ECO-EFFICIENT CONCRETE - IMPACT OF USE OF CONTAMINANTS ON THE MECHANICAL PROPERTIES OF CONCRETE

A Project Report

Submitted by

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In partial fulfillment for the award of the degree

of

Bachelor of Engineering
In
Civil Engineering

DEPARTMENT OF CIVIL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE – 641 006

ANNA UNIVERSITY: CHENNAI 600 025

APRIL 2009

BONAFIDE CERTIFICATE

Certified that this project report titled **"ECO-EFFICIENT CONCRETE - IMPACT OF USE OF CONTAMINANTS ON THE MECHANICAL PROPERTIES OF CONCRETE"** is the bonafide work of MADHANRAJ.M , PRABHU.L REVANTH.R.S , VINODH KRISHNAN.D who carried out the research work under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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Submitted for the project Viva voice examination held on 29.4.09 at Kumaraguru College of technology, Coimbatore-641 006.

ACKNOWLEDGEMENT

First and foremost we submit our thanks to **THE ALMIGHTY**, through whom all things are possible. This work was not by our might or power, but by **His spirit**.

We take pride and immense pleasure in expressing our deep sense of gratitude and indebtedness to our Guide Prof. **Dr. P.Eswaramoorthi**, Professor of Civil Engineering Department for his innovative ideas continued conduce, untiring efforts and encouragements which enabled the successful completion of project work.

We would like to say sincere thanks to the **Department of Biotechnology** for helping us in crushing the ceramics (through jaw crusher) in their laboratory.

We deem great pride in expressing our heartfelt gratitude to **Dr.S.L.Narasimhan,** H.O.D, Department of Civil Engineering, KCT, for allowing us to do this project and the facilities extended throughout the project in our Structural Technology Center (STC) laboratory.

We express my profound gratefulness to **Principal** for providing the necessary facilities for the successful completion of the project work.

We also sincerely thank the **faculty members, non-teaching staffs** of Civil Engineering Department for helping us to do this project.

Lastly we extend our immense gratitude to **our parents** for their Unceasing, prayerful Encouragement and Moral Support without which we would not be what we are.

SYNOPSIS

SYNOPSIS

The constant depletion of sand beds at all major sources of availability is a major concern and thus effects are taken in order to either abolish or replace sand in construction activities particularly in concrete. Ceramic waste from ceramic and construction industries is one of the most important parts in the global volume of construction and demolition wastes (CDW).

The major sources of ceramic waste are ceramic industry, building construction and building demolition. In ceramic industries, a significant part of the losses in manufacturing of ceramic elements is not returned to the production process. In building construction, ceramic waste is produced on the transportation to the building site, on the execution of several construction elements (facades and partition walls, roofs, and precast joist slabs) and on subsequent works, such as opening of grooves. This waste is regionally deposited in dumping grounds, without any separation or reuse.

Recycling of waste materials is another step towards a cleaner environment. Thus here ceramic waste after certain initial processing was used to replace fine aggregate partially and completely. The main objective here in this project is to study the effect on concrete properties by replacing sand with ceramic waste and to suggest possible application of the same in construction practices.

In this project, five batches were produced such as without any replacement, 25%, 50%, 75% and 100%by weight of fine aggregate replaced by ceramic waste as substitute for fine aggregate. Thus totally 30 cubes, 10 cylinder, 5 beam specimens were casted and allowed for a curing period of 28 days. Four standard tests were conducted on the specimens such as compressive (7 days& 28 days), flexural, split tensile and modulus of elasticity test. Basic tests were conducted for cement and aggregates that includes standard consistency of cement, initial and final setting time for cement, specific gravity of aggregates, fineness modulus tests for sand, ceramic waste, sand ceramic mixture and coarse aggregate.

These results were analyzed in comparison to the control specimens. The main findings of this investigations revealed that ceramic waste materials could be used successfully as partial and complete substitutes for fine aggregate in concrete composites. Thus paving open a door to selective recycling of ceramic tile waste and its use in production of concrete.

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LIST OF SYMBOLS AND ABBREVIATIONS

CA - Coarse Aggregate

FA - Fine Aggregate

IS - Indian Standards

PPC - Pozzolona Portland Cement

CM - Control mix

CDW - Construction and Demolition Waste

CCWS - Concrete Ceramic Waste Slab

INTRODUCTION

CHAPTER-1

INTRODUCTION

1.1 GENERAL

The aim of this study was to investigate some of the mechanical properties of concrete mixed under laboratory conditions, where different proportions of fine aggregate materials were substituted by ceramic waste which accounts for huge fraction in the global construction and demolition wastes (CDW).

The use of recycled wastes for preparing concrete products has been successfully implemented and is gaining wider acceptance. The reason for the replacement concept's acceptance is that the reuse of hazardous wastes from construction and demolition is one of the most important advancements in concrete making leading to a greener environment. Ceramic waste is selected for this purpose due to its wide range of reuse possibilities.

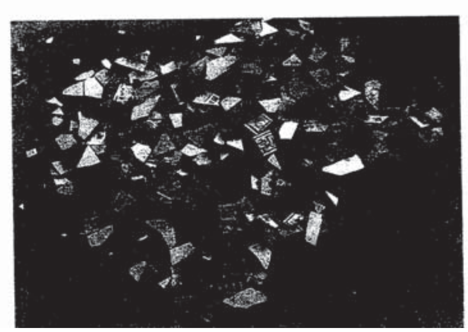
The major sources of ceramic waste are ceramic industry, building construction and building demolition. In ceramic industries, a significant part of the losses in manufacturing of ceramic elements is not returned to the production process. In building construction, ceramic waste is produced on the transportation to the building site, on the execution of several construction elements (facades and partition walls, roofs, and precast joist slabs) and on subsequent works, such as opening of grooves. This waste is regionally deposited in dumping grounds, without any separation or reuse.

Ceramic wastes that were reduced to fine aggregate size fraction (less than 4.75mm,) exhibits properties similar to fine aggregate or sandy material, with relative high stability due to angular nature of ceramic particles.

Cubes, cylinders and beam specimens were cast and four standard tests were conducted on the specimens such as compressive, flexural, split tensile and modulus of elasticity test. The compressive, split tensile strength, flexural strengths of the concrete mixtures were determined. The results of the mechanical properties were analyzed in comparison to the control specimen results.

1.2 CERAMIC WASTE

The ceramic wastes from various sources such as construction sites, and wholesale warehouses are used in this project to replace fine aggregate in concrete composites. The ceramic tiles are broken to small pieces of required size and clear off any wastes as shown in fig-1



1.3 JAW CRUSHER

The ceramic wastes are crushed using the Jaw Crusher. The broken ceramic pieces are passed into funnel shaped mouth of the Jaw crusher and they are closed by a plate to prevent the wastes from expelling outside when it is switched on. The handle which is placed at the side of the crusher is used to adjust the size of the waste which is to be crushed. The pan is placed at the bottom to collect the crushed ceramic waste aggregates. After adjusting the size of the handle and placing the pan to collect the crushed aggregates, the crusher is switched on and the waste is crushed and collected at the pan which is kept at the bottom. Fig-2 shows the Jaw Crusher available in the Bio-Tech lab which was used for the purpose.

Fig.2- Jaw Crusher available in Bio-Tech lab.

1.4 CRUSHED CERAMIC WASTE AGGREGATE

The crushed tile wastes from Jaw crusher are passed through 4.75mm sieve and retained on 150 micron are used to replace the fine aggregate both partially and completely.Fig.3 & Fig.4 shows the crushed ceramic aggregates in closer look.

