"EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH CRUSHED BRICKS ON CONCRETE PROPERTIES"

A PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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to

DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH CRUSHED BRICKS ON CONCRETE PROPERTIES"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by *Ravi Kumar(141605),Atishay Jain(141695), Shubham Kumar Singh (141696)* during a period from June 2017 to May 2018 under the supervision of Mr. Abhilash Shukla, Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat..

The above statement made is correct to the best of our knowledge.

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ABSTRACT

Various kinds of coarse aggregates are used around the world for construction purpose and most of these coarse aggregates are naturally originated. Due to the gradual decrement of natural aggregates, society is facing a challenge in concrete works which demands a huge amount of coarse aggregate.

Issue related to the diminishing of good quality and quantity of coarse aggregate has kept the construction industries into a crisis in finding an alternative to overcome this situation. The issue is getting worse as the current aggregates used in the construction industries are non-renewable aggregates from the quarrying activities. Rapid development in the recent years has increased the need of coarse aggregate at an alarming rate. Besides that, the growth of the construction industry is also producing a lot of waste materials. Land filling is the most common waste management practice but due to population growth, availability of land has also become a major problem. The high amount of construction waste generated from the construction industries has also caused a scarcity of the landfill area. The present study is conducted to investigate the use of brick waste as a coarse aggregate replacement in concrete production. The objective of this study is to determine the appropriateness of crushed brick waste as partial replacement of coarse aggregate in concrete production. Furthermore, to investigate the mechanical and physical properties of brick waste concrete, and to compare the performance of brick waste as partial replacement of coarse aggregate in concrete with the conventional concrete. In order to fulfil the objective, various tests were conducted to determine concrete performance. The data was collected and analyzed to satisfy the study on brick waste as an alternative in coarse aggregate partial replacement in concrete production.

CHAPTER 1 - INTRODUCTION

1.1 General

Concrete is produced by mixing cement, coarse aggregates, fine aggregates and water. The major volume concrete is filled with aggregate. Aggregates are generally cheaper than cement and give volumetric stability, density and durability to concrete. Coarse and fine particles are so graded that voids in mixture are packed to minimum and cement-sand mortar matrix fills the gaps and interspaces and binds the entire matrix to form rock solid substance called concrete. Natural aggregates are derived from any one of rocks belonging to igneous, sedimentary or metamorphic origin.

The inclusion of aggregate in concrete reduces its drying shrinkage properties and improves many other properties such as compressive strength etc. But it is costly to transport, so local sources are needed to reduce the cost of transport, but due to geographical constraints this is not available at all places, therefore it necessitates finding other sources and alternative from local sources. Many materials are utilized as a substitute for natural coarse aggregate like recycled crushed bricks, coconut shell, air cooled blast furnace slag, recycled plastic aggregate, well-burnt brick, waste etc. For this study selection of crushed brick waste as an alternative for coarse aggregates is done. This material was chosen because of the demolition of the building, a large number of bricks are rejected. These rejected bricks can also be a potential source of coarse aggregate compounds. Bricks may be natural mud blocks cut to sizes or artificial manufactured in kilns. Under burnt bricks shall not be used to make brick aggregate. However normal or over burnt bricks make good aggregate. Bricks aggregate possess all properties of other well recognized light aggregate. Therefore brick aggregate can very well be considered as light weight aggregate with due protection against corrosion given and with increased cover given to steel reinforcement, brick aggregate can be adopted for R.C.C works also.

There is a huge demand for Construction aggregate which is more than 26.8 billion tons in all over the world. There is a quiet increment in the utilization and demand of the natural aggregates in India due to housing, road, construction and infrastructure development. Recently the Uttarakhand high court put a ban on utilization of river aggregates for construction purposes because of various environmental concerns. This step caused a crisis of construction aggregates in and around the Uttarakhand state and the prices of aggregates skyrocketed. Because of these types of scenarios which are expected to occur frequently in near future, it is a high time to search for alternatives to cater coarse aggregate need of humans.

During the Second World War, the use of demolished concrete waste was started; it was utilized in the construction of the pavements. According to Union Environment Ministry, 15 million tons of the construction and demolition waste is generated in the year of 2017 but the current method adopted for the management of this waste is land filling which causes a giant amount of the construction and demolished waste deposition and such huge amount affect the environment adversely.

India's present demand for bricks is over 100 billion bricks per year which stands second in demand of the construction materials after the cement. The fuel used for burning of air dried bricks itself cost around 30 to 40% of production cost of bricks. The conventional practice of firing clay bricks in traditional kilns consumes large quantity of coal, wood and biomass fuel. Next to china, India is second largest producer of bricks in the world and consumer of coal wood and fossil fuels more than 24 million tons per annum. Construction industry as a whole contributes 17% of CO2 in our country out of which cement contributes about 17% and bricks industry contributes about 3%. Bricks have a high carbon footprint so they should be definitely recycled to maintain sustainability in their usage in construction. Land filling of such a useful resource is not sustainable as it can be used in many other constructive activities like being used as coarse aggregate in concrete production.

Recently In India concrete, bricks, sand, mortar, and tile residues are the main materials found in the demolished waste of buildings. This waste can be recycled or process into the recycled demolished aggregates which can be utilized in the concrete mixes. The main purpose of this work is to determine the basic properties of concrete made of crushed brick aggregates and then to compare it with the properties of conventional concrete made with natural aggregate.

1.2 Thesis Arrangement

The remainder of the thesis is arranged as follow: Chapter 2 provides a brief literature review of the various past work done with crushed bricks as coarse aggregates. This chapter also defines the aim of the research work. Chapter 3 describes the materials used in research work and the experimental program carried out to develop the mixture proportions, the mixing process, the tests on concrete performed to study the behaviour and the short term engineering properties of the fresh concrete and the hardened concrete are also described and the mix design proportions used in the present work. Chapter 4 presents various tests done on natural and crushed bricks aggregate and their comparative results. Chapter 5 gives the various results obtained by different tests on concrete. Chapter 6 states the conclusions of this study. The thesis ends with a Reference List and an Annexure of detailed mix design.

CHAPTER 2 - LITERATURE REVIEW

2.1 Literature Review

Many pieces of research showed the fact that brick aggregate could be a better alternative to the usual aggregates.

Rashid et al. found that higher strength concrete (f_{cu} = 31.0 – 45.5 N/mm^2) with brick aggregate is achievable. Crushed bricks may be used satisfactorily as coarse aggregate for making concrete, the strength of which is much higher than that of bricks considered. The unit weight of such concrete is around 13% lower than that of normal weight concrete. Similar to normal weight concrete a drastic reduction in the compressive strength of brick aggregate concrete due to the increase in water-cement ratio has been found.

Cachim reported that natural aggregate could be replaced by 15% of brick aggregate without affecting the strength. Observed results indicate that brick residuals could be used as partial replacement of natural aggregates in concrete without reduction of concrete properties for 15% replacement and with reductions up to 20% for 30% replacement. The type and the manufacturing process of bricks seem to influence the properties of the resulting concrete. The properties and aesthetics of concrete with bricks indicate the possibility of using this type of concrete in precast applications

According to Sable and Walke, up to 30% brick aggregate replacement for natural coarse aggregate is found feasible and economical.

Aguwa studied the properties of brick aggregate concrete and reported the concrete as lightweight concrete**.**

Fadia reported that the percentage of water to cement ratio increases for constant slump when the percentage of crushed bricks increased. The use of crushed bricks as coarse aggregate decreases the compressive strength of concrete about 11-87 % at age of 28 days.

Gopinandan Dey and Joyanta Pal concluded that Crushed bricks can be used satisfactorily to produce M25 and M30 concrete keeping water-cement ratio in the range of 0.35 to 0.40. High water absorption (12% to 20% by mass) of brick aggregate is a major problem to use it in the actual work, thus an attempt has been made to suggest a realistic solution for real field application.

Benmalek Larbi, Harbi and Boukor concluded that Brick waste aggregate induces a progressive decrease of the 28 day compressive strength and decreases the sorptivity of the mortars because of the large pore generated by their incorporation in the prepared mixtures.

Debieb and Kenai concluded that Recycled brick aggregates present relatively lower bulk density and higher water absorption compared to natural aggregates. Concrete with 100% of coarse and fine aggregates presented some segregation and hence de-moulding was delayed until 56 h after casting.

Praveen, Dhanya Sathyan and K M Mini observed that Quality of concrete can be improved by conducting proper quality check for brick aggregate. The optimum percentage of micro-silica as a replacement of cement is 10% for M30 concrete. The use of waste over burnt bricks along with micro-silica promises a sustainable way of construction by reducing the excess use of naturally available coarse aggregate and cement.

2.2 Objectives of the Study

- To determine the suitability of crushed bricks as partial replacement of coarse aggregate in concrete production.
- To investigate the mechanical and physical properties of crushed brick Concrete.
- To compare the performance of brick aggregate concrete and conventional concrete
- To optimize the proportion of crushed brick as coarse aggregate in concrete.

CHAPTER 3 - METHODOLOGY

3.1 Introduction

An extensive experimental Program involving the various processes of material testing, mix proportioning, mixing, casting and curing of specimens and testing of specimens was done. The forthcoming sections elaborate the various physical properties of each material separately.

3.2 Materials

3.2.1 Cement

PPC grade has been used in the study conforming to recommendations stated in IS: 1489 (part 1) -1991. It was procured from college's material store.

Figure 3.1- Cement bag

3.2.2 Fine Aggregate

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 – 1970.

Figure 3.2- Fine aggregate

3.2.3 Coarse Aggregate

The coarse aggregate used was conforming to IS: 383 – 1970. In this study, the crushed angular coarse aggregates were used, which was bought from the nearby crusher. Aggregates of 12.5 mm were chosen for the experiment which is clean and free from deleterious materials.

Figure 3.3- Coarse aggregate

3.2.4 Crushed brick

Clay bricks were taken and were crushed with a hammer. The size of brick aggregate used was graded between 16 mm sieve passing and 4.75 mm retained.

Figure 3.4- Brick aggregate

3.2.5 Water

As per recommendation of IS: 456 (2000), the water used for mixing and curing must be clean and free from substances that may be deleterious to concrete or steel. The pH value of water shall be not less than 6. In the present investigation, tap water is used for both mixing and curing purposes.

3.3 Mixing Of Concrete, Casting and Curing Of Test Specimens

Mixing was done using tilting mixers. Initially, the dry mixing of cement, fine aggregate, coarse aggregate and crushed bricks was done for two minutes and then water was added and mixing continued for another 2 minutes. The total mixing time was kept at 5 minutes approx. for all the trials until a homogeneous mixture was obtained. Compaction was achieved by placing cubes on vibration table until finished surface obtained. All specimens were de-molded after 24 hours and placed in curing tanks till the day of testing i.e. for 7 & 28 days.

Figure 3.5- Dry mix (left) and concrete mould (right)

3.4 Tests on Concrete

Test methods include the tests of the fresh concrete mix for workability and hardened concrete specimens for the compressive strength test.

3.4.1 Workability Test

Slump test for fresh concrete was done conforming IS: 1199-1959 in order to measure the workability of concrete mixes.

Figure 3.6- Slump Cone

3.4.2 Compressive Strength

In this investigation, the cube specimens of size 150×150×150mm are tested in accordance with IS: 516 – 1969. After 7 & 28 days of curing, cube specimens were removed from the curing tank and test for compression. The test was repeated for the three specimens and the average value was taken as the mean strength.

