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A Study on the Effect of Size of Aggregate on the Strength and Sorptivity Characteristics of Cinder Based Light Weight Concrete

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Abstract

It is known that the largest maximum size of aggregate possible to handle could be used in concrete under a given set of conditions. There are benefits of choosing a correct maximum size of aggregate (MSA), viz. reduction in the cement content and drying shrinkage. Variation in the size of aggregate alters the micro cracking of concrete which there by modifies the strength and durability as well. Also, the strength and durability of concrete is dependent on sorptivity, an index of concrete permeability. The pore structure in LWA, which is otherwise porous in nature, can be modified with fly ash inclusion, which not only modifies the density but also enhances the durability of concrete. In the present study, the strength and sorptivity characteristics of concrete made with cinder-based lightweight aggregates are investigated. Prior to this the size of cinder based light weight aggregate was optimized. The present investigation aims at developing two grades, 20Mpa and 30Mpa, of light weight concrete using cinder based aggregate of different sizes. The results indicated that Light Weight Concrete can be developed with all sizes of graded aggregate satisfying the fresh and hardened state characteristics. The mechanical properties viz., compressive strength and split tensile strengths were studied at the end of 3, 7 and 28 days for medium grade concretes with different sizes of aggregate. It was noted that with 12.5mm size aggregate and 30% flyash replacement, the mechanical properties were superior in 20Mpa Light weight Concrete, while 10 mm size aggregate with a 30% fly ash replacement improved the properties of 30Mpa concrete. There was also an improved performance in terms of sorptivity of fly ash based Light weight Aggregate Concrete.

Keywords: Coarse aggregate, optimal strength, sorptivity, light-weight concrete, fly ash and cinder.

Introduction

Light Weight Concrete (LWC) has numerous applications owing to its better performance and durability[1]. In structural applications, the self-weight of the structure is quite important as it represents a major portion of the load. Replacing partially or entirely the coarse part of normal weight aggregate concrete with low weight aggregates produces lightweight concrete that can reach a reasonably good compressive resistance. The advantage of lightweight concrete is its reduced mass and improved thermal and sound insulation properties, while maintaining adequate strength. The reduced weight has numerous advantages, including reduced demand on energy during construction. The reduced self-weight of LWC will reduce the gravity load and seismic inertial mass leading to reduced member sizes and foundation forces. Aggregates play an important role in concrete and they account for 60 to 75 percent of the total volume of concrete and thus have an influence on the different material properties[2,3]. In addition to their role as economical filler, aggregates help control the dimensional stability of cement-based materials, which may be considered to consist of a framework of cement paste with relatively large shrinkage movements restrained by the aggregate particles. Aggregates strongly influence concrete's fresh and hardened state properties, mix proportions, and economy. Grading limits and maximum aggregate size are specified since they affect the amount of aggregate used, cement and water requirements, workability, pumpability, and durability of concrete. The size of the aggregate particles has a significant influence on the fracture properties of the matrix. An optimum size of aggregate gives a workable and dense concrete mix, improves the performance of concrete. The increase in fracture toughness with increasing aggregate size is the result of the increased resistance to propagating crack[4,5]. Ibragimov[2] investigated the effect of maximum size of coarse aggregate on the main parameters of concrete. Tumidajski and Gong[3] studied the effect of coarse aggregate size on strength and workability properties of concrete by varying the proportions of 37.5 and 19.5 mm stone in the coarse aggregate. Saouma et al.[4] studied the effect of aggregate and specimen size on fracture properties of Dam Concrete. Chen and Liu[5] investigated on high-strength concretes with 10, 15, and 20 mm sizes of crushed limestone as coarse aggregate. The results depicted that the concretes made with 10-16 mm and 16-20 mm fraction aggregates achieve maximal and the lowest compressive strengths respectively. Alengaram et al.[6] studied the physical and mechanical properties of different sizes of Palm Kernel Shells (PKS) used as lightweight aggregates (LWA) and their influence on mechanical properties of concrete. The flexural and splitting tensile strengths were found respectively 12 and 7% of the compressive strength. Tasdemir[7] investigated the effect of mineral admixture and curing condition on the sorptivity of concrete and showed that the effect of curing condition on the sorptivity coefficient is higher in low strength concretes. Oliveia and Pereira[8] studied sorptivity of self-compacting concrete with mineral additives and presented a comparative study of the sorptivity, accomplished in mixtures of self-compacting concrete with different types of additives and a normal concrete compacted by vibration. The results concluded that the mixtures with fly ash have a better performance as a result of capillary absorption. Tumidajsk[9] and P. Rathish Kumar etal[10], studied the effect of slag, silica fume, and finishing on the sorptivity of field concretes and found that the addition of 40% ground granulated blast furnace slag or 8% silica fume and effective surface finishing is very effective in reducing Sorptivity of field concrete. This work deals with the study of the effect of maximum size of aggregate on the strength and sorptivity properties of 20 MPa and 30 MPa light weight concretes.

