AN EXPERIMENTAL STUDY ON RIGID PAVEMENTS AS CONCRETE BLOCK BY USING RECYCLING MATERIAL

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Abstract This paper presents the development of Bauxite residue (red mud) based cement composite mortar blocks for applications in pavement construction. Transportation contributes to the economic, industrial, social and cultural development of any country (Khanna & Justo). Among various modes of transportation road transport is considered to be one of the cost-effective and preferred modes of transport for passengers as well as for freight. It is estimated that more than 60 percent of freight and 85 percent of passenger traffic in the country is being handled by roads. India has a road network of over 5,603,293 km, the second largest road network in the world as per Basic Road Statistics of India. The concrete used for the construction of rigid pavements, runways etc. is known as pavement quality concrete (PQC). In highway pavements, due to variation in the traffic condition, the formation of microcracks in the PQC layer takes place under the combined effect of stresses due to wheel load and temperature. Formation of such type of cracks in PQC leads to decrease in both compressive and flexural strength characteristics, thus PQC layer deteriorates rapidly. Rigid pavements suffer from deterioration therefore various alternatives have been adopted to increase the quality and strength of PQC. In previous years materials like flyash, manufacturing sand (MS), marble dust, GGBS, superplasticizers etc have been used to increase the properties of PQC.

The present work is incorporation of Bauxite residue (red mud) with the ratios of 5,10,15 and 20 respectively in cement composite mortar blocks for applications in pavement construction. The experimental techniques considered include the compressive, split, flexure etc., The load bearing applications of the composites are discussed to influence the adoption of the calcined red mud as supplement in the production of low-cost Portland cement based composite mortar blocks for the construction industry.

I INTRODUCTION

“Natural surfaces are composed of vegetation and moisture-trapping soils that absorb solar energy to assist evapotranspiration, which releases water vapor making the surrounding air cooler, whereas built surfaces are composed of high percentages of nonreflective, water-resistant materials, absorbing a significant amount of solar energy, which is reflected to the microclimate as heat.” Built Environment (Architectural Science) is more or less growing artificial environments by replacing the natural environment. Nevertheless, the danger is that modern concrete technologies are unable to decrease the impact to the natural environment, such as weather rain evaporation, etc. Therefore, the world should look for eco-friendlier materials, which may be much more suitable for replacing natural setting. Earth is a building material that closely follows the natural setting. For instance, earth materials can absorb heat more than concrete and act as thermal mass. As well as earth materials assist evapotranspiration of water better than concrete.

In additional following advantages are there to use earth as construction materials;

- Reduction of initial cost and energy costs related to transportation.
- Reduction of construction waste generation.
- Support of local businesses and resource bases. Most studies have suggested that the reduction of the cost, as well as the energy cost of the building materials, can be reduced by using earth as the main building material. Earth as construction materials do not produce waste; because the earth (soil) can be, degrade back to the earth in its similar form. In addition, the manufacturing process of earth materials can be done in local context and which help to produce local materials industry.

This study and the experiments focused on producing earth-paving materials to replace the heat producing concrete pavements. Not only the heat island effect but also there are health concerns in designing pavements that indicated the walkways should be designed to provide safe, attractive, interesting and comfortable space for pedestrians. The qualitative level of pedestrian comfort might be promoted under six broad aspects: safety, security, convenience and comfort, continuity of the walkway, system coherence and attractiveness. They provide motivation for people to use the walkways resulting in an environmental benefit by minimizing motorized transportation. More than 95% of road users wish to have roadside walkways with visual identification from the traffic path. The albedo value of construction material is another important factor to be considered when selecting material for outdoor development, especially in countries with hot climatic conditions. In order to achieve this user comfort and environment-friendly outdoor urban development, a new construction material should be invented. The use of earth itself is an interesting solution. Thus, earthen walkways become drenched during rainy seasons and dusty during dry seasons. In addition, there are major health and environmental hazards. However, many artificial paving materials are available in the construction industry such as brick, asphalt, granite, concrete, etc. They have their own advantages as well as disadvantages relating to economic, technical and environmental aspects. The clay bricks are the most preferred artificial construction material to cover outdoor surfaces, among the general public and it is recommended that further development of new paving materials could either be based on clay burnt bricks or on its beneficial characteristics. Asphalt, concrete and cement concrete play an important role in pavement construction. They are usually used for the construction of most outdoor facilities such as road parking lots, walkways, etc.. Cement concrete paving blocks have lately become an attractive & economical engineering material in outdoor construction. Because they are considered to be consistent and durable. Although several research studies have been done to improve the engineering properties of cement concrete blocks while managing solid waste issues, little attention has been paid to the user discomfort caused by using these artificial materials. In order to develop energy-efficient construction methods and promoting sustainable material that minimizes the negative environmental impact produced by artificial outdoor surfaces. The idea of developing clay bricks as paving materials merely because of cost concern. The economic value of construction materials is one factor to consider in sustainable development. Consequently, with rising construction costs, there is a need to develop low-cost materials and technology for the construction industry.

