Experimental Study On Partial Replacement Of Cement With Tyre, Wood And Jute Ash Wastes In Rigid Pavements

B.A.V. Ram Kumar, G. Akhil Kumar

Abstract: Rigid pavements are mostly constructed with cement concrete which possesses high flexural strength, durability properties and also provide long-term serviceability for the given climatic and loading conditions. In general, cement is used as binding material in concrete. Cement production is leading to emission of 7 % of global CO2. With increasing industrialization, the industrial by products (wastes) are being accumulated to a large extent, leading to environmental and economic concerns related to their disposal (land filling). In the present investigation, an attempt has been made with the addition of supplementary cementations material to conventional concrete. In the present study, three types of wastes are being considered as a replacement to cement. Jute ash, Wood ash and tyre ash were used as substitutes for cement. Five mixes have been prepared for the present investigation. First, mix with 100 % of cement. Second, mix with 5% jute ash, 5% wood ash and 5% with tyre ash as a replacement to cement. Similarly, for 6%, 7% and 8% trial mixes were being prepared for finding optimum content. For the aforesaid percentages of replacement cubes of size 150 X 150 X 150 mm have been cast and tested for 7 and 28 days, compressive strength, prisms of size 500 X 100 X 100mm for flexural strength and cylinders of size 300 X 150mm for tensile strength respectively. It has been observed from the results that mix with 18% replacement i.e. 6% of each of three materials has shown higher compressive, flexural and tensile strength values when compared with other mixes.

Index Terms: Compressive strength, Flexural strength, Jute ash, Tensile strength, Tyre ash, Wood ash, Pavement, Cost analysis.

1 INTRODUCTION

Concrete Concrete is a three phase material with three phases being coarse aggregate, mortar, interfacial transition zone. Concrete is the world's most consumed man-made material which attracted great interest as a possible way to recycle solid waste products. The production of 1 ton of Portland cement generates around an equal amount of CO2(1). It is estimated that cement industry contributes around 5% to 8% of the annual global green-house gas emissions (2). Various by-product materials such as fly ash, slag and silica fume are effectively used daily in the production of concrete as supplementary cementitious materials (SCM) (3,4). Wood ash is the residue produced from the incineration of wood and its products (chips, saw dust, bark). Rajamma et al. analyzed the wood ash from Electrostatic precipitator from fuel plant using X-ray diffractometry. Results of XRD tests showed the presence of silica and calcite. It also confirmed the presence of SiO2, Al2O3 and Fe2O3 in the wood ash, which controls the pozzolanic reactivity. As India is one of large producers of jute, these fibres can be used in order to overcome the brittle behavior of concrete. Jute also is one of the most affordable natural fibers and is second only to cotton in amount produced. The accumulation of waste tyres is one of major environmental problems worldwide including Malaysia. Abdullah [1] stated the fact that one scrap tyre per person is generated constantly from all cars in the world every year. As scrap tyres are non-degradable materials, they can cause serious problems to the environment and public health.

For example, they can become breeding sites for mosquitoes and rodents as the water becomes stagnant inside the tyres. It also causes diseases, accidental fires and takes up landfill space. The situation can worsen if it is illegally dumped in cities, disposed in lakes, streams, forest and not in the right places such as landfills. Other than that, there are also some people who use the easiest way to get rid of waste rubber tyres through open burning and using them as a source of fuel. These processes can lead to very serious health problems [2-9]. One way to solve the increasing amount of waste tyres is by incorporating waste rubber in concrete mixtures to produce rubberized concrete. Pyrolysis is a word basically based on the Greek words “pyr” which means fire and “lysis” which means separation. This means that pyrolysis is a process of decomposing material and usually the process operates at higher temperatures above 430 °C (800 °F). This process is done in the absence of oxygen otherwise the organic material is burned. Pyrolysis is also defined as one way of reprocessing scrap tyres through thermal degradation in the absence of oxygen. The products are fuel gas, oils, and a solid residue (char) which contains appreciable quantities of mineral matter and low-grade carbon black [20]. Products of tyre pyrolysis experiments are gases, liquid oils and solid carbon residues. The typical weight percentage of tyre pyrolysis are 33-38 wt. % char, 38-55 wt. % oil, and 10-30 wt. % gas which are affected by conditions such as temperature and heating rate. Gases produced from tyre pyrolysis are mainly hydrogen, carbon dioxide, carbon monoxide, methane, ethane and butadiene, with lower concentrations of propane, butane and other hydrocarbon gases. If water is present during the process, the production of hydrogen and carbon monoxide can increase from the occurrence of carbon gasification by steam. The yield of oil from tyre pyrolysis is high (50% of initial tyre rubber), reflecting the potential of tyre rubber as a substitute for fossil fuel and chemical feedstock. It is a potential source of energy and chemicals and can be used directly as fuel or added to petroleum refinery feedstock. Furthermore, tyre pyrolysis can also be performed in an inert environment which can produce 33-38 wt. % of carbon residue and can become a marketable product if the properties are

