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Studies on Lightweight Concrete with Vermiculite as Fine Aggregate

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***Abstract* - Generally, concrete with low density material will have its dead weight reduced which in turn takes up reduced earthquake load. This lightweight concrete can be obtained by replacement of aggregate by materials like Scoria, Ciders, Pumice, Polystyrene beads, Perlite, Vermiculite, etc.,. In this study, exfoliated vermiculite is used as partial replacement for fine aggregate and silica fume as mineral admixture in the production of light weight concrete. Fine aggregate is partially replaced for M30 grade of concrete with exfoliated vermiculite from 0 to 50% by volume and silica fume is added as mineral admixture from 0 to 15% by weight of cement. Compressive strength, water absorption and Young's modulus of the concrete were tested at various ages. Results shows that there is decrease in density of concrete with increase in exfoliated vermiculite content thereby making the concrete lightweight. The compressive strength and Young's modulus of the concrete decreases with increase in exfoliated vermiculite content and increases while increasing silica fume content. On replacement of fine aggregate by 20% with exfoliated vermiculite and addition of silica fume for 15% the compressive strength was found to be comparable to that of reference mix. Hence, lightweight concrete can be obtained by using the above combination of exfoliated vermiculite and silica fume without any considerable loss in compressive strength.**

Key words: Compressive strength, Exfoliated vermiculite, Lightweight, Silica fume, Water absorption, Young's modulus.

1.0 INTRODUCTION

The river sand has become expensive due to scarcity from natural sources and sand mining from river has become objectionably excessive. As environmental constraints make the availability and use of river sand less attractive, a suitable replacement product for concrete industry need to be found. The seismic effect that influence any civil engineering structure depends on the mass of that structure and so reducing the mass of the structure can make the structure less vulnerable to seismic damage[1].Generally, concrete with low density material will have its dead weight reduced which in turn takes up reduced earthquake load[2]. This lightweight concrete can be obtained by replacement of aggregate by materials like Scoria, Ciders, Pumice, Polystyrene beads, Perlite, Vermiculite, etc.,. In this study, exfoliated vermiculite is used as partial replacement for fine aggregate. Use of exfoliated vermiculite in concrete reduces the structural load, making the structure lightweight and thereby reducing the seismic effect to the structure.Abdeen and Hodhod (2010)reported a reduction in the bulk density of concrete containing exfoliated vermiculite by replacing natural sand by volume. The reductionin the 28 days bulk density was 16.1% and 23% with the inclusion of 70% and 100% exfoliated vermiculite[3].

Vermiculite is a mica like mineral with a shiny flakes which is one member of the phyllosilicate group. It can be expanded upto 20 times its original volume when heated at 650-950°C[4].The main countries that accounts for major world production of vermiculite are India, South Africa, United States, Brazil, Zimbabwe and Bulgaria.The expanded vermiculite(EV) exhibits properties such as low bulk density, low thermal conductivity and chemical inertness. Schackow et al. (2014)reported that concretes containing1% air-entraining agent and small amount of vermiculite provided 28 daysthermal conductivity of 0.34 W/m K, which can be considered asa low thermal conductivity[5].

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2.0 Materials Used

2.1 Cement

Ordinary Portland cement of 43 grade confirming to IS 8112-1989, is used in this study. The specific gravity and standard consistency of the cementwere tested following IS 4031 – 4 and IS 2720 – 3 andwere found to be 3.17 and 27%.

2.2 Silica fume

Silica fume used in this study ismicro silica with specific gravity of 2.22, bulk density of 130 – 600 kg/m³ and average particle diameter of 0.15µm.

2.3 Fine aggregate

Locally available river sand passing through 4.75mm sieve was used as fine aggregate in this study. The properties of fine aggregate are determined as per IS 2386-1963 and IS 383-1970 and was found to have specific gravity of 2.65, fineness modulus of 2.4 confirming to zone II, water absorption of 0.8% and bulk density of 1550 kg/m³.

