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Partial Replacement of Coarse Aggregate by Using Recycled Coarse Aggregate and Fly Ash in Concrete by Two Stage Mixing Approach

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Abstract - *The construction of concrete is growing across the country due to its strength, durability, better serviceability & overall economy in long run. The requirement is to develop best quality pavement sections, which can bear heavy loads. This can be achieved by using high compressive strength concrete (>40MPa) made up of hydraulic cement having fine & course aggregates. In the work included construction work is done with the help of wastage from industry. Fly ash is a by-product of burned coal from thermal plants and over burnt brick often known as the vitrified brick as it is fired at high temperature and for a longer period of time than conventional bricks. As a result, the shape is distorted and the absorption capacity is high. The strength is higher or equivalent to first class brick and it is used as supplementary material to improve the properties of cement concrete.*

The present study is done to develop pavement and concrete quality by partially replacement of aggregate and cement with over burnt brick & fly ash. The objective of study is to compare the strength characteristics of concrete which is achieved by concrete mixture. The work done in this study shows the effect on the behaviors of concrete produced from cement and aggregate with combination of fly ash and over burnt bricks at different proportions on the mechanical properties of concrete such as compressive strength, flexural strength, and tensile strength. The replacement of aggregate were done at four level are 25%, 50%, 75% and 100% with over burnt brick and cement by 10% with fly ash. The tests on hardened concrete were destructive in nature which includes compressive test on cube for size (150mm×150mm×150mm) and flexural strength on beam (150mm×150mm×700mm) and on cylinder (150mm×300mm) at 7 days and 28 days of curing as per IS 516-1959. The samples were prepared with W/C ratio as 0.45. The result so obtained showed that it is possible to achieve saving in aggregate and cement if replacement is done. The study proves to be useful in area where traffic load is less, also will use wastage released from thermal plants & rice mills also reduces economy as this material is easily available. The waste material from industries is in bulk amount, as lesser amount of their application, we can use it as supplementary aggregate and cementing materials so these can be used as filling soil in subgrade of highway pavement.

Key Words: Recycled Coarse Aggregate (over burnt brick), Fly Ash, , Two Stage Mixing Approach (TSMA), Normal Mixing Approach (NMA), Water - Cement ratio (W/C) Workability, Compressive Strength, Flexural Strength, Tensile Strength.

1. INTRODUCTION

Concrete is the second most widely used material for construction in the world. Major constituents of concrete is coarse aggregate, fine aggregate, water and cement. Cost of aggregate is rapidly increasing also the availability of the aggregate is getting decreased. Cost of concrete mainly depends on coarse aggregate. 70% - 80% of volume of concrete is consumed by coarse aggregate.

The conservation in natural resources is reduced by the replacement of over burnt brick bat in concrete. Over burnt brick waste reduces the weight of concrete maintains strength and its performance. Many places where natural aggregates are not easily available then brick bats are used there. These brick bats they are absorbed less water and are hard in nature. Burning of good quality of brick leads to the production of over burnt brick. Since, the shape of over burnt brick is distorted, it is considered as waste. Although it is considered as waste it can be used as a source of aggregate for construction purpose. They are very helpful in solving the problem of shortage of aggregate.

Environmental problems due to curing and transportation of aggregates have also been solved by the use of recycled materials. Use of recycled material in concrete saves both resources and time. This recycled concrete are widely used in road construction work, load grade concrete production work, drainage and brick work, backfill of retaining walls and block work for low cost housing.

Fly ash is produced of coal fired power plant that is composed of the particulates which are driven out of coal-fired boilers together with the fuel gases, which has also been used in this project. Over burnt brick is used as a replacement for natural coarse aggregate in concrete to identify the physical and chemical properties for it. During construction large amount of waste generates that pollutes our environment and also destroy the cultivated land. Fly ash increases the strength of construction material.

