# LIME AND SODIUM SILICATE STABILIZED FLY ASH IN GEOTECHNICAL APPLICATIONS

**K Durga Prasada Rao** [1]

*Civil Engineering ,Gokul Group of Institutions , Jntuk University, (India)*

## ABSTRACT

*The Major challenge on behalf of engineers especially civil engineers are the disposal of industrial waste products and their storage. Now a days most of the industries reusing the wastes in different areas like civil constructions, treatment of materials and others. This reuse of wastes is essential to overcome the hazardous effects of wastes on environment. Fly Ash is one of the industrial wastes produced every year throughout the country. Fly ash is a fine powder obtained from burning of coal during the production of electricity. Disposal of Fly ash is a big problem, to minimize the disposal of Fly ash into large land, it was used as a construction material in civil engineering works like building materials embankments, and bricks making etc.*

*In the present study, an experimental investigation was carried out to determine the strength properties of Fly ash with lime and Sodium silicate. Individual geotechnical parameters like grain size distribution, liquid limit, OMC, MDD, Specific gravity and angle of internal friction of Fly ash were determined and then Fly ash was mixed with different proportions of lime (2-15%) and sodium silicate (1-4%). These mixes were tested to obtain optimum percentage of lime and sodium silicate. The variation in shear parameters like cohesion and angle of shearing resistance were studied by conducting direct shear test. All the tests were performed after a time period of 3hours starting from the completion of preparation of sample. Each test was performed for the normal stresses of 0.5kg/cm$^2$, 1kg/cm$^2$, 1.5kg/cm$^2$, 2kg/cm$^2$ and 2.5 kg/cm$^2$. The results are complied in a graphical form to observe the trends for shear parameters. The results show remarkable improvement in strength characteristics for higher percentages of lime and sodium silicate.*

***Keywords : Density, Specific Gravity, Density, Shear Strength, Moisture Content***

## I. INTRODUCTION

Fly ash is a predominantly inorganic residue obtained from the flue gasses of furnaces at pulverized coal power plants. It has small particle size less than 75µ in major percentage. These micron-sized earth elements consist primarily of silica, alumina and iron. In India, about 70 million tonnes of coal ash is produced per year from burning about 200 million tonnes of coal per year for electric power generation. Coal-ash management poses a serious environmental problem for India and requires a mission-mode approach. Disposal of wastage requires costly land at thermal power plants and the transport of Fly ash to the ash ponds entail heavy expenditure. Considerable research and development work have been undertaken across the country towards confidence building and developing suitable technologies for disposal and utilization of Fly ash in construction industries.

At present about 10% Ash is utilized in Ash dyke construction and land filling and only about 3% of Ash is utilized in other construction industries. This is very much in contrast with 80% or more Fly ash used in

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developed countries for the manufacture of bricks, cellular concrete blocks, road construction, land fill application, ceramics, agriculture, insulating bricks, recovery of metals and dam constructions etc. Currently, about one acre land is needed for one metric tonnes of Ash disposal.

Malhotra and others report on the use of Fly ash in America in 2002 they estimate that only 30% of the Fly ash produced is used. Two thirds is used in the concrete which has reached a maximum consumption figure. Foner and other Emphasize the role of developing a new application of Fly ash in 1999. By pointing out that Israel would produce 1.3 mega tonnes of coal ash per annum by 2001 and that 0.6 mega tonnes could be used by the cement industry. In the U.K approximately 50% of the Fly ash produced is used where as in India 6% Fly ash is used out of the total production.

Highway engineers are utilizing bulk quantities of Fly ash in embankments and road constructions. Fly ash settles very negligible amount during construction period and not afterwards. Its lesser density is suitable for high embankments. Lime stabilized Fly ash gains cementinious properties due to formation of silicates and aluminate hydrates at the time of pozzolanic reaction. Due to cementations properties, lime stabilized Fly ash gain in strength which is the better alternative for stable sub-grade or sub-base. Cement stabilized Fly ash has better performance in load carrying capacity and reduction of heave compared to lime or un-stabilized Fly ash sub-grade. By using additives like sodium silicate can increase the strength of lime stabilized Fly ash.

