

STRENGTH PARAMETERS OF PIGMENTED CONCRETE

BY

AFOLAYAN, JACOB OYENIYI

B.Sc (Bldg.), P.GD (Surveying) ABU

M.SC/ENG/3662/89-90(Structural Engineering)

A Thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in Partial fulfillment of the requirements **for the** award **of** Master of Science Degree in structural Engineering.

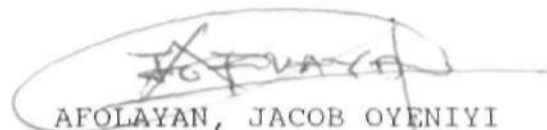
Department **of** Civil Engineering
Ahmadu Bello University, Zaria

JUNE, 1997

DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree.

All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

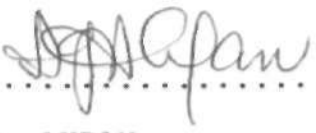



AFOLAYAN, JACOB OYENIYI

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CERTIFICATION

This thesis entitled " STRENGTH PARAMETERS OF PIGMENTED CONCRETE by AFOLAYAN, JACOB OYENIYI meets the regulations governing the award of the degree of master of science of Ahmadu Bello University, and is approved for it's contribution to knowledge and literary presentation.


.....
DR. A.J. AKPAN Date: 20/3/98
Chairman, Supervisory Committee


.....
S.S. LETCHA Date: 20/3/98
Member, Supervisory Committee


.....
DR. S. P. EJEH Date: 20/3/98
Head of Department


.....
Dean Date: 24/6/98
Post Graduate School

DEDICATION

This thesis is dedicated to my late sister Mrs.
Oluwafunmilayo Aduke Niniola Suberu.

ACKNOWLEDGEMENTS

Grateful acknowledgements is made to God Almighty for His sustenance and grace throughout this work.

My sincere appreciation also goes to the caring family of Mall S.O. Suberu for their unflinching supports and assistance.

The immense contribution of my supervisors Engr. Dr. A. J. Akpan and S. S. Letcha was commendable. I am grateful for their proper guardian and critical appraisal of my works. Special thanks goes to my beloved wife Mrs Margaret Ojoma Oluwonseyi Afolayan for her encouragement and financial assistance.

The management and staff of Am-Anfang Consultants Kaduna is acknowledged for releasing me for the research work, despite the need for my presence in the office as at the time the research work commenced.

I am grateful to my friends - Arc. Davidson Awomukwu, Arc. Moses Oyeleke, Emmanuel Essien, Sunday Idoko, Samuel David, the family of Mal. Fatai Sadiq and others whose names were not mentioned.

To all staff of Civil Engineering Department. I am grateful.

ABSTRACT

The study investigates the effect of pigments as a tinctorial source of colour concrete (colour-crete) with the aim of assessing the dosage level required for an appreciable tinctorial strength for aesthetic purposes. The objective of the study is to produce an alternative to the usual practice of painting of concrete structures after rendering, by now incorporating some percentage of colouring agent into the concrete, when it is plastic. Hence the need to assess the effect(s) of these colouring agents on the strength parameters of the concrete.

Two basic locally sourced pigments were used. Their chemical analyses classify them as basically red oxide and carbon black compounds. These pigments were in powdery form and the percentage of the colouring agent added or incorporated was a fractional weight of the cement content in the mix as recommended in BS 1014:1961. The percentage of the pigments incorporated varies from 0% - 6%.

Nominal mix ratio of 1:2:4: and 1:3 were chosen, with water cement ratio of 0.48 and 0.58 respectively.

A total number of 192 specimen were produced that is 64 cubes , 64 cylinder and 64 miniature beams. They were tested at 28 days of cast using the destructive techniques. The results obtained shows that with the increase in the percentage of pigment introduced into the concrete, there was negligible reduction in strength compared with the control specimen. And in some cases an increase in strength was observed.

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LIST OF SYMBOLS

F_{cu} -	Characteristic strength of concrete
δ -	Standard deviation
W -	Water cement ratio kg/m^3
A -	Aggregate content kg/m^3
P_a -	specific gravity of aggregate
e_c -	Specific gravity of cement
P -	The compressive load on the cylinder
L -	The length of the cylinder
D -	Diameter of the cylinder
l -	Span between the supports
d -	Depth of the beam
b -	Width of the beam

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CHAPTER 1

1.0 INTRODUCTION.

In this era of high cost of construction materials and the attendant labour charges. There is need to involve a practical approach to the choice and method of application of construction material to reduce cost. The focus of this research therefore is to seek the possibility of achieving the aesthetic requirement of a given structure through the colouration of plastic

concrete as against the usual practice of painting after rendering, without adverse effect on it's strength parameters.

Concrete can either be cast in-situ, precast or prestressed.

In recent years, many developments have taken place using concrete because of better understanding of the constituent materials.

The outstanding merits of concrete is always appreciated as a flexible and moldable construction materials.

Although substantial works have been carried out on unpigmented concrete materials regarding strength, however the studies on the effects of pigment or colouring agents on the strength properties of concrete are limited.

This research work investigates the effects of two locally sourced pigments on the strength parameters of coloured concrete under laboratory conditions.

Concrete pigmentation can be achieved by incorporating pigment into the mix when concrete is plastic. This makes the pigment an integral part of the concrete mass and therefore needs no routine maintenance.

1.1 PROBLEM DEFINITION

It is an obvious expectation that when an admixture is introduced into the concrete, strength variation will be noticed.

However, to determine to what extent the introduction or addition of pigment into the concrete affects its strength parameters and how much of the pigment is required to achieve noticeable tinctorial strength without appreciable decrease in strength is the target of this study.

1.2 OBJECTIVE OF STUDY

The focus of the study is to assess the effect of pigment on the strength parameters of coloured concrete. The object of pigment addition was to achieve aesthetics without violation of requirements for good concreting.

CHAPTER TWO2.0 LITERATURE REVIEW

The strength test results on concrete of different grades and types have been done over the ages and such as facts could be found in different journals and codes of practice produced by the standard organisation and association such as British Standard code of practice CP 110: 1972 and Cement and Concrete Association. The facts relates to their characteristic strength, durability and behaviour under different conditions.

However, the amount of work published on the physical properties of pigmented concrete is very limited and there is practically no data reported on the durability and performance of such concrete. The majority of the published work has been carried out by pigment manufacturers. This chapter presents a review of the relevant studies already undertaken by researchers.

Levitt (1980) has defined a pigment (organic or inorganic) as a fine dry powder, inert to the ingredients of concrete and intends to impart a specific colour to the product. Inorganic pigments are either natural or synthetic. Natural pigments are not often used in concrete due to their low tinting strength and low saturated colour shades caused by the masking effect of impurities and a wide range of particle sizes within the same pigment [Kozhalt, 1985].

In contrast synthetic pigments are produced with narrowly controlled chemical composition, predominant particle size and particle size distribution. These properties make them superior to the natural pigments in producing strong colour shades and colour saturation. Pigments used for the production of coloured concrete must be completely alkali stable, lightfast and weather resistant and should have a reasonable high tensile strength. They must be just as insoluble in water as the aggregates are and would be immovably embedded with fines in the cement as it hardens.

Iron oxide pigments are known to fulfil all these requirements [Raber, 1974 and Puttbach, 1987]. They are the commonly and widely used pigments to produce yellow, black, and red brown colours.

Iron oxide pigments come in different shades, for example iron oxide red pigments can vary in shade from brick red to violet red depending on their particle size and particle shape which varies roughly cubical to spherical [Kozhalt, and puttbach et al 1985].

Chromic oxide is used to produce green and titanium dioxide to produce white colour. Cobaltic oxide produces blue colour, however, it is not suitable for use with concrete due to its zinc and lead impurities which affect the setting time of concrete, [Levitt. 1980]

Copper complexes of phthalocyanine are used to produce blue and green colours in concrete. Although their use is allowed by the relevant British standards.

Pigment particles are much finer than cement particles, typically less than 1µm in diameter, which is about 10 times smaller than cement particles [Teichmann, etal 1983]. It is due to this reason that they have a strong masking effect to cement colour [Hof, etal 1984].

These fine particles are not obtained simply by grinding coarser particles but are produced during manufacturing.

The haematite form of iron oxide [Fe_2O_3] is the most stable iron oxide pigment, and any other composition of iron oxide can be converted into haematite under certain conditions [Kozhalt, 1985].

The shade of a finished concrete product is influenced not only by the pigment type and dosage used but by other factors such as colour of the cement and aggregate the water/cement ratio and the curing conditions [Puttbach,1987] a small quantity of the pigment is added to a concrete mix, the cement particles are not thoroughly covered by the pigment particles and the colour of the final product is influenced by the colour of the cement. When larger quantities of pigment are available in the mix, virtually all cement particles are covered and the colour achieved is influenced by the colour of the pigment. If however excess of pigment is added the cement particles are covered by several layers of pigment without yielding a deeper colour [Hof, Jungk etal, 1984], therefore small percentages of pigment additions achieve a larger variation in colour, and the relationship between colour achieved and

pigment dosage exhibits a ceiling at high dosage levels [Teichman et al 1983].

The level of dosing of pigment ranges between 1% to 10% of cement, 10% being the highest permissible level allowed by British and American standards, BS 1014: [1975] and ASTM [1982] for the production of coloured concrete. The dosage normally used ranges from 3% and 6%. However, this depends on the desired architectural effect. 1% dose is normally used for tinting, 5% for definite colour and 10% for deeper shade [Levitt, 1983].

The colour of the pigmented and unpigmented concrete is affected by the water/cement ratio, the higher the ratio the lighter the colour [Buchner, et al 1987].

A variation in the water/cement ratio of between 0.34 to 0.38 has been found to have relatively little influence on concrete colour, greater variations however, lead to significant colour differences [Buchner, 1987].

The colour of the fine and coarse aggregates used is another factor which influences the final colour of concrete [Spence, 1988].

Colour concrete ages in the same manner as normal concrete, with age it gradually shows a yellow cast [Hof, 1984]. As far as the red oxide pigments themselves are concerned, they are known to be colour stable and no change of colour with time is experienced. The main factors which affect the colour stability of pigmented concrete are the quality of the concrete and the conditions to which the concrete is exposed to. Good concreting practice is

essential to provide the desired colour stability. This includes the use of a low water/cement ratio, the proper choice of aggregates (regarding colour and grading), effective compaction and proper curing. The control over such parameters reduces capillary porosity, increases strength and makes the concrete tolerant to mechanical abrasion and the action of freezing and thawing [Lynsdale 1989]. There is another factor regarding colour stability which mainly concerns pigments with very fine particles such as carbon black. This is the leaching out and the washing away of the pigment from the surface of concrete, causing the black colour of concrete to revert back to its original grey colour, even if excess quantities of this pigment are used. [Blakey, 1988]

The selection of aggregates with colour closer to the colour of the final concrete produces longer colour stability, since the exposure of the aggregate surfaces caused by weathering causes little colour changes [Kresse et al, 1982]. Colour stability is better assessed by long term outdoor exposure tests; however accelerated tests are used by some producers for example weatherometer (a device which stimulates rainfall and sunshine) and Kesternich test which stimulates an industrial atmosphere by the use of sulphur dioxide (SO_2). Some investigators [kresse et al, 1982] have not found correlation between the results of accelerated and long term stability tests and thus concluded that accelerated tests are not reliable for prediction of colour weathering.

