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A LABORATORY STUDY ON CONCRETE THAT INVOLVES THE PARTIAL SUBSTITUTION OF CEMENT WITH METAKAOLIN, GLASS POWDER, AND SILICA FUME

[1]Naresh Burra Goud,[2]Bakshetty Snehalatha,[3]Naresh Kummari
[1,2,3]Assistant Professor
Department of Civil Engineering

Kshatriya College of Engineering

ABSTRACT

The growth of concrete technology during the last decade has been mainly based on finding a suitable and eco-friendly substituent for cement. This project is synonymous to the same perception of finding an eco-friendly and feasible cementitious material. The main aim of our project is to investigate the mechanical behaviour of concrete as partial replacement of cement with Metakaolin, silica fume and glass powder. In this project the mix proportion of M40 grade of concrete is adopted in accordance with IS: 456-2000 and cement of 53 grade is used. The concrete is tested for strength parameters of conventional concrete and Metakaolin, silica fume and glass powder concrete in whichMetakaolin, silica fume and glass powder are replaced by weight of cement in different proportions. Compressive strength, split tensile test, flexural strength tests are conducted for 7, 14 and 28 days.

Keywords: Metakaolin, Silica fumes, Glass powder, compression test, Split tensile test, flexural test.

I.INTRODUCTION

1.1. GENERAL

Concrete is the most essential element of infrastructure development across the world and a well-designed concrete could be a durable construction material. There is growing concern about the environmental aspect of Portland cement, as the cement industry is responsible for about 2.5% of all global emissions from industrial sources.. Particularly, CO_2 emission has been a severe problem in the world due to the greenhouse effect. After the Rio-de Janeiro Earth Summit in 1992 and following the Kyoto Protocol in 1997, many countries have agreed to reduce the emission of CO_2. These environmental concerns require a reduction of clinker production in the cement industry that is possible only by using the cementitious materials, called the mineral admixtures or pozzolans (also known as supplementary cementing materials). As per ASTM C 595, a pozzolana is said to be as ‘ siliceous ,aluminous material, in finely divided product and in the presence of moisture, chemically react with $Ca(OH)_2$ to produce compounds possessing cementitious properties’. Thus, Pozzolanic material needs Ca (OH) 2 to produce strength products. Portland cement contains calcium hydroxide as a hydration product.

Cement which is hydrated paste contains 70% C-S-H, 20% lime, 7% of sulpho-aluminate and 3% of secondary phases. The calcium, which appears as a results of the hydration, effect the quality of the concrete negatively by forming cavities because of its solubility in water and its low strength. The use of admixtures has a positive effect on quality of concrete by binding the lime. The hydration reactionand pozzolanic reactions are as below:

Cement Hydration Reaction:

Cement (C_3S ,C_2S) + H_2O $\rightarrow$ C-S-H gel + $Ca(OH)_2$ …(1.1)

Pozzolanic Reaction:

$Ca(OH)_2 + SiO_2 \rightarrow$ C-S-H gel …(1.2)

Therefore, when introduced in Portland cement paste, as a partial replacement, pozzolanic material reacts with calcium hydroxide to form calcium-silicatehydrate gel. Some of the general examples of pozzolans or mineral admixtures are grain granulated blast furnace slag, fly ash, silica fumeetc.

1.2. METAKAOLIN

- It is form of the clay mineral which is kaolinite . china clay has more kaolinite so it is also knownas china clay.
- Metakaolin which is manufactured from selected kaolin, after refinement and calcination underspecific conditions
- Metakaolin is an admixture, It is used as partial replacement of cement in High Strength Concrete

- high strength concrete means compressive strength is more than 40MPa.
- it is manufactured under controlled conditions. It is formed by heating kaolin, clay minerals, totemperatures of 650-900°C.
- It has Pozzolonic properties and its chemical formula is $Al_2O_3.2SiO_2.2H_2O$
- It reacts with Ca $(OH)_2$ one of the by-products of hydration reaction of cement and form C-S-Hgel and it increases the strength
- Metakaolin is a fine, natural white clay which contains the siliceous, so called as High ReactivityMetakaolin (HRM).
- Cement + Water = C-S-H gel + Ca (OH)2
- Ca (OH)2 + Metakaolin = C-S-H gel
- Efflorescence Reduction
- Effect of Color on using Metakaolin

Advantage of metakaolin that it does not affect the colour of concrete made with white Portland cement as relative to Other pozzolans such as silica fume or fly ash impart a dark gray or light gray color,

Effect of Metakaolin on Acid Stains

Metakaolin generally associated with an acid staining defect due to its properties to consume calcium hydroxide in a very aggressive manner. The Metakaoline may lead to disappointment. Acidic stains require the reaction of calcium hydroxide and if it is not present, the color may not develop sufficiently. In the cement hydration process, water reacts with Portland cement and produces calcium-silicate hydrate (CSH).

