

Experimental Study of Ultrafine Calcium Carbonate Powder and Fly Ash in Concrete

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ABSTRACT: To obtain high strength at early ages of about 2 or 3 days, the available options have been to add micro silica in concrete but this being too costly in Indian scene. Hence alternate materials to obtain high early age strength need to be investigated. The materials should be such as not to have any adverse effects on the long term strength of concrete. With these objects use of ultrafine calcium carbonate powder along with fly-ash was studied in the present project work.

KEYWORDS: Ultrafine Calcium Carbonate, Fly Ash, Super Plasticizer, Durability, Vaporlite-90t, Compressive Strength, Tensile Strength.

I. INTRODUCTION

Now-a-days, high strength at early ages and high long term strength is required in many projects. The challenge of mix proportioning of such concretes is having two folds:

1. To achieve high strength of the order of 30 MPa or more at an age of 1 or 2 days with cementitious material, it requires use of high amount of cement for concrete, whereas maximum quantity of cement to be used in concrete is limited to 450 N/mm² by IS: 456: 2000 from durability considerations.
2. On the other hand, strength of the order of 50 MPa or more at an age of 28 days or 56 days is required in many applications such as construction of columns of high rise buildings, bridges, bridge girders etc. This again can either require high cement quantity or use of low calcium fly ash with super plasticizers (if cement content in the concrete is to be limited). But in such cases too, strength at 1 or 2 days age may not reach 30 MPa or so on.

II. LITERATURE REVIEW

The primary objective of this report is to introduce the general behaviour of concrete when a percentage of cement is replaced by fly ash. Fly ash is becoming a major part of the mix design for the application of concrete. This includes the effects of fly ash has on the placement of fresh concrete, the setting of concrete, and the durability of hardened concrete. Strength improvements due to the addition of the mineral admixtures like fly ash, silica fume etc. is due to the pozzolanic reaction taking place, which typically starts after 7 days and cause in increase in the amount of C-S-H gel which is known to be the strength imparting component in concrete. Fly ash offers the possibility of reducing the temperature rise almost in direct proportion to amount of Portland cement replaced. Durability to chemical attacks is improved with the use of most fly ashes and slag's mainly due to the pore refinement of concrete made with such materials. Experiments have shown that cement paste 10-30% low calcium fly ash causes significant pore refinement in 28 to 90 days curing period. Fly ash is the finely divided residue that results from the combustion of pulverized coal.

A pozzolana is a siliceous or aluminous material, when mixed with lime and water, forms a cementitious compound. Fly ash one of the most commonly used pozzolanic material. The ultrafine fly ash is used at a replacement rate of 5 to 15 per cent of the cement weight. At these dosage levels, it has been observed that ultrafine fly ashes contribute more to concrete strength gain and permeability reduction than common AASHTO M 295 (ASTM C 618) fly ash, and will

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perform comparable to highly reactive pozzolana such as silica fume. Concrete durability properties such as resistance to alkali-silica reaction, sulphate attack, and corrosion are also enhanced by ultrafine fly ash.

S.A.K. Reddy and K.C. Reddy (2015) studied the effect of fly ash on strength and durability parameters of concrete and found that consistency increases greatly with increase in percentage of fly ash. The optimum 7 and 28 day compressive strength was obtained in the range of 20% fly ash replacement level. It also led to the increase in split tensile strength of concrete.

III. EXPERIMENTAL INVESTIGATIONS

3.1 Material Used

VAPORLITE 90 t: Vaporlite 90 t is an ultra-fine sub-micron natural calcium carbonate.

Table-3.1 shows properties of vaporlite 90 t as an ultra-fine sub-micron calcium carbonate.

Table 3.1 Properties of Vaporlite 90 t

| S.No. | Description | Units | Specifications | Result |
|-------|-------------------------------|-----------|----------------|----------|
| 1. | Physical form | - | Powder | 1 powder |
| 2. | Brightness | % | 90-94 | 91 |
| 3. | Bulk density (loose) | gm/lit. | 300-400 | 345 |
| 4. | Oil absorption | gm/100 gm | 30-40 | 33.28 |
| 5. | PSD-D(50)-50% particles below | Microns | .8-1.2 | .99 |
| 6. | PSD-D(97)-97% particles below | Microns | 2-4 | 2.95 |
| 7. | Below 2 micron | % | 87-93 | 90 |
| 8. | Moisture (ex-work) | % | 0-.5 | .26 |
| 9. | pH (10% aq. Slurry) | - | 9-10 | 9.50 |
| 10. | Residue on 325 mesh | ppm | 0-200 | 95.65 |

GLENIUM B 233: GLENIUM B 233 (Polycarboxylic Ether Based Superplasticizer) which we have used in our project as a super-plasticizer is basically an admixture of a new generation based on modified poly-carboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required.