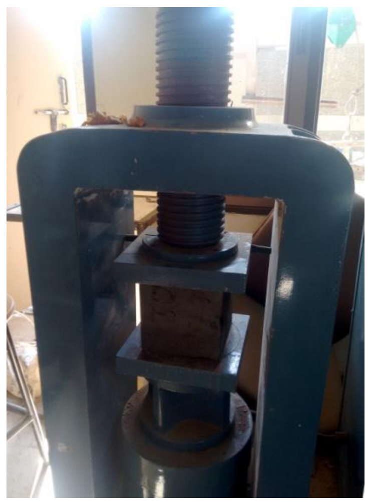

Figure 3.7- Compression testing of concrete cube

3.4.3 Split Tensile Strength

In this project, the cylinder specimens of 100 mm diameter and 200 mm height were tested. After 7 & 28 days of curing, cylinder specimens were removed from the curing tank and tested for compression load taken i.e. “P”. The Split Tensile Strength is calculated using the following formulae

Split Tensile Strength = $\frac{2 \times P}{\pi \times D \times L}$

P = applied load

D = diameter of the specimen

L = length of the specimen

The test was repeated for the three specimens and the average value was taken as the mean strength.

Figure 3.8- Split Tensile testing of Cylinder

3.4.4 Stress-Strain Behavior

To study the stress-strain behaviour, cylindrical specimens of 150 mm diameter and 300 mm height were tested after 28 days of curing. Testing was done in a universal testing machine (UTM) to get the load applied and the corresponding change in sample length. Stress at corresponding strain was calculated and plotted graphically.

Figure 3.9- Sample in UTM

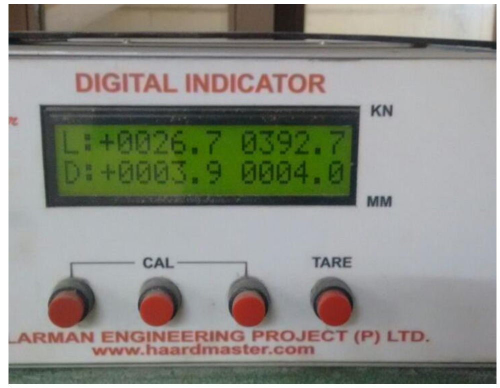

Figure 3.10- UTM digital indicator

3.5 Concrete Mix Design

In this study M20 concrete mix design was prepared using IS 10262-2009. M20 mix design with 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate with crushed bricks was done. Annexure-1 contains the detailed mix design process. The mix proportions for M20 conventional concrete and with 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate with crushed bricks respectively is shown in this section.

The Table 3.1 shows the volumetric proportions of concrete constituents used in the experimental work.

Table 3.1 - Mix Proportions

Coarse Aggregate Replacement(%)	0 %	10 %	20 %	30 %	40%	50%
Cement (kg/m^3)	372	372	372	372	372	372
Water	186	186	186	186	186	186
W/C	0.50	0.50	0.50	0.50	0.50	0.50
Coarse aggregate(kg/m^3)	1197.62	1077.72	958.1	838.2	718.57	598.81
Fine Aggregate(kg/m^3)	588.75	588.75	588.75	588.75	588.75	588.75
Crushed Brick(kg/m^3)	0	91.45	182.91	274.36	365.82	457.27

CHAPTER 4 - AGGREGATES TESTING

4.1 Testing Of Aggregate

4.1.1 Sieve Analysis

Sieve analysis of various aggregates is important for mix design and to get inference of aggregate size. The zone of fine aggregates is determined by their sieve analysis.

The following section contains sieve analysis of coarse aggregates, fine aggregates, brick aggregates and also the sieve analysis of aggregate combination i.e. coarse aggregate and its replacement by crushed bricks in different proportions.

Coefficient of uniformity (C_u) and coefficient of curvature (C_c) are important aggregate gradation parameters and are calculated by following formula

$C_u = D_{60} / D_{10}$

$C_c = (D_{30})^2 / (D_{60} \times D_{10})$

For well graded aggregates the value of C_u should be greater than 4 and C_c should lie in the range 1 to 3.

The forthcoming tables gives the sieve analysis of coarse aggregates, fine aggregates, brick aggregates and also the sieve analysis of aggregate combination i.e. coarse aggregate and its replacement by crushed bricks in different proportions. Particle size distribution curves are also plotted with the sieve analysis tables.

Table 4.1-Sieve Analysis of coarse aggregate

Sieve Size	Retained on each		Cumulative Retained(%)	Passing (%)
	Weight(g)	Percentage(%)		
40 mm	0	0	0	100
20 mm	42	2.10	2.10	97.90
12.5 mm	1416	70.80	72.90	27.10
10 mm	340	17	89.90	10.10
6.3 mm	50	2.50	92.40	7.60
4.75 mm	2	0.10	92.50	7.50
Pan	150	7.50	100	0

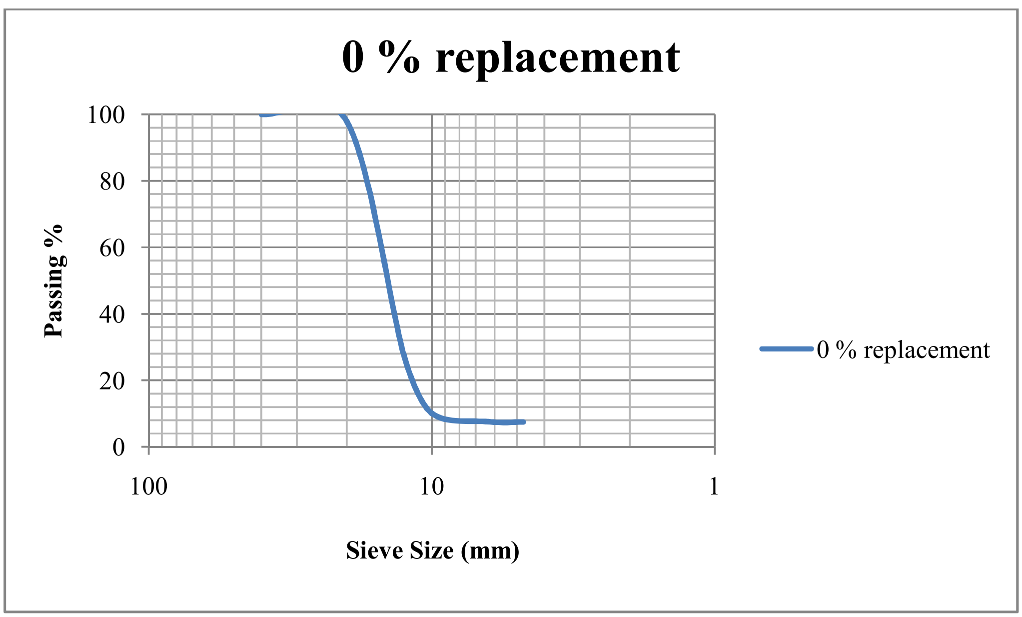

Figure 4.1- Sieve Analysis - 0% replacement

Table 4.2-Effective size, 0% replacement

D_{10}	10
D_{30}	13
D_{60}	16
C_c	1.05
C_u	1.60

The C_u value is 1.60 i.e. less than 4 and C_c lies between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.3 - Sieve Analysis of Fine Aggregate

Sieve Size	Retained on each		Cumulative Retained (%)	Passing through (%)
	Weight(g)	Percentage		
4.75 mm	50	2.50	2.50	97.50
2.36 mm	130	6.50	9	91
1.18 mm	262	13.10	22.10	77.90
600 µ	828	41.40	63.50	36.50
300 µ	590	29.50	93	7
150 µ	125	6.25	99.25	0.75
Pan	15	0.75	100	0

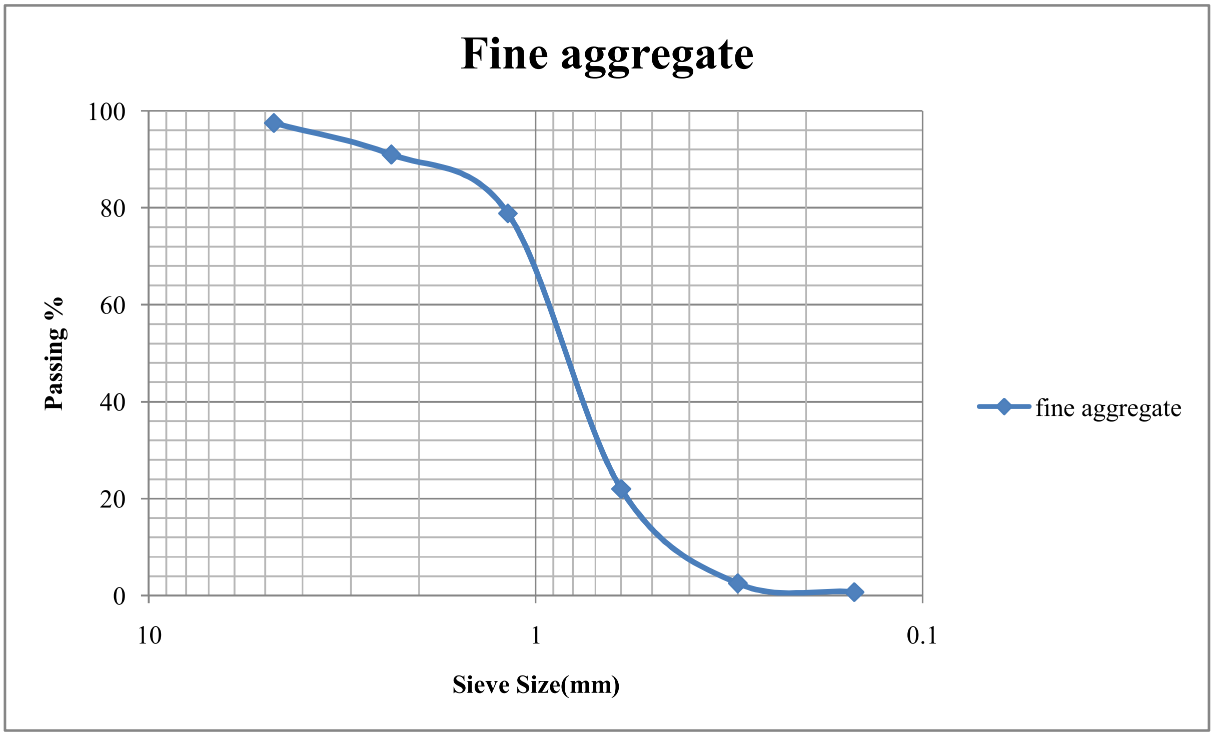

Figure 4.2- Sieve Analysis -Fine Aggregate

Table 4.4-Effective size, Fine Aggregate

D_{10}	0.45
D_{30}	0.70
D_{60}	0.90
C_c	1.21
C_u	2

According to IS 383-1970 the zone of fine aggregates is determined by the percentage of fine aggregates passing 600 μ sieve. Here, 36.5 % of fine aggregates pass through 600 μ sieve so, the given fine aggregate is of zone 2.

The value of C_u is 2 which means that the given fine aggregates are uniformly graded.