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similar to those of manufactured carbons. Chars, 15 wt. % of ash, with the majority of this ash being zinc oxide are parts of the products from tyre pyrolysis. Factors that increase the char yield include a decrease in pyrolysis temperature and an increase in heating rate. Pyrolysis should also be performed under mildly oxidizing conditions, especially in the case of granulated tyres.

2 METHODOLOGY

2.1 Flow Chart

![Flow Chart](image)

2.2 Material Specification

Cement used in this study is of OPC Grade 53. The tests on cement revealed that specific gravity as 3.14. Natural sand has been used as fine aggregate confirming to zone II. The specific gravity conducted as per IS 2386 Part-3 found as 2.6, whereas fineness modulus and water absorption as 3.75 and 1%. Crushed stone of nominal maximum aggregate size 20 mm have been used and the specific gravity is found as 2.75, fineness modulus and water absorption of crushed stone were found as 7.44 and 0.63%. The specific gravity of the jute ash, tyre ash and wood ash used in this study are about 1.50, 2.17, 1.7 respectively. The chemical composition of jute ash, tyre ash and wood ash when compared with cement, is tabulated in the below table no. 01.

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Cement</th>
<th>Jute ash</th>
<th>Wood ash</th>
<th>Tyre ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{SiO}_2$</td>
<td>21.6</td>
<td>67.20</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>$\text{Al}_2\text{O}_3$</td>
<td>6.2</td>
<td>4.09</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>$\text{Fe}_2\text{O}_3$</td>
<td>3.9</td>
<td>2.26</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>61.7</td>
<td>9.98</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2.4</td>
<td>5.80</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>$\text{K}_2\text{O}+\text{Na}_2\text{O}$</td>
<td>0.47</td>
<td>0.08</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>$\text{SO}_3$</td>
<td>1.5</td>
<td>0.45</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>1.1</td>
<td>4.67</td>
<td>7.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Chemical composition of materials

2.3 Mix Design

In this study, control mix was designed as per IRC 44-2017, IS 456-2000 for M30 grade. Later wood, jute, tyre ash were replaced in 5%, 6%, 7%, 8% by weight of cement for the designed mix.

<table>
<thead>
<tr>
<th>Grade designation</th>
<th>M30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of cement</td>
<td>opc 53 grade</td>
</tr>
<tr>
<td>Maximum nominal size of aggregate</td>
<td>20mm</td>
</tr>
<tr>
<td>Minimum cement content</td>
<td>330 kg/m$^3$</td>
</tr>
<tr>
<td>Maximum water cement ratio</td>
<td>0.45</td>
</tr>
<tr>
<td>Exposure condition</td>
<td>Good</td>
</tr>
<tr>
<td>Wood, Jute, Tyre ash particle size</td>
<td>90 microns</td>
</tr>
</tbody>
</table>

Table 2. Mix design values

<table>
<thead>
<tr>
<th>Mix proportion</th>
<th>Cement</th>
<th>Water</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
<th>Chemical admixture</th>
<th>Water-cement ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>388 kg/m$^3$</td>
<td>147.456 liters</td>
<td>651.56 kg/m$^3$</td>
<td>1303 kg/m$^3$</td>
<td>3.880 kg/m$^3$</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Table 3. Mix Proportions

2.4 Samples Preparation

In order to determine the mechanical characteristics such as compressive, flexural strengths, and tensile strength different samples are prepared. Later they were tested on compressive testing machine and UTM. Samples are prepared different percentages of wood ash, jute ash, tyre ash partial replacement and tested. The compressive strengths of concrete has been evaluated by testing cubes of size 150mmx150mm. The flexural strength of concrete have been evaluated by testing prisms of dimension 500mmx100mmx100mm. The tensile strength of concrete have been evaluated by testing cylinders of dimensions 150mmx300mm. After casting of these specimens these are kept in moulds for 24 hours at a temperature of 27 ± 2 °C. After 24 hours these are removed from the moulds and are placed in curing tank and tested for 7, 28 days respectively.

