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Effect of Partial Replacement of Cement with Granite Stone Dust and Microfine Slag in a Ternary Blend

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Abstract*: Exploration for alternate materials for use in cement and concrete is gaining more importance to reduce the manmade CO_2 release into the atmosphere and also to use otherwise waste and hazardous materials in concrete. Using alternative materials in binary, ternary and quaternary blends with cement in carefully determined proportions such that advantages of using supplementary cementitious materials in concrete are maximized is becoming the norm. In this study, stone dust and a propriety microfine slag are used in binary and ternary blend as partial replacement of cement. It is seen that when the supplementary cementitious materials are used in a ternary blend synergetic effect on the resulting concrete is obtained.*

Keywords: *stone dust, microfine slag, binary and ternary blends.*

1. Introduction

Environmental degradation and sustainability concerns are major issues before the construction industry. Approximately 829 million metric tonnes of CO_2, forming about 3.4% of all manmade CO_2 was produced by the cement industry alone in 2001 [1]. While there appears to be no alternative to cement at present, reduction in the calcinations of limestone through the use of alternative materials in cement and concrete appears to be the way forward.

Most raw materials used by the construction industry are facing fears of depletion. Reuse, recycle or energy recovery, in that order, needs to be practiced [2]. Hence there is a need to search for alternative materials which can be used by the construction industry. Use of waste materials generated through different processes in industries, in either cement or concrete will have the dual advantages of reduction of CO_2 produced and also the use of an environmentally hazardous material in concrete. However, while using any new material by the construction industry, it needs to be ensured that the quality of the concrete and construction are not compromised [2].

Stone dust passing 75 micron sieve, is a waste material which does not appear to have any alternative use. This material is said to comprise about 13-15% of the rocks quarried for the purpose of production of size stones, aggregates and related materials used by the construction industry [3]. Propriety microfine slag manufactured by some cement companies have gained acceptance as pozzolanic material and are being used for enhancing the performance of several properties like workability, high early strength of concrete.

Researchers [4, 5, 6, 7, and 8] have found that stone dust can be utilized for partial replacement of cement or for partial replacement of fine aggregates or as an additional material in concrete. Most such research suggest that percentage introduction of stone dust should be less than 10 % to gain better results. The research also indicates that although granite stone dust is an inert material it acts as a filler to enhance the availability of nucleation sites for better hydraulic reaction and also refines the pore structure of concrete making it less permeable. Gesoglu et al. [9] used fly ash in a quarternary blend with marble powder, limestone powder and cement to overcome reduction in the workability of concrete due to use of marble and lime stone powder. They also found that mechanical and durability properties of the concrete were enhanced with the use of marble and limestone powder. Similarly several researchers in India have studied [10,11 and 12] the effect of partial replacement of cement with this proprietary microfine slag and have determined that cement can be partially replaced with such microfines by about 20% by weight. These studies indicate that granite stone dust can be used for partial replacement of cement and better gains can be made if used in a ternary blend with pozzolanic materials to overcome disadvantages.

This investigation uses granite stone dust and a propriety microfine slag in binary and ternary blend with cement to study the properties of the resulting concrete and to evaluate the performance of these

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materials as Supplementary Cementitious Materials (SCMs).

2. Materials

Commercially available 53 grade ordinary Portland cement conforming to IS 12269: 2013 [13] was used in the study. The specific gravity of the cement was 3.12. Natural sand of specific gravity 2.63 and 2.5 respectively of zone 4 and zone 1 were used in the study. Similarly 20 mm and 10 mm granite coarse aggregates of specific gravity 2.82 and 2.81 were used in the study.

The granite dust was sourced from a local quarry in Goa and particles passing through 75 micron sieve were used. The specific gravity of the granite dust was 2.77 Microfine slag used in the study was a propriety material conforming to IS 12089:1987 [14]. It has a specific gravity of 2.90.

Potable water was used in the study. Conplast SP500 KL of Fosroc constructive solutions was used as the plasticizer. The chemical properties of cement, stone dust and the microfine slag used are given in Table 1.

