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Investigations on Masonry Strength of Bricks Developed from Mine Tailings

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Abstract—*This paper aims to investigate the response to determine unreinforced masonry strength of newly developed bricks from mine tailing in order to manufacture green bricks keeping in view the economy, material availability and subsequent carbon emission reductions. Attempts have been made to view waste i.e. mine rejects as a potential raw material for brick making. Objectives involve analyzing the mine rejects for its proprieties to check its suitability as a brick making material by conducting preliminary visual tests followed by other physical laboratory tests. Later, conducting an experimental study on masonry prisms under compressive loading in the form of UDL with 0%, 50% and 75% eccentricity. Savings in mortar and reduction in carbon emissions are the two major contributions observed in the study.*

Keywords*: Mine tailings; carbon credits; masonry prisms; bricks.*

1. INTRODUCTION

1.1GENERAL

In the Civil Engineering industry most CO2 emissions are due to the production of construction materials and construction of structure. The energy consumption during the operational phase of the building depends on a wide range of interrelated factors such as climate and location, level of demand, supply and source of energy, function and use of building, building design and construction material and the level of income and behavior of occupants.

With the advent of industrialization, modernization and new technological developments on one side we are witnessing deterioration, degrading climate change leading to resource crunch on the other side. This grim situation forces Civil Engineering community to innovate and identify eco-friendly materials for modern construction as an alternative building material modifying the basic building block i.e. brick. This study involves usage of Mine tailings in developing bricks.

1.2 MINE TAILINGS

Mine rejects or mine tailings are basically the end products after the beneficiation of ore which are not of any use to the plant. These rejects over a period of time get piled up and pose an environmental threat. Their production includes the following three steps:

1. Crude ore extracted from the mine has to meet certain standards of size and quality which is thus dry screened and crushed in order to produce calibrated ore.
2. Inferior quality of ore having high alumina and silica contents is subjected to the process of beneficiation. Ore is scrubbed and screened along with water and passed through different equipments to improve its quality by eliminating fine ferruginous clays, quartz etc.,
3. Good quality ore produced is sold in the market while the tailings are in a slurry form with 8-10% solids. These tailings are then directed to thickener to recover water and rest thickened tailing slurry is pumped to tailing ponds.

1.2 CARBON CREDITS

Carbon credits are tradable permit scheme which are the outcome of Kyoto Protocol and are a simple non compulsory way to counteract the green house gasses that contribute to climate change and global warming. Emissions are reduced by giving a monetary value to the cost of polluting the air. It is a new currency and represents one tone of CO_2 either removed from the atmosphere or saved from being emitted. They are also known as emission permits and is a subject under Environment and Pollution Control. They can be treated as certificates awarded to countries that are successful in reducing emissions of green house gasses. Carbon credits can be awarded in the following two ways:

1. Sequestration (capturing or retaining CO_2 from atmosphere) such as afforestation and reforestation activities.
2. CO_2 saving projects such as use of renewable energies.

Carbon credits need to be authentic and scientific with necessary verification. It is an innovative method of controlling emissions using the free market.

1.3MASONRY PRISM TEST

Compressive strength of masonry is an important performance characteristic used by engineers in the design of masonry structures. It may be defined as maximum compressive force resisted per unit of net-cross sectional area of masonry. Primarily masonry walls are vertical load bearing elements in which resistance to compressive stress is the predominant factor in design. Compressive strength of prism must be equal to or greater than strength of masonry used in structural design.

As per IS 1905-1987 Clause 5.4.1 Appendix B the basic compressive strength of masonry is tested by prism test[2]. Masonry prisms are built as a representative of actual construction with a minimum height-to-thickness ratio requirement. It is a combination of masonry units and mortar with masonry being laid in stack bond and are examined extensively as prototypes of the buildings. Care is taken to ensure that prepared masonry prisms have similar materials, conditions and bonding arrangements as that of the real structure. In building the prism, moisture of the units at the time of laying, the consistency of mortar, the thickness of mortar joints and workmanship are ensured to be similar if not the same.

2. METHODOLOGY ADOPTED

Primary consideration to be made is to determine the feasibility of soil for brick production i.e. to check its quality and feasibility. In the present scenario mine tailings are being used as a substitute to clay used in conventional bricks. Mine rejects are the undesirable fragments left behind after the process of beneficiation of ore. These rejects pose a great environmental threat from the point of view of its disposal and storage. Prolonged process of washing ore has left behind huge ponds of such rejects resulting in environmental degradation. Thus from the viewpoint of availability of soil for brick making it may be concluded that there is no dearth of raw material.

