Partial replacement of cement concrete by waste materials

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Abstract—**The aim of the study is to reduce the corn cob and saw dust waste materials and reduce the cost of concrete. Chemical composition of corn cob ash (CCA) and saw dust ash (SDA) as well as the workability and compressive strength properties of varying percentage of corn cob ash and saw dust ash cement concrete and 100% cement concrete of mixing ratios 1: 1.5: 3, 1:1:2 and water – cement ratios of 0.5 which later increased to 0.6 were examined and compared. Slump test was carried out to check the effect of corn cob ash and saw dust ash on the workability of fresh concrete. A total of 90 concrete cubes of size 150mm x 150mm x 150mm with different percentages by weight of corn cob ash and Saw dust ash to Portland cement in the order of 0%, 10% and 15% were cast. The concrete cubes were tested at the ages of 7, 14, 21, 28 and 56 days. The results showed that the corn cob ash and saw dust ash are a good pozzolans. The slump value decreased as the CCA and SDA contents increased indicating that concrete becomes less workable as the ashes content increased. The compressive strength of the concrete cubes increased as the days of curing increased and decreased with increasing ashes replacement. The highest compressive strength was 24.9N/mm2 and 22.4N/mm2 at 56 days for 0% and 10% of CCA (M25) and 24.9N/mm2, 23.9N/mm2 forSDA (M25) respectively. It was concluded that the use of CCA and SDA as a partial replacement for cement in concrete, particularly in plain concrete works and non – load bearing structures, will improve waste to wealth initiative though only 10% CCA and SDA replacement is adequate to enjoy maximum benefit of strength gain.**

IndexTerms—**Compressive strength, Corn cob ash, Saw dust ash.**

I. INTRODUCTION

Concrete is used more than any other man made material on this planet. It can be used for the construction of any type of structure. Because cement remains the most expensive ingredient in making a concrete. Concrete and the price of cement is increasing day by day, it is therefore important to find means of economizing the use of cement.The current cement production rate of the world is approximately 1.2 billion tons per year. This is expected to grow to about 3.5 billion tons per year by 2015.India is the second largest cement producer in the world and accounts for 6.7 per cent of world's cement output.It was gathered that the production of every ton of cement emits carbon dioxide (CO_2) to the tune of about one ton. When expressing it in another way, it can be concluded that 7% of the world's carbon dioxide emission is attributable to Portland cement industry. Because of the significant contribution to the environmental pollution, to the high consumption of natural resources like limestone and the high cost of Portland cement etc. we cannot go on producing more and more cement. There is need to economize the use of cement in concrete production. To reduction of waste materials like Fly Ash (FA) ,Ground Granulate Blast-furnace Slag (GGBS) ,Silica-fume , saw dust ash (SDA) , Rice Husk Ash (RHA) ,Phosphogypsum (PG) ,Ceramic Wastes (CW) ,Sewage Sludge (SS) and corn cob ash (CDA) are used in replacement of cement and reduce the cost of concrete production by making use of locally available materials.

1.1 SAW DUST

Saw dust is a waste material from the timber industry. It is produced as timber is sawn into planks at saw mills located in virtually all major towns in the country. This process is a daily activity causing heaps of saw dust to be generated after each day. The need to convert this waste product into a useful by-product is the focus of the study.

There is need for affordable building materials in providing adequate housing for the teaming populace of the world. The cost of conventional building materials continue to increase as the majority of the population continues to fall below the poverty line. Thus, there is the need to search for local materials as alternatives for the construction of functional but low-cost buildings in both the rural and urban areas. Some of the local materials that have been used are earthen plaster, lateritic interlocking blocks and Palm kernel shell.

Fig 1.1Saw DustFig 1.2Corn Cob

Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal.

.1.2 CORN COB

Corn cob is the hard thick cylindrical central core of maize (on which are borne the grains or kernels of an ear of corn). It is produced as timber and sawn into planks at saw mills located in virtually all major towns in the country. This process is a daily activity causing heaps of saw dust to be generated after each day. The need to convert this waste products (corn cob and saw dust) into a useful by – product is the focus of the study.

