National Conference on 'Advances in Engineering, Technology and Applied Sciences' - NCAETAS-2019
© 2019 IJSRSET | Volume 5 | Issue 6 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099

# Experimental Investigation On Industrial Waste Material For Green Concrete

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**ABSTRACT**

The raw materials of concrete consist of cement, sand and crushed aggregates. Partial replacement of these raw materials by waste products may decrease the cost, reduce the energy consumption and also reduce the environment pollution. Wastes can be used to produce new products or can be used as admixtures so that natural sources are used more efficiently and the environment is protected from waste deposits. Fly ash can be used as filler materials and helps to reduce the total voids content in concrete and metakaoline can be used as admixtures/additive in concrete. The use of steel dust in concrete is desirable of benefits such as useful disposal of a byproduct, reducing of river sand consumption and increased strength. However, the use of steel dust leads to a reduction in the workability of concrete. In this project the flyash, metakaoline and steel dust waste are utilized as a replacement with cement and fine aggregate in concrete mix, the size of the concrete cube is 150mm×150mm×150mm and they were tested with different mix proportions of 0%, 10%, 20%, for flyash, metakaoline and 30%, 40% for steel dust In this study, the main constituents of the concrete cube are Ordinary Portland Cement, Fine aggregate and the replaced material. However, This paper deals with the idea of finding suitable proportions of steel dust, flyash and metakaoline that could be related in attaining the target strength of concrete. Experiments were conducted to find the compressive strength of concrete for M25 grade, with OPC 43 grade of OPC cement. Based on the test results, can be conclude that combine use of steel dust and fly ash and metakaoline can be shown improved or decrease the strength in concrete and also preserve the environment.

**Keywords:** Flyash, Metakaoline, Steel Dust, Partial Replacement

## I. INTRODUCTION

GREEN concrete has nothing to do with color, It is a concept of using eco-friendly materials in concrete, to make the system more sustainable. Green concrete is very Often and also cheap to produce, because for example, waste products are used as a partial substitute for cement, charges .India there is large quantity of industrial waste generated , so it is very difficult to disposed off all these waste for land fill and incineration due to lack of space available and it is harmful for environment. Since the utilization of these waste becomes very necessary. So we are trying to utilize these waste products as a partially replacement of cement and fine aggregare in concrete. Today construction cost is very high with using routine material like cement, fine aggregate and coarse aggregate. This study includes use of different waste material as a partial replacement of cement and fine aggregate. It is a concept of using eco-friendly materials in concrete, to make the system more sustainable. In India, large amount of fly-ash and steel dust is generated in thermal power plants and steel plant respectively with an imperative blow on environmental and living organism. The use of fly-ash, metakaoline and steel dust in concrete can reduce the consumption of natural resources and also diminishes the effect of pollutant in environment. In recent studies, many researchers found that the use of additional cementitious materials like fly-ash, metkaoline and steel dust in concrete is economical and reliable. India is 2nd largest cement market country in the world after china, both in production and consumption. As of FY17, a total of 575 operational cement plants in the country has Capacity of 460 MTPA as of December 2017. This process is responsible for 5 to 8 percent of all carbon dioxide ($CO_2$) emissions worldwide.

## II. OBJECTIVE

In this project objective is to study the influence of partial replacement of fly-ash, metkaoline and steel dust in concrete subjected to different curing environments. In India, large amount of fly-ash, steel dust is generated in thermal power plants and steel plant with an imperative blow on environmental and living organism. The use of fly-ash and steel dust in concrete can reduce the consumption of natural resources and also diminishes the effect of pollutant in environment. The problem arising from continuous technological and industrial development is the disposal of waste material, the utilization of waste material in concrete, not only can reduce the cost of construction, but also proves to be a safest method of its disposal. To reduce the $CO_2$ emission in cement plant, reduce cost of the construction material and also reduce waste disposal problems of industries and wastes material and which are turned into a valuable by products and reduce the environmental pollution. This project deals with the idea of finding suitable proportions of steel slag, flyash and metakaoline that could be related in attaining the target strength of concrete.