2. MATERIAL SPECIFICATION

1.1 The reason behind using the over burnt brick bats for partial replacement of coarse aggregate

- The production of over burnt brick is done by burning of good quality of brick along with raw materials.
- Over burnt bricks are considered as wastage due to their distorted shape.
- The over burnt brick which is usually considered as wastage, can be good replacement of aggregate for construction.
- It is also maintain the problem due to shortage of aggregate.
- In a certain places where natural aggregate are not available as sufficient in that matter, the brick bats of these over burnt brick can be used as one of the type of aggregate.

1.2 Material Properties

Here, in this project we are using the material which is locally available in Bihta, Patna (Bihar) and all the laboratory tests regarding the material and to know their properties before using it in preparation of concrete for making the samples to be tested were done in concrete and road material lab, NSIT Bihta.

1.2.1 Fine Aggregate

We were used the Falgu river sand which is locally available in near-by of Bihta, Patna (Bihar) as fine aggregate and it contains these following properties are mention below

Properties	Results
Specific gravity	2.67
Unit weight	1.671 gm/cc
Fineness modulus	2.60
Water absorption	0.44 %
Bulking of sand	25 %

To know the grading of sand, we have to do the sieve analysis and then after doing of sieve analysis, we get to know that the sand we have, it was of Zone-II as per IS 383 – 1970. Here is the data of sieve analysis shown below in tabular form-

Table -1: Sieve Analysis of Fine Aggregate

IS Sieve (mm)	Weight Retained (Kg)	Cumulative Weight (Kg)	Percentage Retained (%)	Percentage Passing (%)
4.75	0.036	0.036	3.60	96.40
2.36	0.028	0.064	6.40	93.60
1.18	0.142	0.206	20.60	79.40
600µ	0.160	0.366	36.60	63.40
300µ	0.430	0.796	79.60	20.40
150µ	0.189	0.985	98.50	1.50

1.2.2 Coarse Aggregate

For the coarse aggregate we were used the locally available black crushed stone (Pakur stone) in Bihta, Patna. The size of this aggregate was of between 20mm to 10mm mainly of coarse aggregate as per IS 2386 – 1963 which give us following values of test and their respective results as

Properties	Results
Aggregate crushing value	24.2 %
Aggregate impact value	29.1 %
Specific gravity	2.74
Water absorption	0.94 %
Unit weight	1.60 gm/cc
Fineness modulus	6.15

These are the observed value and remarks of locally available coarse aggregate after sieve analysis is given in tabular form below-

Table -2: Sieve Analysis of Coarse Aggregate of 20mm size

IS Sieve (mm)	Weight Retained (Kg)	Cumulative Weight (Kg)	Percentage Retained (%)	Percentage Passing (%)	Rem - arks
40	0.000	0.000	0.00	100	60%
20	0.473	0.473	9.46	90.54	
12.5	3.465	3.938	78.76	21.24	
10	0.458	4.396	87.92	12.08	
4.75	0.560	4.956	99.12	0.88	

Table -3: Sieve Analysis of Coarse Aggregate of 10mm size

IS Sieve (mm)	Weight Retained (Kg)	Cumulative Weight (Kg)	Percentage Retained (%)	Percentage Passing (%)	Rem - arks
40	0.000	0.000	0.00	100	40 %
20	0.000	0.000	0.00	100	
12.5	0.000	0.000	0.00	100	
10	1.420	1.420	28.40	71.60	
4.75	3.314	4.734	94.68	5.32	

1.2.3 Fly Ash

- The sample of fly-ash was taken 400mm from National thermal power plant, Bihta (Patna) were used in this study.