A light weight concrete using granulated of corn cob (without corn) as aggregate is proposed in this research work. Taking into account that corn cob, after extracting the corn, is generally considered an agricultural waste, an interesting economic and sustainable benefit may result by using it as a building material. Therefore, it can be an alternative sustainable lightweight aggregate solution in comparison to the most current applied ones such as expanded clay, particles of cork, particles of expanded polystyrene (EPS), among other. The density, the compressive strength and the thermal insulation

II. METHODOLOGY

Manufacture of Portland cement

Portland cement is made by blending the appropriate mixture of limestone and clay or shale together and by heating them at 1450 ^oC in a rotary kiln. The sequence of operations is shown in following figure. The preliminary steps are a variety of blending and crushing operations. The raw feed must have a uniform composition and be a size fine enough so that reactions among the components can complete in the kiln. Subsequently, the burned clinker is ground with gypsum to form the familiar gray powder known as Portland cement.

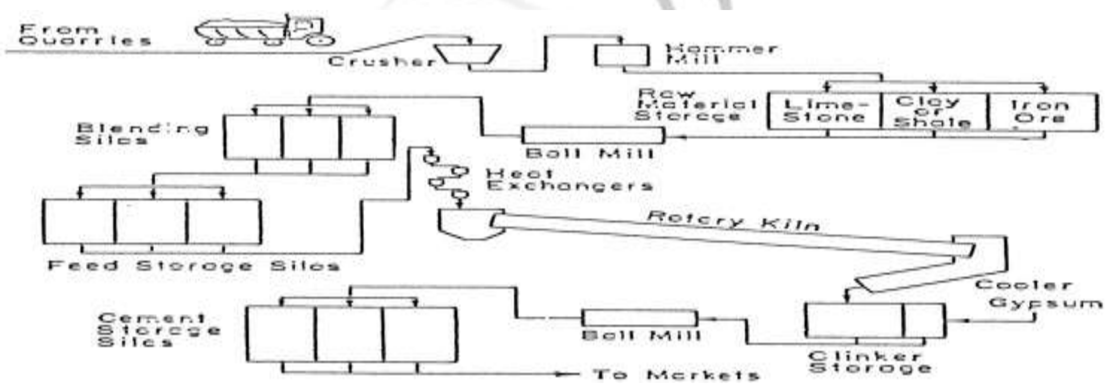


Fig 1.3 Manufacture of Portland cement

The raw materials used for manufacturing Portland cement are limestone, clay and Iron ore.

a). Limestone (C_aCO_3) is mainly providing calcium in the form of calcium oxide (*CaO*)

$$C_aCO_3 (1000^oC) \rightarrow CaO + CO_2$$

b). Clay is mainly providing silicates (SiO_2) together with small amounts of $Al_2O_3 + Fe_2O_3$

$$Clay\ (1450^oC) \rightarrow SiO_2 + Al_2O_3 + Fe_2O_3 + H_2O$$

c). Iron ore and Bauxite are providing additional aluminum and iron oxide (Fe_2O_3) which help the formation of calcium silicates at low temperature. They are incorporated into the raw mix.

Limestone 3 $CaO^o SiO_2$

High temperature 2 $CaO^o SiO_2$

Clay (1,450 ^{o}C) 3 $CaO^o Al_2O_3$

Iron Ore, Bauxite 4 $CaO^o Al_2O_3^o Fe_2O_3$

d). The clinker is pulverized to small sizes (< 75 µm). 3-5% of gypsum (calcium sulphate) is added to control setting and hardening.