## II. METHODOLOGY

The tests for Index properties (GrainSizeAnalysis, Atterberg'sLimits, SpecificGravity, LightCompaction, DirectShear Test) of the soil are conducted wth different Proportions Fly ash with lime and sodium silicate results are analysised

## III. RESULTS AND DISCUSSIONS

Fly ash was collected from GMR Therml power Plant in Rapur .An expermental investigation was carried out to determine the engineering, Index and physical properties of Fly Ash. The properties and chemical composition of Fly Ash are shown below.

Table No: 3.0(a)

| Property | Values |
|---|---|
| Gravel (%) | 0 |
| Sand (%) | 28 |
| Fines (%) | 72 |
| a. Silt(%) | 72 |
| b. Clay(%) | 0 |
| Liquid Limit (%) | 28 |
| Plastic Limit (%) | NP |
| Specific gravity | 2.1 |
| IS heavy Compaction | |
| Optimum moisture content (%) | 21 |
| Maximum dry density (g/cc) | 1.28 |
| California bearing ratio | 3 |

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**3.1.Chemical composition of Fly ash**

Table No: 3.1(a)

| Compound Formula | Percentage |
|---|---|
| SiO2 | 59.83 |
| Al2O3 | 30.48 |
| CaO | 1.74 |
| MgO | 0.86 |
| TiO2 | 6.91 |
| V2O5 | 0.09 |
| ZnO | 0.09 |

Chemical composition of laboratory hydrated lime is $Ca(OH)_2$, in this CaO is 90% pure.

Chemical composition of laboratory Sodium silicate (gel) $Na_2SiO_3.5H_2O$.

### 3.1.1 Grain Size Distribution

The test was carried out according to IS: 2720(part-IV). The set of sieves according to IS: 2720 are 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.15mm and 0.075mm.

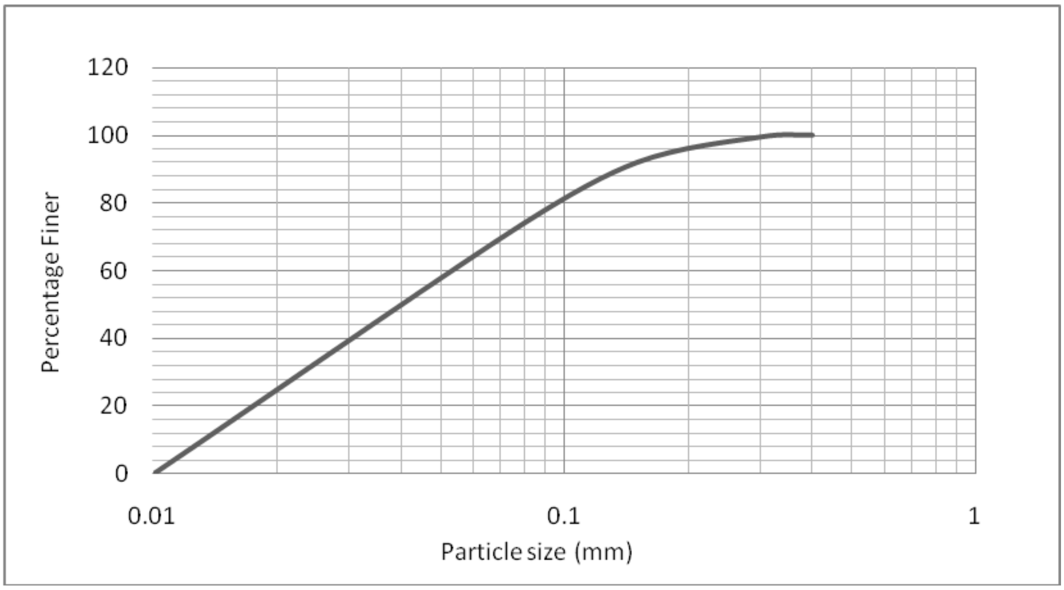


Fig No: 3.1.1(a)

Coefficient of uniformity: Cu = 28.89;

Coefficient of curvature: Cc = 2.13

### 3.2 Compaction Characteristics:

### 3.2.1 Compaction Characteristics of Fly ash Lime Mixes:

Different percentages of lime by weight of dry Fly ash has taken and mixed with the Fly ash and tested for OMC and MDD as per IS: 2720 (part VII) - 1980.

