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Studies On High Strength Coloured Concrete Mixes

Mr. Babu Bhaskar S G
Dayananda sagar college of Engineering Bengaluru
Dr. Santhosh Malkapur
Assistant professor
Dayananda sagar college of Engineering Bengaluru

Abstract

Concrete forms the basic element of any construction assignment and since decades many different forms of concrete have been developed to serve different purposes. Over the years enhancement has been made in the field of appearance, performance and the strength of the concrete. A simple concrete can be moulded to any form and structure and texture. Architectural concrete is one such type that which along with the desired and improved strength servers the aesthetic purpose also. Many different types of architectural concrete have been manufactured till now. In our work we have presented the architectural concrete with best and improved results.

Concrete using different materials have been tested in our work involving red mud (which is industrial waste generated while manufacturing of the aluminium from the bauxite ore), different colouring pigment (namely yellow, blue) and oxide such as red oxide and green oxide are used as colouring pigments, with a combination of these elements with white cement and gray cement (OPC-43 grade). In this work, the feasibility and suitability of colouring pigment is also studied by preparing some sample. This project also focuses on evaluation of the fresh properties such as slump, consistency and setting time and hardened properties of concrete such as compressive strength and split tensile strength. It also involves the colour identification of the concrete produced using different materials (colouring pigments).

Keywords—architectural concrete, high strength coloured concrete, colour pigments, red mud.

INTRODUCTION

Concrete is one of the fundamental elements in the world of construction and architecture. It is a composite material containing a binding element (fluid) and fine or coarse aggregate which hardens over the time. It is one of the most versatile materials in the world of construction which can be engineered to the keep up the rising standards of the performance. Since it is so versatile there are many types of concrete which can be generalised.

Concrete comprises of a mixture of cement, fine aggregate, coarse aggregate along with a fluid cement which starts to harden as the time passes. Lime based concretes for instance Portland cement is one of the most familiar concretes that are used

Fluid slurry is generated when the aggregate water and the dry Portland cement are mixed together in the appropriate ratios, this slurry is then moulded to desired shape by pouring into the moulds of desired shape and size. Once the slurry is formed, with time the cement reacts with water and the aggregate to form a hard substance which is similar to stone and can be used in number of forms. The basic tests in fresh and hardened properties are done to ensure the physical properties of cement. fresh properties like slump cone test, initial setting time, final setting time and shrinkage properties are known where as in hardened properties the cube are casted and kept for curing for 7 and 28 days to know the compression strength, tensile strength, flexural strength .In order to improve the texture and the physical properties of the resultant concrete some additives are added to it when the slurry is being formed. The additives include pozzolans, superplastisizers etc to enhance the performance.

General concrete assures good quality when worked with proper workmanship. Concrete are most commonly used in almost all type of construction. By properly maintaining the water cement ratio a desired

strength can be achieved. Usually specified by the engineer, architect or designer, it is usually manufactured to achieve a particular strength. One of the great advantages of concrete is that its properties (workability, strength, and durability) can be engineered/designed as required by adjusting the mix parameters. The mix like W/C, cement content, aggregate/cement ratio etc can be controlled

Architectural concrete refers to the type of concrete which along with the strength serves the purpose of aesthetic use also. These can be developed of different size, shape, colour and texture (rough/smooth) using both white and grey cement. The materials used which gives the aesthetic view for architectural concrete can be varied can be used for different shading. Traditionally paintings were done externally once the plaster was set. But these painting did not last longer to all the changing conditions. The development of architectural concrete with chosen pigments that satisfy the standards and properties such as resistance to changes in environment, light, temperature gave them a long lasting life. Additionally designing them with some other feature and property with the upcoming technologies added more importance to it other than aesthetic value. The various materials that are used in developing such concrete mixes are discussed below.