Material and Methods

The current study is aimed at investigating the effect of size of light-weight aggregate (cinder) on the compressive strength of Light Weight Concretes (LWC) containing fly ash yielding optimal compressive strength, split tensile strength and sorptivity. Fresh and hardened concrete tests have been conducted on LWC mixes prepared with and without fly ash. The workability tests such as slump and compaction factor were conducted on fresh concrete, while the hardened concrete cube specimens were tested for direct compression and in split tension[11,12]. Sorptivity test was performed on cube specimens to assess the permeability of concrete. Non-Destructive evaluation was carried out on specimens employing Rebound Hammer and Ultrasonic Pulse Velocity (UPV) equipment. The experimental program comprised of two phases. In the first phase, a total of 72 cubes were cast with 20MPa and 30MPa concretes, designed as per ACI 211.2-98[13]. Standard cube moulds (150mm X 150mm X 150mm) were used for casting. The specimens were tested periodically at the end of 3, 7 and 28 days of curing. The maximum size of the aggregate (20 mm, 16mm, 12.5 mm and 10 mm) was the main variable parameter in this phase of the investigation. At the end of this phase, the optimum maximum size of the aggregate was arrived for each grade of concrete. In the second phase of the study, a total of 192 cube specimens were cast, 96 for each of the concrete mixes using optimum sizes of coarse aggregate arrived in the first phase of study. The details of the test program are shown in table-1.

In the second phase, in order to enhance the properties of an other wise inferior cinder based concrete a pozzolanic material, fly ash, in optimum dosages was used as a replacement for cement in the range 10-40% with a step of 10% i.e.10%, 20%, 30% and 40%. The cube specimens of second phase were cured for 7, 14, 28 and 56 days and tested under axial compression and in split tension. Non-Destructive tests Viz., Rebound Hammer and Ultrasonic Pulse Velocity were also conducted at the end of the various ages of curing prior to the destructive testing. Sorptivity tests[8,9,10] were performed on cubical test specimens to determine the sorptivity of concrete.

Materials: Ordinary Portland Cement of 53 MPa strength was used in the study. Locally available river sand was used as fine aggregate. Cinder (burnt coal) waste obtained from the local paper industry is used as lightweight coarse aggregate in the study. The cinder aggregate of different particle sizes 20 mm, 16mm, 12.5mm and 10mm was used for study. Fly ash from VTPS, Vijayawada and potable water were used in this investigation. The physical properties of the materials are given in table 2, while the details of the mix proportions used are presented in table 3.

Table-1
Details of Specimens Cast

S.No	**Strength of mix** (MPa)	**Phase-I**		**Phase-II**		
		MSA (mm)	**No. of Cubes**	**MSA (mm)**	**% Fly ash Content**	**No. of Cubes**
1	20	20.0	9	12.5	10	24
2	20	16.0	9	12.5	20	24
3	20	12.5	9	12.5	30	24
4	20	10.0	9	12.5	40	24
5	30	20.0	9	10.0	10	24
6	30	16.0	9	10.0	20	24
7	30	12.5	9	10.0	30	24
8	30.0	10.0	9	10.0	40	24
Total			**72**	**Total**		**192**

Table- 2
Physical Properties of Cement and Aggregates (FA and CA)

Cement		**Property**	**Value**	
Property	**Value**		**FA**	**CA**
Normal consistency (%)	34	Specific Gravity	2.54	1.45
Specific gravity	3.15	Fineness Modulus	3.00	2.85
Initial and Final setting time (min)	45,18	Porosity (%)	42.8	0.636
Fineness (%)	6	Voids Ratio	0.75	1.75
		%Water Absorption	2	17.24
		%Moisture Content	1	3.45
		Unit Weight kg/m^3	-	840
		Dry Weight kg/m^3	-	780
		% Aggregate Crushing	-	53
		% Aggregate Impact	-	49

Table-3
Details of the Quantities of Materials

Strength of mix.	**Aggregate size(mm)**	**Cement (kg/m^3)**	**Water (kg/m^3)**	**Fine Aggregates (kg/m^3)**	**Coarse Aggregate (kg/m^3)**
20MPa	20	404	202	598.61	621.84
	16	418	209	602.44	592.58
	12.5	434	217	608.00	557.83
	10	456	228	647.67	475.53
30MPa	20	476.4	202	526.21	621.84
	16	492.90	209	527.54	592.58
	12.5	511.79	217	530.21	557.83
	10	537.74	228	565.94	475.53

Mixing procedure of Concrete: Aggregates with relatively low or high water absorption need to be handled carefully. The absorptive nature of the lightweight aggregate requires pre-wetting to have uniform moisture content as possible prior to the addition of other ingredients of concrete. The surface of the mixer is damped with a wet cloth before mixing began and the coarse aggregate was made damp by adding water as per its absorption value. The batched aggregates (both fine and coarse) were added into the mixer with one-half to two-thirds of the mixing water and mixed for a short period before adding cement and admixture to minimize slump loss. Cement was then added into the mixer containing aggregates and remaining water was added into the mixer while the mixing of aggregate and cement was in progress. Thus, the concrete was thoroughly mixed in an electrical drum mixer of 60 litres capacity, for about 5 minutes from the point of addition of water.

Sorptivity Test: The cube specimens of size 150 x 150 x 150 mm were used to conduct sorptivity test after conventional wet curing for 7, 14, 28 and 56 days of age. The sorptivity can be determined by the measurement of capillary rise absorption rate on reasonably homogeneous materials. The test specimen was exposed to water on one face by resting it on rods in the pan to allow free access of water to the inflow surface (figure 1). The water level in the pan was maintained at about 5 mm above the base of the specimens during the experiment. The lower areas on the sides of the specimens were coated with paraffin to achieve unidirectional flow. Surface water on the specimen was wiped off with a damped tissue paper. Then, the quantity of absorbed water in a time period of 30 minutes was measured by weighing the specimen.

