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# Experimental Study of HPC including with Ultra-Fine Slag and Fly Ash

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**ABSTRACT:** This research investigates the effects of incorporating Alccofine at varying percentages (8%, 10%, 12%, and 14%) in conjunction with a fixed percentage (15%) of fly ash in high performance concrete. The study focuses on evaluating the compressive strength of the concrete at two critical curing ages: 7 days and 28 days. A series of concrete mixes were prepared and subjected to compressive strength testing according to relevant standards. The experimental results reveal the influence of Alccofine and fly ash proportions on the compressive strength development of the concrete. Analysis of the data sheds light on the optimal combination of Alccofine and fly ash for enhancing the mechanical properties of high performance concrete. This research contributes to advancing the understanding of supplementary cementitious materials in concrete mix design and offers valuable insights for engineers and practitioners seeking to optimize the performance of concrete structures.

**KEYWORDS:** Alccofine, FlyAsh, High performance Concrete.

## I. INTRODUCTION

### 1.1 Background:

Concrete is the backbone of the construction industry, and the demand for solid pavements in road construction is also growing. However, the production of cement in large quantities causes environmental problems such as the release of greenhouse gases (CO) and the depletion of natural resources. Therefore, it is necessary to use industrial by-products such as Ash, Alccofine, etc. without changing the technical properties of the concrete. Today, most concrete mixes contain additional cementitious materials that form part of the cement component. These materials are mostly byproducts from other processes. Developing countries like India are witnessing massive construction activities in infrastructure sectors. The transport sector in particular has seen significant construction of highways, roads, ports, railways and airports in the last decade. The vast amount of civil infrastructure in the world includes a vast stretch of the road network. Today, high performance concrete (HPC) is mostly used for highway pavements due to its high durability even under high repeated loads. Due to the high resistance and strength, HPC demand in the construction industry from railways, bridges, buildings, pavements. Sidewalks are an important part of the road infrastructure. The need for HPC is growing due to its high demands in road construction. The initial cost of concrete may be higher than asphalt pavement, but concrete costs less over the life cycle of the pavement. Roads can be opened faster than ever and can be easily repaired with the right equipment, materials, processes or procedures. Concrete road infrastructure around the world requires innovative and cost-effective rehabilitation solutions. An extensive literature is presented on recent research on high-quality concrete using different admixtures in different proportions to improve physical and mechanical properties in order to design high-strength concrete that can be used in road pavements. This research deals with the mechanical and rheological properties of high-performance concrete with the replacement of cement with industrial by-products such as Alccofine and Ash. The study is conducted to check the behavior of HPC using fly ash and Alccofine for road applications. Because Alccofine and Fly ash exhibit cementing properties, they can be easily used to produce high-performance concrete. The main objective of the study is to design HPC class M60 according to the ACI method and to determine the mechanical properties. Concrete is produced by mixing a solid proportion of fly ash (25%) and various proportions of Alccofine (8%, 10%, 12%, 14%). Mechanical properties such as compressive strength, tensile strength and flexural strength are determined at the age of 28 days. Alccofin and Fly ash increase rheological properties due to their smaller particle size. The addition of Alccofine and Fly ash helps to gain strength

properties and makes the concrete environment friendly without much impact on the price. Keywords: Alccofine, Fly ash, concrete, Portland cement, rheological properties.

Due to increase in infra structure use of cementitious materials is abundantly increased up to a greater extent, also manufacturing of these causes a lot of environmental disturbances. So, to overcome these issues we have come up with a concept of using ultra fine slag (i.e. Alccofine 1203) as well as fly ash which may partially replace cementitious materials and also fine aggregates by increase in properties of concrete.

### Ultra-Fine Slag

- Ultra-Fine slag is a micro-fine material of particle size much finer than other hydraulic materials like cement, fly-ash, ground-granulated blast furnace slag (GGBS), silica fume, etc. being manufactured in India.
- Ultra-Fine slag has special attributes to enhance the performance of concrete because of its optimized particle size distribution.
- Ultra-Fine Slag is produced in completely controlled conditions with special types of equipments/instruments to manufacture optimized particle size distribution
- The two types of Ultra-Fine Slag/Alccofine that are most widely used are as follows:-
  1. **Alccofine 1101**
  2. **Alccofine 1203**

- 1 **Alccofine 1101:-** It's an Alccofine with high-calcium silicate. It's micro finer cementitious grouting material for rock anchoring and soil stabilization. The performance of Alccofine is best overall admixture used in India because of its high-calcium oxide (CaO) content.