IJARSE
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Table No: 3.2.1(a)

| LIME (%) | OMC (%) | MDD (g/cc) |
|---|---|---|
| 0 | 21 | 1.28 |
| 2 | 21.4 | 1.26 |
| 4 | 21.8 | 1.24 |
| 6 | 22.3 | 1.23 |
| 8 | 22.8 | 1.21 |
| 10 | 23.3 | 1.18 |
| 12 | 23.6 | 1.16 |
| 15 | 24.0 | 1.14 |

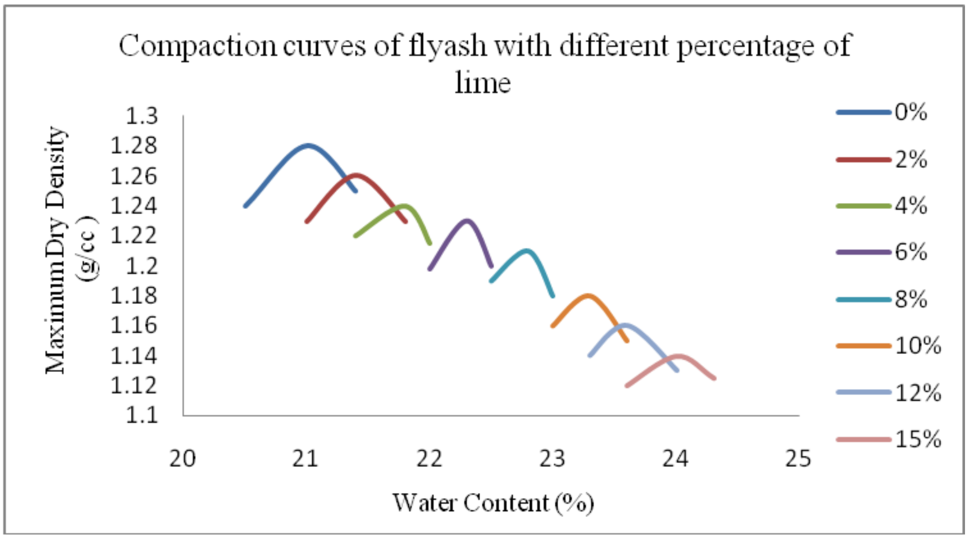


Fig No: 3.2.1(a)

Table No: 3.2.1(a) and Fig No: 3.2.1(a) show the variation of maxmium dry density (MDD) and optimum moisture content (OMC) of Fly ash-Lime mixes. The MDD decreases significantly with increasing Lime content (0-15%) from 1.28 g/cc to 1.14 g/cc, and OMC increases with increase of Lime(0-15%) from 21-24%. As Lime content increases more water is needed for the hydration process so that the OMC increases with increase in lime content.

### 3.2.2 Variation in Ø Values for Different percentage additions of Lime

The variation in shear parameters was tested for Fly Ash samples at different percentages of water content. The samples were tested at Dry of optimum, OMC and Wet of Optimum conditions. All water contents tested at $0.5kg/cm^2$,$1.0kg/cm^2$ and $2.0kg/cm^2$ normal pressures respectively. Each test was conducted after a curing period of 3 hours. All samples were cured in a cover in which the water lose is negligible.