Metakaolin reduces size of pores in concrete , Metakaolin increases compressive, flexuralstrength. it reduces efflorescence in concrete

Advantages

- It controlthe shrinkage and cracks
- It is used for waterretaining structures and structures near water bodies
- It is used in concrete due tolesser rebound
- It increases compressive strength of concrete
- It increases tensile strength of concrete
- It is eco friendly and does not causes pollution
- Metakaolin increases , flexural strength and reduces efflorescence in concrete.

Table 1.1. Mineral Composition of OPC and Metakaolin.

Major Minerals	Abbrevation	Percentage	
		Cement	Metakaolin
Lime	Cao	60.2-66.3	2.00
Silica	SiO_2	18.6-23.4	51.52
Alumina	Al_2O_3	2.4-6.3	40.18
Iron oxide	Fe_2O_3	1.3-6.1	1.23
Magnesium Oxide	MgO	.6-4.8	0.12
Sodium Oxide	Na_2O	.05-1.2	0.08
Sulphur	SO_3	1.7-4.6	0

Minerals	Function of Minerals
Lime	Controls strength and soundness
Silica	Gives strength, excessive qty causes slow setting
Alumina	Quick setting, exess lowers strength
Iron oxide	Imparts color
Magnesium Oxide	Color and excess cause cracking
Sodium Oxide	Controls residues, excess causes cracking
Sulphr	Makes cement unsound

1.3. ROLE OF SILICA FUME IN CONCRETE

Silica fume is the result during the manufacture of silicon or of various silicon alloys. Silica fume, which contains more than 80% to 85% of SiO2 in amorphous form, is suitable to be used in cement and concrete industries. The typical particle size of silica fume is around 0.1-0.5μm and the nitrogen BET surface is 20,000 m3 /kg. It is used increasingly in the world as a mineral admixture to produce high performance concrete. Silica fume is light and has a low bulk density of 250-300 kg/m3. It was utilizedfirst in 1970's as an additive.

This action is in the refinement of void system of cement paste; mainly the transition zone due toits extremely small size. This type of physical action provides a denser, more homogenous and uniform paste. A replacement of 15% of cement by silica fume will add approximately 20,00,000 particles to each cement grain, in such a manner that the fine particles surround each cement grain, thus densifying the matrix, improving the bond with aggregate and reinforcing materials such as glass fibers. The phase consists of the reaction that transforms the weak $Ca(OH)_2$ crystals into the strong C-S-H gel. It affects the concrete properties by the following mechanisms:

- It eliminates the growth of $Ca(OH)_2$ at the cement – aggregate interface, or transforms $Ca(OH)_2$ into $CaSiO_3$ hydrate by the pozzolanic reaction between silica and lime.
- It removes large pores at the cement – aggregate interface, making it denser
- It is capable of packing between the cement grains due to its extremely fine particle size, thus lowering the capillary pores, and increasing the density of the material.

As a result of these actions of silica fume, it gives significant improvement in mechanical properties and drastic improvement in durability and impermeability. While providing significant strength and durability, silica fume can create an increase in water demand to reach specific workability levels due to the increase in specific area. It has very low bulk density, which causes difficulty in transporting and handling. If silica fume is densified and compacted in order to improve transporting andhandling properties, high degree of agglomeration of silica fume takes place, which considerably decreases its chemical reactivity with calcium hydroxide. Along with this, it can cause plastic shrinkage problems in concrete if not properly used. These factors, coupled with the higher cost of silica fume as compared to Portland cement and other pozzolans, has been barrier to its wider use in routine 'day to day' concreting jobs.

1.4. GLASS

Glass is non - crystalline solid material, a glass is transition material and also the reversible transition in amorphous materials. Glass may be a hard and brittle state ,and it can be molten or rubber state. Glasses are typically brittle and optically transparent. It has extensive practical, technological anddecorative usage like window panel, tableware, and optoelectronics.

The types of glass are the chemical compound of silica. It has Silicon dioxide (SiO_2), Sodium carbonate (Na_2CO_3), Sodium oxide (Na_2O) and), Lime (CaO). Silica is the high constituent of the glass.

1.5. TYPES OF GLASS

Depending upon the chemical composition and application the glass was classified asfollows:

- Soda - lime glass
- Lead glass
- Boron glass
- Aluminosilicate glass
- High silica fused quartz glass
- Coloured glass

1.5.1. Soda lime glass

The soda - lime glass is the most common variety of glass available in the market prepared by heating sodium carbonate and silica. Silica is the glass forming oxide and lime provides chemical stability, and soda ash acts as the fluxing agent. Globally, more than fifty present of soda - lime glass was produced by glass industries. It is relatively inexpensive, easy to melt and easy to get the desired shape.