#### **Reason Why it is not being used?**

The Alccofine 1101 has high-content of Cao and Calcium Silicate, therefore the water demand for curing of high strength concrete is more which increases the time required for heat of hydration which emits large amount of CO<sub>2</sub> gas into atmosphere and directly affects our Environment.

- 2 **Alccofine 1203:-** It's an alccofine with low calcium silicate. Alccofine 1203 represent fine, micro-fine and ultra-fine particle sizes. Alccofine 1203 is a slag-based Supplementary Cementitious Material having ultra-fineness with optimized particle size distribution.



*Fig.1.1 Alccofine-1203 packaged bag*

#### **Reason Why it is being Used?**

As it has low calcium silicate and due to its ultra-fineness it gives reduced water demand for a given workability of concrete even up to 40% substitution level as per requirement and it triggers the primary reaction during hydration.

### Fly ash

Fly ash (FA) is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical glassy particles

called fly ash. Due to the fusion-in-suspension these fly ash particles are mostly minute solid spheres and hollow cenospheres with some particles even being plerospheres, which are spheres containing smaller spheres. The size of the fly ash particles varies but tends to be similar to slightly larger than type I Portland cement. The fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. Chemical make up of fly ash is primarily silicate glass containing silica, alumina, iron and calcium. Colour generally ranges from dark.



*Fig. 1.2 Fly ash*

A pozzolan is a siliceous or aluminosiliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland cement to form additional calcium silicate hydrate and other cementitious compounds. The hydration reactions are similar to the reactions occurring during the hydration of Portland cement. Thus, concrete containing fly ash pozzolan becomes denser, stronger and generally more durable long term when compared to straight Portland cement concrete mixtures. to yellowish tan for fly ash used for concrete. In addition it has a pozzolanic property.

### **1.2 Problem Statement:**

- By using ultra-fine slag (i.e. Alccofine F1203), the water demand for Concrete gets reduced resulting low heat of hydration.
- Now-a-days, use of high strength concrete is necessary for the constructions of Dams, high rise buildings, Bridges etc. addition of different fibres improves the effective strength of structure.
- Increase in use of concrete requires more and more consumption of water which can be a greater issue, it can be tackled by the addition of Alccofine.

### **1.3 Objectives:**

1. To Study effect of Ultra fine slag and Fly Ash on Physical Properties of HPC.
2. To Evaluate Optimum Percentage of Alccofine for HPC.
3. To design Mix Proportion for HPC with Alccofine.

### **1.4 Scope of the Project Work:**

- To reduce the impact on environment
- To reduce water demand
- Get more strength to concrete
- To Improve the Overall performance of the structure
- Helps in Reducing the Carbon Emission by using the ultra-fine slag
- To achieve the effective workability and durability of concrete.

### **1.5 Research Methodology:**

The adopted methodology for the following will be 30 cubes with different combinations of dose for fly ash and Alccofine.

Size of 1 Cube = 150 X 150 X 150 mm

To find the optimum dosage of Alccofine and Fly ash for maximum strength in concrete cube following tests are to be conducted: -

- Primary test on Material: -

Sieve Analysis

- Secondary test on Hardened Concrete: -  
Compression Strength test

## II. LITERATURE REVIEW

### 2.1 General

All the research paper gave a brief idea about the building concept and analysis method which can be implemented in our project and gives better results.

### 2.2 Literature Review:

**Raj Bahadur, Miss Shivani, (2023),** “*Nature Of High-Performance Concrete For Highway Pavement Using Alccofine And Fly ash*”, This paper investigates that High performance concrete is modified by mixing with fly ash and Alccofine as SCM. These modifications reduce CO<sub>2</sub> emissions and make the concrete environmentally friendly. From the compressive strength of different mixture ratios considering all available SCMs, it was found that the mixture containing fly ash and Alccofine gave good results. There was a significant improvement in the flexural behavior of the concrete mixture containing fly ash and Alccofine.