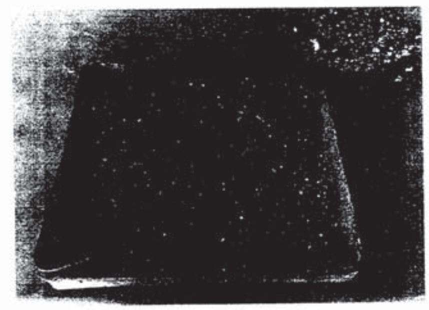


Fig.3- Crushed Ceramic Waste Aggregates sample

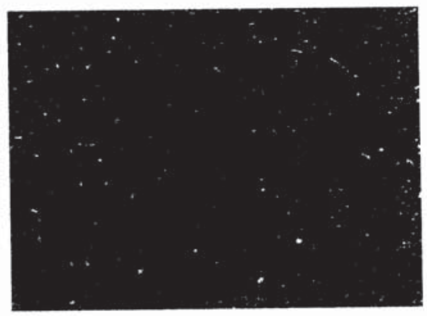


Fig.4- Crushed Ceramic Waste Aggregates dumped for use in Concrete

LITERATURE REVIEW

CHAPTER - 2

LITERATURE REVIEW

2.1 LITERATURES OF CERAMIC WASTE

1. Effect of crushed ceramic and basaltic pumice as fine aggregates on concrete mortar properties.(2006)

HANIFI BINCI
Kahramanmaras sutchu Imam University, department of Civil Engineering, turkey

- In this study the suitability of ceramic industrial wastes and huge amounts of basaltic pumice as a possible substitute for conventional crushed fine aggregate has been examined
- Abrasion resistance test, chloride penetration depth test, compression tests were carried out on the concrete specimens with ceramic waste and basaltic pumice fine aggregates
- The test results were compared with control mixes and the results showed that crushed ceramic and crushed basaltic pumice could be conveniently used for low abrasion and higher compressive strength concretes.

2. Ceramic wastes as alternative raw materials for Portland cement clinker production (2007)

BARBA.A
GAZULLA.M.F
GOMEZ.M.P
PUERTAS.F
Eduardo Torroja Institute for construction sciences (CSIC), Madrid, Spain
Institute of ceramic technology, Jaume I University, castellon, Spain

alternative raw materials in Portland cement clinker production.

- This study explores the reactivity and burnability of cement raw mixes containing fired red or white ceramic wall tile wastes and combinations of the two as alternative raw materials in Portland cement clinker production.

- The results showed that the new raw mixes containing this kind of waste to be technically viable, and to have higher reactivity and burn ability than a conventional mix.

- The mix of red and white ceramic wall tile waste was found to perform equally or better than each type of waste separately, a promising indication that separation the two would be unnecessary for usage in the manufacture of Portland cement clinker production.

3. Incorporation of fine ceramics in mortars (2009)

BRITO
JORGE
JOAO
ROSARIO
SILVA
Article from Construction and Building materials journal dated 1st Jan 2009

- The paper explains the viability of improving the performance of cementitious mortars through the addition of very fine aggregates from crushed red clay ceramics.

- The various tests carried out were namely compressive, flexural, split tensile, water absorption, shrinkage, and durability tests.

- The authors have stated the results obtained look very promising even though this line of research needs to be further pursued.

4. Recycling study for some kinds of industrial wastes to concrete.

ONO HIRONOBU (Chubu University)
KANEKO RINJ (Mejjo University)
HIRANUMA KO (Mejjo University)
TAZAWA IKUMASA (Toyotasoken)
JAPAN (Translated from Japanese)

- The experimental study was carried out to investigate the useful recycle methods of cement mortar and concrete by using the following three kinds of refuse,

    1. ceramic tile waste,
    2. ceramic roof tile,
    3. Dissolution slag.

- The various tests that were carried out are flow test of cement mortar, flexural, compressive strength and modulus of heat conduction.

- According to the test result it was justified that every industrial refuse has useful application as an aggregate of cement mortar.

5. A Study on Concrete-Based Cement containing recycled Ceramic Waste Aggregates.(2008)

NORAZIAN.M.N
CHE MOHD RUZIADI.G
NUR HIDAYAH.A.Z
(Online article)

- The main focus of this research is to evaluate the potential of recycled ceramic waste as a substitute for coarse aggregate and to study the strength of concrete with ceramic waste as coarse aggregate.

- Three standard tests namely compression, split tensile and flexural tests were carried out on the specimens with water cement ratios of 0.4, 0.5 and 0.7.

- The results show that the concrete mixes containing recycled ceramic waste aggregates achieve strength levels between 80-95% compared to the conventional concrete.

6. Concrete Ceramic Waste Slab (CCWS)

KAMARUDIN HUSSIN
CHE MOHD RUZIADI
SHAMSUL BAHARAIN
NUR KHAIRIATUN NISA
(Online article 2008)

- In this study an attempt has been made to find the suitability of ceramic industrial wastes as a possible replacement for conventional crushed stone coarse.

- The main focus of this research is to study the strength of concrete with ceramic waste as coarse aggregate.

- Standard tests such as compression split tensile and flexural and modulus of elasticity tests were carried out on the specimens and the results were compared with the conventional mix.

- From the results the compressive strength of concrete with ceramic waste coarse aggregate was 85-100%, which indicates the result is comparable to conventional concrete.

7. Concrete with Ceramic Waste and Quarry Dust Aggregates

KAMARUDIN HUSSIN
CHE MOHD RUZIADI
SHAMSUL BAHARAIN
NUR KHAIRIATUN NISA
(Online article 2007)

- In this study an attempt has been made to find the suitability of ceramic industrial wastes and quarry dust as a possible substitution for conventional crushed stone coarse and fine aggregate.

- Standard strength tests were carried out to determine the strength of concrete with ceramic waste coarse aggregate and quarry dust fine aggregate and the results were compared with the conventional mix.

- The test results proved promising with the strength of concrete with ceramic and quarry dust aggregates were 80-90% of that of the conventional mix.

8. Concrete with Ceramic Waste Aggregate (2005)

SENTHAMARAI.R.M
MANOHARAN.P.DEVADAS

- In this study an attempt has been made to find the suitability of ceramic industrial waste as a possible substitute for crushed stone coarse aggregate

- Standard tests such as compression split tensile and flexural and modulus of elasticity tests were carried out on the specimens and the results were compared with the conventional mix.

- The test result indicates that the workability of ceramic waste coarse aggregate concrete is good and the strength characteristics are comparable to those of the conventional mix.

9. Use of white Ceramic Powder as Fine Aggregates in Concrete

LOPEZ.V
LLAMAS.B
JUAN.A
MORAN.J.M
University of Leon, Portugal

- The aim of this research was to investigate some of the physical and mechanical properties of a laboratory produced concrete to which had been added varying proportions of white ceramic powder as fine aggregate.

- Standard tests such as compression split tensile and flexural and modulus of elasticity tests were carried out on the specimens and the results were compared with the conventional mix.
- The results show that the concrete thus obtained has the same mechanical characteristics as that made with conventional sand.

10. Effects on Concrete durability of using Recycled Ceramic Aggregates (2005).

CORREIA.J.R
DE BRITO.J
PEREIRA.A.S
Technical University of Lisbon, Portugal

- In this study ceramic wastes from construction industries were used as a substitute for conventional stone coarse aggregate.
- Here in this study water absorption tests either by capillarity or by immersion and abrasion resistance tests related to long term concrete durability were carried out.
- The test results proved that both water absorption test and abrasion resistance tests had better results justifying the long term durability of ceramic waste concrete.

2.2 OBJECTIVES AND SCOPE OF THE INVESTIGATION

From the literature review, the usage of ceramic waste as fine aggregate replacement was justified and various percentages of fine aggregate replacement were decided upon. In this study, 25%, 50%, 75%, and 100% by weight of fine aggregate is replaced with waste crushed ceramic waste. All the specimens are tested for four standard tests such as compressive, flexure, split tensile and modulus of elasticity tests. The results of the mechanical properties were analyzed in comparison to the control specimens.

SAMPLE PREPERATION AND TESTS ON MATERIALS

CHAPTER-3

SAMPLE PREPERATION AND TESTS ON MATERIALS

3.1 SAMPLE PREPARATION OF CERAMIC AGGREGATE

- The ceramic tiles are broken into small pieces
- The broken pieces are then placed in the inlet chamber of Jaw crusher
- The crushed ceramic is collected at the bottom.
- Then it is passed through the sieve 4.75mm to get the materials for fine aggregate replacement.
- The waste retained on 4.75mm sieve is again crushed until all the materials pass through 4.75mm sieve.
- The waste which passes through 4.75mm sieve and retained on 150 micron is taken for replacing sand.