Clay burnt brick is one of the most popular materials in many countries for construction because of its valuable properties such as durability, relatively low cost, availability, sound and heat insulation, acceptable fire resistance, adequate resistance to weathering and attractive appearance. Though clay burnt brick is one of the most popular construction materials, the energy consumption and environmental pollution during the manufacturing process are the main disadvantages in respect of sustainability. An alternative type of brick identified as mud concrete block, which has received attention due to low energy content and carbon emission. The mud concrete block is an advanced development of soil cement block. The soil is the principal ingredient of mud concrete block. Therefore, the properties of the soil greatly affect the strength and durability of the block. The major components of soil are gravel, sand, silt, and clay, which influence the soil properties. The properties of the soil in generally shown in Fig. This research investigates the possibility of producing an environmentally and user-friendly paving block using the mud concrete technology

The search for recycling alternatives of several industrial wastes has become a very common practice aimed at reducing cost of industrial waste disposal and protection of the environment. One of such industrial waste is bauxite red mud; an alkaline leaching waste with typical pH of 10–13, which is generated during the Bayer process or bauxite calcination method for alumina production. Bauxite consists of ∼75% of hydrated alumina ($Al_2O_3·3H_2O$ and $Al_2O_3·H_2O$) with the main impurities including iron oxide (goethite, $Fe_2O_3·H_2O$), hematite (Fe_2O_3), anatase (TiO_2), rutile (TiO_2) and silicate impurities. The silicate impurities in bauxite are primarily quartz (SiO_2) and kaolinite. During the treatment of the bauxite ore by the Bayer process (Fig. 1), it is initially crushed and digested with a hot solution of sodium hydroxide (NaOH), and lime liquor at ≈175 °C and subjected to attack at high pressure and temperature. This condition makes it possible to convert the hydrated alumina into sodium aluminate solution, while the impurities remain in a solid state.

OBJECTIVE OF THESIS

The main aim of this research is to study the effect of chemical composition and physical properties of Indian fly ashes and red mud strength. The objectives of this thesis work are listed below.

1. To understand which of the characteristics of red mud important for strength development in mortar.
2. Utilization of red mud is established in manufacturing, partial cement refilling, in the concrete industry process.
3. To investigate the effect of red mud characteristics on the pavement concrete blocks.
4. A wide variety of potential uses of red mud have been reviewed, yet there is no economically viable and environmentally acceptable solution for the utilization of large volumes of red mud.
5. To investigate the effect of red mud characteristics on transport.
6. It should be easily adopted in field.
7. To model the effect of the physical characteristics of red mud on strength development of mortars.
8. Using the wastes in useful manner.
9. To reduce the cost of the construction.

II LITERATURE REVIEW

• McLaren and Digioiab presented that the specific gravity of fly ash is relatively lower than that of soils. The density of the ash fills gets reduced which is a major advantage in terms of its use as various filler materials. Now these fillers can be used in spongy walls and ridges particularly when the foundation is weak.

• Sridharan et al., studieds the micrographs of FA particles through SEM. These particles are mostly solid spheres with glassy appearance, hollow spheres with smooth-edged porous grains, asymmetrical agglomerates and irregular absorbent scraps of unburnt carbon. Presence of particles which are dark grey in color can be identified as pointed grain.

• Mitchell and Brown said that the soil, FA and lime displays unique behavior and are much more dependent on the physicochemical properties of the fly ash and soil like porosity, segregation, lime content, time and pressure applied during compaction.