Table 4.5-Sieve Analysis of Brick aggregate

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	40	4	4	96
16 mm	227	22.7	26.7	73.3
12.5 mm	708	70.8	97.5	2.5
10 mm	17	1.7	99.2	0.8
6.3 mm	0	0	100	0
4.75 mm	0	0	100	0
Pan	0	0	100	0

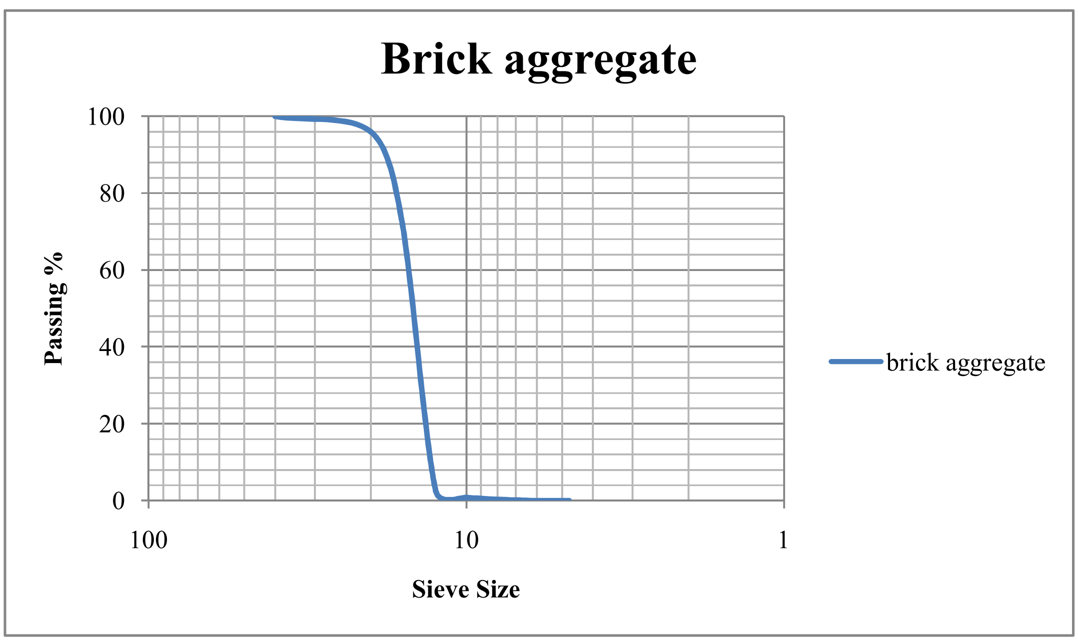

Figure 4.3- Sieve Analysis - Brick aggregate

Table 4.6-Effective size, Brick Aggregate

D_{10}	13
D_{30}	12
D_{60}	10
C_c	1.10
C_u	0.77

The C_u value is 0.77 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.7-Sieve Analysis of coarse aggregate with 10% replacement by crushed bricks

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	156	7.80	7.80	92.20
16 mm	598	29.45	37.25	62.75
12.5 mm	964	48.20	85.45	14.55
10 mm	224	12.20	97.65	2.35
6.3 mm	48	2.25	99.90	0.10
4.75 mm	2	0.10	100	0
Pan	0	0	100	0

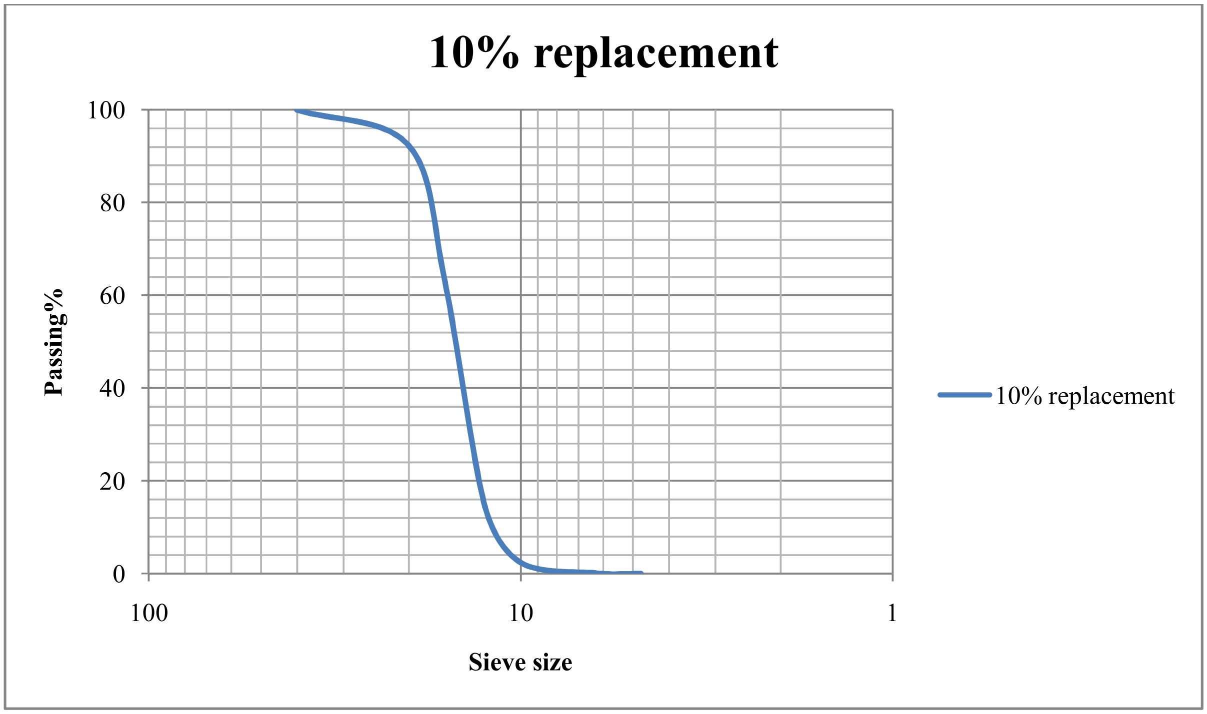

Figure 4.4- Sieve Analysis - 10% replacement

Table 4.8-Effective size, 10% replacement

D_{10}	12.20
D_{30}	15
D_{60}	16
C_c	1.15
C_u	1.31

The C_u value is 1.31 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.9-Sieve Analysis of coarse aggregate with 20% replacement

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	122	6.10	6.10	93.90
16 mm	592	29.60	35.70	64.30
12.5 mm	1062	53.10	88.80	11.20
10 mm	174	8.70	97.50	2.50
6.3 mm	39	1.95	99.45	0.65
4.75 mm	0	0	100	0
Pan	0	0	100	0

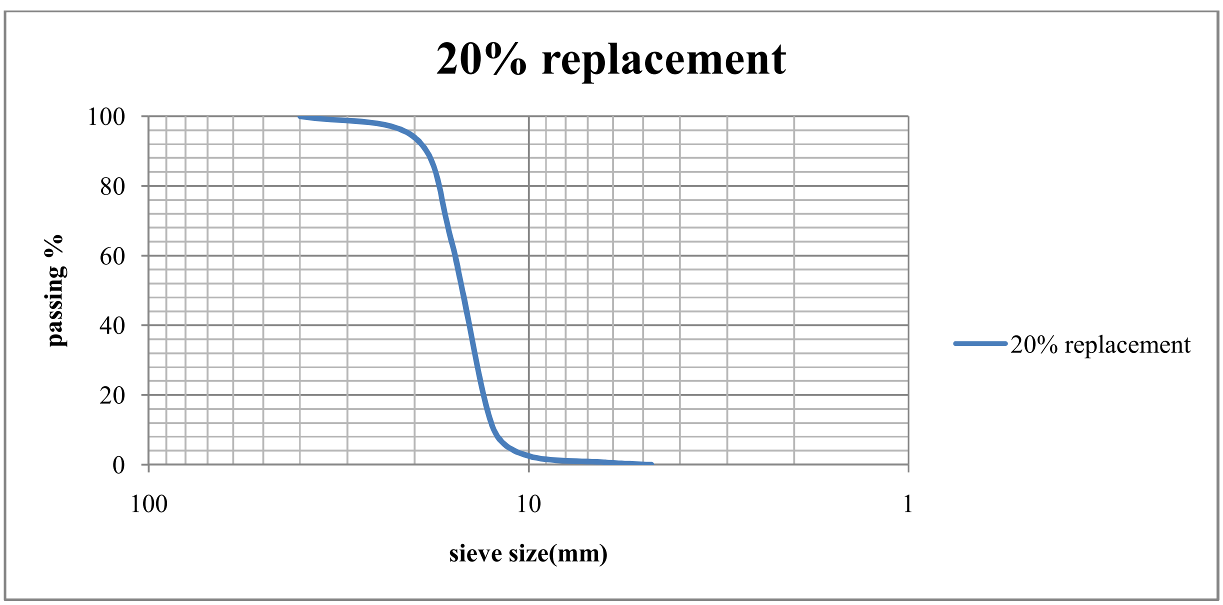

Figure 4.5-Sieve Analysis - 20% replacement

Table 4.10-Effective size, 20% replacement

Aggregate Parameters	Value
D_{10}	12.60
D_{30}	15.10
D_{60}	16.20
C_c	1.10
C_u	1.28

The C_u value is 1.28 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.11-Sieve Analysis of coarse aggregate with 30% replacement

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	261	13.05	13.05	86.95
16 mm	692	34.6	47.65	52.35
12.5 mm	836	41.8	89.45	10.55
10 mm	181	9.05	98.50	1.50
6.3 mm	19	1.45	99.85	0.15
4.75 mm	2	0.10	99.95	0.05
Pan	0	0	100	0

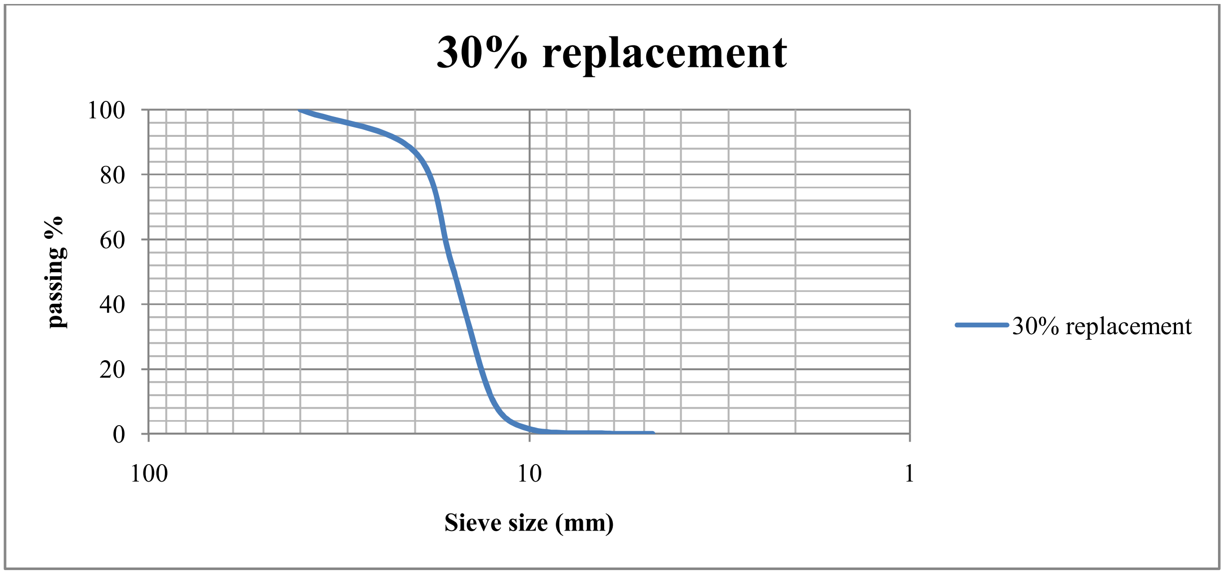

Figure 4.6-Sieve Analysis - 30% replacement

Table 4.12-Effective size, 30% replacement

Aggregate Parameters	Value
D_{10}	13
D_{30}	15.30
D_{60}	16.90
C_c	1.06
C_u	1.30

The C_u value is 1.30 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.13-Sieve Analysis of coarse aggregate with 40% replacement