3.2 OTHER MATERIALS USED IN CONCRETE

- Coromandal 43 grade PPC is used for cement.
- Coarse aggregate of size 20mm and 12.5mm is used in the ratio 65:35.
- Fine aggregate of size passing through 4.75mm sieve and retaining on 150 micron is taken.
- Water cement ratio of 0.45 is used.
- Mix design used in concrete is 1:1.28:2.55

3.3 TESTS FOR MATERIALS - SPECIFIC GRAVITY TEST:

Specific gravity of aggregate is made use of in design calculations of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Specific gravity of aggregate is also required to be considered when we deal with light weight and heavy weight concrete.
Average Specific gravity of rocks vary from 2.6 to 2.8

3.3.1 SPECIFIC GRAVITY OF FINE AGGREGATE:

PROCEDURE:

- ✓ Mass of Pycnometer is taken as (M1) g.
- ✓ Nearly half of the bottle is filled with fine aggregate and mass of Pycnometer plus aggregate is taken as (M2) g.
- ✓ Remaining part of the bottle is filled with water and the mass of Pycnometer plus sand and water is taken as (M3) g.
- ✓ Then the aggregate in the bottle is cleaned and filled with water up to the lid. Then its mass is taken as (M4) g.

SPECIFIC GRAVITY = M4

3.3.2 SPECIFIC GRAVITY OF COARSE AGGREGATE:

PROCEDURE:

- ✓ A sample of aggregate not less than 2kg is taken.
- ✓ It is thoroughly washed to remove the finer particles and dust adhering to aggregate.
- ✓ It is then placed in a wire basket and immersed in distilled water at a temperature between 22° C to 32°C.
- ✓ After immersion the entrapped air is removed from the sample by lifting the basket 25mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second.
- ✓ Care is taken that the basket and the aggregate remain completely immersed in water.
- ✓ The set up is kept in water for a period of 24 ± 0.5 hours.
- ✓ The basket and the aggregate are jolted and welded (A1) in water at a temperature between 22° C to 32°C.
- ✓ The basket and aggregate are removed from water and are allowed to drain for a few minutes. Then the aggregate is taken out from the basket and placed on a dry cloth. the surface
- ✓ The empty basket is immersed in water and jolted 25 times and weighted in water (A2).
- ✓ The aggregate is exposed to atmosphere away from direct sunlight for not less than 10 minutes, until it appears completely surface dry and its weight is taken as (B).
- ✓ The aggregate is then kept in the oven at a temperature of 100°C for 24 ± 0.5 hours. It is then cooled in a air tight container and weighed as (C).

The test results are shown in the table 2.4.4

$$\text{SPECIFIC GRAVITY} = \frac{C}{(B - A)}$$

Where,

A = Weight in gram of saturated aggregate in water (A1-A2)

B = Weight in gram of the saturated surface dry aggregate in air and

C = Weight in gram of oven dry aggregate.

3.3.3 SIEVE ANALSIS:

The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. The

of 40mm, 20mm, 10mm,4.75mm, 2.36mm,600 micron, 300 micron and 150 micron.

The aggregate fractions from 40mm to 4.75mm are treated as coarse aggregate and those fractions fro 4.75mm tò 150 micron are termed as fine aggregate.

PROCEDURE:

- ➢ All the sieves are mounted one over the other in order of size, with large sieve on the top.
- ➢ The material retained on each sieve after shaking, represents the fraction of aggregate coarser then the sieve in quotient and finer then the sieve above.
- ➢ Sieving can be done either manually or mechanically.
- ➢ In manual operation, the sieve is shaken in all the possible directions to give chance to all the particles to pass the sieve.
- ➢ Shaking should be continued since no particles pass through.

Fineness modulus is a empirical factor obtained by adding cumulative percentage of aggregate retained on the standard sieves ranging from 40mm to 150 micron and dividing this by arbitrary No. 100.

The following limits may be taken guidance,

Fine sand = fineness modulus = 2.2 to 2.6

Medium sand = fineness modulus = 2.6 to 2.9

Coarse sand = fineness modulus = 2.9 to 3.2

The test results of sieve analysis for fine aggregate, 20mm coarse aggregate, 12.5mm coarse aggregate is tabulated in table 3, 5, 6 respectively.

3.3.4 SPECIFIC GRAVITY OF CEMENT:

Type : 43 grade Portland Pozzolona Cement (PPC)

Brand name: COROMANDAL CEMENT

SPECIFIC GRAVITY ANALYSIS:

TABLE-1

S.NO	OBSERVATION	NOTATIONS USED	TRIAL I
1	Mass of density bottle	M1 (g)	35
2	Mass of bottle + cement	M2 (g)	45
3	Mass of bottle + cement + kerosene	M3 (g)	60
4	Mass of bottle +kerosene	M4 (g)	72
5	Mass of bottle + water	M5 (g)	84
6	Specific Gravity 3.15		

3.3.5 SPECIFIC GRAVITY OF FINE AGGREGATE:

Type: locally available river sand (confirming to IS 383:1970)

SPECIFIC GRAVITY ANALYSIS:

TABLE-2

S.NO	OBSERVATION	NOTATIONS USED	TRIAL I
1	Mass of Pycnometer	M1 (g)	1524
2	Mass of Pycnometer +FA	M2 (g)	1875
3	Mass of Pycnometer +FA + water	M3 (g)	554
4	Mass of Pycnometer + water	M4 (g)	538
5	Specific Gravity 2.65		

3.3.6 FINENESS MODULUS TEST:

TABLE-3

IS SIEVE SIZE	WEIGHT RETAINED (g)	CUMULATIVE WEIGHT RETAINED (x) (g)	CUMULATIVE PERCENTAGE RETAINED (y) (g)	CUMULATIVE PERCENTAGE PASSED (g)
10 mm	0	0	0	100
4.75mm	5	5	1	99
2.36mm	14	19	3.8	96.2
1.18mm	81	100	20	80
600micron	121	221	45	55
300 micron	236	457	91	9
150 micron	39	496	99	1
Pan	4	500	0	0
FINENESS MODULUS = 2.59 (ZONE II)				

3.3.7 SPECIFIC GRAVITY OF COARSE AGGREGATE:

Type: locally available angular coarse aggregate

(Confirming to IS 383:1970)

Maximum size: 20mm

Minimum size: 12.5mm

SPECIFIC GRAVITY ANALYSIS:

TABLE-4

S.NO	OBSERVATION	NOTATIONS USED	TRIAL I
1	Mass of wire basket	M1 (g)	1535
2	Mass of wire basket +CA	M2 (g)	1815
3	Mass of surface dry CA	M3 (g)	455
4	Mass of oven dried CA	M4 (g)	452
5	Specific Gravity 2.60		

3.3.8 FINENESS MODULUS TEST:

(20mm COARSE AGGREGATE)

TABLE-5

IS SIEVE SIZE	WEIGHT RETAINED (g)	CUMULATIVE WEIGHT RETAINED (x) (g)	CUMULATIVE PERCENTAGE RETAINED (y) (g)	CUMULATIVE PERCENTAGE PASSED (g)
40	0	0	0	100
20	111	111	6	94
10	1886	1997	99	1
4.75	3	2000	100	0
FINENESS MODULUS = 2.05 (SINGLE SIZE)				

LIMITATIONS:

SIEVE SIZE	- GRADE	- SINGLE SIZE
40	- 100	- 100
20	- 95 to 100	- 85 to 100
10	- 25 to 55	- 0 to 2
4.75	- 0 to 10	- 0

3.3.9 FINENESS MODULUS TEST:

(12.5mm COARSE AGGREGATE)

TABLE-6

IS SIEVE SIZE	WEIGHT RETAINED (g)	CUMULATIVE WEIGHT RETAINED (x) (g)	CUMULATIVE PERCENTAGE RETAINED (y) (g)	CUMULATIVE PERCENTAGE PASSED (g)
16	0	0	0	100
12.5	186	186	9	91
10	1159	1345	68	32
4.75	645	1990	99	1
PAN	10	2000	100	0

FINENESS MODULUS = 2.76 (SINGLE SIZE)

LIMITATIONS:

SIEVE SIZE	**GRADE**	**SINGLE SIZE**
20	100	100
12.5	90 to 100	85 to 100
10	40 to 85	0 to 45
4.75	0 to 10	0 to 10

3.3.10 SIEVE ANALYSIS BEFORE BATCHING

The ceramic wastes that were crushed out of jaw crusher were of coarser nature and thus separate sieve analysis was performed in order to ensure that the fineness modulus of the various mixtures were according to the IS specifications.

The following limits are provided by the IS codes

Fine sand = fineness modulus = 2.2 to 2.6

Medium sand = fineness modulus = 2.6 to 2.9

Coarse sand = fineness modulus = 2.9 to 3.2

Thus four sieve analysis for the various proportions of sand ceramic mixtures were carried out and the results of the same are tabulated in the tables that follow (Tables 7-11).

