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

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Degree of Master of Science

Department of Materials Science and Engineering

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

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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.

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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.

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

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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

1. INTRODUCTION

Most of the countries moved to produce energy using renewable energy resources. Because renewable energy resources have low potential costs and can be continuously supplied as renewable. From these resources, biomass is a major source. Because agricultural wastes and natural forestry are very much common in the industry as power plants use them. The main reason is to use them is it has a low operational cost and plentiful resources available. The main drawback of biomass energy production is produced ash as a byproduct. It provides a major issue to the environment. So that utilization of this by-product is essential. It can be much beneficial if we can replace this by-product as a cement replacement material. It reduces the greenhouse gas effect and cost. So, it is beneficial in both environment and economically as well.

In recent years the demand for cement has been increased due to the boom in the construction sector. Cement is the primary constituent in the production of concrete and concrete-based products. For the production of cement huge number of raw materials and energy are consumed and also it released a higher amount of carbon dioxide gas into the environment. So, the production enhancement in the cement industry results from heavy environmental degradation and pollution [1]. So, it is very much beneficial to find out a solution to utilize wood ash by-products.

Some literature shows better results by replacing wood ash cement partial replacement. Hence it provides solutions for product utilization and energy consumption along with the eco-friendly process. Also, it is economically beneficial [2-5]. Determining Energy dispersive analysis of X-ray (EDAX) and Chemical analysis of wood ash shows some pozzolanic properties [6].

Based on previous studies we have decided to introduce a low-cost and performance-effective product to the market with this wood ash by-product. So we have modified the mix design of concrete paving block mix design which is under the strength class 04 as per SLS 1425 standard.

Nowadays CPB is commonly used as a decorative method of paving. The reason for the popularity of concrete paving blocks is, they can be easily replaced without damaging the structure of the surface. Also, less labor is required to place it and repair it. Much more work is yet to be accomplished in the Sri Lankan CPB industry up to the standard requirements. Various designs of paving blocks are available in the market. There are various types of paving block manufacturers in Sri Lanka, among them few of them acquire the SLS standard. Most of the CPB manufacturers are not complying with the standard and do not approach consistent quality. Also, most of the manufacturers do not perform a test to evaluate the properties of CPB are following SLS requirements.

Also, most of the suppliers do not perform a test to evaluate the properties of CPB are following SLS standards. So, it is important to have standard certification as well as consistent quality. Also, it is vital to improving the quality of paving blocks by complying with the SLS 1425 standard.

According to the market research, it is important to approach improved quality, low-cost CPB products. Improved quality can be achieved by manufacturing the blocks to the standard requirements. Cost can be reduced by reducing the raw materials cost and manufacturing cost. The highest cost of manufacturing CPB is coming with cement. This cost can be reduced by replacing other compatible materials for cement such as wood and fly ash.

Using modern technology Tokyo Cement□ Company produces electricity by using Gliricedia wood. Burned Gliricidia produced ash 20 tons per month. This study was conducted to utilize Gliciridia ash to produce CPB, as a cost-effective and standard requirement complying product while minimizing CO2 emission during cement manufacturing.

In this project, we have replaced Gliricidia wood ash and fly ash from cement content by weight. Both are by-products of the biomass power plant and thermal power plant respectively.

2. LITERATURE SURVEY

2.1 Basic Composition of Concrete

Concrete includes cement, water, fine aggregates, and coarse aggregates. Chemical admixtures were added if required.

2.1.1 Cement

Cement is a manufactured powdered material that can chemically react with water and produce tougher material. With only fine aggregates it produced mortar and with both fine and coarse aggregates it produced concrete. Cement is the main binding material of mortar and concrete. Reduce the usage of cement using suitable low-cost material, cost of the product can be reduced.

2.1.2 Crushed Sand

Crushed Sand is a successful alternative material for river sand that can be used in the construction industry. It is manufactured as a byproduct of stone crusher plants. Nowadays it is purposely manufactured to be used in major building constructions. Using this crushed sand is an economical and eco-friendly alternative for river sand.

Also, it has better durable properties than river sand. The strength, workability of concrete can be enhanced by using crushed sand. Also, it reduces fresh and hardened concrete failures such as bleeding, segregation, air content, honeycombs, voids, and capillary absorption.[8]

Table 2.1 Technical Specifications of Manufactured sand

Property	**Specification**	**Test Method**
Loose bulk density	1600kgm^{-3}	BS 812 – 2
Particle density	2700 kgm^{-3} - 2800 kgm^{-3}	BS 812 – 2
Water Absorption	0.5 % – 0.7	BS 812 – 2
75micron passing %	1.0% - 15.0 %	BS 812 - 103

2.1.1 Wood ash

Wood ash has produced by burning wood chips at a plant. Wood type may vary from plant to plant such as wood bark and sawdust. The outcome of wood resulted from 6-10% of wood ash other than electricity. The composition of the wood ash can be varied due to the wood source and the geographical area.

Table 2.2 Chemical Composition of Wood Ash from Various Timber Species [9]

Biomass group	SiO_2	CaO	K_2O	P_2O_5	Al_2O_3	MgO	Fe_2O_3	SO_3	Na_2O
Bitch bark	4.38	69.06	8.99	4.13	0.55	5.92	2.24	2.75	1.85
Forest residue	20.65	47.55	10.23	5.05	2.99	7.2	1.42	2.91	1.6
Pine bark	9.2	56.83	7.78	5.02	7.2	6.19	2.79	2.83	1.97
Pine chips	68.18	7.89	4.51	1.56	7.04	2.43	5.45	1.19	1.2
Poplar	3.87	57.33	18.73	0.85	0.68	13.11	1.16	3.77	0.22
Poplar bark	1.86	77.31	8.93	2.48	0.62	2.36	0.74	0.74	4.84
Sawdust	26.17	44.11	10.83	2.27	4.53	5.34	1.82	2.05	2.48
Spruce bark	6.13	72.39	7.22	2.69	0.68	4.97	1.9	1.88	2.02
Spruce wood	49.33	17.2	9.6	1.9	9.4	1.1	8.3	2.6	0.5
Wood residue	53.15	11.66	4.85	1.37	12.64	3.06	6.24	1.99	4.47

According to the literature most of the wood ash is used for landfilling purposes nearly about 70%. 20% is used as soil supplementary material and also rest is used for other purposes [10].

As Tokyo power LTD, nearly 80-85% is dumping and 15-20% is used as soil supplementary material.

Basic pozzolanic material is fly ash in Sri Lanka. After analyzing the composition of fly ash and wood ash, it has some similarities in composition. So that it may chemically react with calcium hydroxide in the presence of moisture at room temperature and produce some little cementitious properties [11].

2.2 Properties of Concrete Paving Block (CPB)

The quality of CPB can be determined by different properties. Those properties are tested by the standard test method. Good quality concrete must be compatible with the relevant international standards.

2.2.1 Workability

Workability of concrete is exactly the working ability of fresh concrete in several scenarios such as mixing, transporting, placing, compacting and finishing, etc. [12].
The workability of concrete can be categorized into two,
•Consistency (Slump test) - how easy to flow – BSEN 12350 – 2: 2009[13]
•Cohesiveness (Flow table test) - tendency to bleed and segregate – BSEN 12350 – 3: 2009[14]

2.2.2 Dimensions

Dimensions of CPB is important when manufacturing paving block. A better dimension of PCB can be achieved by using good quality concrete. Also, it is important to identify the actual dimensions which are following standards. Also, it is important when conducting mechanical properties, actual dimensions should be identified. Here selected the most basic shape of CPB as per SLS 1425[15] so that calculating dimensions were much easy.

2.2.3 Verification of Visual aspects

Does not include defects on the upper face layer of the CPB such as cracks or flaking as per the standard. For two layers consisting of CPB's, it shall not be delamination between the two layers. The effect of the efflorescence of any CPB should be negligible and should not affect its performance while in use.