Applications of Architectural Concrete

Applications for Architectural Concrete are many and include:

- Cladding panels (close cladding and ventilated facades)
- Unitized curtain wall (integrated with glazing assembly or opaque units)
- Cast corners matching the thickness of panels
- Shading devices or light reflectors
- Screens and lattices (hung or self-supporting)
- Acoustical barrier and/or diffusion/ reflection parts
- Fins, copings, sills and headers, water tables, etc. for masonry facades
- Manufactured permanent formwork for high quality finish face of structural elements
- Planters, benches, bollards, and other landscape elements
- Columns, beams, and floor spanning slabs

Karterina et al. (2001) Presented a study on the white cement, its properties, manufacture and prospects. It tends to have many architectonic applications which make use of white cement in many areas namely finishing of large panels, blocks, renderings, in developing concrete, mortars, treatment of worn out buildings and traditional sculptures, for decorative purposes and also for manufacturing of marble products, reflecting concrete surfaces etc. it also finds use in other domains such as controlling of ducts during floods or any other under water operations. Since there are number of applications, the production of white cement should be efficiently increased along with some methods that are energy and power conserving. They also presented a survey according to which developing a white cement clinker which followed the same procedures as the traditional one's but with some adjustments in the clinker cooling. And white cement with satisfying amount of whiteness can be developed with least amount of energy. This is possible by making use of gypsum-free cements based on white cement clinker as refractory materials in view of the low content of Fe2O3 in the clinker.

Sawant A B et al. (2016) presented the utilisation of industrial waste (red mud) in concrete construction. The importance of red mud compared to Portland cement by partially replacing the quantity of cement to some extend was presented in their work. Since the recent trends, accumulations of waste products which are produced during a natural process are reported to be in bulk. Such waste products sometimes can conventionally be used, and one such material is red mud which is a waste product produced during the natural process of Bayer's method of extracting aluminium, the process is nothing but an alkaline digestion of bauxite, around 2.5 T of bauxite yields alumina and 105 T waste product i.e. red mud Bayer's method of extracting aluminium. Nearly 4 million tonnes of waste red mud containing a varying amount of SiO2, Al2O3

and Na2O3 and an inert material Fe & Ti. The results show that a decrease in the initial setting time of the concrete is achieved at 5% and 10% of red mud in it, beyond 10% the initial setting time increases. The compressive strength with different amount of red mud was tested and found that the average compressive strength decreases with increase neutralised red mid content except for few % of replacement. Economically it was found that the conventional concrete costs 13.7% more than the red mud replaced one.

Scope and objective of the study

This work presents the technical information of how a high strength coloured concrete is developed in order to obtain the high performance and aesthetic view by using natural materials like colouring pigments, possessing relevant properties in terms of durability and performance. The behaviour of cement by varying the amount of colour pigments in both white and grey cement is studied, and the amount of colour that gives the best results is considered. The fresh and hardened properties of the concrete tested and colour identification is evaluated.

- To study the physical and chemical properties of white cement, ordinary Portland cement and red mud.
- To study and evaluate the feasibility, suitability and optimization of percentage dosage of variety of colouring pigment (red mud and red oxide, green oxide) for developing of architectural concrete.
- To study the fresh and hardened property of red mud, colour pigments, red oxide, and green oxide incorporated white cement and ordinary Portland cement concrete mixes.

Materials used in study

The various types of material which are considered for project are ordinary Portland cement (OPC), white ordinary Portland cement (WOPC), colouring agents, red mud, red oxide, chromium oxide, GGBS, super plasticizer, water, course aggregate, fine aggregate.

Sl. no.	Tests conducted	Test results	As per standards
1	Specific gravity	3.14	3.15
2	Fineness of cement	280.32m^2/Kg	≥225m^2/Kg
3	Normal consistency (%)	31.25	28-35
4	Initial setting time	34 min	≥30min
5	Final setting time	543 min	≤600min

Table 1: Test results of Physical properties of OPC 43 grade cement

Sl.no.	Tests conducted	Test results	As per standards
1	Specific gravity	3.14	3.15
2	Fineness of cement	425m^2/Kg	≥225m^2/Kg
3	Normal consistency (%)	31.25	28-35
4	Initial setting time	42 min	≥30min
5	Final setting time	400 min	≤600min

Table 2: Test results of Physical properties of white cement

Mix Design for Concrete Mixes

Mix design of various mixes were carried out according to IS 10262-2009 standards for different types of colouring pigment to get the correct mix proportions.