The main advantage of soda - lime glass is having excellent durability, chemically resistant and having good thermal shock resistance. It plays a significant role because it is used to make windows, bottles, light bulbs and jars. Up to 75 % of soda - lime glass comes as waste from the residential area.

1.5.2. Lead glass

Lead glass, which is also known as "crystal," is a replaces the calcium content of a typical potashglass. Lead glass contains typically 18 - 40 % weight lead oxide, while new lead crystal, also known as flint glass contains a minimum of 24 % lead oxide. Lead glass is owing to its aesthetic properties.

1.5.3. Boron glass

The main glass - forming constituents of Boron glass is silica and boron trioxide. Its main advantage is having very low coefficient of thermal expansion (3×10-6 / o C at 20o C) thus making them resistance to thermal shock. This kind of glass reduces material stresses caused by temperature gradients, so it is used to make reagent bottles. In addition, it is used to make cookware, medical devices and lenses. The density of boron glasses is also less due to the low atomic weight of boron. Up to 70 % of Boron glass comes as waste from hospitals and laboratories.

1.5.4. Aluminosilicate glass

A small but important type of glass; Aluminosilicate contains 20 % of Aluminum Oxide (Alumina - Al_2O_3) often including Magnesium Oxide, Calcium Oxide and Boric Oxide in relatively little amounts but with only minuscule amounts of soda or potash. It can endure high temperatures and thermal shock and used in combustion tubes, gauge glasses for high - pressure steam boilers, and in halogen - tungsten lamps capable of operating at a temperature as high as 750°C.

1.5.5. High silica fused quartz glass

Fused Quartz or Silica is the glass contains silica in amorphous (non - crystalline) form. It differs from traditional glass which contain no other ingredients, which are typically added to glass to lower the melt temperature. Fused Silica, therefore, has an excellent working and melting temperatures. .fused glass is superior in optical and thermal properties .

1.5.6 Colored glass

Glass has many forms. It includes bottle, jars, windows, windscreen, bulb glass and cathode raytube glass and finely powdered waste glass are of different colors and are called colored glass powder.

II.TESTS ON MATERIALS USED IN THE EXPERIMENTAL PROGRAMME AND MIX DESIGN

2.1 Materials

The materials used in this project.

2.1.1. Cement

Cement is one of the important building material in today's construction world in which 53 grade (OPC) conforming to IS: 8112-1989 is used in this project. The following table gives the properties of cement used.

Figure-2.1 OPC 53 grade Cement

Different types of cement have different water necessities to produce pastes of standard consistence. As well as, the strengths at early stage can be considerably influenced by the particular cement used. It is also important to make sure compatibility of the chemical and mineral admixtures with cement.

Table-2.1 Physical properties of 53 Grade ordinary Portland cement

Sl. No	Test	Experimental Values	Suggested valuesas per IS 12269- 2013
1	Specific Gravity	3.15	3.10 -3.15
2.	Normal Consistency	31.2%	30% - 35%
3.	Setting Time	-	-
	a. Initial	160 minutes	>30 minutes
	b. Final	310 minutes	<600minutes
4.	Compressive Strength	-	-
	a. 3 days	30 N/mm2	>27 N/mm2
	b. 7 days	44.5 N/mm2	>37 N/mm2
	c. 28 days	57.5 N/mm2	>53 N/mm2
5.	Soundness	1mm	<10mm
6.	Fineness of Cement	7.5%	Max 10%

Table-2.2 Chemical composition of 53 grade of cement

S.No.	Constituent	Weight (percent)
1.	Calcium Oxide(CaO)	60.81%
2.	Silica(SiO2)	19.50%
3.	Alumina (Al2O3)	4.12%
4.	Iron Oxide(Fe2O3)	6.06%
5.	Magnesia(MgO)	1.52%
6.	Sulphur anhydrite	2.48%
7.	Insoluble Residue	1.51%
8.	Na2O, K2O	0.33%
9.	Miscellaneous	3.67%

2.1.2.Fine aggregate

Locally available river sand conforming to Grading zone II of IS: 383 –1970.

Figure-2.2 Fine aggregate

Table-2.3 Physical properties of fine aggregates

S.NO	PROPERTIES	VALUE
1.	Specific Gravity	2.65
2.	Fineness Modulus	2.25
3.	Water absorption	1.5%

2.1.2. Coarse aggregate

Locally available crushed granite stones conforming to aggregate of nominal size 20 mm as per IS: 383 – 1970.Crushed granite aggregate with specific gravity of 2.77 and it is passing through 4.75 mm sieve.