The majority particle size of cement is from 2 to 50 µm. A plot of typical particle size distribution is given below. (Note: "Blaine" refers to a test to measure particle size in terms of surface area/mass)

Chemical composition of cement

a). Abbreviation:

CaO = C, SiO_2 = S, Al_2O_3 = A; Fe_2O_3 =F, $Ca(OH)_2$ = CH,

H_2O = H, SO_3 = *S* (sulphur trioxide)

Thus we can write 3 CaO = C_3 and 2 $CaO^o SiO_2$ = C_2S.

b). Major compounds

TABLE: 1 CHEMICAL COMPOSITION OF CEMENT

Compound	Oxide composition	color	Common name	Weight percentage
Tricalcium Silicate	C_3S	White	Alite	50%
Dicalcium Silicate	C_2S	White	Belite	25%
Tricalcium Aluminate	C_3A	White/grey	---	12%
Tetracalcium Aluminoferrite	C_4AF	C_4AF	Black Ferrite	8%

Since the primary constituents of Portland cement are calcium silicate, we can define Portland cement as a material which combine $CaOSiO_2$ in such a proportion that the resulting calcium silicate will react with water at room temperature and under normal pressure.

c). Minor components of Portland cement

The most important minor components are gypsum, MgO, and alkali sulfates.

Gypsum ($2CaSO_4^o 2H_2O$) is an important component added to avoid flash set (to be discussed in a latter section).

Alkalies (MgO, Na_2O, K_2O) can increase pH value up to 13.5 which is good for reinforcing steel protection. However, for some aggregates, such a high alkaline environment can cause alkali aggregate reaction problem.

Chemical Composition

Table 2 shows the elemental oxides present in the SDA sample. The result showed that SDA has combined percentages of (SiO2 +Al2O3 +Fe2O3) of 73.07% which is more than 70%, indicating that it is a good pozzolanic material in accordance with the requirements in ASTM C 618 (1991). The SDA has slightly lower silica content with a SiO2 of 65.75% as against that of SWIFA which is 67.20% (Elinwa and Ejeh, 2004) and CCA with a value of 66.38% (Adesanya and Raheem, 2009a).

TABLE:2 CHEMICAL COMPOSITION OF SAW DUST

Chemical constituents	Percentage composition (%)			
	Sample 1	Sample 2	Sample 3	Average
SiO2	65.42	66.05	65.79	65.75
Al2O3	5.69	5.12	4.88	5.23
Fe2O3	2.16	2.09	2.01	2.09
CaO	9.82	9.65	9.39	9.62
MgO	4.23	4.11	3.92	4.09
SO3	1.09	1.20	0.98	1.09
Na2O	0.04	0.08	0.07	0.06
K2O	2.38	2.22	2.68	2.43
CaCO3	7.89	7.32	8.54	7.92
LOI	4.89	4.05	3.95	4.30
LSF	1.09	1.98	2.07	1.71
SR	10.53	11.03	10.45	10.67
AR	11.35	12.88	12.73	12.32
Total SiO2 + Al2O3	71.11	71.17	70.67	70.98
Total SiO2 + Al2O3 + Fe2O3	**73.27**	**73.26**	**72.68**	**73.07**

Specimen Preparation

SDA was used to replace ordinary Portland cement at 5%, 10% and 15% by weight of cement. Concrete with no SDA present serves as the control experiment. The mix ratio used was 1:1.5:3 (binder, sand and granite) and 1:1:2 with water to binder ratio of 0.5 which was later increased to 0.6.

Slump and compacting factor tests were carried out to check the effect of SDA on the workability of fresh concrete. The tests were carried out in accordance with the requirements of BS 1881: Part 102 (1983) for slump test and BS 1881: Part 103 (1983) for compacting factor test.

Specimen preparation for compressive strength test was performed using 150mm cube steel moulds. The specimens were cast in three layers, each layer being tamped with 35 strokes of the tamping rod spread uniformly over the cross section of the mould. The top of each mould was smoothened and leveled and the outside surfaces cleaned. The moulds and their contents were kept in the curing room at temperature of 27 ± 50C and relative humidity not less than 90% for 24hours. De-moulding of the cubes took place after 24hours and the specimens were transferred into water bath maintained at 27 ± 50C in the curing room. Compressive strength was determined at curing age 3, 7, 28 and 56 days. The compressive strength was determined using compression machine with maximum capacity of 1500kN. The strength value was the average of three specimens.