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In Set Mix-1 Mix design is done for white cement and 8% of different types of colouring pigment (8% of the weight of cement) along with fixed quantity of GGBS in all mixing. The fixed quantity of GGBS (30 percentage of cement) and colour pigment (8% of cement) for all individual colour was considered for mix design-1.In Set mix-2 Mix design is done for ordinary Portland cement(OPC-43 grade) and 8% of different types of colouring pigment (8% of the weight of cement) along with fixed quantity of GGBS in all mixing. The fixed quantity of GGBS (30 percentage of cement) and colour pigment (8% of cement material) for all individual colour were considered.

In the present work, the compressive strength is achieved around 65 Mpa for various trial mixes for white cement and grey cement with GGBS, and it is cast and tested. A slump of 250 mm is targeted for the trial mixes. The water to binder ratio is taken as 0.3. Poly-Carboxylate Ether (PCE) based (Glenium 8233) superplasticizer is used in the work. Along with the cement GGBS is used(30% by weight of cement) in both set-1 and set-2 mix.

Set - I Mix (white cement with colour)		
Mix no.	**Pigments**	**Description**
1.	CCW	White cement with GGBS(30%)
2	WR	White cement with GGBS(30%) and red mud(8%)
3	WB	White cement with GGBS(30%) and blue colour(8%)
4	WY	White cement with GGBS(30%) and yellow colour(8%)
5	WRD	White cement with GGBS(30%) and red oxide(8%)
6	WGD	White cement with GGBS(30%) and green oxide(8%)
Set – II Mix (OPC with colour)		
7	CCG	Ordinary Portland cement (OPC) with GGBS(30%)
8	GR	Ordinary Portland cement (OPC) with GGBS(30%) and red mud(8%)
9	GB	Ordinary Portland cement (OPC) with GGBS(30%) and blue colour (8%)
10	GY	Ordinary Portland cement (OPC) with GGBS(30%) and yellow colour (8%)
11	GRD	Ordinary Portland cement (OPC) with GGBS(30%) and red oxide(8%)
12	GGD	Ordinary Portland cement (OPC) with GGBS(30%) and green oxide(8%)

Table 3: V**arious trail mixes are worked for of project work**

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Sl.no.	Pigment	Sample	remarks
1	White cement		Commercially available white cement is used . (Birla White cement) .
2	Red mud		Red mud is procured from hindalco industry Belgaum.
3	Blue colour		Colouring pigments (blue) procured from Johnson Endura industry.
4	Yellow colour		Colouring pigments (yellow) procured from Johnson Endura industry.
5	Red oxide		Commercially available red oxide are procured from locally available hardware shop.
6	Green oxide		Commercially available green oxide are procured from locally available hardware shop.

Table 4: Different types of colouring pigments

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RESULTS AND DISCUSSION

In this section, result of several tests conducted on test concrete mixes, both the fresh and hardened states are discussed. In fresh state, their workability and in hardened state, their physical properties (compressive, split tensile, colour) at 7 and 28 days of curing are evaluated and are discussed.

Fresh Properties of Concrete Mixes

Various tests are conducted for the fresh properties of cement. Test for which the control concrete mixes and different types of colouring pigments mixes used are done by workability, consistency, setting time. The test results are tabulated below

Workability

Slump cone test is carried out on the concrete mixes as per IS 7320-1974 for control concrete and coloured concrete.