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	50	5	5	95
16 mm	316	31.60	36.60	63.40
12.5 mm	437	43.70	80.30	19.70
10 mm	150	15	95.30	4.70
6.3 mm	45	4.50	99.80	0.20
4.75 mm	1	0.10	99.90	0.10
Pan	1	0.10	100	0

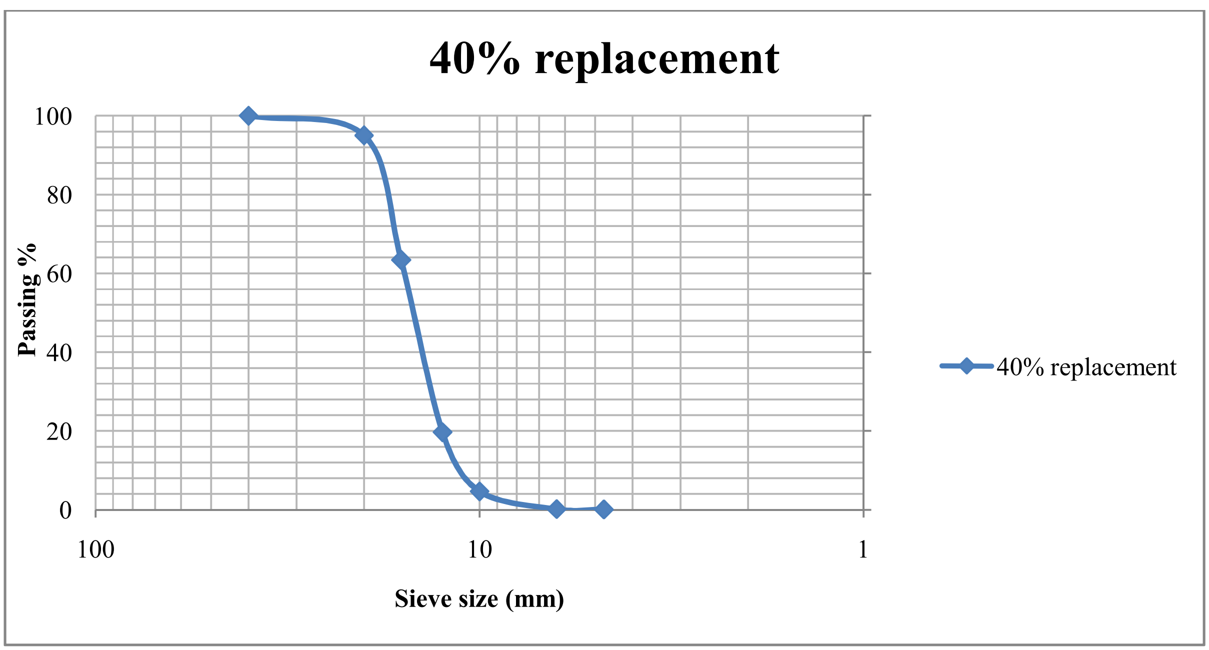

Figure 4.7- Sieve Analysis - 40% replacement

Table 4.14-Effective Size 40% replacement

Aggregate Parameters	Value
D_{10}	13
D_{30}	15.10
D_{60}	16
C_c	1.09
C_u	1.23

The C_u value is 1.23 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Table 4.15-Sieve Analysis of coarse aggregate with 50% replacement

Sieve Size	Retained on each		Cumulative Retained(%)	(%) finer
	Weight(g)	Percentage		
20 mm	23	2.30	2.30	97.70
16 mm	365	36.50	38.80	61.20
12.5 mm	366	36.60	75.40	24.60
10 mm	171	17.10	92.50	7.50
6.3 mm	66	6.60	99.10	0.90
4.75 mm	8	0.80	99.90	0.10
Pan	1	0.10	100	0

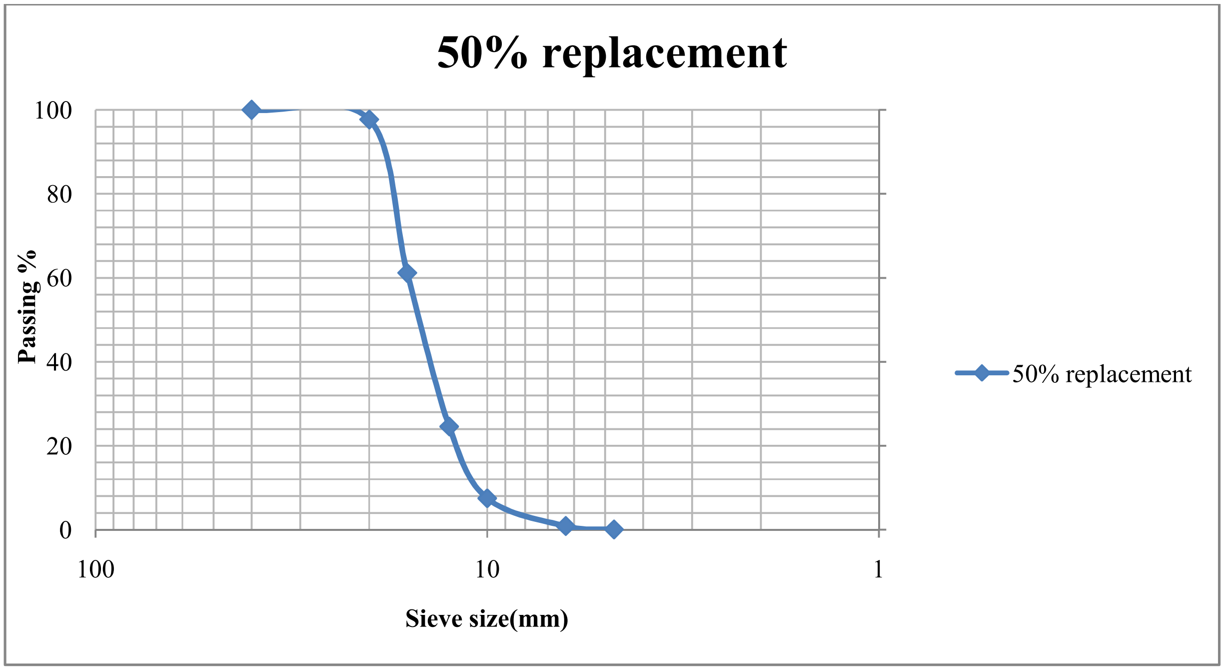

Figure 4.8- Sieve Analysis - 50% replacement

Table 4.16-Effective size 50% replacement

Aggregate Parameters	Value
D_{10}	11.30
D_{30}	14.80
D_{60}	16
C_c	1.21
C_u	1.42

The C_u value is 1.42 i.e. less than 4 and C_c lie between 1 and 3 so the aggregates used are poorly graded / uniformly graded.

Here it can be observed that the coarse aggregates and the combined aggregates i.e. replacement of coarse aggregate with crushed bricks are poorly graded. The aim of using poorly graded aggregates is to depict the condition of a site with minimum level of control.

4.1.2 Water Absorption Test

Table 4.17-Water Absorption Test (Aggregate)

Immersed weight of aggregate + basket(W_1)	1600 g
Immersed Weight of basket(W_2)	485 g
Basket in air(W_3)	580 g
Basket + Aggregate in air(W_4)	2330 g
Specific Gravity	$W_3/(W_3-(W_1-W_2))$ = 2.75
Water absorption	$((W_3-W_4)/W_4)\times100$ = 2.33 %

Table 4.18-Water Absorption Test (Crushed Brick)

Immersed weight of aggregate + basket(W_1)	1405 g
Immersed Weight of basket(W_2)	470 g
Basket in air(W_3)	545 g
Basket + Aggregate in air(W_4)	2325 g
Specific Gravity	$W_3/(W_3-(W_1-W_2))$ = 2.10
Water absorption	$((W_3-W_4)/W_4)\times100$ = 11.94%

Table 4.19-Water Absorption with Time

Time (mins)	weight of the container (g)	Wet weight of (aggregate+container)(g)	Dry weight of (aggregate+container)(g)	% absorption
2	19	125	116.50	60.70
4	19	133	123	71.40
6	20	100	89	78.50
8	22	114.50	102.30	87.14
10	19	146	132.40	97.14
12	19	115	101	100
14	20	134	119.90	100
24(hrs)	20	124	110	100

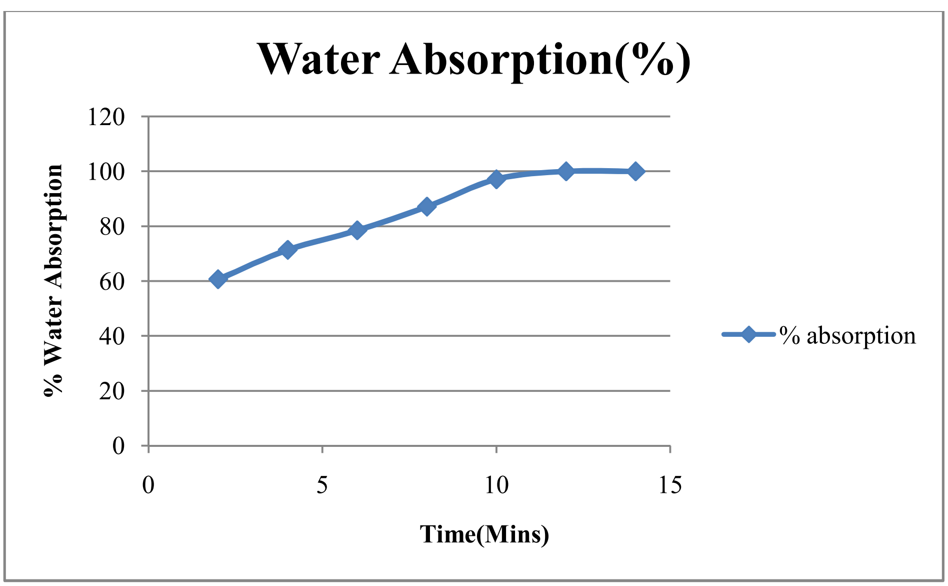

Figure 4.9- Water absorption with time

4.1.3 Aggregate Impact Value Test

Table 4.20-Aggregate Impact value test (Aggregate)

Sample weight (W)	588 g
2.36 mm passing (w_1)	174 g
Impact value	$(w_1/W)\times100$ =29.59 %