2.5 Test Results

From the analysis of results for each percentage ratios 5% 6% 7% and 8%, replacement of, wood, jute, tyre ash and of replacement of waste materials utilizing mix with concrete is optimum dosage in concrete for improving mechanical properties of concrete. Strength performance also good results compare to conventional concrete.

Table 4. Compressive Strength at 7&28 days
Bradbury’s coefficients for calculation of warping stress in the x and y directions are:

\[ L_x / l = 375 \text{ cm}/63.18\text{ cm} = 5.93 \]

From table 4.1, for \( l / y = 375 \text{ cm}/63.18\text{ cm} = 5.53 \)

For Andhra Pradesh assuming a thickness of 15 cm, the temperature differential \( = 17.3 \cdot C \) (From table 1 of IRC:58-2011).

Thermal expansion of concrete \( \alpha = 10 \times 10^{-6} / { ^\circ C } \)

Maximum warping stress at the edge is calculated as per IRC SP 62-2014 = 21.48 kg/cm²

Maximum limit of total stress at edge due to warping stress and axle load
\[ = 43.95+21.48 =65.43 \text{ kg/cm}^2 < f_{90} (96.91 \text{ kg/cm}^2) \]

Note: if the above criterion is not satisfied, the slab thickness should be suitably increased and the above process of calculation is repeated until the criterion is satisfied

Stress at the corner by wheel load as per IRC SP 62-2014=50.28 kg/cm²

At the corner wheel load .50.28kg/cm² is smaller than the value of \( f_{90}(96.91 \text{ kg/cm}^2) \)

Hence provide cement concrete slab of thickness 15 cm.

### 3.1 Cost Analysis

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Material</th>
<th>Quantity (kg)</th>
<th>Rate per kg in Rs.</th>
<th>Cost in Rs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cement</td>
<td>388.04</td>
<td>7</td>
<td>1527.90</td>
</tr>
<tr>
<td>2</td>
<td>Fine aggregate</td>
<td>651.5</td>
<td>0.038</td>
<td>13.92</td>
</tr>
<tr>
<td>3</td>
<td>Coarse aggregate</td>
<td>1303.12</td>
<td>0.437</td>
<td>320.32</td>
</tr>
<tr>
<td>4</td>
<td>Super plasticizer</td>
<td>2.037</td>
<td>62</td>
<td>126.294</td>
</tr>
</tbody>
</table>

Total cost in Rs. = 1988.43/-

### 3.2 Scope of Future Improvement

The main theme of this project is to find alternative material for cement because now a day's there is scarcity of cement and day by day cost of cement is increasing. The present study indicates that there is significant improvement in the strength properties of the concrete by using wood ash, tyre ash, jute ash. This study can be extended to know the potential sources of the wastes used and measure the effect of using these wastes on environment quantitatively.

### 4. CONCLUSIONS

- Based on the experimental investigation carried out...
during the study, the following conclusions were drawn.

- The results obtained after testing mechanical properties depicted that optimum dosage of replacement of cement by wood ash, jute ash and tyre ash was 6%.
- There is a decline in mechanical properties at earlier stages of curing i.e. 7 days with partial replacement of cement with wood ash, tyre ash & jute ash.
- Flexural strength and tensile strength of concrete have significantly increased although compressive strength is found to decrease at 6% replacement of each material. Flexural strength and tensile strength have increased by 5.23% and 22.5% respectively compared to conventional concrete at 28 days.
- A rural rigid pavement designed with concrete of optimum dosage of wood ash, tyre ash & jute ash had satisfied for minimum thickness i.e. 15cm similar to conventional concrete.
- The construction cost of the pavement is reduced by 17.95 % by using wood ash, jute ash, tyre ash per m$^3$ of concrete compared to conventional concrete.

5 ACKNOWLEDGMENT

This is the place to admit that while there appears only author on the cover, this work just as any other, is a product of the interaction with and support during our thesis work, among them, first I express my gratitude to my guide B.A.V.RAM KUMAR and K.GOPI SHANKAR for their throughout guidance, advice and encouragement. Thanks to all my family members for their affection, care and encouragement. Special thanks to my college for giving me the invaluable knowledge. Above all I am thankful to almighty God for everything and all researchers whose research papers in this field have been referred for our study. My heart full thanks to my parents for the wonder full support and encouragement.

6 REFERENCES

[25] 19. IRC: 44-2008, “Guidelines For Cement Concrete Mix Design for Pavements”. the strength compressive and tensile and flexural strength properties and to recommended to use this type of waste in replaced by cement material.