There are various surface textures available for CPB's and they should have been mentioned by the manufacturer.

No such significant difference is allowable between the textures of the samples when examined. But unavoidable variations are not considered as significant such as variation in shade properties, variation in hardening, and variation in raw materials.

Manufacture can decide whether the color of the block is only for the facing layer or to the entire block.

2.2.4 Flexural Strength

Maximum flexural stress that can be applied to a solid material under gradually applied load can be sustained without bending fracture is the 'flexural strength'. CPB can be subjected to such load while in use.

2.2.5 Compressive strength

The maximum stress that can be bare by CPB under gradually increasing load at a constant specific loading rate up to its fracture is the compressive strength. The categorization of CPB is based on the strength class of the CPB as per SLS 1425.

Table 2.3 Strength Class Classification of CPB

Strength class	Average Compressive strength (MPa)	Individual Compressive strength (MPa)	Block thickness (mm)
01	50	40	80,100
02	40	32	80,100
03	30	25	80,100
04	15	12	60

As per SLS 1425 standard.

2.2.6 Total Water Absorption

The total water absorption of a specimen should be less than 6%. It is determined as per SLS 1425[16]. This is a durability factor of CPB. When the total water absorption value has a lower value, the durability of CPB increases.

3. MATERIALS AND METHODOLOGY

3.1 Material Selection and Preparation

This research project was carried out based on a grade 15 mix design. All the materials were selected according to table no 3.1.

Table 3.1 Grade 15 Mix Design

Materials	**Quantity per 01M^3**
Cement	252Kg
Fly ash	28Kg
Wood ash	0kg
Water	174Kg
Crushed sand	887Kg
Coarse Aggregate 01	353Kg
Coarse Aggregate 02	737Kg
Admixture (Ecomix® 30)	2250ml

Most of the materials were taken from companies related to Tokyo Cement Company®. Cement was taken from Tokyo cement factory, crushed sand from Tokyo Aggregates (Pvt) LTD, fly ash from Norochcholai power plant, wood ash from Mahiyanganaya biomass power plant (Tokyo power (Pvt) LTD), admixture was from St'Anthony's chemicals.

To select good quality materials, several tests were carried out.

3.1.1 Sieve Analysis and Specific gravity for Crushed Sand

Sieve analysis and specific gravity tests were carried out to crush sand according to test methods mentioned in table 3.2.

Table 3.2 Test Results of Manufactured Sand

Specification	Test result	Test Method
75-micron passing percentage	5.2%	BS 812 – 103
600-micron passing percentage	42.2%	BS 812 – 103
Specific gravity	2.78gcm^{-3}	BS 812 -2

Figure 3-1 Sieve analysis of crushed sand

3.1.2 Sieve Analysis, Specific Gravity, Flakiness Index and Impact Value of Coarse Aggregate 01 and 02

Sieve analysis, specific gravity, flakiness index, and impact value test was carried out to characterize the coarse aggregate using the test method mentioned in tables 3.3 and 3.4.

Table 3.3 Test Results for Coarse Aggregate 01

Specification	Test result	Test Method
75-micron passing percentage	0.2%	BS 812 – 103
10mm passing percentage	38.1%	BS 812 – 103
Specific gravity	2.78gcm^{-3}	BS 812 -2
Flakiness index	14%	BS 812 – 105.1
Impact value	24%	BS 812 – 112

Table 3.4 Test Results of Coarse Aggregate 02

Specification	Test result	Test Method
75-micron passing percentage	0.5%	BS 812 - 103
10mm passing percentage	2.5%	BS 812 - 103
Specific gravity	2.77gcm^{-3}	BS 812 -2
Flakiness index	12%	BS 812 – 105.1
Impact value	24%	BS 812 - 112

3.1.3 Chemical and Physical Tests for Cement

Chemical analysis & physical tests were carried out to characterize cement using the test method mentioned in table 3.5.

Table 3.5 Test Results of Cement

Specification	**Test result**	**Test Method**
Insoluble residue	0.74%	SLS ISO 29581-1
Loss on ignition	1.15%	SLS ISO 29581-1
Sulfur trioxide	2.18%	SLS ISO 29581-1
Chloride	0.01%	SLS ISO 29581-1
Specific surface area	$3400 cm^2/g$	SLS 107 - 2
Compressive strength 2 days	$25.7\ Nmm^{-2}$	SLS ISO 679
Standard consistency	29.00%	SLS ISO 9597
Initial setting time	2h 35 mins	SLS ISO 9597
Soundness	1mm	SLS ISO 9597

3.1.4 Technical Specifications of Admixture

Chemical analysis & physical tests were carried out to admixture using the test method mentioned in table 3.6.

Table 3.6 Test Results of Admixture

Specification	**Test result**
Appearance	Clear aqueous liquid
Color	Pale yellow
Density	1.07±0.02Kg/l
Chloride	Nil
P^H	4.0±1 @ 27C°

3.1.5 Tests results for fly ash and wood ash

Table 3.7 EDAX of Fly ash

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
O K	46.42	61.47	580.92	8.82	0.1498	1.0604	0.3043	1.0000
NaK	0.05	0.04	0.72	99.99	0.0002	0.9642	0.3941	1.0027
MgK	0.63	0.55	17.37	23.33	0.0035	0.9810	0.5615	1.0051
AlK	19.28	15.14	637.80	5.06	0.1287	0.9449	0.7031	1.0048
SiK	24.37	18.38	758.33	5.51	0.1523	0.9658	0.6460	1.0018
ClK	0.00	0.00	0.00	69.79	0.0000	0.9001	0.7784	1.0091
K K	0.58	0.32	13.70	30.44	0.0048	0.8959	0.8978	1.0203
CaK	4.89	2.58	100.79	8.46	0.0422	0.9123	0.9305	1.0158
TiK	1.27	0.56	23.26	22.61	0.0103	0.8270	0.9592	1.0279
FeK	2.51	0.95	29.76	21.75	0.0215	0.8137	0.9969	1.0561

