Study and Characterisation of Various Industrial Fly Ash

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Abstract

Fly ash is the hollow spherical particles obtained during coal burning process. So, it can be used as filler material in producing light weight composites. Therefore properties of composited will be improved and cost of production will be decrease. This work is aimed to study and characterization of industrial fly ash. For this purpose, three types of industrial fly ash have been collected from the industries namely "Nagarjuna AgriChem Limited, Silver Industry, Paper industry". The collected samples of fly ash were divided into six fractions with fly ash diameter sizes: under 75µm, 75-90µm, 90-150µm, 150-300µm, 300-600µm and above 600µm by performing "Sieve Analysis". To know the chemical properties, morphology using Scanning (EDX), phase composition using X-ray Diffraction (XRD) has been performed. To know the physical properties Shear test, Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Water content have been performed. In this way, the present works have been performed for study and characterization of industrial fly ash for the collected samples.

Keywords - *Fly Ash; Physical properties, Chemical properties.*

I. INTRODUCTION

Fly ash is a result of the burning of pounded coal in warm power plants. It is expelled by the residue accumulation framework as a fine particulate build up from the ignition gases before they are released into the climate. The scope of molecule sizes in any given fly slag is to a great extent dictated by the kind of residue accumulation hardware utilized. The concoction organization of fly fiery debris is dictated by the sorts and relative measures of incombustible issue in the coal utilized. Over 85% of most fly ash includes substance mixes and glasses shaped from the components of silicon, aluminium, iron, calcium and magnesium.[1-8].

The synthetic creation of fly ash is controlled by the sorts and relative measures of incombustible issue in the coal utilized. Over 85% of most fly cinders involve substance mixes and glasses framed from the components of silicon, aluminium, iron, calcium and magnesium. For the most part, fly ash from the ignition of sub-bituminous coals contains more calcium and less iron than fly slag from bituminous coal.

Fly ash display pozzolanic movement. A pozzolan is characterized "as a siliceous and aluminous material which in itself has next to zero cementitious esteem however which will, in finely partitioned shape and within the sight of dampness, synthetically respond with calcium hydroxide at common temperature to frame mixes having cementitious properties".

Physical properties of the coal fly ash remains, for example, dampness content, molecule mass, glass arrangement, and the bit of unburnt carbon, are subject to coal properties, the burning temperature of the coal, the wind current/fuel proportion, coal pounding size, and the rate of ignition. Coal ash remains has an incredible potential for usage in creating building materials, for example, bond, solid blend, blocks, pozzolana and squander water treatment other than its agronomic incentive as a diet conditioner and a wellspring of soil major and miniaturized scale supplements. Since the arrangement of fly ash remains change contingent on wellspring of coal, portrayal of fly cinder from various warm power stations all through the nation was felt important. The portrayal of fly ash remains, it's potential for use and potential dangers to plants and creature were looked into.

Present Scenario on Fly Ash in India:-

- Over 73 % of the total installed power generation is thermal
- 230 - 250 million MT coal is being utilized every year
- High ash contents varying from 30 to 50%
- More than 110 million MT of ash generated every year
- Ash generation likely to reach 170 million MT by 2010
- Presently 65,000 acres of land occupied by ash ponds
- Presently as per the Ministry of Environment & Forest Figures, 30% of Ash is being used in Fillings, embankments, construction, block & tiles, etc.

II. INDUSTRIAL FLY ASH

Fly ash is the finely separated build up that outcomes from the ignition of pounded coal and is transported from the burning chamber by debilitate gases. Fly ash is delivered by coal-let go electric and steam producing plants. Normally, coal is pounded and blown with air into the kettle's burning chamber where it instantly touches off, creating heat and delivering a liquid mineral deposit solidify and frame powder. Right now, more than 20 million metric tons (22 million tons) of fly ash are utilized every year in an assortment of designing applications [9-12]. Average interstate designing applications include: Portland bond concrete (PCC), soil and street base adjustment, flow able fills, grouts, auxiliary fill and black-top filler. Fly ash usage, particularly in concrete, has noteworthy natural advantages including:

- Increasing the life of concrete roads and structures by improving concrete durability.
- Net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement.
- Reduction in amount of coal combustion products that must be disposed in landfills.
- Conservation of other natural resources and materials.