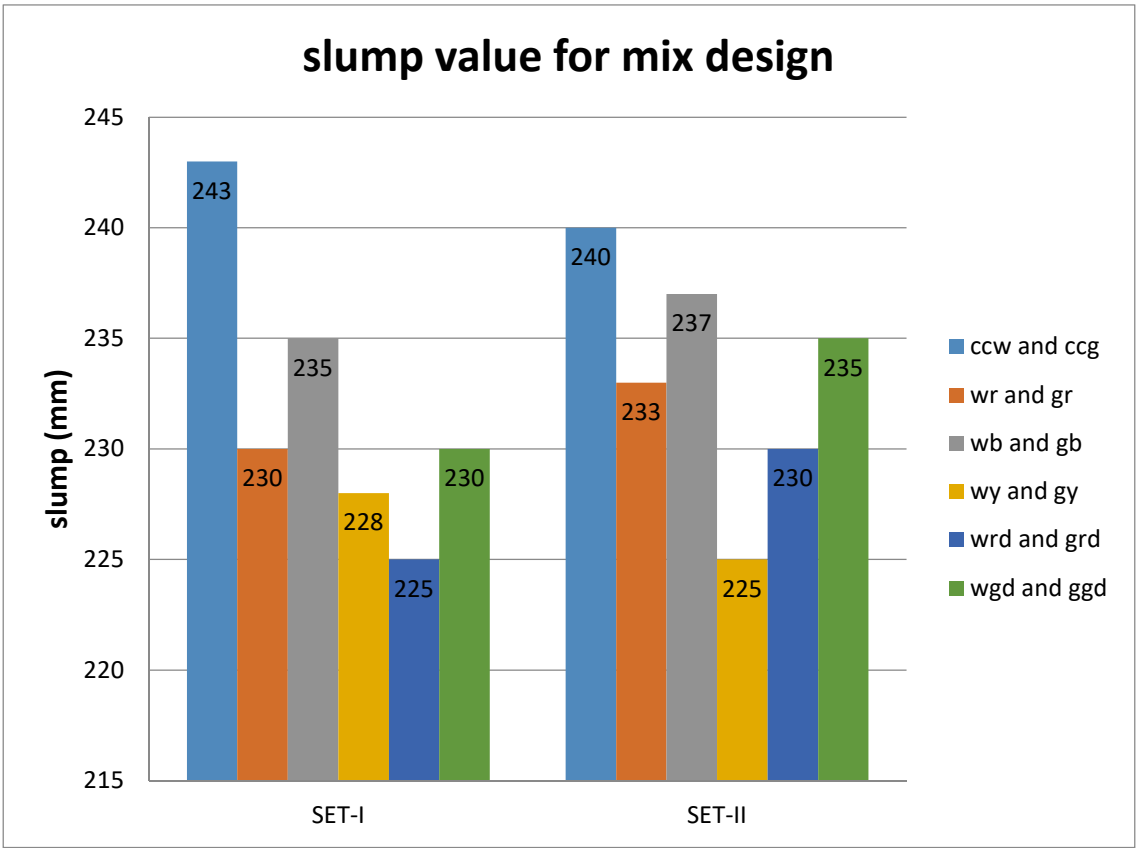

Fig 1: Graph of slump values of various mixes

A 250mm of slump is targeted and it is observed that the slump value remains almost constant when compared to control concrete. Hence considering the workability the concrete can be demonstrated as a flow of concrete. High workability of the mixes may be due to the percentage of super plasticizer which increases the flow of the concrete. Hence the colouring pigments do not have any effect on workability characteristics.

Consistency Test

Standard consistency test is conducted for white cement and gray cement and also consistency for cement with colouring pigments. The colouring pigments are added 8% of weight of cement

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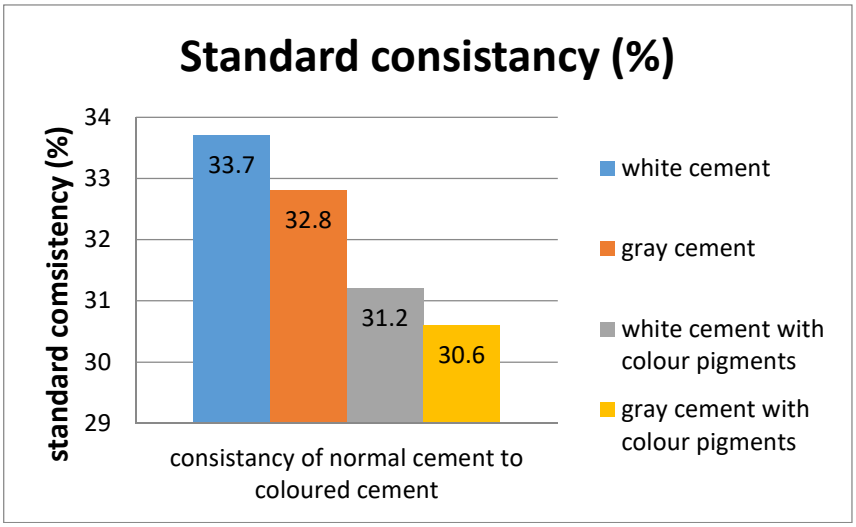

Fig 2: Standard consistency results for set-1 and set-2 mixes

It is observed from the figure 4.6: the standard consistency, which majorly shows the % change in the amount of water used with colour and without colour for both white cement and grey cement. It is also observed that the white cement with colour shows 7.4% decrease in the water demand compared to white cement without colour. Similarly a 6.7% decrease in water demand is seen when colour is mixed with gray cement.