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Table No: 3.2.2(a)

| % OF LIME | OMC (-2) | OMC (-1) | OMC | OMC (+1) | OMC (+2) | OMC (+3) |
|---|---|---|---|---|---|---|
| 0 | 25 | 28 | 30 | 29 | 26 | 24 |
| 2 | 27 | 30 | 31 | 30 | 28 | 26 |
| 4 | 29 | 31 | 32 | 31 | 30 | 27 |
| 6 | 30 | 32 | 34 | 33 | 31 | 29 |
| 8 | 31 | 33 | 36 | 34 | 32 | 30 |
| 10 | 32 | 35 | 37 | 35 | 34 | 31 |
| 12 | 32 | 35 | 38 | 36 | 34 | 31 |
| 15 | 32 | 36 | 38 | 37 | 34 | 31 |

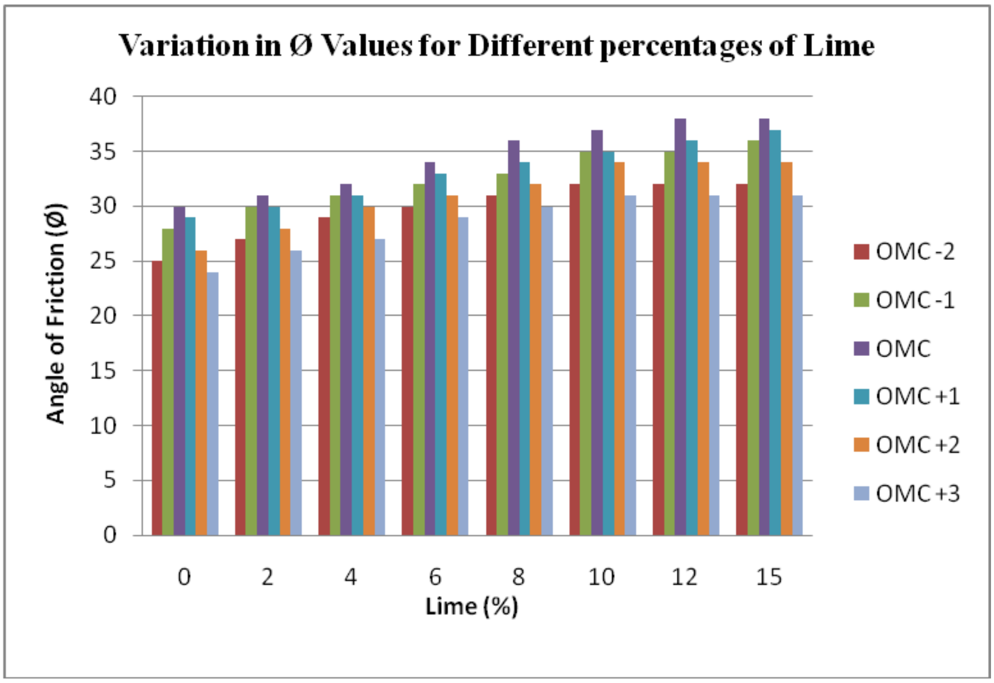


Fig No: 3.2.2(a)

The values are maximum for 15% addition of lime mix in which the friction among the particles is greater. The flocculation done in the mixes is effective with increase in percentage of lime. The friction values are greater at OMC water content, beyond that the values decreased because the increase in water content leads to the loss of friction among the particles. In Dry of Optimum conditions like OMC-2, OMC-1water contents also the values are lesser than OMC water content because the water content is not sufficient to form flocculated structure in the mixes.

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**3.2.2.1 Variation of Ø values with different water contents**

The Trend observed in the shearing resistance values for every percentage of lime and for all water contents are shown below.