Workability

The results of the slump and compacting factor, indicating the workability of the SDA concrete are shown in Table 5 and Table 6.. The table indicates that the slump value decreases as the SDA content increases.From these results, it was noticed that concrete became less workable as the SDA percentage increases meaning that more water is required to make the mixes more workable. This was what led to increasing the water binder ratio from 0.5 to 0.6 for the 15% substitution since the mix was becoming stiff.

The high demand for water as SDA increases is due to increased amount of silica in the mixture. This is typical of pozzolan cement concrete as the silica-lime reaction requires more water in addition to the water needed during hydration of cement.

CORN COB

Corn cob is the hard thick cylindrical central core of maize (on which are borne the grains or kernels of an ear of corn). as the agricultural waste product obtained from maize or corn;.). The United States was the largest maize producer having 43% of world production. Africa produced 7% of the world's maize (IITA Records; 2002). Nigeria was the second largest producer of maize in Africa in the year 2001 with 4.62 million tons. South Africa has the highest production of 8.04 million tons (FAO Records; 2002).

There had been various research efforts on the use of corn cob ash (CCA) and other pozzolan as a replacement for cement in concrete. Olutoge et al (2010); presented a comparative study on fly ash and ground granulated blast furnace slag (GGBS) high performance concrete, Ogunfolami (1995); considered mixing of the CCA with Ordinary Portland cement at the point of need (i.e. on site). Adesanya and Raheem (2010); studied the workability and compressive strength characteristics of Corn cob ash (CCA) blended cement concrete.. This present while investigating the strength of corn-cob ash concrete, also attempted an examination of split tensile and high strength properties of such concrete.

EXPERIMENTAL STUDIES

Compressive strength tests were carried out on concrete cubes (150mm × 150mm × 150mm). Batching operation by weight approach was used adopting a mixes of 1:1.5:3 and 1.1.2 (cement: fines: coarse aggregates) with water/cement ratio of 0.50. Grade 20MPa and 25Mpa concrete was also designed using the Indian standard method of mix proportioning with water/cementitious material ratio of 0.5

Mix Proportioning and Casting of Concrete Cubes

Batching by weight was adopted in the study. A mix of 1:1.5:3 and 1.1.2 (cement: fines: coarse aggregates) was investigated with water/cement ratio of 0.50. The fine aggregate used was sharp sand. Granite was used as coarse aggregate. A wooden mould of size 150 × 150 × 150 mm³ was used for casting. The mould was assembled prior to mixing and properly lubricated for easy removal of hardened concrete cubes.

The molded concrete cubes were given 24 hours to set before striking out the moulds. They were then immersed into curing tank in order to increase the strength of the concrete, promote hydration, eliminate shrinkage and absorb heat of hydration until the age of test. Cubes were cured for 7 days, 14 days, 21 days, 28 days and 56 days. The compressive strength tests were carried out by a Compression Machine. The maximum capacity of the machine was 1500KN. The strength values were the average of three specimens tested in each case.

EXPERIMENTAL PROCEDURE

Preparation and Collection of Materials

SAW DUST

The saw dusts used for the study also were collected from saw mills. The samples were carefully collected to avoid mixing the saw dusts with sand. They were obtained in dry form and sundried for 24 Hours.


Fig 1.4 saw dustFig1.5 burning of saw dust

The collected samples were then burnt into ash by burning in a open surface area. The idea of burning them in a furnace was dropped because it will be time – consuming and uneconomical for most people especially those at the rural areas.

Burnt corn cob and saw dust was then grounded separately after cooling using mortal and pestle and the burnt ashes were sieved separately through Indian Standard sieve of 90µm. The portion passing through the sieve would have the required degree of fineness of 90µm.


Fig 1.6 collecting saw dust ashFig 1.7 Sieving saw dust ash with IS 90 microns

CORN COB

The corn cobs used for this study were obtained from crop fields. They were obtained in dry form and sundried for 1 week.