**Wei Li, Liming Yi, et al, (2022),** “*Effects of Ultrafine Blast Furnace Slag on the Microstructure and Chloride Transport in Cementitious Systems under Cyclic Drying–Wetting Conditions.*” This paper investigates the effects of ultrafine blast furnace slag on hydration, microstructural formation, and chloride transport in cementitious specimens. The role of the degree of saturation in the resistance to chloride penetration is emphasized. It is normally considered that higher fineness results in higher reactivity of slag powders. However, higher fineness will inevitably increase the amount of water needed to maintain fluidity, and slag powders react more drastically at an early age.

**Zhishu Y, Chen Wang, et al, (2021),** “*Experimental study on the dynamic mechanical properties of high-performance hybrid fiber reinforced concrete of mine shaft lining*” This paper investigates the HFRC has significantly higher dynamic strength and compressive deformation capacity with a well-improved brittleness compared with the reference concrete. The addition of hybrid fibers increased the cracking resistance and enhanced the toughness. The HFRC investigated herein can effectively resist impact loading under variable strain rates, which was an ideal construction material for the structure of mine shaft lining under dynamic loading.

**Sheharyar Rehmat, Amir Sadeghnejad, et al, (2021),** “*Experimental study on concrete filled steel tubes to footing connection using ultra-high performance concrete*”, This paper investigates the reinforcement dowels are used for force transfer between the UHPC layer and the concrete footing. Due to high mechanical strength of UHPC, the development length of dowels can be reduced compared to grouted or NSC layer. Two variations of the detail, an encased and an embedded, were studied based on the location of the UHPC layer. For the embedded detail the UHPC was partially embedded in the footing. In the encased connection, the UHPC layer was placed completely outside the footing.

**Junjie Zhang, Hongbo Tan, et al, (2020),** “*Ultra-fine slag activated by sodium carbonate at ambient temperature.*” This paper investigates the Compressive strength of NC-activated slag was enhanced by increasing NC, but the improving effect was reduced with time. The growth of sodium ion increased the pH value obviously to promote the dissolution of slag, and the more sodium ions provided the more C-N-A-S-H formed.

**Bharat Bhushan Jindal, Parveen Jangra, et al, (2020),** “*Effects of ultra fine slag as mineral admixture on the compressive strength, water absorption and permeability of rice husk ash based geopolymer concrete*”, This paper investigates Rice husk based geopolymer concrete with the inclusion of ultrafine slag with different proportions was investigated experimentally to ascertain the effects of rice husk as well as UFS content on compressive strength, water permeability in terms of depth of water penetration and percentage water absorption value. Since rice husk ash is an industrial by-product, the disposal of which is a serious concern, the results obtained from experimental observing predict that the RHA-GPC showed a significant improvement in strength and durability properties on the inclusion of UFS at normal room temperature.

**Saowarot Hasita, Apichat Suddeepong, et al, (2020),** “*Properties of Asphalt Concrete Using Aggregates Composed of Limestone and Steel Slag Blends*” This paper investigates the mechanical properties of asphalt concrete using

aggregates consisting of limestone (L) and steel slag (S) blends. The properties of the L/S asphalt concrete were compared with those of L asphalt concrete. Two commercially available asphalt cements were used: asphalt cement penetration grade AC60/70, and polymer-modified asphalt (PMA). Test results indicated that S replacement improves the stability of L asphalt concrete. The flow value and the strength index were found to be insignificantly affected by the asphalt cement and aggregate.

**Saowarot Hasita, Runglawan Rachan, et al,** (2020), “*Performance Improvement of Asphalt Concretes Using Steel Slag as a Replacement Material*” This paper investigates the performance tests of asphalt concretes using limestone, granite, and steel slag as coarse aggregate in asphalt mixtures were performed to determine the advantage of replacement with S. For a particular asphalt cement, the stability of both L:L:L:L asphalt concrete and L:G:G:G asphalt concretes was essentially the same. The S replacement enhanced significantly the stability of asphalt concrete.