- The sample of this fly ash satisfied the necessary requirement of IS 3312 (Part I).
- Here fly ash is used as a partial replacement of cement. Only 10% of total cement is getting replaced by using fly ash, in all cases of the experiment.
- There are mainly two types of fly ash which are commonly used in concrete, i.e. "Class C" and "Class F", but we have used the fly ash of "Class F" in our project.
- The fly ash of Class F are produced from bituminous or anthracite classes.
- The fly ash of "Class F" contains two calcium fly ashes with carbon contents less than 5%, and it may be as high as 10% sometimes.
- The performance of fly ash of "Class F" mainly depends on or may be vary depending on their physical properties and interaction of ash with cement in concrete.
- The fly ash of "Class F" having only the pozzolanic properties.
- For fly ash of "Class C" :-
  - The fly ash of "Class C" contains high calcium fly ashes with carbon content less than 2%.
  - In general, the fly ash of "Class C" are produced from burning of lignite coals or sub-bituminous from industries.
  - The performance of fly ash of "Class C" mainly depends or may be vary depending and interaction of ash with cement in concrete.
  - It (Class C) has both cementitious and pozzolanic properties.

1.2.3 Cement

- In this project, we are going to use ordinary Portland cement (OPC) of grade – 43 of brand Ambuja cement as per according to (Indian Standard) IS 8112 - 1989.
- In this project, we are going to use ordinary Portland cement (OPC) of grade – 43 of brand Ambuja cement as per according to (Indian Standard) IS 8112 - 1989.
- This cement has a specific growing to be 3.005.
- The basic ingredient of cement of concrete is an ordinary Portland cement. Here concrete is formed in such a way that firstly we are going to make a paste of Portland cement with water that binds with sand and rock to harden.
- The manufacturing of cement is done through a chemical combination of calcium, silicon, iron and other ingredients into controlled way.
- Here OPC of 43 grade is used for the entire work.
- These are the following physical characteristic of having an OPC cement of 43- grade as per IS- 8112 : 1989 –
  - Specific gravity – 3.005
  - Fineness of cement – 334 m^2/kg
  - Soundness of cement –
    (a) Le – Chateleir- 1.5
    (b) Autoclave (%)- 0.02
  - Initial setting time – 44 minute
  - Final setting time – 255 minute
  - Consistency of cement – 30%
  - Compressive strength –
    (a) 7 days- 32.46 MPa
    (b) 28 days- 45.14 MPa

1.2.4 Over Burnt Brick Aggregate

Bricks are durable and versatile building and construction material having good load bearing properties.

- The bricks are burnt up to temperature of 800-900 degree centigrade in the brick kiln. Therefore this type of bricks is known as over burnt bricks and is also known as Jhama bricks.
- Here, in this project we are using over burnt brick aggregate which is locally available near Bihta, Patna (Bihar) area.
- These are the following properties of over burnt bricks which are mentioned below in tabular form-

Properties	Results
Size	20 mm – 10 mm
Shape	Angular
Unit Weight	0.9386 gm/cc
Water Absorption	4.67 %
Specific Gravity	1.74
Fineness Modulus	2.98

1.2.4 Water

Here, we are using water for mixing, curing purpose, so it should be clean, portable and fresh at the same time it should be free from any bacteria, because water is a key ingredient in the manufacture of concrete.

In this project, we are using the portable water which is locally available in our NSIT college campus which is situated at Bihta, Patna (Bihar).

2. METHODOLOGY

2.1 Nominal mix approach (NMA)

NMA follows these following steps for preparing the concrete mix design-

- Firstly, we are going to mix coarse and fine aggregate together with their required optimum quantities.
- Then after proper mixing of fine and coarse aggregate, we are adding the water and cement in a proper way and mix it properly to get the desired concrete mix.

2.2 Two stage mix approach (TSMA)

TSMA follows the following steps-

- Mixing of coarse and fine aggregate together at least for 60 second and then adding the half water for the specimen is added and mixing it throughout for another 60 second.
- Now, add the remaining cementitious material and mix it properly for 30 second.
- The remaining water for specimen is added and mixed it properly for at least 120 second.

The procedure of TSMA, which is specific approach creates a thin layer of cement slurry on the outer surfaces of recycled aggregate, which is passes to get into the porous old mortar and also fills the old cracks and voids.

