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Experimental Study on Mechanical Properties of Sintered Fly Ash Aggregate in Concrete

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ABSTRACT

There is heavy demand for the building materials in the domestic market, which is becoming scarce day by day. Presently in India the power sector depends on coal based thermal power station, which produce a huge amount of fly ash approximately to be around 200 million tones annually. The mass utilization of fly ash in concrete, essentially focused on sintered fly ash aggregate replaced by natural coarse aggregate is thought of in this investigation.

Keywords: *Sintered fly ash, fly ash, conventional concrete, compressive strength, natural course aggregate*

1. INTRODUCTION

1.1. GENERAL

In many countries, due to the increasing cost of raw materials and the continuous reduction of natural resources, the use of waste materials is a potential alternative in the construction industry. Waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications. The continued and expanding extraction of natural aggregate is accompanied by serious environmental problems. Often it leads to irremediable deterioration of rural areas, since quarrying of aggregates alters land topography and causes other potential problems, such as erosion. The artificial aggregates from industrial and post-consumer wastes are not only adding extra aggregate sources, but also reduce environmental pollution.

Fly ash disposed from thermal power plant is being beneficially utilized for various civil engineering applications such as for the production of blended cement, fly ash bricks, lightweight concrete blocks and lightweight aggregates. Presently in India the power sector depends on coal based thermal power station which produce a huge amount of fly ash approximately to be around 200 million tonnes annually. However, the utilization of fly ash is about 30% in concrete applications as cement replacement material. This replacement level needs to be increased and high volume fly ash addition in the future is well anticipated. The mass utilization of fly ash in concrete essentially focused as cement Replacement material or as aggregate fillers.

1.2. CHARACTERISTIC FEATURES OF FLY ASH

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitation. It is the most widely used pozzolanic material all over the World. In recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete. Extensive research has been done all over the world on the benefits that could be accrued in the utilization of fly ash as a supplementary cementitious material.

ASTM broadly classify fly ash into two classes,

Class F: Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has the pozzolanic properties only.

Class C: Fly ash normally producing by burning lignite or subbituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also possesses cementitious properties.

Use of quality fly ash results in reduction of water demand for desired slump. With the reduction of unit water content, bleeding and drying shrinkage will also be reduced. Since fly ash is not highly reactive, the heat of hydration can be reduced through replacement of part of the cement with fly ash. Fly ash when used in concrete, contributes to the strength of concrete due to its pozzolanic reactivity. Since the pozzolanic reaction proceeds slowly, the initial strength of fly ash concrete tends to be lower than that of concrete without fly ash. Due to continued pozzolanic reactivity concrete develops greater strength at later age, which may exceed that of concrete without fly ash. The pozzolanic reaction also contributes in making the texture of concrete dense, resulting in decrease of water permeability and gas permeability. The pozzolanic reactivity reduces the calcium hydroxide content, which results in reduction of passivity to the steel reinforcement and at the same time the additional secondary cementitious material formed makes the paste structure dense, and thereby gives more resistance to the corrosion of reinforcement. The addition of fly ash contributes to the reduction of the expansion due to alkali-aggregate reaction. The dilution effect of alkali and reduction of the water permeability due to dense texture may be one of the factors for reduction of alkali-aggregate reaction.

The fly ash in optimum proportion improves the quality of concrete by lowering the heat of hydration, thermal shrinkage, increasing the water tightness, improving the chemical resistance, reducing the alkali-aggregate reaction, improving the rate of strength development, improving corrosion resistance, improving the early strength, workability and extensibility.

1.3. SINTERED FLY ASH AGGREGATE
The fly ash collected from Thermal power stations burning pulverized fuel, is mixed with water and coal slurry in screw mixers and then fed onto rotating pans, known as pelletizers. The sintered fly ash aggregate is being produced by Pelletization and Sintering done at temperature range of 1100 to 1300 degree centigrade. The burning of the carbon in the pellets and loss of moisture creates a cellular structure bonded together by the fusion of fine ash particles. By heat treatment these small particle can be made of combine, thus forming the pellets or nodules which have considerable strength.

1.4 NEEDS FOR THE PRESENT STUDY
At present, 290 million tonnes of coal is consumed every year which constitutes nearly 40% of total power generation which in turn produces 175 million tonnes of fly ash and this is expected to increase to 225 million tonnes by 2017. Serious environmental problems are caused due to this large volume of fly ash. So there is a need to develop technologies for production of value added products on sustainable basis.

With increasing concern over the excessive exploitation of natural aggregates and environmental pollution, there is a need to look for an alternative aggregate which is economically viable and suitable for the construction industry. Fly ash aggregate is a viable new source of structural aggregate material. Usage of fly ash aggregate in concrete is the best disposal route of fly ash and also solves the problem of environmental pollution.

In view of the above, an attempt has been made in the present work to develop a concrete with partial replacement of coarse aggregates by SFA aggregates. This fulfils the need of alternative aggregates in concrete and prevent the environmental pollution due to the disposal of fly ash.

1.5. AIM AND OBJECTIVES
An attempt has been made in the present work to develop a concrete using Sintered fly ash aggregates and to assess its strength characteristics.

The following are the set objectives in the present work,
1. To study the properties of natural course aggregate and sintered fly ash aggregate.
2. To arrive the mix design for M30 grade concrete.
3. To study the fresh concrete properties of both conventional and SFAA concrete.
4. To study Mechanical properties of conventional concrete (CC) and sintered fly ash aggregate concrete.

1.6. SCOPE OF THE STUDY
This study deals with the preliminary concrete properties such as fresh and hardened concrete properties of the SFAA concrete are compare with conventional Concrete with a grade of M30.