After concluding that sufficient raw material was available the next step to be considered was the suitability of these mine rejects for brick making. This included a series of tests to be performed to correctly analyze and understand the characteristics and behaviour of mine rejects so as to use them as a potential source of raw material.

There are mainly two methods to determine the parameters of the soil for brick making: Practical field low cost methods and complex laboratory analysis. Low cost field methods test for the soil are mainly performed to obtain a first impression of its properties to produce good quality bricks. For confirmative tests it is always recommended to get the soil tested for its constituents. Visual tests were performed as a first step in this regard to have a rough idea of soil characteristics and to classify them as being claye, silty or granular. Under visual tests following were performed:

1. Smear test
2. Wet ball test
3. Dry ball test
4. Sedimentation test and
5. Shape test

From the visual tests it could be concluded that mine tailings basically exhibited clayey nature. Physical tests were however performed for confirmation. Various Laboratory tests performed include:

1. Specific Gravity Test
2. Determination of Liquid Limit
3. Determination of Plastic Limit
4. Determination of Shrinkage Limit
5. Proctor Test
6. Masonry strength of prisms
7. Determination of carbon credits

All the above tests were conducted on mine tailings as per IS2720[1]

3. RESULTS

Entire experimental programme was structured into four major setups namely:

1. Visual tests
2. Laboratory tests
3. Determination of Prism strength
4. Calculation of Carbon Credits

After performing the visual tests following observations were made:

1. Smear Test

Soil when felt did not have any coarse or granular fragments. Soil formed a thin film which was smooth, shiny and evenly spread. After drying layer was found to be sticky to the hand and did not fall off easily.

2. Wet Ball Test

Surface of the ball when observed was found to be smooth and uniform. Upon dropping the ball from shoulder height, ball retained its shape and did not crumble into pieces.

3. Dry Ball Test

Surface of the ball when observed was found to be smooth and uniform even when dried. Upon dropping the ball from shoulder height ball crumbled into lumps but did not crumble into fine grains.

4. Sedimentation Test

There was no separation of different layers. Entire sediment layer was uniform in size and distribution.

5. Shape Test

While making the ball, water was not released out. Washing hands was difficult due to sticky nature of soil.

All the above observations pointed to the fact that mine tailings were claye in nature and may be used as a potential brick building material. For confirmation various tests like Specific gravity test, Atterberg limits test and Proctor tests were carried out in the laboratory adopting standard codal procedure.

After performing the laboratory tests following observations were made:

1. Specific Gravity Test Results

Table 1: Results of Specific Gravity test.

Sr. No	Samples	Specific Gravity
1.	Sample 01 (R3)	3.11
2.	Sample 02 (R2)	2.58
3.	Sample 03 (TS-2/F)	2.89
4.	Sample 04 (TS-3/F)	2.96

2. Liquid limit test

Table 2: Results of liquid limit test.

Sr. No	Samples	Liquid limit
1.	Sample 01 (R3)	34.87
2.	Sample 02 (R2)	36.89
3.	Sample 03 (TS-2/F)	32.35
4.	Sample 04 (TS-3/F)	41.46

3. Plastic limit test

Table 3: Results of liquid limit test.

Sr. No	Samples	Plastic limit(%)
1.	Sample 01 (R3)	100
2.	Sample 02 (R2)	100
3.	Sample 03 (TS-2/F)	21.54
4.	Sample 04 (TS-3/F)	Non Plastic

4. Shrinkage limit test

Table 4: Results of shrinkage limit test.

Sr. No	Samples	Shrinkage limit(%)
1.	Sample 01 (R3)	40.16
2.	Sample 02 (R2)	28.87
3.	Sample 03 (TS-2/F)	50.85
4.	Sample 04 (TS-3/F)	29.60

5. Proctor Test

Table 5: Results of Proctor Test

Sr. No	Samples	OMC (%)	MDD(g/cm^3)
1.	Sample 01 (R3)	19.96	2.2
2.	Sample 02 (R2)	22.29	1.99
3.	Sample 03 (TS-2/F)	21.60	2.11
4.	Sample 04 (TS-3/F)	21.02	2.14