## III. LITERATURE SURVEY

**Fattuhi and Hugle (1987)** In his presentation stated that different cement pastes and concrete mixes were prepared using ordinary Portland cement and subjected to sulphuric acid attack. The main parameters investigated included w/c ratio (and cement content) and age of the cementitious materials. 102 mm cubes were immersed in a channel containing an approximately 2% solution of continuously flowing sulphuric acid. The changes in weight with time for each cube were determined continuously up to a maximum exposure period of 50 days. The results indicated that the deterioration of the cubes for this high acid concentration decreased with a decrease in the cement content. The effect of age was slightly more significant for cement paste than for concrete cubes.

**Fareed Ahmed Memon et al (2010)** in this study concrete cube are made with OPC (Ordinary Portland Cement) and with different configurations of fly-ash by replacing cement and fine aggregate. To achieve the aim of this study, total 81 concrete cubes were cast. Among 81 cubes, 9 cubes were made with normal concrete, 36 cubes were made by replacing 25, 50, 75 and 100% of fine aggregate with fly-ash and 36 cubes were made by replacing 10, 25, 50 and 75% of cement with fly ash. The cubes were 6”X6” in crosssection, and the mix design was aimed for 5000 psi. After proper curing of all 82 cubes, they were tested at 3, 7 and 28 days curing age. The cubes were tested in Forney Universal Testing Machine. The compressive strength of concrete cubes made by replacing 100% fine aggregate by fly-ash was higher than the concrete cubes made with OPC at all 3, 7 and 28 days curing ages. On the other hand, the compressive strength of concrete cubes made by replacing 50 and 75% of cement by fly-ash were quite lower than the concrete cubes made with OPC at all curing ages.

**Alvin Harison et al (2014)** conducted a peculiar study on the utilization of materials which can fulfill the expectations of the construction industry in different areas. In this study cement has been replaced by fly-ash accordingly in the range of 0%,10%,20%,30%,40%,50%,60%by weight of cement for M-25 mix with 0.46 water cement ratio. Concrete mixtures were produced, tested and compared in terms of compressive strength. It was observed that

20% of replacement of Portland pozzolana cement (PPC) by fly-ash strength is increased marginally (1.9% to 3.2%) at 28 days and 56 days respectively. It was observed that upto 30% replacement of PPC by fly-ash strength is almost equal to the referral concrete after 56 days. PPC gained strength after 56days curing because of slow hydration process.

**Jian Tong Ding (2002**) investigated the MK or SK on the workability, strength, shrinkage and resistance to chloride penetration of concrete were investigated and compared in this study. For the given mixture proportions, MK offers better workability than does SF. As the replay\cement level was increased, the strength of the MK – modified concrete increased at all ages. The increase in the strength was similar to that of the SF – modified concrete. The incorporation of the both MK and SF in concrete can reduce the free drying the free drying shrinkage and restrained shrinkage cracking width. The initial cracking appeared earlier in the SF- and MK- in concrete can reduce the chloride diffusion rate significantly, with the SF concrete performing somewhat better.

**Patil (2012)** studied the compressive strength of concrete increases with increase in HRM content up to 7.5%. Thereafter there is slight decline in strength for 10%, 12% and 15% due excess amount of HRM which reduces the w/b ratio and delay pozzolanic activity. The higher strength in case of 7.5% addition is due to sufficient amount of HRM available to react with calcium hydroxide which accelerates hydration of cement and forms C-S-H gel. The 7.5% addition of high reactivity metakaolin in cement is the optimum percentage enhancing the compressive strength at 28 days by 7.73% when compared with the control mix specimen. The 7.5% addition of high reactivity metakaolin in cement is enhanced the resistance to chloride attack. The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 3.85% as compared with the reduction of strength of control mix specimen is by 4.88%. The 7.5% addition of high reactivity metakaolin in cement is also enhanced the resistance to sulfate attack. The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 6.01% as compared with the reduction of strength of control mix specimen by 9.29%. The present study deals with the compressive strength, split tensile strength and flexural strength for cement replacement by metakaolin based concrete.