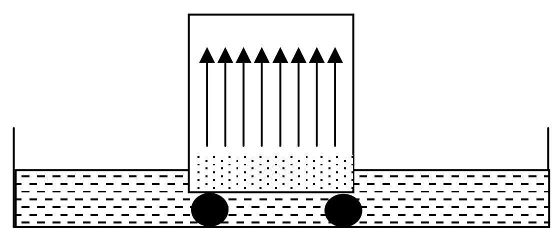

Figure-1
Sorptivity Test Setup

Sorptivity value[8,9,10] is calculated using the formula for sorptivity, i.e: $s = I / t^{1/2}$, where s is sorptivity in mm / √(min); t is the elapsed time in min; and $I = \Delta W / Ad$ where ΔW is the increase in weight, A is the surface area of specimen through which water penetrates and d the density of the medium, here it is water.

Non-Destructive testing of concrete: The results of Non-destructive testing, based on the Ultrasonic Pulse Velocity (UPV) test equipment and rebound hammer, were recorded at the end of 7, 14, 28 and 56 days of curing, in accordance with IS 13311. (Part 1): 1992[11] and IS 13311-(Part2):1992[12] respectively.

Results and Discussion

Phase-I: Optimizing the size of LWA: In this phase, 20MPa and 30MPa concretes were designed using cinder as coarse aggregate (lightweight aggregate) in accordance with ACI-211.2-1998[13]. The details of mix proportions are as shown in **Table-2**. For each of 20MPa and 30MPa concretes, four different concrete mixtures with different maximum sizes of aggregates viz., 10mm, 12.5mm, 16mm and 20mm were designed and cast. Workability, wet and dry densities and the compressive strength at different curing periods were determined for these concrete mixes. Optimum sizes of aggregate based on optimum strength for the two different strength grades of lightweight concrete are arrived in this phase of experimentation.

Effect of Coarse Aggregate size on workability of Light Weight Concrete: Table-4 depicts the variation of slump and compaction factor values with coarse aggregate size. The workability of concrete improved with decrease in the size of cinder aggregate. The slump and compaction factor decreased in respect of 20MPa and 30MPa concretes with decreasing size of lightweight coarse aggregates. The slump values ranged from 82-91 mm and 79-87 mm for 20MPa and 30MPa concretes respectively. The compaction factor values ranged from 0.91-0.94 and 0.90-0.93 for 20MPa and 30MPa concretes respectively. These values suggest that all the mixes possessed good workability.

Table-4
Slump and Compaction Factor Values

S.No	Concrete Strength	MSA (mm)	Slump and Compaction Factor
1	20 MPa 30 MPa	20.0	85mm, 0.92 82mm, 0.91
2	20 MPa 30 MPa	16.0	82mm, 0.91 79mm, 0.90
3	20 MPa 30 MPa	12.5	88mm, 0.93 84mm, 0.92
4	20 MPa 30 MPa	10.0	91mm, 0.94 87mm, 0.93

Table-5
Wet and Dry Densities of LWC Mixes

S.No	Concrete Strength	MSA (mm)	Wet and Dry Densities (kg/m^3)
1	20 MPa 30 MPa	20.0	1940, 1819 1980, 1870
2	20 MPa 30 MPa	16.0	1949, 1830 1996,1889
3	20 MPa 30 MPa	12.5	1961, 1846 2013,1908
4	20 MPa 30 MPa	10.0	1979, 1866 2035,1931

Effect of Size of Coarse Aggregate on Densities of Lightweight Concrete: Table-5 presents the variation of wet and dry densities with coarse aggregate size. The density of both 20MPa and 30MPa concretes increased with the decrease in the size of aggregates. The wet density values ranged from 1940-1979 kg/m^3 and 1980-2035 kg/m^3 for 20MPa and 30MPa concretes respectively as against the dry density which ranged from 1819-1866 kg/m^3 and 1870-1931 kg/m^3 respectively for the same concrete mixes. In general, in both the grades of concrete, the wet and dry densities increased with decrease in the size of aggregates. This also suggests increased strength and durability with lower size of aggregate from identical concrete grades.

Effect of Coarse Aggregate size on Compressive strength of Lightweight Concrete: Figures 2 and 3 depict the variation of compressive strength with coarse aggregate size for cinder-based light weight concretes of 20 MPa and 30 MPa strengths respectively. The compressive strengths of 20 MPa lightweight concrete mixes prepared with 20 mm, 16mm, 12.5mm and 10mm aggregate size met the desired design strength of 20 N/mm^2. It could be observed that at the end of 3, 7 and 28 days the compressive strength of concrete with 12.5mm size aggregate were found to be higher. Thus the cinder based lightweight concrete of 20MPa attained optimum strength with the use of 12.5mm aggregate size. The 28-day compressive strength of concrete mixes prepared with 20 mm, 16 mm and 10 mm size aggregate were less by 20.03%, 21.86% and 12.54% respectively, in comparison to the one with 12.5 mm size aggregate. Similarly, in the case of 30MPa concrete, the optimum strength was obtained with 10 mm size aggregates. The compressive strength at 28 days for concretes with 20 mm, 16 mm and 12.5 mm size aggregate are lesser by 17.86%, 22.94% and 10.16% respectively, in comparison to those of concrete with 10 mm size aggregate.