It has also been reported that most pigments have no significant effect on setting times when used at the recommended dosages [Van Wallendael, 1974]. However, carbon black pigment may produce flash setting [Moilvaganam, 1984].

Pigments generally have no effect on the air content of concrete, with the exception of carbon black pigment and other pigments of very fine particle sized [moilvaganam etal, 1984]. The ASTM specified that pigments should not alter the air content of concrete by more than 1%.

Neither the British nor the ASTM specify any requirements for testing for bleeding and stability [Lynsdale, 1989] It has been reported that incorporation of pigments in mortar or concrete has no adverse effects on these properties when used at recommended level [moilvaganam etal, 1984].

However, higher than recommended dosages of pigment dispersions or the use of low C_3A content cement results in reduced cohesiveness which promotes bleeding [Mailvaganam, 1984].

Shrinkage increases with the level of dosing of pigment due to the increased water demand, [Mowat etal, 1982]. It was reported that where the water/cement ratio was kept constant, the shrinkage of mixes pigmented with either carbon black, magenta or ultramarine was higher than that of the unpigmented mixes by 15% to 30% [Kroone etal, 1988].

However, {[Kroone etal, 1988] and [kozhalt 1985]} both concluded that variations are too small to be of serious concern. [Levitt 1985] suggested that if a water repellent is used in the pigmented mix, drying shrinkage will be reduced, however no actual data was reported.

Studies on the durability of pigmented concrete and their resultant performance in different environmental conditions are very limited. From the literature one find two studies limited only to the freeze-thaw resistance of pigmented concrete and these are enumerated below.

The free-thaw resistance of pigmented concrete paving blocks of various colours [red, black, yellow, iron oxides and green chrome] were assessed [Lynsdale etal, 1989] and results found to be in consistent and therefore not conclusive when the Australian method was used. However the German method proved reliable and that all pigments tested passed the test.

However [Kresse, etal, 1982] concluded that if the cube compressive strength of the concrete block was higher than that specified in DIN 1980 [60N/mm²] then the free-thaw resistance of the concrete block was found to be satisfactory [Van Szadkkowski, 1981].

Van Wallenddel, 1974] carried an investigation in which about 100 different pigments were studied and only the concrete containing carbon black pigment was found to exhibit poor freeze-thaw resistance.

The addition of large amount of pigment suspensions was reported to produce concrete with a high water/cement

ratio, which reduces the permeability of such concrete [Moilvaganam, 1984]. The reduction in the permeability by increasing the water/cement ratio is however, opposite to the norm of concrete behaviour.

[Levitt, 1985] on the other hand, claims that the use of water repellent agents can reduce the permeability of pigmented concrete. However no data were presented to that effect.

CHAPTER 3.3.0 METHODOLOGY AND EXPERIMENTAL SETUP3.1 MATERIALS USED3.1.1 CEMENT

The most widely used cement in this country and indeed the world, is ordinary Portland Cement. It is made by heating limestone and clay or other suitable raw materials, together to form clinker rich in calcium silicate. This clinker is ground into a fine powder with a small proportion of gypsum (calcium sulphate) which regulates the rate of setting time when the cement is mixed with water. Over the years, several varieties of Portland Cement have been developed: rapid hardening sulphate - resiting, white and low heat. Others are made or produced by incorporating other materials during the process of manufacture when the clinker is being ground.

The cement is used in this research is basically ordinary Portland Cement. Although cement test was not carried out but the result shows the cement is okay.

3.1.2 AGGREGATES

The term "aggregates" is used to describe the ground crushed stones and other materials which are mixed with cement and water to make concrete. Aggregates is classified into fine and coarse aggregates. The term fine aggregate is used to describe natural sand, crushed rock, crushed gravel or other material, most of which passes through a 5mm Bs sieve.

Coarse aggregate on the other hand is the term used in describing material such as natural gravel, crushed gravel or crushed rock most of which is retained on this sieve coarse.

The fine and the aggregate used in this research are the river sand and the granite crush stones. The maximum size of coarse aggregate is 14mm and this conforms with Bs 410

3.1.3 AGGREGATES CEMENT RATIO:

The choice of the aggregate/cement ratio is made either on the basis of personal experience of the mix designer or alternatively from charts and tables prepared from comprehensive laboratory tests, [Neville, 1983]

The aggregates used are the crushed stone of maximum size 12.5mm and naturally occurring sand of nominal size 5mm and 2.35mm. These aggregates were well graded and cleaned.

Based on the conversion chart for aggregate/water ratio content produced by cement and concrete Association (1954), and shown in APPENDIX 1, aggregate /cement ratio of 4 was adopted resulting in specific gravity of 2.65 for the "all in aggregate".

3.1.4 WATER CEMENT RATIO:

Water has two fundamental functions in a concrete mix, firstly to enable the chemical reactions which cause setting and hardening to proceed and secondly to lubricate the mixture of coarse aggregate, fine aggregate and cement in order to facilitate placing.

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3.1.4 WATER CEMENT RATIO:

Water has two fundamental functions in a concrete mix, firstly to enable the chemical reactions which cause setting and hardening to proceed and secondly to lubricate the mixture of coarse aggregate, fine aggregate and cement in order to facilitate placing.

For given concrete materials the strength depends on only one factor - the ratio of water to cement, so long as we have a workable mix.

Since, unguided increases in the water/cement ratio have adverse effect on such properties of concrete as permeability, resistance to weathering, abrasion, tensile strength, creep, modulus of rupture and shrinkage.

Having established the fact that there is direct relationship between the mean strength achieved and the ratio of water to cement, a standard graph which depicts the relationship between compressive strength and water cement ratio was used to determine the required water cement ratio based on the target mean strength. The graph is shown in APPENDIX 2.

From the graph water cement ratio of 0.48 and 0.58 was adopted for the nominal mix 1:2:4 and 1:1½:3 respectively.

3.1.5 ADMIXTURE

Admixture ranging from additions of purpose designed chemicals to the use of waste materials for which an outlet is being sought, have been advocated for use in concrete almost from time when cement was first invented Murdorock (1991). The use of admixture is appropriate where it is desired to modify for a particular reason the properties of either fresh or hardened concrete or both.

The purpose of introducing pigment into the concrete in this research was to add colour into the concrete to enhance the aesthetic performance of the concrete without

substantial or appreciable decrease in the strength properties of the concrete as compared with the concrete of the same mix without coloration.

The two basic pigments used are the redoxide and carbon blacks. They are expensive, colour fast to both light and the alkalis in cement, temperature - stable and they have good tensorial strength.

It is recommended that, that the degree of control should be higher than is usual for ordinary concrete work, to ensure that over dosages are unlikely to occur because of relatively minute quantity normally added to the mix.

3.2 EXPERIMENTAL SET UP3.2.1 MIX PROPORTIONS

The mix proportions for the parameters tested are set out below in the tables 1 - 3.

Table 1 : Mix Proportions for Compressive strength test

MATERIAL	WEIGHT OF REQUIRED (KG)	
	NOMINAL MIX	
	1:2:4	1:1½:3
Cement	4.39	4.22
Water	2.11	2.44
Fine	7.03	6.73
Medium	4.39	4.22
Coarse	6.15	5.89

Table 2: Mix proportions for tensile strength test

MATERIAL REQUIRED	WEIGHT MATERIAL (KG)	
	NOMINAL MIX	
	1:2:4	1:1½:3
Cement	9.23	8.86
Water	4.43	5.13
Fine	17.77	14.15
Medium	9.23	8.86
Coarse	12.92	12.38

Table 3: Mix proportion for the flexural strength test.

MATERIAL	WEIGHT MATERIAL REQUIRED (KG)	
	NOMINAL MIX	
	1:2:4	1:1½:3
Cement	1.76	1.93
Water	0.84	0.98
Fine	2.81	2.69
Medium	1.76	1.69
Coarse	2.46	2.36

3.2.2 VOLUME COMPOSITION OF PIGMENT

The amount of pigment added to each mix varies 0% - 6%.

The percentage addition being the fraction of the cement content in the mix as specified in Bs.1014: 1961.

The pigments were in powdery form. The percentage fraction used are 0%, 2%, 4% and 6% of the cement content of the concrete mix. Table 4 shown the weight of pigments used for each of the mix and the strength properties tested.

Table 4: Percentage Weight of pigment added Mix for strength test.

Percentage of Pigment	PARAMETERS TO BE TESTED					
	Compressive Strength		Tensile Strength		Flexural Strength	
	Nominal Mix					
	1:2:4	1:1½: :3	1:2:4	1:½: 3	1:2: 4	1:1½: :3
2%	0.09	0.08	0.18	0.18	0.04	0.04
4%	0.18	0.17	0.37	0.35	0.07	0.08
6%	0.26	0.25	0.55	0.53	0.11	0.12

3.2.3 COMPRESSIVE STRENGTH TEST.

The specimen are casted in steel or cast-iron moulds of 150mm x 150mm x 150mm. In compliance to the standard practice prescribed by BS 1881: part 3, 1970, the moulds are filled in three layers. The mould is filled to overflowing and after compaction, excess concrete is finished by means of a trowel. A total of 64 cube were produced, the control specimen contain no pigment. The pigment added to each mix ratio used are 2%, 4% & 6% of the cement content. After cast the cubes are stored undisturbed for 24 hours. At the end of this period the mould is stripped and the cube is further cured in water for 28 days. Tests were carried on the cubes on a hydraulically operated machine.