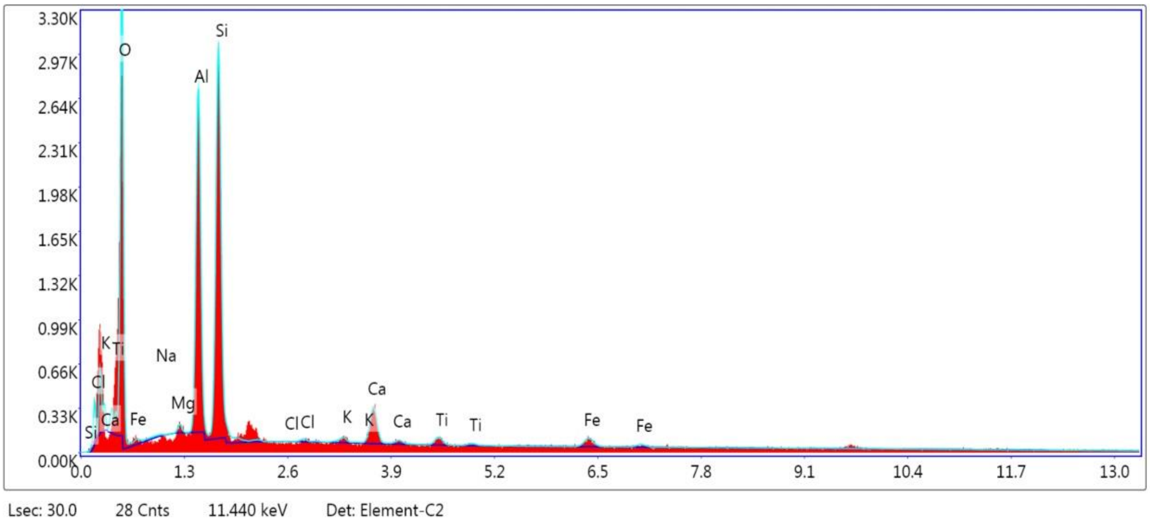

Figure 3-2 EDAX of Fly ash

Table 3.8 EDAX of Wood Ash

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
O K	46.30	66.76	320.38	10.79	0.0684	1.0755	0.1373	1.0000
NaK	0.93	0.93	14.03	22.83	0.0029	0.9790	0.3137	1.0015
MgK	2.02	1.92	55.96	11.15	0.0094	0.9963	0.4634	1.0026
SiK	0.52	0.43	22.44	17.03	0.0037	0.9814	0.7274	1.0081
P K	1.08	0.81	40.99	10.19	0.0085	0.9430	0.8227	1.0131
S K	2.07	1.49	83.32	9.16	0.0180	0.9618	0.8857	1.0190
ClK	4.27	2.78	156.44	5.90	0.0369	0.9153	0.9204	1.0252
K K	17.32	10.22	538.33	3.04	0.1560	0.9113	0.9604	1.0284
CaK	25.49	14.67	622.50	3.35	0.2156	0.9282	0.9080	1.0032

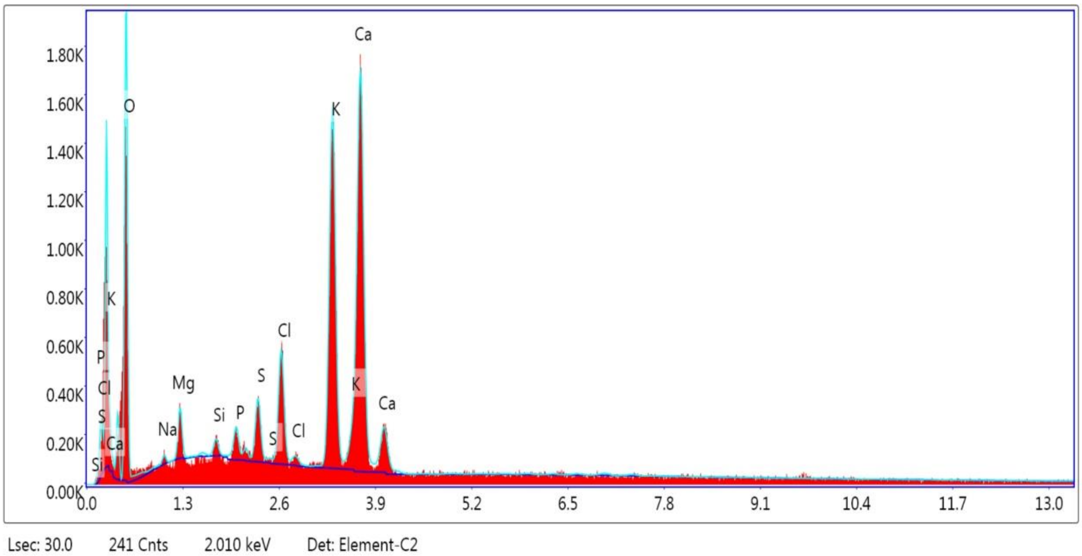

Figure 3-3 EDAX of Wood ash

Table 3.9 XRF of Wood Ash and Fly Ash

Compound	Fly Ash/%	Wood Ash/%
Silica	51.6	8.0
Alumina	31.0	2.0
Iron oxide	3.4	1.3
Calcium oxide	6.4	31.0
Magnesium oxide	2.3	9.5