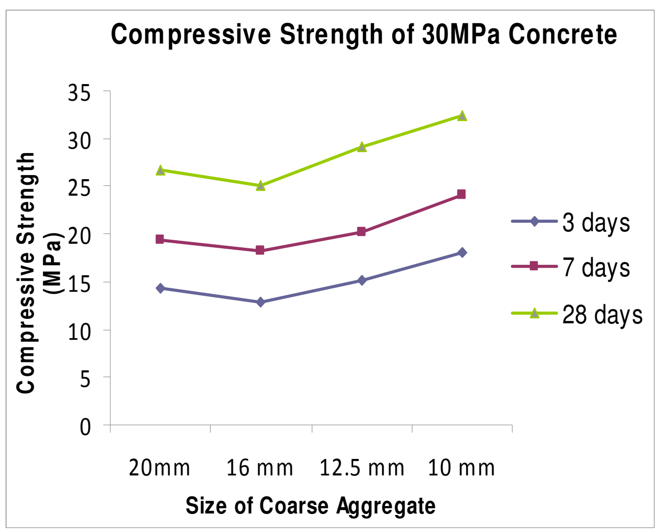

Figure-2
Comp. Strength Vs Size of Coarse Aggregate (20 Mpa)

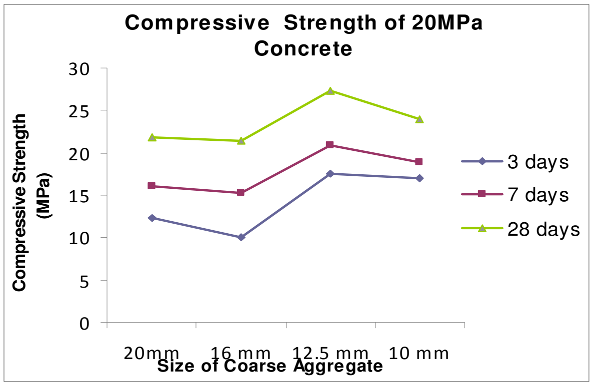

Figure-3
Comp. Strength Vs Size of Coarse Aggregate (30 Mpa)

Phase-II: Optimizing the dosage of Flyash: In this phase of study, fly ash concrete mixes of 20MPa and 30MPa concretes were developed based on the reduction factor method[16] using the already obtained 12.5mm and 10mm optimized sizes of cinder aggregates obtained in phase-I study. The fly ash in cinder-based light weight concrete was varied from 10% - 40%, in steps of 10% in both 20MPa and 30MPa concretes. The fresh state properties were evaluated and the hardened concrete properties were determined at the end of 7, 14, 28 and 56 days of curing. The sorptivity of the specimens was also determined at the end of 7, 14, 28 and 56 days of curing to assess the permeability of concrete. Non-destructive evaluation in terms of rebound number and ultrasonic pulse velocity of concrete specimens was also performed at different ages of concrete. Table-6 presents the slump and compaction factor values of 20MPa and 30MPa light weight aggregate concretes with different dosages of fly ash. Table-7 shows wet and dry density values of 20MPa and 30MPa light weight aggregate concretes with fly ash.

Table-6
Slump and Compaction Factor Values

S. No.	Concrete Strength	% Fly Ash	Slump and Compaction Factor
1	20 MPa 30 MPa	10	80mm, 0.92 76mm, 0.91
2	20 MPa 30 MPa	20	83mm, 0.93 77mm, 0.92
3	20 MPa 30 MPa	30	86mm, 0.94 80mm, 0.93
4	20 MPa 30 MPa	40	88mm, 0.95 82mm, 0.94

Effect of Fly Ash Percentage on Workability of Lightweight Concrete: It can be noted from table 6 that the slump and compaction factor values of 20MPa and 30MPa light weight concretes increased with increasing percentage of fly ash in concrete. The slumps ranged from 80-88 mm and 76-82 mm while the compaction factors are in the range of 0.91-0.93 and 0.92-0.94 respectively for 20MPa and 30MPa concretes. These values suggest that all the mixes are having good workability.

Table-7
Wet and Dry Densities

S.No	Concrete Strength	% of Fly Ash	Wet and Dry Densities (kg/m^3)
1	20 MPa 30 MPa	10	1950, 1840 2070,1952
2	20 MPa 30 MPa	20	1939, 1834 2060,1945
3	20 MPa 30 MPa	30	1930, 1826 2049,1936
4	20 MPa 30 MPa	40	1923, 1819 2036,1924

Effect of Fly Ash Percentage on Densities of Lightweight Concrete: Table-7 presents the variation of wet and dry densities with percentage of fly ash. The densities of both 20MPa and 30MPa concretes decreased with the increase in percentage of fly ash. In case of LWC with fly ash, wet density ranged from 1950-1923 kg/m^3 and 2030-1996 kg/m^3 for 20MPa and 30MPa concretes respectively as against the dry density range of 1819-1840 kg/m^3 and 1885-1922 kg/m^3 for 20MPa and 30MPa concretes. This decrease in density may be attributed to the light weight nature and low specific gravity of fly ash replaced in concrete.