AGGREGATES: - Fine Aggregates: - Banas Sand under Zone-II.

Coarse Aggregates: - TYPE I- 20 mm

TYPE II- 10 mm

We have used the type I and type II coarse aggregates in the ratio 2:3 so that the grading of coarse aggregates confirm the grading limits for coarse aggregates as per IS 383-1970.

The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mix proportions, and economy. Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm (0.2 inch). Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (0.2 inch) and generally between 9.5 mm and 37.5 mm.

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Table 3.2 Grading of aggregates

| IS Sieve Designation | Percentage passing for graded aggregate of nominal size (by weight) |
|----------------------|---|
| 80 mm | 100 |
| 63 mm | 100 |
| 40 mm | 100 |
| 20 mm | 95 |
| 16 mm | 80 |
| 12.5 mm | 60 |
| 10 mm | 55 |
| 4.75 mm | 5 |
| 2.36 mm | 1 |

CEMENT: Cement used:-OPC 43 Grades.

FLYASH: The fly-ash which we have used in our project was not an ultrafine fly-ash; it was an ordinary fly-ash locally available in Kota, Rajasthan, India.

WATER: While using water in concrete following points were considered, that it should be free from carbonates and bicarbonates of sodium and potassium, free from chlorides and sulphates, free from manganese, tin, zinc, copper and lead, sodium iodide, sodium phosphate and sodium borate. Turbidity of water should be less than 2000 ppm.

3.2 Mix Proportioning

First of all we have made the calculations for the mix design of M 40 grade concrete using the I.S: code 10262:2009. We made calculations under two heads:-

- Concrete consisting of fly ash and cement as binders.
- Concrete consisting of fly ash, cement and vaporlite 90 t as binders. We have used proportions of fly ash and Vaporlite 90t in three quantities as percentage of cement shows in table 3.3.

Table 3.3 Mix Proportions of Various Mixes

| Mix Name | Cement (kg/m ³) | Flyash (kg/m ³) | Water (L/m ³) | Vaporlite (kg/m ³) | Fine agg. (kg/m ³) | Coarse agg. (kg/m ³) | Super plasticizer (L/m ³) |
|----------------|-----------------------------|-----------------------------|---------------------------|--------------------------------|--------------------------------|----------------------------------|---------------------------------------|
| C.M. | 450.0 | 0.0 | 172 | 0.0 | 550 | 1179 | 3.7 |
| 20% F | 360.0 | 72.0 | 165 | 0.0 | 557 | 1192 | 3.0 |
| 20% F & 0.5 V | 358.2 | 71.6 | 164 | 1.8 | 558 | 1194 | 2.9 |
| 20% F & 1% V | 356.4 | 71.3 | 163 | 3.6 | 558 | 1196 | 2.9 |
| 15% F | 315.0 | 47.2 | 138 | 0.0 | 599 | 1273 | 2.6 |
| 15% F & 0.5% V | 313.4 | 47.0 | 138 | 1.6 | 600 | 1285 | 2.6 |
| 15% F & 1% V | 311.8 | 46.8 | 137 | 3.2 | 601 | 1287 | 2.6 |
| 40% F | 360.0 | 144.0 | 192 | 0.0 | 510 | 1092 | 3.0 |
| 40% F & 1% V | 356.4 | 142.5 | 191 | 3.6 | 512 | 1096 | 2.9 |
| 2% V | 352.8 | 70.5 | 162 | 7.2 | 560 | 1199 | 2.9 |
| 4% V | 345.6 | 69.1 | 158 | 14.4 | 563 | 1206 | 2.8 |
| 6% V | 338.4 | 67.6 | 155 | 21.6 | 567 | 1213 | 2.8 |

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3.3 Test Results

Table 3.4 gives the compressive strength at 2 days, 28 days and 56 days as well as split tensile strength for different mixes of concrete.