2. LITERATURE REVIEW
2.1. LITERATURE STUDY
P. Gomathi and a. Sivakumar (2014) has carried out a on **" Cold Bonded Fly Ash Lightweight Aggregate Containing Different Binders"** This study investigates the production of alkali activated flyash aggregate containing different types of binders such as metakaolin, furnace slag and bentonite. The lightweight aggregate properties are greatly altered with the addition of binder material which can result in good binding properties to the flyash aggregate. The production of activated fly ash aggregate depends on the type and dosage of binders in the pelletizer. Pelletization process depends on the efficiency of production, gradation and crushing strength of aggregates which depends on the type and percentage of binder used, angle of disc, speed of disc and duration of pellet formation. The fly ash aggregates were produced and the effects of various binder materials (furnace slag (GGBS), bentonite and metakaolin) substituted at 10, 20 and 30% respectively of total binder material for various time duration were studied. The effect of alkali activator (sodium hydroxide) at a concentration of 8, 10 and 12 M, respectively were studied in flyash aggregates and the aggregates were cured in the hot air oven at 100ºC up to 7 days. Test results also exhibited that water absorption flyash aggregates made using GGBS binder was found to be lower than (12.88%) compared to bentonite (16.39%) and metakaolin (17.86%). The crushing strength test results showed that a maximum strength of 22.81 MPa was obtained in the case of fly ash-furnace slag aggregate, 17.62 MPa for fly ash-metakaolin aggregate and 14.51 MPa for fly ash-Bentonite aggregate.

Erhan Guneyisi, Mehmet Gesog˘lu, Ozgur Pursunlu, Kasım Mermerdas (2013) carried out work on **"Durability aspect of concretes composed of cold bonded and sintered fly ash lightweight aggregates"** This study reports the finding of an experimental study carried out on the durability related properties of the lightweight concretes (LWCs) including either cold bonded (CB) or sintered (S) fly ash aggregates. Two concrete series with water-to-binder (w/b) ratios of 0.35 and 0.55 were designed. Moreover, silica fume (SF) with 10% replacement level was also utilized for the purpose of comparing the performances of LWCs with and without ultrafine SF. The durability properties of concretes composed of CB and S aggregates were evaluated in terms of water sorptivity, rapid chloride ion permeability, gas permeability, and accelerated corrosion testing after 28 days of water curing period. The compressive strength test was also applied to observe the strength level at the same age. Cold bonded (CB) and sintered (S) aggregates were produced with water absorption values of 16.3% and 11.7%, respectively. The combined use of S aggregate and SF provided the compressive strength values of 54 MPa and 44 MPa for w/b ratios of 0.35 and 0.55, respectively.

S. Lokesh, m. G. Ranjith kumar, s. Loganathan (2013) Made On Investigaon On**"Effective Utilization of High Volume Flyash with Light Weight Aggregate in Concrete for Construction Industry"** has studied the properties, such as compressive strength and tensile strengths of lightweight concrete containing fly ash aggregate. Fly ash Aggregates are weaker than Natural Granite and hence they influence significantly the strengths of concrete. So replacing coarse aggregates up to 40% by Fly ash Aggregate the strength of concrete can be retained. In these Fly ash Aggregate Concretes substantial amount of Fly ash is used as a cement replacement material and these concretes can be considered as Light Weight Aggregate Concrete masonry grade. High Volume Fly ash Aggregate Concrete provided with cement replacement by 40% Fly ash by weight of total binder, resulted in reduced compressive, tensile and flexure strengths in the early days of hydration. Silica Fume used as replacement of Fly ash, by 10% of total binder weight, compensated the loss of strengths in initial days. Fly ash Aggregate Concretes can be produced by having strength more than 25N/mm2 which can be used in structural components of the structures.

Mehmet Gesog˘lu (2013) made a work on **"Effect of silica fume and steel fiber on the mechanical properties of the concretes produced with cold bonded fly ash aggregates "**The production of concretes with artificial cold bonded fly ash aggregates having proper mechanical properties was proved to be possible through incorporation of silica fume and steel fibers. Use of SF as a replacement material provided improved mechanical properties of concretes when compared to plain ones for both w/b ratios. The highest compressive strength values were measured as 49.2 and 34.3 MPa for concrete groups with w/b ratios of 0.35 and 0.55, respectively. The inclusion of steel fibers also contributed to the compressive strength. The long fibers (St1) provided higher compressive strength development than St2 incorporated concretes with increase in volume fraction. The level of improvement was more pronounced for SF concretes than plain ones. As steel fiber volume fraction increased, the bond strength also increased remarkably. The steel fiber with aspect ratio of 80 indicated the best bond strength value when compared with aspect ratio of 55 and 65. The strength of the concrete was significantly affected by artificial fly ash aggregate content. The compressive strength of the concrete increases up to 35% and split tensile strength increases up to 70%. Addition of steel fiber is effective up to 0.70% above which the compressive strength starts to fall.

A.Siva Kumar., et.al-(2011) - Pelletized fly ash lightweight aggregate concrete Crushed aggregates are commonly used in concrete which can be depleting the Natural resources and necessitates an alternative building material. Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. The use of cost effective construction materials has accelerated in recent times due to the increase in the demand of light weight concrete for mass applications. This necessitates the complete replacement or partial replacement of concrete constituents to bring down the escalating construction costs. In recent times, the addition of artificial aggregates has shown a reasonable cut down in the construction costs and had gained good attention due to quality on par with conventional aggregates. The cost effective and simplified production techniques for manufacturing fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects.

Glory Joseph, K. Ramamurthy (2011) made on investigation on **"Influence of fly ash on strength and sorption characteristics of cold-bonded fly ash aggregate concrete.** Cold-bonded fly ash aggregate concrete with fly ash as part of binder or fine aggregate facilitates high volume utilization of fly ash in concrete with minimum energy consumption. This paper investigates the influence of fly ash on strength and sorption behavior of cold-bonded fly ash aggregate concrete due to partial replacement of cement and also as replacement material for sand. While cement replacement must be restricted based on the compressive strength requirement at desired age, replacement of sand with fly ash appears to be advantageous from early days onwards with higher enhancement in strength and higher utilization of fly ash in mixes of lower cement content. Microstructure of concrete was examined under BSEI mode. Replacement of sand with fly ash is effective in reducing water absorption and sorptivity attributable to the densification of both matrix and matrix–aggregate interfacial bond. Cold bonded fly ash aggregate concrete with a cement content of 250 kg/m3, results in compressive strength of about 45 MPa, with a total inclusion of around 0.6 m3 of fly ash in unit volume of concrete.