Figure-2.3 Coarse aggregate

Table-2.4 Physical Properties of Coarse aggregate

S.NO	PROPERTIY	VALUES
1.	Specific Gravity	2.68
2.	Size Of Aggregates	20mm
3.	Fineness Modulus	5.96
4.	Water absorption	2%
5.	Impact Test	15.2%
6.	Crushing Test	22.5%

2.1.3. METAKAOLIN

The interest for Portland concrete is expanding significantly in developing nations. Portland concrete manufacturing is one of the significant purposes behind CO2 outflows into climate. It is because of the utilization of petroleum products, including the energizes needed to create power during concrete assembling measure. The utilization of pozzolanas for making concrete is considered productive, as it utilization while working on the strength and durable properties of the concrete.

Chemical composition of Metakaolin

Chemicals	Percentage (%)
SiO2	62.62
Al2O3	28.63
Fe2O3	1.07
MgO	0.15
CaO	0.06
Na2O	1.57
K2O	3.46
TiO2	0.36
LOI	2.00

Table. Chemical Properties of Metakaolin

Chemical Properties	Percentage (%)
Silicon dioxide(SiO2)	51% to 31%
Aluminium dioxide(Al2O3)	40% to 44%
Titanium dioxide(TiO2)	<3.5
Ferrous oxide(FeO)	2.0% to 2.3%
Calcium oxide(CaO)	<2.0%
Magnesium oxide(MgO)	<1.0%
Oxides of potassium and others	0.5% to 1.0%

Uses

2.1.4.Use of High Strength Concrete

Metakaolin finds its use in strength concrete, concrete of equivalent strengthsand other additional properties were seen like workability, permeability etc.,

Figure 2.4METAKAOLIN

2.1.4.1. Makes Finishing Easier

Table Physical Properties of Metakaolin

S.No.	Properties	Value
1	Physical form	powder
2	Colour	white /grey
3	Fineness	700 to 900 m^2/kg
4	Specific surface	8 to 15 m^2/g
5	Specific Gravity	2.50

2.1.4.2. Silica Fume

SF is a waste by-product in the production of silicon and silicon alloys. SF is available in different forms, of which the most commonly used, now, is in a densified form.. The physicaland chemical properties of SF are shown in Tables.

Figure-2.5 Silica Fumes

Table-2.5. Physical properties of silica fume

S. No.	Properties	Values
1.	Size	0.15 micron
2.	Fineness	8.09
3.	Specific gravity	2.25

Table.2.6. Chemical properties of silica fume

Chemical properties	SF (%)
Al2O3	0.4
SiO2	97.1
Fe2O3	0.3
CaO	0.3
SO3	0.2
Na2O	0.0
L.O.I	1.7
MgO	0.0

SF particles are smooth, spherical size which is 1/100th diameter of Portland cement 0.1 to 0.2 micron ranges. Specific surface area of SF as measured by nitrogen absorption method usually lies between 13 m2/g to 28 m2/g. The color of SF depends - on carbon content.

Usually, ferrosilicon furnaces manufacturing low silicon content alloys show darker silica fume.

2.1.5. Glass powder

Glass powder is finely ground glass. These sort of fine glass particles help you to remember bath powder. Utilize outrageous consideration when dealing with this dry powder shade to forestall breathing the residue particles. Ensure you wear a respiratory cover when working with this powder, ideally one that is NIOSH supported. Verify that the powder has a similar COE as your other melding glass. This will guarantee that your ventures won't have developed pressure. Powder glass is so adaptable and helpful. It very well may be bought in each shade of the rainbow. Glass is an inflexible fluid for example super cooled fluid, which is static, not strong, too, not a gas but rather doesn't change microscopically among liquefying and cementing in to an ideal shape. Glass is perhaps the most flexible substances on earth utilized in numerous applications and in a wide assortment of structures. Glass frames normally when rock high in silicates dissolve at a high temperature and cool before they can shape a glasslike structure. A notable illustration of normally happening glass is Obsidian orvolcanic glass. When produced by human's the glass is a combination of silica, sand, lime and different materials. The components of glass are warmed to 9820 Celsius. eat can returnthe glass to a fluid and useful structure, making it simple to reuse and reuse.

Figure-2.6 Glass powder

Table- 2.8.Chemical composition of glass powder

Chemical Composition	Glass powder(%)
SiO2	67.33
Al2O3	2.64
K2O	-
Na2O	-
CaO	12.45
Fe2O3	1.42
MgO	2.73

Table-2.9 Physical properties of glass powder

S.NO	Property	Value
1.	Specific gravity	2.6
2.	Fineness passing 150 µm	99.5
3.	Fineness passing 90 µm	98

