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Effect of Fly-Ash on the mechanical properties and workability of light weight Concrete

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Abstract; This paper investigates the effects of Fly-ash on the compression and splits tensile strength of concrete . Concrete mix of grade M20 was tested . The cubes of size 15cmx15cm and cylinders specimens of size 15cm diameter and 30cm length are cast to test for compression and split tensile strength respectively and compared with the control specimens. Fly-ash and Cinder was used as a partial replacement for cement and coarse aggregate in normal strength concrete at 10%, 20%, 30% by weight and cinder by 20%,40%,60% by weight. The slump cone test and compaction factor tests were carried out to check the effect of Fly-ash on the workability of concrete. The increment in the cement substitution by Fly-ash caused decreasing the workability of concrete. It showed a 48% reduction of workability with 30% replacement as compared to plain concrete in the slump cone test. The optimum dosage of fly-ash for the compression strength and splitting tensile strength is 20% .

Keywords: Light weight concrete, Workability, Compression strength, Split tensile strength.

1.INTRODUCTION

The composition of light weight concrete is similar to that of conventional concrete, with the exception of the use of light weight aggregates or a mix of light weight aggregates and standard aggregates. Low weight materials can occasionally be used in place of fine aggregates. Compared to normal standard concrete, the connection between the Concrete made of light-weight cement and particles has strength. For structural purposes, concrete need to be stronger .In structural light weight construction, materials such expanded shale, slate, cinder, pumice, and other light weight aggregates are frequently used concrete.

It has several benefits, including a decrease in dead loads, superior thermal insulation, faster construction, and cheaper handling expenses. Concrete that is lightweight can be used for walls and floors to save on structural costs. It also uses less power in bad weather because of its low thermal conductivity. Lightweight concrete is increasingly extensively used in precast and prestressed components. Lightweight concrete offers design flexibility and considerable cost savings by giving reduced dead load, enhanced seismic structural response, increased fire rating, lower storey height, fewer structural parts, less foundation cost, and less reinforcing steel. Other countries including the United States, the United Kingdom, and Sweden frequently use it.

FLY ASH: This by product of coal combustion is made up of flue gases and particulates, which are small fragments of burnt fuel. Ash that collects at the bottom of a boiler's firebox, or combustion chamber, is called bottom ash. In contemporary coal-fired power plants, fly ash is frequently captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. When it is mixed with bottom ash that has been removed from the bottom of the boiler, it is referred to as coal ash. The ultimate strength of concrete made with fly ash is higher than that of concrete made without it because fly ash comprises bigger or less reactive particles than Portland cement and a significant moisturization phase that can persist for six months.

Class F fly ash is pozzolanic in nature and contains roughly 7% lime (Cao). Due to its pozzolanic properties, Class F fly ash requires the reaction of a cementing agent, such as Portland cement, quicklime, or hydrated lime mixed with water, to produce cementitious compounds. Additionally, a Class F ash and a chemical activator like sodium silicate can be used to create a geopolymer (water glass).

Over time, Class C fly ash becomes stronger and harder. Class C fly ash often contains more than 20 percent lime (Cao). Self-cementing Class C fly ash doesn't need an activator, in contrast to Class F fly ash, which must. Class C fly ashes often include greater concentrations of alkali and sulphate (SO4).

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OBJECTIVES OF STUDY

1. To add Fly-ash as a partial replacement (10%, 20%, and 20 wt%) to cement and Cinder as partial replacement (20%,40%,60%) to coarse aggregate.
2. To check the workability of the specimens with the addition of Fly-ash.
3. Testing compression and split tensile strength into cubes and cylinders respectively.