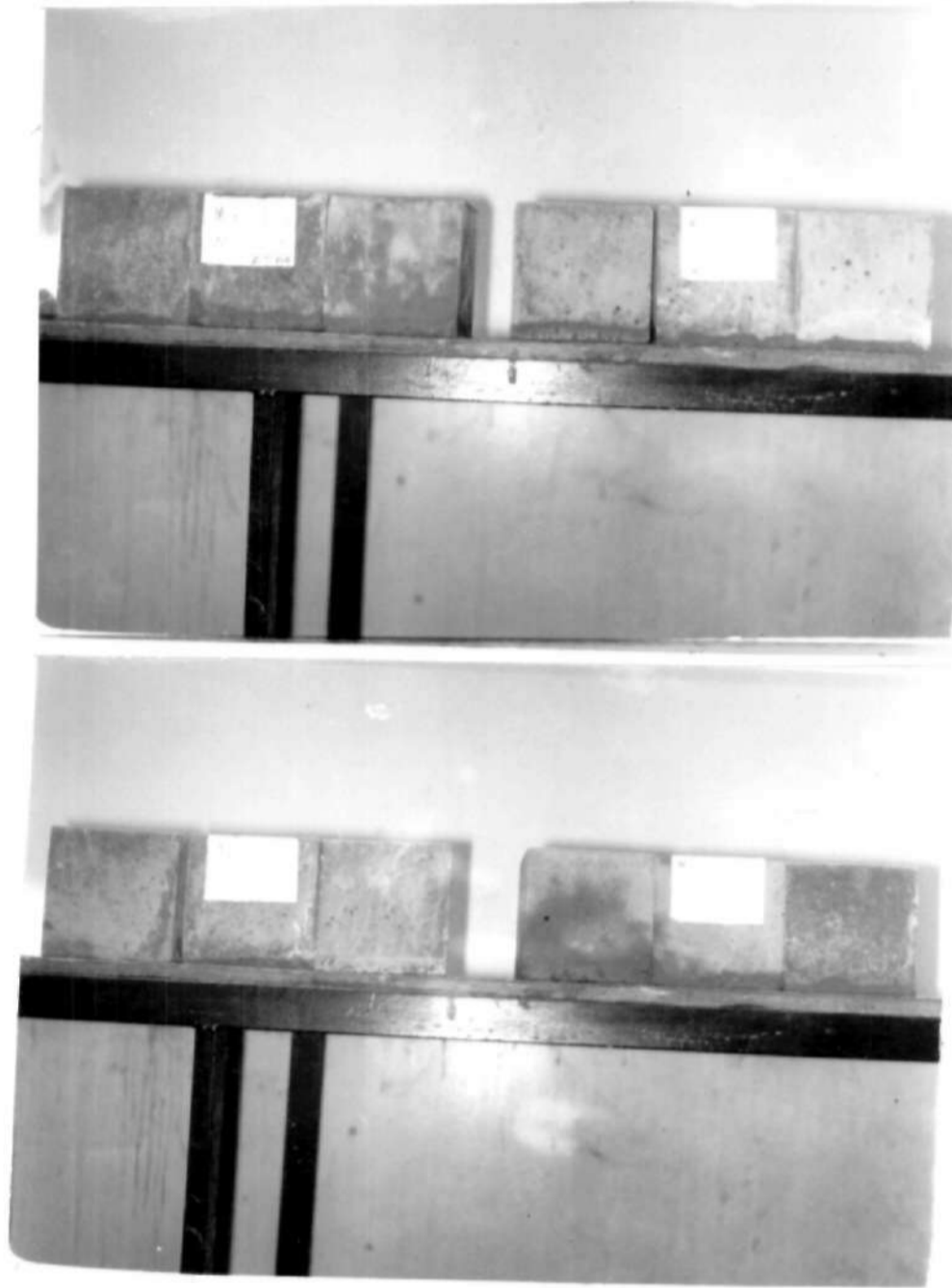


PLATE 1 Red Oxide Concrete Cubes.

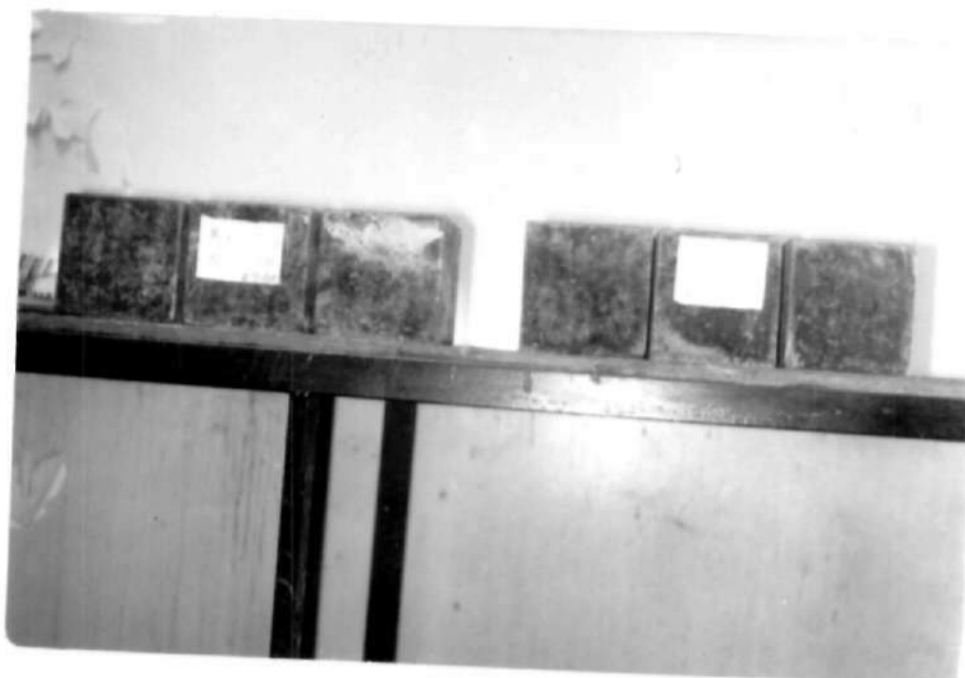


PLATE 2 Carbon black Concrete Cubes

3.2.4 TENSILE STRENGTH TEST.

The tensile strength of the specimen are tested using splitting test method. Although, concrete is not normally designed to resist tension, the knowledge of tensile strength is of value in assessing the load under which cracking will develop. The absence of cracking enhances the continuity of concrete structure thereby preventing corrosion of reinforcement.

A concrete cylinder is placed with it's axis horizontal between the platens of the testing machine, the load increased to failure. Figure 1 shows the testing procedure.

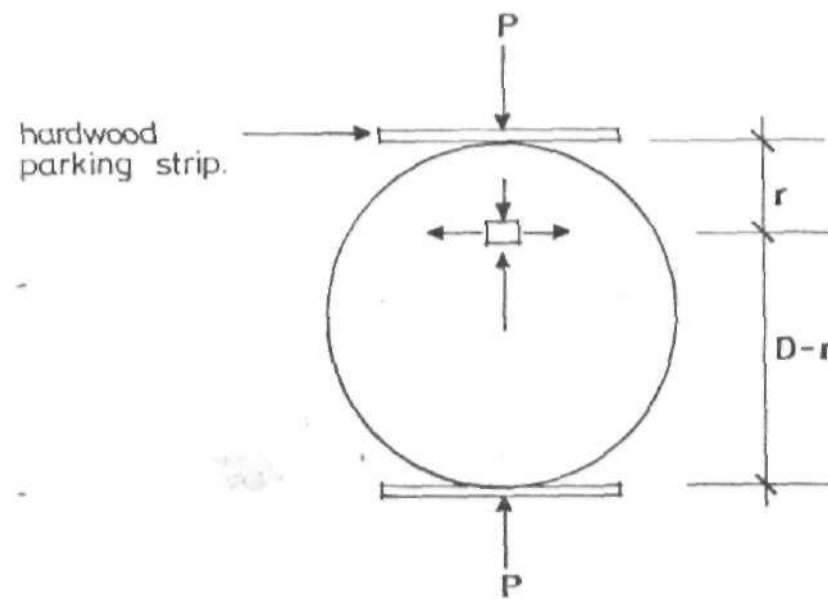


Fig. 1: Tensile strength test arrangement.

When the load is applied along the generatrix the element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of

$$\frac{2P(2D-r)}{\pi LD(D-r)}$$

and a horizontal tensile stress of

$$\frac{2P}{\pi LD}$$

where P = the compressive load on the cylinder.

L = the length of the cylinder.

D = it's diameter

r and (D-r) are the distances of the element from the two loads respectively.

For the indirect tensile strength test a cylinder size of 150mm diameter and 300mm long specimen is produced.

3.2.5 FLEXURAL STRENGTH TEST

A miniature beam of size 100x100x400mm is used for this test.

The Figure 2 shows the arrangement of the flexural test as recommended by Bs 1881: part 118 1983.

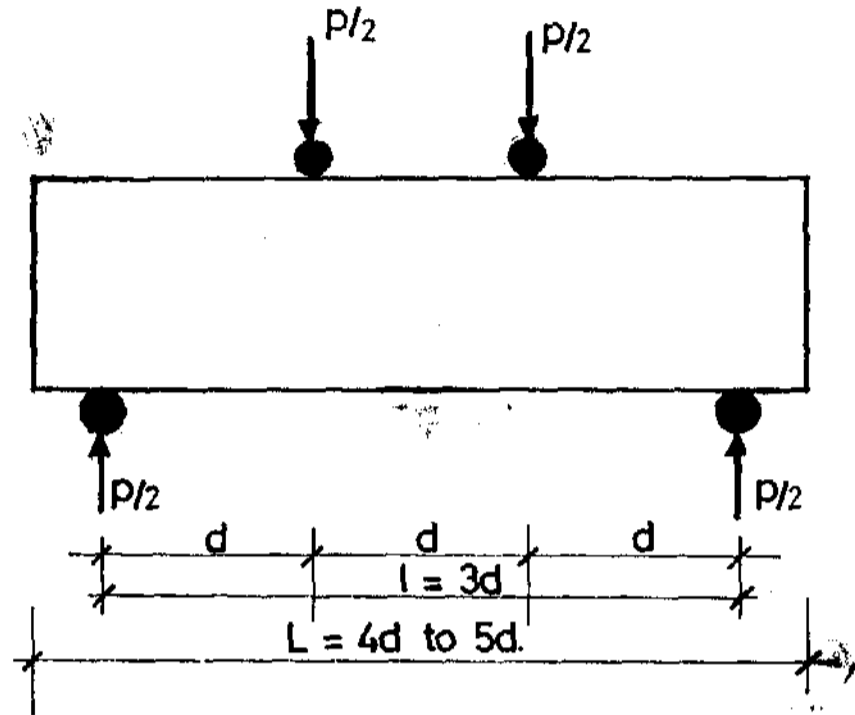


Fig. 2: Typical arrangement of loading for the prototype beam.

In this test the beam specimen used is of size 100mmx100mmx400mm. The modulus of rupture is computed using the elasticity theory, if the fracture occupy within the middle one third of the beam.

$$f_{br} = \frac{PL}{bd^3}$$

where P = maximum total load applied.

L = Span

d = depth of the beam

b = width of the beam.

RESULT OF THE TESTS

Table 5 COMPRESSIVE STRENGTH TEST RESULTS
For nominal mix 1:2:4

PIGMENT %	COMPRESSIVE STRENGTH		MEAN COMPRESSIVE STRENGTH (N/mm ²)	
	REDOXIDE	CARBON BLACK	REDOXIDE	CARBON BLACK
0%	WATER CEMENT RATIO = 0.48		REDOXIDE	CARBON BLACK
	25.78	25.78	25.48	25.48
	25.78	25.78		
	24.89	24.78		
2%	24.44	25.78	24.15	26.22
	24.00	26.67		
	24.00	26.22		
4%	23.11	25.78	22.81	25.63
	21.33	25.73		
	24.00	25.33		
6%	22.67	24.89	21.93	24.67
	22.22	24.44		
	20.89	24.67		

Table 6: For nominal mix 1:1½:3.