Table 3.4 Compressive and Tensile Strength Results

| Mix name | Compressive Strength (N/mm ²) | | | Split Tensile Strength (N/mm ²) |
|----------------|---|---------|---------|---|
| | 2 days | 28 days | 56 days | 56 days |
| C.M. | 38.88 | 68.44 | 69.33 | 2.46 |
| 20% F | 15.90 | 61.20 | 73.33 | 3.01 |
| 20% F & 0.5 V | 30.00 | 60.61 | 77.73 | 3.19 |
| 20% F & 1% V | 33.30 | 68.80 | 78.00 | 3.20 |
| 15% F | 26.67 | 52.44 | 65.77 | 3.51 |
| 15% F & 0.5% V | 42.20 | 54.33 | 68.50 | 3.59 |
| 15% F & 1% V | 51.11 | 60.00 | 70.01 | 3.74 |
| 40% F | 35.55 | 65.33 | 75.11 | 3.82 |
| 40% F & 1% V | 40.00 | 72.44 | 79.61 | 3.90 |
| 2% V | 17.90 | 69.30 | 75.55 | - |
| 4% V | 17.00 | 68.40 | 72.00 | - |
| 6% V | 16.90 | 61.50 | 64.44 | - |

The below figure 4.1 shows the hardened state of 28 days age concrete formed by the 2% vaporlite with cement. Some particle of vaporlite is present without forming cementitious material.

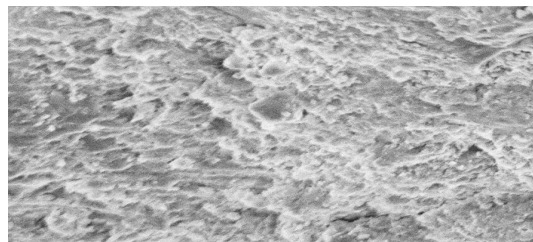


Fig. 4.1 2% VAPORLITE
28 DAYS (1 KX)

The below figures 4.2 and 4.3 are show that at hardened state after 56 days age of concrete formed with 2% vaporlite. Some vaporlite particles are present unused.

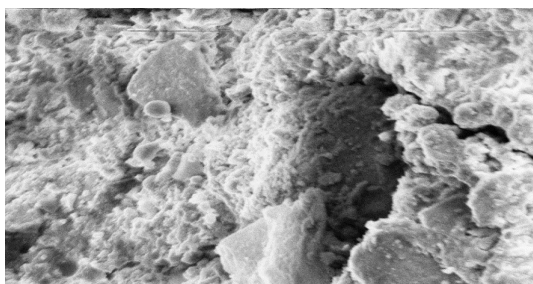


Fig. 4.2 2% VAPORLITE
56 DAYS (1.01 KX)

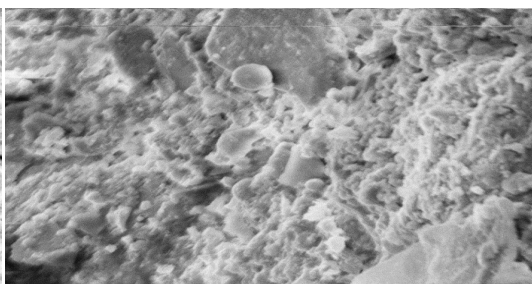


Fig. 4.3 2% VAPORLITE
56 DAYS (1.55 KX)

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In the below figures 4.4 and 4.5 we can clearly see that most of the part of vaporlite particles are unused after 28 days age of concrete.

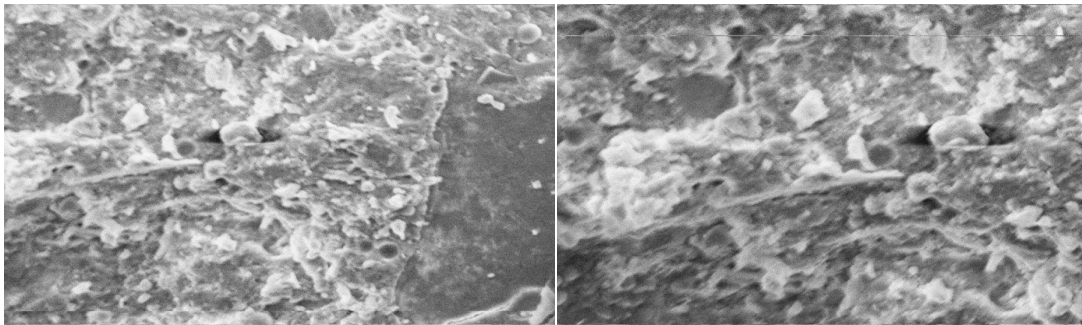


Fig. 4.4 4% VAPORLITE
28 DAYS (1.04 KX)

Fig. 4.5 4% VAPORLITE
28 DAYS (2.08KX)

In the below figure 4.6 one particle of flyash is seen unused and at another place a void is also present.