2. LITERATURE REVIEW

C. V. Siva Rama Prasad (1), "Light Weight Concrete using FlyAsh Aggregate", This research focuses on the investigation and application of fly ash aggregate in concrete. Along with the goal of the study, a thorough literature review has been carried out. In this investigation, fly ash aggregates in fly ash concrete totally took the place of the fine and coarse aggregates. For concrete of the M20 grade, a mix design using the IS approach was completed. In order to create fly ash aggregates, ordinary Portland cement of grade 53 was used and fly ash was combined with cement and water. The characteristics of fly ash coarse aggregates and fly ash fine aggregates were investigated. Additionally investigated were fly ash coarse aggregates' aggregate crushing value and aggregate impact value. Fly ash coarse aggregates' aggregate crushing value and aggregate impact value were also investigated. To create the fly ash aggregates, the cement and fly ash mixtures of 15:85, 20:80, and 25:75 were tested with an appropriate water content of 20 percent by total weight. The fly ash aggregates produced from the aforementioned three cement fly ash proportions were used to cast the concrete cubes, cylinders, and beams. Following that, tests were conducted on the compressive strength, split tensile strength, and flexural strength, and results were compared to control concrete. In comparison to traditional concrete, the weight of the concrete cubes is reduced by around 27.5 percent. The evolution of the compressive strength of fly ash aggregate concrete at various ages is briefly discussed in this work. At various curing times, the split tensile strength and flexural strength of each concrete mix were also examined.

S Punlert , P Laoratanakul (2) , "Effect of lightweight aggregates prepared from fly ash onlightweight concrete performances" .The fly ash of paper industry byproducts was converted into lightweight aggregates. On the characteristics of lightweight aggregates, the effects of processing conditions and the ratio of clay to fly ash were examined. The porosity of light-weight aggregates was discovered to be directly impacted by the quantity of fly ash. Bulk density of 1.66 g cm-3, compressive strength of 25 MPa, and water absorption of 0.55 percent are all displayed by lightweight aggregates with a clay to fly ash weight ratio of 80:20 and a sintering temperature of 1210C. The ultimate properties of concrete with a density of 1780 g cm-3, water absorption of 3.55 percent, compressive strength of 40.94 MPa, and thermal conductivity of 0.77 W m-1K-1 were revealed by the replacement of coarse aggregates with lightweight aggregates at a 100 weight percent ratio for the production of concrete. The concrete was lighter by more than 25% while maintaining a comparable compressive strength to regular concrete. This demonstrates that lightweight aggregates might be used in structural concrete because they could minimise labour demands and raise building sites' safety levels.

N Ghazali (3), "Effect of Fly Ash as Partial Cement Replacement on Workability and Compressive Strength of Palm Oil Clinker Lightweight Concrete", The current study investigates the effects of fly ash (FA) as a partial cement substitute on the workability, compressive strength, and flexural strength of lightweight aggregate concrete made from palm oil clinker. Five different types of mixtures, each with a different percentage of FA to replace cement, were used: 0%, 10%, 20%, 30%, and 40%. Up until the testing date, all specimens underwent a curing process that involved submerging them in water. At 7 and 28 days, concrete specimens underwent compressive strength and flexural strength tests. The characteristics of this lightweight aggregate concrete are affected by the use of fly ash as a partial cement substitute. This ground breaking discovery demonstrates how adding up to 20% FA to palm oil clinker lightweight aggregate concrete improves workability and strengthens the material.

Midhun Mohan (4), "Light Weight Aggregate Concrete using Bottom Ash and Fly Ash", This paper summarizes about the preparation of the light weight aggregates and its properties and also discuss about the properties of concrete incorporated with light weight aggregate. Fineness of fly ash and bottom ash impacts the physical properties of the produced aggregates. Among various binders, bentonite is the normally utilized one. Its best dose is between 15 to 35% of the powder content. . The free bulk density varied somewhere in the range of 765 and 936 kg/m3.Economically accessible aggregates have water absorption limit around 10–25%.It is conceivable to deliver concrete having compressive strength between 23.12 to 74 MPa and density 1651 to 2017 kg/m3. Likewise, the tensile strength hand e-modulus ranges from 2 to 4.9 MPa and 16.7 to 30.65GPa, respectively. Every one of these reaches are positive for the advancement of structural concretes. When compared to the conventional normal density concretes, the structural efficiencies of these concretes are much higher. The strength of concrete should be higher than 17.0 MPa used for structural purposes. The 28-day compressive strength of all HPLWCs ranged from 14.8 to 38.1 MPa.