Table 4.21-Aggregate Impact value test (Crushed brick)

Sample weight (W)	400 g
2.36 mm passing (w_1)	134 g
Impact value	$(w_1/W)\times100$ =33.50 %

4.1.4 Aggregate Crushing Value Test

Table 4.22- Aggregate Crushing Value Test

Sample weight (W)	2000 g
2.36 mm passing (w_1)	465 g
Impact value	$(w_1/W)\times100$ =23.25 %

Table 4.23-Aggregate Crushing Value Test (Crushed Bricks)

Sample weight (W)	2000 g
2.36 mm passing (w_1)	687 g
Impact value	$(w_1/W)\times100$ = 34.35 %

4.1.3 Aggregate Flakiness and Elongation

Size of aggregates		Weight of sample (g)	Thickness gauge size, mm	Weight of aggregates in each fraction passing thickness gauge, g	Length gauge size, mm	Weight of aggregates in each fraction retained on length gauge, g
Passing through IS Sieve, mm	Retained on IS Sieve, mm					
63	50	0	33.90	0	–	–
50	40	0	27.00	0	81.00	0
40	31.5	0	19.50	0	58.00	0
31.5	25	0	16.95	0	–	–
25	20	32	13.50	0	40.50	0
20	16	465	10.80	8	32.40	0
16	12.5	501	8.55	4	25.50	0
12.5	10	176	6.75	2	20.20	3
10	6.3	260	4.89	-	14.70	16
Total		W = 1434		X = 14		Y = 19

Table 4.24- Aggregate Flakiness and Elongation

Flakiness Index (X/W) x 100	0.97 %
Elongation Index (Y/W) x 100	1.32 %

CHAPTER 5 - EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Introduction

The M20 grade concrete mix was prepared. In this work, the effects of the percentage of crushed brick aggregate over the properties of concrete like workability, compressive & tensile strength, bulk density, stress-strain behavior were studied. In this report, the effect crushed brick aggregate on the properties of concrete has been investigated in laboratory and results are obtained. Presenting the results graphically. The study has been carried out by preparing concrete cubes of M20 mix and tested after 7 and 28 days of curing. Cubes were casted for 0%, 10%, 20%, 30%, 40% and 50% replacement of Coarse aggregate by crushed bricks.

5.2 Observations

5.2.1 Bulk Density Of Concrete

Table 5.1-Bulk Density of concrete

S.NO	Weight of cube (kg)	Volume (m^3)	Density of concrete (kg/m^3)	Average density of concrete (kg/m^3)
M20(without replacement)				
1.	8.50	0.003375	2518.52	2518.52
2.	8.40	0.003375	2488.89	
3.	8.60	0.003375	2548.14	
10%replacement				
1.	8.15	0.003375	2414.81	2428.64
2.	8.25	0.003375	2444.44	
3.	8.19	0.003375	2426.67	

20%replacement				
1.	7.84	0.003375	2322.96	2325.92
2.	7.86	0.003375	2328.89	
3.	7.85	0.003375	2325.92	
30%replacement				
1.	7.51	0.003375	2225.18	2226.67
2.	7.52	0.003375	2228.14	
3.	7.51	0.003375	2226.67	
40%replacement				
1.	7.40	0.003375	2192.59	2193.57
2.	7.45	0.003375	2207.40	
3.	7.36	0.003375	2180.74	
50%replacement				
1.	7.12	0.003375	2109.62	2137.25
2.	7.22	0.003375	2139.25	
3.	7.30	0.003375	2162.96	

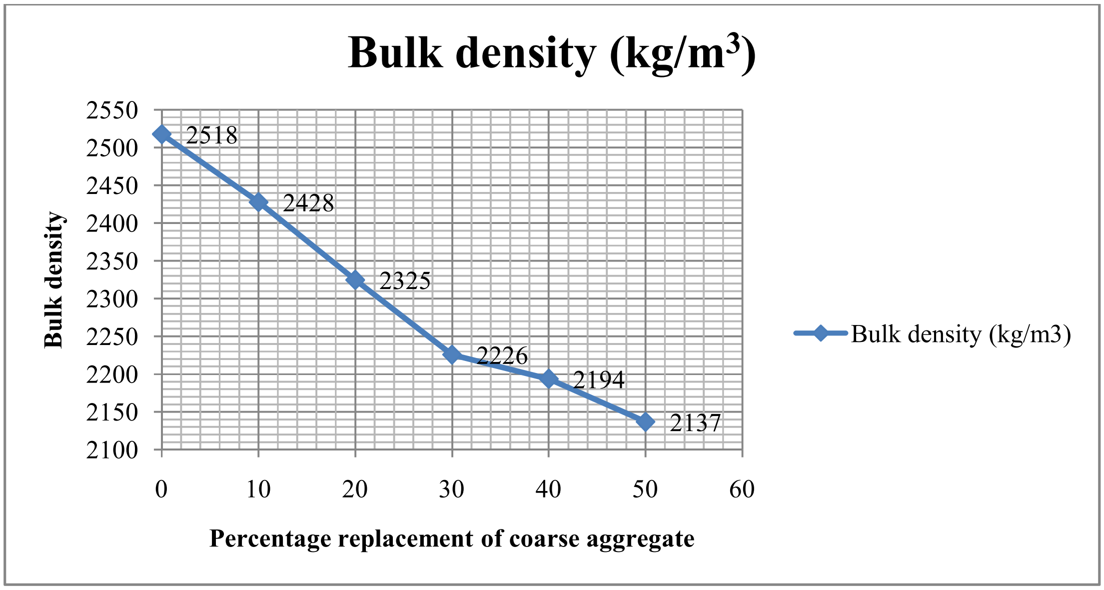

Figure 5.1- Graph, bulk density

5.2.2 Slump Test

Table 5.2-Slump test

s.no	% of brick	Slump value (mm)
1.	0	60
2.	10	55
3.	20	50
4.	30	45
5.	40	18
6.	50	12

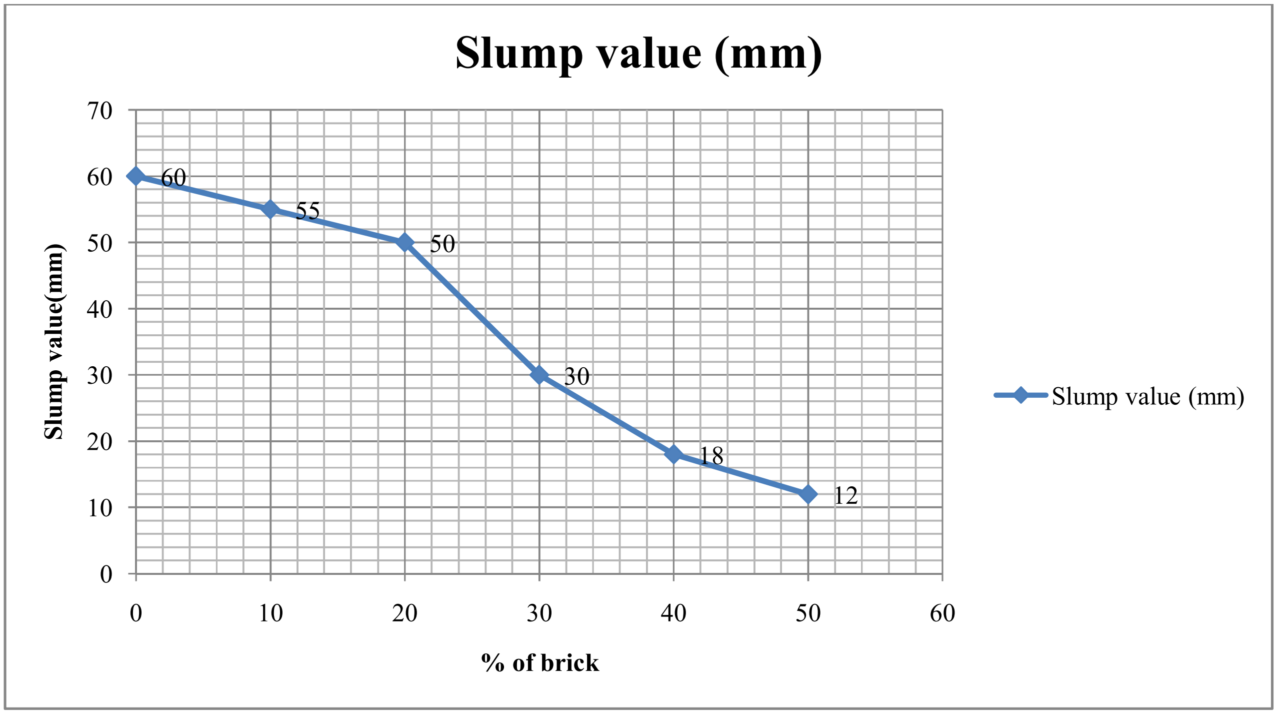

Figure 5.2-Graph, Slump value

Figure 5.3- Slump cone test

5.2.3 Compressive Strength

Table 5.3-Compressive Strength Result (7 days)

S.no	% of brick	Date of Casting	Load (kN)	Comp. Strength (N/mm^2)	Avg. Comp. Strength (N/mm^2)
1.	0%	22/09/17	440	19.55	18.96
2.		22/09/17	408	18.13	
3.		22/09/17	432	19.20	
4.	10%	02/10/17	290	12.89	12.97
5.		02/10/17	300	13.34	
6.		02/10/17	285	12.67	
7.	20%	16/11/17	312	13.87	14.06
8.		16/11/17	322	14.31	
9.		16/11/17	315	14.00	
10.	30%	16/11/17	340	15.11	15.63
11.		16/11/17	355	15.78	
12.		16/11/17	360	16.00	
13.	40%	01/03/18	257	11.42	
14.		01/03/18	262	11.64	11.46
15.		01/03/18	255	11.33	
16.	50%	01/03/18	213	9.46	
17.		01/03/18	210	9.33	9.52
18.		01/03/18	220	9.77	

Table 5.4- Compressive strength (28 Days)

S.no	% of brick	Date of Casting	Load (kN)	Comp. Strength (N/mm^2)	Avg. Comp. Strength (N/mm^2)
1.	0%	22/09/17	644	28.62	27.82
2.		22/09/17	625	27.77	
3.		22/09/17	609	27.06	
4.	10%	02/10/17	460	20.44	20.93
5.		02/10/17	457	20.31	
6.		02/10/17	480	21.33	
7.	20%	16/11/17	500	22.22	21.85
8.		16/11/17	490	21.77	
9.		16/11/17	485	21.55	
10.	30%	16/11/17	560	24.89	25.2
11.		16/11/17	541	24.04	
12.		16/11/17	600	26.67	
13.	40%	28/02/18	397	17.65	17.66
14.		28/02/18	393	17.46	
15.		28/02/18	402	17.87	
16.	50%	28/02/18	304	13.51	13.42
17.		28/02/18	290	12.88	
18.		28/02/18	312	13.87	

