

**MODIFICATION OF MIX DESIGN TO UTILIZE FLY  
ASH AND GLIRICIDIA ASH IN CONCRETE PAVING  
BLOCK**

Herath Mudiyansele Tikiri Mahendra Amunugama

179427C

Degree of Master of Science

Department of Materials Science and Engineering

University of Moratuwa

Sri Lanka

January 2022

# **MODIFICATION OF MIX DESIGN TO UTILIZE FLY ASH AND GLIRICIDIA ASH IN CONCRETE PAVING BLOCK**

Herath Mudiyansele Tikiri Mahendra Amunugama

179427C

Thesis submitted in partial fulfillment of the requirements for the degree Master of  
Science

Department of Materials Science and Engineering

University of Moratuwa

Sri Lanka

January 2022

## **Declaration**

“I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person where the acknowledgment is made in the text.

Also, I hereby grant to the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

***UOM Verified Signature***

Signature

Date: 20.01.2022

The above candidate has carried out research for the Master’s thesis under my supervision.

***UOM Verified Signature***

Signature of the supervisor

Date 21.01.2022

## **Abstract**

Last few decades demand for renewable energy has increased. Among those resources, biomass is widely used to produce energy as it renewable and low-cost material. Therefore, it has led to the accumulation of industrial byproducts such as wood ash. Wood ash is the byproduct produced from the biomass power plant as used for the generation of electricity. The production of cement leads to emitting a large number of greenhouse gases caused environmental disasters all around the world. Also, cement is the expensive cost factor in manufacturing cement-based products. Concrete paving block (CPB) is a successful alternative for asphalt or concrete pavement. It is different from other paving methods from manufacturing, structural design, installation and replacing techniques, etc. It can be easily placed and removed when it is damaged. The present study was conducted to produce low-cost and performance-effective (complying with the standard requirements) paving blocks by using industrial by-products produced from the Tokyo Cement □ biomass power plant. Laboratory trials were carried out at the Tokyo cement construction research center laboratory which has been accredited as per ISO 17025. The 15MPa mix designs were used as per SLS 1425 standard. 5%, 10%, 15%, 20% of wood (Gliricidia) ash was replaced from cement content for mix design. workability, dimensions, verification of visual aspects, compressive strength, flexural strength, total water absorption were determined. Workability was reduced when increasing the percentage of wood ash. Dimensions were measured of all of the paving blocks. The length, width, and height of the B05 block have deviated from standard specifications. Visual aspects have shown that when increasing the wood ash percentage texture of those blocks was roughened. Smoothness has gradually decreased when increasing the wood ash percentage. Flexural strength and compressive strength have also been reduced when increasing the wood ash percentage. Total water absorption value has increased when increasing the wood ash percentage. Due to the increase of porosity of the paving block. Therefore, from all the results observed it can be concluded that 20% replacement of wood ash (B05) results were exceeded the standard requirements in SLS 1425. Also, we observed the scanning electron microscope (SEM) images of cross-sections of all 05 block types. It shows a gradual increment in porosity by increasing the wood ash percentage. Materials cost per cubic meter of every block type were calculated. The lowest materials cost is shown by the B05 type. 15% wood ash replacement (B04) results were complying with the standard requirements and show 2nd lowest materials cost from all block types.

### **Keywords:**

Concrete Paving block, Wood ash, Fly ash, Concrete Flexural strength, Concrete Compressive strength, Total water absorption.

## **Acknowledgment**

I would like to pat my regards at the beginning of this acknowledgment to the Department of Materials science and Engineering for giving me this opportunity to do such a beneficial project. I am immensely grateful to Professor S.U Adikary, as my project supervisor for sharing his pearls of wisdom with me during this research project. I am highly indebted to him for his guidance, effort, and constant supervision to make this project successful throughout the entire period. And also, I thank Mr. V. Sivahar, Head - Department of Material Science and Engineering, and Dr. Asha – M.Sc. Coordinator for allowing the chance to choose a title by our preference.

I would like to thank all other lecturers at the Department of Materials Science and Engineering for sharing their knowledge with us. I would also like to thank the technical officers and all the other non-academic staff members of the Department of Materials Science and Engineering for helping me on this project by providing laboratory facilities.

Also, I would like to thank my colleagues in Tokyo Cement<sup>®</sup> Construction Research Centre<sup>®</sup> given the chance to use the laboratory and for helping me with using laboratory equipment.

I would like to express my special gratitude towards my parents and wife for their kind co-operation and encouragement which helped me in the completion of this project.

Finally, I would like to thank all the colleagues of the M.Sc. in Materials Science batch who helped me to make this project successful. My thanks and appreciations also go to all others whose name is not mentioned in his/her effort gave me the best.