Gao Li-xiong et al (2011) have presented a research on **"sintered fly ash aggregate"**. The aggregate was manufactured through material orthogonal test and quick chilled firing schedule test. It displayed high strength and low water absorption. Light weight aggregate concrete made with this aggregate showed high compressive strength, workability and expansibility. Such properties meet the modern concrete requirements for high strength and pump-ability. This new technology has important economic and social impacts on the use of industrial waste residue and on the environmental protection.

Niyazi Ugur Kockal, Turan Ozturan (2010) carried out work on **"Effects of lightweight fly ash aggregate properties on the behavior of lightweight concretes"** The performance characteristics of lightweight concretes (LWCs) and normalweight concrete (NWC) were investigated through compressive strength, modulus of elasticity and splitting tensile strength. Lightweight concretes with 28-day compressive strength ranging from 42.3 to 55.8MPa and modulus of elasticity varying between 22.4 and 28.6 GPa were produced with cold-bonded and sintered fly ash aggregates. Lightweight concretes with cold-bonded fly ash aggregate had lower compressive strength and modulus of elasticity compared to the sintered fly ash aggregate.

Workability of fresh lightweight concrete was positively affected by the spherical shaped lightweight fly ash aggregates which may also result in a decrease of water demand for constant slump. Low specific gravities of cold-bonded and sintered fly ash aggregates were beneficial to produce lightweight concretes with densities in the range of 1860–1943 kg/m3. Splitting tensile strength of the lightweight concretes varied from 3.7 to 4.9MPa exhibiting the lowest values with cold-bonded fly ash aggregates.

Song Mu, Bao-guo Ma, Geert De Schutter, Xiang-guo Li, Yao-cheng Wang, Shouwei Jian (2010) carried out work on **"Effect of shale addition on properties of sintered coal fly ash"** In this paper, these characteristics of sintered fly ash with or without shale (binder) were investigated by physical property, X-ray diffraction and scanning electron microscopy. The results show that shale addition ranging from 30% to 50% (in weight) can be beneficial for properties of sintered products at temperature ranging from 950 to 1050oC. However, a higher amount of shale easily caused significant bloating at 1100oC. Considering energy saving and best performance, the sintering mix for shale and fly ash (50% in weight respectively, the same as below) fired at 1000oC for 2 h was an optimal option.

Rajamane et al (2009) made a **work "Studies on development of bonded fly ash aggregates for use as coarse aggregate in structural grade concretes** "have reported that it is possible to produce coarse aggregates from fly ash by Pelletization techniques for use in structural grade concrete. They also studied the properties like bulk density, specific gravity, water absorption and aggregate crushing value. The concrete made with the bonded fly ash coarse aggregate has high slump, low density and also to produce minimum structural grade concrete as recommended in IS 456- 2000.The permeability indicating tests such as sorptivity, rate of water absorption, rapid chloride permeability test etc. indicate satisfactory durability characteristics.

O. Kayali (2007) carried out work on **"Fly ash lightweight aggregates in high performance concrete"** has studied that the concrete made with FAA was 25% stronger than that made using pelletized fly ash based lightweight aggregates. Further, the strength of the lightweight concrete manufactured with FAA was higher than the traditional normal weight concrete by 20%. These results open the prospect of investigating the opportunity to be able to reduce the quantity of cement that is required to produce concrete of a specific strength. Such reduction would reduce carbon dioxide emission and hence would be beneficial to the environment. The reduction in weight of the structure may also produce an opportunity to investigate the possible reduction in the overall cost of the construction.

3. MATERIAL PROPERTIES

3.1. GENERAL

The main ingredients of the sintered fly ash aggregate concrete are

- Cement
- Fine aggregate
- Coarse aggregate
- sintered fly ash aggregate
- Water
- Superplasticizer – SP conplast 430

3.2. CEMENT

In general, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment, and cement. The chemical composition and fineness of cement can influence the age – strength relation of concrete quite significantly. The early strengths of cement are generally attributed to higher content of tri-calcium silicate (c3s) than di-calcium silicate (c2s). Ordinary Portland cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is classified into three types, 33 grade, 43 grade, 53 grade. The 33, 43, 53 represents the compressive strength of cement mortar at 28 days. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. In the present work 53 grade cement is used for casting.The physical properties of cement are obtained by conducting following tests as per the IS a standard namely IS 1727:1967 and IS 4031(Part – 5):1988.

TABLE 3.1 PHYSICAL PROPERTIES OF CEMENT

SL. NO	PROPERTIES	TEST RESULTS	As per IS code
1	Specific gravity	3.15	3.10 – 3.20
2	Normal consistency	33%	25 – 35%
3	Initial setting time	35minutes	>30 minutes
4	Fineness test by sieve analysis	4%	Should not greater than 10%

3.3. AGGREGATES

The aggregates are generally classified into two types natural and manufactured. Natural aggregates are either dug from a pit or dredged from the river or creek. Processed coarse aggregates are obtained by quarrying solid rock and then crushing it to a suitable size and grading. Aggregate properties greatly influence the behavior of Concrete, since they occupy about 75% of the total volume of concrete. The aggregate are classified as

1. F i n e aggregate
2. C o a r s e aggregate

.3.4. FINE GGREGATES

Sand is the granular form of silica (sio2). The grains vary in size and shape and they may be rounded or angular. The weathered product of stone and rock are natural sand. In India, river sand is used as a fine aggregate.

The grains of river sand or not sharp and angular and mostly they are rounded due to mutual attrition under the action of water current. Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge. Usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as a fine aggregate. The sand used for the experimental works was locally procured and conformed to grading zone II.

Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS383-1970. According to IS 383:1970 the fine aggregate is being classified into four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. The following tests are carried out on fine aggregate as per IS: 2386 (Part3) - 1963 to find out its physical properties

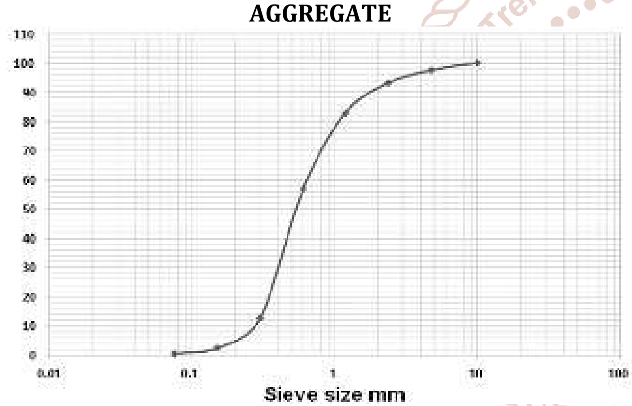
TABLE 3.2 PROPERTIES OF SAND

S. NO	PROPERTIES	TEST RESULTS
1.	Specific gravity	2.64
2.	Water gravity	1 %
3.	Fineness modules	2.548
4.	Sieve analysis	Conforming to zone II

TABLE 3.3 TEST RESULT OF SIEVE ANALYSIS FOR FINE AGGREGATE

IS Sieve Size	Weight Retained (gm)	Percentage weight Retained (gm)	Cumulative Percentage Weight Retained (gm)	Percentage Passing %
10mm	0	0	0	100
4.75mm	25	2.5	2.5	97.5
2.36mm	44	4.4	6.9	93.1
1.18mm	104	10.4	17.3	82.7
0.60mm	258	25.8	43.1	56.9
0.30mm	443	44.3	87.4	12.6
0.15mm	102	10.2	97.6	2.4
0.075mm	20	2	99.6	0.4
PAN	4	0.4	100	0

FIGURE3.1 SIEVE ANALYSIS GRAPH OF FINE AGGREGATE



3.5. COARSE AGGREGATE

Coarse aggregate for structures consist of materials within the range of 5mm to 150 mm size. The materials which are retained on a 4.75 mm sieve are called coarse aggregate. Rock having absorption greater than 3% or specific gravity or less than 2.5 or not considered suitable for mass concrete. However in practice mixes of same workability a round shaped aggregate requires less water than angular shaped aggregate. Coarse aggregate forms the main matrix of the concrete. The nature of work decides the maximum size of the coarse aggregate.

Coarse aggregate in cement concrete contributes to the heterogeneity of the cement concrete and there is weak interface between cement matrix and aggregate surface in cement concrete. This results in lower strength of cement concrete by restricting the maximum size of aggregate and also by making the transition zone stronger. Locally available coarse aggregate having the size of 4 . 7 5 m m t o 1 2.5 mm was used in the present work. Types of Coarse Aggregates used in this research work

1. Natural coarse aggregate
2. Sintered fly ash aggregate

3.6. SINTERED FLY ASH AGGREGATE

Fly ash is finely divided residue, comprising of spherical glassy particle, resulting from the combustion of powered coal. The sintered fly ash lightweight aggregate is being produced by Pelletization and Sintering done at temperature range of 1100 to 1300 degree centigrade. The burning of the carbon in the pellets and loss of moisture creates a cellular structure bonded together by the fusion of fine ash particles. By heat treatment these small particle can be made of combine, thus forming the pellets or nodules which have considerable strength. SFAA used in this investigation were bought form GBC India limited, Gujarat. SFAA passing through 12.5mm sieve and retained in 4.75mm sieve were used in this investigation.

The physical properties of natural coarse aggregate and sintered fly ash aggregate are obtained by conducting following tests as per the IS a standard namely IS 2386 – 1963 part – I, part – II, part – III and IS 9142 – 1979.

FIGURE 3.2 PHOTOGRAPH OF SINTERED FLY ASH AGGREGATE (Purchased from GBC India private limited, Gujarat)

TABLE 3.4 PROPERTIES OF NATURAL COARSE AGGREGATE AND SINTERED FLYASH AGGREGATE

SL. NO	PROPERTIES	NATURAL AGGREGATE	SINTERED FLYASH AGGREGATE	IS CODE AS PER CODE
1	Specific Gravity	2.65	1.395	-
2	Aggregate Crushing Value (in percentage)	13	20	45
3	Aggregate Impact Value (in percentage)	16	28	45
4	Bulk density Loosest state (kg/m^3)	1490	830	-
5	Bulk density Densest state (kg/m^3)	1625	890	-
6	Water absorption (in percentage)	0.9	16.8	10
7	Void ratio (in percentage)	38.65	35.84	-

TABLE 3.5 TEST RESULT OF SIEVE ANALYSIS FOR NATURAL COARSE AGGREGATE

IS Sieve Size	Weight Retained(gm)	Cumulative weight retained (gm)	Cumulative Percentage Weight retained (%)	Percentage Passing (%)
20mm	0	0	0	100
16mm	125	125	2.5	97.5
12.5mm	1282	1407	28.14	71.86
10mm	2186	3593	71.86	28.14
4.75mm	1390	4983	99.96	0.34
PAN	17	5000	100	0

TABLE 3.6 TEST RESULT OF SIEVE ANALYSIS FOR SINTERED FLY ASH AGGREGATE

IS Sieve Size	Weight Retained (gm)	Cumulative weight retained (gm)	Cumulative Percentage Weight retained (%)	Percentage Passing (%)
20mm	0	0	0	100
16mm	239	239	4.78	95.22
12.5mm	1007	1246	24.92	75.08
10mm	1890	3136	62.72	37.28
4.75mm	1812	4948	98.96	1.04
PAN	52	5000	100	0

FIGURE 3.3 SIEVE ANALYSIS GRAPH OF NATURAL COARSE AGGREGATE

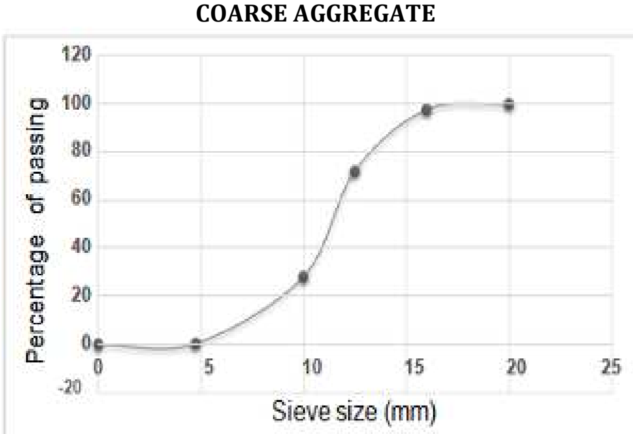


FIGURE 3.4 SIEVE ANALYSIS GRAPH OF SINTERED FLY ASH COARSE AGGREGATE

3.7. WATER
Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Portable water is generally considered satisfactory. In the present investigation, tap water was used for both mixing and curing purposes.