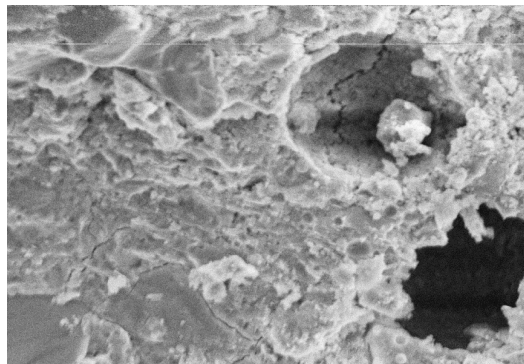


Fig 4.6 20% FLYASH
28 DAYS(1.5KX)

These below figures 4.7 and 4.8 show the C-S-H gel formed by Controlled Mix (CM) without any flyash and vaporlite.

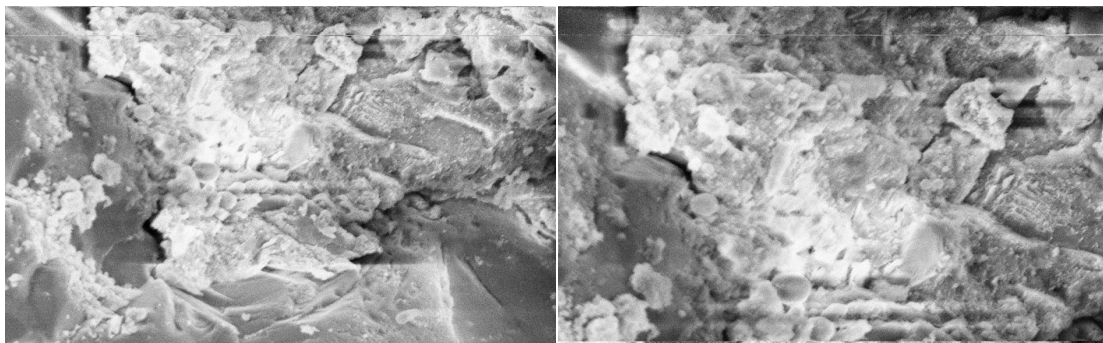


Fig. 4.7 CM (2 DAYS) (1.07 KX)
IT2

Fig. 4.8 SLIGHTLY PROCESS (1.55 KX)
HCP

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These below figures 4.9 and 4.10 are show the C-S-H gel formed by 0.5 % vapoortalite with cement.

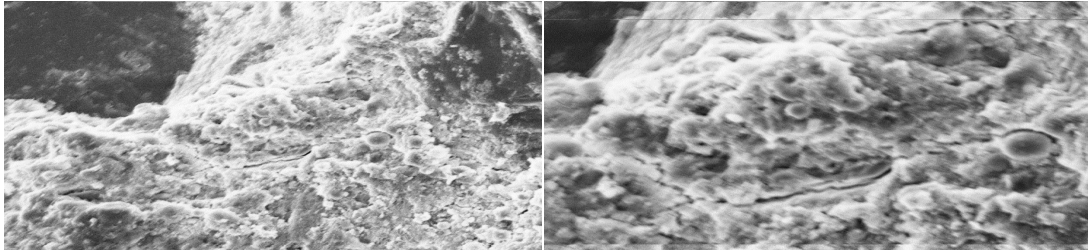


Fig.4.9 0.5% VAPORLITE
2 DAYS (1.01 KX)

Fig 4.10 0.5% VAPORLITE
2 DAYS (2.01 KX)

The below figures 4.11 and 4.12are show the C-S-H gel formed by 6% vaporlite after 3days age of concrete.