PIGMENT %	COMPRESSIVE STRENGTH N/mm ²		MEAN COMPRESSIVE STRENGTH	
	WATER CEMENT RATIO = 0.58		REDOXIDE	CARBON BLACK
	REDOXIDE	CARBON BLACK		
0%	25.78	25.78	25.76	25.76
	25.70	25.70		
	25.80	25.80		
2%	24.60	24.89	24.77	24.44
	24.90	24.44		
	24.80	24.00		
4%	23.80	22.22	23.78	21.63
	23.90	21.33		
	23.65	21.33		
6%	23.20	20.88	22.82	21.03
	22.95	21.33		
	22.30	20.88		

Table 7: TENSILE STRENGTH TEST RESULTS:
Nominal Mix 1:2:4

PIGMENT %	TENSILE STRENGTH		MEAN TENSILE STRENGTH N/mm ²	
	WATER CEMENT RATIO = 0.48		RED OXIDE	CARBON BLACK
	RED OXIDE	CARBON BLACK		
0%	3.54	3.54	3.54	3.54
	3.26	3.26		
	3.40	3.40		
2%	2.40	2.69	2.49	2.75
	2.82	2.79		
	2.26	2.80		
4%	2.20	2.50	2.20	2.67
	2.26	2.69		
	2.15	2.83		
6%	2.10	2.45	2.03	2.45
	2.00	2.40		
	2.00	2.50		

Table 8: Nominal Mix 1:1½:3

PIGMENT %	TENSILE STRENGTH		MEAN TENSILE STRENGTH N/mm ²	
	WATER CEMENT RATIO = 0.58		RED OXIDE	CARBON BLACK
	RED OXIDE	CARBON BLACK		
0%	3.50	3.50	2.90	2.90
	2.69	2.69		
	2.50	2.50		
2%	2.45	2.50	2.51	2.55
	2.60	2.55		
	2.48	2.60		
4%	1.84	1.90	1.78	1.85
	1.70	1.85		
	1.80	1.80		
6%	1.56	1.84	1.61	1.65
	1.60	1.41		
	1.68	1.70		

Table 9: FLEXURAL STRENGTH TEST RESULTS:

Table 9: Nominal Mix 1:2:4

PIGMENT %	FLEXURAL STRENGTH N/mm ²		MEAN FLEXURAL STRENGTH	
	WATER CEMENT RATIO = 0.58		RED OXIDE	CARBON BLACK
	RED OXIDE	CARBON BLACK		
0%	3.0	3.0	3.13	3.13
	3.2	3.2		
	3.2	3.2		
2%	3.0	2.8	3.33	2.67
	3.10	3.2		
	3.10	2.6		
4%	2.80	1.80	2.92	1.60
	2.90	1.60		
	2.95	1.40		
6%	2.60	1.20	2.72	1.39
	2.80	1.50		
	2.75	1.46		

Table 10: Nominal Mix 1:1½:3.

PIGMENT %	FLEXURAL STRENGTH N/mm ²	MEAN FLEXURAL STRENGTH	
		RED OXIDE	CARBON BLACK
		WATER CEMENT RATIO = 0.58	
		RED OXIDE	CARBON BLACK
0%	3.28	3.28	2.76
	2.20	2.20	
	2.80	2.80	
2%	2.00	2.00	2.43
	2.50	2.20	
	2.80	1.90	
4%	2.40	1.60	2.38
	2.30	1.40	
	2.45	1.52	
6%	2.25	1.50	2.12
	2.00	1.60	
	2.10	2.10	

CHAPTER 4

4.00 RESULTS ANALYSIS AND DISCUSSIONS:

This Chapter presents the strength results for all the test conducted (namely flexural, tensile and Compressive). The graphical plots of the strength results are equally presented in Fig. 3 to Fig. 14. Fig. 2 and Fig. 3 shows the graph as the compressive strength against the percentage of pigment by weight in the mix for the two mix ratio used namely 1:2:4 and 1:1½:3 respectively for both the red oxide and the carbon black pigmented concrete. The Histograms is also plotted along side the graphs to help in appreciating the differences in strength recorded.

In both cases there is an observable decrease in the compressive strength as the percentage of pigment in the mix increase. The decrease in strength of red oxide for the 1:2:4 mix shows a sharp departure in trend from the observations with the 1:1½:3 mix. This could be due to experimental error that may have arisen during the taking of the readings. However the observation is singular. It is not reflective in other experiments.

In both cases however, up to the 6% dosage, the cube strength of the Carbon Black pigmented. Concrete are 25.2 and 22.2N/mm² for the 1:2:4 and the 1:1½:3 mix respectively. The strength loss is low, observably 1.17 and 12.2 percent for the 1:1½:3 and the 1:2:4 mix for Carbon black pigmented concrete.

Because the carbon black pigment as well as red oxide pigment have an organic base, their reaction with concrete (granted the limitation in percentage addition by weight will be minimal). In other words the chemical composition of the constituent mix will remain practically unaltered. The pigment virtually provides the tinctorial base. The Red Oxide strength loss is approximately 1.24 percent for the 1:1½:3 Red Oxide pigmented concrete. The strength loss is small and does not over emphasize weak concrete at the expense of tinctorial advantage.

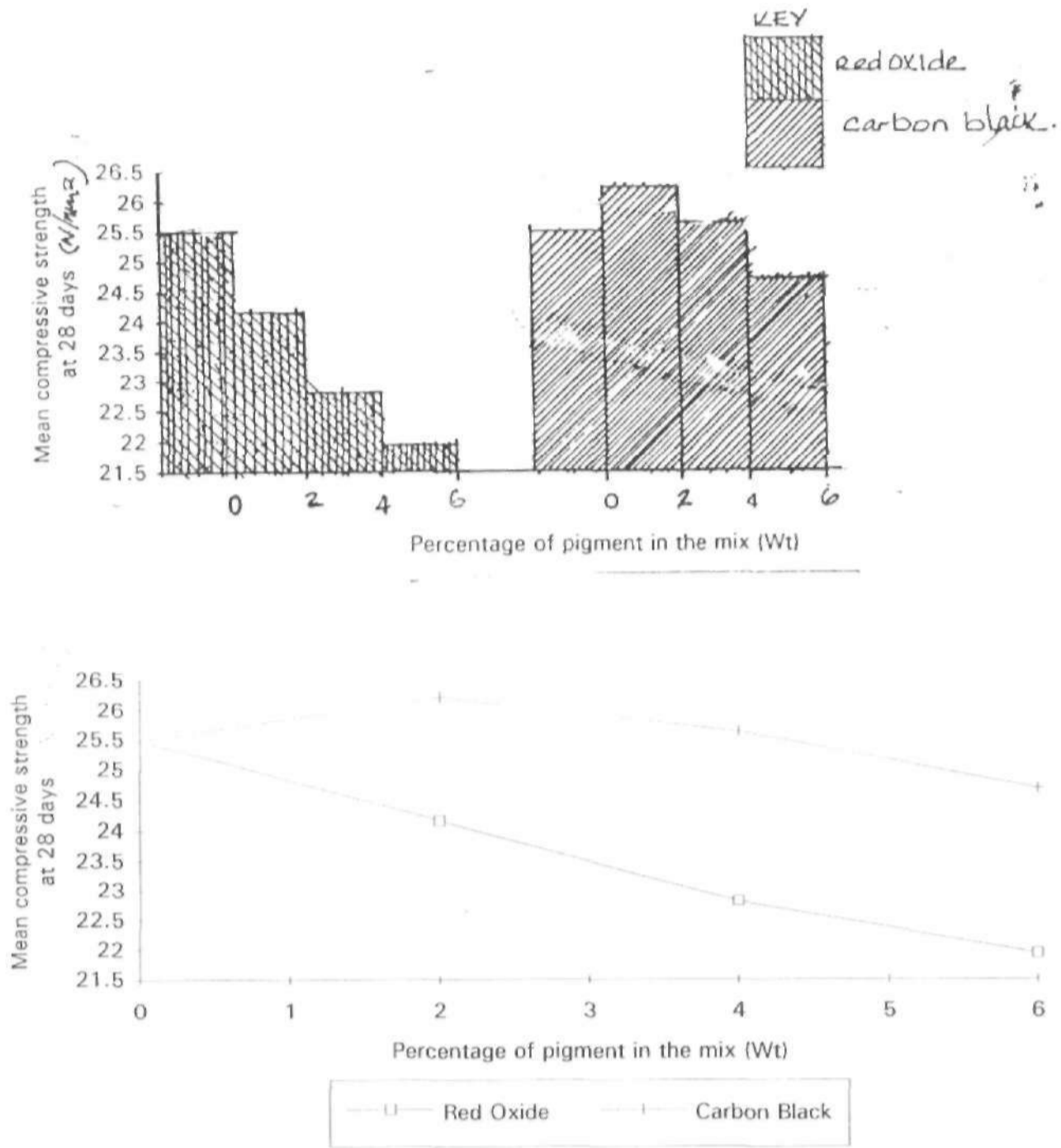


FIG. 3 Effect of pigments on the compressive strength of coloured concrete (mix ratio 1:2:4)

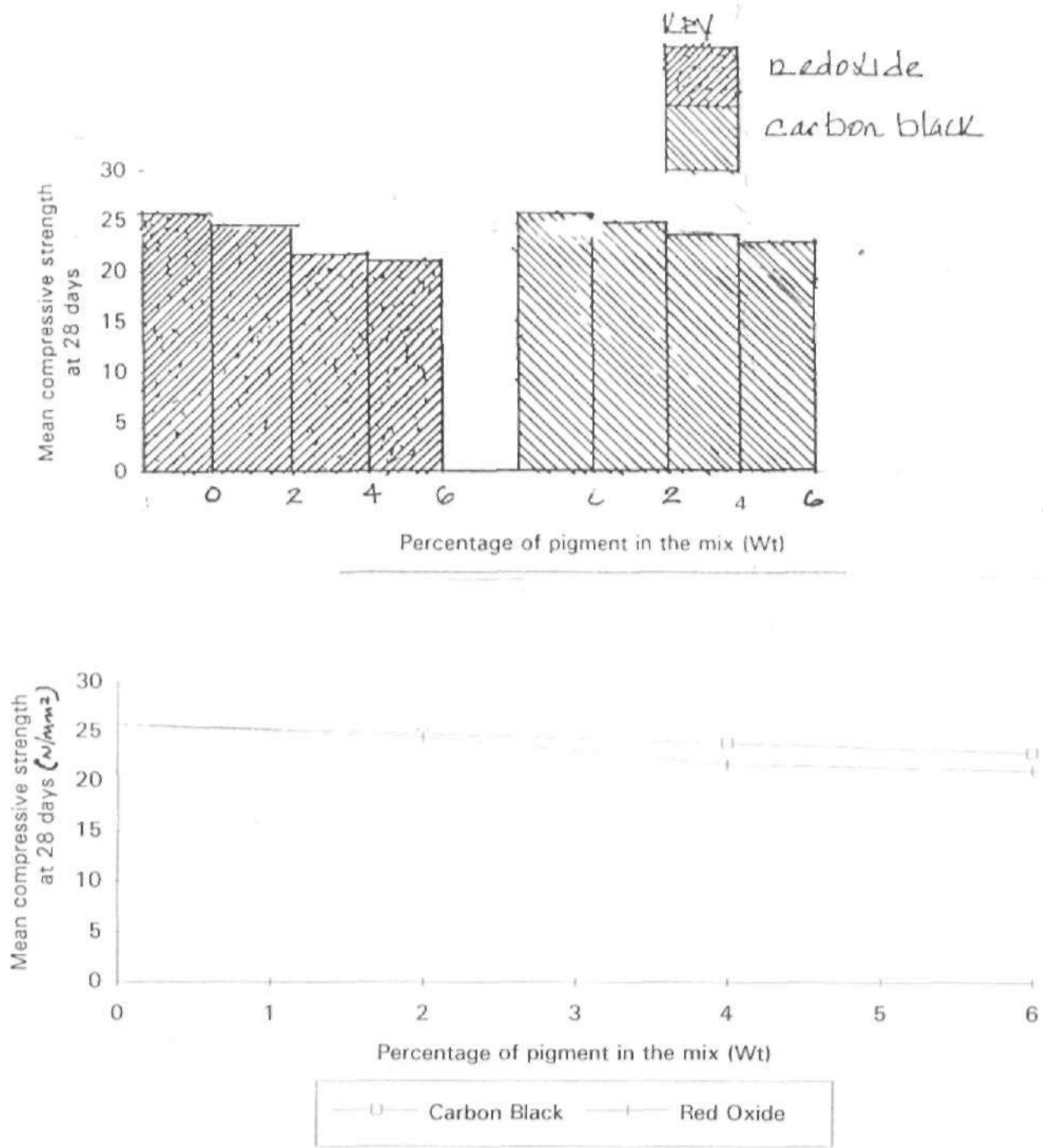


FIG. 4 Effect of pigments on the compressive strength of coloured concrete (mix ratio 1:1½:3)

4.2 Tensile Strength

The graphical trend of the tensile strength plot against the percentage of pigment in the mix is as presented in figures 5 and 6. A strength fall of 3.54N/mm^2 to 2.45N/mm^2 at 6% by Carbon Black and Red Oxide, respectively is observed for the 1:2:4 mix (Table 7 and 8), Figure 5. For the $1:1\frac{1}{2}:3$ mix, a correspond strength fall of $[2.90 - 1.65] \text{N/mm}^2$ is observed.