3. EXPERIMENTAL OBSERVATION

3.1. Mixing Details

The following table shows the experimental observation of the test samples made from two stage mix approach (TSMA) and nominal mix Nominal mix approach (NMA).

- M-30 (10-25) signifies the specimen mix having 10% fly ash and 25% RCA content.
- M-30 (10-50) signifies the specimen mix having 10% fly ash and 50% RCA content.
- M-30 (10-75) signifies the specimen mix having 10% fly ash and 75% RCA content.
- M-30 (10-100) signifies the specimen mix having 10% fly ash and 100% RCA content.

3.2. Workability

Workability is the ease with which a concrete mix can be handled from the mixer to its finally compacted shape. Concrete is workable if it is easily transported, placed, compacted and finished without any segregation.

Table -4: Workability Test Data

Sl. No.	Designation of Cubes	Slump (mm)	Percentage (%) of Over Burnt Brick	Percentage (%) of Fly Ash
1	A-0	27	0	10
2	A-1	34	25	10
3	A-2	43	50	10
4	A-3	49	75	10
5	A-4	52	100	10

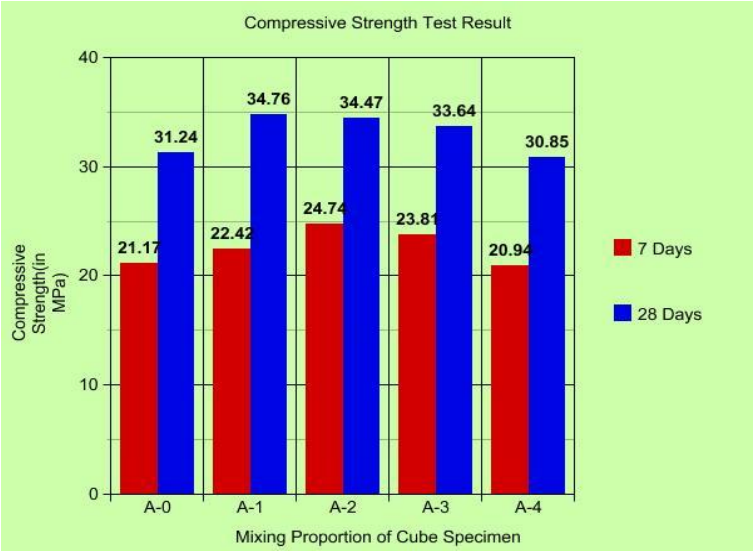
3.3 Compressive Strength

Compressive strength of concrete is the strength of hardened concrete measured by compression test. Compressive strength of concrete is a measured of the concrete's ability to resist loads which tends to compress it. It is measured by crushing cubical and cylindrical concrete specimen in the compression testing machine. Compressive strength test was carried out on 150mm × 150mm × 150mm cube specimen and 150mm × 300mm cylinder specimen. Strength of cube and cylinder were calculated after 7 days and 28 day. The compressive strength of machine has capacity of 2000 kN.

Table -5: Compressive Strength Data

Name of Cube	Mix Design	Percentage (%) of Over Burnt Brick	Percentage (%) of Fly Ash	Comp. Strength after 7 Days (N/mm²)	Comp. Strength after 28 Days (N/mm²)
A-0	M 30	0	10	21.17	31.24
A-1	M 30	25	10	22.42	34.76
A-2	M 30	50	10	24.74	34.47
A-3	M 30	75	10	23.81	33.64
A-4	M 30	100	10	20.94	30.85

Graph chart 1: Compressive Strength Test Result



3.4 Split Tensile strength

The strength of concrete is ability of concrete to resist tensile force or stress applied to it. Tensile strength of concrete was tested by preparing specimen mould of standard cylinder of diameter 150mm and length of 300mm. the test was conducted in accordance with IS 5816:1999. The split tensile strength was calculated after 7 days and 28 days.