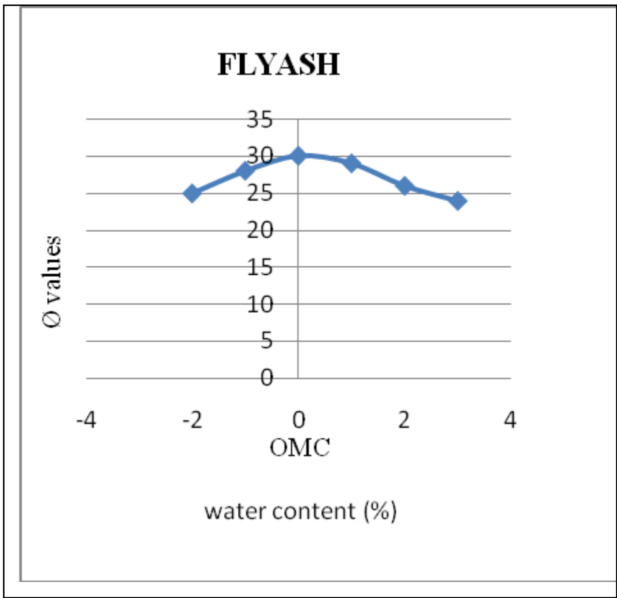


**Fig No: 3.2.2.1(a)**

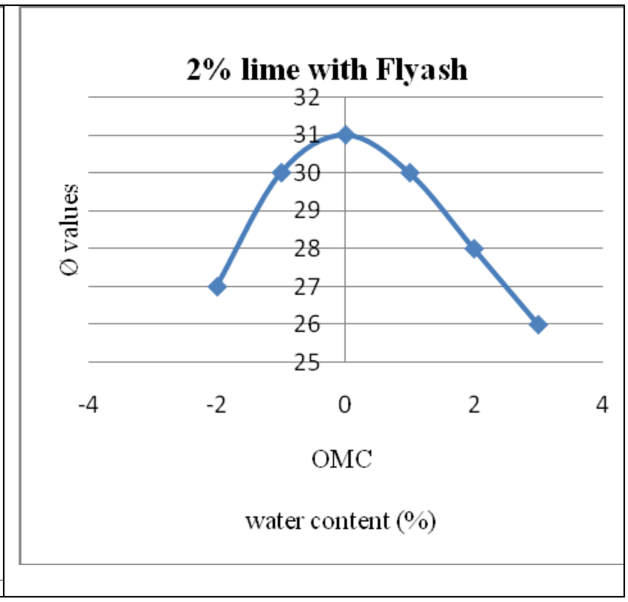


**Fig No: 3.2.2.1(b)**

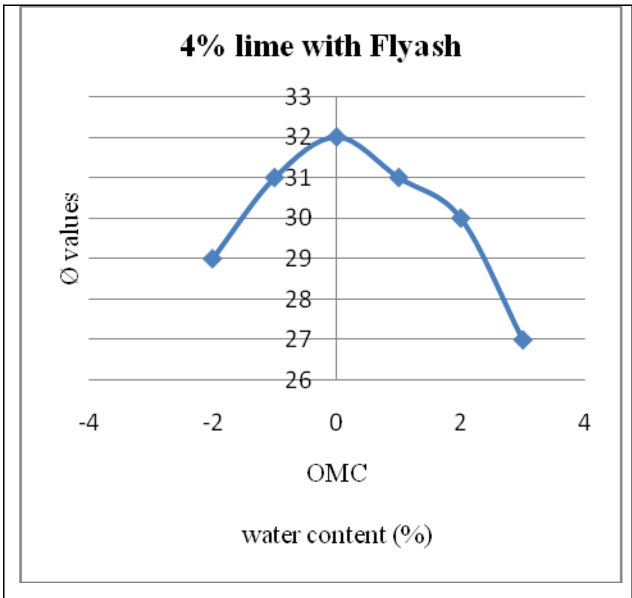


Fig No: 3.2.2.1(c)