**R.Srinivasan, K.Sathiya & M. Palanisamy** reported on "Experimental investigations in developing low cost concrete from paper industry waste". Over 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials pose problems of disposal and health hazards. The wastes like phosphor gypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them.

**A Balwaik & SP Raut** reported on "Utilization of waste paper pulp by partial replacement of cement in concrete". The use of paper-mill pulp in concrete formulations was investigated as an alternative to landfill disposal. The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. By using adequate amount of the waste paper pulp and water, concrete mixtures were produced and compared in terms of slump and strength with the conventional concrete.

## IV. CONCLUSIONS FROM LITERATURE

In concrete cement can be replaced with 10% to 20% Flyash with maximum increase in strength beyond starts decreases. 10% to 20% cement replacement by Metakaolin is superior to all other mixes.The increase in Metakaolin content improves the compressive strength and split tensile strength up to 10% to 20% cement replacement. Compressive strength and workability increased with increase in steel slag content. Fine aggregate with 30% to 40% replacement showed better mechanical properties in the hardened state. Compressive strength increased upto 30% of replacement with steel dust, and then decreased at all ages.

## V. METHODOLOGY

### Experimental program and Mix Proportions

Concrete mix design for the mix design procedure given in IS: 10262 were followed with minor modification for M25 grade for a target mean strength of 31.6 MPa. Taking into considerations, the minimum requirements for cement, fine aggregate and coarse aggregate content in kg/m$^3$ of concrete for M25 is 438 kg/m$^3$,812 kg/m$^3$ and 1033 kg/m$^3$ respectively. In the present experimental investigation on fly-ash, metakaoline and steel dust has been used as a partial replacement of cement and fine aggregate as an additional ingredient in concrete mixes. The effect of adding different percentages of fly-as (10%-20% of cement), metkaoline (10%-20% of cement) and steel dust (30%-40% of fine aggreagte) has additional material to concrete mixes on their compressive strength were studied.

### Casting of Cube

The standard size of cube is 150 mm. Cubes of 150 mm size are suitable for concrete having a nominal maximum aggregate size 10mm to 20 mm. After the sample has been remixed, immediately fill the cube moulds and compact the concrete, either by hand or by vibration. Any air trapped in the concrete will reduce the strength of the cube. Hence, the cubes must be fully compacted. However, care must also be taken not to over compact the concrete as this may cause segregation of the aggregates and cement paste in the mix. This may also reduce the final compressive strength. Immediately after making the cubes they should be marked clearly. This can be done by writing the details of the cube in ink on a small piece of paper and placing on top of the concrete until it is demoulded.

### Curing

The minimum period for curing concrete to attain maximum strength is 28 Days. The period for curing is 7 days, 28 days and 45 days. From the above graph, it is clear that concrete attains 50% of its design strength when it cured for 3-7 Days. 75% of Compressive strength achieved in 14 days and 90% of strength by 28 days as time goes on the strength increase gradually. Early strength of concrete is more important, and it is responsible for the ultimate strength of concrete. We should do proper curing as per the environment condition, type of member, etc. Maintaining the proper temperature also plays an important role in concrete as mentioned, it should not be cooler than 5deg C. It is recommended to keep concrete moist for 28 days. Nowadays Due to lack of time, the curing can be achieved by following modern techniques in 14-20 Days. But it is always recommended to keep concrete moist for at least 14 days. As per **IS 456 – 2000** concrete should not be cured less than 7 days for OPC

### Testing

Compressive Strength Test a digital compressive testing machine is used for determine the compressive strength of hardened concrete as per the requirements of IS 516-1959 using standard 150mm cubes. The test was conducted on 150mm x 150mm x 150mm cube specimen at 7, 28, and 45 days. The sample cubes were placed in the testing machine. Loading were applied on the sample until the sample fails, where the reading started to decline. The test was repeated conducted on another two more cubes and the value was taken as the average.