2.2. Mix Design

Mix design can be selecting suitable material of concrete and determining their relative properties with the object of producing concrete of certain minimum strength as economically possible. These are various methods of proportioning to obtain the concrete mix. These are the following methods: Arbitrary proportion method, Maximum density method, Fineness modulus method, Surface area method, ACI committee method, Grading curve method (road no.4), IRC-44 method, High strength concrete mix design, IS mix design method.
Out of the above method the first four are widely used these days to inherent drawbacks in the procedures of mix adopted for arriving at satisfactory proportions. The procedure of mix design recommended by ACI, IRC- road no:4 and IS mix design are widely adopted. IS institutions have brought out the mix design method. It is used for both medium and high strength concrete . The steps present in the mix design are:

TABLE-2.10 Mix design proportion for M-40 grade

	Water (lit.)	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)
By weight (gms)	197	438	647	1135
By Volume (m^3)	0.45	1	1.47	2.59

Table-2.11 Mix Proportions

Ingredients	Unit	M0	M1	M2	M3	M4	M5	M6	M7	M8	M9
Water	Lit/m^3	197	197	197	197	197	197	197	197	197	197
Cement	Kg/m^3	438	372	329	285	350	307	263	329	285	241
Fine aggregate	Kg/m^3	647	647	647	647	647	647	647	647	647	647
Course aggregate	Kg/m^3	1135	1135	1135	1135	1135	1135	1135	1135	1135	1135
Water cement ratio	By mass	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Metakaolin	Kg/m^3	-	21.9	21.9	21.9	43.8	43.8	43.8	65.7	65.7	65.7
Silica fume	Kg/m^3	-	21.9	43.8	65.7	21.9	43.8	65.7	21.9	43.8	65.7
Glass powder	Kg/m^3	-	21.9	43.8	65.7	21.9	43.8	65.7	21.9	43.8	65.7

III.EXPERIMENTAL METHODOLOGY

3.1.CEMENT TESTS:

OPC 53 grade cement is used in this experimental investigation, and it is tested according to IS 4031 code book for its physical properties.

3.1.1. FINENESS OF CEMENT:

Fineness of cement is a measurement of the size of cement particles . It is denoted in surface area of cement. Fineness can be measuring the particle size (sieve analysis) or by using the process of air permeability or sedimentation. Sieve analyzes the particle size of the cement.

Cement fineness has a direct effect on the rate of hydration and hence on the rate of strength gain as well as the rate of heat evolution. Fine cement provides a larger surface area for hydration, and thus faster strength growth. Throughout the years the fineness of grinding improved. So it has almost stabilized now. Various cements are ground to varying fineness. The particle size fraction below 3 microns has been found to have the prevailing effect on the strength at one day while the fraction of 3-25 microns has a significant impact on the strengthof 28 days. Improved cement fineness is also shown to improve drying shrinkage.

3.1.2. SPECIFIC GRAVITY OF CEMENT:

Specific gravity is defined as the ratio of the weight of a given material volume to the weight of an equivalent water volume. Specific gravity is one factor that determines material density. Material density is one of the vital parameters which determines the concrete design. Since concrete mixing proposal is made on the basis of weighing not volumetric, density is therefore the most important factor. Since concrete with higher density are longer lasting and have better properties than concrete which is less thick.

The explanations for this are fewer air voids in denser concrete that make concrete impermeable for water and thus improve its longevity.
Kerosene is used in the specific gravity of cement .kerosene is doesn't react with cement.

Figure.3.1. Specific gravity bottle

3.2. SPECIFIC GRAVITY OF FINE AGGREGATE:

Specific gravity is means it is the ratio of the weight of given volume of material / theweight of an equal volume of water. The specific gravity is done in accordance with IS 2386 part III 1963
G = density of soil/density of same volume of water
G = mass of dry soil/mass of and same volume of water.

Figure-3.2. Pycnometer
Result: the specific gravity of given sample = 2.54

3.3. SPECIFIC GRAVITY OF COARSE AGGREGATE:

Specific gravity is defined as the ratio of the weight of an aggregate given volume / the weight of an equivalent volume of water. It is the intensity or consistency indicator of the material in question. In general, aggregates with a low specific gravity are lower than those with higher gravity. The basic gravity of the coarse aggregate conducted in compliance with part III 1963 of IS 2386.
Specific aggregate gravity test is performed to measure the material strength or consistency while the water absorption test decides the aggregates ' water holding capacity.
It is also a measure of quality of material.

3.4. WORKABILITY TEST ON CONCRETE SLUMP TEST:

The concrete slump test is the measurement of the consistency of freshly made concrete before it sets down. It is used to test the workability of freshly made concrete, and the ease with which concrete flows. This is also be used as an indicator for an improperly mixed concrete sample. Due to the simplicity of the apparatus ,it is used and it is simple procedure, the test is common.

concrete slump value is used to know the workability, such as water-cement ratio, but there are number of factors including properties of materials used , mixing methods, sizes of aggregates and admixtures more on. also affect the concrete slump value.