**R.A.C.J. Seneviratne, G. Tharmarajah,** (2017), “*Experimental Study on Addition of Pine Fibers to High Strength Concrete*” This paper investigates the reduction in compressive strength was observed when pine fibres added to the concrete. A sharp reduction (38%) in compressive strength was observed between 0% fibre added concrete and 2% fibre added concrete. However, the reduction in compressive strength was relatively lower between 2% fibre added concrete and 6% fibre added concrete, Reduction in flexural tensile strength was obtained when fibres were added to concrete. An 18% reduction in tensile strength. As the fibre content was increased, an increase of flexural tensile strength was obtained.

**Henry H.C. Wong and Albert K.H. Kwan,** (2016), “*Packing Density: A Key Concept for Mix Design of High Performance Concrete*”, This paper investigates that the concept of packing density has been introduced. It is believed that maximisation of the packing density of the cementitious materials and the packing density of the aggregate particles could improve the overall performance of the resulting concrete mix and thus should be the general guideline for mix optimisation. On the other hand, despite the increasing popularity of HPC, a systematic mix design method for HPC is still lacking. Nevertheless, the proposed three-tier system design method points to a new direction for the development of a mix design method that is applicable not only to HPC but also to ordinary concrete.

**M. Ondova, N. Stevulova, et al,** (2012), “*The study of the properties of fly ash based concrete composites with various chemical admixtures.*” This paper investigates the development of new specifications and tests leads to reduction of materials related problems when fly ash is used in concrete construction for transport infra-structure. Additionally, the rational tests based on documented research prove that the increase of the fly ash utilization provides a net of environmental benefits. Also, the cost reducing of the road building is more important economic benefits.

**Darren T.Y. Lim, Da Xu, et al,** (2011), “*Effect Of Ultra Fine Slag Replacement On Durability And Mechanical Properties Of High Strength Concrete*” This paper investigates the UFGGBS has a larger total surface area, and thus, more of it is available for hydration and pozzolanic reaction, compared to normal GGBS. In addition, better workability and higher consistency were achieved by utilizing UFGGBS. This will lead to an early strength development in terms of compressive and flexural strength, as studied. A higher compressive and flexural strengths compared to the control concrete was achieved at age of 3 days. This early development of strength is contrary to well established knowledge of ordinary GGBS.

### 2.3 Summary:

From this literature review, we studied the detailed concept of High-Performance Concrete with the addition of Fly ash and Alccofine in partial replacement of Cement and Fine aggregate. Also gained information for how many percent of replacement can be done in concrete with Alccofine and Fly ash. Following Research papers concluded need for use of Alccofine in concrete, which clarified need of optimum proportion for mixing of Alccofine.

## III. METHODOLOGY

### 3.1 General:

For Study of optimum dosage of Alccofine and Fly ash for Addition in concrete casting of 30 Cubes are held in carrying different dosages.

Size of 1 Cube = 150 X 150 X 150 mm

Different dosage of Alccofine and Fly ash in partial replacement of Cement and Fine Aggregate respectively are

**Table no 3.1 Percentage replacement of Alccofine and Fly Ash w.r.t cubes**

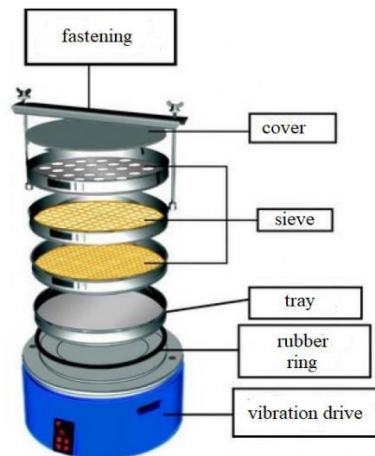
No. of Cubes	Alccofine % (in partial replacement with cement)	Fly ash % (in partial replacement with Fine aggregate)
6 Cubes	0%	0%
6 Cubes	8%	15%
6 Cubes	10%	15%
6 Cubes	12%	15%
6 Cubes	14%	15%

**3.2. Primary test on Material: -**

Sieve Analysis

➤ **Sieve Analysis: -**

Sieve analysis is the traditional method for determining particle size distribution. Solid particles ranging in size from 125 mm down to 20 µm can be measured quickly and efficiently by dry or wet sieving using standard test sieves.



*Fig.3.1 Sieve analysis*

- **Fly Ash** - Sieve Analysis is carried out for checking the fineness of the Fly ash to replace fine aggregate in the concrete.
- **Alccofine** - Sieve Analysis is carried out for checking the fineness of Alccofine to replace cement in the concrete.