S.Azzaruddin (5), "Effect And Behaviour Of Light Weight Concrete Using Fly Ash Aggregate", In this study, the fine and coarse aggregates were completely replaced by fly ash aggregates in fly ash concrete .a mix design was done for

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M20 grade of concrete by IS method. Ordinary Portland cement of 53 grade was selected and fly ash aggregates were prepared by mixing fly ash with cement and water. The properties of fly ash fine aggregates and fly ash coarse aggregates were studied. The aggregate crushing value and aggregate impact value of fly ash coarse aggregates were also studied. The cement and fly ash proportions of 15:85, 20:80 and 25:75 were tried with a suitable water content of 20% by total weight to get the fly ash aggregates. The concrete cubes, cylinders and beams were cast with the fly ash aggregates obtained from the above three cement fly ash proportions. Then the compressive strength, split tensile strength and flexural strength were tested and compared with control concrete. This paper briefly presents the compressive strength development of fly ash aggregate concrete at different ages. The weight of the concrete cubes compared to the conventional concrete is reduced to about 27.5% by Weight .The split tensile strength and flexural strength of all the concrete mixes were also investigated at different days of curing.

Anil Kumar R. (6), This study examines the strength characteristics of structural light weight concrete made by substituting coarse aggregate with light weight aggregates such cinder and leca blended in various percentage proportions of 0:100, 10:90, 20:80, 30:70, 40:60, and 50:50 by volume of concrete. 33 basic cube specimens with measurements of 150 x 150 x 150 mm are cast in cylindrical moulds with dimensions of 150 x 300 mm to test the mechanical properties. M20 grade light weight concrete has an average compressive strength and split tensile strength of 60 percent cinder and 40 percent leca GGBFS (Ground Granulated Blast Furnace Slag), which is used to replace 20 percent of the cement in the mixture, bringing the compressive strength closer to that of M20 grade light weight concrete.

Dr. V. Bhaskar Desai (7), In the current study, the strength characteristics of light weight cinder aggregate cement concrete in various percentage amounts of 0, 25, 50, 75, and 100 by volume of light weight aggregate concrete are explored. Five distinct M20 concrete mixes with a mix proportion of 1:1.55:3.04 and a water cement ratio of 0.50 were made using the ISI method. A total of 105 samples, including 15 plain cube specimens measuring 150 x 150 x 150mm, 60 DCN specimens measuring 150 x 150 x 150mm, and 30 cylinders measuring 150 mm in diameter and 300 mm in height, were cast and tested to determine the mechanical properties. It is discovered that when the proportion of cinder increases, the cylinder compressive strength, split tensile strength, and young's modulus all gradually drop. The cinder aggregate is not substandard to the natural aggregate in any manner.

Hanuman Sai Gupta, E (8) This paper discusses the effects of cinder aggregate and powder on the mechanical properties of concrete. The trials are conducted by replacing different portions of the granite coarse aggregate with cinder aggregate that has a water-cement ratio of 0.47. Similarly, fine aggregate is partially replaced with cinder powder (sand). A 20 mm nominal size cinder coarse aggregate and cinder powder were used at varying percent replacement levels in typical M25 grade design mix concrete. Standard-size cube, cylinder, and beam specimens are cast, and after 28 days, they are assessed for compression, split, and flexural stress. The results of the tests show that cinder, despite its greater price, is one of the best options for coarse and fine aggregates in the manufacture of conventional concrete in terms of density and workability. Strength gain is minimal at different replacement levels. The target mean strength of cinder aggregate concrete with a 40% cinder replacement level was equivalent to that of conventional concrete. This shows that the requisite mean strength may be achieved after 28 days by substituting 40% of the granite aggregate with cinder aggregate.

Sanjana M. (9), In this study, an effort has been made to compare traditional concrete and light weight aggregate concrete for M20 Grade by partially substituting Natural Course Aggregate with Cinder and totally replacing sand with Fly Ash Granules. Lightweight concrete is made by partially replacing coarse aggregate with varying amounts of cinder, such as 20%, 40%, 60%, and 100%. This study aims to identify the compression strength, flexural strength, and split tensile strength parameters of light weight aggregate concrete in order to choose the optimum replacement with the aforementioned alternatives. The results of this study show that a percentage reduction in strength is balanced by a percentage reduction in weight as a result of the addition of light-weight cinder, resulting in a reduction in the total dead weight of the structure. Additionally, as the percentage of cinder increases, the strength of the concrete in compression, tension, and flexure decreases. Cinder can partially or completely replace natural coarse aggregates.