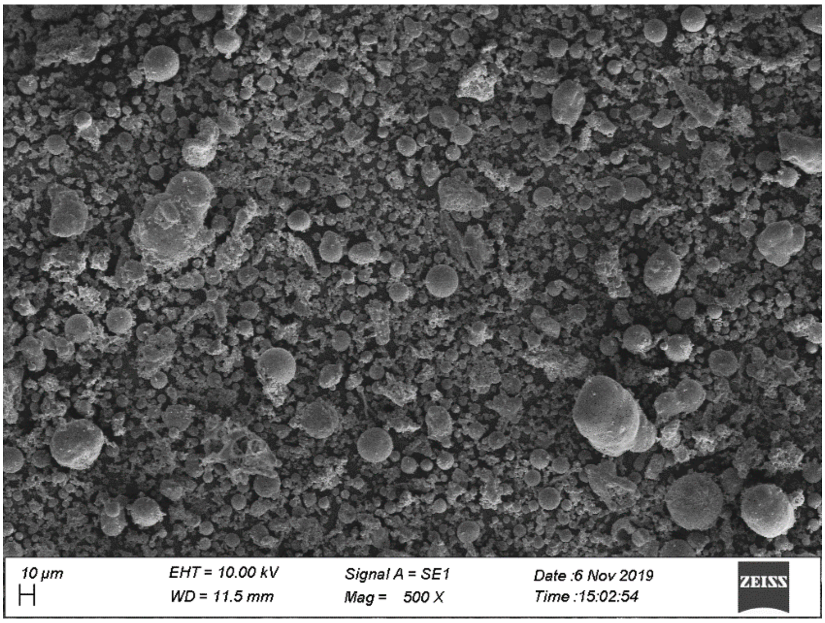

Figure 3-4 SEM image of Fly Ash 0.5K Magnification

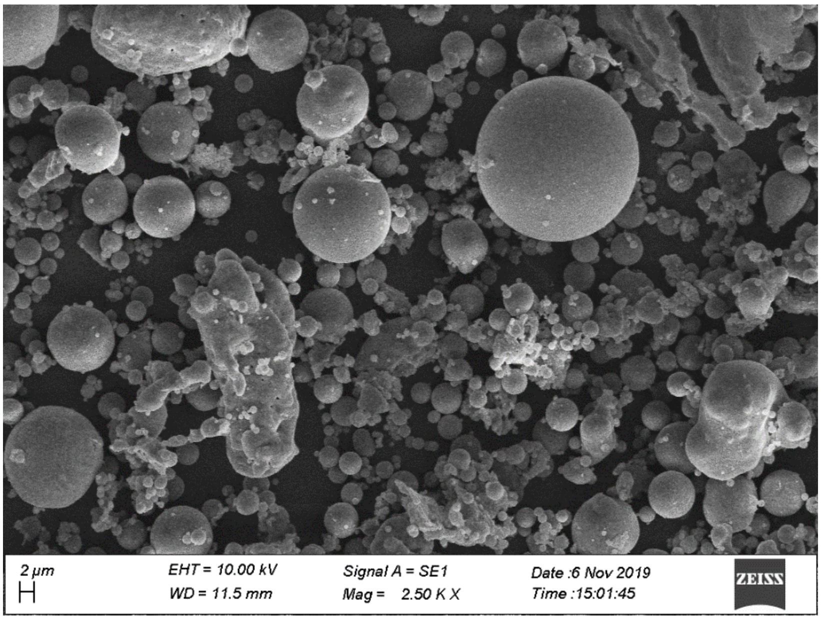

Figure 3-5 SEM image of Fly Ash 2.5K Magnification

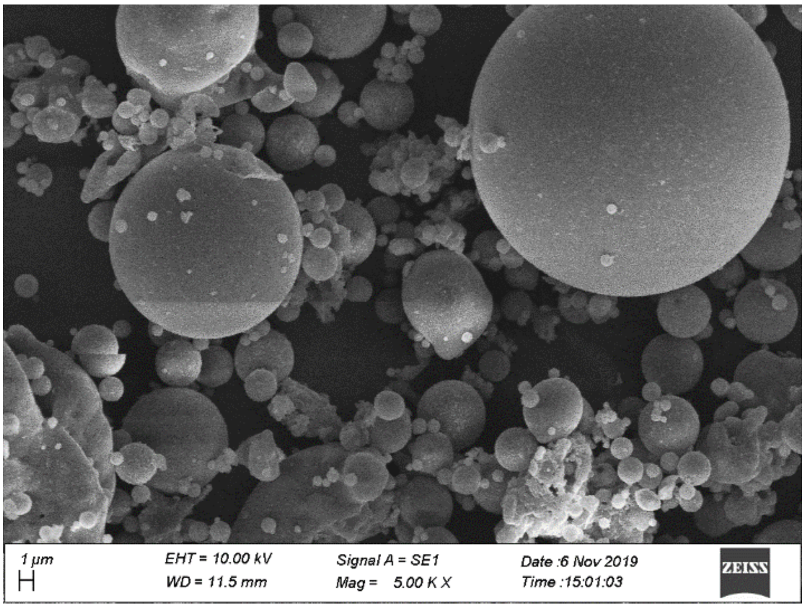

Figure 3-6 SEM image of Fly Ash 5K Magnification

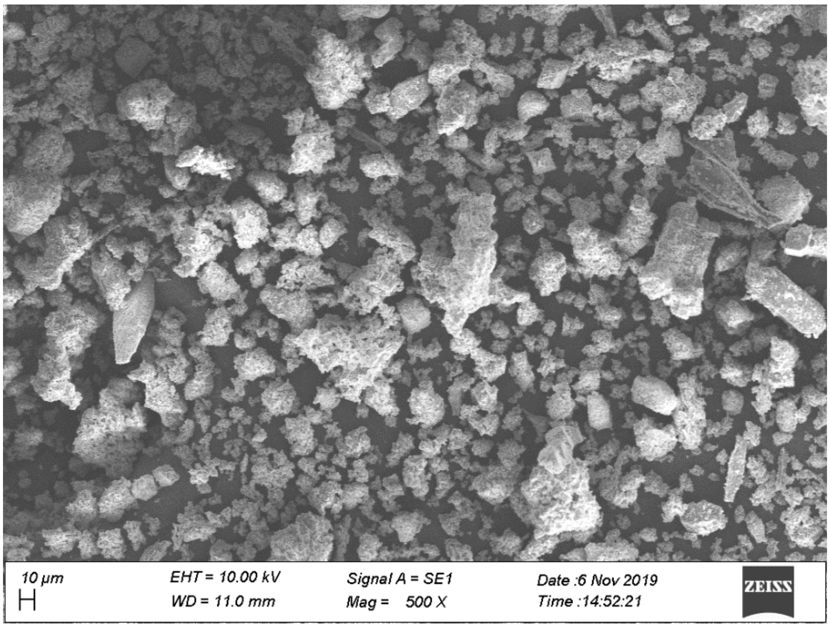

Figure 3-7 SEM image of Wood Ash 0.5K Magnification

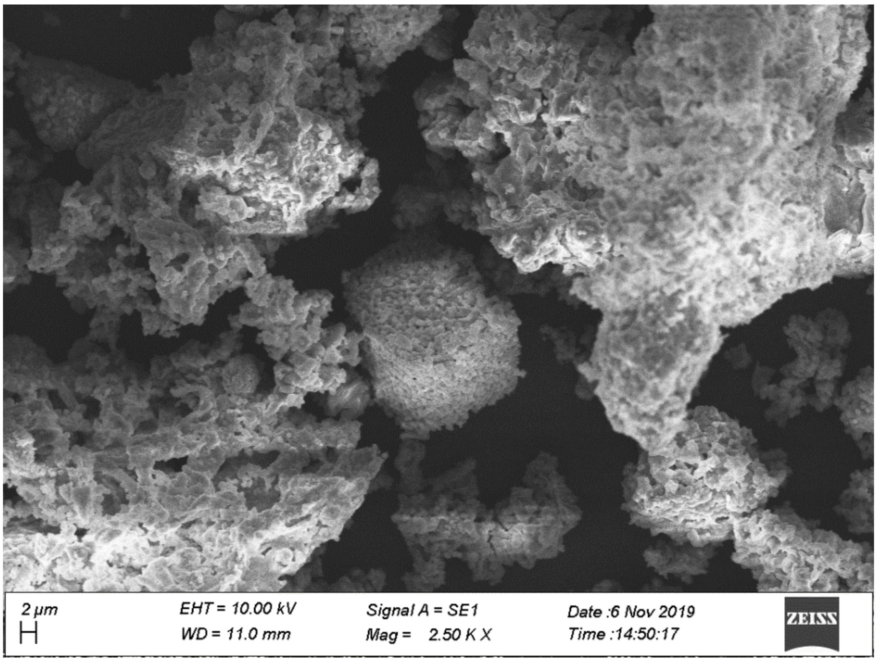

Figure 3-8 SEM image of Wood Ash 2.5K Magnification

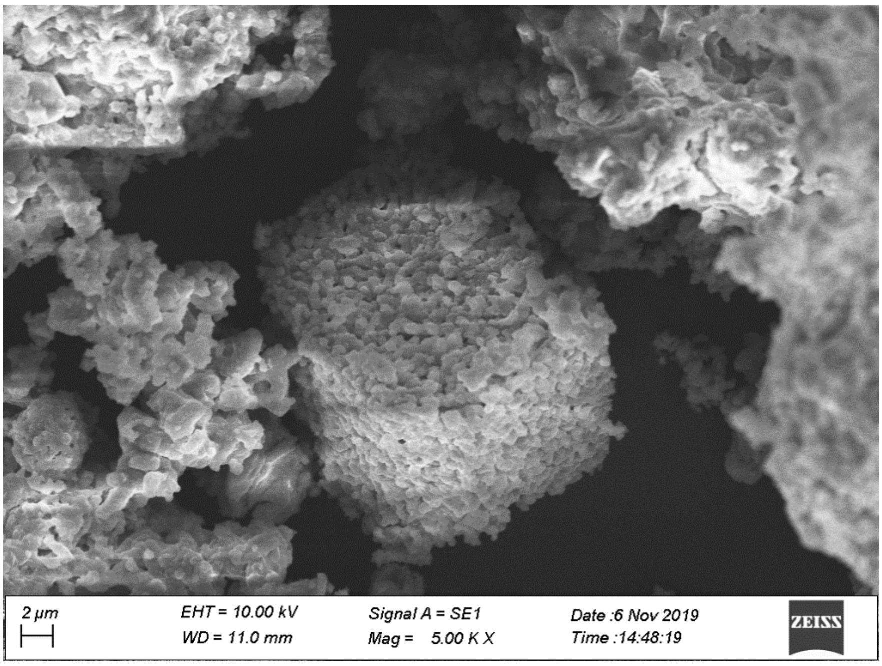

Figure 3-9 SEM image of Wood Ash 5K Magnification

Nippon□ ordinary Portland cement was used for five trial mixes. Drinking quality tap water was used to mix the concrete and St Anthony's□ Ecomix® 30 superplasticizer was used as the chemical admixture. chemical, physical tests, and X-ray fluorescence (XRF) were carried out for cement at Tokyo Cement Factory® (SLAB accredited TL44-01) and physical tests for aggregates were carried out at Construction Research Centre® laboratory (SLAB accredited TL44-02). EDAX and SEM test for wood ash and finished product carried out at the University of Moratuwa.

3.2 Experimental Methodology

As per the properties to be tested, 30L of concrete was decided to batch for each trial mix. Before starting the trail mixes, all the materials except admixture and water were weighed and packed in sealed polythene bags. Sealed polythene bags, weighing scales, slump set, concrete mixture, and paving block molds were taken out to the concrete mixing area. Water and admixture were weighted. All the materials were mixed according to the weight stated in table 3.8. All the trail mixes were mixed separately to obtain a homogenized mixture. Then workability test was performed for five trail mixes. After that paving block molds were cast.