Initial and final setting time

Initial and final setting time tests are conducted for various combinations of mixes by following the similar procedure as that of the cement. The test are conducted for white cement, gray cement, and combination of white cement with colour pigment (red mud, blue, yellow, red oxide and green oxide) and gray cement with colour pigments (red mud, blue, yellow, red oxide and green oxide) and the results obtained. From the graph it can be observed that there is no change in initial setting time and final setting time by adding colour when compared with control concrete.

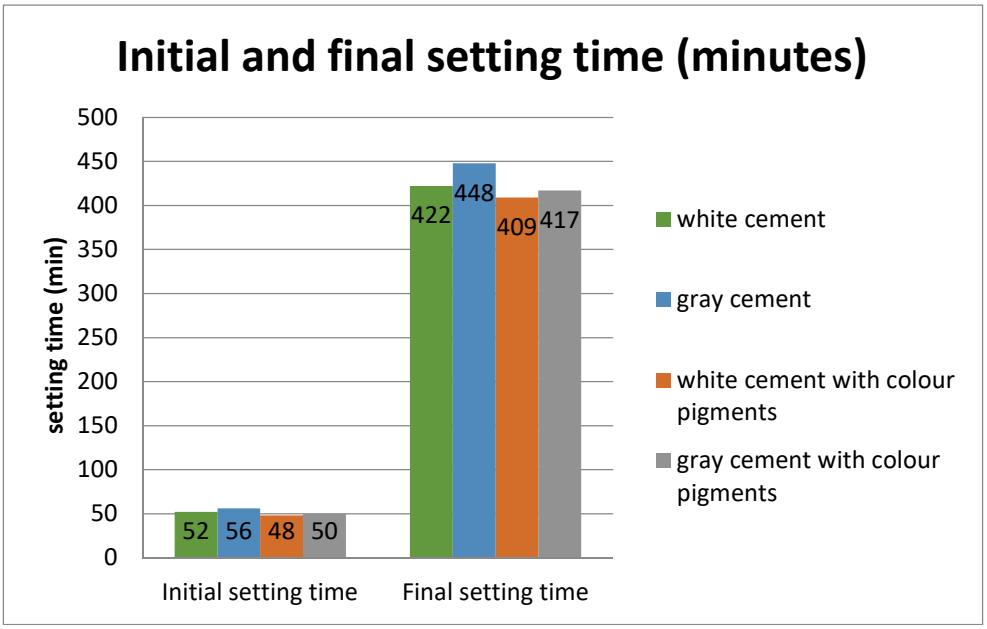

Fig 3: Initial and final setting time

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Test on Hardened Properties of Concrete

Several hardened properties are evaluated for different combination of mixes for compression strength and split tensile strength as per relevant IS standards.