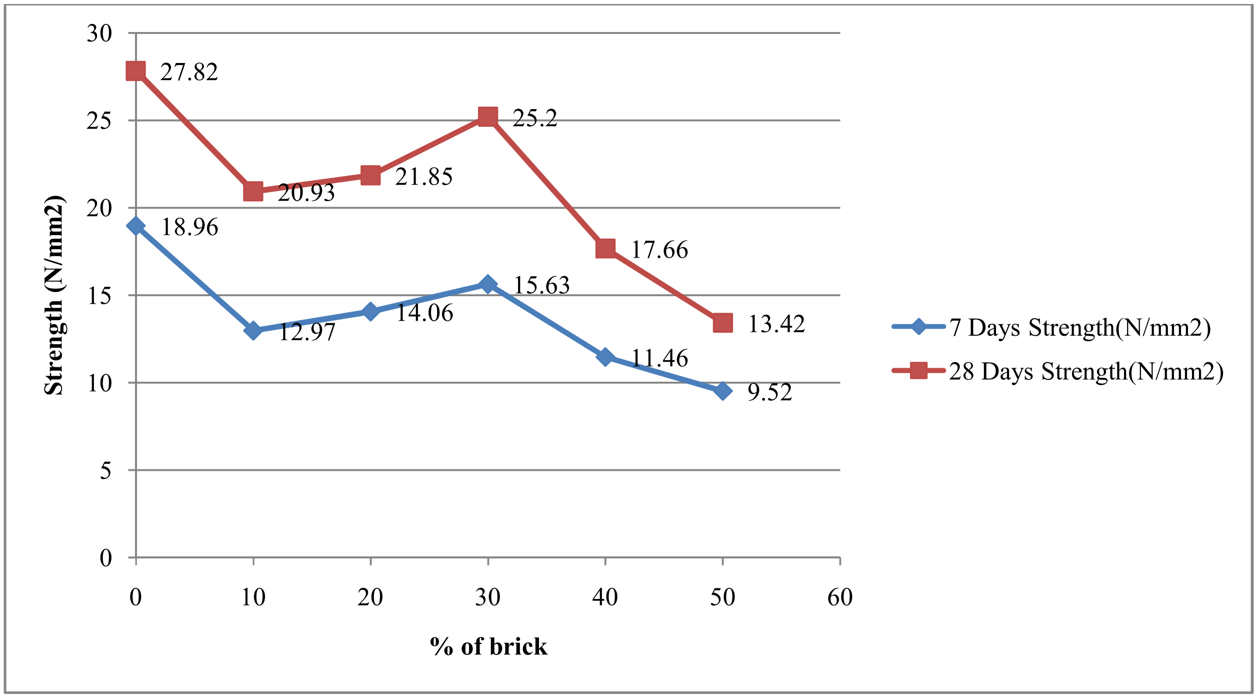

Figure 5.4- Graph, Compressive Strength

5.2.4 Split Tensile Strength

Table 5.5- Tensile strength (7 days)

S.no	% of brick	Date of Casting	Load (kN)	Tensile Strength (N/mm^2)	Avg. Tensile Strength (N/mm^2)
1.	0%	28/02/18	50	1.59	1.56
2.		28/02/18	50	1.59	
3.		28/02/18	48	1.52	
4.	10%	01/03/18	55	1.75	1.72
5.		01/03/18	53	1.68	
6.		01/03/18	55	1.75	
7.	20%	01/03/18	58	1.84	1.75
8.		01/03/18	56	1.78	
9.		01/03/18	52	1.65	
10.	30%	14/03/18	60	1.91	1.82
11.		14/03/18	58	1.84	
12.		14/03/18	54	1.72	
13.	40%	14/03/18	51	1.62	1.64
14.		14/03/18	51	1.62	
15.		14/03/18	53	1.68	
16.	50%	15/03/18	44	1.40	1.34
17.		15/03/18	41	1.30	
18.		15/03/18	42	1.33	

Table 5.6- Tensile Strength (28 Days)

S.no	% of brick	Date of Casting	Load (kN)	Tensile Strength (N/mm^2)	Avg. Tensile Strength (N/mm^2)
1.	0%	28/02/18	81	2.58	2.46
2.		28/02/18	73	2.32	
3.		28/02/18	78	2.48	
4.	10%	01/03/18	86	2.73	2.70
5.		01/03/18	81	2.58	
6.		01/03/18	88	2.80	
7.	20%	01/03/18	81	2.58	2.72
8.		01/03/18	82	2.61	
9.		01/03/18	93	2.96	
10.	30%	14/03/18	88	2.80	2.78
11.		14/03/18	90	2.87	
12.		14/03/18	84	2.67	
13.	40%	14/03/18	74	2.36	2.33
14.		14/03/18	77	2.45	
15.		14/03/18	69	2.20	
16.	50%	15/03/18	67	2.13	2.18
17.		15/03/18	74	2.36	
18.		15/03/18	65	2.07	

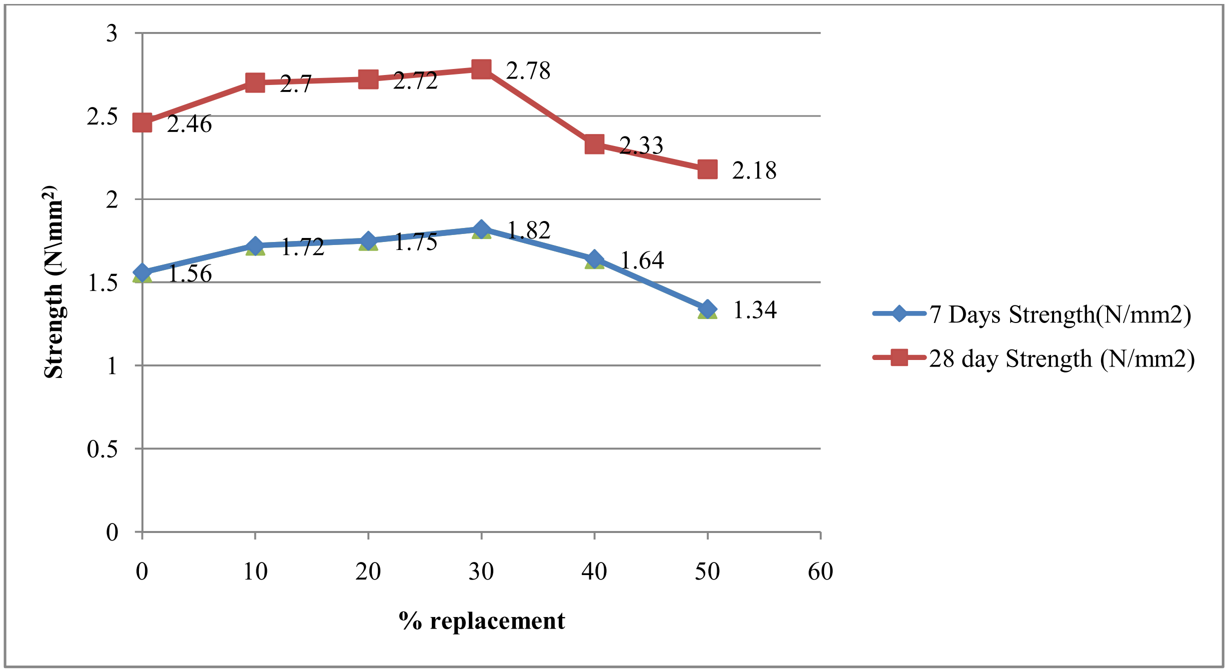

Figure 5.5- Graph, Tensile strength (7 Days)

Figure 5.6- Split Tensile Test Samples

5.2.5 Stress-Strain Relation in Compression

Stress-strain relation in compression is an extremely important property in order to correctly model concrete, since the softening branch of the stress-strain curve might have some remarkable effects on the failure behavior of the structures so it is important to verify the same. Since crushed brick aggregates are weaker than natural aggregates, differences in the stress–strain curves from conventional concrete are observed. The forthcoming tables and graphs shows the stress-strain relation of concrete with different proportions of coarse aggregate replacement with crushed bricks.

Table 5.7- 0% Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	18.10	18.64
Strain	0.0000	0.0022	0.0051	0.0064	0.0086	0.0096	0.0010	0.0122	0.0137

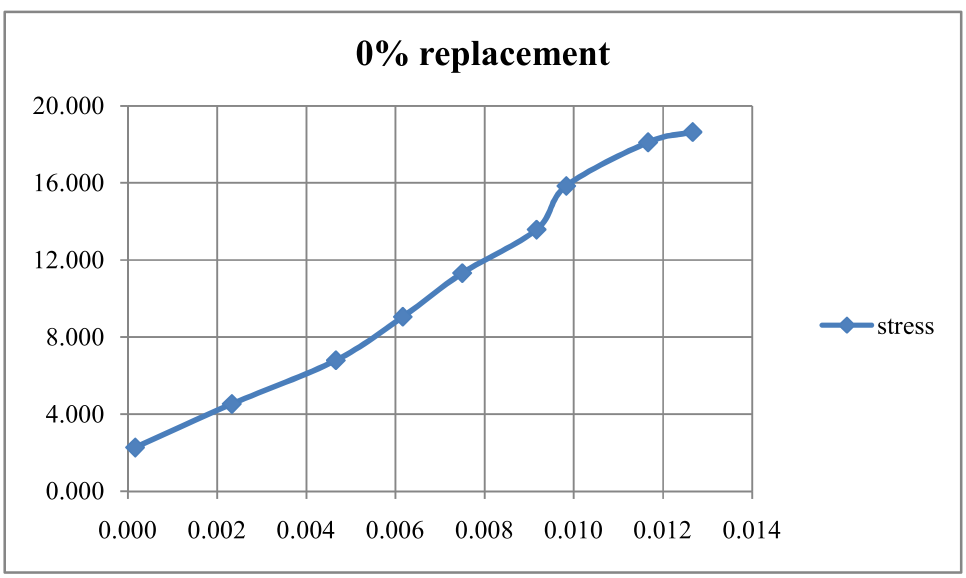

Figure 5.7- Stress strain curve for 0% replacement

Table 5.8- 10% Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	18.10	20.37	22.63	22.64
Strain	0.0010	0.0025	0.0033	0.0056	0.0062	0.0074	0.0083	0.0093	0.0098	0.0102	0.0111