Effect of Fly Ash Percentage on Compressive strength of Lightweight Concrete: Figure 4 and 5 depict the variation of compressive strength for 20MPa and 30MPa cinder-based lightweight concretes containing different percentages of fly ash. For 20MPa concrete, the compressive strengths obtained for concrete mix with 20%, 30% and 40% fly ash met the desired design strength of 20 N/mm^2 beyond 28 days of age as against at 28 days for concrete with 10% fly ash.

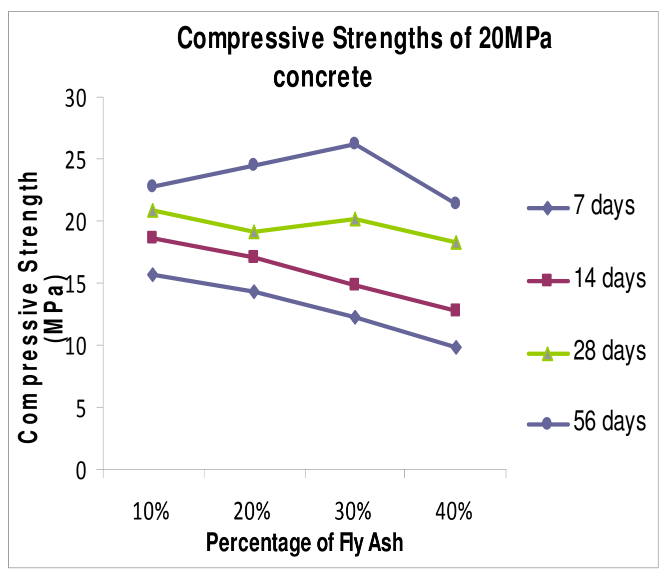

Figure-4
Compressive Strength VS % Flyash (20Mpa)

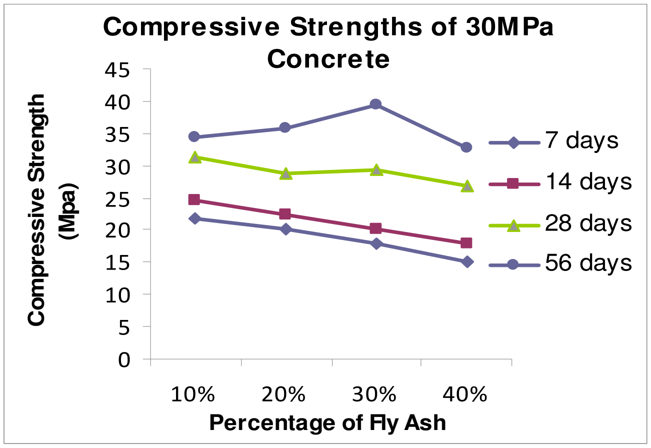

Figure-5
Compressive Strength VS % Flyash (30Mpa)

At 56 days, 30% fly ash mix concrete obtained the optimum compressive strength of 25.17 N/mm^2. The compressive strength of 10%, 20% and 40% fly ash mix concretes were found to be lesser by 9.69%, 6.91% and 11.04% respectively in comparison to the of concrete with 30% fly ash replacement. At all the ages, the compressive strengths of concrete with 40% fly ash have been lesser than the strengths of concretes containing 10%, 20% and 30% fly ash. It could be observed that optimum strength is obtained for concrete with 30% fly ash and the strength gets depleted with the use of higher percentages of fly ash in concrete. For 30MPa concrete, the compressive strengths obtained for concrete mix with 20%, 30% and 40% fly ash meets the desired characteristic strength of 30 N/mm^2 beyond 28 days of age as against at 28 days of age for concrete with 10% fly ash. At 56 days 30% fly ash mix concrete obtained the optimum compressive strength of 38.32 N/mm^2. The compressive strength of 10%, 20% and 40% fly ash mix concrete were found to be decreased by 10.57%, 6.45% and 11.82% respectively in comparison to the of concrete with 30% fly ash replacement. The compressive strength of concrete with 40% fly ash mix is found to be lesser than that of concrete with 10%, 20% and 30% at all the ages. It could be observed that optimum strength is obtained for concrete with 30% fly ash and the strength gets depleted with the use of higher percentages of fly ash in concrete.

It can be noted at this stage that at higher ages of curing, the reactive silica in flyash reacts with free calcium hydroxide in cement, producing C-S-H gel and contributing to the later gain in strength. The late gain in strength noticed at 56 days is evident of the pozzolanic nature of flyash concretes.

Effect of Fly Ash Percentage on Split Tensile Strength of Lightweight concrete: Figures 6 and 7 respectively depict the variation of split tensile strength with percentage of flyash for 20MPa concrete and 30MPa concretes cured by conventional wet curing. The trends of the tensile strengths are similar to those for compressive strength. At 56 days, 30% fly ash mix concrete obtained the optimum split tensile strength of 1.85 N/mm^2. The split tensile strength of 10%, 20% and 40% fly ash mix concretes were found to decrease by 5.94%, 3.24% and 7.57% respectively in comparison to those of concrete with 30% fly ash replacement. The split tensile strength of concrete with 40% fly ash mix is found to be lesser than that of concrete with 10%, 20% and 30% at all the ages. It could be observed that optimum strength is obtained for concrete with 30% fly ash and the strength gets depleted with higher percentages of fly ash in concrete.