• Martinet al. stated that FA in wet but unsaturated state displays cohesive properties which are due to the tensile stress developed by the capillary action of water. Since this property limits the long term solidity of the compacts. He concluded that for improving the mechanical strength angle of shearing is more important.

• Indraratna et al. showed a comparison between the intercept of cohesion and angle of shearing resistance of dry and wet fly ash specimens. He reported that there is 100% loss of cohesion mainly to dry specimen with no change is resistant shearing angle.

• Rajasekhar specified that fly ash particles are mostly amorphous (glassy) with shape. Te low specific gravity is due to the existence of large number of small hollow spheres enclosed in big spheres (plero spheres). Reasons behind that the trapped air cannot be detached from hollow spheres or due to the differences in configuration of these particles. • Singh and Panda determined shear strength of newly made fly ash compacts in the presence of different volumes of water content. He concluded that the shearing strength of the compacts is due to the internal friction.

Wang et.al studied the response of rigid pavements subjected to wheel loadings using linear finite element model. The slab was modeled with medium thick plate elements assuming Kirchoff plate theory. The foundation was considered to be as an elastic half space. Slab stresses and deflections were computed using finite element model with both a continous foundation and Winkler foundation, and were compared to stresses computed using Westergaard's equation. In general Westergaard's solution agreed closely with the finite element method results assuming Winkler foundation; however the finite element model results assuming a continuous foundation yielded higher stresses and displacements.

Huang presented finite element for rigid concrete paving systems. In this model, the effect of an adjacent slab, connected by shear transfer devices at a transverse joint was considered. The load transfer efficiency was assumed to be perfect. In addition, stresses due to temperature curling were considered. The foundation was modeled as an elastic continuum, and loss of contact was considered. The model was verified by comparison to analytical solutions and the results were found to compare well.

Tabatabaie and Barenberg developed a more general finite element program called ILLI-SLAB which is still in use today. ILLI-SLAB utilizes the same medium as thick plate elements employed in earlier models. The effect of a bonded or unbonded base can be incorporated using a second layer of plate elements below the slab. The subgrade is modeled as Winkler's foundation . Verification of models developed with ILLI-SLAB was achieved by comparison with theoretical solutions for stresses and displacements. The results compared well.

Chou analyzed subgrade contact pressures under rigid pavements using the finite element method for concrete slabs on elastic subgrades. It was found that when the maximum bending stress in the slab is made in agreement in the two analyses, the deflections and subgrade contact pressures are much greater for elastic than for liquid subgrades. Although initial bending stresses in the concrete slab are well below the concrete strengths, excessive subgrade pressures undoubtedly cause large permanent deformations in the subgrade soil, possibly increasing the stresses in the concrete slab rapidly and eventually leading to early failure of the concrete pavement. The computation of large subgrade pressures at slab edges only in pavements with weak subgrade soil supports the Corps of Engineers design practice of reduction of pavement thickness for pavements with high subgrade k values, although bending stresses in the concrete slab are only slightly affected by variations in k values. Once initial cracking in the concrete slab has occurred, the large contact pressures at slab edges computed for concrete pavements on weak subgrade must have escalated multiple cracking in the concrete slab. The subgrade contact pressures under rigid pavements should be experimentally measured to verify the results computed by the finite element method.

III: MATERIALS

Materials Used

In making any type of concrete, selection and type of materials is very important as all the properties depends on them.

The following materials are being used and are listed below.

- Cement
- Fine aggregate (sand)
- Recycled aggregates (replacement of coarse aggregate)
- Water
- Red Mud

Cement	Fine Aggregate	Coarse Aggregate	Water
420 kg/m³	768 kg/m³	1111 kg/m³	197liters