**3.3. Secondary test on Hardened Concrete: -**

Compressive Strength test

➤ **Compressive Strength Test: -**

Compressive testing shows how the material will react when it is being compressed. Compression testing is able to determine the material's behavior or response under crushing loads and to measure the plastic flow behavior and ductile fracture limits of a material.



*Fig.3.2. Compressive strength test*

**IV. RESULTS & DISCUSSION**

**4.1 General**

In this study, we have study the change in strength of High Pressure Concrete when addition of Alcofine and Fly Ash in the concrete. To analyze strength differences we have casted 30 no of cubes for different combinations of Alcofine and Fly ash. Each combination included 6 cubes for strength check of 7 days and 28 days. The main aim of the study is to finalize the optimum dosage of Alcofine and Fly ash with respect to HPC to improve strength. Study was conducted for M60 grade of concrete where the mix design of concrete was made as **1 : 1.35 : 2.19** . All the casting of cubes where conducted and sponsored by RMC plant operated under Ultratech cement. All the different proportions of Alcofine and Fly Ash would be compared with the Normal Cube with 0% Alcofine and 0% Fly Ash. All the testing of cubes were conducted on CTM (Compression Testing Machine) in Concrete Laboratory at SITS, Narhe.

**4.2 Experimental Results**

**A) Normal Cube – 0 % Alcofine & 0 % Fly Ash**

In this study, Normal cube were casted in order to analyse and compare the experimental results of different cubes including Alcofine and Fly Ash. Mix proportion adopted for normal cubes is 1: 1.35: 2.19

**Table No. 4.1 Compressive Strength of Normal Cube**

Cubes	7 days	28 days
0% Alcofine & 0% Fly ash	<b>35.55</b>	<b>48.8</b>
	<b>37.77</b>	<b>54.66</b>
	<b>40</b>	<b>51.78</b>
<b>Mean Strength</b>	<b>37.77</b>	<b>51.74</b>

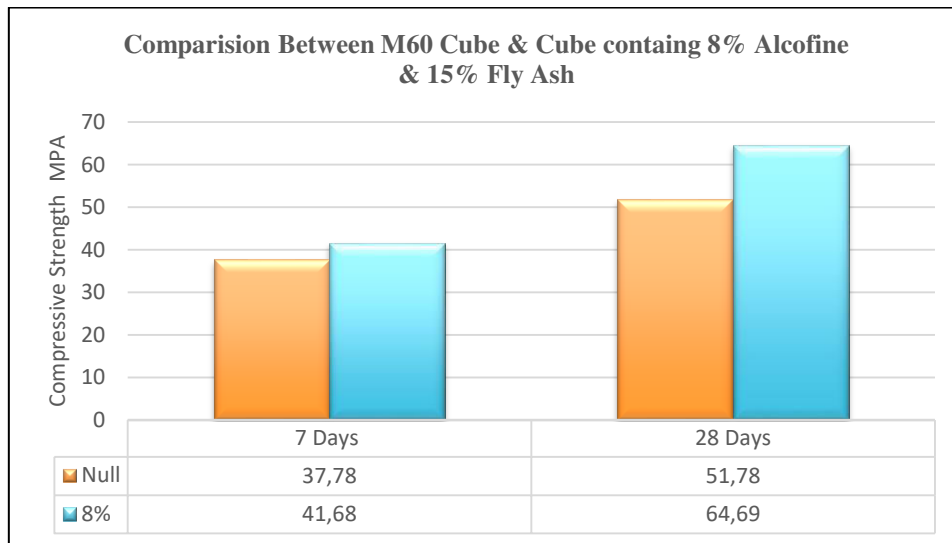
**B) Experimental Cube – 8 % Alcofine & 15 % Fly Ash**

Following table shows the 7 days and 28 days compressive strength test of experimental cube containing 8 % Alcofine & 15 % Fly Ash.