6. Behaviour under Uniformly Distributed Load

Table 6: Comparative results of bricks under UDL

Type of brick		101 Mark	Fly ash	FRI
Type of loading		UDL	UDL	UDL
Load at first crack	N	16000	26000	32000
Load when crushed	N	46000	128000	138000
Masonry strength at first crack	(N/m^2)	625454.5	804664	990355.7
Masonry strength at crushing	(N/m^2)	1798182	3961423	4270909

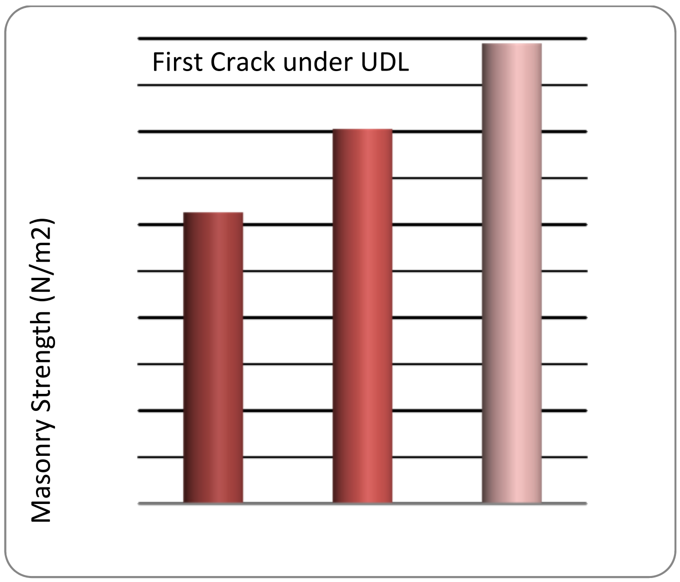

Fig. 1: Masonry strength at appearance of first crack under UDL.

7. Behaviour under Point Load At 0% Eccentricity

Table 7: Comparative study of bricks under point load at 0% eccentricity.

Type of brick		101 Mark	Fly ash	FRI
Type of loading		Point (0%)	Point (0%)	Point (0%)
Load at first crack	N	10000	8000	10000
Load when crushed	N	16000	12000	14000

Masonry strength at first crack	(N/m^2)	390909.1	247588.9	309486.2
Masonry strength at crushing	(N/m^2)	625454.5	371383.4	433280.6

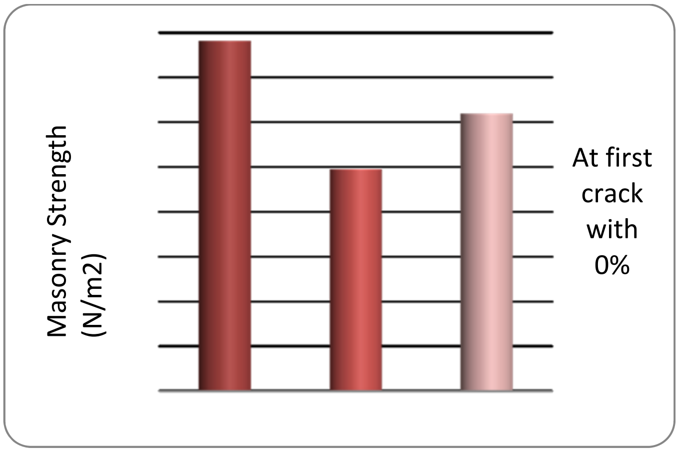

Fig. 2: Masonry strength at appearance of first crack under point load at 0% eccentricity.

8. Behaviour under Point Load At 75% Eccentricity

Table 8: Comparative study of bricks under point load at 75% eccentricity.

Type of brick		101 Mark	Fly ash	FRI
Type of loading		Point 75%	Point 75%	Point 75%
Load at first crack	N	6000	6000	16000
Load when crushed	N	6000	6000	16000
Masonry strength at first crack	(N/m^2)	234545.5	185691.7	495177.9
Masonry strength at crushing	(N/m^2)	234545.5	185691.7	495177.9