Mix Details

CC	NORMAL MIX
MIX-1	CEMENT + RED MUD 5%
MIX-2	CEMENT + RED MUD 10%
MIX-3	CEMENT + RED MUD 15%
MIX-4	CEMENT + RED MUD 20%

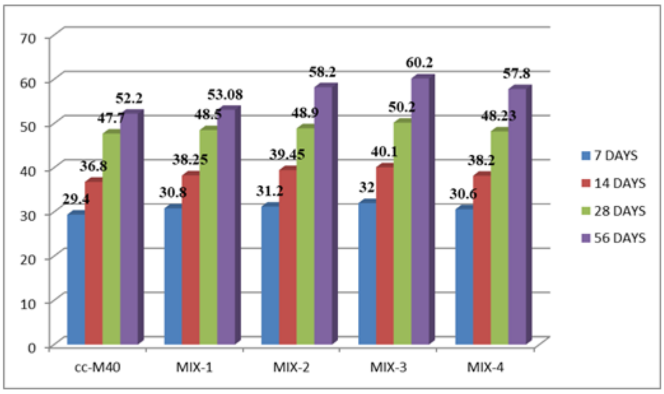
The following are the strength tests which was conducted in the project:

- Compressive strength test
- Split tensile strength test
- Flexural strength test

IV EXPERIMENTAL INVESTIGATION

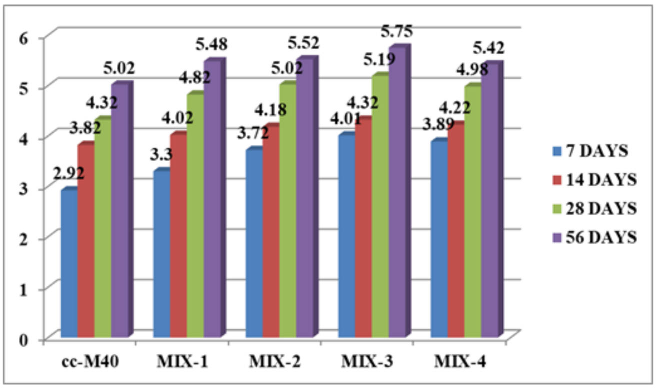
Compressive strength of concrete with mix design of M40

Mix id	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	29.4	36.8	47.7	52.2
MIX-1	30.8	38.25	48.5	53.08
MIX-2	31.2	39.45	48.9	58.2
MIX-3	32.0	40.1	50.2	60.2
MIX-4	30.6	38.2	48.23	57.8



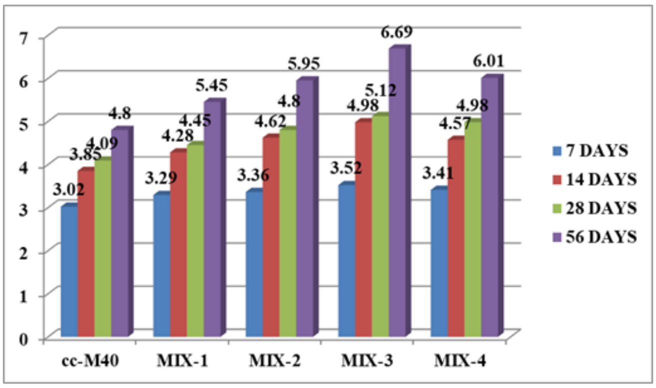
Split tensile strength of concrete with mix design of M40

Mix id	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	2.92	3.82	4.32	5.02
MIX-1	3.30	4.02	4.82	5.48
MIX-2	3.72	4.18	5.02	5.52
MIX-3	4.01	4.32	5.19	5.75
MIX-4	3.89	4.22	4.98	5.42



Flexural strength of concrete with mix design of M40

Mix id	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	3.02	3.85	4.09	4.8
MIX-1	3.29	4.28	4.45	5.45
MIX-2	3.36	4.62	4.8	5.95
MIX-3	3.52	4.98	5.12	6.69
MIX-4	3.41	4.57	4.98	6.01



% WATER ABSORPTION TEST RESULT

CONVENTIONAL CONCRETE	BACTERIAL CONCRETE				
	CC-M40	MIX-1	MIX-2	MIX-3	MIX-4
2.362	1.231	0.992	1.263	1.432	1.23
2.536	0.952	0.925	1.325	1.235	1.25
2.532	1.628	1.301	1.072	1.232	1.35

Ultrasonic pulse velocity test

S.No.	Property of concrete	RCC Member	Prob. Distance mm	Time Micro sec	Velocity Km/sec	Probing Method
1	Conventional concrete	Cube	150	29.3	5.12	Direct
2	MIX-1 MIX-2 MIX-3 MIX-4	Cube Cube Cube Cube	150 150 150 150	29.8 28.3 29 30.2	5.03 5.30 5.17 4.97	Direct Direct Direct Direct