For 30MPa concrete, at 56 days 30% fly ash mix concrete obtained the optimum split tensile strength of 2.73 N/mm^2. The split tensile strength of 10%, 20% and 40% fly ash mix concrete were found to decrease by 8.05%, 2.93% and 11.35% respectively in comparison to the concrete with 30% fly ash replacement. The split tensile strength of concrete with 40% fly ash mix is found to be lesser than that of concrete with 10%, 20% and 30% at all the ages. It could be observed that optimum strength is obtained for concrete with 30% fly ash and the strength gets depleted with higher percentages of fly ash in concrete.

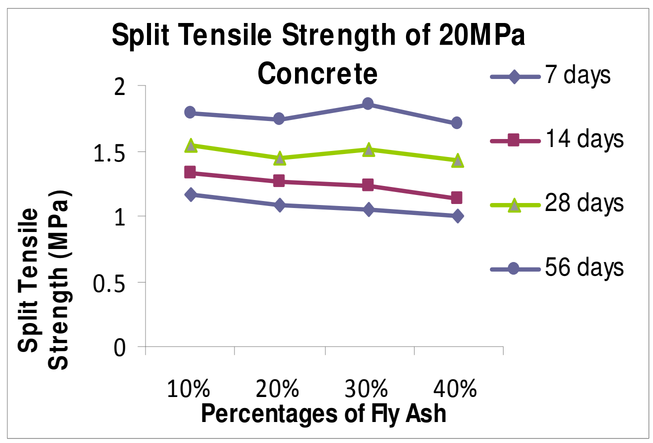

Figure-6
Split Tensile Strength VS % Flyash (20Mpa)

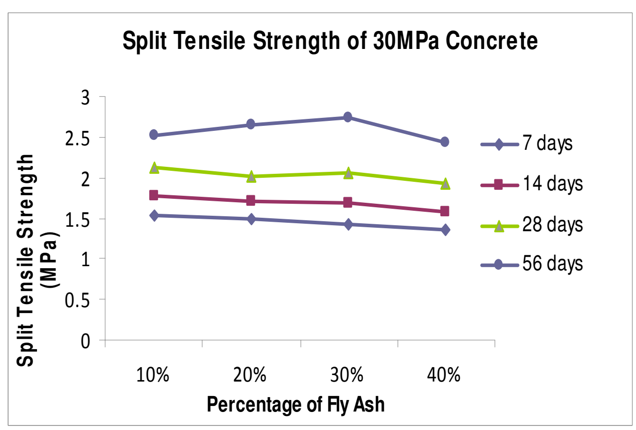

Figure-7
Split Tensile Strength VS % Flyash (30Mpa)

Effect of Fly Ash Percentage on Sorptivity of Lightweight Concrete: Figures 8 and 9 show the variation of sorptivity of 20MPa and 30MPa light weight concretes developed with different percentages of fly ash. The sorptivity values decreased with increase in the percentage of fly ash and age of concrete, indicating the decrease in porosity of concrete. This is due to the improved gel structure that contributes to the imperviousness of concrete. The Sorptivity values for 10%, 20% and 30% fly ash concrete mixes of 20MPa and 30MPa strengths had a marginal decrease of 12.3% and 10.96% respectively for concrete mixes of 40% fly ash. The decrease in sorptivity, an indirect measure of permeability, confirms non-porous nature of concrete, ensuring good durability. The sorptivity values are lower in case of 30Mpa concrete as compared to 20Mpa concrete.

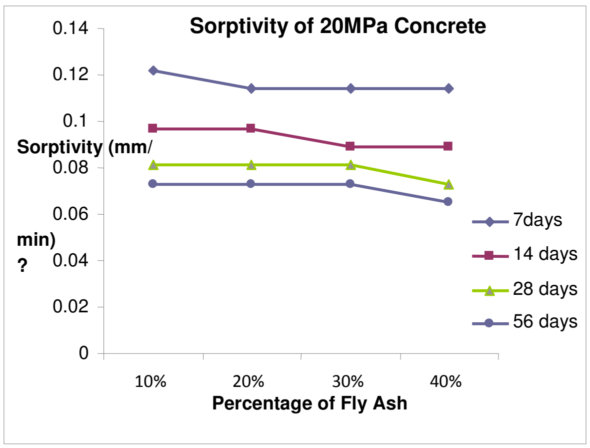

Figure-8
Sorptivity VS % Flyash (20 Mpa)

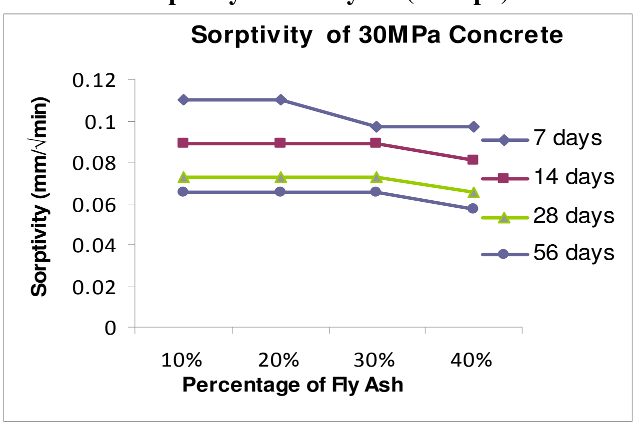

Figure-9
Sorptivity VS % Flyash (30 Mpa)