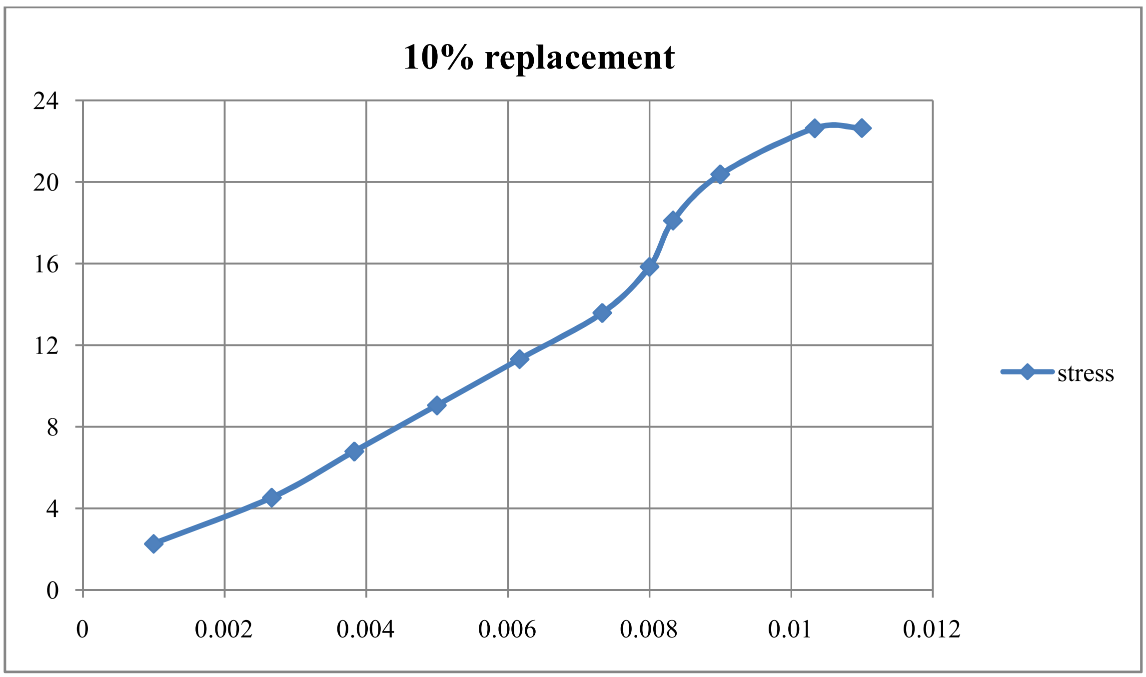

Figure 5.8- Stress Strain curve for 10% replacement

Table 5.9- 20% Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	18.10	18.67	18.68
Strain	0.0040	0.0063	0.0098	0.0105	0.0116	0.0122	0.0130	0.0143	0.0150	0.0161

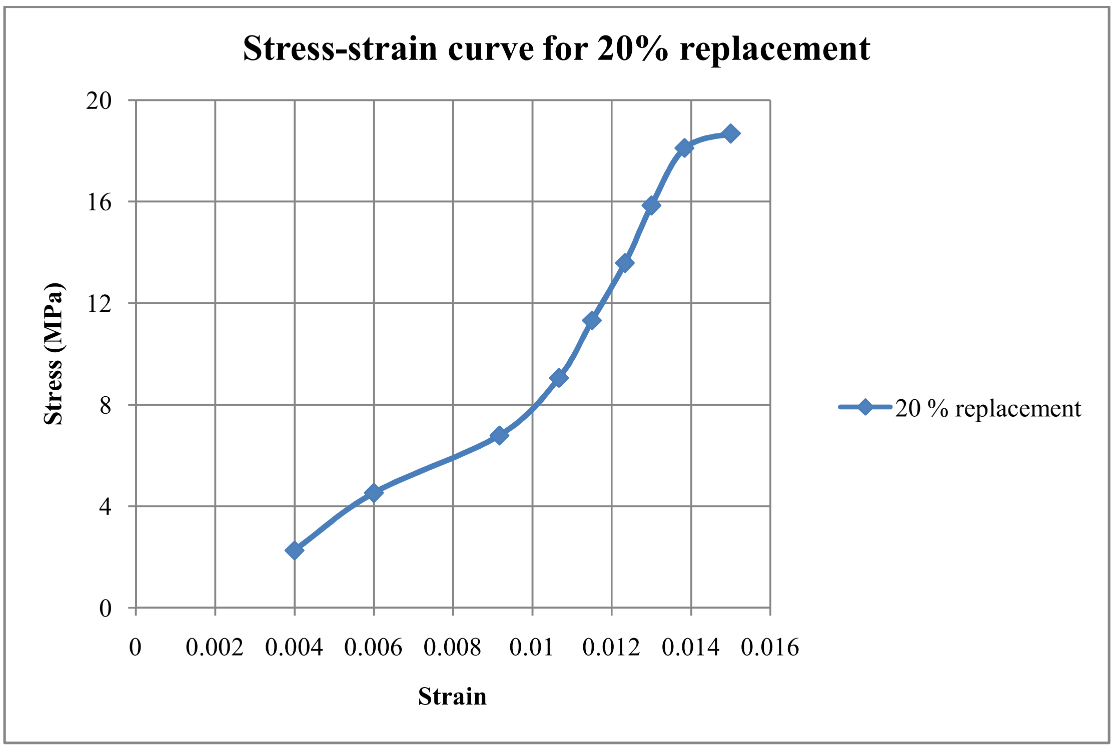

Figure 5.9- Stress Strain curve for 20% replacement

Table 5.10- 30 % Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	18.10	18.52
Strain	0.0011	0.0030	0.0039	0.0044	0.0050	0.0064	0.0069	0.0073	0.0086

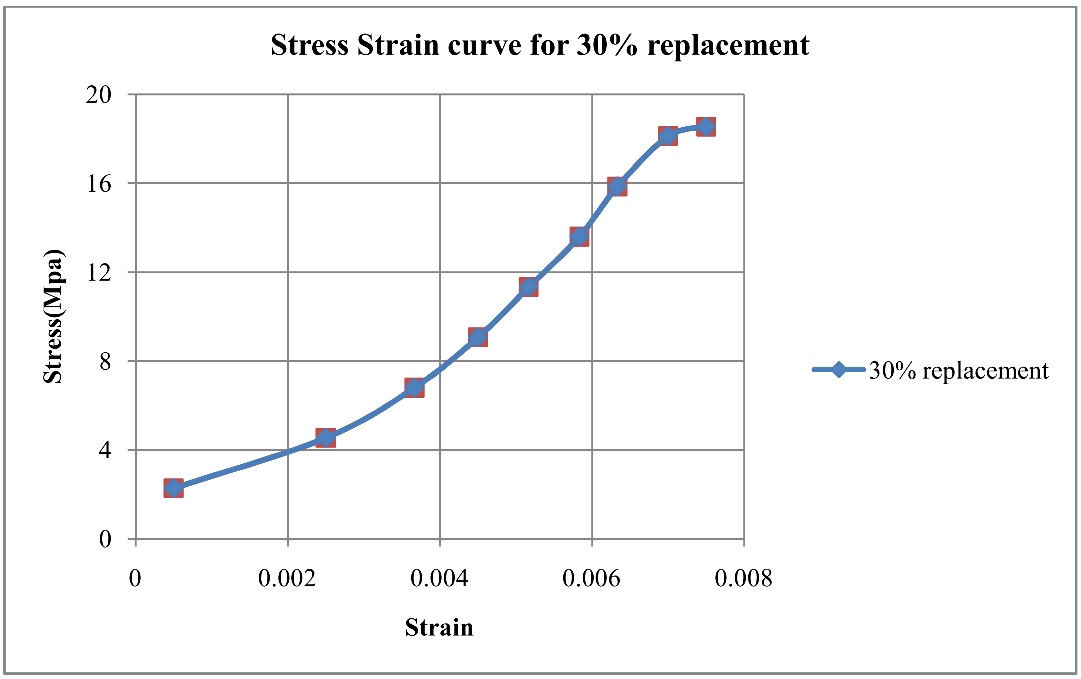

Figure 5.10- Stress Strain curve for 30% replacement

Table 5.11- 40 % Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	16.52
Strain	0.0010	0.0017	0.0025	0.0044	0.0052	0.0068	0.0100	0.0115

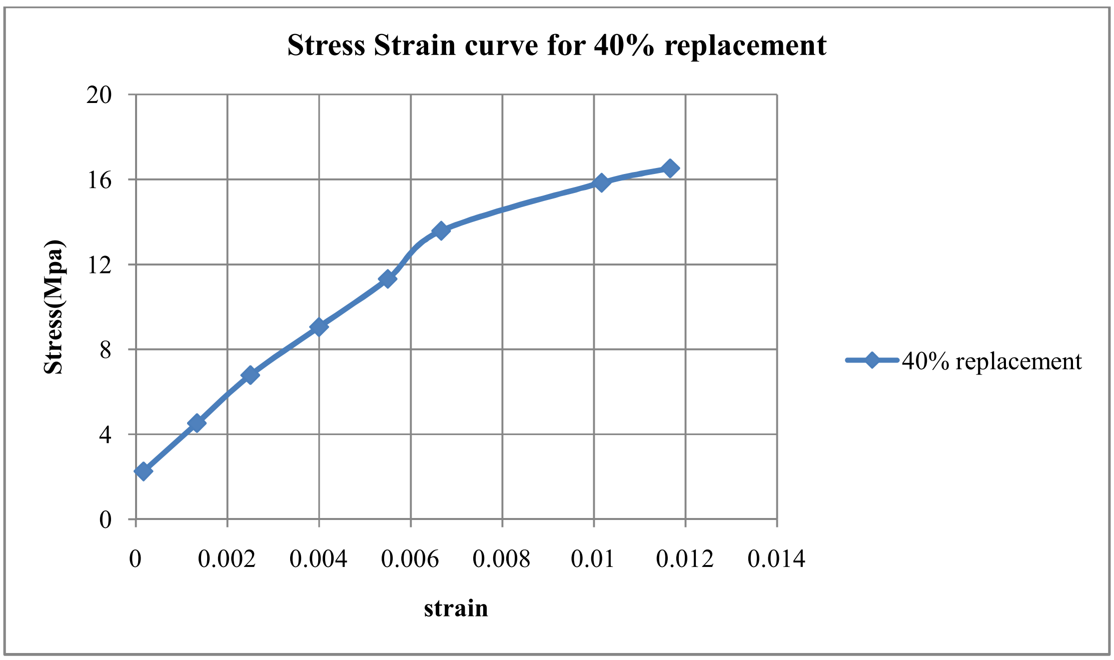

Figure 5.11- Stress Strain curve for 40% replacement

Table 5.12- 50 % Replacement

Stress	2.26	4.52	6.79	9.05	11.31	13.58	15.84	18.10	20.37	22.63	23.43
Strain	0.0005	0.0020	0.0030	0.0040	0.0042	0.0053	0.0062	0.0069	0.0076	0.0087	0.0119