3.8. SUPERPLASTICIZER
In this study, SP conplast 430 sulphonated naphthalene polymers based super plasticizer is used. Conplast SP430 is a chloride free, superplasticising admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively. The very high levels of water reduction possible allow major increases in strength to be obtained.

TABLE 3.7 PHYSICAL PROPERTIES OF SUPERPLASTICIZER

Appearance	Brown liquid
Specific gravity	1.220 at 30°C
Chloride content	Nil to IS 456
Air entrainment	Typically less than 2% additional air is Entrained at normal dosages
Alkali content	Typically less than 72.0 g Na2O equivalent/litre of admixture

4. MIX DESIGN – M**30** grade concrete
4.1. STIPULATIONS FOR PROPORTIONING
A. Grade designation=M_{30}
B. Type of cement=OPC 53 grade conforming to IS 12269
C. Maximum nominal size of aggregate=12.5mm
D. Minimum cement content=320 kg/m³
E. Maximum water-cement ratio=0.45
F. Workability=100mm slump
G. Exposure condition=severe (for heavily reinforced section)
H. Degree of supervision=Good
I. Type of aggregate=crushed angular aggregate
J. Maximum cement content=450 kg/m3
K. Chemical admixture type=super plasticizer

4.2. TEST DATA FOR MATERIALS
A. Cement used=OPC 53 grade conforming to IS 12269
B. Specific gravity of cement=3.15
C. Chemical admixture=SP conplast 430
D. Specific gravity of coarse aggregate=2.65
E. Specific gravity of Fine aggregate=2.64
F. Water absorption of coarse aggregate=0.9%
G. Water absorption of Fine aggregate=1%
H. Sieve analysis coarse aggregate=Conforming to Table 2 of IS 383
I. Sieve analysis Fine aggregate=Conforming to Zone II of IS 383

4.3. TARGET STRENGTH FOR MIX PROPORTIONING
f'ck = fck + 1.65 *s*
Where,
f'ck = target average compressive strength at 28 days,
fcc = characteristic compressive strength at 28 days, and
s= standard deviation.

From Table I, standard deviation, *s* =5 N/mm2•
Therefore, target strength =30 + 1.65 x 5 =38.25 N/mm2•

4.4. SELECTION OF WATER-CEMENT RATIO
From Table 5 of IS 456, maximum water-cement ratio = 0.45.
Adopt water-cement ratio as 0.35.
0.35< 0.45, hence O.K

4.5. SELECTION OF WATER CONTENT
From Table 2, maximum water content =202.5 litre (for 100 mm slump range) for 12.5 mm aggregate

Estimated water content for 100 mm slump =202.5+ 6/100 X 202.5 =214.65 litre

As super plasticizer is used, the water content can be reduced up 20 percent and above. Based on trials with super plasticizer water content reduction of 29 percent has been achieved. Hence, the arrived water content =214.65 x 0.71 =152.5 litre

4.6. CALCULATION OF CEMENT CONTENT
Water-cement ratio 0.35
Cement content = (152.4/0.35)
= 435.4 kg/m3
From Table 5 of IS 456, minimum cement
Content for 'severe' exposure condition = 320 kg/m3
435.4kg/m3 > 320 kg/m3, hence, O.K

4.7. PROPORTION OF VOLUME OF C.A AND F.A CONTENT
From Table 3. Volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone II)
For water-cement ratio of 0.50 =0.60

In the present case water-cement ratio is 0.35. Therefore. Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02(at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio). Therefore corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.35 = 0.52.

Volume of fine aggregate content = 0.52 m3
Volume of fine aggregate content =1 - 0.52 =0.48 m3

4.8. MIX CALCULATIONS
The mix calculations per unit volume of concrete shall be as follows
A. Volume of concrete = 1 m3
B. Volume of cement= mass of cement/specific gravity of cement x 1/1000
= [435.4/3.15] x [1/1000]
=0.1524 m3
= 0.137 m3
C. Volume of water= [152.4/1] x [1/1000]
=0.1524 m3
D. Volume of admixture = [8.71/1.220] x [1/1000]

=0.0071 m3

E. Volume of all in aggregate = (1 – (a+b+c+d))
=1-(0.111 +0.1+0.0071) e
= 0.743 m3

F. Mass of coarse aggregate = *e* x Volume of coarse aggregate x Sp. gravity of coarse Aggregate x I 000
=0.7035 x 0.52 x 2.65 x 1000
=969.42kg

G. Mass of fine aggregate = *e* x Volume of coarse aggregate x
Sp. gravity of coarse Aggregate x
I 000
=0.7035 x 0.48 x 2.64 x 1000
=891.5 kg

4.9. MIX PROPORTIONS

M30 CONCRETE
CEMENT CONTENT = 435.4 kg/m3
FINE AGGREGATE = 891.5kg/m3
COARSE AGGREGATE = 969.4 kg/m3
WATER CONTENT = 152.4 kg/m3
SUPER PLASTICIER = 2% By Weight of Cement Content

TABLE 4.1 MIX PROPORTION

Sl. No	Mix Id	Mix Proportion	Water Cement Ratio
1	CC	1:2.05:2.23	0.35

4.10. MIXES INCLUDED IN THE STUDY

❑CC – Natural Coarse aggregate
❑SFAA-20 – Natural coarse aggregate with 20% of SFA
❑SFAA-40 – Natural coarse aggregate with 40% of SFA
❑SFAA-60 -Natural coarse aggregate with 60% of SFA

TABLE 4.2 QUANTITIES OF MATERIAL

MATERIALS (Kg/m³)		MIX DESIGN AS PER IS 10262-2009 M30 GRADE			
		CC	SFAA-20	SFAA-40	SFAA-60
CEMENT		435	435	435	435
FINE AGGAREGATE		891.5	891.5	891.5	891.5
COARSE AGGREGATE	NA	969.4	775	581	388
	FAA	-	194.4	388.4	581.4
	TOTAL	969.4	969.4	969.4	969.4
WATER		152.4	152.4	152.4	152.4
SUPER PLASTICIER (SP conplast 430) (2% by weight of cement)		8.7	8.7	8.7	8.7