Figure-3.3. Slump

Result: the slump value for given concrete = 40mm

3.5. MIXING OF CONCRETE:

First all the materials are weighed and then the aggregate and fine aggregate are thorough mixed and then cement, quartz powder, silica fumes with glass powder are added and all the above materials are thoroughly mixed such a way that all the mix is uniform and then water mixed.

CASTING OF CUBES:

The cube moulding plates should be removed, assembled properly cleaned and all the bolts should be absolutely secure. A layer of oil is then added to both sides of the mould. It is necessary that the side faces of a cube should be parallel.

The cubes shall be casted as soon as possible after taking concrete samples and mixing them together. The concrete sample in layers about 5 cm deep shall be poured into the cube moulds. In putting each scoopful of concrete, the scoop shall be shifted as concrete slides across the top edge of the mould to ensure a symmetrical distribution of the concrete in the mould. Each layer shall be compacted manually or by vibration

The concrete was placed in the molds, the inside surface of the molds and the base plates oiled once the concrete was poured as the concrete was put in a cube of 150 mmX150 mmX150 mm. The concrete is filled to 1/3rd mould height. With the aid of a tamping rod, each layer should be tamped for 25 strokes and after 24 hours the specimens from the moulds removes and put at a temp. of 27 ± 2°C in clean fresh water.

Figure-3.4 Casting of cubes

3.6. CURING OF CUBES:

Concrete curing is a process by which the concrete is preserved from moisture loss needed for hydration and maintained within the prescribed temperature range. Curing can increase the hardened concrete and decrease its permeability. Curing is also helping to reduce cracks which could have a severe impact on structural durability.

The cast cubes shall stored in shed place, and it is free from vibration place at a temperature of 22C to 33C for 24 hours, there were closed with wet straw or gunny sacking.

At the end of 24 hours, the cube shall submerged in clean water at $24^{O}C$ to $30^{O}C$ until the testing age is 7 or 28 days. The cubes shall be measured in dry condition.

For the correct representation of concrete strength in the structure, it is very important to cast, store and identical extra cubes

After 7, 14 and 28 days of curing, the specimens cubes examin, measured from the timespecimen put for curing

Figure-3.5 Curing of cubes

3.7. COMPRESSIVE STRENGTH OF CONCRETE

The compressive strength of any material under the action of compressive forces is defined as resistance to failure or cracks. Compressive strength is an important parameter particularly for concrete, to evaluate the material's efficiency during service conditions. The concrete mix can be formulated to obtain the necessary properties of engineering and durability as needed by the design engineer.

No cushioning material was mounted between machine plates for testing in compression. In (CTM) the uniform loading is applied to the sample.

In order to test the compressive strength concrete, test specimens of scale 150mmX150mmX150 mm were prepared. The concrete mixes of various percentages such as 0%, 5%, 10%, and 15% of Metakaolin, silica fumes and glass powder are used as partial substitute of cement and were cast into cubes for subsequent testing. for this work, we have take the best aggregate sizes to make the concrete ,such as coarse aggregate size 20 mm and fine aggregates zone II, Ordinary Portland cement (OPC), metakaolin, silica fumes and glass powder were mixed properly.

Figure-3.6 Compression testing machine

The load was applied without shock axially, until the specimen with varying proportions of metakaolin, silica fumes and glass powder (5 percent,10 percent,15 percent) asa substitute at 7 days, 14 days, and 28 days were noted.

Compression testing machine (CTM) was used to test the cubes. P / A= stress compressor. Where, P= Load (N) and A= Area (mm2).This check is conducted as per code book IS: 516–1959.

3.8. SPLIT TENSILE STREGTH:

It is a process of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. It is an another method of testing tensile strength of concrete.

Cylinders were mounted and load applied in Compressive Testing Machine (C.T.M). The readings were registered up to the cylinder's final crack, and Split tensile strength was measured.

Split tensile strength test is done on specimens with dimensions 150mm diaX300mm depth. For each case 28 days strength can be obtained by testing with compression testing machine.

Figure-3.7 Split tensile test

3.9. FLEXURAL STRENGTH:

It means the maximum stress that applied to that material before it yields. The most general way of obtaining the flexural strength of a material is by employing a transversebending test using a three-point flexural test technique. The Universal Testing machine (UTM) is used to test all the specimens. The beam as washed and its surface was cleaned for clear visibility of cracks after the curing period of 28 days had been over. The load arrangement most widely used for beam testing may consist of two-point loading. It has the advantage of a large region of almost uniform moment combinedwith very small shears, allowing for an evaluation of the bending ability of the central section. The load must usually be distributed at an acceptable shorter distance from a support if the member's shear ability is to be measured.