Table 1: *Chemical composition of binder materials*

Property (%)	Cement	Stone dust	Microfine Slag
Silica (SiO_2),	19.50	58.58	31.03
Alumina (Al_2O_3),	4.20	11.94	21.04
Ferric Oxide (Fe_2O_3)	6.06	9.97	1.06
Titanium Oxide (TiO_2)	0.15	0.83	0.66
Calcium Oxide (CaO)	60.82	6.84	34.70
Magnesium Oxide (MgO)	1.52	2.91	6.41
Sodium Oxide (Na_2O)	0.05	4.37	1.09
Potash (K2O)	0.28	1.65	1.10
Loss on Ignition	2.39	0.72	0.67

From Table 1, it can be noted that the cement used in the study conforms to IS 12269:2013 **[13].** From the chemical composition of the microfine slag it can be noted that its values are closer to GGBS with SiO_2 content at 31.03%, Al_2O_3 at 21.04% and CaO at 34.70%. Microfine slag has a hydraulic activity index of 1.79, which is closer to the higher value of the range of 1.65 to 1.85 suggested [15]. Hence good pozzolanic and hydraulic properties can be anticipated from this supplementary cementitious material.

3. Experimental Program

The following binary and ternary binder composition given in Table 2 was proposed to evaluate the properties of the microfine slag and stone dust.

Mix design as per IS 10262:2009 [16] was performed for M20 grade of concrete. The raw materials for the concrete were weight batched and mixed in laboratory motorized mixer. Vibration was done on a laboratory motorized vibrating table. Minimum of three specimens were cast for each binder specification for each test. The moulds containing the concrete was kept covered with a wet cloth for 24 hours after which the concrete specimens were demoulded and cured in a shaded curing tank for the required period.

Table 2: *Binder Compositions*

Specimen Code	Binder Composition (%)		
	Cement	Stone dust	Microfine slag
C20	100	0	0
CS5	95	5	0
CS10	90	10	0
CM5	95	0	5
CM10	90	0	10
CSM5	90	5	5
CSM10	80	10	10

Slump test was performed to measure the workability of the different concretes as per IS 1199:1959 [17]. Compressive strength of 150 mm size cubical specimens was determined at 3, 7,and 28 days, in accordance with IS 516:1959 [18] . The chloride ingress into the concrete was measured using the rapid chloride permeability test (RCPT) as per ASTM C 1202 [19] on 100 mm diameter, 50.8 mm thick specimens which were sliced from 28 day, 100 mm diameter, 200 mm height cylindrical specimens.

4. Results and Discussion

4.1. Slump

A constant plasticizer amount of 0.8% of binder quantity by weight was used for the various mixes and the slump value was recorded. The slump values obtained for different binder compositions are given in the Figure 1.

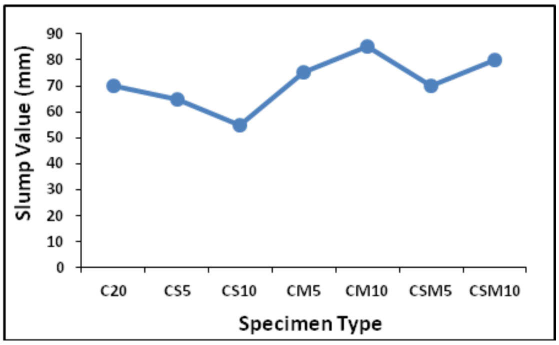

Figure 1: *Variation of slump value with binder composition*

From the Figure 1, it can be noted that the slump value of the reference mix is more than that of the two binary blends containing stone dust. When stone dust is at 5 %, the reduction in the slump value is rather marginal, but at 10 %, the slump value has decreased considerably indicating that the workability of the concrete mix could be adversely affected. In the binary blends containing microfine slag at 5 and 10 %, the slump values are more than that of reference mix indicating enhancement of workability. Also when microfine slag and stone dust are used in ternary blends with cement, the slump values are either higher or on par with that of the reference mix indicating that the ternary combination does have a synergetic effect. While the particles of stone dust are rough and angular, microfine slag particles are smooth and spherical which could result in a synergetic effect.

4.2. Compressive strength

Figure 2 shows the variation of compressive strength for various mixes at different ages. It can be noted that introduction of stone dust and microfine slag in binary and ternary blends has a positive impact on the compressive strength. There is reduction in strength only when stone dust is used in binary blend at 10 % replacement level. The strength of binary blend of stone dust at 5% replacement level is slightly higher than that of the reference mix. The binary blends of 5 and 10 % replacement with microfine slag have shown enhancement in compressive strength and very interestingly in the ternary blend of the two materials with Portland cement at 5 % replacement each and 10% replacement each, synergetic effect can be noticed, as the compressive strength is higher than that of the respective binary blends and also that of the control concrete. It can therefore be assessed that in ternary blends the performance is additive due to better pore refinement and densification of the concrete. The contribution of microfine slag in the hydration and pozzolanic activity converting the CH in the concrete to CSH could also be a reason for this.