Compression Strength of Concrete

Set-1 mix

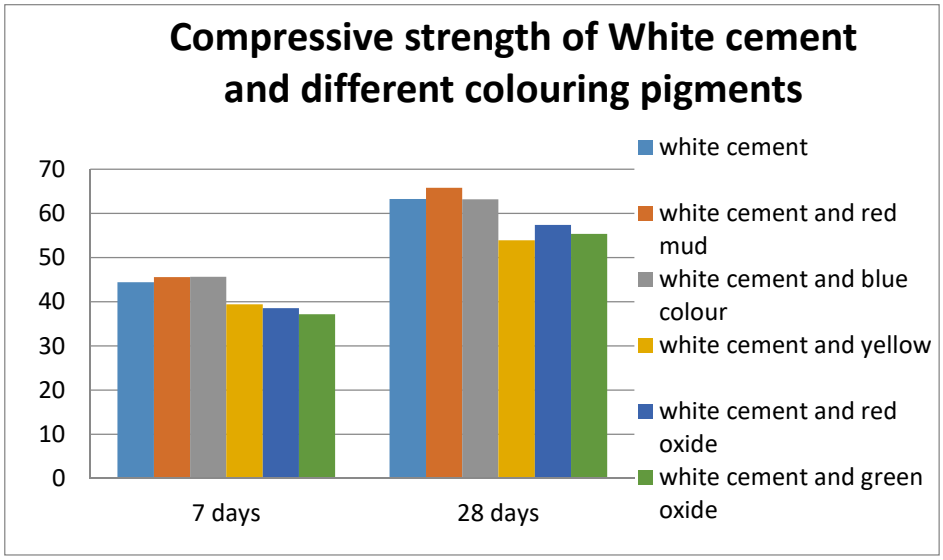

Fig 4: Compressive Strength of White Cement and Different Pigments (Mix SET-I)

It is observed from table the average compressive strength, for cement and different colours used in combination with cement. A percentage change in the average compressive strength compared to the strength of white cement for 28 days is also listed. The average compressive strength for white cement is calculated to be 63.3 MPa and 3.9% increase in the avg. strength is observed for red mud. Similarly 0.15%, 14.8%, 9.3% and 12.4% decrease in avg. strength is observed when colouring pigments blue, yellow, red oxide and green oxide are used respectively when added to white cement.

Set-2 mix

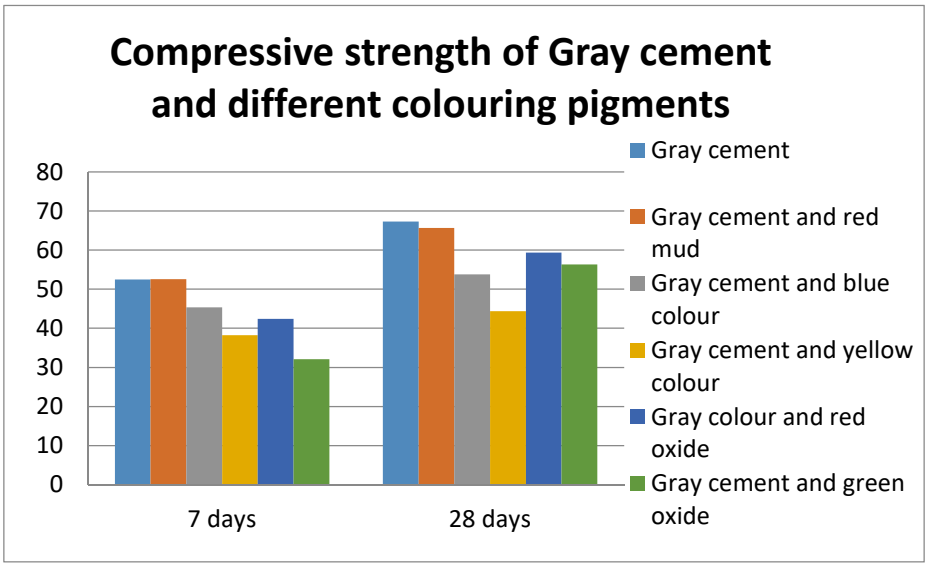

Fig 5 :Compression Test of OPC Cement and Different Pigments (mix SET-II)

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It is observed from the table the average compressive strength readings for gray cement and colouring pigments for 28 days. A decrease in the strength of 2.37%, 20%, 34%, 11.7% and 16.3% for red mud, blue, yellow, red oxide and green colouring pigment respectively when added to the grey cement.

Split Tensile Strength of Concrete

The results of split tensile strength of all the mixes of architectural concrete are carried on standard cylindrical specimen as per IS standards. The results are measured for 7 and 28 days of curing.

Set -1 mix

The average split tensile strength of white cement for 7 days and 28 days are tabulated in the above table. Variation the strength when colouring pigments are used, compared the white cement are also listed. A 5.1% ,15.3 %, 17.9%, 20.5%, 25.6% decrease in the strength is observed when red, blue, yellow red oxide and green oxide are used respectively when used in white cement.