**Figure 1.** compressive testing machine

Workability test by Slump test Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the most simple workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922.

**Experimental Analysis**

To study and compare the behavior of concrete using flyash, metakaoline and steel dust as partially replacement of cement and fine aggregate experimental investigations as mentioned were carried out on concrete samples for their strength and properties. The concrete samples were cast with mix 1:1.85:2.35. The tests were carried out after 7, 28, 45 days of the casting of concrete specimen. Summary of the test result for concrete mixes with partially replacement of fine aggregate using steel dust and the partially replacement of cement with flyash and metakaoline as recorded.

## VI. MATERIALS USED

**Flyash**

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($SiO2$) (both amorphous and crystalline) and calcium oxide ($CaO$), both being endemic ingredients in many coal bearing rock strata. About 43 percent is recycled and often used to supplement Portland cement in concrete production.

Chemical Properties of cement and Fly Ash

**Table 1**

| Properties | Cement | Flyash |
|---|---|---|
| Ca O | 63 | 12.9 |
| Si O2 | 34 | 44.5 |
| Al2 o3 | 5.5 | 21.1 |
| SO3 | 1.92 | 7.87 |
| Na2o | - | 6.25 |
| K2O | 0.48 | 0.8 |
| Specific gravity | 3.15 | 2.1-3.0 |

**Figure 2.** Flyash

**Metakaoline**

Meta kaolin is not a by-product. I t is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 6500 C and 8500 C, followed by grinding to achieve a finesse of 700-900 m2/kg. It is a high quality pozzolonic material, which is blended with cement in order to improve the durability of concrete. When used in concrete it will fill the void space between cement particles resulting in a more impermeable concrete. Meta kaolin, is a relatively new material in the concrete industry, is effective in increasing strength, reducing sulphate attack and improving air-void network. resulting in an increased strength and reduced porosity and therefore improved durability.

Chemical Properties of Cement and Metakaolin

Table 2

| Properties | Cement % | Metakaolin % |
|---|---|---|
| Silica ($SiO_2$) | 34 | 54.3 |
| Alumina $Al_2O_3$ | 5.5 | 38.3 |
| Calcium oxide CaO | 63 | 0.39 |
| Ferric oxide Calcium oxide ($Fe_2O_3$) | 4.4 | 4.28 |
| Magnesium oxide (MgO) | 1.26 | 0.08 |
| Potassium oxide ($K_2O$) | 0.48 | 0.50 |
| Sulphuric anhydride ($SO_4$) | 1.92 | 0.22 |
| Specific gravity | 3.15 | 2.5 |

**Figure 2.** Metakaoline

**Steel Dust**

Slag is a partially vitreous by-product of the process of smelting ore, which separates the desired metal fraction from the unwanted mass. slag is usually a mixture of metal oxides and silicon dioxide. Ground granulated slag is often used in concrete in combination with Portland cement as part of blended cement. Ground granulated slag reacts with water to produce cementitious properties. Concrete containing ground granulated slag develops strength over a longer period, leading to reduced permeability and better durability. Since the unit volume of Portland cement is reduced, this concrete is less vulnerable to alkali-silica and sulphate attack.

Chemical Properties of cement and Steel dust

**Table 3**

| Properties | Cement | Steel dust |
|---|---|---|
| $Al_2O_3$ | 5.5 | 21.4 |
| CaO | 63 | 0.32 |
| $Fe_2O_3$ | 4.4 | 64.35 |
| MgO | 1.26 | 0.17 |
| $SiO_2$ | 34 | 13.21 |
| MnO | - | 0.06 |
| Specific gravity | 3.15 | 2.68 |

**Figure 3.** steel dust

**Cement**

Ordinary Portland Cement (43 grade) conforming to IS IS 8112 : 2013 was used for the experimental work. Laboratory tests were conducted on cement to determine specific gravity, fineness, standard consistency, initial setting time, final setting time and compressive strength. In this work 10%-20% of cement was replaced by fly ash and metakaoline. Specific gravity of cement was 3.15.