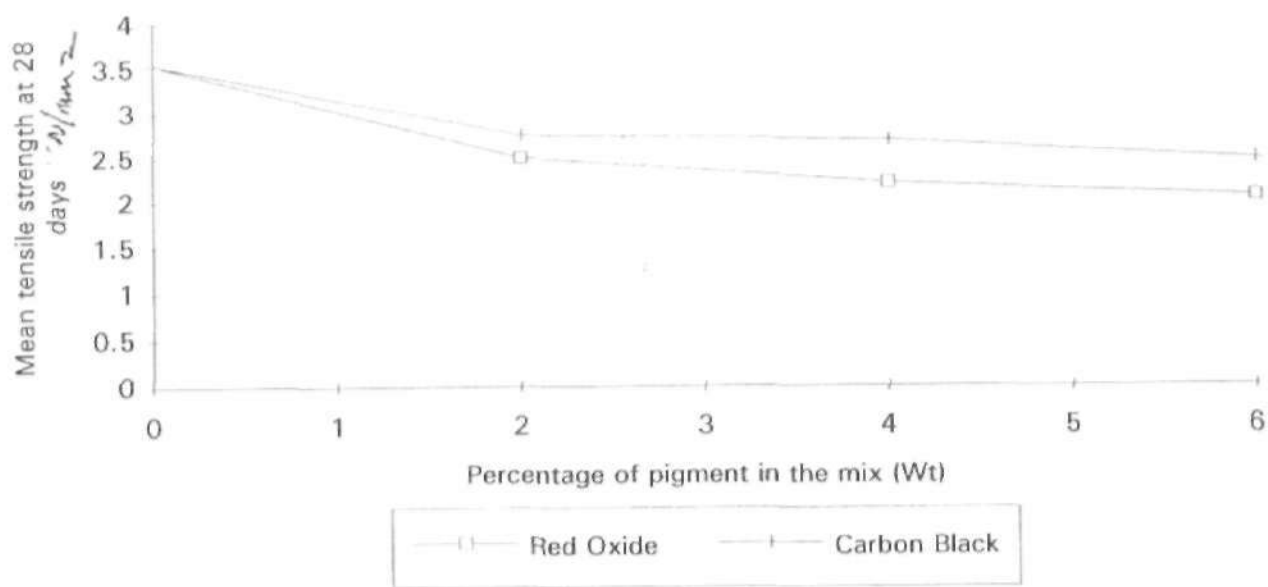
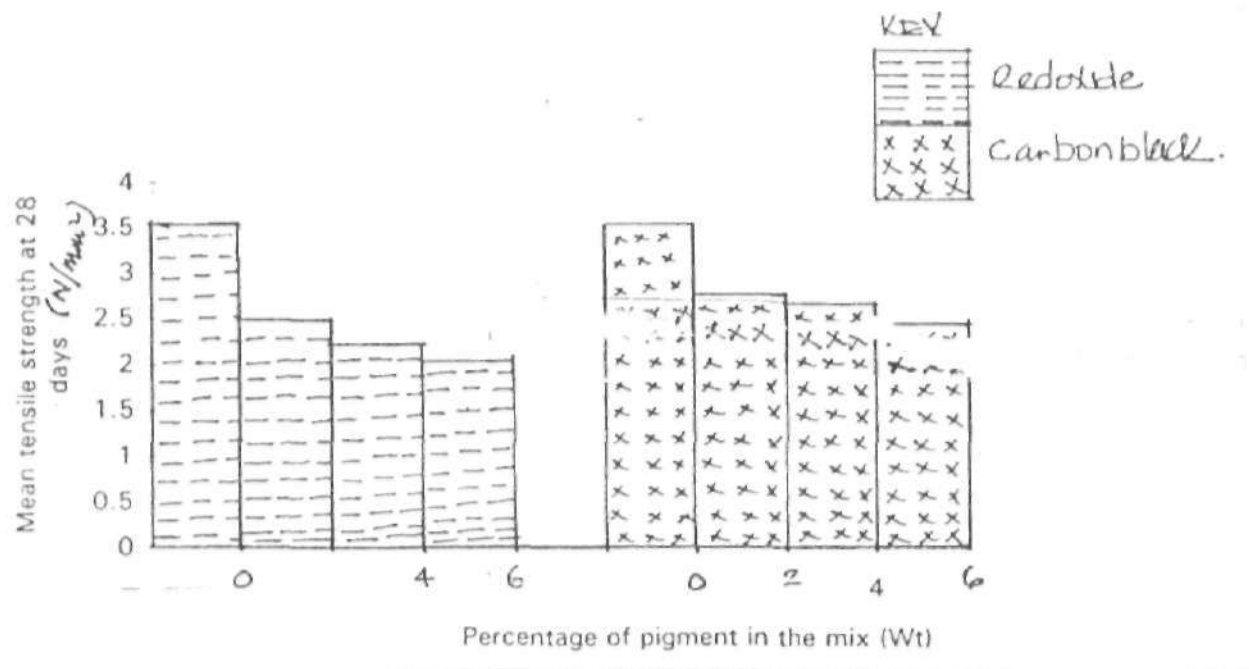


FIG. 5 Effect of pigments on the tensile strength of coloured concrete (mix ratio 1:2:4)

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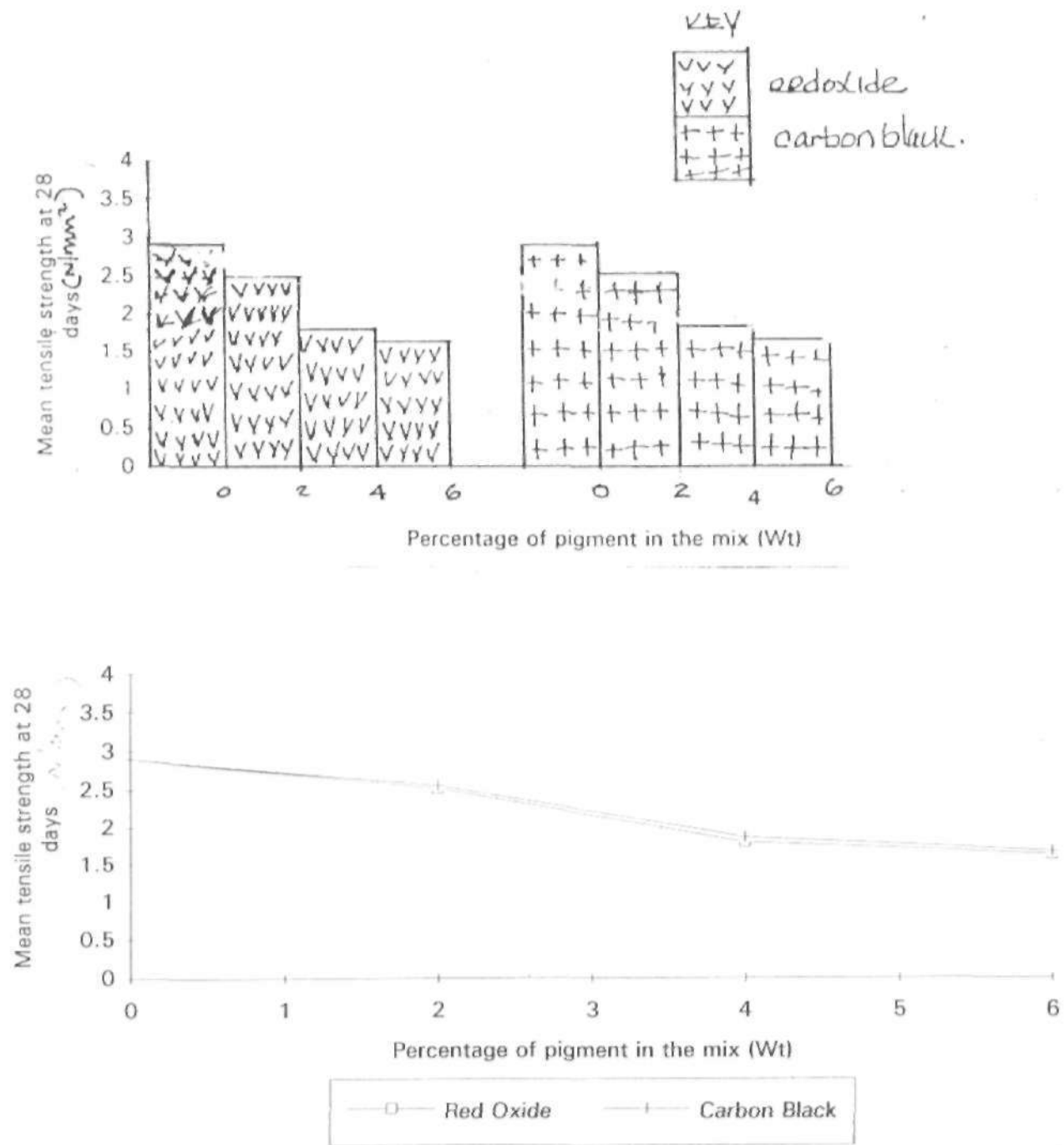


FIG. 6. Effect of pigments on the tensile strength of coloured concrete (mix ratio 1:1½:3)

4.3 FLEXURAL STRENGTH:

The graphical plot of the flexural strength versus the pigment in the mix is presented in Figure 7 and 8 for the 1:2:4 and 1:1½:3 mix respectively.

At 2 percentage of pigment there is a strength fall which progress as the percentage of pigment in the mix increases. This phenomenon is more pronounced in the 1:2:4 mix than in the 1:1½:3 mix. The 1:1½:3 mix helps in containing the chemical effect of the pigment on the concrete itself. In a chemical process ordinarily tap water which is used in mixing concrete is pure than the colloidal suspended matured liquid that involves after the addition of pigment.