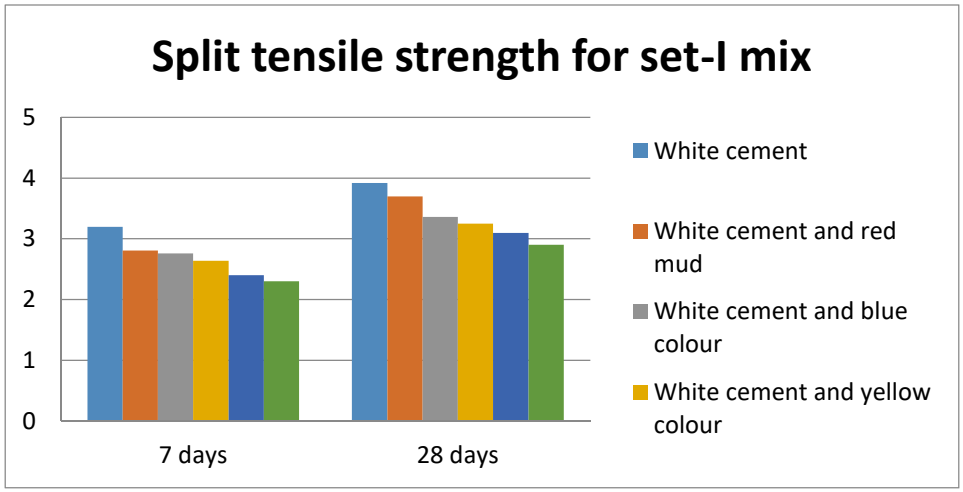

Fig 6: Split tensile strength results for set-I mix

Set –II mix

The average split tensile strength of gray cement for 7 days and 28days are tabulated. A % decrease in the strength is observed when colouring pigments are added to the gray cement. A 15.95%, 4.54%, 22.72%, 22.72%, and 27.2% decrease in the strength is observed when red, blue, yellow, red oxide, and green oxide are used as pigments respectively when added to gray cement.

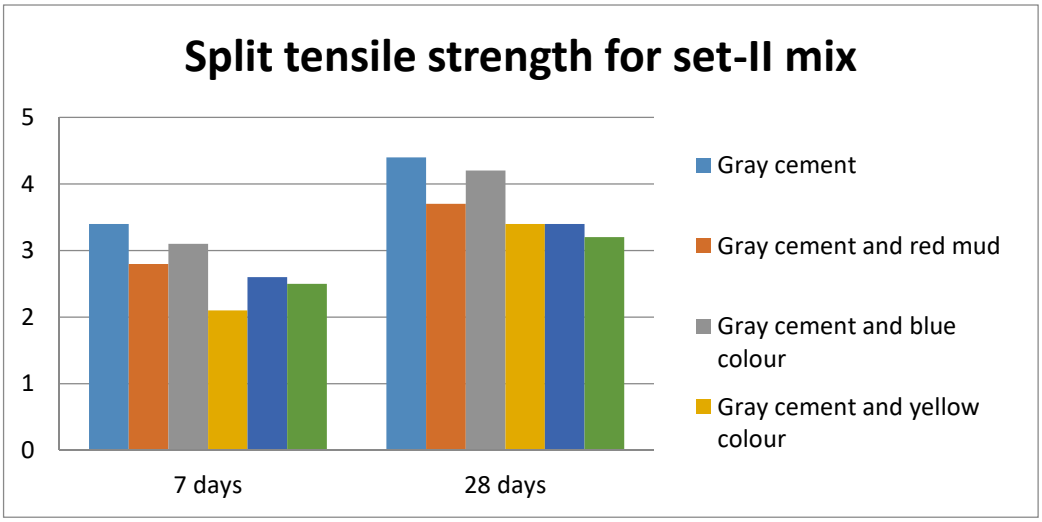

Fig 7: Split tensile strength results for mix design-II

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COLOUR IDENTIFICATION

Colour identification is carried out to know the exact shade of colour after 28 days of curing. The colour identification for different mixes of colour added to both white cement and gray cement as shown in set-1 and set-2 mixes

Sl.no.	Content	Hex code	Colour	RGB value	Strength (Mpa)
1	White cement	#E9EAE1	White	233,234,225	63.3
2	White cement and red mud	#DFB27A	orange	223,178,122	65.8
3	White cement and blue	#2B5E8A	blue	43,94,138	63.2
4	White cement and yellow	#FDE980	Light-yellow	253,233,128	53.9
5	White cement and red oxide	#975A45	Brown-orange	151,90,69	57.4
6	White cement and green oxide	#6D7D5C	Gray-green	109,125,92	55.4