Split tensile strength calculated as:-

$$f_{ck} = 2P / \pi LD$$

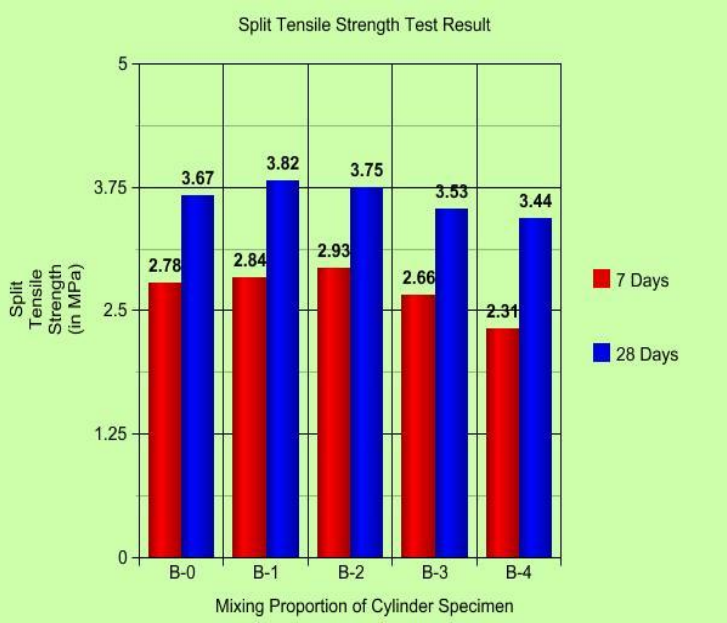
where,

P- Maximum load applied to the specimen (in Newton),
L- Length of the specimen (in mm)

D- Cross-sectional dimension of specimen (in mm)

Table -6: Split Tensile Strength Data

Name of Cylinder	Mix Design	Percentage (%) of Over Burnt Brick	Percentage (%) of Fly Ash	S. Tensile Strength after 7 Days (N/mm²)	S. Tensile Strength after 28 Days (N/mm²)
B-0	M 30	0	10	2.78	3.67
B-1	M 30	25	10	2.84	3.82
B-2	M 30	50	10	2.93	3.75
B-3	M 30	75	10	2.66	3.53
B-4	M 30	100	10	2.31	3.44



Graph chart 2: Split Tensile strength

3.5 Flexural strength

Flexure strength represents the highest stress experienced within the material at its moment of yield. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 150mm × 150mm × 700mm concrete beams with a span. Flexural test on concrete can be conducted using either three point load test (ASTM C78) or center load test (ASTM C293). Flexural strength was calculated after 7 days and 28 days.

Flexural strength of the specimen calculated as:-

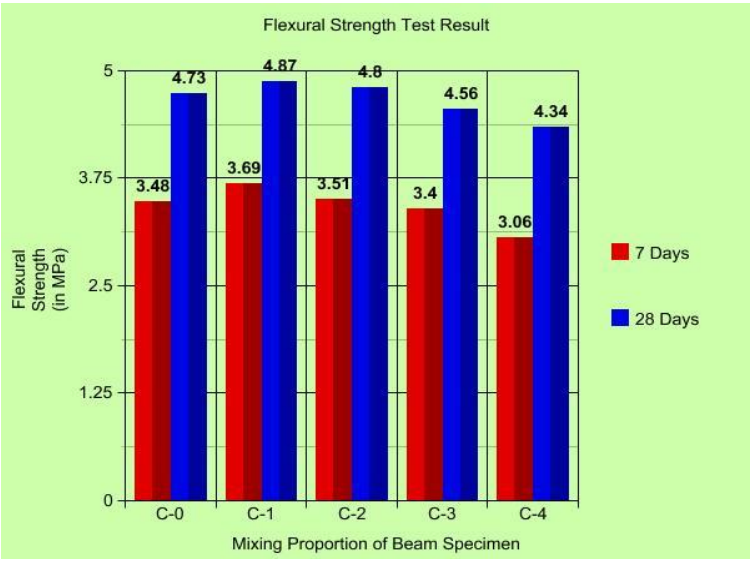
$$F_b = (Pl) / (bd^2)$$

where,

P- Maximum load applied to the specimen (in Newton),
l- Supported length of the specimen (mm)
b- Measured width of the specimen (mm)
d- Measured depth of the specimen at the point of failure (mm)