Ankit Kumar Agrawal (10), In this investigation, cinder and cinder powder have been used in place of some of the fine and coarse particles. Utilizing cinder material has several advantages, but its main advantages are cost savings, waste disposal savings, and help in lowering dead load. In this study, the mechanical properties of M25 grade concrete were examined by replacing coarse aggregate with cinder at various percentages, such as 0 percent, 20 percent, 40 percent, 60 percent, 80 percent, and 100 percent, and fine aggregate with cinder powder at 10 percent, 20 percent, 30 percent, 40 percent, and 50 percent, with a 28-day curing period. The strength characteristics of concrete were shown to be unaffected significantly by the use of cinder powder. The strength decrease as a percentage is not too significant when fine aggregate is partially replaced with cinder powder. The target mean strength of cinder aggregate concrete was the same as conventional concrete when cinders made up 40% of the aggregate. This shows that to achieve the desired mean strength after 28 days, granite aggregate can be substituted with cinder aggregate at a 40% replacement rate.

Nagashree B. (6) In this study, it is first examined how leca and cinder are used as coarse aggregates to make lightweight aggregate concrete. Concrete mixtures of grades M20 and M30 have been developed. Various volumes of

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blended aggregates (leca and cinder) replace coarse materials. By modifying the proportions of leca and cinder, 150x150x150mm cubes are formed from concrete mixtures of grades M20 and M30. A slump test is carried out on brand-new concrete for each ratio. For each mixed proportional percent, cubes and cylinders are cast in order to test the hardened properties of concrete. The experimental results show that substituting 40% leca and 60% cinder aggregates for the proportion of coarse aggregate produced better results in terms of strength and weight.

3. EXPERIMENTAL WORK

CEMENT: In this experiment OPC 53 grade was used. Ultra-Tech brand cement was used for all the mixes. Fresh and lumps free cement with a specific gravity 3.15 was used. The design strength for 28 days is a minimum of 53MPa.It sets quicker then OPC 43 and has quite low initial setting time.

FINE AGGREGATE : M-Sand is artificial sand produced from crushing hard stones into small sized angular shaped particles ,washed and finely graded to be used as construction aggregate .It is superior alternative to river sand for construction purposes .The M-sand used in this study has specific gravity of 2.65 with particles size smaller than 2.63 mm used as fine aggregate.

COARSE AGGREGATE: In construction, coarse aggregates are larger-sized filler materials. The particles that retain on a 4.75 mm sieve are known as coarse aggregates. The primary sources of coarse aggregate are dolomite aggregates, crushed gravel or stone, and natural rock disintegration. Coarse aggregate used in this study has specific gravity of 2.95 and size less then 10mm.

WATER : Water used for the experimentation was taken from the laboratory.

FLY-ASH: Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The fly ash from boilers at some older plants, where mechanical collectors alone are employed, is coarser than from plants using electrostatic precipitators.

S. No	Chemical composition	Percentage (%)
1	Silica (SiO_2)	49-67
2	Alumina (Al_2O_3)	16-29
3	Iron oxide (FeO_3)	4-10
4	Calcium oxide (CaO)	0.2-2
5	Magnesium oxide (MgO)	0.1-2
6	Sulphur(SO_3)	0.5-3
7	Loss of ignition	0.32

CINDER: Cinder is a naturally occurring light weight rock of igneous origin. It is a pyroclastic material. Cinder of size 10 mm were used.