Fig 1.8 Corn CobFig 1.9 Burning of Corn Cob

The collected samples were then burntopen surface area. The idea of burning them in a furnace was dropped because it will be time – consuming and uneconomical for most people especially those at the rural areas.

Each burnt corn cob and saw dust was then grounded separately after cooling using mortal and pestle and the burnt ashes were sieved separately through Indian Standard sieve of 90µm. The portion passing through the sieve would have the required degree of fineness of 63µm and the residue was thrown away.

Fig 1.10 Corn Cob Ash

The ordinary Portland cement (53 grade) used was obtained. The choice of ordinary Portland cement for this project experiment conforms to the requirements of IS 12269 (1987). River sand was used as fine aggregates and granite with maximum size of 20mm as coarse aggregates. The aggregates used were obtained from a local supplier.

Production of Concrete Cubes with saw dust

Batching of Concrete

It is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume. Percentage of accuracy for measurement of concrete materials

Fig 1.11 Batching of concrete

The SDA were used to replace ordinary Portland cement at 0%, 5%, 10% and 15% by weight of cement. The mix ratio used was 1:1.5: 3 (cement – binder, sand and coarse) with water to binder of 0.45 for M25 and 1:1:2 with water to binder 0.5, which was later increased to obtain proper mix.

Concrete cubes were cast using 150mm x 150mm 150 mm cube steel moulds. The cube steel moulds were assembled prior to mixing and properly lubricated with engine oil for easy removal of hardened concrete cubes. Each mould was then filled with prepared fresh concrete in three layers and each layers was tamped with tamping rod using twenty five (25) strokes uniformly distributed across the seldom of the concrete in the mould . The top of each mould was smoothened and leveled with hand trowel and then the outside surfaces cleaned.

Fig 1.12 mould

The CCA were used to replace ordinary Portland cement at 0%, 5%, 10%, 15% and 20% by weight of cement. The mix ratio used was 1:1: 2 (cement – binder, sand and coarse) with water to binder of 0.45 for M25 and 1:1.5:3 with water to binder 0.5, which was later decreased to obtain proper mix.

Fig 1.13 Curing concrete cubes in water

TESTS

CONCRETE SLUMP CONE TEST [IS: 7320 - 1974]

Figs 1.14 &1.15 Slump Test

Fig 1.16Subsidence of Slump Test

Fig1.17 Collapse slump

Fig 1.18True SlumpFig1.19Shear slump

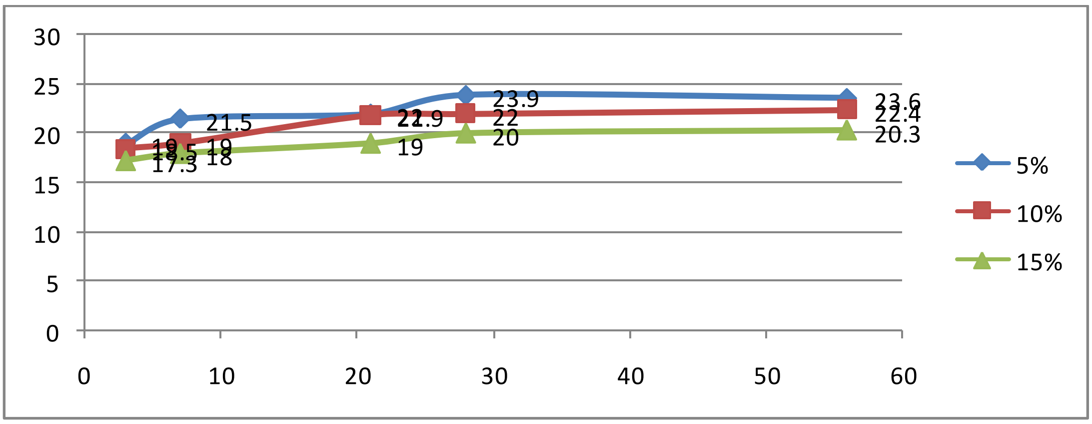
COMPRESSIVE STRENGTH TEST OF CONCRETE (IS: 516-1959)