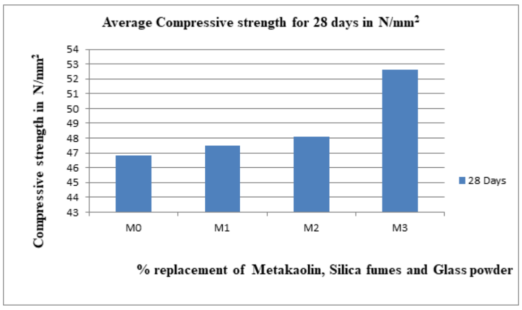
Flexural strength test is conducted on specimens with dimensions 750mmX150mmX150mm and test results are obtained.

Figure-3.8 Flexural strength test

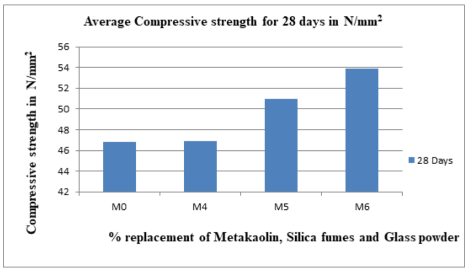
IV.EXPERIMENTAL RESULTS

TABLE-4.01 Compressive strength test results

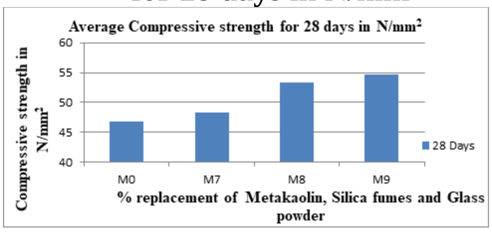
Mix	METAKAOLIN	Silica fumes	Glass powder	Compressive Strength 7 Days (N/mm^2)	14 Days (N/mm^2)	28 Days (N/mm^2)
M0	0	0	0	28.5	35.4	46.8
M1	5	5	5	31.2	36	47.5
M2	5	10	10	33	38.9	48.1
M3	5	15	15	35.7	40.2	52.6
M4	10	5	5	33	35	46.9
M5	10	10	10	34.5	40.1	51
M6	10	15	15	38.6	42.6	53.9
M7	15	5	5	32	36	48.4
M8	15	10	10	36.9	41.5	53.3
M9	15	15	15	38.9	46.6	54.7



Graph-4.1 Graphical representation of compressive strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 1, 2, 3) for 28 days in N/mm^2



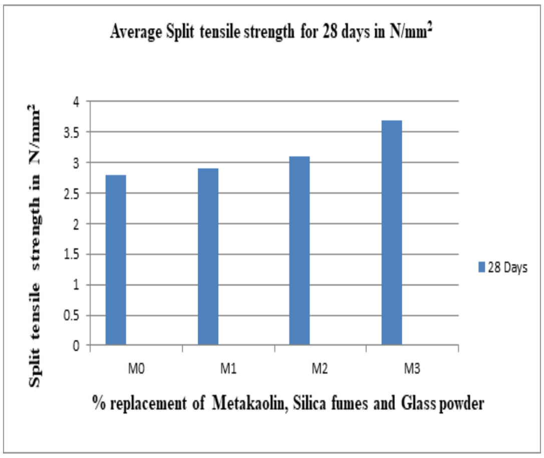
Graph-4.2 Graphical representation of compressive strength of concrete replaced with Quartz powder, Silica fumes and Glass powder in different proportion(Mix0, 4, 5, 6) for 28 days in N/mm^2



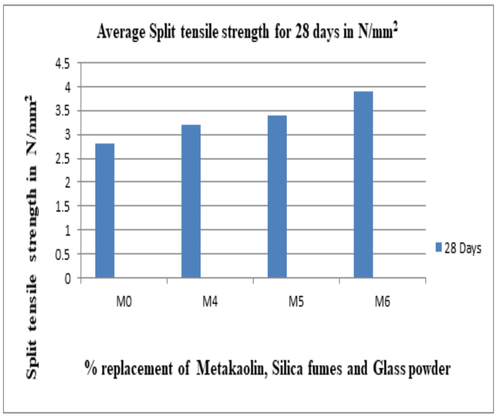
Graph-4.3 Graphical representation of compressive strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 7, 8, 9) for 28 days in N/mm^2