Table -7: Flexural Strength Data

Name of Beam	Mix Design	Percentage (%) of Over Burnt Brick	Percentage (%) of Fly Ash	Flexural Strength after 7 Days (N/mm²)	Flexural Strength after 28 Days (N/mm²)
C-0	M 30	0	10	3.48	4.73
C-1	M 30	25	10	3.69	4.87
C-2	M 30	50	10	3.51	4.80
C-3	M 30	75	10	3.40	4.56
C-4	M 30	100	10	3.06	4.34



Graph chart 3: Flexural strength

4. RESULTS

The experimental analysis that provides us, the following results as

- The compressive strength of M-30 grade nominal concrete made by NMA gives 7 days and 28 days strength as 21.17 MPa and 31.24 MPa respectively. The same mix design shows the split-tensile strength at 7 days and 28 days as 2.78 MPa and 3.67 MPa respectively. And the flexural strength at 7 days and 28 days as 3.48 MPa and 4.73 MPa respectively.
- Using TMSA, addition of 10% fly ash, the specimen made by 25% RCA gives compressive strength at 7 days and 28 days as 22.42 MPa and 34.76 MPa respectively. The same mix design shows the split-tensile strength at 7 days and

28 days as 2.84 MPa and 3.82 MPa respectively. And the flexural strength at 7 days and 28 days as 3.69 MPa and 4.87 MPa respectively.

- Using TMSA, addition of 10% fly ash, the specimen made by 50% RCA gives compressive strength at 7 days and 28 days as 24.74 MPa and 34.47 MPa respectively. The same mix design shows the split-tensile strength at 7 days and 28 days as 2.93 MPa and 3.75 MPa respectively. And the flexural strength at 7 days and 28 days as 3.51 MPa and 4.80 MPa respectively.
- Using TMSA, addition of 10% fly ash, the specimen made by 75% RCA gives compressive strength at 7 days and 28 days as 24.81 MPa and 33.64 MPa respectively. The same mix design shows the split-tensile strength at 7 days and 28 days as 2.66 MPa and 3.53 MPa respectively. And the flexural strength at 7 days and 28 days as 3.40 MPa and 4.56 MPa respectively.
- Using TMSA, addition of 10% fly ash, the specimen made by 100% RCA gives compressive strength at 7 days and 28 days as 20.94 MPa and 30.85 MPa respectively. The same mix design shows the split-tensile strength at 7 days and 28 days as 2.31 MPa and 3.44 MPa respectively. And the flexural strength at 7 days and 28 days as 3.06 MPa and 4.34 MPa respectively.

5. CONCLUSIONS

Samples after casting were tested and gave the above results depicted by graph chart 1, 2 and 3. The outcome of this work reveals that concrete made by replacement of 25% and 50% RCA and addition of 10% fly ash using TSMA gives more compressive as well as split-tensile and flexural strength for both 7 days and 28 days strength that the referred nominal concrete specimen made by NMA. However on using 75% RCA the concrete shows increase in compressive strength but a decrease in split-tensile and flexural strength. On using 100% RCA, the concrete shows decrease in compressive as well as split-tensile and flexural strength then the nominal concrete.

The maximum 28 days compressive, split-tensile and flexural strength is obtained by concrete made by using TSMA involving replacement of 25% RCA and addition of 10% fly ash. This concrete shows made will be strong as well as cost effective and can be used in any constructional works in place of normal concrete.

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