Table 3.10 Mix Percentages of OPC, Fly ash, and Wood ash

Trial mix number	**Variable**		
	OPC (%)	**Fly ash (%)**	**Wood ash (%)**
01(Block01)	90	10	0
02(Block02)	85	10	5
03(Block03)	80	10	10
04(Block04)	75	10	15
05(Block05)	70	10	20

Table 3.11 Trial Mix Proportions

Materials	Kilograms Per 30L				
	T01	T02	T03	T04	T05
Cement	7.560	7.140	6.720	6.300	5.880
Fly Ash	0.840	0.840	0.840	0.840	0.840
Wood Ash	0	0.420	0.840	1.260	1.680
Water	5.220	5.220	5.220	5.220	5.220
Crushed sand	26.610	26.610	26.610	26.610	26.610
5-13mm	10.590	10.590	10.590	10.590	10.590
14-20mm	22.110	22.110	22.110	22.110	22.110
Ecomix 30	67.5ml	67.5ml	67.5ml	67.5ml	67.5ml

Figure 3-10 Raw Materials packed in sealed polythene bags

Figure 3-11 Mixing of raw materials

Figure 3-12 Measuring the slump

Figure 3-13 Casting of CPB

3.3 Properties Tested

After 24hours of casting, the molds were demolded and put into a curing tank for seven days. After 07 days, flexural strength & compressive strength tests were performed. Compressive strength, total water absorption tests were carried out on the 28th day of the cast. The results of five trials were recorded. All the tests were carried out as per the international standard test methods stated in table 3.9. SEM images were taken for five trails blocks types after 28 days.

Table 3.12 Tested Properties

<table>
<tr><th>No</th><th>Test</th><th>Standard</th></tr>
<tr><td>1</td><td>Workability</td><td>BSEN 12390-2</td></tr>
<tr><td>2</td><td>Dimensions</td><td rowspan="5">SLS 1425</td></tr>
<tr><td>3</td><td>Verification of visual aspects</td></tr>
<tr><td>4</td><td>Compressive strength</td></tr>
<tr><td>5</td><td>Flexural strength</td></tr>
<tr><td>6</td><td>Total water absorption</td></tr>
</table>

Figure 3-14 De molded samples

Figure 3-15 Determination of total water absorption

4. RESULTS AND DISCUSSION

4.1 Analysis of Test Results

05 concrete trials have been done for every block type. Determining properties and observed results are revealed from here onwards.

4.1.1 Workability (Slump)

Slump test was carried out as per BSEN 12350 – 2[13] test method in all the trial mixes. The graph for average slump values of each trial includes in Figure 4.1. The graph gives a clear idea about the behavior of slumps with different mix percentages. As expected, the slump has gradually decreased when the wood ash percentage is increasing. The reason is absorption capacity of wood ash is higher and it produces the harder (non–workable) mixture. According to the mix design, the designed (required) slump is 150±25mm. In block types B01, B02, B03, B04 observed slump is within the range, but in B05 shows a very low slump value. Previous studies showed wood ash replacement from cement content influenced the workability of the concrete mixture significantly. To provide the same workability (Slump) water-cement ratio should have to be increased in the wood ash added to concrete. [3,16]

Another previous research showed that changing the percentages of waste wood ash by 5%, 10%, 15%,20%, 25%, and 30% replacement from cement content resulted in a gradual reduction in workability. Increasing wood ash percentage is inversely proportional to the workability. The reason for this may be the porosity and the higher organic content of wood ash [3].

The same results were observed in another research, workability(slump) has reduced by 5-40mm when the wood ash percentage increased up to 5-30% from cement content. When compared to control concrete mix [1]. A study based on G25 concrete showed that 5-30% wood ash replaced from total binder content, also reduced the workability.[2]

When we examine at on the SEM images clusters of wood ash particles are there, it has more surface area, and also it has a more porous structure. So that wood ash particles require more water than fly ash. But increasing the wood ash content gradually water demand is increasing and for the same water, content workability has gradually decreased. The round shape of fly ash particles improved the workability of concrete. By adding 10% of fly ash workability has increased also fly ash could bear the required limit up to B04. But adding 20% of wood ash caused higher workability loss due to its porous structure.

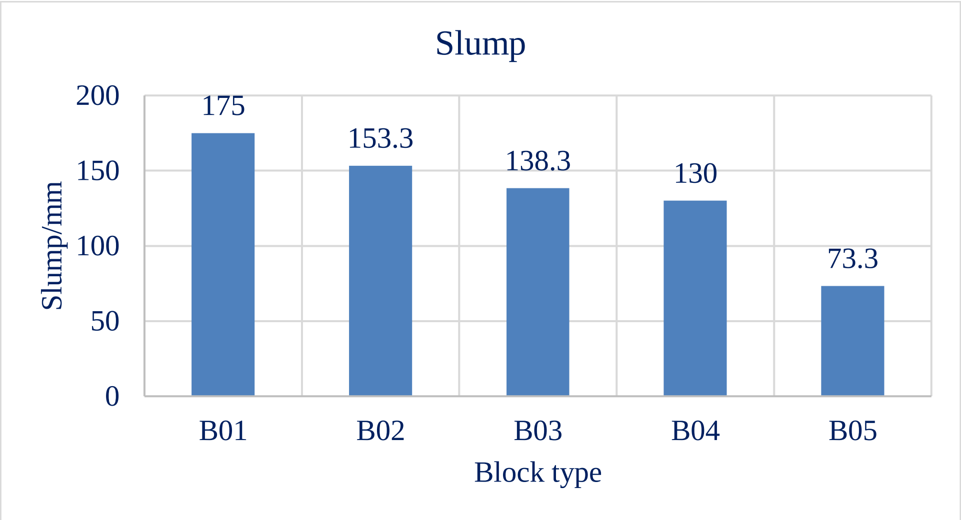

Figure 4-1 Slump Value

Table 4.1 Slump Test Results

	Sump (mm)			**Mean**	**SD**
T01	170	180	175	175.0	5.0
T02	155	160	145	153.3	7.6
T03	140	135	140	138.3	2.9
T04	130	125	135	130.0	5.0
T05	75	65	80	73.3	7.6

4.1.2 Compressive Strength

The compressive strength of hardened concrete can be determined by BSEN 12390 -3 test method [14]. ELE ADR V 2.0 (S.N. 1881-1-10232 / Calibrated: SLSI)) compression machine was used. According to the test results of 07 days and 28 days, strength is decreasing when increasing the wood ash percentage. As per SLS 1425, this block type belongs to strength class 04, so that in the 28th-day block has to reach 15MPa. All block types achieved a 15MPa mark even in 07 days except type B05. B05 fails to reach 15MPa in 28 days as well. In many studies, compressive strength has decreased significantly (around 20%) by replacing wood ash with total cement content [17,18]. Similar studies reported that replacing 5% - 30% wood ash from total binder content and observed the compressive strength on 3, 7, 14, 28, and 90 days, reported an increment of wood ash resulted in decreased compressive strength [3].

The specific gravity of wood ash has a lower value, therefore the density of concrete gradually decreased with increasing wood ash percentage. Due to the porosity of the wood ash, it has more entrapped air in the concrete. According to table 4.2 cube weight has decreased and therefore compressive strength has also gradually decreased.

Due to the higher porosity of wood ash resulting in lower workability, therefore the water required for hydration reaction is lesser at B05. If concrete is in proper workability, a hydration reaction is occurring properly. But lesser in water, hydration reaction occurs in a lesser amount, it resulted in lower compressive strength.