**Table No. 4.2 Compressive Strength of Cube containing 8% Alcofine & 15% Fly ash**

Cubes	7 days	28 days
8% Alcofine & 15% Fly ash	<b>39.5</b>	<b>66.1</b>
	<b>41.33</b>	<b>68.4</b>
	<b>44.22</b>	<b>59.5</b>
<b>Mean Strength</b>	<b>41.8</b>	<b>64.67</b>





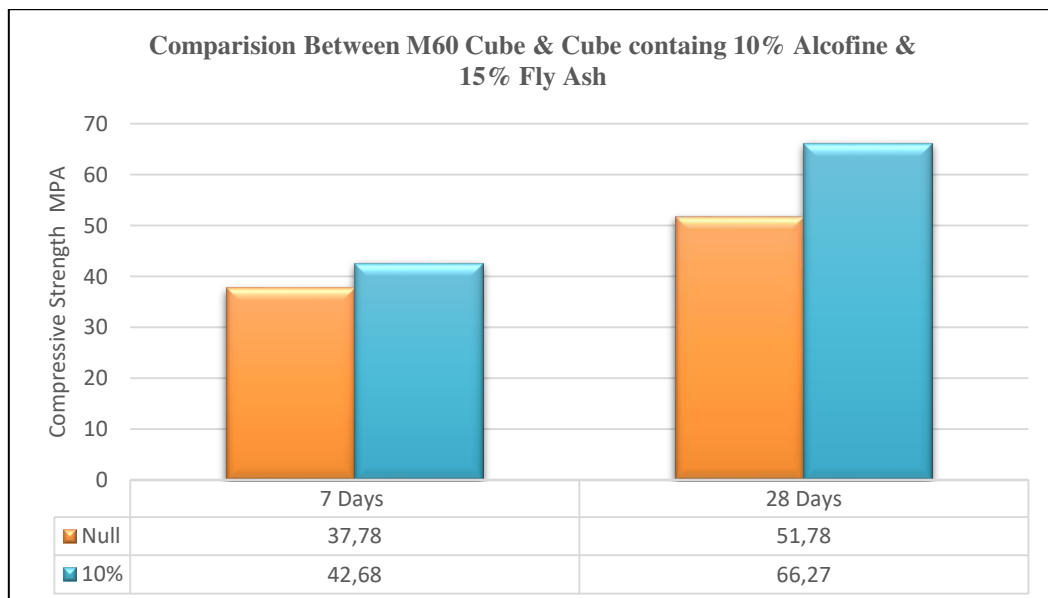
**Graph no. 4.1 Comparison of M60 Cube & Cube containing 8% Alcofine & 15% Fly Ash**

**C) Experimental Cube – 10 % Alcofine & 15 % Fly Ash**

Following table shows the 7 days and 28 days compressive strength test of experimental cube containing 10 % Alcofine & 15 % Fly Ash.

**Table No. 4.3 Compressive Strength of Cube containing 10% Alcofine & 15% Fly ash**

Cubes	7 days	28 days
10% Alcofine & 15% Fly ash	<b>42.26</b>	<b>63.1</b>
	<b>40.8</b>	<b>65.53</b>
	<b>44.44</b>	<b>70.22</b>
<b>Mean Strength</b>	<b>42.68</b>	<b>66.28</b>



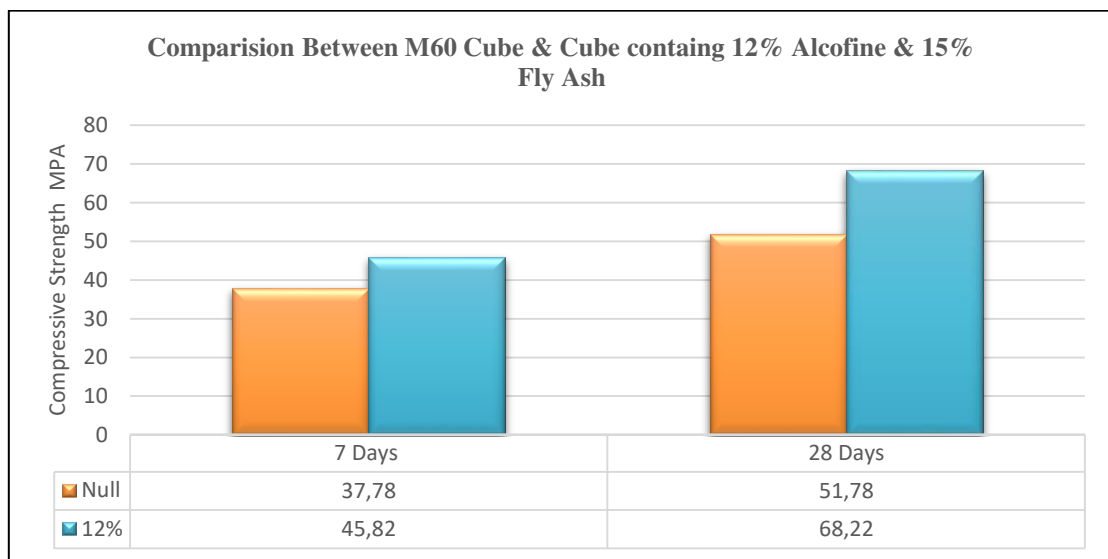
**Graph no. 4.2 Comparison of M60 Cube & Cube containing 10% Alcofine & 15% Fly Ash**