Table 4.9 : Colour Identification of Set – II Mix

Sl.no.	Content	Hex code	Colour	RGB value	Strength (Mpa)
1	Gray cement	#706f6f	Grey	112,111,111	67.3
2	Gray cement and red mud	#7C6451	Faded-brown orange	124,100,81	65.7
3	Gray cement and blue colour	#738385	Gray-cyan	115,131,133	53.8
4	Gray cement and yellow	#7F825D	Faded-green yellow	124,100,81	44.7
5	Gray cement and red oxide	#8E5646	Brown-red	142,86,70	57.4
6	Gray cement and green oxide	#69735F	Gray- green	105,115,95	56.3

Table 4.10 : Colour Identification of Set – I1 Mix

CONCLUSION

In this work initially different pigments were selected and trails were conducted to evaluate the suitability of their use in cement. The percentage dosage of the colour pigments is set based on the trails conducted. Hence cement paste of 8 percent is prepared to satisfy the feasibility and mortar samples were casted. The fresh and hardened properties (compression, tensile strength) of the coloured concrete are studied. Using software the colour identification with exact colour shade and the RGB value are detected.

1. As the 8 percentage of colour (by the weight of cement) is added to the cement ,the feasibility, suitability of percentage dosage of colouring pigment to both white cement and gray cement is satisfied.
2. By adding colouring pigment to both white cement and gray cement paste it was observed that standard consistency, initial setting time final setting time is decreased.
3. A slump of 250mm of slump is targeted and it is observed that the slump value remains almost constant when compared to control concrete. Hence the colouring pigment do not have any effect on workability characteristics.
4. The compressive strength at 28 days is 63.4MPa, 65.8MPa, 63.2MPa, 53.9MPa, 57.4MPa, 55.4MPa for CCW, WR, WB, WY, WRD, and WGD. By adding 8% of colour (by weight of cement) with white cement and GGBS respectively at 28 days. The compressive strength at 28 days is 67.3MPa, 65.7MPa, 53.8MPa, 44.3 MPa, 59.4MPa, 56.3MPa for CCG, GR, GB, GY, GRD, GGD, by adding 8% of colour (by weight of cement) with gray cement and GGBS respectively at 28 days.
5. Compressive strength is increase by 3.9% when 8% of red mud (with GGBS) is mixed with white cement at 28 days. Compressive strength is decreased by 0.15%, 14.8%, 9.3% and 12.4% , when 8% of colour pigments WB, WY, WRD and WGD (by the weight of cement)is added to white cement respectively at 28 days.
6. Compressive strength is increased when red mud and GGBS is added to white cement and when compared to control concrete of white cement. The rest colouring pigment and GGBS shows the decreasing in strength when added to white cement and compared to control concrete of white cement.
7. Compressive strength is decreased in the strength of 2.37%, 20%. 34%, 11.7% and 16.3% for red mud, blue, yellow, red oxide and green colouring pigment respectively when added to the grey cement at 28 days.
8. Split tensile strength at 28 days is 3.92MPa ,3.7MPa ,3.3MPa, 3.2MPa,3.1 MPa and 2.9MPa for CCW,WR,WB,WY,WRD,WGD. By adding 8% of colour (by weight of cement) with white cement and GGBS respectively at 28 days.
9. Split tensile strength at 28 days is 4.4MPa, 3.7MPa, 4.2 MPa, 3.4MPa, 3.4MPa and 3.2MPa for CCG, GR, GB, GY, GRD, GGD . By adding 8% of colour (by weight of cement) with gray cement and GGBS respectively at 28 days.
10. The percentage decrease in split tensile strength of 5.1% ,15.3 %, 17.9%, 20.5%, 25.6% decrease in the strength is observed when red, blue, yellow red oxide and green oxide are used respectively when used in white cement and GGBS
11. The percentage decrease in split tensile strength of 15.95%, 4.54%, 22.72%, 22.72%, and 27.2% decrease in the strength is observed when red, blue, yellow, red oxide, and green oxide are used as pigments respectively when added to gray cement and GGBS.
12. Different colours were obtained, that belong to the shade card are tabulated.

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