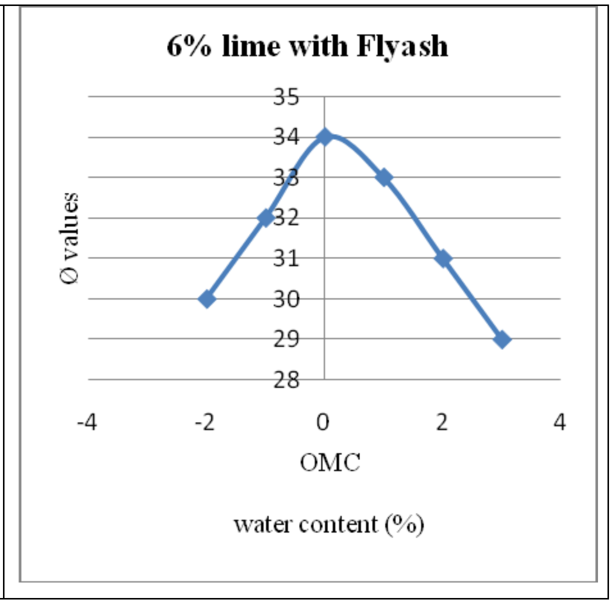


Fig No: 3.2.2.1(d)

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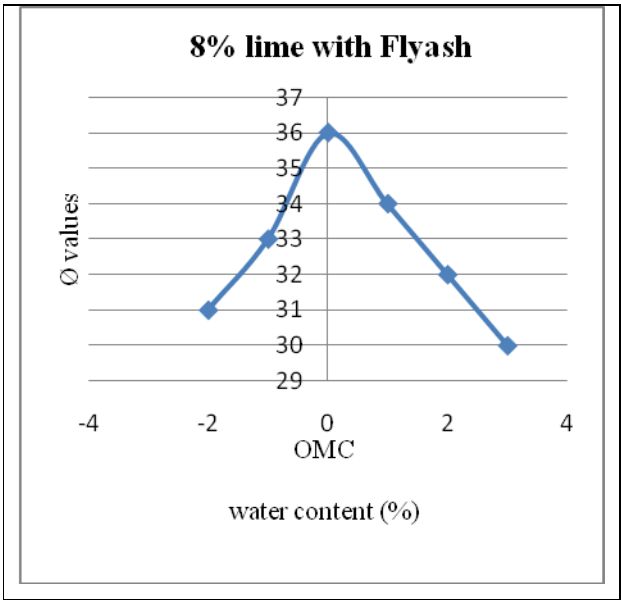


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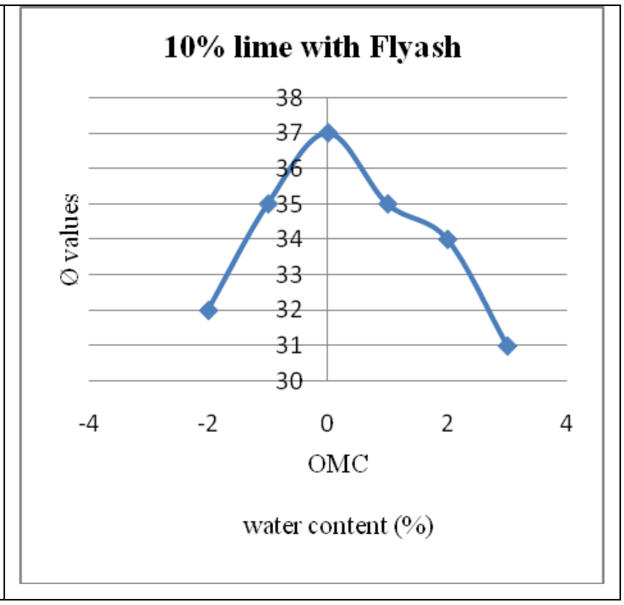


Fig No: 3.2.2.1(f)