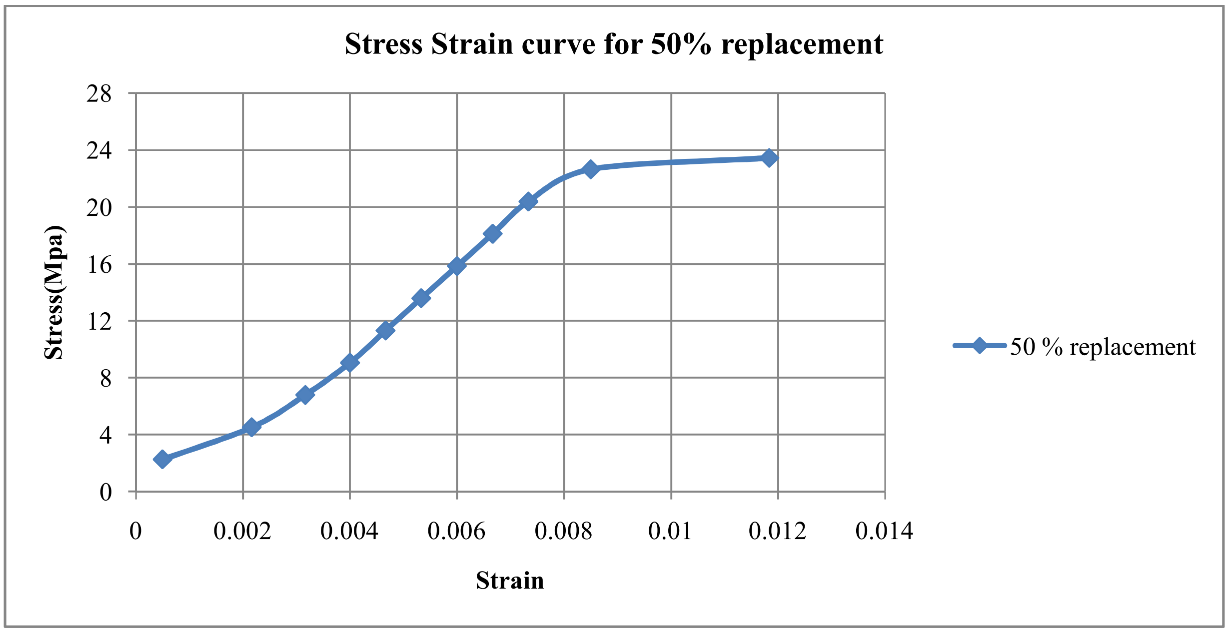

Figure 5.12-Stress Strain curve for 50% replacement

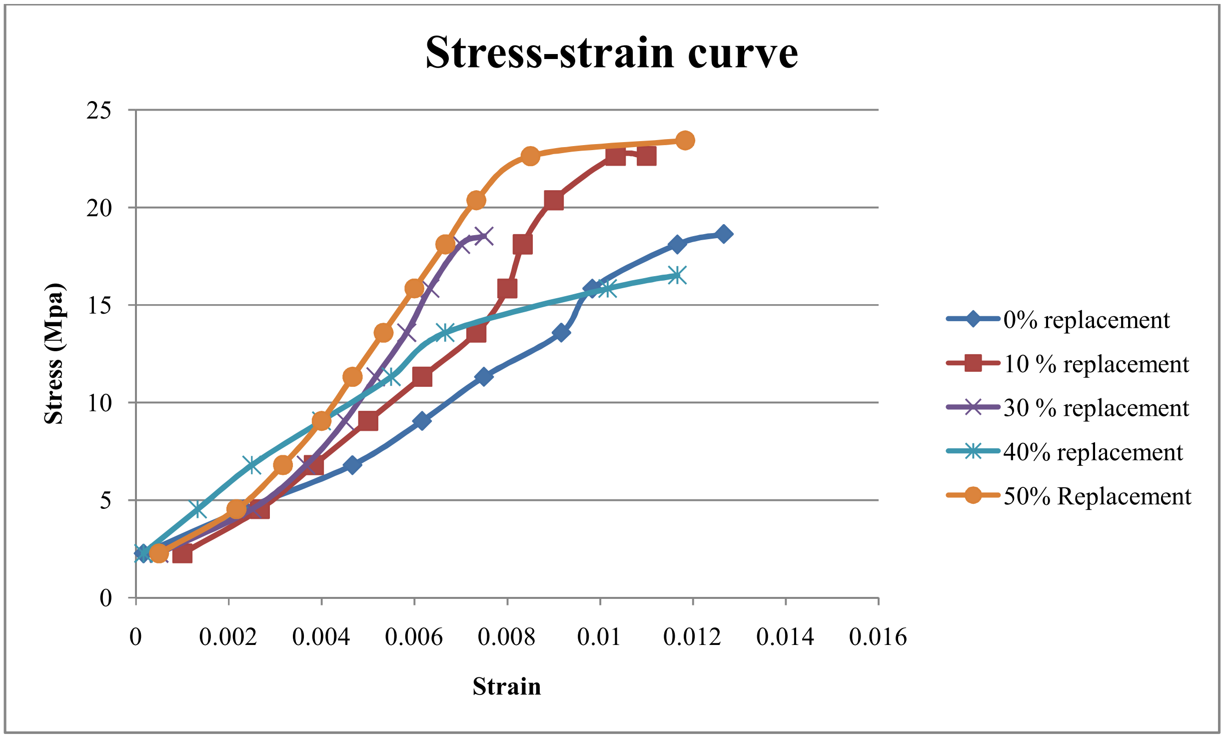

Figure 5.13 - Stress-strain comparison curve

CHAPTER 6 - CONCLUSIONS

Based on the experimental work done in this study, the following inferences are drawn:

- Crushed bricks can be suitably used for partial replacement of coarse aggregate in concrete production as they adhere to the various specifications of aggregates as specified in IS 383:1970.

- The workability of crushed brick concrete was observed to decrease with increase in the proportion of crushed brick aggregate due to the elated water absorption of crushed brick aggregates.

- The bulk density of the crushed brick concrete was observed to decrease by 15 % on 50 % replacement of coarse aggregates with crushed bricks, decreasing dead load of concrete member.

- The compressive strength of crushed brick concrete was observed to be lower than conventional concrete but it was increasing with increase in brick aggregate proportion up to 30 % replacement of natural aggregate then started decreasing on the further replacement.

- The tensile strength of concrete was observed to be higher than conventional concrete, maximum at 30 % replacement of natural aggregate then decreasing on further replacement.

- The experimental results clearly show that crushed bricks can be used as natural aggregates substitutes in percentages up to 30% with little compressive strength reduction and increased tensile strength.

- The stress-strain behaviour of crushed brick concrete was observed to be similar to conventional concrete.

- Crushed bricks concrete can be used in non structural elements like pavement blocks due to its lower performance than conventional concrete and lack of durability studies.

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ANNEXURE - 1

Concrete Mix Design

In this study M20 concrete mix design was prepared using IS 10262-2009. M20 mix design with 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate with crushed bricks was done. The following annexure gives the step by step mix design process and the mix proportions for M20 conventional concrete and with 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate with crushed bricks respectively.

Specified minimum strength	M 20
Maximum Aggregate Size	12.5 mm
Minimum cement content	240 kg/m^3
Maximum W/C ratio	0.60
Exposure	Moderate
Workability	Medium(75mm)
Type of Aggregate	Crushed angular
Maximum water content	186 kg/m^3

Sand 600 micron passing	43.10 %
Zone of sand	Zone 2
Target Mean Strength	
Standard Deviation	4
Value ‘t ‘ selected	1.65
Target Mean strength	26.6 MPa
Let us assume w/c ratio	0.50
Maximum water content for 12.5 mm MAS	186 kg/m^3

Calculation of Cement Content	
Cement Content	186/0.50 = 372 kg/m^3
Minimum cement content	220 kg/m^3 372 > 220 Hence Ok
Coarse Aggregate Proportion :-	
For zone 2 of fine aggregate and MAS=12.5mm the % coarse aggregate in total aggregate (for 0.5 w/c ratio) = 0.65 (65 %) corrected coarse aggregate = 65 % corrected fine aggregate = 100-65 = 35 %	
Specific Gravity of Coarse Aggregate	2.75
Specific Gravity of fine Aggregate	2.50

The forthcoming tables give the volumetric calculation and weight batching details of M20 concrete with different proportions of replacement of coarse aggregates with crushed bricks.

Volumetric calculations for Coarse Aggregate replacement by 0% Crushed brick aggregate

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372/(3.15*1000) – (186 / 1* 1000) = 0.67m^3
volume of aggregate	0.67 m^3
volume of coarse aggregate	65 % of volume of aggregate = 0.4355 m^3
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 1197.62 kg /m^3
volume of fine aggregate	35 % of volume of aggregate = 0.2345 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3

Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	1197.62 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50

Volumetric calculations for Coarse Aggregate replacement by 10% Crushed brick aggregate

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372 / (3.15*1000) – (186 / 1* 1000) = 0.67 m^3
volume of aggregate	0.67 m^3

volume of coarse aggregate	65 % of volume of aggregate = 0.4355 m^3
Volume of crushed brick aggregate	10% of volume of coarse aggregate = 0.04355%
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 1077.72 kg /m^3
Mass of Crushed Brick Aggregate	Specific gravity of crushed brick aggregate * volume * 1000 = 91.45 kg / m^3
volume of fine aggregate	35 % of volume of aggregate = 0.2345 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3
Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	1077.72 kg
Crushed Brick Aggregate	91.45 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50

Volumetric calculations for Coarse Aggregate replacement by 20% Crushed

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372 / (3.15*1000) – (186 / 1* 1000) = 0.67m^3
volume of aggregate	0.67 m^3
volume of coarse aggregate	65 % of volume of aggregate = 0.4355 m^3
Volume of crushed brick aggregate	20 % of volume of coarse aggregate = 0.0871%
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 958.1 kg /m^3
Mass of Crushed Brick Aggregate	Specific gravity of crushed brick aggregate * volume * 1000 = 182.91Kg / m^3

volume of fine aggregate	35 % of volume of aggregate = 0.2345 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3
Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	958.1 kg
Crushed Brick Aggregate	182.91 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50

Volumetric calculations for Coarse Aggregate replacement by 30% Crushed brick aggregate

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372 /(3.15*1000) – (186 / 1* 1000) = 0.67m^3
volume of aggregate	0.67 m^3
volume of coarse aggregate	65 % of volume of aggregate = 0.43 m^3
Volume of crushed brick aggregate	30% of volume of coarse aggregate = 0.130%
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 838.20 kg /m^3
Mass of Crushed Brick Aggregate	Specific gravity of crushed brick aggregate * volume * 1000 = 274.36 kg / m^3

volume of fine aggregate	35 % of volume of aggregate = 0.23 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3
Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	838.20 kg
Crushed Brick Aggregate	274.36 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50

Volumetric calculations for Coarse Aggregate replacement by 40% Crushed

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372 /(3.15*1000) – (186 / 1* 1000) = 0.67m^3
volume of aggregate	0.67 m^3
volume of coarse aggregate	65 % of volume of aggregate = 0.4355 m^3
Volume of crushed brick aggregate	40% of volume of coarse aggregate = 0.1742%
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 718.57 kg /m^3
Mass of Crushed Brick Aggregate	Specific gravity of crushed brick aggregate * volume * 1000 = 365.82 kg / m^3

volume of fine aggregate	35 % of volume of aggregate = 0.23 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3
Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	718.57 kg
Crushed Brick Aggregate	365.82 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50

Volumetric calculations for Coarse Aggregate replacement by 50% Crushed brick aggregate

Volume of Concrete	1 m^3
Volume of Concrete	(Mass of Cement/Specific Gravity of Cement*1000) +(Mass of Water/Specific Gravity of Water*1000) + (volume of aggregate)
Mass of Cement	372 kg
Mass of Water	186 kg
Volume of aggregate= Mass of Aggregate/Specific Gravity of Aggregate*1000)	1 – (372 / (3.15*1000) – (186 / 1* 1000) = 0.67m^3
volume of aggregate	0.67 m^3
volume of coarse aggregate	65 % of volume of aggregate = 0.4355 m^3
Volume of crushed brick aggregate	50% of volume of coarse aggregate = 0.21%
Mass of coarse aggregate	Specific gravity coarse aggregate* volume * 1000 = 598.81 kg /m^3

Mass of Crushed Brick Aggregate	Specific gravity of crushed brick aggregate * volume * 1000 = 457.27 kg / m^3
volume of fine aggregate	35 % of volume of aggregate = 0.23 m^3
Mass of fine aggregate	Specific gravity fine aggregate * volume * 1000 = 588.75 kg/m^3
Weight Batching	
Cement	372 kg
Water	186 kg
Coarse Aggregate	598.81 kg
Crushed Brick Aggregate	457.27 kg
Fine Aggregate	588.75 kg
w/c ratio	0.50