A. *different types of fly ash*

Lately, there has been an acknowledgement that fly ash remains vary in critical and perceptible terms, mirroring their organization and, to some degree, their beginning. Canadian and U.S determinations perceive two general classes of fly ash remains:

- Class C, produced from lignite or sub-bituminous coals;
- Class F, produced from bituminous coals.

Class F and Class C fly ash remains are results of the burning of coal in extensive power plants. Fly ash remains is gathered in electrostatic precipitators or bag houses, at that point exchanged to substantial store houses for shipment. Whenever required, fly ash remains is grouped by exact molecule measure prerequisites, in this manner guaranteeing a uniform, quality item. Class F fly ash is accessible in the biggest amounts. Class F is for the most part low in lime, ordinarily under 15%, and contains a more noteworthy mix of silica, alumina and iron (more prominent than 70%) than Class C fly ash. Class C fly ash ordinarily originates from coals which may deliver a ash with higher lime content-by and large over 15% regularly as high as 30%. Lifted CaO may give class C one of kind self-solidifying qualities [13-19].

The Class C powders vary from the Class F materials mainly in having a limit with respect to self-solidifying without concrete. The most outstanding compound distinction between these two classes of ash is that the Class C ash remains contain elevated amounts of calcium. This has prompted the utilization of an option and in some ways ideal phrasing: high-calcium and low-calcium slag for classes C and F, individually. This distinction has not been made in North American specifications. These presently make no reference to CaO content [20-22].

III. EXPERIMENTAL METHODS

There are several methods to test the industrial fly ash.

A. *Fly ash sieve analysis:*

The size distribution is regularly of basic significance to the manner in which the material performs being used. A sifter investigation can be performed on a non-natural or natural granular materials including sands, smashed shake, muds, rock, soil, coal, an extensive variety of made powders, grain and seed, down to a base size contingent upon the correct technique. Being such a straight forward strategy of molecule estimating, it is likely the most well-known [23-25].

A gradation test is performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). See the separate mesh (scale) page for details of sieve sizing. A representative weighed sample is poured into the top sieve which has the largest screens openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver. The section is commonly set in a mechanical shaker. The shaker shakes the segment, as a rule for settled measure of time. After the shaking is finished the material on each sieve is weighed. The heaviness of the example of each sieve is then partitioned by the aggregate weight to a given rate held on each strainer. The span of the normal molecule on each strainer is then broke down to get a cut-off point or particular size range, which is then caught on a screen.

The results of this test are utilized to describe the properties of the total and to check whether it is fitting for different civil engineering purposes, for example, choosing the suitable total for concrete blends and asphalt blends and in addition estimating of water generation well screens. The consequences of this test are given in graphical form to recognize the sort of gradation of the total. The total technique for this test is laid out in the American society for testing and materials and the American association and state highway and transportation officials. An appropriate sieve size estimate for the total underneath the nest of sieves to collect the aggregate that passes through the smallest. The entire nest is then disturbed, and the material whose diameter is smaller than the mesh opening go through the sieves. After the total achieves the container, the measure of material held in each sieve is then weighed.

B. *Scanning Electron Microscope (SEM)*

A scanning electron microscope (SEM) is a sort of electron magnifying instrument that produces of an example by checking the surface with an engaged light emission. The electrons cooperate with particles in the example, creating different signs that contain data about the example's surface geography and arrangement. Raster scan pattern is used to scan the electron beam and beam position is combined to produce an image with the detected signal. SEM can accomplish determination superior to 1 nanometer. Specimens can be observed in high vacuum in conventional SEM, or in low vacuum or wet conditions in variable pressure or environmental, and at an extensive variety of cryogenic or raised temperatures with specific instruments.