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Fig 3 – Cement, Fine aggregate , Coarse aggregate , Water , Fly-Ash , Cinder ,

Mix Proportion Of Concrete Used :

OBTAINED RATIO = CEMENT : FINE AGGREGATE : COARSE AGG.
FOR M20 GRADE = 335.48 :817.949 :1068.903
(W/C RATIO = .6) =**1** **:2.43** **:3.18**
Fly Ash And Cinder Are Replaced By Cement And Coarse Aggregate By The Following Percentages

FLY ASH IN CEMENT	CINDER IN COARSE AGGREGATE
10%	20%
20%	40%
30%	60%

3.2.Specimens Preparation

For the compression strength test, three 15cm size cubes(150mm*150mm) are considered which contain Fly-ash in the dosage of 10%, 20%, and 30wt% of cement and compared with the control specimen (without Fly-ash). Three cylinders of size 15cm in diameter and 150cm in length are considered for the split tensile strength test. The results will be compared with the control specimen.

3.3.Workability Of Concrete

Concrete slump cone test: The test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete. The test is carried out using Indian Standard: 1199-1959: Methods of sampling and analysis of concrete. The test is carried out using a conical frustum known as a slump cone which is open at both ends and has attached handles and has an inside diameter of 10cm at the top and 20cm at the bottom with a 30cm height.

Compaction factor test: It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability. The test is carried out using Indian Standard: 1199-1959: Methods of sampling and analysis of concrete. The test was carried out by adding Fly-ash in the percentage of 10%, 20%, and 30wt% to cement to check the effect of HNCs on the workability of concrete.

3.4 Compression Strength Test

Compressive strength test is carried out to find the capacity of concrete to withstand loads before failure. The test was carried out on 15cm*15cm size cubes following the IS 516 – 1959 (Methods of tests for strength of concrete).The specimens shall be placed in a compression testing machine in such a manner that the load shall be applied to opposite sides of the cubes as cast. Tighten the top portion to the top of specimens without a gap.After the specimen is fitted into the CTM as explained above manner, the load of 500kg/div was applied until the specimen failure then noted down the dial gauge values to find out the failure load by using the below formula
Compression strength = maximum load applied/cross-sectional area of the specimen.

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Fig 3.4- Compression test

3.5. split tensile strength test

Tensile strength can be defined as the maximum stress that a material can bear before breaking when it is allowed to be stretched or pulled.A method of determining the tensile strength of concrete using a cylinder that splits across the vertical diameter. It is an indirect method of testing the tensile strength of concrete.The test was carried out on 150mm (Diameter) * 300mm (Length) cylindrical specimens as per IS 5816:1999 (Splitting tensile strength of concrete – Method of test).The procedure is similar to the compression testing but the load is applied along a line on the surface of the specimen.

Splitting tensile strength = 2F/3.14*D*L

Fig 3.5 split tensile test

4. RESULTS AND DISCUSSIONS

4.1 WORKABILITY TEST

a. Concrete slump test.:

The test is carried out using Indian Standard: 1199-1959: Methods of sampling and analysis concrete.The influence of adding Cinder and fly-ash on the consistency of concrete is shown in the below graph. Generally, .the increment in the cement substitution by Cinder and fly-ash caused decreasing the workability of concrete.

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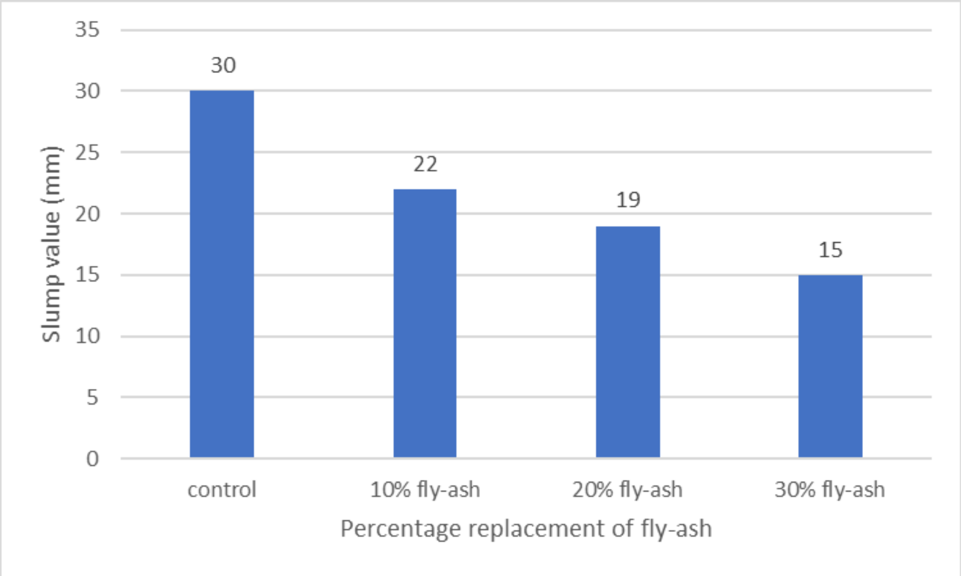