**Fine Aggregate**

Tests were done according to IS 2386 (part 3):1963. M sand passing through 4.75mm sieve conforming to zone II as per IS 383:1970 was used for the experiment.

The properties of fine aggregate are,Specific gravity 2.61 and Fineness modulus 2.97.

**Coarse Aggregate**

Coarse aggregate used in this study were 20mm nominal size, and were tested as per the Indian Standard Specifications IS 383:1970. Its physical properties and sieve analysis results are shown in Table 3.5 and 3.6 respectively. The particle size distribution curve in Figure 3.4 shows that the coarse aggregate belongs to the standard zone.

## VII. EXPERIMENTAL INVESTIGATION

In the present experimental investigation on fly-ash, metakaoline and steel dust has been used as a partial replacement of cement and fine aggregate as an additional ingredient in concrete mixes. The effect of adding different percentages of fly-as (10%-20%), metkaoline (10%-20%) and steel dust (30%-40%) has additional material to concrete mixes on their compressive strength were studied.

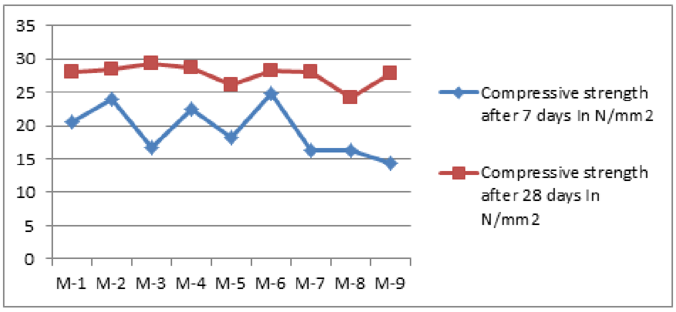
## VIII. TEST RESULTS & DISCUSSION

The test was conducted on 150mm x 150mm x 150mm cube specimen at 7, 28, and 45 days. The sample cubes were placed in the testing machine. Loading were applied on the sample until the sample fails, where the reading started to decline. The test was repeated conducted on another two more cubes and the value was taken as the average.(IS:516-1959)

The mix proportion design and compressive test result after 7 and 28 days are presented in Table.

**Mix design-1.** (flyash + steel powder)

| Mix design | OPC Cement with replaced | | FA replaced with steel dust | Compressive strength after 7 days in N/mm2 | Compressive strength after 28 days in N/mm2 |
|---|---|---|---|---|---|
| | Flyash | Metakaoline | | | |
| M-1 | - | - | - | 20.55 | 28.11 |
| M-2 | - | - | 30 | 24.00 | 28.44 |
| M-3 | - | - | 40 | 16.66 | 29.33 |
| M-4 | 10 | - | - | 22.44 | 28.66 |
| M-5 | 20 | - | - | 18.11 | 26.11 |
| M-6 | 10 | - | 30 | 24.88 | 28.22 |
| M-7 | 10 | - | 40 | 16.22 | 28.11 |
| M-8 | 20 | - | 30 | 16.33 | 24.22 |
| M-9 | 20 | - | 40 | 14.44 | 27.72 |