In a run of the SEM, an electron beam is thermionically produced from an electron gun fitted with a tungsten fiber cathode. Tungsten is ordinarly utilized as a part of thermionic electron guns since it has the most noteworthy dissolving point and least vapour weight all things considered, in this way enabling it to be electrically warmed for electron outflow, and due to its minimal effort. Different kinds of electron producers incorporate lanthanum hexaboride cathodes, which can be utilized as a part of a standard tungsten fiber SEM if the vacuum framework is updated or field emanation guns (FEG), which might be of the cool cathode compose utilizing tungsten single precious stone producers or the thermally helped schokkty type, that utilization producers of zirconium oxide.

When the primary electron beam interacts with the sample, the electrons lose energy by repeated random scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to approximately 5 µm into the surface. The size of the interaction volume depends on the electron's landing energy, the atomic number of the specimen and the specimen's density. The energy exchange between the electron beam and the sample results in the reflection of high-energy electrons by elastic scattering, emission of secondary electrons by inelastic scattering and the emission of electromagnetic radiation, each of which can be detected by specialized detectors.

C. *Energy-Dispersive X-Ray (Edx)*

Energy-dispersive X-ray(EDS, EDX, EDXS or XEDS), some of the time called Energy-dispersive X-ray (EDXA) or Energy-dispersive X-ray microanalysis (EDXMA), is an expository method utilized for the essential investigation of an sample. It depends on a connection of some wellspring of X-ray excitation and an example. Its characterization capacities are expected in extensive part to the essential rule that every component has a one of a kind nuclear structure permitting an extraordinary arrangement of tops on its electromagnetic emanation range (which is the fundamental rule of spectroscopy).

To empower the discharge of characteristic X-rays from an example, a high-vitality light emission particles, for example, electrons or protons or a light emission rays, is engaged into the example being examined. Very still, a molecule inside the example contains ground state (or unexcited) electrons in discrete vitality levels or electron shells bound to the core. The occurrence pillar may energize an electron in an inward shell, catapulting it from the shell while making an electron gap where the electron was. An electron from an external, higher-vitality shell at that point fills the opening, and the distinction in vitality between the higher-vitality shell and the lower vitality shell might be discharged as a X-ray. The number and vitality of the X-ray produced from an example can be estimated by a vitality dispersive spectrometer. As the energies of the X-rays are normal for the distinction in vitality between the two shells and of the nuclear structure of the emanating component, EDS permits the basic synthesis of the example to be estimated.

D. *X-ray Diffraction (XRD)*

In 1912 Max von Laue showed that X- rays could be diffracted by crystals and established their wave nature. He won the Nobel Prize in physics in 1914. In 1912-13 Henry Bragg made an X- ray spectrometer for the further study of the properties of X-rays. During a discussion with his father, Larence Bragg was interested in X-ray Diffraction. Then he has examined and found a way to explain Laue's diffraction problem and Formulated Bragg's Law which is the main principle of XRD (m* wavelength (λ) = 2d sin θ).

X-ray Diffraction or X-ray crystallography is a technique utilized for deciding the nuclear and sub-atomic structure of a crystal, in which the crystalline molecules cause a light emission X-rays to diffract into numerous particular directions. By estimating the points and forces of these diffracted pillars, a crystallographer can deliver a three-dimensional photo of the thickness of electrons in the crystal. From this electron thickness, the mean places of the particles in the crystal can be resolved, and additionally their substance bonds, their confusion, and different other data.

E. *Water Content*

Water content is a very important quantity in the various tests.it affects the engineering performance of soils in general. Water Content is defined as the ratio of the weight of water in the soil to the weight of the oven dried soil, expressed as a percentage.