From the nature of the graphical representations, it becomes necessary to limit the percentage of pigment to 2. The tinctorial strength would have been achieved even at this percentage.

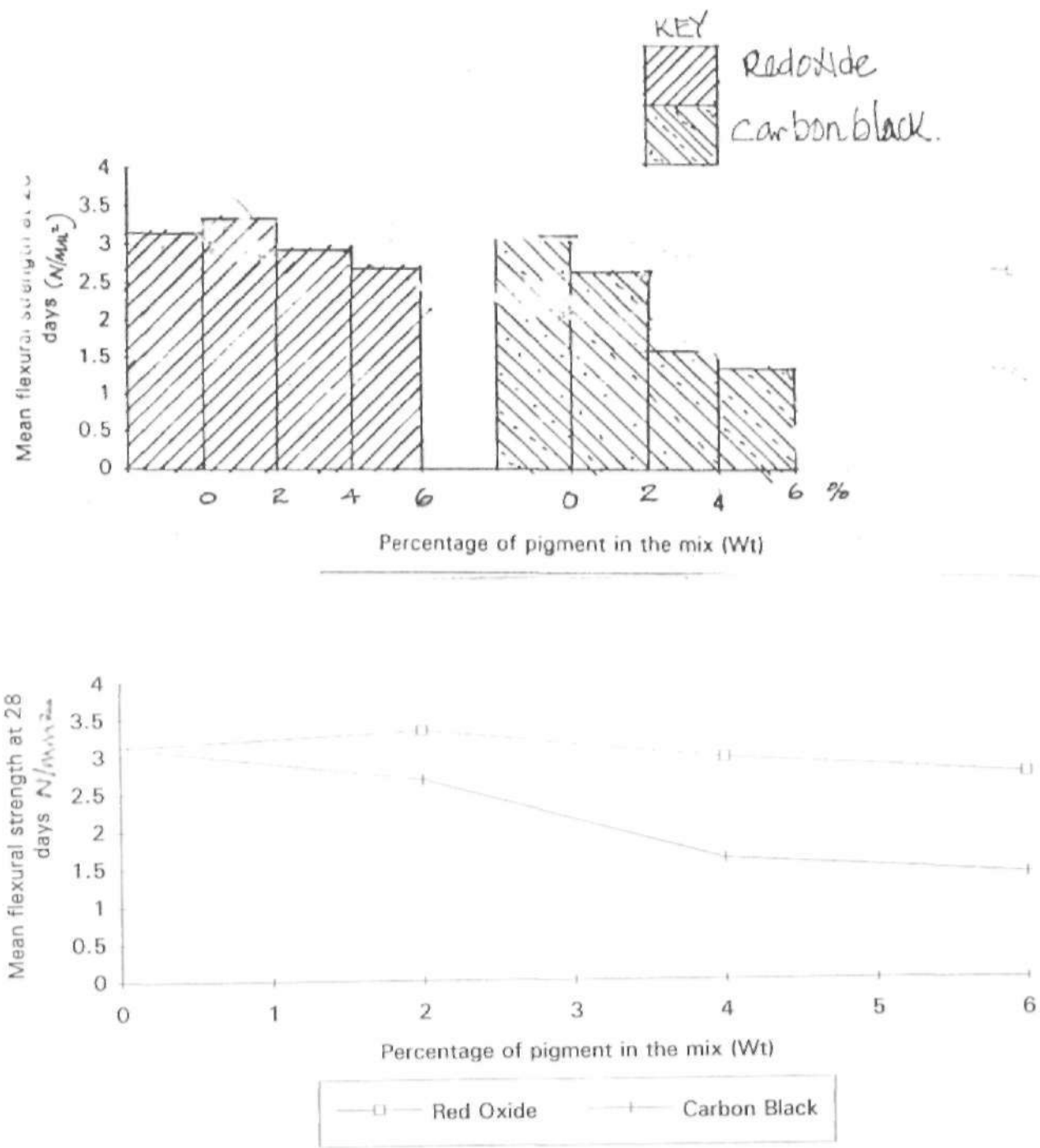


FIG 7 Effect of pigments on the flexural strength of coloured concrete (mix ratio 1:2:4)

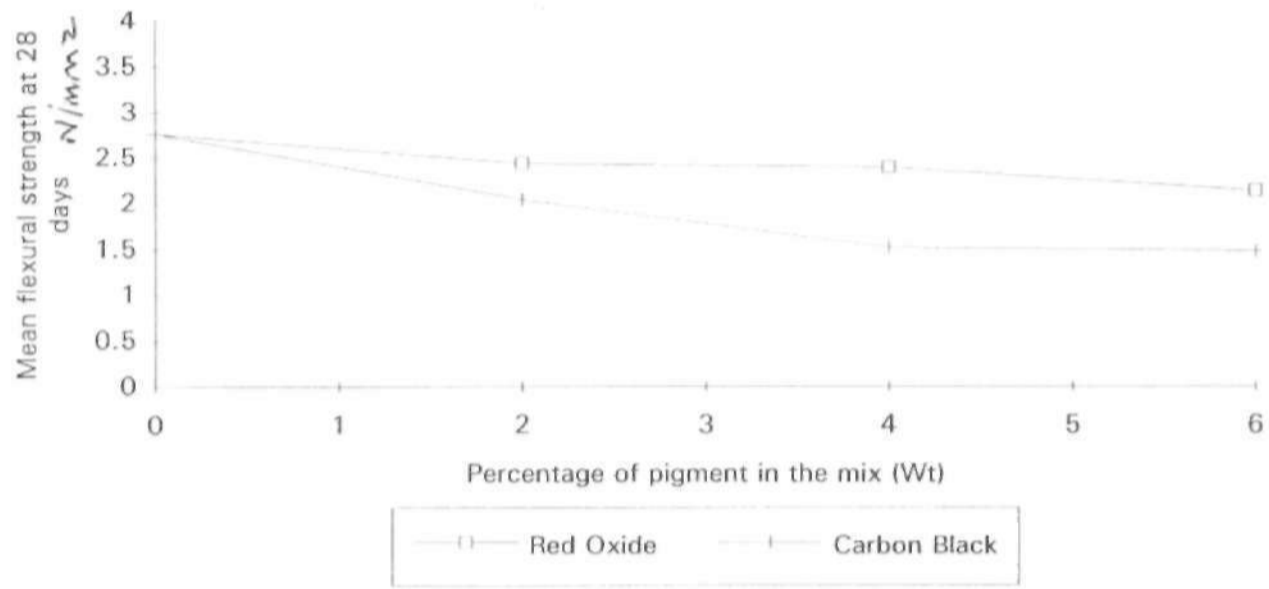
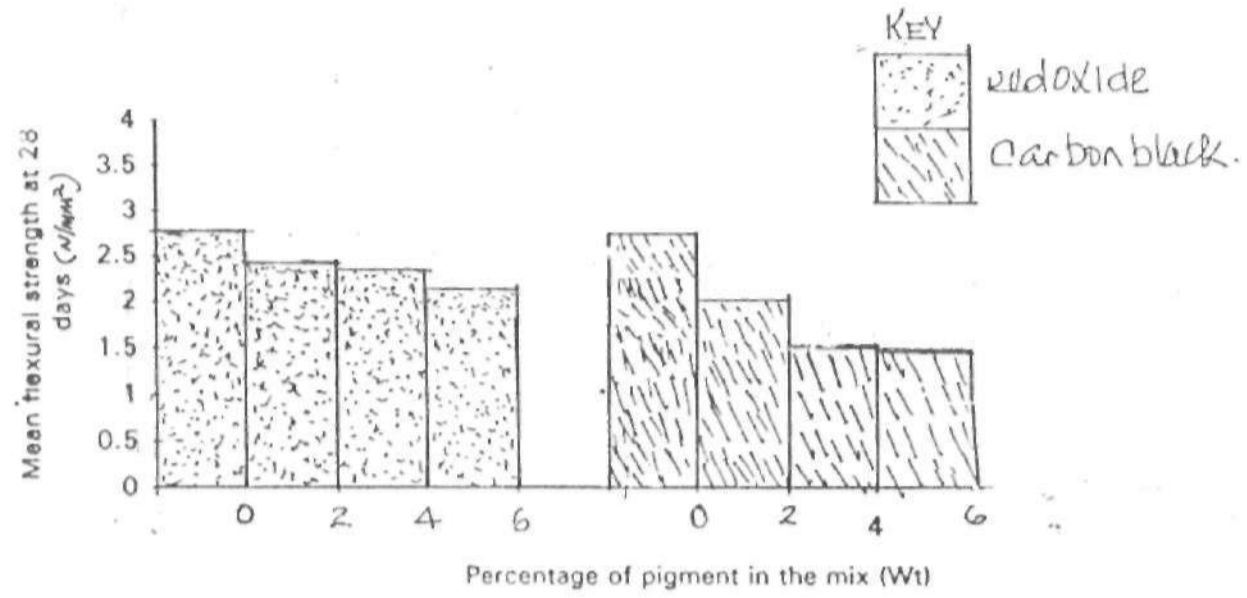


FIG. 8 Effect of pigments on the flexural strength of coloured concrete (mix ratio 1:1½:3)