Rebound Number: Non-destructive testing based on rebound hammer and ultrasonic pulse velocity tests were carried out prior to the destructive tests. Figures 10 and 11 shows the variation of rebound number values of 20MPa and 30MPa lightweight concretes developed with different percentages of fly ash content respectively. Rebound number values are more or less same and found to range from 26-28 and 26-30 for 20MPa and 30MPa respectively.

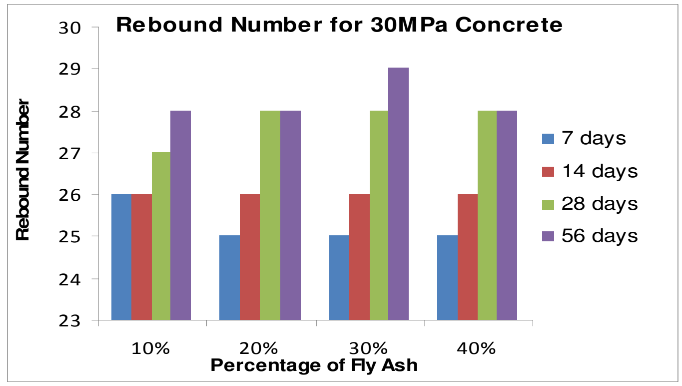

Figure-10
Rebound Number Vs % Flyash (20 Mpa)

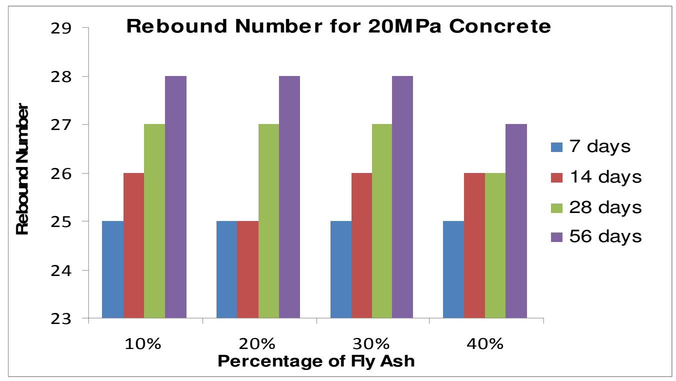

Figure-11
Rebound Number Vs % Flyash (30Mpa)

Ultrasonic Pulse Velocity (UPV): Figures 12 and 13 depict the variation of UPV values of 20MPa and 30MPa concretes developed with different percentages of fly ash. The UPV values of 30MPa concrete followed the similar trend as that of the 20MPa concrete. The pulse velocity values of 20MPa and 30MPa concretes, with 30% cement replaced by fly ash, have been respectively 1.05%, 2.11% and 5.82% and 2.27%, 1.52% and 4.54% more than those for concretes with 10%, 20% and 40% fly ash replacement. The pulse velocities obtained for both concretes suggest "good" concrete quality grading as per IS: 13311-1992 (Part-1)[11].

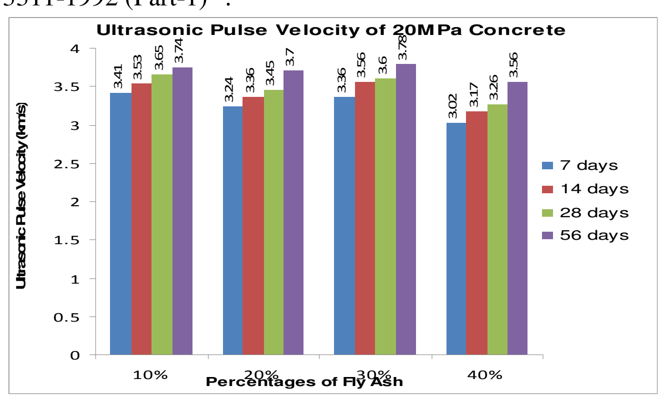

Figure-12
UPV VS % Flyash (30Mpa)

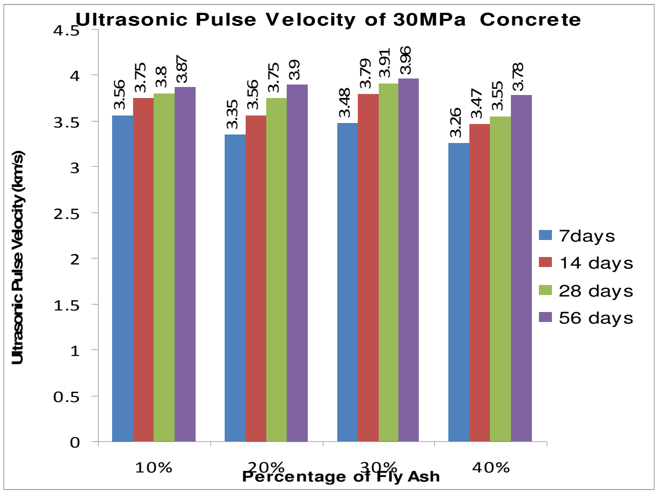

Figure-13
UPV VS % Flyash (20Mpa)