F. *Specific Gravity*

The specific gravity of fly ash is an important auxiliary factor, which is useful in the computation of

quantity like the void ratio and the unit weight of the flyash.it is also useful in the grain size analysis of silts and clays, The specific gravity of the soil is generally taken to be the average value of soil grains, which means that the voids present in the soil, are excluded value of fly ash grains divided by the unit weight if distilled water.

G. OMC (Optimum Moisture Content) & MDD (Maximum Dry Density)

FLY ASH at a given sit may not be often ideal for the construction of a civil engineering structure or a facility.it may be necessary to improve the engineering properties of such soils. Compaction is one of the methods of making such improvement and involves densification by applying mechanical energy on a soil mixed with suitable water content, which also produces the maximum dry unit weight, is determined from this test. This test has been developed by R.R.pro ctor in 1933 and is therefore named after him.

H. Direct Shear Test

Safety of foundations and stability of slopes and retaining walls depend upon the shear strength of the soil. Shear strength equation of fly ash is known as mohr coulomb equation

$$S=C+\sum\tan \omega$$

Where,
S= Shear strength
C= cohesion
∑=normal stress on plane of shear
ω=Angle of internal friction in degrees

IV. RESULT AND DISCUSSION

A. Sem Images

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition.

SEM Pictures are taken for Fly Ash of 75 µm size Fly ash for every industry at 3 different positions for every sample.

1) For fly ash sample of paper industry.

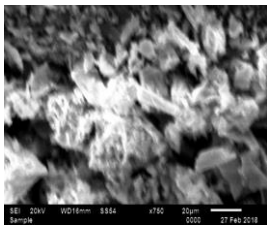

Fig.1

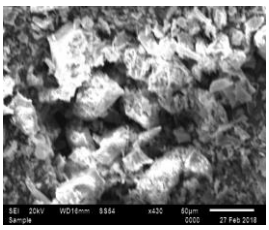

Fig.2

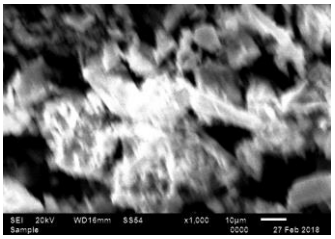

Fig.3

2) For fly ash sample of nacl industry.