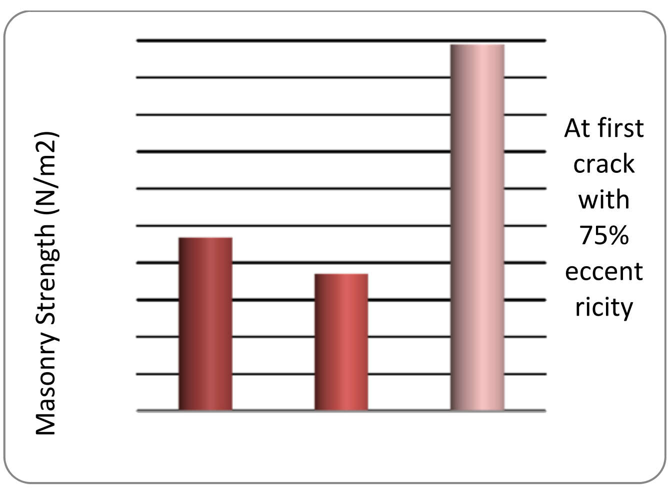

Fig. 3 : Masonry strength at appearance of first crack under point load at 75% eccentricity.

9. Calculation of carbon credits for 101 mark bricks

Table 9: Carbon emission for every 1000 bricks produced.

Material	Quantity Kg	Embodied Carbon $KgCO_2/Kg$	Quantity of Carbon emitted	Quantity in Tones
Sand	1678.00	0.005	8.39	0.008
Clay	839.40	0.22	184.67	0.185
Lime	279.80	0.74	207.05	0.207
Fuel				0.3
Total 0.7001				

10. Calculation of carbon credits for flyash bricks

Table 10: Carbon emission for every 1000 bricks produced.

Material	Quantity kg	Embodied Carbon $KgCO_2/Kg$	Quantity of Carbon emitted	Quantity in Tonnes
Gypsum	153.15	0.12	18.38	0.018
Lime	459.45	0.74	339.99	0.340
Flyash	2144.00	0	0.00	0.000
Sand	306.3	0.005	1.5315	0.0015
Cement	260.3	0.83	216.049	0.2160
Total 0.5760				

11. Calculation of carbon credits for flyash bricks

Table 11: Carbon emission for every 1000 bricks produced.

Material	Quantity (Kg)		Embodied Carbon $KgCO_2/Kg$	Quantity of Carbon emitted	Quantity in Tonnes
	44	1000			
Cement	7.5	170.45	0.83	141.48	0.141
Lime	10	227.27	0.74	168.18	0.168
Flyash	20	454.55	0	0.00	0.000
Clay	nil		0	0	0
Fuel	nil		0	0	0
Total 0.3097					

4. CONCLUSIONS

Based on the study carried out, experiments conducted to achieve objectives, the following conclusions are drawn:

General Conclusions

1. Material available in abundance as Mine Tailings for making bricks
2. These tailings are stored as huge heaps which needs attention during monsoon with regard to their stability
3. Coarser particles named as rejects are also available for making bricks along with fines
4. Tailor made sizes of bricks can be made/manufactured as needed by consumer
5. Tailor made quality of bricks can be made/manufactured as needed by consumer
6. These bricks are eco friendly

7. Do not require burning for their stability
8. Do not require continuous curing
9. Can be used immediately after three days of their press
10. Save substantial quantum of mortar
11. Can be used in load bearing requirements

Specific Conclusions

1. Visual tests indicated mine tailings are basically clayey in nature and can be used as alternate brick making material
2. Laboratory tests confirmed that these tailings behaved like clayey soil.
3. Prism tests indicated percentage of Mortar saved being 45.25% and 19.23% for 101 mark and Fly ash bricks respectively.
4. FRI Masonry prisms when subjected to uniform compressive load exhibited a maximum strength of 4270.91KN/m^2 which was almost 2.4 times and 1.2 times greater than 101 mark and Fly ash bricks.
5. FRI prisms when subjected to point load at 75% eccentricity exhibited to take a maximum load of 16 KN which was almost 10 times higher than both 101 mark and Fly ash bricks.
6. Use of eco-friendly materials has led to reduced carbon emissions which marks a step towards adopting green construction practices. Production of these bricks has led to reduce carbon emissions by 1.86 times and 2.3 times for fly ash and 1o1 mark bricks respectively.
7. At an overview FRI bricks outperformed all other bricks under study in all respects ranging from requirements of strength, durability, appearance, dimensional stability and all other characteristics of a good brick.

Scope for further study

This promising material can be viewed as potential in developing the following:

1. **Production of light weight blocks**
2. **Production of Pavers**

REFERENCES

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[4] ASTM C 1314, 2003:"Standard Test Method for Compressive Strength of Masonry Prisms"

[5] Prof.Geoff Hammond and Craig Jones, "Inventory of Carbon and Energy ICE",University of BATH, Version 1.6a, 2008 pg 13-14