Fig 4: Slump values

b. Compaction factor test

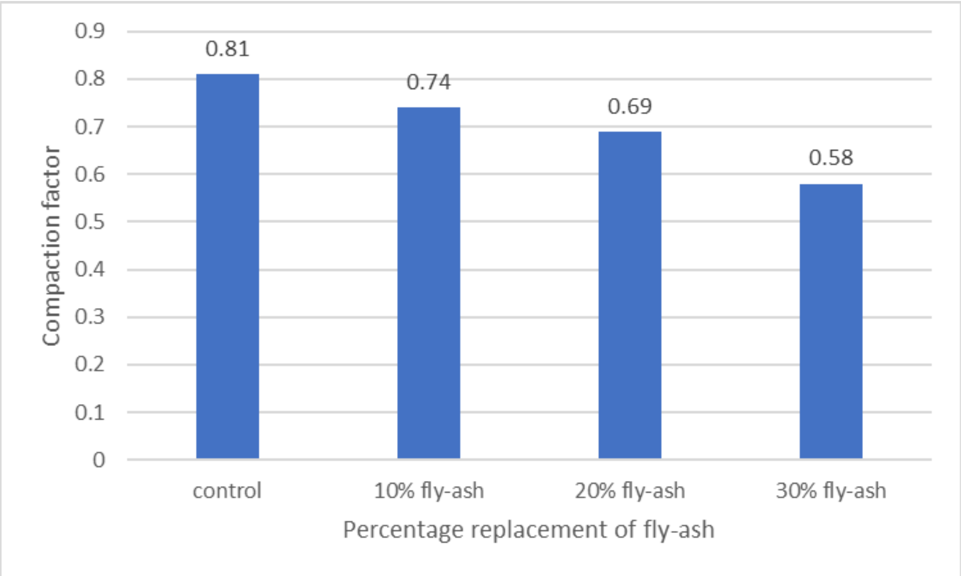

Fig 5: Compaction factor values

4.2. Compression Strength Test

It is seen that as the % of fly-ash and Cinder increases the Compressive strength decreases.

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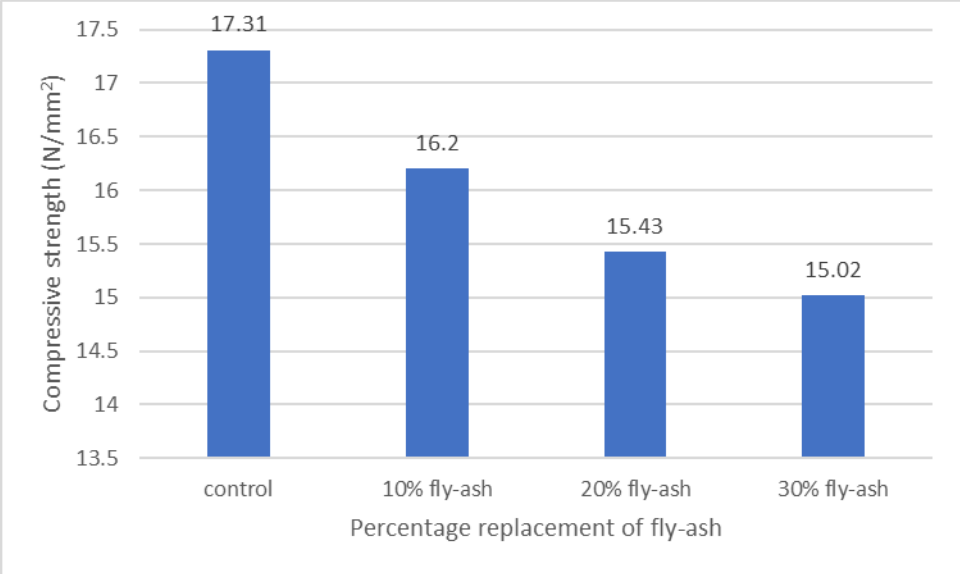