Sample specification : ceramic waste
Sample quantity : 1000gm

TABLE-7

IS Sieve Size	Weight retained gm	Percentage weight retained	Cumulative percentage retained	Cumulative percentage passing
4.75 mm	6	.6	.6	99.4
2.36 mm	194	19.4	20	80
1.18 mm	312	31.2	51.2	48.8
600 micron	180	18	69.2	30.8
300 micron	144	14.4	83.6	16.4
150 micron	84	8.4	92	8
Lower than 150 micron	80	8		0
Total	1000 gm		316.6	

Fineness modulus = 316.6/100
=3.17 (coarse sand 2.9 – 3.2)

Sample specification : 75% replacement
Sample quantity : Sand =125 gm
Ceramic waste =375 gm

TABLE-8

IS Sieve Size	Weight retained gm	Percentage weight retained	Cumulative percentage retained	Cumulative percentage passing
4.75 mm	6	1.2	1.2	98.8
2.36 mm	80	16	17.2	82.8
1.18 mm	144	28.8	46	54
600 micron	94	18.8	64.8	35.2
300 micron	102	20.4	85.2	14.8
150 micron	52	10.4	95.6	4.4
Lower than 150 micron	22	4.4		0
Total	500 gm		310	

Fineness modulus =310/100
=3.10 (coarse sand 2.9 – 3.2)

Sample specification : 50% replacement
Sample quantity : Sand =250 gm
Ceramic waste =250 gm

TABLE-9

IS Sieve Size	Weight retained gm	Percentage weight retained	Cumulative percentage retained	Cumulative percentage passing
4.75 mm	10	2	2	98
2.36 mm	42	8.4	10.4	89.6
1.18 mm	114	22.8	33.2	66.8
600 micron	122	24.4	57.6	42.4
300 micron	140	28	85.6	14.4
150 micron	50	10	95.6	4.4
Lower than 150 micron	22	4.4		0
Total	500 gm		284.4	0

Sample specification : 25% replacement
Sample quantity : Sand =375 gm
Ceramic waste =125 gm

TABLE-10

IS Sieve Size	Weight retained gm	Percentage weight retained	Cumulative percentage retained	Cumulative percentage passing
4.75 mm	8	1.6	1.6	98.4
2.36 mm	30	6	7.6	92.4
1.18 mm	80	16	23.6	76.4
600 micron	110	22	45.6	54.4
300 micron	180	36	81.6	18.4
150 micron	76	15.2	96.8	3.2
Lower than 150 micron	16	3.2		0
Total	500		256.8	

Fineness modulus =256.8/100
=2.57 (fine sand 2.2-2.6)

TABLE-11

Sample	**Fineness modulus**
Sand	2.45
25/75 ceramic sand mixture	2.57
50/50 ceramic sand mixture	2.84
75/25 ceramic sand mixture	3.1
Ceramic waste	3.16

It is evident from the result that the coarse nature of the fine aggregate is considerably increased steadily along with the increase in the percentage of replacements.

3.3.11 BULK DENSITY TEST

BULK DENSITY

The bulk density or unit weight of an aggregate gives the valuable information regarding the shape and grading of the aggregate for a given specific gravity the angular aggregate show a lower bulk density.

TEST FOR DETERMINATION OF BULK DENSITY

Bulk density is normally expressed in kg per litre. A cylindrical measure preferably machined to accurate internal dimensions is used for measuring bulk density. The size of the container for measuring bulk density are shown below

Size of the largest particle	Nominal capacity	Inside diameter	Inside height	Thickness of metal
	Litre	cm	cm	mm
4.75 mm and under	3	15	17	3.15
Over 4.75 mm to 40 mm	15	25	30	4.00
Over 40mm	30	35	31	5.00

The cylindrical measure is filled about 1/3 each time with thoroughly mixed aggregate and tamped with 25 strokes by a bullet ended tamping rod, 16 mm diameter and 60 cm long. The measure is carefully struck off level using tamping rod as straight edge.

Bulk density = <u>net weight of the aggregate in Kg</u> / Capacity of the container in litre

Thus both sand and ceramic wastes were less than 4.75 mm and thus the cylinder with nominal capacity of three litres was chosen for the test.

CALCULATIONS

Weight of empty mould =7.4 kg
Weight of mould with sand =12.314 kg
Weight of sand = 12.314 - 7.4
= 4.914

Bulk density of sand = net weight of the aggregate in Kg / Capacity of the container in litre

=4.914/3
= 1.638 kg/litre

Weight of empty mould =7.4 kg
Weight of mould with sand =11.642 kg
Weight of sand = 11.642 - 7.4
= 4.242

Bulk density of ceramic wastes = net weight of the aggregate in Kg / Capacity of the container in litre

=4.242/3
= 1414 kg/litre

MIX DESIGN

CHAPTER – 4

MIX DESIGN

4.1 CONCRETE MIX DESIGN

1. DESIGN STIPULATIONS:

- Characteristic compressive strength required in the Field at 28 days - 20 N/mm^2
- Maximum size of aggregate - 20 mm (angular)
- Degree of workability - 0.9 Compacting factor
- Degree of quality control - Good
- Type of exposure - Mild

2. TEST DATA FOR MATERIALS:

- Cement used – Portland Pozzolona Cement Satisfying the requirements of IS: 269-1976.
- Specific gravity of cement – 3.15
- Specific gravity
  - Coarse aggregate – 2.60
  - Fine aggregate – 2.65
- Water absorption
  - Coarse aggregate – 0.5 percent
  - Fine aggregate – 1.0 percent
- Free (surface) moisture
  - Coarse aggregate – nil (observed moisture also nil)
  - Fine aggregate – 2.0 percent

Coarse aggregate – Single size (as per IS: 383 – 1970)

Fine aggregate – Zone II (as per IS: 383 – 1970)

3. TARGET MEAN STRENGTH OF CONCRETE:

For a tolerance factor of 1.65 and using table I of IS: 10262-1972, the target mean strength for the Specified characteristic cube strength

(20+ (4.6 x 1.65)) = 27.6N/mm^2

4. SELECTION OF WATER CEMENT RATIO:

From Fig.1 of IS: 10262-1972, the free Water-cement ratio required for the target Mean strength of 27.6N/mm^2 = 0.45

This is lower than the maximum value of 0.65 prescribed for "mild" exposure in Appendix A of IS: 456-1978.

5. SELECTION OF WATER AND SAND CONTENT:

From table 4 of IS: 10262-1972, for 20mm nominal maximum size aggregate and sand conforming to grading zone II,

Water content per cubic metre of concrete = 191.58 kg and

Sand content as percentage of total aggregate by absolute volume = 35 percent

6. DETERMINATION OF CEMENT CONTENT :

Water cement ratio = 0.45

Water =191.58 kg/m^3

Cement $= \dfrac{160}{0.45} = 425.73$ kg/m^3

This cement content is adequate for mild exposure condition according to Appendix A of IS: 456-1978.

7. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT:

From table 3 of IS: 10262-1972,for the specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2 percent. Taking this into account and applying equations such as,

$$V = \left[W + \frac{C}{S_C} + \frac{f_a}{P * S_{fa}} \right] \times \left[\frac{1}{1000} \right]$$

$$V = \left[W + \frac{C}{S_C} + \frac{c_a}{(1-P) * S_{ca}} \right] \times \left[\frac{1}{1000} \right]$$

Where,

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air,

W= mass of water (kg) per m^3 of concrete,

C = mass of cement (kg) per m^3 of concrete,

S_C= specific gravity of cement,

P = ratio of fine aggregate to total aggregate by absolute Volume,

f_a, c_a = total masses of fine aggregate and coarse aggregate (Kg) per m^3 of concrete respectively,

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine aggregate and coarse aggregate respectively.

Here, f_a = 543.52 kg/m^3

c_a =1088.87 kg/m^3

The mix proportion then becomes,

WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
191.58 Kg/m^3	425.73 Kg/m^3	543.52 Kg/m^3	1088.87 Kg/m^3
0.45	1	1.28	2.55
MIX DESIGN RATIO = 1:1.28:2.55			

CASTING AND CURING

CHAPTER – 5

CASTING AND CURING

5.1 CASTING

After preparing the materials and arriving mix design ratio, the specimens such as cubes, cylinders and beam moulds are casted.