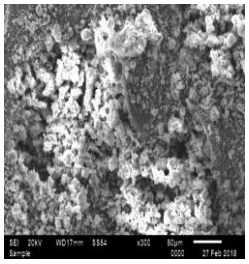

Fig.4

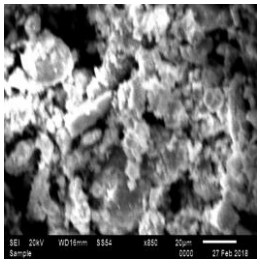

Fig.5

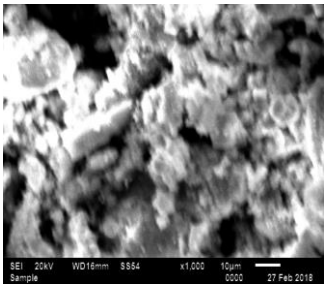

Fig.6

3) For Fly Ash Sample Of Silver Industry

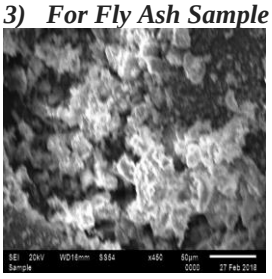

Fig.7

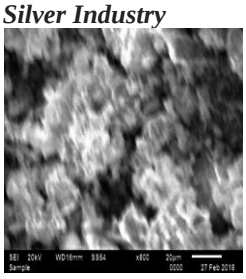

Fig.8

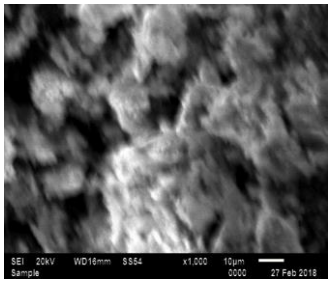

Fig.9

B. Xrd Analysis

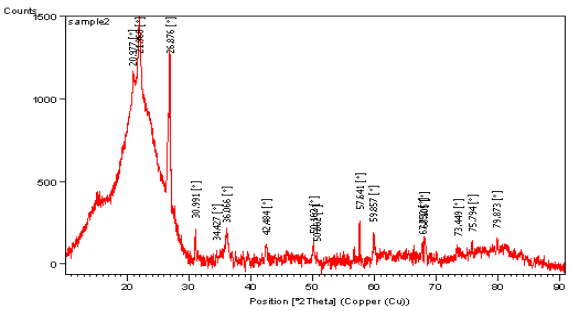

Fig.10 Fly Ash sample of paper industry

This Graph is based on the XRD Analysis of Paper Industry where X-axis is No. of counts and Y-axis is Position of the sample where the peak value is 79.873[⁰] and the lowest value is 20.927[⁰].

TABLE 1

PAPER INDUSTRY			
ZONES	**Highest Peak Value**	**Lowest Peak Value**	**Mean Value**
0-30	26.876	20.977	23.9265
30-60	57.641	30.991	44.316
60-90	79.873	59.857	69.865

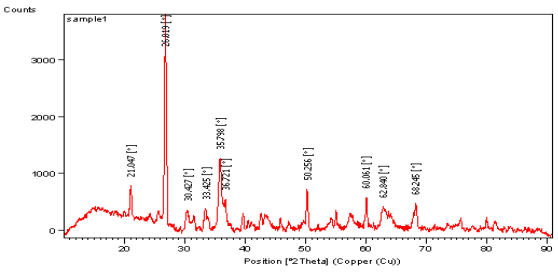

Fig.11 Fly Ash sample of NACL industry

This Graph is based on the XRD Analysis of NACL Industry where X-axis is No. of counts and Y-axis is Position of the sample where the peak value is 68.840[⁰] and the lowest value is 21.047[⁰].

TABLE 2

NAGARJUNA AGRICHEM LIMITED			
ZONES	**Highest Peak Value**	**Lowest Peak Value**	**Mean Value**
0-30	26.819	21.047	23.733
30-60	50.256	30.427	40.3415
60-90	68.245	60.061	64.153

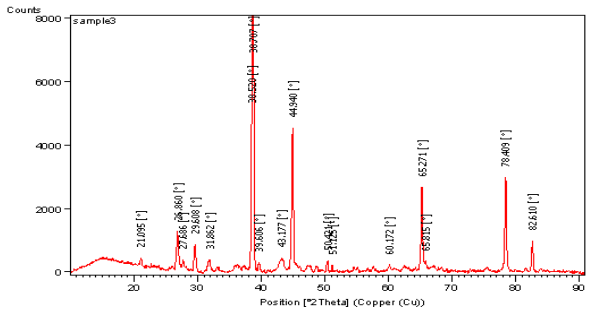

Fig.12 Fly Ash sample of Silver industry

This Graph is based on the XRD Analysis of Silver Industry where X-axis is No. of counts and Y-axis is Position of the sample where the peak value is 82.610[⁰] and the lowest value is 21.095[⁰].

TABLE 3

SILVER INDUSTRY			
ZONES	**Highest Peak Value**	**Lowest Peak Value**	**Mean Value**
0-30	29.608	21.095	25.3515
30-60	51.125	31.862	41.4935
60-90	82.610	60.172	71.391

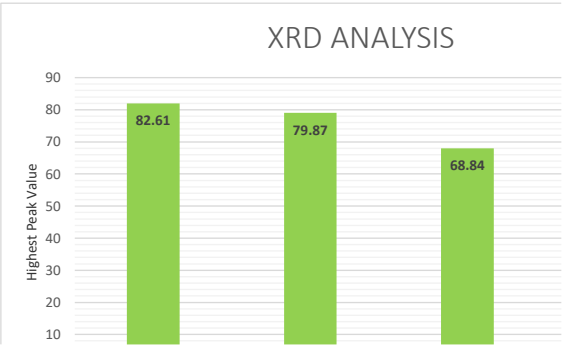

Fig.13 Overall XRD analysis of Fly Ash

TABLE 4

XRD ANALYSIS			
INDUSTRIES	**Highest Peak Value**	**Lowest Peak Value**	**Mean Value**
PAPER	79.873	20.977	50.425
NACL	68.245	21.047	44.646
SILVER	82.610	21.095	51.8525