5.1. GENERAL

This research work presents the results of an experimental work on the effects of sintered fly ash aggregate in concrete. It is proposed to replace partially, the sintered fly ash aggregate (SFAA) in different percentage for the conventional aggregate. Initially the Properties of sintered fly ash aggregate were studied and compared with natural coarse aggregate for its suitability. Based on IS 10262 – 2009, mix design for M30 grade of concrete was done and it was arrived as 1: 2.05: 2.23. Here for the coarse aggregate, the sintered fly ash aggregate were replaced by 20%, 40%, and 60% in that mix ratio. Using this mix, the standard specimens were cast to ascertain the Mechanical properties and stress strain relationship of conventional concrete and SFAA concrete.

5.2. MIXING OF CONCRETE

The various materials used in the concrete mix were weighed as per the requirements arrived from the mix design. As the water absorption of SFAA is 16%, the SFAA is soaked in water for 24 hour and it's used in saturated surface dried condition. The materials were mixed using batch mixer at room temperature. The cement, fine aggregate, sintered fly ash aggregate, coarse aggregate and was fed one by one into the batch mixer and mixed in the dry state for 2 minutes. 80% of the required water content was mixed with the dry mix. The remaining 20% was mixed with the super plasticizer dosage and then added with the concrete mix. It was allowed to mix for 1 minute to improve the homogeneity

FIGURE 5.1 MATERIALS

FIGURE 5.2 MIXING OF CONCRET

5.3. TESTS ON FRESH CONCRETE

Fresh concrete or plastic concrete is freshly mixed material, which can be moulded into any shape. The relative quantities of cement aggregates and water mixed together control the properties in the wet state as well as in hardened state.

Workability is the important quality of fresh concrete. Workability is defined as the ease with which sample given set of materials can be mixed into concrete and subsequently handled, transported, placed and compacted with minimum loss of homogeneity. The word workability or workable concrete signifies much wider and deeper meaning than terminology the 'consistency' which is often used loosely for workability. Consistency is the general term to indicate degree of mobility.

The fresh concrete properties of concrete is done by conducting slump test for concrete as per IS 1199: 1959. The measurement workability is done by slump test as described below.

5.4. SLUMP TEST

Slump test is the most commonly used method of measuring workability of concrete. The apparatus for conduction the slump test consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as follows,

Bottom Diameter : 200mm
Top Diameter : 100 mm
Height : 300 mm

The mould is filled with concrete in three layers. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. The mould is removed from the concrete by raising it slowly and carefully in a vertical direction. The difference in level between the height of the mould and height of subsided concrete is noted and it is taken as slump value.

5.5. CASTING AND CURING OF SPECIMENS

The specimens are cast by using required size of moulds. The concrete is placed by the three layers for proper compaction. After casting, specimens are left for 24 hours for setting and then it is demoulded. Identification marks are made on face of the specimen and it is immersed in curing tank.

5.6. TESTS ON HARDENED CONCRETE

5.7. COMPRESSIVE STRENGTH TEST (AS PER IS 516-1959)

The cube specimens were tested for compressive strength at the end of 3, 7, 28days. The surface water and grit were wiped of the specimen and any projecting finds were removed the dimensions of the specimens and their weight were recorded before testing.

The bearing surfaces of the testing machine was wiped clean and again the surface of the specimen was cleaned from sand and other materials which may come in contact with the compression plates. While placing the specimen in the machine care was taken such that the load was applied to opposite sides of the specimen as casted and not to the top and bottom. The axis of the specimen was carefully aligned with the center of thrust of the spherically seated plate. As the spherically seated block is brought to bear on the specimen, the movable portion was rotated gently by hand so that uniform seating was obtained. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load broke and no greater load could be borne. The maximum load applied to the specimen was recorded and any usual appearance in the type of failure was noted.

The measured compressive strength of the specimen was scalculated by the following equation.

Compressive Strength (fck) =Ultimate load/Area of specimen (mm2)

FIGURE 5.5 COMPRESSIVE TEST IN CTM

FIGURE 5.6 CRACK PATTERN OF TESTED CUBES

5.8. SPLIT TENSILE STRENGTH TEST ON CONCRETE (AS PER IS 516-1959)

The cylinder specimens were tested for split tension at the end of 7, 28days. The surface water and grit were wiped of the specimen and any projecting finds were removed the dimensions of the specimens and their weight were recorded before testing. The bearing surfaces of the testing machine was wiped clean and again the surface of the specimen was cleaned from sand and other materials which may come in contact with the compression plates. While placing the specimen in the machine care was taken such that the load was applied to longitudinal direction of the specimen as casted and not to the top and bottom. The axis of the specimen was carefully aligned with the center of thrust of the spherically seated plate.

As the spherically seated block is brought to bear on the specimen, the movable portion was rotated gently by hand so that uniform seating was obtained. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load broke and no greater load could be borne. The maximum load applied to the specimen was recorded and any usual appearance in the type of failure was noted. As per the IS standards the splitting tensile strength was carried out by the below formula,

Split tensile strength (ft) = 2P/πDL (N/mm2)
Where,P= Collapse load in Newton
D=Diameter of the cylinder in mm and
L= Length of the cylinder in mm.

FIGURE 5.7 SPLIT TENSION TEST IN CTM

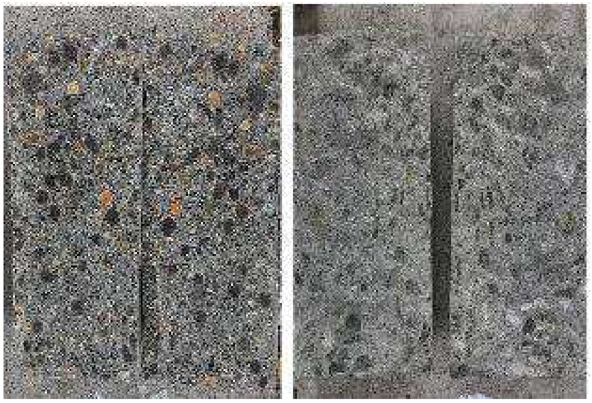


FIGURE 5.8 FAILURE PATTERN OF THE CYLINDER

5.9. FLEXURAL STRENGTH TEST ON CONCRETE (AS PER IS 516-1959)

The prism was tested for flexure strength at the end of 28days. The surface water and grit were wiped of the specimen and any projecting finds were removed the dimensions of the specimens and their weight were recorded before testing.