Fig 6 -Variation of compressive strength with different % of fly-ash

4.3 Split Tensile Strength Test

The concrete develops crack when subjected to Tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the Load at which the concrete member cracks .The experimental results are tabulated in the below table and variation of tensile strength with respect to cinder and fly-ash replacement is show in the figure .It is observed that increased % of fly-ash and Cinder the tensile strength is reducing.

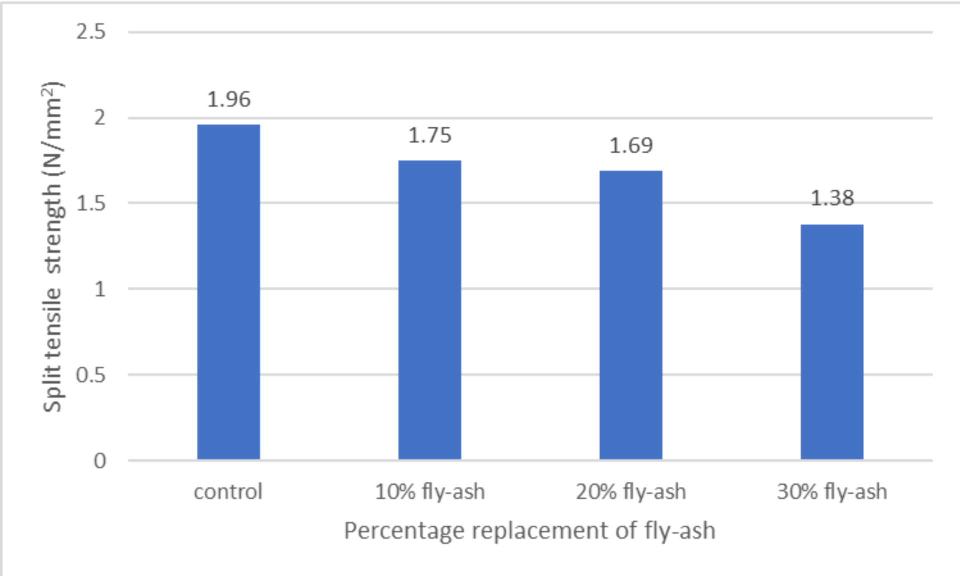

Fig7– Variation of split tensile strength with different % of fly-ash

5. CONCLUSIONS

- Generally, the increment in the cement substitution by Fly-ash caused decreasing the workability of concrete. The lowest reading reached 15 mm with the cement replacement 30% HNC. It showed a 49% reduction of workability with 30% replacement as compared to plain concrete (30mm).
- It is recorded that the peak of the compression strength after 28 days of curing there is decrease in the compression strength.
- The compressive strength and split-tensile strength of concrete have been proven to decrease when fly ash and cinder content has increased. The concrete cube reaches its maximum compressive strength at replacement rates of 20% for fly ash respectively.

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- The substitution of fly ash will result in a maximum drop in compressive strength and split-tensile strength of approximately 30% respectively.