Table 4.2 07 Days Compression Strength Results

Block type	Specification	Specimen	CW/Kg	IL/KN	CL/KN	CS/MPa	Mean/MPa	SD
B1	OPC 90% FA 10% WA 0%	1	2.214	434.6	442.9	22.1	22.2	0.235
		2	2.185	441.3	449.6	22.5		
		3	2.226	432.4	440.6	22.0		
B2	OPC 85% FA 10% WA 05%	1	2.187	420.8	428.8	21.4	21.4	0.157
		2	2.215	417.6	425.6	21.3		
		3	2.159	423.8	431.9	21.6		
B3	OPC 80% FA 10% WA 10%	1	2.143	371.4	378.7	18.9	19.2	0.310
		2	2.225	383.6	391.1	19.6		
		3	2.170	377.2	384.6	19.2		
B4	OPC 75% FA 10% WA 15%	1	2.095	363.7	370.9	18.5	18.6	0.359
		2	2.110	372.4	379.7	19.0		
		3	2.125	358.4	365.5	18.3		
B5	OPC 70% FA 10% WA 20%	1	1.845	247.9	253.3	12.7	12.5	0.313
		2	1.860	237.6	242.9	12.1		
		3	1.795	248.6	254.0	12.7		

Table 4.3 28 Days Compressive Strength

Block type	Specification	Specimen	CW/Kg	IL/KN	CL/KN	CS/MPa	Mean/MPa	SD
B1	OPC 90% FA 10% WA 0%	1	2.225	567.8	578.0	28.9	28.7	0.203
		2	2.265	561.6	571.7	28.6		
		3	2.310	560.3	570.4	28.5		
B2	OPC 85% FA 10% WA 05%	1	2.186	521.2	530.7	26.5	26.5	0.409
		2	2.214	527.6	537.2	26.9		
		3	2.210	511.6	521.0	26.0		
B3	OPC 80% FA 10% WA 10%	1	2.165	452.9	461.4	23.1	23.4	0.446
		2	2.187	469.8	478.6	23.9		
		3	2.165	457.1	465.7	23.3		
B4	OPC 75% FA 10% WA 15%	1	2.210	425.8	433.9	21.7	21.7	0.218
		2	2.185	430.4	438.6	21.9		
		3	2.175	421.8	429.9	21.5		
B5	OPC 70% FA 10% WA 20%	1	1.935	278.8	284.7	14.2	13.7	0.442
		2	1.995	263.2	268.9	13.4		
		3	1.895	264.3	270.0	13.5		

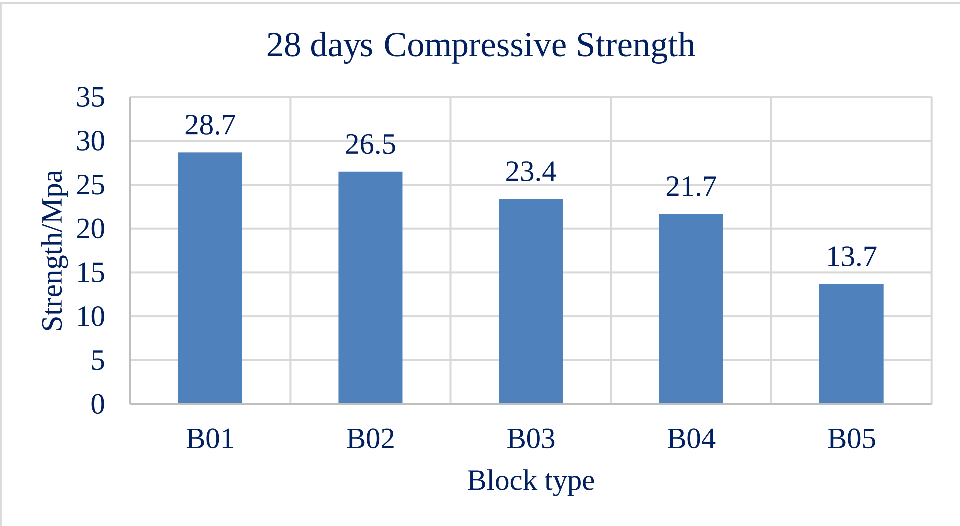

Figure 4-2 Compressive Strength in 28 days

4.1.3 Flexural Strength

It is important that when placed a paving block, it was subjected to compression and flexural loads at the same time. So it is better to consider flexural strength. It was done as per SLS ISO 679. Testing combined compression / flexural machine (S.N. 022/ Calibrated: SLSI) was used to determine flexural strength. By comparing every block type results in 07 and 28 days, B05 shows the lowest values. B04 shows the highest value among them. B04 has the maximum flexible capacity. Several studies also reported flexural strength has decreased by increasing the wood ash percentage. But the reduction rate of compressive strength is higher than that of flexural strength [3]. 0% percent wood ash containing samples flexural strength is higher than that of 30% wood ash containing samples. A study showed that 28 days of concrete FS has varied, this may be due to the little pozzolanic activity of wood ash [6]. In similar cement mortar prepared by replacing 0%, 10%, 20%, 30% from total cement content showed that increment in wood ash percentage caused in reduction of fly ash [19].

In tables 4.4 and 4.5, the 07- & 28-days flexural strength shows some different patterns as to slump & compressive strength. In figure 3.7, SEM image with the magnification of 0.5K, wood ash contains some round particles as well as flaky particles. If the content of the flaky particles increased it may be a reason for lower flexural strength. But if round particles and flaky particles consist in a proper way the concrete is also packed hence it may be a reason for the increase in flexural strength. We can't control the particle distribution of wood ash so that it distributes unevenly in the concrete mixture then the well-packed cube has more flexural strength than the others. It may be a reason for this abnormality.

Table 4.4 07 Days Flexural Strength

Block type	Specification	Specimen	FS/MPa	Mean/MPa	SD
B1	OPC 90% FA 10% WA 0%	1	1.45	1.45	0.455
		2	1.44		
		3	1.46		
B2	OPC 85% FA 10% WA 05%	1	1.49	1.50	0.818
		2	1.50		
		3	1.51		
B3	OPC 80% FA 10% WA 10%	1	1.53	1.54	0.353
		2	1.56		
		3	1.54		
B4	OPC 75% FA 10% WA 15%	1	1.55	1.57	0.437
		2	1.57		
		3	1.58		
B5	OPC 70% FA 10% WA 20%	1	0.85	0.85	0.302
		2	0.83		
		3	0.86		

Table 4.5 28 Days Flexural Strength

Block type	Specification	Specimen	FS/MPa	Mean/MPa	SD
B1	OPC 90% FA 10% WA 0%	4	1.65	1.64	0.031
		5	1.61		
		6	1.67		
B2	OPC 85% FA 10% WA 05%	4	1.82	1.82	0.025
		5	1.79		
		6	1.84		
B3	OPC 80% FA 10% WA 10%	4	1.61	1.61	0.025
		5	1.58		
		6	1.63		
B4	OPC 75% FA 10% WA 15%	4	1.79	1.76	0.031
		5	1.75		
		6	1.73		
B5	OPC 70% FA 10% WA 20%	4	1.25	1.25	0.040
		5	1.29		
		6	1.21		

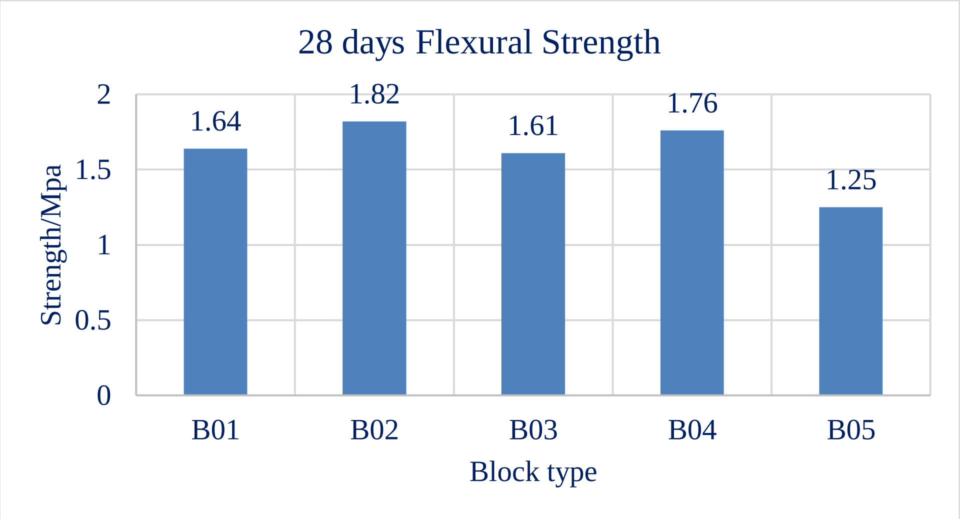

Figure 4-3 Flexural strength in 28 days

4.1.4 Dimensions

Dimensions have been measured and recorded as per SLS 1425-2 test method. In that standard for block type R two, three, and four measurements have to be taken for length, width, and thickness respectively. The values should have to be nearest 1mm.