2.4 Exfoliated vermiculite

Exfoliated vermiculite passing through 4.75mm sieve was used as fine aggregate in this study. The properties of exfoliated vermiculite are determined as per IS 10555-2002 and IS 383-1970 and was found to have fineness modulus of 2.43 confining to zone I and Bulk density of 245 kg/m³. The specific gravity of exfoliated vermiculite ranges between 0.06 – 0.12.

2.5 Coarse aggregate

Crushed granite stones passing through 20mm and retaining on 4.75mm sievewas used as coarse aggregate. The properties of coarse aggregate are determined as per IS 2386-1963 and were found to have specific gravity of 2.7 with fineness modulus of 8.58, water absorption of 0.9% and bulk density of 1410 kg/m³.

2.6 Superplasticizer

In order to improve the workability of fresh concrete Napthalene formaldehyde based super plasticizer is used for the concrete mixture as water reducing agent.

2.7 Water

For casting and curing of concrete specimens potable water was used in this study.

3.0 Methodology

Based on recommended guidelines for mix proportions provided in IS: 10262-2009, mix proportion for M30 grade of concrete was arrived as 1: 1.7: 2.9with water/cement ratio of 0.45. Superplasticizer was used from 0.75% to 1.5% by weight of cement to maintain workability.

Table 1: Mix proportion of concrete.

Cement (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)	Water (L/m³)
400	680	1173	163

A total of 144 samples of cube specimens of size 100mm x 100mm x 100mm and 18 numbers of cylindrical specimens of 300mm height and 150mm diameter were cast and tested for compressive strength at 7 and 28 days, Water absorption and Young's modulus at 28 days.

4.0. Resultsand Discussions

4.1. Compressive strength

The compressive strength was determined following the recommendations as per IS: 516-1959 where 3 cube specimens were cast for every proportion and were tested in compression testing machine.

Fig 1: Compression test

Cube specimens containing exfoliated vermiculite as partial replacement for fine aggregate from 0 to 50% by volume was tested at 7 and 28 days. [Fig. 2] shows compressive strength of specimens with different proportions of vermiculite. In

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general, compressive strength of concrete was decreased with increase in partial replacement of vermiculite from 10 to 50% by volume. Maximum reduction in compressive strength of about 66.7%was noticed at 50% vermiculite level. This reductioncould be related to the increase in porosity with the inclusion of exfoliated vermiculite. It is completely known that the more porosity, the morecompressive strength loss[6].

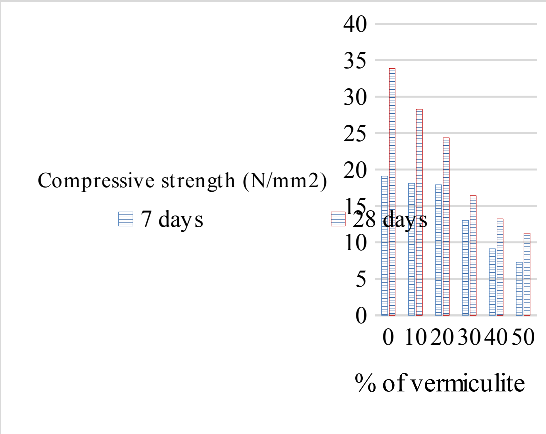

Fig 2: Compressive strength of specimen with different proportions of vermiculite.

When silica fume was added as mineral admixture, compressive strength of concrete was increased with increase in percentage of silica fume up to 15% [Fig.3]. Rate of increase in compressive strength at later ages was more when compared to early age. Maximum compressive strength of 43MPa was attained at 15% of silica fume at 28 days. Compressive strengthwas increased by about 25.7% with increase in silica fume content in the mix.

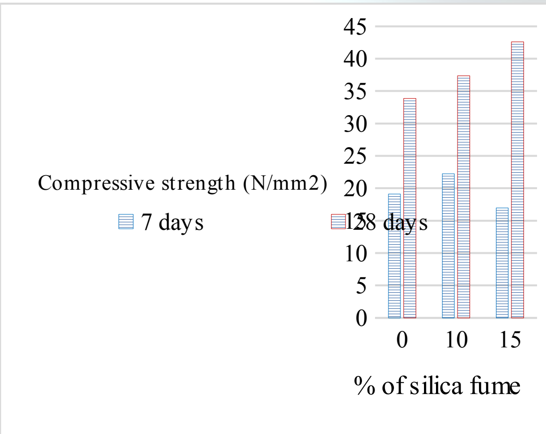

Fig 3: Compressive strength of specimen with different proportions of silica fume.