C. Water Content

Weight a clean non-corrodible container with its lid(W1gms) and then place a representative sample of a moist soil in the container and place lid on it then weigh the container with the moist sample and lid(W2gms). Remove the lid, place it on the bottom of the

container and keep the container in the oven. The oven is thermostatically controlled to maintain a temperature of 105-110°c.After the fly ash sample has been dried to a constant weight, which normally occurs at the end of 24 hours take out the container keep in water desiccators and allow it to cool. Replace the lid and weigh the container with the oven dry fly ash specimen (W3gms). Then calculate the water content by using the following expression.

W% = [(W2-W3)/ (W3-W1)] ×100

TABLE 5

INDUSTRY	WATER CONTENT
NACL	0.75
PAPER	0.9
SILVER	0.5

D. Specific Gravity

Clean the density bottle by washing it thoroughly with distilled water and allow it to drain and dry. find the weight of the empty density bottle, together with the stopper(w1g). take about 25g of the oven dried fly ash sample transfer it to the density bottle and determine the weight of the density bottle with the soil in it together with the stopper (W2gm). Take about 50cc of de aired distilled water and put it in the density bottle until the fly ash is fully soaked and high vacuum pump at least 10 minutes. after the de airing process is completed add water carefully up to the level of the volume mark provided on the density bottle. Record the temperature and empty the density bottle by removing all its contents. Fill the density bottle up to the mark with deaired distilled water and weigh it with stopper (w4gm). Calculate the specific gravity at temperature at test temperature using the following expression.

Gr= weight of the fly ash/weight of the equivalent volume of water

= (W2-W1)/ (W4-W1) - (W3-W2)

TABLE 6

INDUSTRY	SPECIFIC GRAVITY
NACL	1.44
PAPER	1.89
SILVER	2.08

E. OMC (Optimum Moisture Content) & MDD (Maximum Dry Density)

Measure the weight of the empty proctor mould and determine its volume fixing the mould to the base plate and attach a collar to the mould. Take around 2 kg of air dried soil which is pummeled and gone through 4.75 mm sieve. Add to the soil, certain underlying level of water in view of the dry weight. Gap the wet soil into three equivalent amounts of. Fill the mould with one part in the soil and reduced it with 25 equally dispersed blows with the standard rammer. Take a spatula and trim along the base edge of the neckline until the point when it falls off effectively. Measure the mould with the compacted fly ash, in the wake of expelling the soil adhering to the mould (trimmings).To ecyrude the fly ash example from shape utilize the example extruder. In the wake of measuring keep then in the hot air broiler for 24 hours to decide the water content. Repeat the method by taking fresh sample of fly powder each time and adding water to it with increases fluctuating somewhere in the range of 2% and 4% until and the readings are to be recorded. The weights of the dampness jars with broiler dried fly ash remains are taken the following day and normal water content(W) decided for each test. The values are to be recorded in table. Compute the dry density (¶d) and plot the results on a graph sheet with ¶d as the ordinate and water content as the abscissa. The dry density is computed from the formula

¶d = ¶b(1+w) =w/[v(1+w)] =(w2-w1)/v(1+w).

Then superimpose on the above curve the zero air voids line for drawing which the densities are obtained using following formula. ¶d=G¶w /(1-WG).

Where G is the specific gravity of the fly ash. Curves corresponding to any degree of saturation and any % air voids can also.be super imposed on this plot. The dry density corresponding to any % air voids (Na) can be obtained by using formula. ¶d= (1-Na) G¶w/(1+WG). The dry density corresponding to any degree of saturation(S) is obtained from the formula.