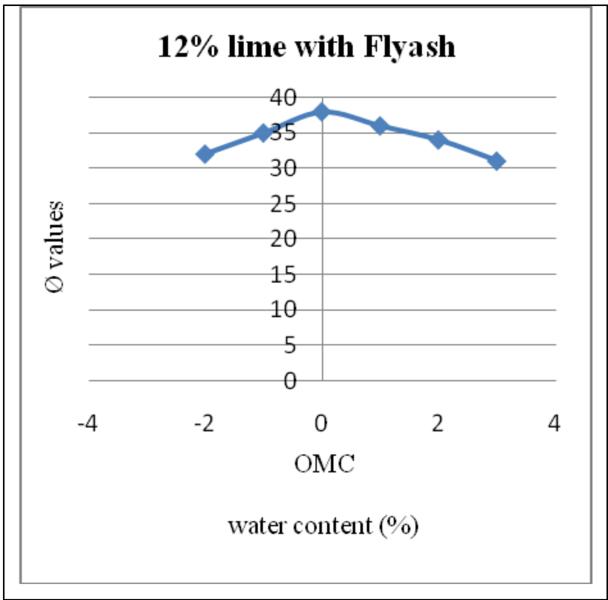


Fig No: 3.2.2.1(g)

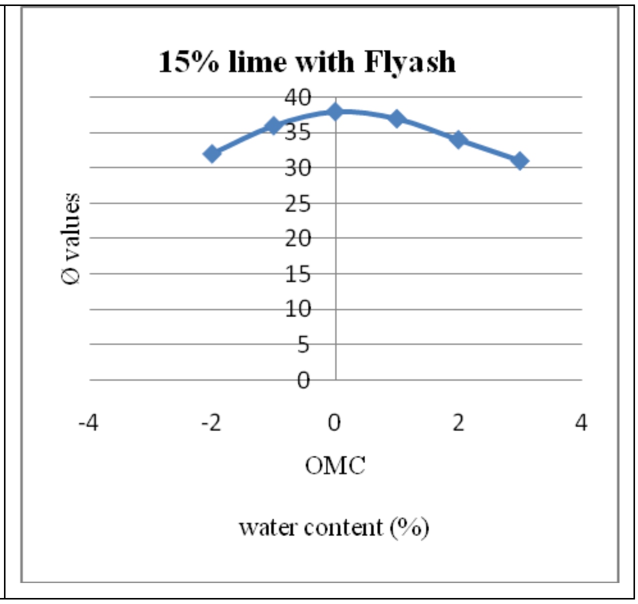


Fig No: 3.2.2.1(h)

The increase in shearing resistance was observed with increase in percentage of lime. The increase in lime content increases the percentage of calcium oxide which helps in improving the resisting capacity of fly ash samples. At OMC the values are maximum because of effective bonding among the particles of fly ash and

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lime. After OMC water content OMC(+1) have shown better resistance against shear compared to other water contents like OMC(-1),OMC(-2). This is due to active participation of calcium oxides and alluminates present in the stabilized mixes. Beyond OMC(+2) water content a decreased trend was observed because further increase in water content makes the structure of the mix dispersed and weak.OMC(-1) water content has given better results than OMC(-2) water content due to strong bond between the particles. This trend is same for all percentage additions of lime. The increase in OMC values increased the shearing resistance whereas the decreases in MDD values do the same. The increase of values with increase in percentage of lime is not only due to increase of calcium oxide but also due to the flocculated structure obtained in the mix. This flocculated structure forms chains in the mix so that a strong bond obtained in the mix. This mechanism involved in the mix helped in improving strengths.

## IV. CONCLUSIONS

From the study of Fly ash stabilized with lime, cement and sodium silicate at compacted condition. The following conclusions have derived:

- Maximum strengths are due to development of pozzolanic reaction between silica alumina with calcium forming calcium silicate accumulate gel. These gels crystalline with time are responsible for development of maximum strengths.
- Flocculation has taken place due to additives such as lime and sodium silicate with time.
- The shearing resistance values are maximum at 15% addition of lime in lime + Fly Ash mixes i.e. 38.
- Addition of 15% lime with 4% sodium silicate gives shearing resistance value 42 which is the maximum value among all other values.
- The values are less at both Dry of optimum and Wet of Optimum conditions because of formation of Dispersed Structure.
- The values are minimum at OMC-2 water content for all percentages of lime and sodium silicate additions because the water content is not sufficient to form flocculated structure.
- For all proportions of mixes the values are maximum at OMC water content in which the flocculation is effective.

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