From B01 to B05 – surface smoothness has decreased gradually. Due to the higher loss of workability in B05, it was not packed properly and has more honeycombs in the specimens. When measuring the specimen – positioning of the caliper is difficult due to those honeycombs, tends to deviations from the standard value. B05 has more standard deviation (SD) values than others. When the layout of the blocks is in a pattern more spaces have been created in between two as well as the surface of every B05 block. No such observations have not seen in B01 – B04 block types.

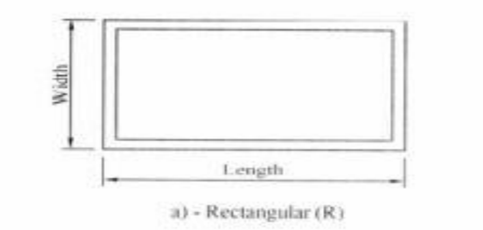

Figure 4-4 Dimensions of CPB

Table 4.6 Dimensions

Block type	Spec	Length /mm	Width /mm	Thickness /mm	Mean Length	Mean Width	Mean Thickness
B01	OPC90% FA 10% WA 0%	200.25 200.65 200.34 200.78	100.64 100.78 100.45 100.58	60.45 60.76 61.04 60.59	200.5	100.6	60.7
B02	OPC85% FA 10% WA 05%	200.59 201.15 200.86 200.69	100.82 100.71 100.64 100.91	60.51 60.72 60.39 60.82	200.8	100.8	60.6
B03	OPC80% FA 10% WA 10%	200.57 200.84 200.62 201.25	100.66 100.89 100.72 100.91	60.72 60.46 60.59 60.64	200.8	100.8	60.6
B04	OPC75% FA 10% WA 15%	200.89 201.32 200.98 200.87	100.56 100.81 100.74 100.98	60.68 60.92 60.54 60.59	201.0	100.8	60.7
B05	OPC70% FA 10% WA 20%	199.65 198.92 199.46 199.78	98.45 99.11 98.76 98.69	60.81 62.09 60.72 59.46	199.5	98.8	60.8

All the linear measurements have been taken from the digital Venire caliper (SN:49-923-300, Model: Lin 8121768, Calibrated: SLSI).

4.1.5 Verification of Visual Aspects

Layout the CPB on the level of the floor as an interlocking pattern likely to square, then it can be examined for the verification of visual aspects.

This should be taken place in natural lighting conditions and should be observed at least 2m from each edge of CPB as per SLS 1425-2.

The texture of every block type has been compared. From type 01 to 05, texture quality is reducing significantly. Type B01 to B04 textures are in an acceptable range, but not as much as type B05.

Figure 4-5 Delamination of type 03 paving Block

4.1.6 Total Water Absorption

Total water absorption was determined as per SLS 1425 at 28 days of age. This is a measure of durability. This should be less than 6%. B02 shows the lowest absorption value while B05 shows the highest water absorption value and it exceeds the standards. When increasing the wood ash percentage in CPB, gradually increasing the water absorption due to the increment of the porosity of wood ash. Some studies observed that water absorption was lower value at lower wood ash content and it was increased when it increased the wood ash percentage [20]. The acceptable limit of total water absorption is 8% for most of the construction materials. Udeoyo et al [3] study showed that water absorption of concrete has increased by increasing the wood ash replacement percentage. In the study, wood ash was replaced from 5% to 30% from total binder materials and increased water absorption. The reason is the porosity of the wood ash.

Here there is an abnormal pattern observed, it may be due to high porous particles included in B03 hence its total water absorption is higher than B01, B02, B04. Because flaky particles do not contain a more porous structure, but in a round shape, particles have a more porous structure. B05 contains 20% of wood ash caused the highest value of total water absorption.

Table 4.7 Total Water Absorption

Block type	Specification	Specimen	SSDW/Kg	ODW/Kg	TWA/%	Mean/MPa	SD
B1	OPC 90% FA 10% WA 0%	7	2176.5	2081.9	4.54	4.7	0.168
		8	2142.6	2042.9	4.88		
		9	2165.3	2067.6	4.73		
B2	OPC 85% FA 10% WA 05%	7	2139.9	2052.6	4.25	4.4	0.142
		8	2102.7	2011.7	4.52		
		9	2129.7	2041.6	4.32		
B3	OPC 80% FA 10% WA 10%	7	2073.5	1955.1	6.06	5.8	0.197
		8	2108.3	1995.3	5.66		
		9	2098.7	1983.2	5.82		
B4	OPC 75% FA 10% WA 15%	7	2137.0	2045.6	4.47	4.6	0.144
		8	2137.3	2041.1	4.71		
		9	2140.6	2044.1	4.72		
B5	OPC 70% FA 10% WA 20%	7	1973.7	1843.5	7.06	7.1	0.227
		8	1904.5	1774.2	7.34		
		9	1923.7	1799.6	6.90		

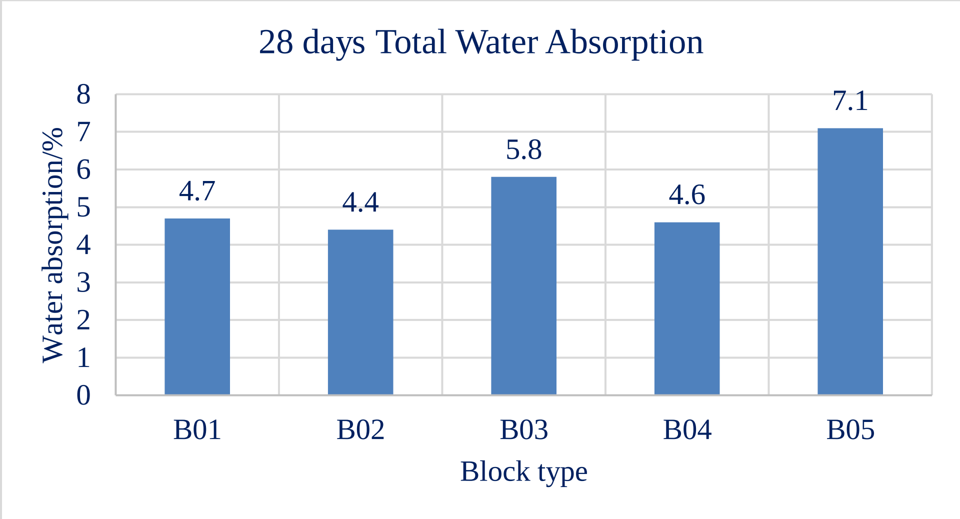

Figure 4-6 Total Water Absorption

4.1.7 Micro Structural Analysis using Scanning Electron Microscope

This analysis has conducted at the University of Moratuwa from SEM (Carl Zeiss Evo 18 Research).