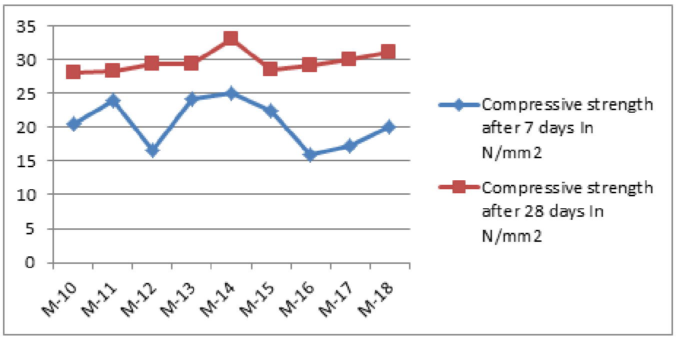



**Graph. 1.0** Compressive strength results of Fly-ash and steel dust in concrete

**Mix design-2.** (metakaoline + steel powder)

| Mix design | OPC Cement with replaced | | FA replaced with steel dust | Compressive strength after 7 days in N/mm2 | Compressive strength after 28 days in N/mm2 |
|---|---|---|---|---|---|
| | Flyash | Metakaoline | | | |
| M-10 | - | - | - | 20.55 | 28.11 |
| M-11 | - | - | 30 | 24.00 | 28.44 |
| M-12 | - | - | 40 | 16.66 | 29.33 |
| M-13 | - | 10 | - | 24.22 | 29.33 |
| M-14 | - | 20 | - | 25.11 | 33.11 |
| M-15 | - | 10 | 30 | 22.55 | 28.55 |
| M-16 | - | 10 | 40 | 16.00 | 29.30 |

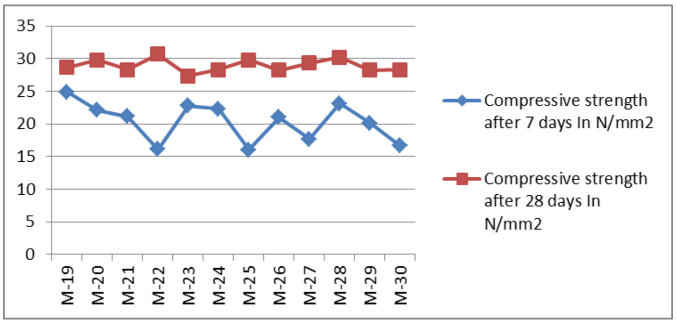
| | | | | | |
|---|---|---|---|---|---|
| M-17 | - | 20 | 30 | 17.22 | 30.11 |
| M-18 | - | 20 | 40 | 20.00 | 31.22 |




**Graph. 2.0.** Compressive strength results of metakaoline and steel dust in concrete

**Mix design-3.** (flyash + metakaoline + steel powder)

| Mix design | OPC Cement with replaced | | FA replaced with steel dust | Compressive strength after 7 days in N/mm2 | Compressive strength after 28 days in N/mm2 |
|---|---|---|---|---|---|
| | Flyash | Metakaoline | | | |
| M-19 | 10 | 10 | - | 24.88 | 28.66 |
| M-20 | 20 | 20 | - | 22.11 | 29.77 |
| M-21 | 10 | 20 | - | 21.11 | 28.31 |
| M-22 | 20 | 10 | - | 16.11 | 30.66 |
| M-23 | 10 | 10 | 30 | 22.77 | 27.33 |
| M-24 | 10 | 10 | 40 | 22.33 | 28.33 |
| M-25 | 20 | 20 | 30 | 16.00 | 29.77 |
| M-26 | 20 | 20 | 40 | 20.98 | 28.22 |
| M-27 | 20 | 10 | 30 | 17.66 | 29.33 |
| M-28 | 10 | 20 | 40 | 23.11 | 30.22 |
| M-29 | 10 | 20 | 30 | 20.11 | 28.22 |
| M-30 | 20 | 10 | 40 | 16.66 | 28.33 |