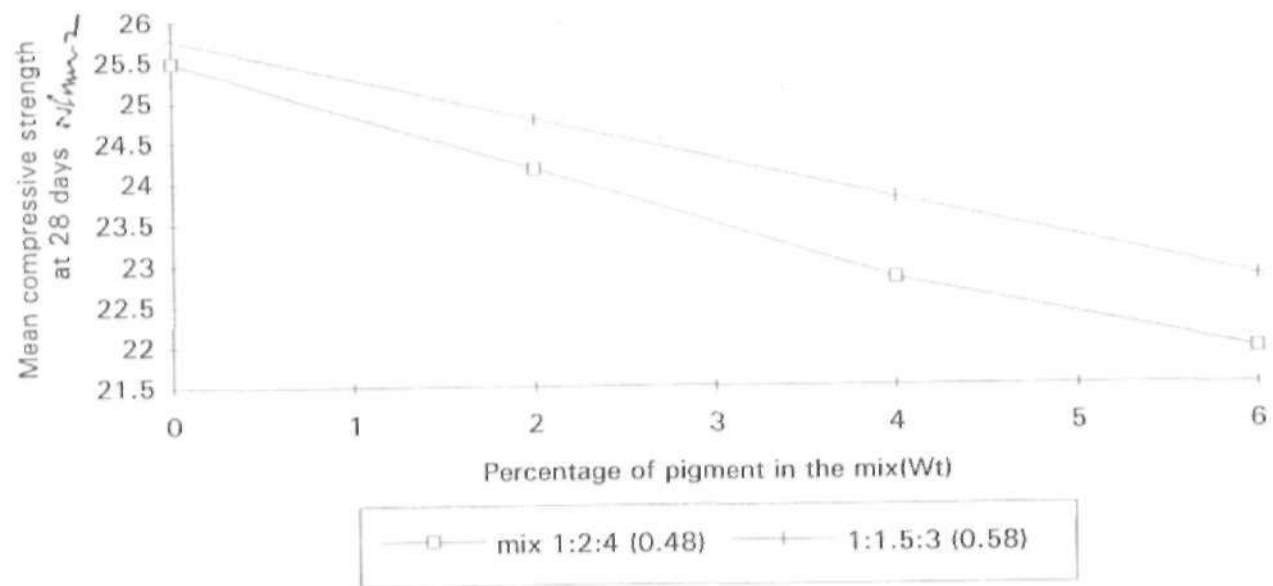


Fig. 9 Relative compressive strength for two mixes with Redoxide

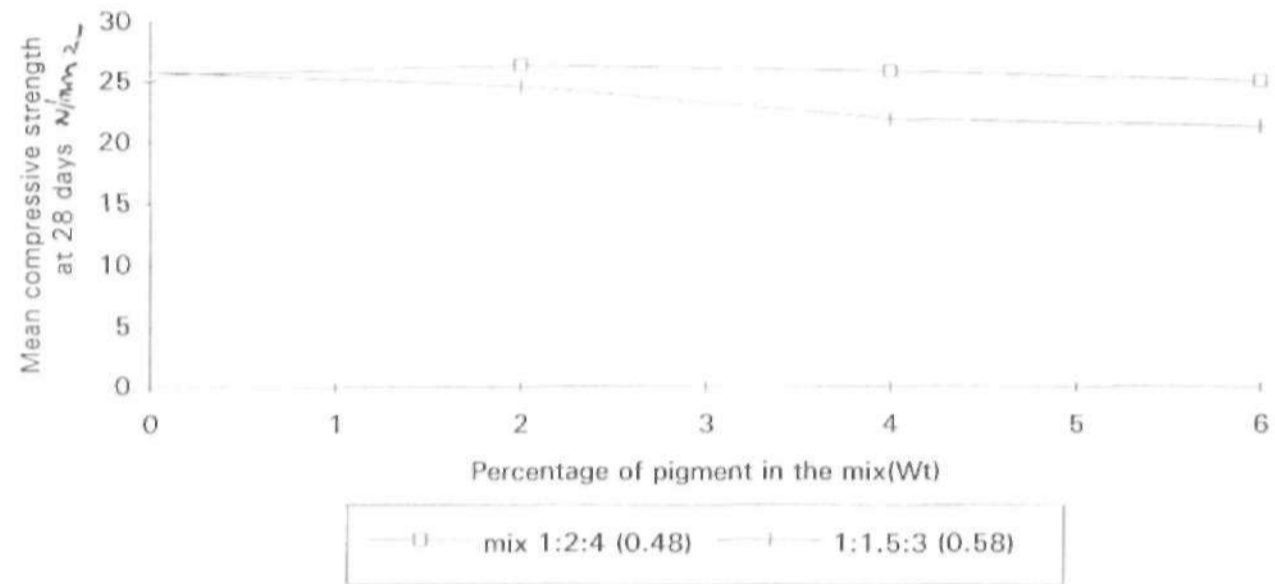


Fig. 10 Relative compressive strength for two mixes with Carbon black

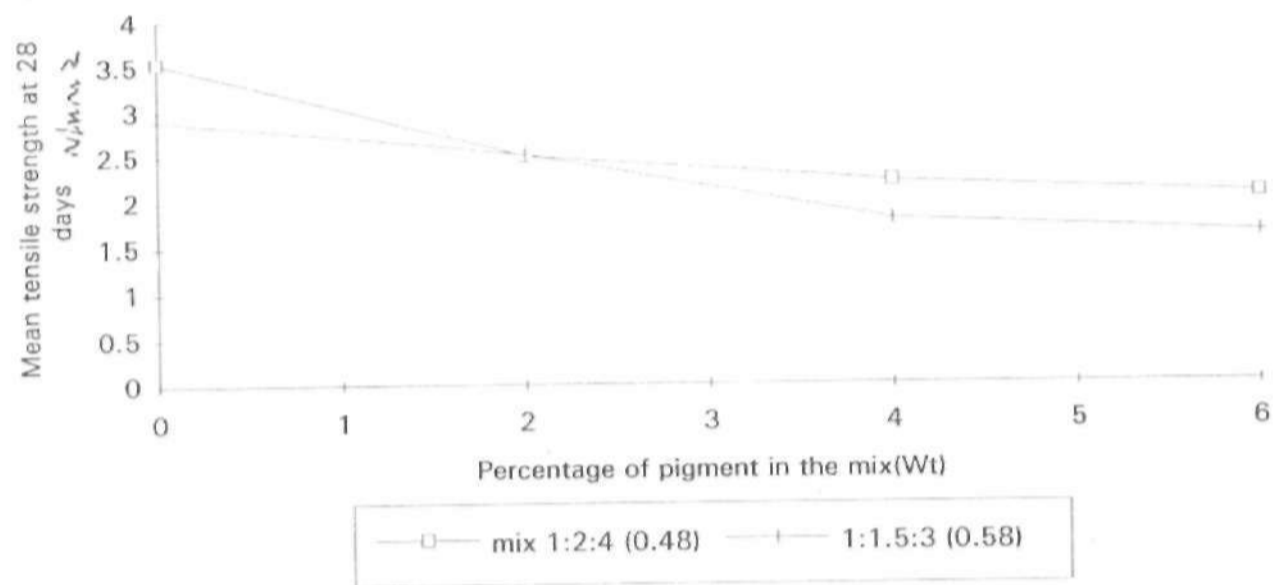


Fig. 11 Relative tensile strength
for two mixes with Redoxide

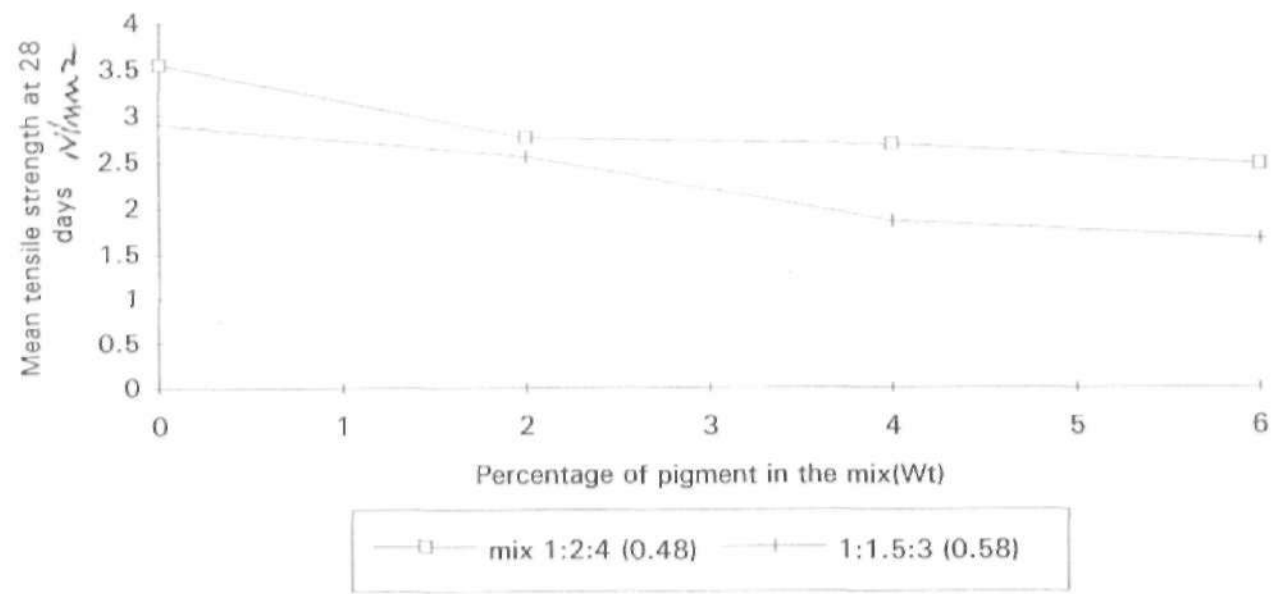


Fig. 12 Relative tensile strength for two mixes with Carbon black

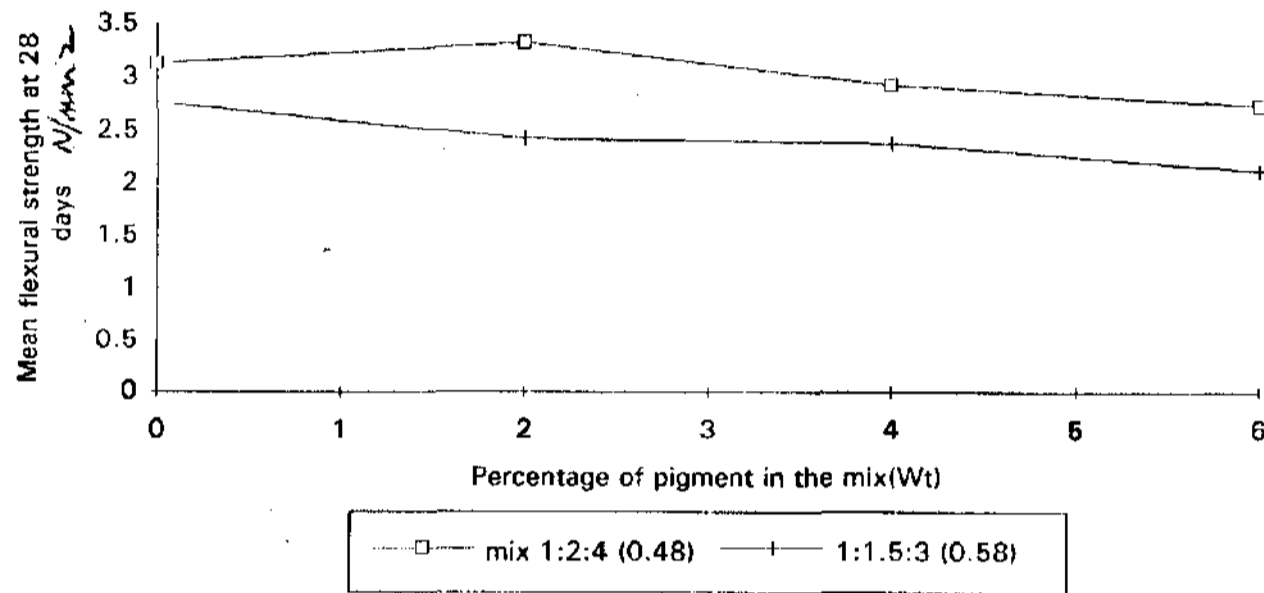


Fig. 13 Relative Flexural strength
for two mixes with Redoxide

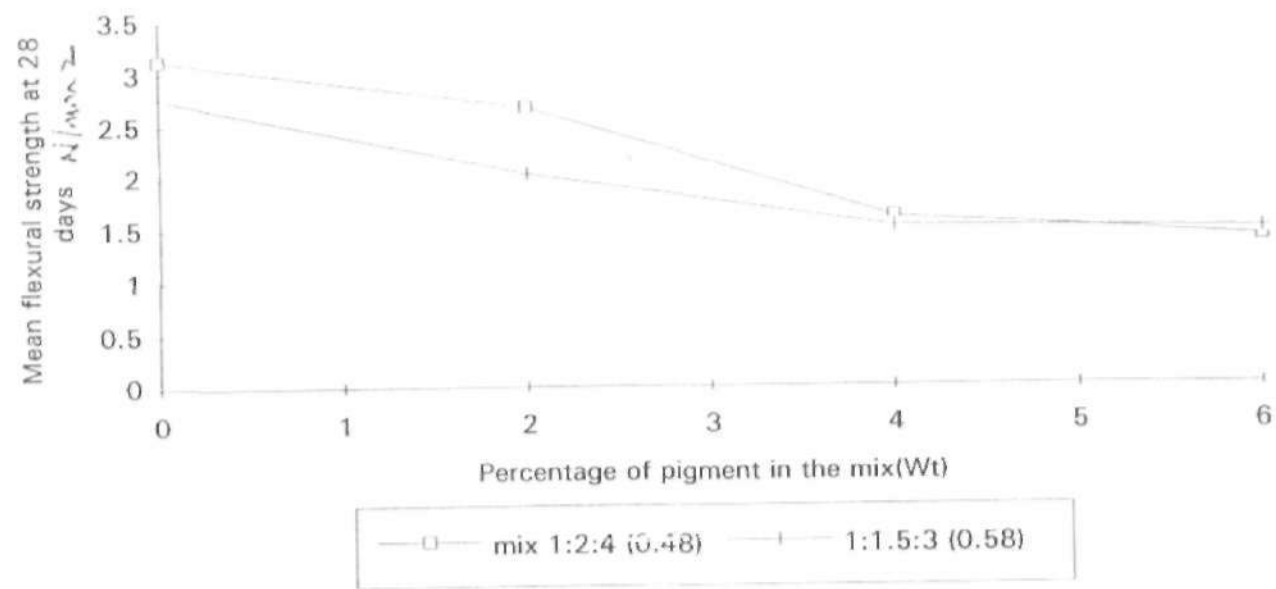


Fig. 14 Relative Flexural strength
for two mixes with Carbon black

CHAPTER 5.6.0 CONCLUSION

The issue of aesthetic is paramount to the Architect in addition to the structural stability of his design. The Engineer on the other hands is conscious of the behaviour, the stability, strength and availability of the component structure of the building he has designed.

It is on this note that extensive studies were carried out on the constructional materials available to ascertain their strength characteristics and behaviours under different climates and loading conditions.

Coloured concrete could be a cost reducing approach to the conventional unpigmented concrete. This study has established that pigments do not have adverse effect on the strength properties of the concrete if the dosage applied does not exceed 4% of the cement content of a particular mix ratio. This amount in a given mix will achieve the required tintorial strength.

Having carried out the necessary test [compressive, tensile and flexural test] on the samples prepared. The two pigments used exhibits negligible effect on the resultant strength of the concrete as shown in chapter 3 and as depicted in chapter 4 from the histograms and graphs produced from the results.

In addition it was be observed that as the percentage of pigment incorporated into the mix increase there was a negligible decrease in strength. The results also show that different pigments have differential effect on the resultant strength.

Generally the purpose of colour incorporation into the concrete is to achieve tintorial effect. It is observed that four percent (4%) pigment addition could achieve appreciable tintorial strength needed for the aesthetic purpose without adverse effect on the resultant strength of the concrete properties.