Material required for casting each specimen

Material	Proportion	Weight of material in grams
Bitumen	5.5	66
19 to 14 mm aggregates	14.175	170.10
14 -7 mm aggregates	15.120	181.44
7 -3mm aggregates	17.955	215.46
3 mm down	45.36	544.32
Filler	2	22.68
Total	100	1200

BC Aggregate blending with 20 MM,10MM,6MM&3mm down							
IS Sieve mm	19-14 Passing (%)	14-7 Passing (%)	7-3 Passing (%)	3mm down	Combined Passing (%)	Specification Limit	
						Lower	Upper
Proportion	15	16	19	48			
19.0	100	100	100	100	100	100	100
13.2	67	100	100	100	95	79	100
9.5	8	60	100	100	79.73	70	88
4.75	1.05	1.69	62	100	62.23	53	71
2.36	0.00	0.74	28.36	90.78	51.08	42	58
1.18	0.00	0.00	24.98	70.50	40.59	34	48
0.600	0.00	0.00	20.04	54.45	31.94	26	38
0.300	0.00	0.00	14.89	36.52	22.36	18	28
0.150	0.00	0.00	8.11	24.70	15.40	12	20
0.075	0.00	0.00	0.00	6.68	5.15	4	10

COMBINEDGRADATION: total weight:30,000gms

IS sieve (mm)	Weight retained	Cumulative weight retained	Cumulative % retained	Passing	Morth limits	
					Lower	Upper
19.00	0	0	0	100	100	100
13.20	1488	1488	4.96	95.04	90	100
9.50	4593	6081	20.27	79.73	70	88
4.75	5250	11331	37.77	62.23	53	71
2.36	3345	14676	48.92	51.08	42	58
1.180	3147	17823	59.41	40.59	34	48
0.600	2595	20418	68.06	31.94	26	38
0.300	2874	23292	77.64	22.36	18	28
0.150	2088	25380	84.60	15.40	12	20
0.075	3075	28455	94.85	5.15	4	10

V CONCLUSION

- Furthermore, this type of mud concrete block doesn’t need any compaction
- It is observed that both the initial and final setting times of the Portland cement mortar decreases with increase in red mud additions thus, the addition of red mud tends to accelerate the setting process.
- This result can be attributed to the high alkalinity of the red mud and the presence of aluminium and sodium hydroxides (known as curing accelerators).
- The standard consistency of the mortar samples increases as the amount of calcined red mud increases as shown in the experiments.
- This observation can be attributed to the fact that the red mud particles are lighter, finer and occupy large volume hence the amount of water needed to obtain the same standard paste as compared to the reference mortar increases.
- Also, as the red mud content increases, the workability of the paste decreases and more water is needed for the wetting and kneading of the paste.
- It can be seen from the work that the compressive strength value decreases for mortars with red mud percentages of 20 percent and value increases for 5%, 10% and 15% red mud replacement in cement with respect to the reference mortar.
- It can be seen from the work that the tensile strength value decreases for mortars with red mud percentages of 20 percent and value increases for 5%, 10% and 15% red mud replacement in cement with respect to the reference mortar.
- It can be seen from the work that the flexural strength value decreases for mortars with red mud percentages of 20 percent and value increases for 5%, 10% and 15% red mud replacement in cement with respect to the reference mortar.
- This decrease in strength could be attributed to the fact that as the red mud content increases, the workability decreases and the packing effect reduces thereby causing the material to be porous and having reduced strength.
- However, for 15% red mud replacement it could be seen from the results that the strength was higher than that of the reference mortar block and this could be attributed to the fact that the bonding between the particles was very strong due to better packing hence the increase in strength.
- Generally, increase in calcined red mud content decreases the compressive as well as flexural strength. However, 15% red mud additions tend to have superior or equal qualities to the reference mortar.

- Workability of mortar generally is decreased with the increase in red mud content and both the initial and final setting times are accelerated mostly due to the presence of aluminium and sodium hydroxides (curing accelerators).

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