Binder Efficiency: Binder efficiency is the efficiency index of binder in units of MPa/Kg. This index is used to indicate the effectiveness of binder used in concrete proportioning to develop its compressive strength. The binder efficiency, at a particular age of concrete, is calculated as the ratio of the compressive strength at the age under consideration to the amount of the binder used in the units of kg/cubic meter of concrete. Figures 14 and 15 depict the variation of binder efficiency values of 20MPa and 30MPa concretes developed with different percentages of fly ash. Both 20MPa and 30MPa concretes followed the same trend in the variation of binder efficiency with percentage of flyash. The binder efficiency values are found to increase with the age of concrete for all percentages of flyash replacement, reaching optimum values with 30% fly ash content at 28 and 56 days of age. The binder efficiency of 30MPa concrete has been higher than that of 20MPa concrete at all ages considered in this study.

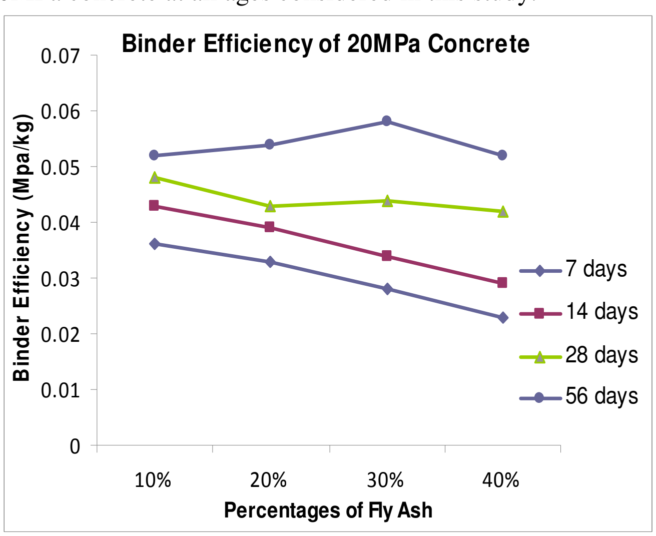

Figure-14
Binder Efficiency VS % Flyash (20 Mpa)

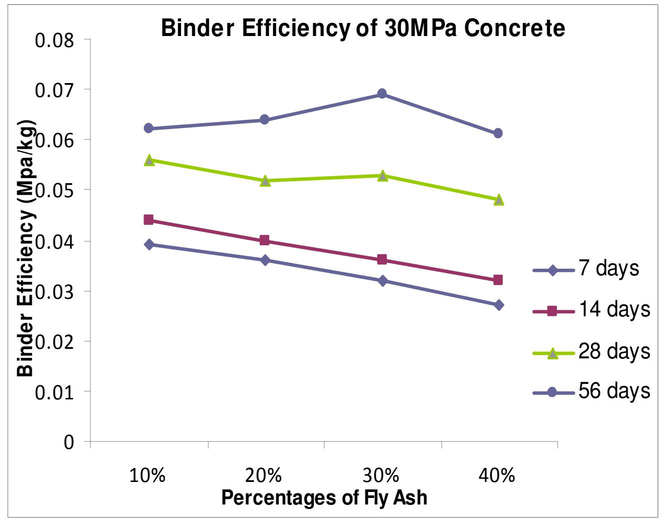

Figure-15
Binder Efficiency VS % Flyash (30 Mpa)

Conclusion

Two aspects are investigated here in the present study; one to evaluate the optimum size of cinder based light weight aggregate and second optimizing the flyash content in light weight concretes. From the study conducted on 20MPa and 30MPa cinder based light weight concretes, the following conclusions are drawn: Lightweight concretes of 20MPa and 30MPa could be developed using cinder based aggregate. Optimum compressive strengths of 20Mpa and 30Mpa could be developed with 12.5 mm and 10 mm size aggregates respectively. Both the optimized lightweight concretes (20MPa and 30MPa) attained the optimum compressive and split tensile strengths at 56 days of age with 30% replacement of cement with fly ash. The sorptivity of 20MPa and 30MPa lightweight concretes decreased with increasing age and percentage fly ash leading to enhancement in imperviousness of concrete. Hence, durable concrete can be ensured with cinder based aggregate with optimum flyash and with 56 days of curing. Workability, in terms of slump and compaction factor, increased with the decreasing size of lightweight coarse aggregates excepting with 16 mm size aggregates in both lightweight concretes of 20MPa and 30MPa. Use of flyash increased the workability in all the mixes with optimized size of aggregate. Both wet density and dry density increased with the decrease in the size of coarse aggregates in both 20MPa and 30MPa lightweight concretes. The densities decreased with increasing percentage of pozzolanic content i.e. fly ash. The non destructive testing based on rebound hammer and Ultrasonic Pulse Velocity test results indicate good quality of concrete. Hence, cinder based light weight concrete is in no way inferior to normal concrete. The binder efficiency, in both 20MPa and 30MPa lightweight concretes, reached optimum values with 30% fly ash content at 28 and 56 days of age.

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