**Graph. 3.0.** Compressive strength results of Fly-ash, metakaoline and steel dust in concrete

## IX. CONCLUSIONS

1. The compressive strengths of concrete (with 0%, 10% and 20%, weight replacement of cement with Flyash and 0%, 30% and 40% weight replacement of fine aggregate with steel dust) cured in water for 7, 28 days indicate that at 10% replacement of flyash and 40% replacement of steel dust there is increase in strength and beyond that the strengths decreased, also the combined mix of flyash 10% of cemet and steel dust 40% of fine aggregate increase in compressive strength beyond that the strengths decreased
2. The compressive strengths of concrete (with 0%, 10% and 20%, weight replacement of cement with metakaoline and 0%, 30% and 40% weight replacement of fine aggregate with steel dust) cured in water for 7, 28 days indicate that at 20% replacement of metakaoline and 40% replacement of steel dust there is increase in strength and beyond that the strengths decreased, also the combined mix of metakaoline 20% of cement and steel dust 40% of fine aggregate increase in compressive strength beyond that the strengths decreased
3. Fine aggregate with 40% replacement with steel dust showed better mechanical properties in the

hardened state. Compressive strength increased upto 40% of replacement with steel dust, and then decreased at all ages. The combined mix of flyash 10% of cement, metakaoline 10% of cement and steel dust 40% of fine aggregate increase in compressive strength at 28th day

## X. REFERENCES


[1]. A.H.L.Swaroop, K.Venkateswararao, and Prof P Kodandaramarao (2013), Durability Studies On Concrete With Fly Ash & Ggbs, International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, pp.285-289.

[2]. Alvin Harison, Vikas Srivastava and Arpan Herbert (2014), Effect of Fly Ash on Compressive Strength of Portland Pozzolona Cement Concrete, Journal of Academia and Industrial Research (JAIR), Vol 2, Issue 8, pp 476-479.

[3]. Sabir B.B, Wild S, Bai J, "Metakaolin and calcined clay as pozzolans for concrete :a review" Cement and concrete composite 23 ,(2001),pp.441-454.

[4]. Jian-Tong Ding and Zongjin Li "Effects of Metakaolin and Silica Fume on Properties of Concrete" ACI Materials Journal/July-August 2002,pp.393-398

[5]. Badogiannis E, Papadakis V.G., Chaniotakis E, Tsivilis S, "Exploitation of poor Greek kaolins: Strength development of metakaolin concrete and evaluation by means of k-value" Cement and Concrete Research 34 (2004),pp.1035–1041.

[6]. S.Tanveer Hussain, K.V.S Gopala Krishna Sastry " Study of strength properties of concrete by using micro silica and nano silica" in IJRET, eISSN: 2319-1163 | pISSN: 2321-7308, Vol-3, Issue: 10, Oct-2014.

[7]. Mohammad Panjehpour, Abang Abdullah, Abang Ali, Ramazan Demirboga "A review for characterization of silica fume and its effects on concrete properties ".

[8]. Aman Jatale, Kartiey Tiwari, Sahil Khandelwal (2013) - "Effects on Compressive Strength When Cement is Partially Replaced by Fly Ash" IOSR Journal of Mechanical and Civil Engineering, e-ISSN 2278-1684, Vol. 5, pp 34-43. [

[9]. Justice J.M, Kennison L.H, Mohr B.J., Beckwith S.L, McCormick L.E, Wiggins B., Zhang Z.Z, and Kurtis K.E, "Comparison of Two Metakaolins and a Silica Fume Used as Supplementary Cementitious Materials" SP-228(Volume1&2) Seventh International Symposium on Utilization of High-Strength/HighPerformance Concrete, June(2005),SP228.

[10]. P.S.Kothai and Dr.R.Malathy (2014), Utilization of Steel Slag in Concrete as a Partial Replacement Material for Fine Aggregates, International Journal of Innovative Research in ScienceEngineering and Technology, Vol 3, Issue 4, pp 11585-11592.

[11]. Parvati V. K and Prakash K.B (2013), Feasibility Study of Fly Ash as a Replacement for Fine Aggregate in Concrete and its Behaviour under Sustained Elevated Temperature, International Journal Of Scientific & Engineering Research, Vol 4, Issue 5, pp 87-90.