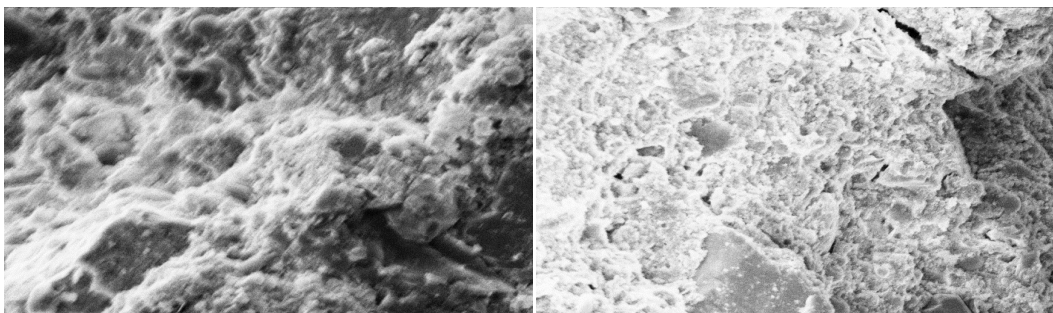


Fig. 4.11 15% FLYASH
2 DAYS (1.51 KX)

Fig. 4.12 6% VAPORLITE
3 DAYS CH GEL (1.07 KX)

The below figure 4.13 shows the coagulation formed by access particle of vaporlite and figure 4.14 shows the hardend concrete formed with 20% flyash.

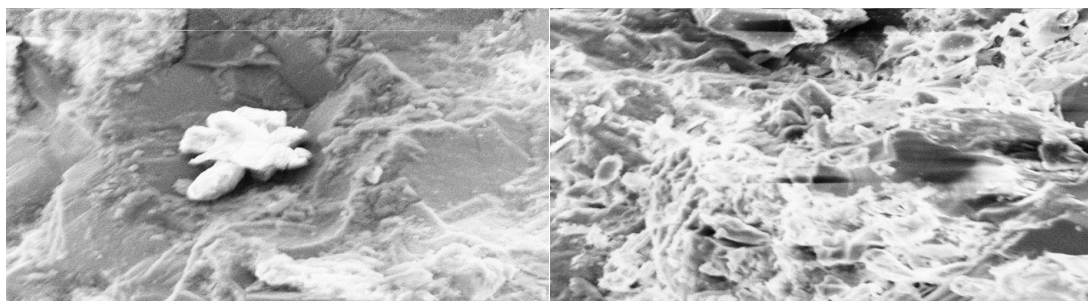


Fig.4.13 4% VAPORLITE
28 DAYS (1.01 KX)
COAGULATION

Fig.4.14 20%FLYASH
28 DAYS (1.01 KX)
HARDENED CEMENT PASTE

Note:- KX= 1000 Times of original sample piece size (i.e., Zoomed picture)

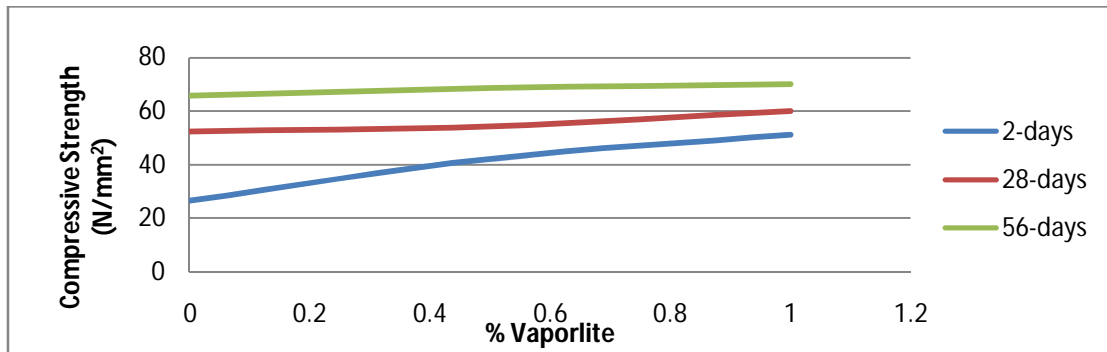
Followings are the curves show the variation of compressive strength of concrete with the quantity of fly-ash and vaporlite:

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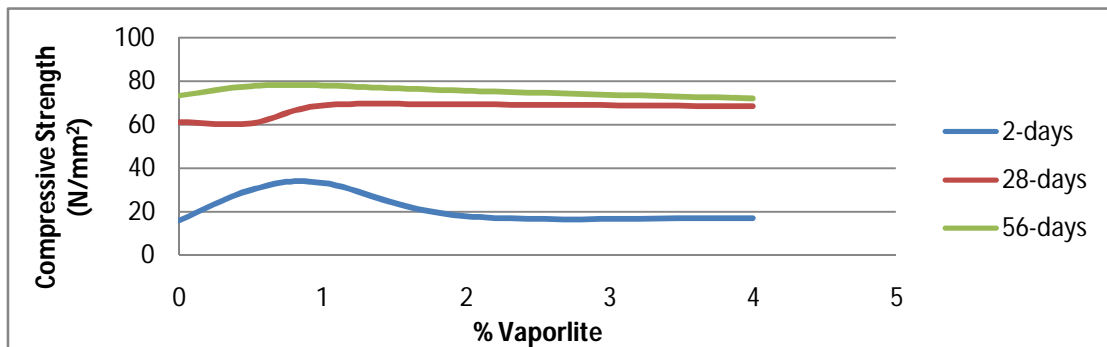
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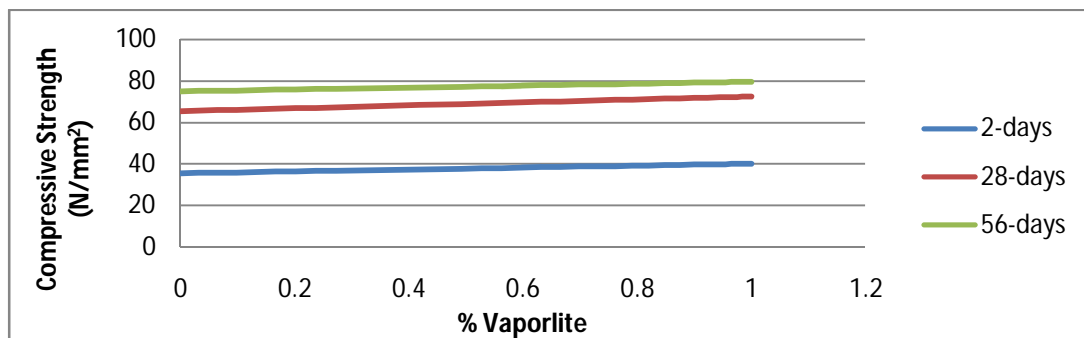
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Graph 3.1 Variation in Compressive Strength with Vaporlite at 15% fly-ash



Graph 3.2 Variation in Compressive Strength with Vaporlite at 20% fly-ash



Graph 3.3 Variation in Compressive Strength with Vaporlite at 40% fly-ash

IV. DISCUSSIONS ON THE TEST RESULTS

1. The above table 3.4 shows that as we are increasing the quantity of vaporlite 90 t in concrete, the strength of concrete is decreasing. So, the quantity of vaporlite90 t introduced in concrete should be less than or at the most equal to 2% of the quantity of cement.
2. The strength obtained in concrete made using vaporlite 90 t with cement and fly-ash is more as compared to that made using fly ash and cement.

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3. From above graphs (Graphs 3.1, 3.2 & 3.3), it is observed:

a. For 20% fly ash: For 0% vaporlite the compressive strength is 15.90N/mm^2 as we increased the amount of vaporlite up to .5%, the strength is increased to 30.00N/mm^2 for 2 days but the same strength is decreased in 28 days from 61.20N/mm^2 to 60.61N/mm^2 & for 56 days the compressive strength is increased from 73.33N/mm^2 to 77.73N/mm^2 , hence the earlier strength is gained within 2 days for 0.5 % vaporlite.

If further we increase the amount of vaporlite the compressive strength got decreased & after some time it becomes constant.

b. For 15% fly ash: 2 days strength is increased as we add the % amount of vaporlite while on the other hand the compressive strength for 28 days & 56 days also got increased.

c. For 40% fly ash: For 40% fly ash there is not much variation in the compressive strength.

V. CONCLUSIONS

1. When we use vaporlite 90 t along with fly ash, in concrete the early strength is high and at an optimum proportion of vaporlite 90 t which is 1% of the weight of cement, strength obtained is maximum.

2. If the 56 days strength of controlled mix and the mix containing 15% fly-ash and 1% vaporlite is compared, it is almost equal.

3. On adding fly ash in some percentage of the weight of cement along with 1% of vaporlite the early strength of 2 days has almost doubled as compared to those mixes which contain same percentage of fly ash only.

Thus, the results show that the increase in early strength of concrete is almost 100% at some optimum percentage of vaporlite along with fly-ash. There is no adverse effect of addition of vaporlite on the long term strength of concrete. Thus, the addition of vaporlite along with fly ash in making high strength concrete can be beneficial and economical.

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