TABLE-4.02 Split tensile strength test results

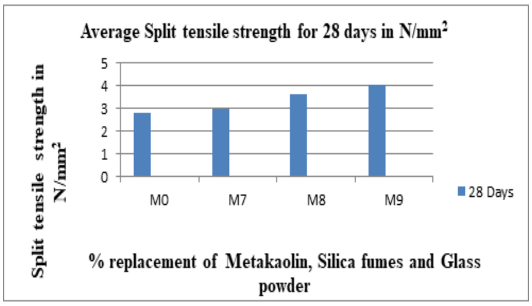
Mix	Metakaolin	Silica fumes	Glass powder	Split Tensile Strength 7 Days (N/mm^2)	Split Tensile Strength 28 Days (N/mm^2)
M0	0	0	0	1.7	2.8
M1	5	5	5	2.1	2.9
M2	5	10	10	2.6	3.1
M3	5	15	15	2.8	3.7
M4	10	5	5	2.5	3.2
M5	10	10	10	2.9	3.4
M6	10	15	15	3.1	3.9
M7	15	5	5	2.6	3.0
M8	15	10	10	3.2	3.6
M9	15	15	15	3.3	4.0



Graph-4.4 Graphical representation of Split tensile strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 1, 2, 3) for 28 days in N/mm^2



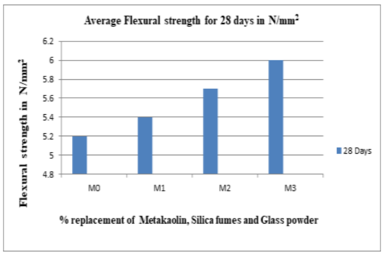
Graph-4.5 Graphical representation of Split tensile strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 4, 5, 6) for 28 days in N/mm^2



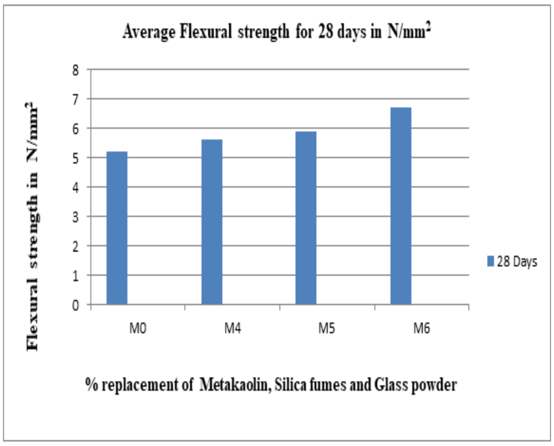
Graph-4.6 Graphical representation of Split tensile strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 7, 8, 9) for 28 days in N/mm²

TABLE-4.03 Flexural strength test results

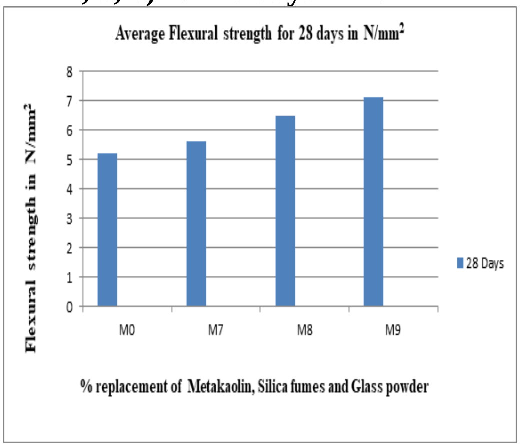
Mix	Metakaolin	Silica fumes	Glass powder	Flexural Strength	
				7 Days (N/mm²)	28 Days (N/mm²)
M0	0	0	0	4.1	5.2
M1	5	5	5	4.6	5.4
M2	5	10	10	4.9	5.7
M3	5	15	15	5.1	6.0
M4	10	5	5	4.8	5.6
M5	10	10	10	5.0	5.9
M6	10	15	15	5.3	6.7
M7	15	5	5	4.9	5.6
M8	15	10	10	5.5	6.5
M9	15	15	15	6.7	7.1



Graph-4.7 Graphical representation of Flexural strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 1, 2, 3) for 28 days in N/mm²



Graph-4.8 Graphical representation of Flexural strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 4, 5, 6) for 28 days in N/mm²



Graph-4.9 Graphical representation of Flexural strength of concrete replaced with Metakaolin, Silica fumes and Glass powder in different proportions(Mix0, 7, 8, 9) for 28 days in N/mm²

V.CONCLUSION

The present study concluded the concrete with the addition Metakaolin, Silica fumes and Glasspowder in different proportions

- From this experimental work it is concluded that, by partially replacing the cement with Metakaolin Silica Fume and Glass powder will increase the strength.
- The combination of 15% Metakaolin, Silica Fume and Glass powder in cement in concrete showed the maximum strength in compressive strength, split tensile strength,flexural strength test.
- The maximum value obtained in compressive strength at 15% replacement

of Metakaolin, Silica Fume and Glass powder in cement is 53.7N\mm^2.

- The maximum value obtained in Split tensile strength at 15% replacement of Metakaolin, Silica Fume and Glass powder in cement is 3.9N\mm^2.
- The maximum value obtained in Flexural strength at 15% replacement of Metakaolin, Silica Fume and Glass powder in cement is 7.5N\mm^2.

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