The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould; the axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers. The load shall be applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 7 kg/sq cm/min, that is, at a rate of loading of 400 kg/min for the 10.0 cm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

The flexural strength of the specimen shall be expressed as the modulus of rupture fb,

Flexural strength (fcr) = PL/BD2 Where,
P = collapse load in newton
L = length of specimen in mm
B = Breadth of specimen in mm
D = Depth of specimen in mm.

5.10. STRESS - STRAIN RELATIONSHIP

The stress – strain relationship is obtained from concrete cylinders of diameter 150 mm and length 300 mm. The testing is done after curing for 28 days. The cylinder is fitted with extensometer having gauge length not less than 10.2 cm and not more than half the length of the specimen. On removing the cylinder from the water and while it is still in the wet condition, the extensometers are attached at the ends, in such a way that the gauge points are symmetrical about the centre of the specimen and in nose are nearer to either end of the specimen. The specimen is immediately placed in the Compression Testing Machine and accurately centred. The load is applied continuously and without shock at a rate of 140 kg / sq cm / min. The extensometer readings corresponding to the load increments were noted.

5.11. DETAILS OF TEST SPECIMENS

M30 grade consisted of four concrete mixes: one conventional mix and three sintered fly ash aggregate of 20%, 40%, and 60% replacement of natural coarse aggregate by weight. Details of test specimen as shown in table 5.11

TABLE 5.1 DETAILS OF TEST SPECIMENS

S.NO	SPECIMEN	REPLACEMENT OF SFAA IN %	NO OF SPECIMEN			TOTAL
			3 D	7 D	28 D	
1	CUBE (100mmX100mmX100mm)	0	3	3	3	36
		20	3	3	3	
		40	3	3	3	
		60	3	3	3	
2	CYLINDER (100mmX200mm)	0	-	3	3	24
		20	-	3	3	
		40	-	3	3	
		60	-	3	3	
3	CYLINDER (150mmX300mm)	0	-	-	3	12
		20	-	-	3	
		40	-	-	3	
		60	-	-	3	
4	PRISM (100mmX100mmX500mm)	0	-	-	3	12
		20	-	-	3	
		40	-	-	3	
		60	-	-	3	

6. RESULTS AND DISCUSSION

6.1. GENERAL

The various tests on aggregate were conducted to determine physical property. In addition using that SFAA concrete were cast and it was tested for strength at various age. The results obtained from the tests were discussed in the following section.

6.2. FRESH CONCRETE PROPERTIES

The consistency of SFAA concrete has been measured by conducting a slump test in Concrete laboratory, In order to find the slump values of SFAA concrete with respect to increase percentage of sintered fly ash aggregate (SFAA). It is indicating that addition of SFA increase the workability of concrete.

SLUMP TEST

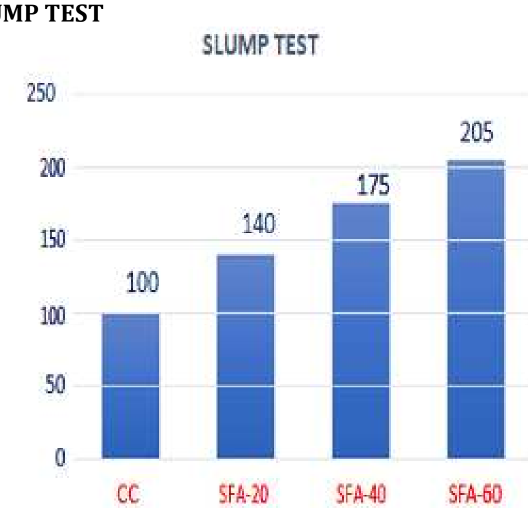


FIGURE 6.1 SLUMP VALUE OF SFAA CONCRETE

The workability of the concrete mixtures was in-creased with the increasing of SFAA from 20% to 60%. The figure 6.1 shows the slump values with respect to addition of SFAA.

6.2. HARDEND CONCRETE PROPERTIES

Fully cured, hardened concrete must be strong enough to withstand the structural and service loads which will be applied to it and must be durable enough to withstand the environmental exposure for which it is intended. When concrete is made with high-quality materials and is properly proportioned, mixed, handled, placed, and finished, it is one of the strongest and most durable of building materials. Here the harden properties of SFAA concrete has been investigated with respect to age of concrete and also effect of SFAA on concrete.

TABLE 6.1 COMPRESSIVE STRENGTH OF CONCRETE CUBE

SL.NO	MIX ID	COMPRESSIVE STRENGTH (MPa)			WET DENSITY (kg/m³)	DRY DENSITY (kg/m³) 28 -DAYS
		3-DAYS	7-DAYS	28-DAYS		
1	CC	22.77	25.87	32.1	2422	2487
2	SFAA-20	30.70	33.83	34.40	2297	2420
3	SFAA-40	33.97	39.6	40.93	2110	2300
4	SFAA-60	29.67	33.76	35.73	2093	2213

TABLE 6.2 SPLIT TENSILE STRENGTH CONCRETE

SL.NO	MIX ID	SPLIT TENSILE STRENGTH (MPa)		WET DENSITY (kg/m³)	DRY DENSITY (kg/m³) 28 -DAYS
		7-DAYS	28 -DAYS		
1	CC	2.21	2.69	2422	2399
2	SFAA-20	2.32	2.80	2297	2272
3	SFAA-40	3.26	3.92	2110	2221
4	SFAA-60	2.49	3.09	2093	2170