5.1.1 DETAILS OF CASTED SPECIMEN:

For compression test,

Number of cubes casted totally = 30

Size of each cube = Length: 150 mm
Width: 150mm,
Depth: 150 mm.

For split tensile test,

Number of cylinders casted totally =10

Size of each cylinder = Diameter: 150 mm,
Height : 300 mm.

For Flexure test,

Number of beam moulds casted totally = 5

Size of each beam mould = Length: 500 mm
Width: 100mm,
Depth: 100 mm.

5.2 BATCHING DETAILS

Each batch consists of six cubes, two cylinders and one beam specimen .After 24 hours of casting, the specimens are demoulded and placed in water for a curing period of 28 days. The replacement of materials used in all the batches is listed in the table 12.

Batching details with percentage replacements

TABLE-12

Batch nomenclature	Percentage replacements
A	Control mix
B	25% by weight of fine aggregate
C	50% by weight of fine aggregate
D	75% by weight of fine aggregate
E	100% by weight of fine aggregate

Quantity of materials required for 6 cubes incorporated from mix design

TABLE-13

Replacement	Cement (Kg)	Fine aggregate (Kg)		Coarse aggregate(Kg)	Water (Kg)
		Sand	ceramic		
Control mix	11.2	14.336	-	28.56	5.04
25%	11.2	10.752	3.584	28.56	5.04
50%	11.2	7.168	7.168	28.56	5.04
75%	11.2	3.584	10.752	28.56	5.04

Quantity of materials required for one beam and two cylinders incorporated from mix design

TABLE-14

Replacement	Cement (Kg)	Fine aggregate (Kg)		Coarse aggregate(Kg)	Water (Kg)
		Sand	ceramic		
Control mix	7.44	9.51	-	18.972	3.348
25%	7.44	7.133	2.378	18.972	3.348
50%	7.44	4.755	4.755	18.972	3.348
75%	7.44	2.378	7.133	18.972	3.348
100%	7.44	-	9.51	18.972	3.348

5.3 CURING

After 24 hours of casting, the specimens are demoulded and placed in water for a curing period of 28 days and then taken up for various testing purposes. The fig-5&fig-6 shows the specimens placed for curing in the curing tank.

Fig-5 Cube specimens placed in curing tank

TEST METHODOLOGIES AND RESULTS

CHAPTER - 6

TEST METHODOLOGIES AND RESULTS

6.1 TESTING OF SPECIMEN

Four standard tests such as Compressive strength, Split tensile, Flexure and Modulus of elasticity tests are conducted over the specimens and the results are found out. These experimental results are compared with the control mix.

6.2 COMPRESSIVE STRENGTH TEST:

PROCEDURE:

- The cubes are placed in the compressive testing machine (Fig-7) and the loads are applied gradually.
- The digital machine moves when the load is applied.
- When ever the cube takes the maximum load, then the readings are returned.
- Those values are noted as the maximum load in KN and the compressive strength is calculated using the following formula.

$$\text{COMPRESSIVE STRENGTH} = \frac{\text{LOAD}}{\text{AREA}}$$

Where,

Load in N

Area in mm^2

Fig-7 Testing of cubes in Compression Testing Machine

6.3 RESULTS OF COMPRESSION TEST

The results of the compressive test for both 7 days and 28 days compressive strength are tabulated in the following tables (Table 15-19) and the graphical representation of the result is shown in the Fig-8.

TABLE-15

S.No	Replacement percentage	7 days strength		28 days strength	
		Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2
1	Control mix	2693.33	20.88	2507.26	27.78
2		2602.67	22.00	2541.63	28.44
3		2532.74	22.88	2438.52	26.89
	Average		21.92		27.71

TABLE-16

S.No	Replacement percentage	7 days strength		28 days strength	
		Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2
1	25%	2452.75	22.44	2437.33	36.13
2		2526.82	21.77	2519.11	35.15
3		2449.19	22.66	2507.85	35.20
	Average		22.29		35.49

TABLE -17

S.No	Replacement percentage	7 days strength		28 days strength	
		Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2
1	50%	2487.11	24.89	2573.63	42.22
2		2456.89	21.55	2525.63	42.22
3		2496.00	20.88	2469.33	45.33
	Average		22.44		43.26

TABLE-18

S.No	Replacement percentage	7 days strength		28 days strength	
		Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2
1	75%	2388.15	23.11	2406.52	37.33
2		2471.11	23.33	2430.81	34.66
3		2418.96	24.00	2365.04	38.22
	Average		23.48		36.73

TABLE – 19

S.No	Replacement percentage	7 days strength		28 days strength	
		Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2
1	100%	2330.67	24.88	2250.07	31.11
2		2234.07	23.77	2307.56	30.22
3		2254.22	24.44	2208.10	28.44
	Average		24.36		29.92

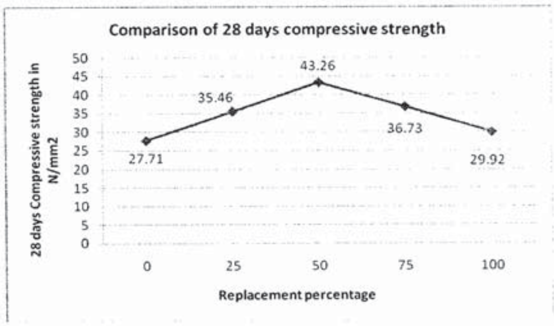


Fig-8 Graphical Representation of Result

6.4 SPLIT TENSILE TEST:

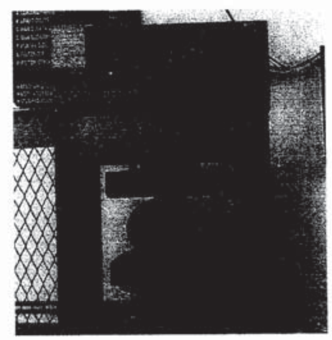
PROCEDURE:

The Cylinders are placed in the compression testing machine (Fig-9) and load is applied as similar applied to the cubes. The cylinders are placed horizontally and the test is performed.

The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded. The tensile strength is calculated using the formula below.

$$\text{SPLIT TENSILE STRENGTH} = \frac{2P}{\Pi \times d \times l}$$

Where,
P = Compressive load on cylinder
l = length of the cylinder = 300mm
d = diameter of the cylinder = 150mm



6.5 RESULT OF SPLIT TENSILE TEST

The result of the split tensile test is tabulated below (Table-20) and the graphical representation of the result is shown in the Fig-10.

TABLE-20

S.No	REPLACEMENT PERCENTAGE	MAXIMUM LOAD IN KN	SPLIT TENSILE STRENGTH FOR 28 DAYS IN N/mm^2
1	CONTROL MIX	186	2.63
2	25%	210	2.97
3	50%	240	3.39
4	75%	216	3.057
5	100%	204	2.887

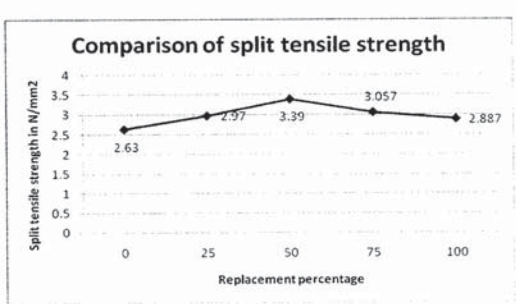


Fig-10 Graphical Representation of Result

6.6 FLEXURE TEST:

PROCEDURE:

The bearing surfaces of the supporting and loading rollers are wiped clean and any other loose sand or other material removed from the surface of the specimen where they are to make contact with the rollers.

The specimen is then placed in the machine (Fig-11) such a manner that the load is applied to the upper most surface as cast in the mould along two lines spaced 20 cm apart

The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded.

The flexure strength (f_b) is calculated using the following formula.

CONDITIONS:

If, a > 13.3 cm, formula 1 is used.
11 < a < 13.3 cm, formula 2 is used.

FORMULA:

$$f_b = \frac{P \times l}{b \times d^2} \quad \ldots\ldots (1)$$

$$f_b = \frac{3P \times a}{b \times d^2} \quad \ldots\ldots (2)$$

Fig-11 Testing of Beam in Universal Testing Machine

6.7 RESULT OF FLEXURAL TEST

The result of the flexural test is tabulated below (Table-21) and the graphical representation of the result is shown in the Fig-12.