Sairam et sailaja, (2017)revealed that though the compressive strength of concrete decreases with increase of percentage of vermiculite, but with the replacement of fly ash at 15% and addition of silica fume at 10% to cement with replacement of vermiculite to fine aggregate up to 20% may be accepted as it is giving required target mean strength[7].Variation of compressive strength of concrete specimens containing exfoliated vermiculite from 0 to 50% by volume and silica fume as mineral admixture from 0 to 15% by weight was shown in [Fig.4].

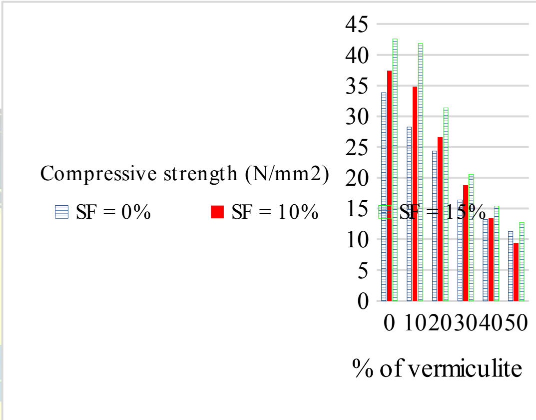

Fig 4: Compressive strength of concrete at 28 days with different proportions of exfoliated vermiculite and silica fume.

Table 2: Compressive strength of specimen with different proportions of exfoliated vermiculite and silica fume.

River sand : Exfoliated vermiculite	Silica fume (%)	SP dosage (%)	Slump (mm)	Compressive strength (N/mm^2)	
				7 days	28 days
100:0	0	0.75	80	19.10	33.88
100:0	10	0.75	65	22.24	37.36
100:0	15	0.75	60	16.69	42.60
90:10	0	0.75	80	18.11	28.27
90:10	10	0.75	60	21.42	34.84
90:10	15	0.75	55	16.80	41.87
80:20	0	1	70	17.90	24.36
80:20	10	1	60	19.65	26.59
80:20	15	1	55	16.60	31.39
70:30	0	1	70	13.01	16.41

70:30	10	1	55	17.32	18.78
70:30	15	1.25	55	15.80	20.57
60:40	0	1	65	9.12	13.22
60:40	10	1.25	65	11.35	13.35
60:40	15	1.25	55	7.17	15.39
50:50	0	1	60	7.27	11.27
50:50	10	1.25	50	8.27	9.42
50:50	15	1.5	50	6.79	12.74

The workability of concrete mixtures decreased with increase in exfoliated vermiculite content and further decreased with increase in silica fume content in the concrete mix. The dosage of superplasticizer was increased to maintain the targeted workability of 50-75mm in the concrete mix.

Rate of decrease in compressive strength was reduced with increase in percentage of silica fume. At 10% partial replacement of vermiculite, addition of silica fume resulted in increased compressive strength of concrete than reference mixture. Maximum compressive strength of about 42 MPa was attained at 10% of vermiculite and 15% of silica fume. Results indicated that on replacing 20% of exfoliated vermiculite and addition of 15% silica fume, the compressive strength achieved was comparable to that of reference concrete mix.

4.2 *Bulk density*

As per BS EN 1992-1-1:2004, concrete with bulk density less than 2200 kg/m^3 can be called as lightweight concrete[8]. The bulk density of concrete was decreased from 2310 kg/m^{3}to 1970 kg/m^{3}with increase in exfoliated vermiculite content from 0 to 50% in the mix thus making the concrete lightweight [Table.3].The reduction in the unit weight is due to the presenceof voids, either in the aggregate or in the interstices betweenaggregate particles[7].

Table 3: Bulk density of concrete with different proportions of exfoliated vermiculite.

