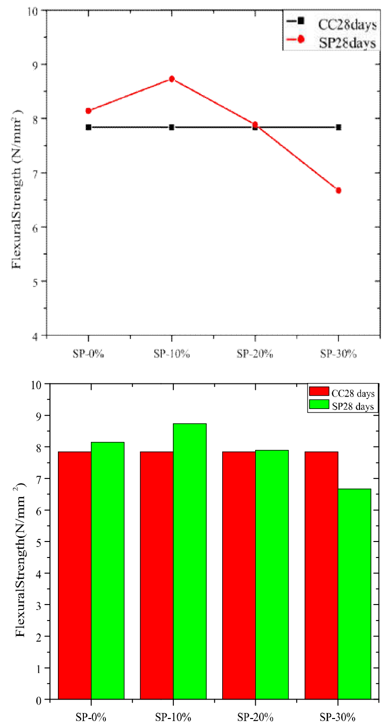

Figure 4 Flexural Strength

CONCLUSIONS

From the present experimental investigation, the following conclusions are drawn using mixture of shale powder as an additive material of cement.

- The Compressive-Strength (CS) of conventional concrete for curing period of 3, 7, 14 & 28 days have been 15.16, 22.7, 31.04 & 36.17 N/mm^2. Identically, the Split-Tensile strength (STS) for 28 days of curing has been 3.32 N/mm^{2}and Flexural-Strength (FS) for curing of 28 days have been 7.84 N/mm^2.

- The maximal Compressive strength has been attained when cement has been additive material with 10% of shale powder. Identically, concrete of split tensile strength and flexural strength is also attained at 10% of shale powder added in cement concrete.
- The Compressive-strength (CS) for the concrete with Shale Powder of 10% for 3, 7, 14 as well as 28 days of curing has been reported as 16.60, 24.874, 32.04 & 36.195N/mm^2. Identically, the Split-Tensile Strength (STS) for the concrete with Shale Powder of 10% for 28 days of curing have been 3.6467 N/mm^2. The Flexural-strength (FS) for the concrete with Shale Powder of 10% have been 8.730 N/mm^2 for curing period of 28 days.
- It finalizes that, natural river sand and collective has been substituted by crushed sand with a shale powder of 10% as an additive cementing material for attaining sustainable strength.

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