TABLE-21

NOTATION USED	REPLACEMENT PERCENTAGE	MAXIMUM LOAD IN KN	DISTANCE "a" IN cm	DISTANCE "b" IN cm	FLEXURAL STRENGTH IN N/mm^2
A	CONTROL MIX	11.281	16	24	**2.35**
B	25%	13.248	16	24	**2.76**
C	50%	15.205	16.5	23.5	**3.24**
D	75%	14.450	15.6	24.4	**2.973**
		13.941	15.7	24.3	**2.869**

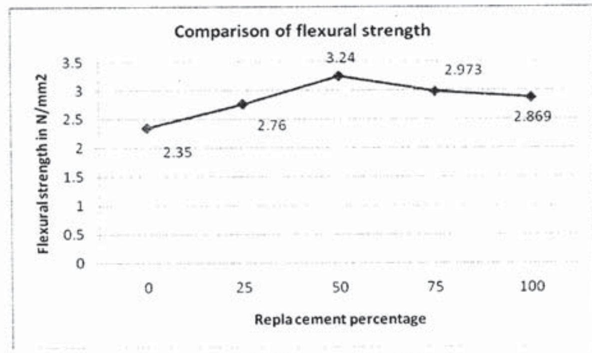


Fig-12. Graphical Representation of Results

6.8 MODULUS OF ELASTICITY TEST

PROCEDURE:

Modulus of elasticity is determined by subjecting a cylindrical specimen to uniaxial compression.

The Cylinders are placed in the compression testing machine (Fig-13&14) and the load is applied uniformly and corresponding dial gauge readings are noted.

The gauge length of extensometer is taken as 190mm and the least count of extensometer dial gauge is 0.002mm.

The ratio of dial gauge reading to the gauge length gives the strain in the specimen.

Similarly the ratio of load applied to the area of cross-section gives the stress.

The modulus of elasticity is achieved from the slope of the stress-strain graph.

FORMULA

Stress = load / area

Strain = dial gauge reading / gauge length

Modulus of Elasticity = stress / strain

MODEL CALCULATION

The calculations for the modulus of elasticity of one of the specimens are depicted as an example of the procedure to calculate the modulus of elasticity.

Gauge length = 190mm.

Cross-section area of cylinder = $(3.14*150^2) / 4$
= $17671.56mm^2$

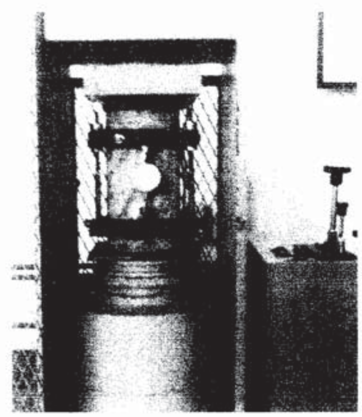


Fig-13 Experimental Setup for Modulus of Elasticity

Fig-14 Experimental Setup for Modulus of Elasticity

MODEL TABULATION: FOR SAMPLE D

TABLE-22

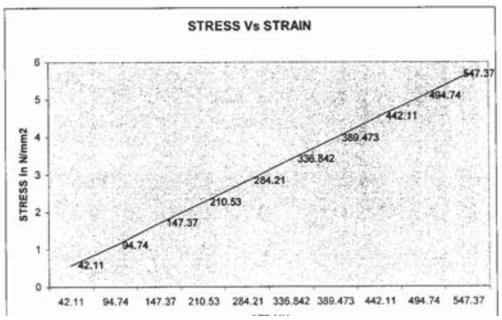
S.No	Load $*10^3$ N/mm^2	Stress N/mm^2	Deformation mm	Strain
1	10	0.566	0.008	42.11
2	20	1.113	0008	94.74
3	30	1.692	0.028	147.37
4	40	2.264	0.04	210.53
5	50	2.829	0.054	284.21
6	60	3.395	0.064	336.842
7	70	3.961	0.074	389.473
8	80	4.527	0.084	442.11
9	90	5.093	0.094	494.74
10	100	5.659	0.104	547.37

Stress = $10*10^3 / 17671.56 = 0.566$ N/mm^2

Strain = $0.008 / 190 = 42.11*10^{-6}$

GRAPH

From the above tabulation a graph is plotted between stress and strain (Fig-12) and the slope of the graph gives the ratio of stress and strain .



From the graph the slope is found

Modulus of elasticity = $[1.7 / 130*10^{-6}]$
$= 13.076$
$= 13.08*10^3$N/mm^2

6.9 RESULT OF MODULUS OF ELASTICITY TESTS

Similarly the moduli of elasticity of the other samples are determined and their values are tabulated (Table-23).and the graphical representation the results is shown in Fig 16.

TABLE-23

Sample	Replacement percentage	Modulus of elasticity x 10^3 N/mm^2
A	Control mix	17.20
B	25%	16.40
C	50%	18.60
D	75%	13.08
E	100%	10.47

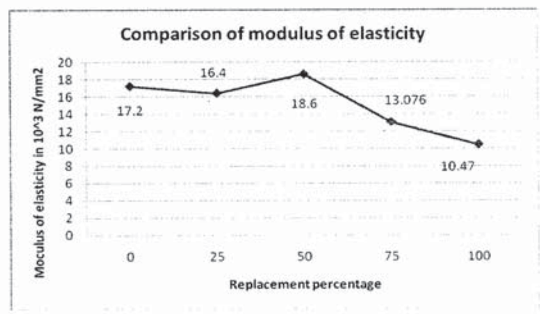


Fig-16. Graphical Representation of Results

DISCUSSION AND CONCLUSION

CHAPTER - 7

DISCUSSION AND CONCLUSION

7.1 DISCUSSION

The above results show that the compressive strength of the 50% replacement ceramic concrete is the highest of all the proportions tested.

The percentage increases in compressive strength are tabulated.

TABLE-24

S.No	Replacement percentage	Percentage increase in compressive strength
1	25%	25-30%
2	50%	55-60%
3	75%	30-35%
4	100%	5-10%

Similarly from the results of flexural test it is inferred that there is a marginal increase in the strength of the 50% replacement specimens while compared to the other percentage specimens.

The percentage increases in flexural strength are tabulated.

TABLE-25

S.No	Replacement percentage	Percentage increase in flexural strength
1	25%	15-20%
2	50%	35-40%
3	75%	25-30%
4	100%	20-25%

Again from the results of split tensile tests it is inferred that there is a marginal increase in the strength of the 50% replacement specimens while compared to the other percentage specimens.

The percentage increases in split tensile strength are tabulated.

TABLE-26

S.No	Replacement percentage	Percentage increase in split tensile strength
1	25%	10-15%
2	50%	25-30%
3	75%	15-20%
4	100%	5-10%

From the results of modulus of elasticity test, it is inferred that there is a marginal increase in the 50% replacement specimens while compared to the other percentage specimens.

The increase in strength may be due to

- The angular nature of ceramic waste particles,
- The coarseness of the ceramic waste aggregates,
- Better bond between the ceramic fine aggregates with other constituents of the concrete.

7.2 CONCLUSION

The results of various tests conducted on ceramic waste concrete are compared with those results of the control mix. Thus this study not only reveals that ceramic waste could be effectively used as partial and complete substitute for fine aggregate in concrete composites but also proves that the mechanical properties of concrete can be substantially increased through the use of the same.

The results show a good impact on the mechanical properties of concrete while using ceramic waste fine aggregates. The strength of the ceramic waste concrete in all replacement proportions is greater than that of the traditional concrete. The replacement of fine aggregate of traditional concrete by various percentages of weights of the fine aggregate is recommended. The highest strength gain (55-60%) was obtained while 50% of the weight of fine aggregates was replaced by ceramic waste fine aggregate substitutes.

Recycling of wastes is another step towards a greener and healthier environment. Thus this investigation paves open the door for selective recycling of ceramic waste leading to a greener environment.