Amunugama H.M.T.M. (179427C)

## Contents

Acknowledgment .....	3
List of figures .....	6
List of tables.....	7
List of abbreviations .....	8
1. INTRODUCTION .....	9
2. LITERATURE SURVEY .....	11
2.1 Basic Composition of Concrete.....	11
2.1.1 Cement .....	11
2.1.1 Wood ash .....	12
2.2 Properties of Concrete Paving Block (CPB).....	13
2.2.1 Workability .....	13
2.2.2 Dimensions .....	13
2.2.3 Verification of Visual aspects .....	14
2.2.4 Flexural Strength.....	14
2.2.5 Compressive strength.....	14
2.2.6 Total Water Absorption .....	15
3. MATERIALS AND METHODOLOGY .....	16
3.1 Material Selection and Preparation .....	16
3.1.1 Sieve Analysis and Specific gravity for Crushed Sand.....	17
3.1.2 Sieve Analysis, Specific Gravity, Flakiness Index and Impact Value of Coarse Aggregate 01 and 02 .....	18
3.1.3 Chemical and Physical Tests for Cement .....	18
3.1.4 Technical Specifications of Admixture .....	19
3.1.5 Tests results for fly ash and wood ash .....	20
3.2 Experimental Methodology .....	25
3.3 Properties Tested .....	28
4. RESULTS AND DISCUSSION .....	31
4.1 Analysis of Test Results .....	31
4.1.1 Workability (Slump) .....	31
4.1.2 Compressive Strength .....	33

4.1.3	Flexural Strength.....	36
4.1.4	Dimensions .....	39
4.1.5	Verification of Visual Aspects.....	40
4.1.6	Total Water Absorption .....	41
4.1.7	Micro Structural Analysis using Scanning Electron Microscope .....	43
4.2	Cost Analysis.....	46
4.2.1	Cost Calculation as per Materials Cost .....	46
4.2.2	Cost per Square feet .....	48
5.	CONCLUSIONS.....	49
6.	RECOMMENDATIONS & FUTURE WORK .....	51
	REFERENCES .....	52

## List of figures

Figure 3-1 Sieve analysis of crushed sand .....	17
Figure 3-2 EDAX of Fly ash.....	20
Figure 3-3 EDAX of Wood ash .....	21
Figure 3-4 SEM image of Fly Ash 0.5K Magnification .....	22
Figure 3-5 SEM image of Fly Ash 2.5K Magnification .....	22
Figure 3-6 SEM image of Fly Ash 5K Magnification .....	23
Figure 3-7 SEM image of Wood Ash 0.5K Magnification.....	23
Figure 3-8 SEM image of Wood Ash 2.5K Magnification.....	24
Figure 3-9 SEM image of Wood Ash 5K Magnification.....	24
Figure 3-10 Raw Materials packed in sealed polythene bags .....	26
Figure 3-11 Mixing of raw materials .....	27
Figure 3-12 Measuring the slump .....	27
Figure 3-13 Casting of CPB.....	28
Figure 3-14 De molded samples .....	29
Figure 3-15 Determination of total water absorption.....	30
Figure 4-1 Slump Value .....	32
Figure 4-2 Compressive Strength in 28 days .....	35
Figure 4-3 Flexural strength in 28 days .....	38
Figure 4-4 Dimensions of CPB .....	39
Figure 4-5 Delamination of type 03 paving Block .....	41
Figure 4-6 Total Water Absorption.....	43
Figure 4-7 SEM of the cross-section of CPB – B01 (5KX).....	43
Figure 4-8 SEM of the cross-section of CPB - B02 (5KX) .....	44
Figure 4-9 SEM of a cross-section of CPB - B03 (5KX) .....	44
Figure 4-10 SEM of the cross-section of CPB - B04 (5KX) .....	45
Figure 4-11 SEM of a cross-section of CPB - B05 (5KX) .....	45



## List of tables

Table 3.1 Grade 15 Mix Design.....	16
Table 3.2 Test Results of Manufactured Sand .....	17
Table 3.3 Test Results for Coarse Aggregate 01 .....	18
Table 3.4 Test Results of Coarse Aggregate 02.....	18
Table 3.5 Test Results of Cement .....	19
Table 3.6 Test Results of Admixture .....	19
Table 3.7 EDAX of Fly ash .....	20
Table 3.8 EDAX of Wood Ash.....	21
Table 3.9 XRF of Wood Ash and Fly Ash.....	21
Table 3.10 Mix Percentages of OPC, Fly ash, and Wood ash .....	25
Table 3.11 Trial Mix Proportions .....	26
Table 3.12 Tested Properties.....	29
Table 4.1 Slump Test Results .....	32
Table 4.2 07 Days Compression Strength Results.....	34
Table 4.3 28 Days Compressive Strength.....	35
Table 4.4 07 Days Flexural Strength .....	37
Table 4.5 28 Days Flexural Strength .....	38
Table 4.6 Dimensions .....	40
Table 4.7 Total Water Absorption .....	42
Table 4.8 Unit Prize of Materials.....	46
Table 4.9 Materials Cost Calculation of Paving Block Types per 01M <sup>3</sup> .....	47
Table 4.10 Modified Mix Design.....	48

## **List of abbreviations**

CPB	Concrete paving block
SLS	Sri Lankan Standard
MPa	Mega Pascal
XRD	X-ray diffraction
SEM	Scanning electron microscope
XRF	X-ray fluorescence
EDAX	Energy dispersive analysis of X-ray
OPC	Ordinary Portland cement
ISO	International organization for standardization
BS	British standard
BSEN	British & European standard
SD	Standard deviation
CW	Cube weight
IL	Indicated load
CL	Corrected load
SSDW	Saturated surface dry weight
ODW	Oven dry weight