TABLE6.4 COMPRESSIVE, TENSILE AND FLEXURAL STRENGTH OF SFAA CONCRETE SPECIMENS

S.NO	MIX ID	Fck (MPa) At 28 Days	EXPERIMENTAL RESULTS		THEORITICAL RESULTS	
			Ft (MPa)	Fcr (MPa)	ft=0.6√fCK (MPa)	fcr=0.7√fCK (MPa)
1	CC	32.1	2.69	7.68	3.39	3.96
2	SFAA-20	34.40	2.80	6.25	3.51	4.11
3	SFAA-40	40.93	3.92	7.25	3.84	4.48
4	SFAA-60	35.73	3.09	6.40	3.58	4.28

FIG 6.2 COMPRESSIVE STRENGTH OF CONCRETE Vs % OF SFAA

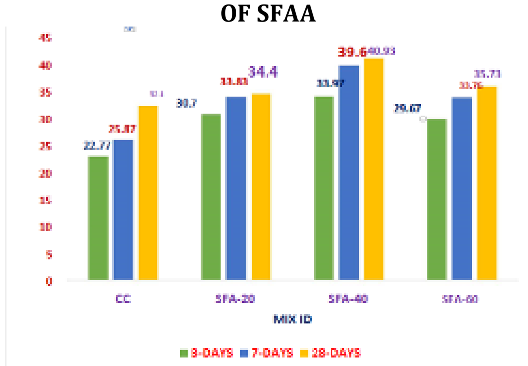


FIG 6.3 SPLIT STRENGTH OF CONCRETES Vs % OF SFAA

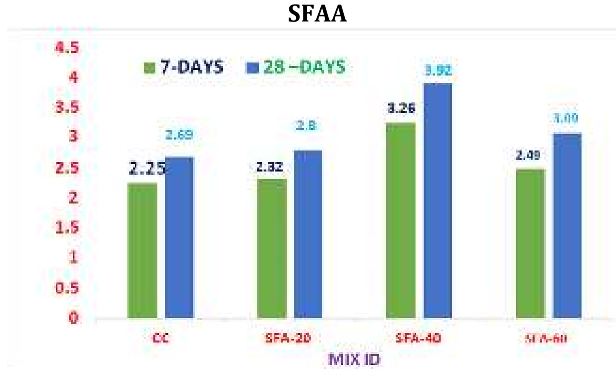


FIG 6.4 FLEXURAL STRENGTH Vs % OF SFAA

FIGURE 6.5 STRESS-STRAINS CURVE FOR CC

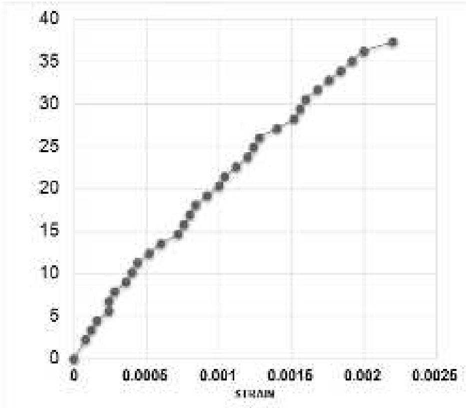


FIG6.6 STRESS- STRAIN CURVES FOR SFAA-20

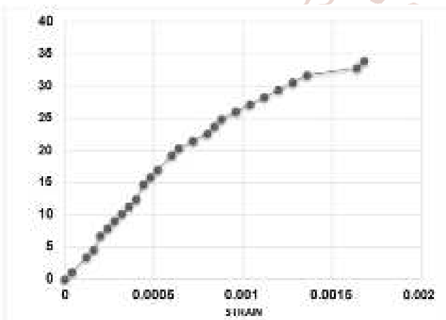


FIG6.7 STRESS-STRAIN CURVE FOR SFAA-40

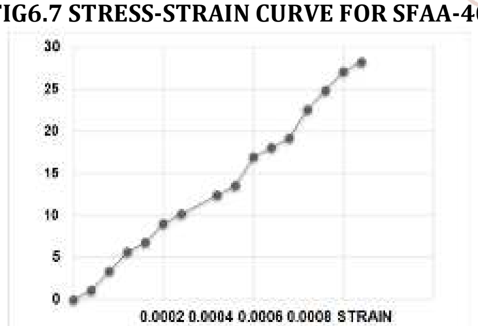


FIG 6.8 STRESS-STRAIN CURVE FOR SFAA-60

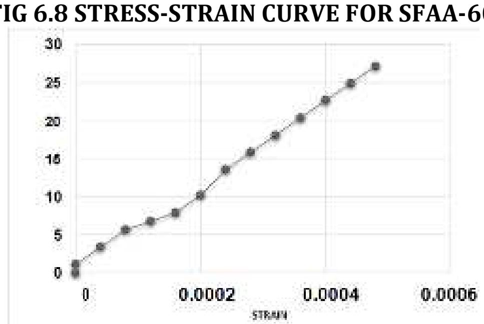
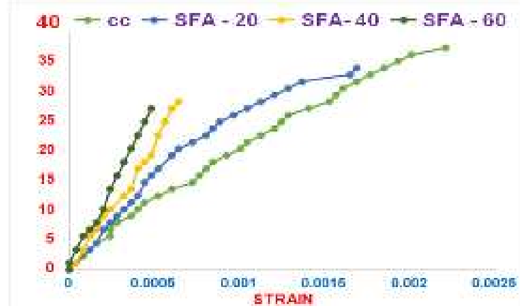


FIG 6.9COMPARISION OF STRESS-STRAIN CURVE-CONVENTIONAL CONCRETE Vs SFAA



7. CONCLUSION

This study present the experimental study of mechanical properties of sintered fly ash in concrete. From the results presented in this study the following conclusions are drawn.

The density of sintered fly ash aggregate (890 kg/m3) is low, compared to natural coarse aggregate (1625 kg/m3).

From the results, it is observed that the increase in the percentage of sintered fly ash aggregate in concrete gives good workability, compared to conventional concrete.

SFAA 40% replacement level gives good mechanical properties.

The dry density of concrete was decreased up to 11%, while compared with conventional concrete. Hence it is concluded that there is reduction in dead load of the specimens.

Obtained results suggest the SFAA concrete has scope for structural application.

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