7.3 FURTHER SCOPE:

This study also has further scope such as

- Usage of ceramic wastes from ceramic industry
- Durability study
- Chemical analysis
- Cost analysis

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APPENDICES

APPENDICES

APPENDICE -1 :

CALCULATIONS

1. COMPRESSIVE STRENGTH:

Compressive Strength =LOAD/AREA

Area of Cube = 150mm X 150mm = 22500mm^2

7 DAYS COMPRESSIVE STRENGTH

CONTROL MIX

Sample 1:

Load = 470 KN
Compressive strength = 470000 / (150*150)
= 20.88 N/mm^2

Sample 2:

Load = 495 KN
Compressive strength = 495000 / (150*150)
= 22.01 N/mm^2

Sample 3:

Load = 515 KN
Compressive strength = 515000 / (150*150)
= 22.88 N/mm^2

25% REPLACEMENT

Sample 1:

Load = 505 KN
Compressive strength = 505000 / (150*150)
= 22.44 N/mm^2

Sample 2:

Load = 490 KN
Compressive strength = 490000 / (150*150)
= 21.77 N/mm^2

Sample 3:

Load = 510 KN
Compressive strength = 510000 / (150*150)
= 22.66 N/mm^2

50% REPLACEMENT

Sample 1:

Load = 560 KN
Compressive strength = 560000 / (150*150)
= 24.89 N/mm^2

Sample 2:

Load = 485 KN
Compressive strength = 485000 / (150*150)
= 21.55 N/mm^2

Sample 3:

Load = 470 KN
Compressive strength = 470000 / (150*150)
= 20.88 N/mm^2

75% REPLACEMENT

Sample 1:

Load = 520 KN
Compressive strength = 520000 / (150*150)
= 23.11 N/mm^2

Sample 2:

Load = 525 KN
Compressive strength = 525000 / (150*150)

Sample 3:

Load = 540 KN
Compressive strength = 540000 / (150*150)
= 24.00 N/mm^2

100% REPLACEMENT

Sample 1:

Load = 560 KN
Compressive strength = 560000 / (150*150)
= 24.88 N/mm^2

Sample 2:

Load = 535 KN
Compressive strength = 535000 / (150*150)
= 23.77 N/mm^2

Sample 3:

Load = 550 KN
Compressive strength = 550000 / (150*150)
= 24.44 N/mm^2

28 DAYS COMPRESSIVE STRENGTH

CONTROL MIX

Sample 1:

Load = 625 KN
Compressive strength = 625000 / (150*150)
= 27.78 N/mm^2

Sample 2:

Load = 640 KN
Compressive strength = 640000 / (150*150)
= 28.44 N/mm^2

Sample 3:

Load = 605 KN
Compressive strength = 605000 / (150*150)
= 26.89 N/mm^2

25% REPLACEMENT

Sample 1:

Load = 813 KN
Compressive strength = 813000 / (150*150)
= 36.13 N/mm^2

Sample 2:

Load = 791 KN
Compressive strength = 7910000 / (150*150)
= 35.15 N/mm^2

Sample 3:

Load = 792 KN
Compressive strength = 792000 / (150*150)
= 35.20 N/mm^2

50% REPLACEMENT

Sample 1:

Load = 950 KN
Compressive strength = 950000 / (150*150)
= 42.22 N/mm^2

Sample 2:

Load = 950 KN
Compressive strength = 950000 / (150*150)
= 42.22 N/mm^2

Sample 3:

Load = 1020 KN

75% REPLACEMENT

Sample 1:

Load = 840 KN
Compressive strength = 840000 / (150*150)
= 37.33 N/mm^2

Sample 2:

Load = 780 KN
Compressive strength = 780000 / (150*150)
= 34.66 N/mm^2

Sample 3:

Load = 860 KN
Compressive strength = 860000 / (150*150)
= 38.22 N/mm^2

100% REPLACEMENT

Sample 1:

Load = 700 KN
Compressive strength = 700000 / (150*150)
= 31.11 N/mm^2

Sample 2:

Load = 680 KN
Compressive strength = 680000 / (150*150)
= 30.22 N/mm^2

Sample 3:

Load = 640 KN
Compressive strength = 640000 / (150*150)
= 28.44 N/mm^2

2. FLEXURAL STRENGTH :

CONDITIONS:

If a > 13.3 cm, formula 1 is used.

If 11 < a < 13.3 cm, formula 2 is used.

$$f_b = \frac{P \times l}{b \times d^2} \quad \ldots\ldots (1)$$

$$f_b = \frac{3P \times a}{b \times d^2} \quad \ldots\ldots (2)$$

CONTROL MIX

Load = 11.281 KN
a = 160 mm
b = 240 mm

Flexural Strength = $(P \times l) / (b \times d^2)$
= $(11281 \times 500) / (240 \times 100^2)$
= 2.35 N/mm^2

25% REPLACEMENT

Load = 13.248 KN
a = 160 mm
b = 240 mm

Flexural Strength = $(P \times l) / (b \times d^2)$
= $(13248 \times 500) / (240 \times 100^2)$
= 2.76 N/mm^2

50% REPLACEMENT

Load = 15.205 KN
a = 165 mm
b = 235 mm

Flexural Strength = $(P \times l) / (b \times d^2)$
$= (15205 \times 500) / (235 \times 100^2)$
$= 3.24\ N/mm^2$

75% REPLACEMENT

Load = 14.450 KN
a = 156 mm
b = 244 mm

Flexural Strength = $(P \times l) / (b \times d^2)$
$= (14450 \times 500) / (244 \times 100^2)$
$= 2.97\ N/mm^2$

100% REPLACEMENT

Load = 13.941 KN
a = 157 mm
b = 243 mm

Flexural Strength = $(P \times l) / (b \times d^2)$
$= (13941 \times 500) / (243 \times 100^2)$
$= 2.869\ N/mm^2$

3. SPLIT TENSILE STRENGTH:

FORMULA

$$\text{Split Tensile Strength} = \frac{2P}{\Pi \times d \times l}$$

Where,

l = 300mm
d = 150mm

CONTROL MIX

Load = 186 KN

Split Tensile Strength = $(2 \times P) / (\Pi \times d \times l)$
$= (2 \times 186000) / (\Pi \times 150 \times 300)$
$= 2.63\ N/mm^2$

25% REPLACEMENT

Load = 210 KN

Split Tensile Strength = $(2 \times P) / (\Pi \times d \times l)$
$= (2 \times 210000) / (\Pi \times 150 \times 300)$
$= 2.97\ N/mm^2$

50% REPLACEMENT

Load = 240 KN

Split Tensile Strength = $(2 \times P) / (\Pi \times d \times l)$
$= (2 \times 240000) / (\Pi \times 150 \times 300)$
$= 3.39\ N/mm^2$

75% REPLACEMENT

Load = 216 KN

Split Tensile Strength = $(2 \times P) / (\Pi \times d \times l)$
$= (2 \times 216000) / (\Pi \times 150 \times 300)$
$= 3.057\ N/mm^2$

100% REPLACEMENT

Load = 204 KN

Split Tensile Strength = $(2 \times P) / (\Pi \times d \times l)$
$= (2 \times 204000) / (\Pi \times 150 \times 300)$
$= 2.887\ N/mm^2$

4.MODULUS OF ELASTICITY

FORMULA

Stress = load / area

Strain = dial gauge reading / gauge length

Modulus of Elasticity = stress / strain

Gauge length = 190mm.

Cross-section area of cylinder = $(3.14 \times 150^2) / 4$
$= 17671.56 mm^2$

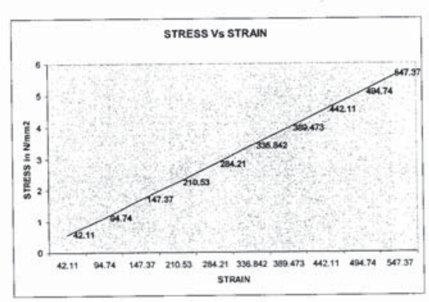
TABULATION: CONTROL MIX

S.no	Load $*10^3\ N/mm^2$	Stress N/mm^2	Deformation mm	Strain
1	10	0.566	0.004	21.05
2	20	1.113	0.008	42.11
3	30	1.692	0.014	73.68
4	40	2.264	0.019	100.00
5	50	2.829	0.024	126.32
6	60	3.395	0.029	152.63
7	70	3.961	0.033	173.69
8	80	4.527	0.037	194.73
9	90	5.093	0.042	221.06
10	100	5.659	0.047	247.36

Stress = $10 \times 10^3 / 17671.56 = 0.566\ N/mm^2$

Strain = $0.004 / 190 = 21.05 \times 10^{-6}$

From the above tabulation a graph is plotted between stress and strain and the slope of the graph gives the ratio of stress and strain