Fine aggregate		Bulk Density (kg/m^3)
River sand (%)	Exfoliated vermiculite (%)	
100	0	2310
90	10	2230
80	20	2170
70	30	2100
60	40	2035
50	50	1970

4.3 Water absorption

Water absorption of concrete specimens with combinations of exfoliated vermiculite and silica fume at 28 days was shown in [Fig. 5]. Test results showed that water absorption was increased with increase in exfoliated vermiculite content. The above trend was changed with addition of silica fume content.On replacing exfoliated vermiculite up to 20% level did not show any comparable difference in water absorption, however, on increasing beyond 20% level, water absorption was increased by about 7 times to that of reference mix. Gencel et al. (2014)reported that percentage of water absorption increased by 7.26% and 14.52%,respectively for 10% and 20% replacement. This is in good agreement with test results obtained[6].

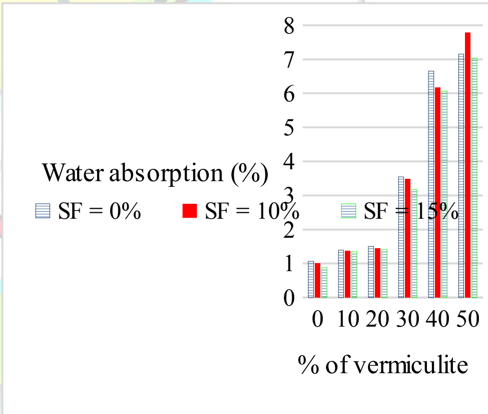

Fig 5:water absorption of concrete at 28 days with different proportions of exfoliated vermiculite and silica fume.

4.4 Young's modulus

The cylindrical specimens cast with different combinations of exfoliated vermiculite and silica fumes was tested on 28 days based on the code ASTM: C 469 – 02. The following expression was used to determine the Young's modulus:

$$E = \frac{(S2 - S1)}{(\varepsilon 2 - 0.000050)}$$

Where:

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E = Modulus of elasticity

S2 = Stress corresponding to 40% of ultimate load

S1 = Stress corresponding to longitudinal strain (0.000050)

ε2 = Longitudinal strain produced by stress S2

Fig 6: Young's modulustest setup

Results showed decrease in Young's modulus with increase in exfoliated vermiculite and while increasing the silica fume content to the specimen, the Young's modulus value increases. [Fig. 7] shows the Young's modulus value of specimens containing different proportions of exfoliated vermiculite and silica fume.

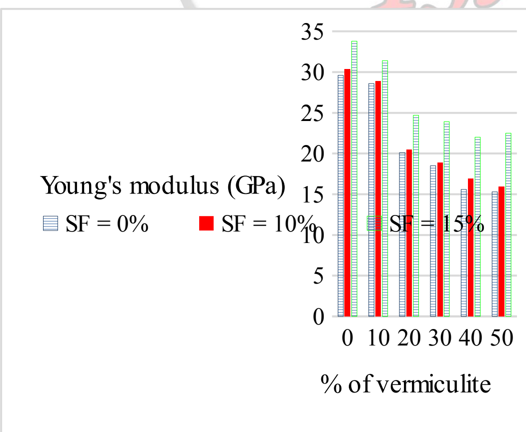

Fig 7: Young's modulus of specimen at 28 days with different proportions of exfoliated vermiculite and silica fume.

5.0 CONCLUSIONS

Based on the test results obtained, it is concluded that:

1. The workability of the concrete decreased with increase in exfoliated vermiculite content in the mix.
2. The bulk density of the concrete decreased with increase in vermiculite content thus making the concrete lightweight. The bulk density decreased by about 15% when fine aggregate was replaced for 50% by exfoliated vermiculite.
3. The compressive strengthand Young's modulus of concrete decreased with increase in exfoliated vermiculite content and when silica fume was added to the mix compressive strength and Young's modulus increased at all ages.
4. On replacing fine aggregate by 20% with exfoliated vermiculite and adding silica fume by 15% the compressive strength of concrete was found to be comparable to the reference mix.
5. The water absorption of concrete specimen increased with increase in exfoliated vermiculite content to the mix and decreased with increase in silica fume content.

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