¶d= G¶w/(1+wG/S)).

TABLE 6

INDUSTRY	MAXIMUM DRY DENSITY (g/cc)	MOISTURE CONTENT (%)
NACL	1.45	16
PAPER	1.49	18.9
SILVER	1.52	21.2

F. Direct Shear Test

Place the gripper plate at the bottom of the box with thee grooves on the specimen side and perpendicular to the direction of movement of movable half of shear box. Place the sample in the shear box. For this take some amount of granular fly ash and weigh it divided into 3 parts and fill the shear box with fly ash and three layers, tamping with each layer with a tamper. The final thickness of the compacted specimen should be 2 cm. place the other plate with grooves facing the fly ash specimens in a direction perpendicular to the direction of movement. Place the loading plate on the top of the gripper plate. Adjust the normal loading yoke and place it centrally on the specimen. Apply the normal loads to the lever pan attached to the hanger.

Place the horizontal deformation measuring dial gauge with its spindle touching the moving half the shear box. Adjust the proving ring dial gauge to

measure the shearing load. Note the initial reading of proving ring dial gage and the deformation dial gauge.

Shear the fly ash specimen after removing the pins from the shear box. Note the readings of the proving ring, dial gauge and deformation dial gauge to corresponding to different percentage strains until failure of specimen has occurred. Repeat the test with 3 or more normal loads.

TABLE 7

NORMAL LOAD (N)	NACL FLYASH (N/mm^2)	PAPER FLYASH (N/mm^2)	ALUMINIUM FLYASH (N/mm^2)
0.5	19	21	29
1.0	31	39	40
1.5	41	49	49

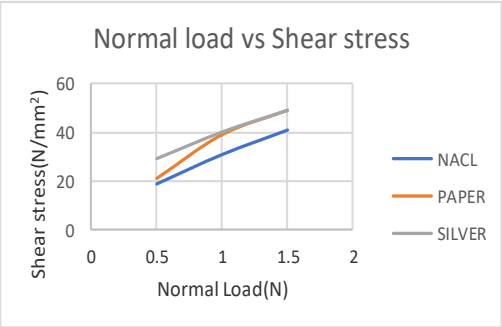

Fig.14

TABLE 8

NORMAL LOAD (N)	NACL FLYASH (N/mm^2)	PAPER FLYASH (N/mm^2)	ALUMINIUM FLYASH (N/mm^2)
0.5	10	9	12
1.0	11	11	16
1.5	13	8	14

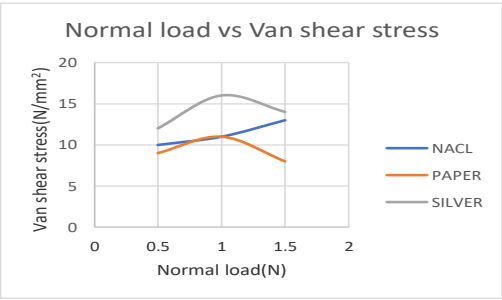

Fig.15

V. CONCLUSION

Thus, we have collected three types of industrial fly ash from the industries namely "NACL, SILVER INDUSTRY, PAPER INDUSTRY" and for the collected samples of fly ash, morphology using scanning electron microscopy (SEM), elemental composition using Energy Dispersive X-ray analysis (EDX) and phase composition using X-ray diffraction (XRD) have been performed. The fly ash samples were divided into six fractions with fly ash diameter sizes: under 75 µm, 90 µm, 90-150 µm, 150-300 µm, 300-600 µm above 600 µm by performing "SIEVE ANALYSIS".

Also, some experiments such as Water Content, Specific Gravity, OMC MDD and Shear Tests have been performed for Fly Ash of 300 µm size to know the Properties of Fly Ash. In this way, the present work has been performed with study and characterisation of industrial fly ash.

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