From the graph the slope is found

Modulus of elasticity = $[0.6 / 35 \times 10^{-6}]$

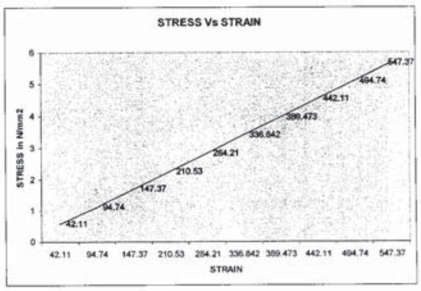
TABULATION: 25% REPLACEMENT

S.no	Load $*10^3$ N/mm^2	Stress N/mm^2	Deformation Mm	Strain
1	10	0.566	0.004	21.06
2	20	1.113	0007	36.84
3	30	1.692	0.012	63.16
4	40	2.264	0.018	94.74
5	50	2.829	0.023	121.05
6	60	3.395	0.028	147.36
7	70	3.961	0.034	178.94
8	80	4.527	0.040	210.52
9	90	5.093	0.046	242.11
10	100	5.659	0.051	273.68

Stress = $10*10^3 / 17671.56 = 0.566$ N/mm^2

Strain = $0.004 / 190 = 21.06*10^{-6}$

From the above tabulation a graph is plotted between stress and strain and the slope of the graph gives the ratio of stress and strain



From the graph the slope is found

Modulus of elasticity = $[0.575 / 35*10^{-6}]$
$= 16.40*10^3$N/mm^2

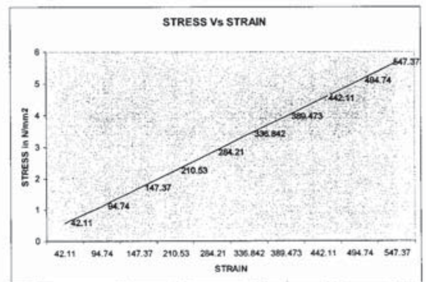
TABULATION: 50% REPLACEMENT

S.no	Load $*10^3$ N/mm^2	Stress N/mm^2	Deformation mm	Strain
1	10	0.566	0.003	15.74
2	20	1.113	0.008	42.67
3	30	1.692	0.012	65.43
4	40	2.264	0.016	84.28
5	50	2.829	0.020	106.23
6	60	3.395	0.025	131.81
7	70	3.961	0.028	148.96
8	80	4.527	0.032	169.32
9	90	5.093	0.037	194.35
10	100	5.659	0.041	214.88

Stress = $10*10^3 / 17671.56 = 0.566$ N/mm^2

Strain = $0.003 / 190 = 15.74*10^{-6}$

From the above tabulation a graph is plotted between stress and strain and the slope of the graph gives the ratio of stress and strain



From the graph the slope is found

Modulus of elasticity = $[0.75 / 40*10^{-6}]$
$= 18.60*10^3$N/mm^2

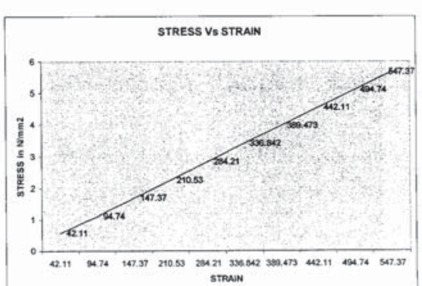
TABULATION: 75% REPLACEMENT

S.no	Load $*10^3$ N/mm^2	Stress N/mm^2	Deformation mm	Strain
1	10	0.566	0.008	42.11
2	20	1.113	0008	94.74
3	30	1.692	0.028	147.37
4	40	2.264	0.04	210.53
5	50	2.829	0.054	284.21
6	60	3.395	0.064	336.842
7	70	3.961	0.074	389.473
8	80	4.527	0.084	442.11
9	90	5.093	0.094	494.74
10	100	5.659	0.104	547.37

Stress = $10*10^3 / 17671.56 = 0.566$ N/mm^2

Strain = $0.008 / 190 = 42.11*10^{-6}$

From the above tabulation a graph is plotted between stress and strain and the slope of the graph gives the ratio of stress and strain



From the graph the slope is found

Modulus of elasticity = $[1.7 / 130*10^{-6}]$
$= 13.08*10^3$N/mm^2

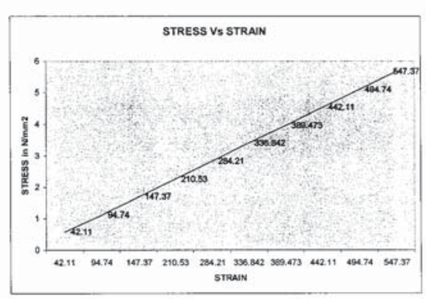
TABULATION: 100% REPLACEMENT

S.no	Load $*10^3$ N/mm^2	Stress N/mm^2	Deformation mm	Strain
1	10	0.566	0.008	42.11
2	20	1.113	0.016	84.21
3	30	1.692	0.024	126.32
4	40	2.264	0.030	157.89
5	50	2.829	0.038	200.00
6	60	3.395	0.046	242.00
7	70	3.961	0.056	294.74
8	80	4.527	0.064	336.84
9	90	5.093	0.072	378.00
10	100	5.659	0.080	421.00

Stress = $10*10^3 / 17671.56 = 0.566$ N/mm^2

Strain = $0.008 / 190 = 42.11*10^{-6}$

From the above tabulation a graph is plotted between stress and strain and the slope of the graph gives the ratio of stress and strain

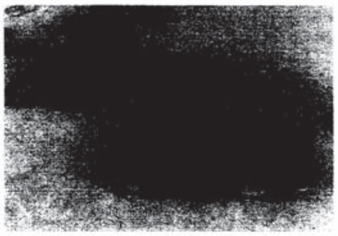


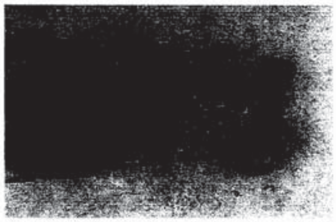
From the graph the slope is found

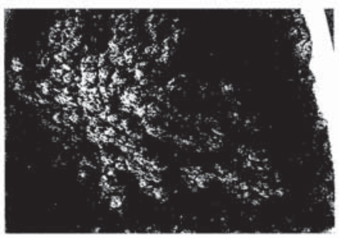
Modulus of elasticity = $[1.65 / 160*10^{-6}]$
$= 10.47*10^3$N/mm^2

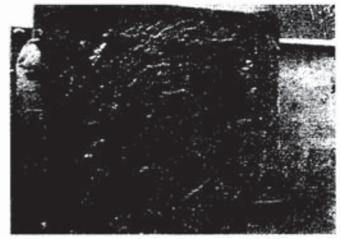
APPENDICE - 2

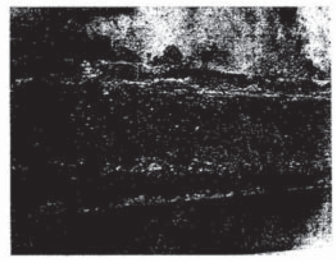
PHOTOGRAPHS OF CASTING

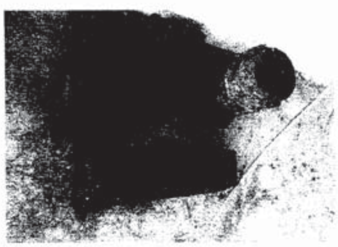


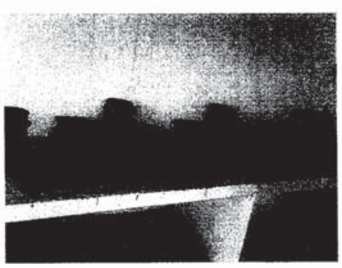






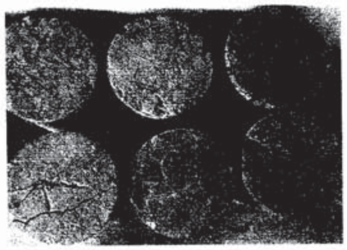


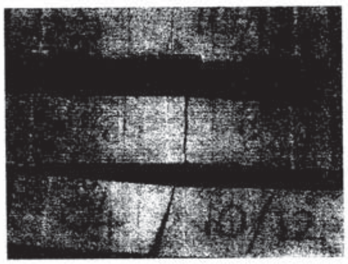




APPENDICE – 3

PHOTOGRAPHS DURING TESTING AND TESTED SPECIMENS




10/12