III. RESULTS

TABLE 3.STRENGTH OF CORN COB ASH (M25)

S.NO	REPLACEMENT	STRENGHT(KN)				
		3 DAYS	7 DAYS	21 DAYS	28 DAYS	56 DAYS
1	0%	18.9	19.5	20.5	24.2	24.9
2	5%	19	21.5	22.9	23.9	23.6
3	10%	18.5	19	22.9	22	22.4
4	15%	17.3	18	19	20	20.3

GRAPH ON CORN COB ASH M25



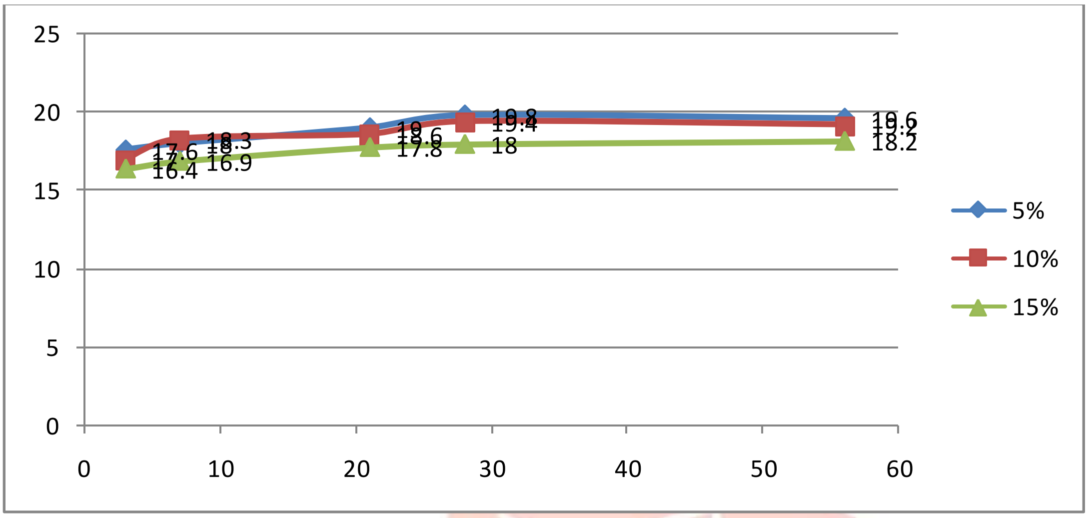
X-axis – No of days

Y-axis - strength

TABLE4. STRENGTH OF CORN COB (M20

S.NO	REPLACEMENT	STRENGHT(KN)				
		3 DAYS	7 DAYS	21 DAYS	28 DAYS	56 DAYS
1	0%	18.8	19	19.5	19.95	20.1
2	5%	17.6	18.3	19	19.8	19.9
3	10%	17	18	18.6	19.4	19.5
4	15%	16.4	16.9	17.8	18	18.2