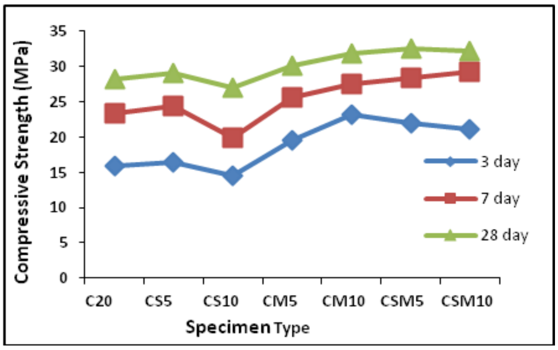

Figure 2: *Variation of compressive strength with binder composition*

4.3. Chloride attack

The results of the rapid chloride permeability test (RCPT) test are given in Figure 3. It can be noted that the charge passed is highest in case of the reference mix containing no supplementary cementitious material (SCM). All the concretes with SCM have lower values of chloride ingress. Even concretes containing stone dust in a binary blend have lower values of chloride ingress, indicating the pore structure is refined and the packing density is enhanced when this material is introduced in concrete, making the concrete less permeable. Concretes containing microfine slag as binary material have recorded lower values than concretes with stone dust as a binary material, indicating that microfine slag is more effective in refining the pore structure. However, in ternary blends containing both these materials, the chloride ingress is even lower, (23.38 % lower than that for control concrete) which reflects the synergetic effect of the two materials.

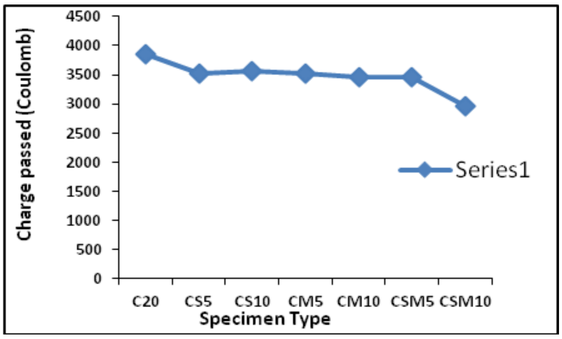

Figure 3: *Variation of charge passed with binder composition*

4.4. Relationship between compressive strength and chloride ingress

In the Figure 4, the compressive strength is compared with the chloride ingress into the concrete. It can be observed that the chloride ingress appears to be inversely proportional to the compressive strength of the concrete, which is in line with the general understanding that reduced chloride ingress is indicative of lowered permeability and better pore refinement and hence higher compressive strength [20]. However, the regression coefficient ‘r’ is rather low to confirm the findings. With more data, a better understanding of the relationship can be made out.

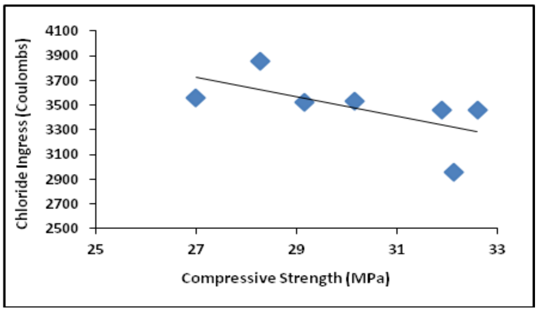

Figure 4: *Relationship between compressive strength and chloride ingress*

5. Summary and Conclusion

The study was conducted to determine the effect of partial replacement of cement with microfine slag and stone dust in binary and ternary blends. Based on this study the flowing conclusions can be drawn.

- Microfine slag with its spherical shape and smooth surface increases the slump value. When these two materials are used in a ternary blend with cement, a synergetic effect giving desired workability to the concrete can be observed.

- With microfine slag in a binary blend there is significant increase in the compressive strength at both 5 and 10 % replacement levels compared to the binary blend of stone dust. However, in a ternary blend of these materials with cement, a synergetic effect with considerable increase in the compressive strength can be obtained.
- The introduction of both stone dust and microfine slag reduces the chloride ingress into concrete and significant reduction (23.38 %) is observed in a ternary blend.
- The compressive strength appears to be inversely proportional to the chloride ingress into concrete, but more data can confirm this finding.

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