6. REFERENCES

1. C. V. Siva Rama Prasad , "Light Weight Concrete using FlyAsh Aggregate", ISSN 2321-8665 Vol.05,Issue.03, March-2017
2. S Punlert , P Laoratanakul , "Effect of lightweight aggregates prepared from fly ash onlightweight concrete performances",IOP Conf. Series: Journal of Physics: Conf. Series 901 (2017) 012086 doi :10.1088/1742-6596/901/1/012086
3. N Ghazali , "Effect of Fly Ash as Partial Cement Replacement on Workability and Compressive Strength of Palm Oil Clinker Lightweight Concrete",,IOP Conf. Series: Earth and Environmental Science 682 (2021) 012038 doi:10.1088/1755-1315/682/1/012038
4. Midhun Mohan , "Light Weight Aggregate Concrete using Bottom Ash and Fly Ash",International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072
5. S.Azzaruddin, "Effect And Behaviour Of Light Weight Concrete Using Fly Ash Aggregate",,2016, IRJET | Impact Factor value: 4.45 | ISO 9001:2008 Certified Journal
6. Mr.Anil Kumar R, Dr. P Prakash. Studies on Structural Light Weight Concrete by Blending Light Weight Aggregates. International Journal of Innovative Research in Engineering & Management (IJIREM). 2015 Jul;Volume-2(Issue-4).
7. George S. Experimental Study of Light Weight Concrete by Partial Replacement of Coarse Aggregate Using Pumice Aggregate . Vol. 4. 2015. Available from: www.ijser.in
8. Desai VB, Sathyam MA. Some Studies on Strength Properties of Light Weight Cinder Aggregate Concrete. International Journal of Scientific and Research Publications . 2014;4(2). Available from: www.ijsrp.org
9. Hanuman E, Gupta S, Kumar VG, Tech (M. Investigations on Properties of Light Weight Cinder Aggregate Concrete [Internet]. Vol. 11, International Journal of Engineering Research. 2015. Available from: www.ijerd.com
10. Babu M v. PERFORMANCE OF LIGHT WEIGHT CONCRETE REPLACING COARSE AND FINE AGGREGATES WITH CINDER AND FLY ASH.
11. Kumar Agrawal A, Singh AK, Tech Scholar M. Experimental Study of Light Weight Concrete by Replacing Fine Aggregates and Coarse Aggregates by Cinder Aggregates . 2020. Available from: http://ijesc.org/
12. Vijaya S. Experimental Study on Light Weight Concrete using Leca and Cinder as Coarse Aggregates . Available from: www.ijert.org
13. C DA, N GS, Manohar Peter W, Patil SC, Sweta Patil AsstProfessor SC. Experimental Investigation on Concrete by Partial Replacement of Coarse Aggregate by Cinder. International Research Journal of Engineering and Technology . 2008;5413. Available from: www.irjet.net
14. Neelima M, Babu NV. Experimental Study on Structural Lightweight Concrete Utilizing Cinder and Pumice as Replacement of Coarse Aggregate Baba institute of technology and sciences, Visakhapatnam (INDIA) Baba institute of technology and sciences, Visakhapatnam (INDIA). International Journal of Research Available . Available from: https://edupediapublications.org/journals
15. Ganapathy PC. An Experimental Study on Feasibility of Cinder as Partial Replacement for Coarse Aggregate [Internet]. Vol. 4, IJSRD-International Journal for Scientific Research & Development|. 2016. Available from: www.ijsrd.com
16. Venkatesh N. @IJAPSA-2016, All rights Reserved Light Weight Aggrigates Of Cinder Mix Concrete With Comparison Between Compressive Strength And Density Values.
17. Veeresh B, Prasad BBCO, Kumar KS. Light Weight Aggregate Concrete by using Cinder. 2015; Available from: www.ijsetr.com
18. Zhong Tao a, Tian-Yi Song , Brian Uy , Lin-Hai Han ,Bond behaviour in concrete-filled steel tubes, Journal of Constructional Steel Research, 120, 81-93. https://doi.org/10.1016/j.jcsr.2015.12.030
19. Qu, X. Chen, Z., Nethercot, D. A., Gardner, L. and Theofanous, M. (2015). Push-out tests and bond strength of rectangular CFST columns. Steel and Composite Structures. 19(1), 21-41.
20. Allouzi, R.A.; Almasaeid, H.H.; Salman, D.G.; Abendeh, R.M.; Rabayah, H.S. Prediction of Bond-Slip Behavior of Circular/Squared Concrete-Filled Steel Tubes. Buildings 2022, 12, 456. https://doi.org/10.3390/ buildings12040456.
21. Marcin abramski, Load-Carrying Capacity Of Axially Loaded Concrete-Filled Steel Tubular Columns Made Of Thin Tubes.
22. Jia-Bao Yan, Bond behaviour of concrete-filled steel tubes at the Arctic low temperatures.