6.11 RECOMMENDATION

The amount of work published on the physical properties of pigmented concrete is very limited and there is practically no data reported on durability and performance of such concrete; There is also no data available to support the current belief that pigments are inert regarding the hydration of cement. This study is recommending more studies on pigmented concrete that could help understand the various effects of pigments on the properties of concrete.

Besides, further studies would also help in establishing the cost benefits that will likely be derivable from the pigmented concrete as compared to the conventional unpigmented concrete.

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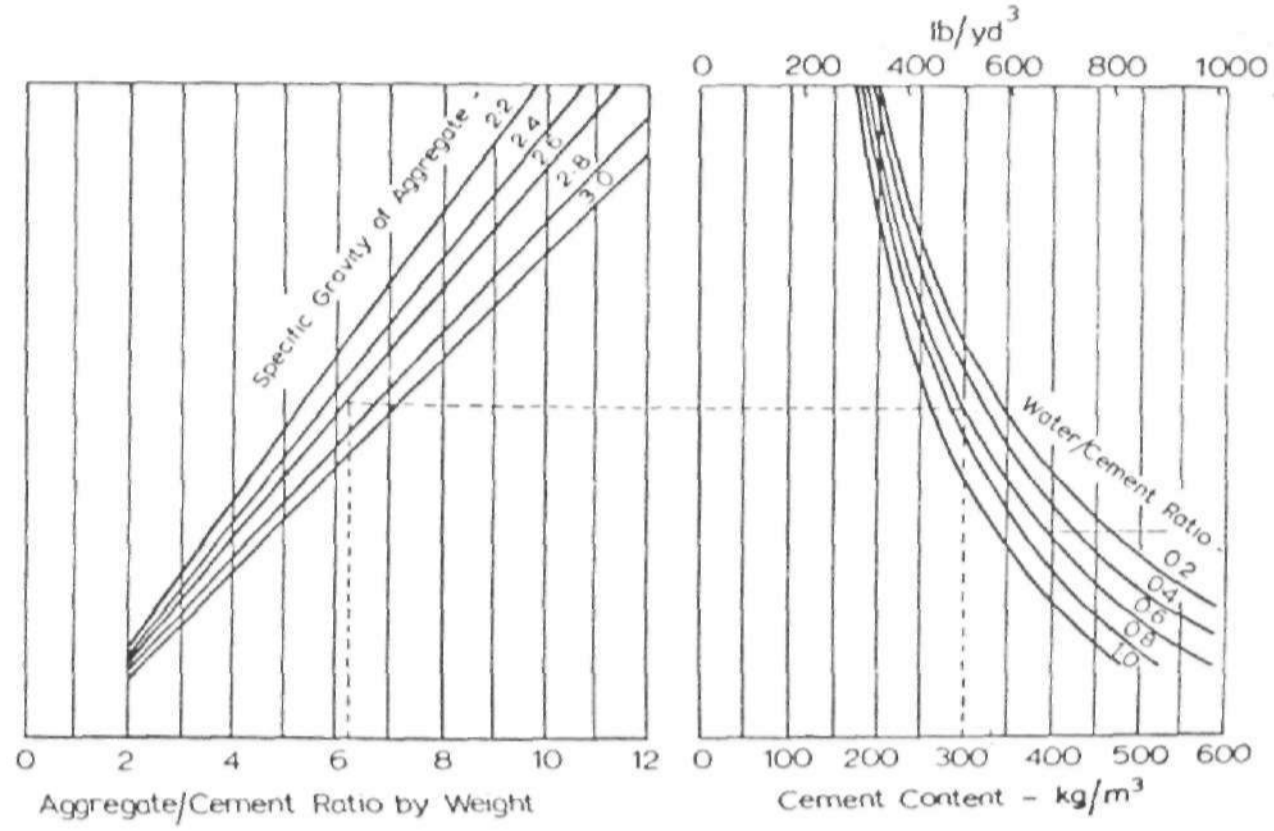
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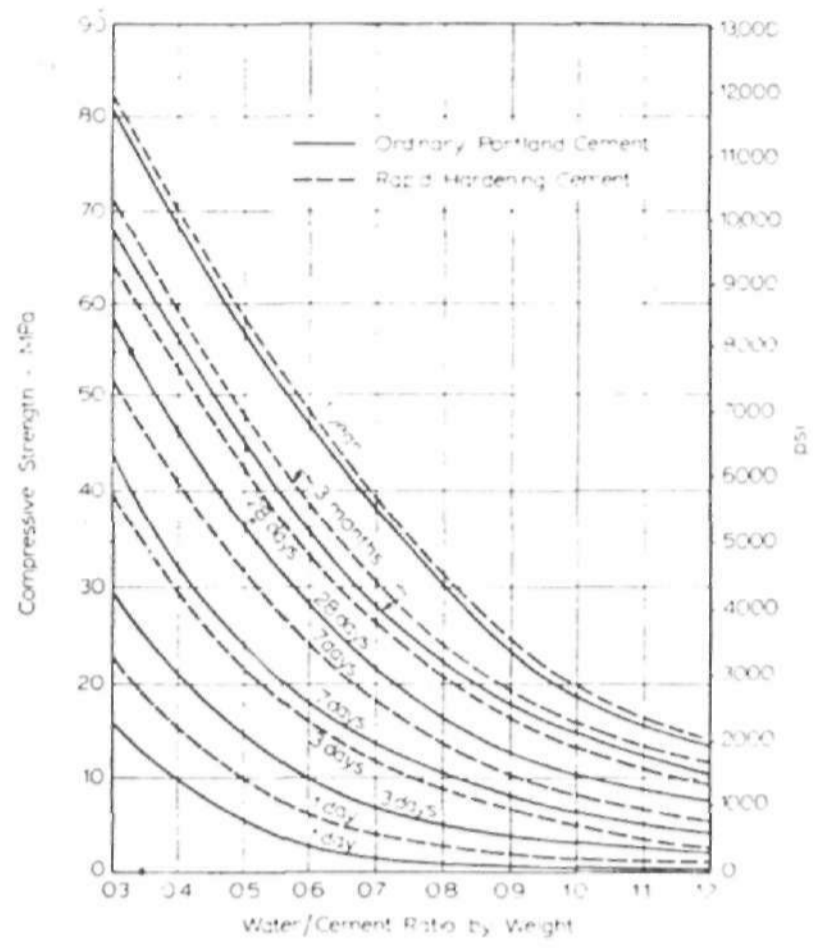
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APPENDIX

APPENDIX 1 CONVERSION CHART FOR AGGREGATE/CEMENT RATIO CONTENT
 PRODUCED BY CEMENT AND CONCRETE ASSOCIATION



APPENDIX 2 THE RELATIONSHIP BETWEEN COMPRESSIVE STRENGTH AND WATER CEMENT RATIO



APPENDIX 3

COMPUTATION OF THE CONSTITUENT MATERIAL

Basic data

(i) Water/Cement ratio

(a) mix 1:2:4 = 0.48

(b) mix 1:1½:3 = 0.58

(ii) Aggregate/Cement ratio = 4

COMPUTATION BY VOLUME:

The ratio of fine medium coarse aggregate was taken as 40:25:35 respectively.

$$\frac{W+C+A}{1000+1000\rho_c+1000\rho_a}=1 \quad (1)$$

where C = Cement content (kg/m³)W = Water content (kg/m³)A = Aggregate content (kg/m³)

ρ_a, ρ_c = specific gravity of aggregate and cement respectively.

For nominal mix 1:2:4

(a) $\frac{W}{C} = 0.48$ \therefore Weight of water = 0.48C -----(ii)(b) $\frac{\text{Aggregate}}{\text{Cement}} = 4$ \therefore Weight of aggregate = 4C-----(iii)

TABLE 1 : The ratio of the aggregates used

Fine	Medium	Coarse	Total
40	25	35	100
8	5	7	20

Since the computation was based on 1 cubic metre of concrete, there is the need to compute the material needed for the production of the specimen for the parameters to be tested - compressive, tensile and flexural strength properties. The weight of materials required for the samples were arrived at based on the standard size of cubes, cylinders or prototype beam as specified in BS 1881. Part 2, 1970.