**D) Experimental Cube – 12 % Alcofine & 15 % Fly Ash**

Following table shows the 7 days and 28 days compressive strength test of experimental cube containing 12 % Alcofine & 15 % Fly Ash.

**Table No. 4.4 Compressive Strength of Cube containing 12% Alcofine & 15% Fly ash**

Cubes	7 days	28 days
12% Alcofine & 15% Fly ash	<b>42.22</b>	<b>75.56</b>
	<b>44.44</b>	<b>62.20</b>
	<b>50.80</b>	<b>66.89</b>
<b>Mean Strength</b>	<b>45.82</b>	<b>68.22</b>



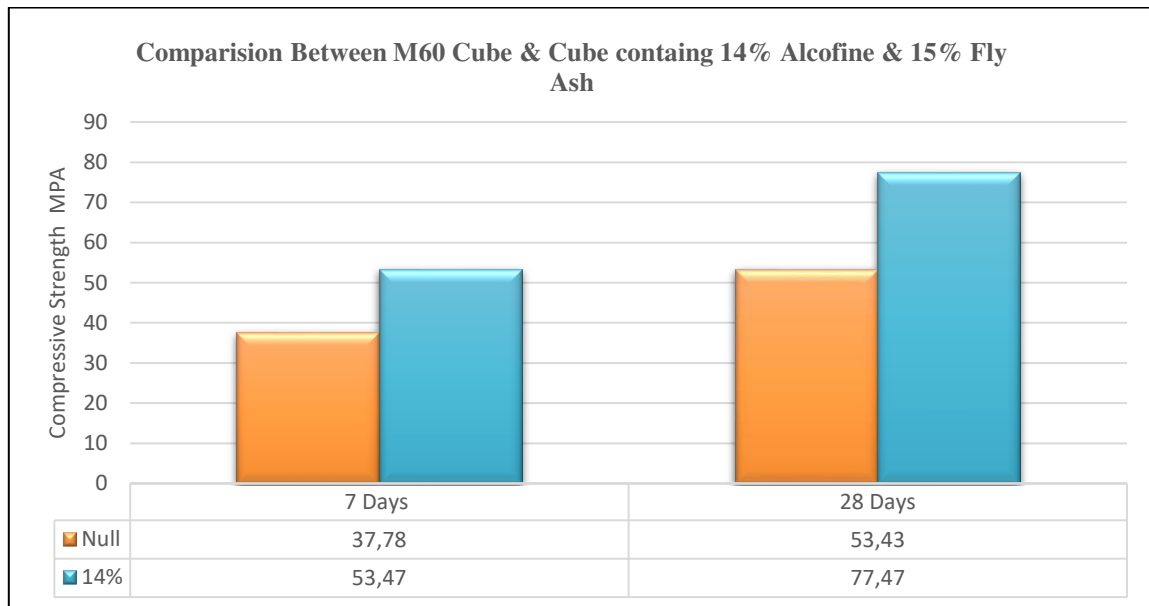
**Graph no. 4.3 Comparison of M60 Cube & Cube containing 12% Alcofine & 15% Fly Ash**

**E) Experimental Cube – 14 % Alcofine & 15 % Fly Ash**

Following table shows the 7 days and 28 days compressive strength test of experimental cube containing 14 % Alcofine & 15 % Fly Ash.