GRAPH ON CORN COB ASH M20



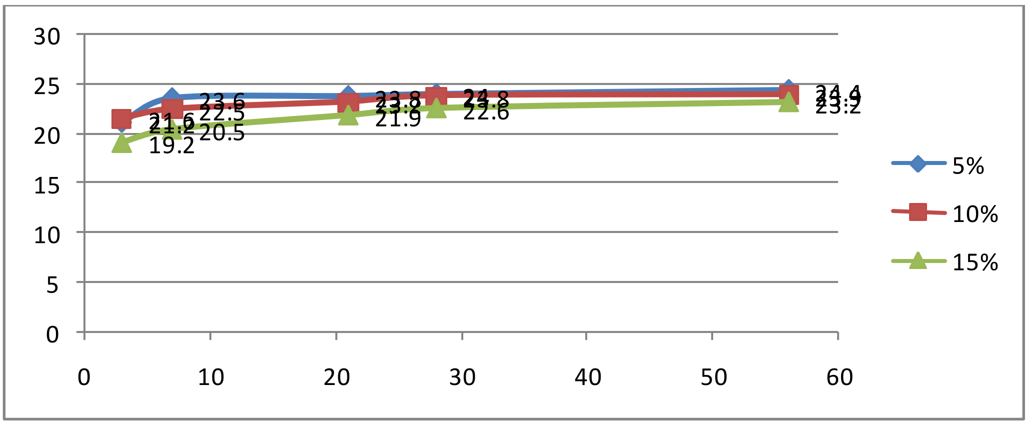
X-axis – Noof days

Y-axis – strength

TABLE 5. STRENGTH OF SAW DUST (M25)

S.NO	REPLACEMENT	STRENGHT(KN)				
		3 DAYS	7 DAYS	21 DAYS	28 DAYS	56 DAYS
1	0%	18.9	19.5	20.5	24.2	24.9
2	5%	21.6	23.6	23.8	24	24.4
3	10%	21.2	22.5	23.2	23.8	23.9
4	15%	19.2	20.5	21.9	22.6	23.2

GRAPH ON SAW DUST M25

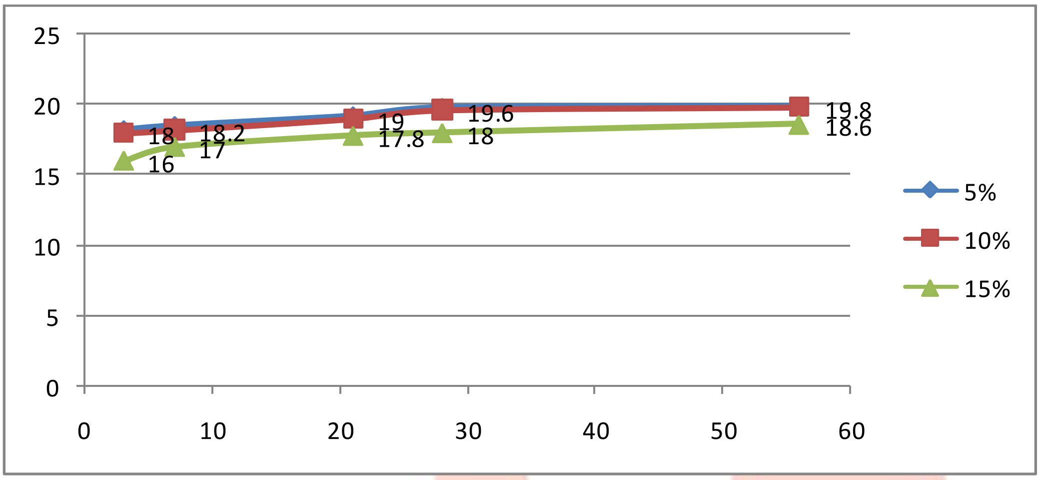


X-axis – No of days

Y-axis – strength

TABLE 6.STRENGTH OF SAW DUST (M20)

S.NO	REPLACEMENT	STRENGHT(KN)				
		3 DAYS	7 DAYS	21 DAYS	28 DAYS	56 DAYS
1	0%	18.8	19	19.5	19.95	20.1
2	5%	18.2	18.4	19.2	19.8	19.9
3	10%	18	18.2	19	19.6	19.8
4	15%	16	17	17.8	18	18.6



X-axis – No of days

Y-axis – strength

IV. CONCLUSION

Based on the limited study carried out on the strength behavior of sawdust and corn cob ash the following conclusions are drawn:

- At the initial ages with the increase in the percentage of replacement of saw dust and corn cob, the strength as well as compressive strength increases.
- Moreover with the use of saw dust and corn cob the weight of concrete reduces, thus making concrete lighter which can be used as light weight concrete for civil engineering works.
- The compressive strength of concrete cubes always increases with curing ages and decreases with the percentage increases of the saw dust and corn cob.
- Although the strength of saw dust and corn cob was lower than that of normal concrete still it can be used for the general work when strength is of less importance such as concrete, floors, moisture of material concrete.

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