**Table No. 4.5 Compressive Strength of Cube containing 14% Alcofine & 15% Fly ash**

Cubes	7 days	28 days
14% Alcofine & 15% Fly ash	<b>48.80</b>	<b>72.44</b>
	<b>58.20</b>	<b>80.89</b>
	<b>53.30</b>	<b>79.1</b>
<b>Mean Strength</b>	<b>53.43</b>	<b>77.47</b>

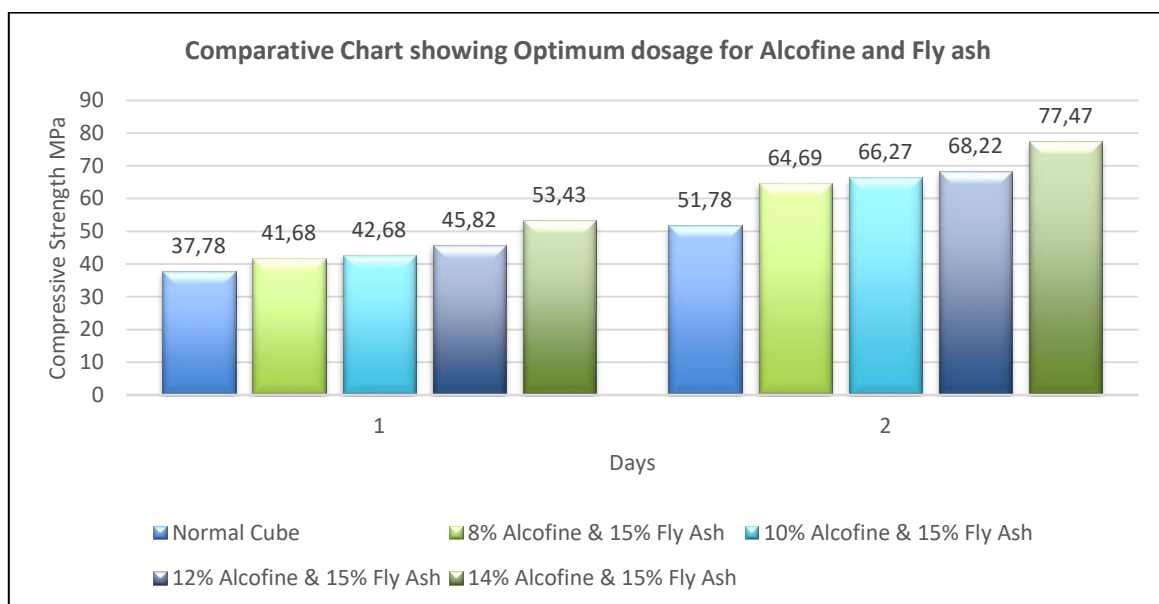


**Graph no. 4.4 Comparison of M60 Cube & Cube containing 14% Alcofine & 15% Fly Ash**

**4.3 Conclusion**

**Table no. 4.6 Selection of Optimum Dosage of Alcofine and Fly Ash**

Cubes	7 days	28 days	Remark
Normal Cube	37.78	51.78	
8% Alcofine & 15% Fly Ash	41.68	64.69	
10% Alcofine & 15% Fly Ash	42.68	66.27	
12% Alcofine & 15% Fly Ash	45.82	68.22	
14% Alcofine & 15% Fly Ash	53.43	77.47	Optimum Alcofine percentage



**Graph no 4.5 Comparative Chart showing Optimum dosage for Alcofine and Fly ash**

## V.CONCLUSION

- The compressive Strength of concrete increases with Alccofine and Fly Ash content.
- As per IS-Code Fly ash can be replaced upto 30 to 35% in concrete but not in case of High Performance Concrete.
- As per research paper, it suggests that by replacing fly ash upto 15% it gives high strength to High Performance Concrete. (Percentage of Fly ash to be kept constant for all percentage of Alccofine).
- The trail has established compatibility of Fly Ash and Alccofine to act simultaneously in the mix.
- By using the Alccofine 1203 it reduces the water demand required for curing and also helps in reducing the emission of green house gases emitted by concrete during its production.
- Our project concludes that the high strength of concrete has been achieved after the replacement of alccofine upto 14%.

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