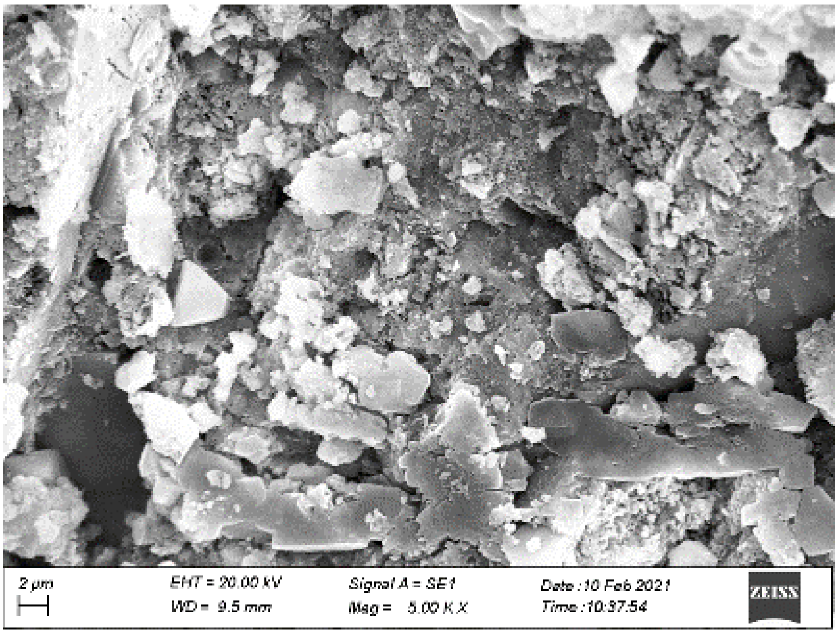

Figure 4-7 SEM of the cross-section of CPB – B01 (5KX)

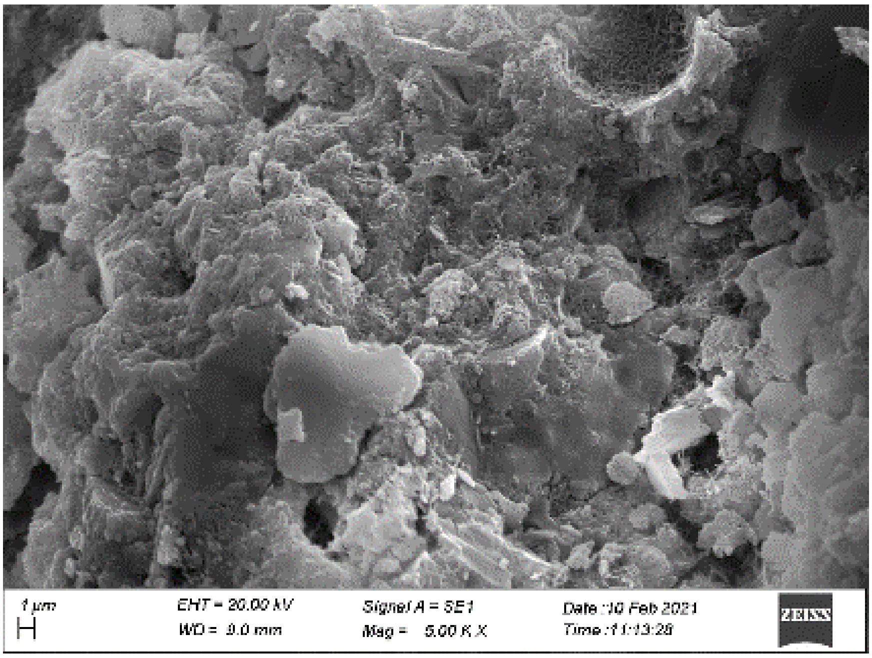

Figure 4-8 SEM of the cross-section of CPB - B02 (5KX)

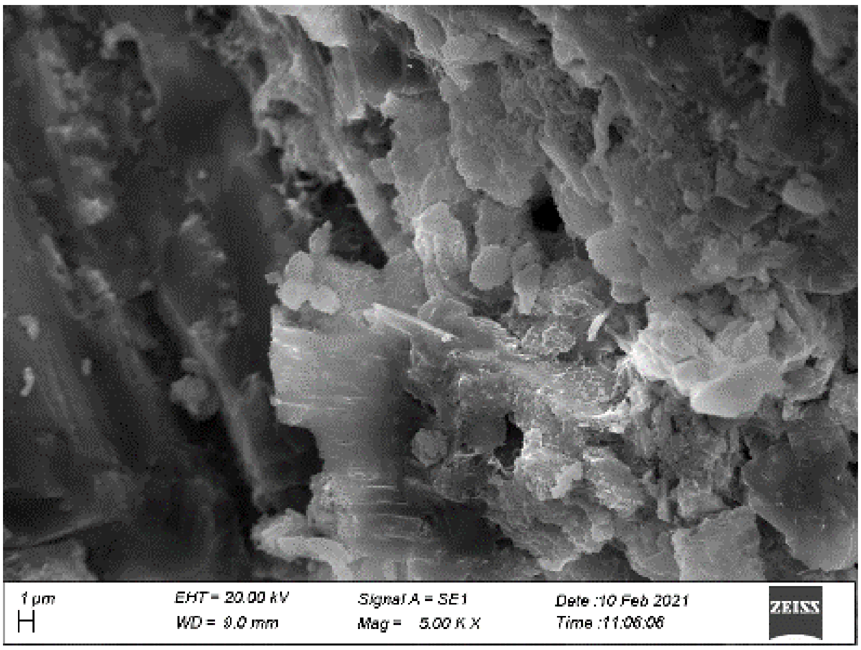

Figure 4-9 SEM of a cross-section of CPB - B03 (5KX)

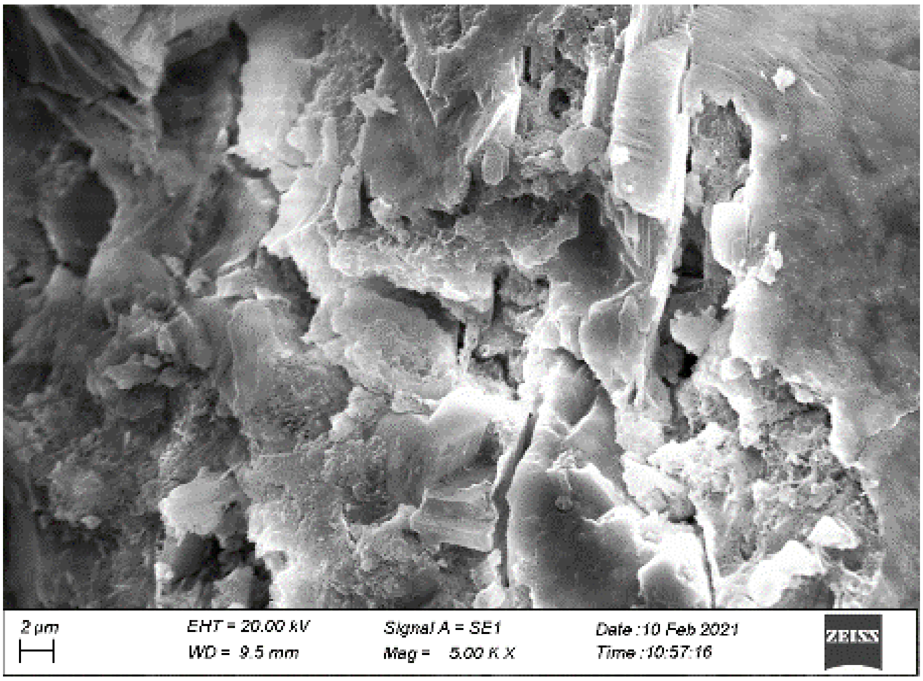

Figure 4-10 SEM of the cross-section of CPB - B04 (5KX)

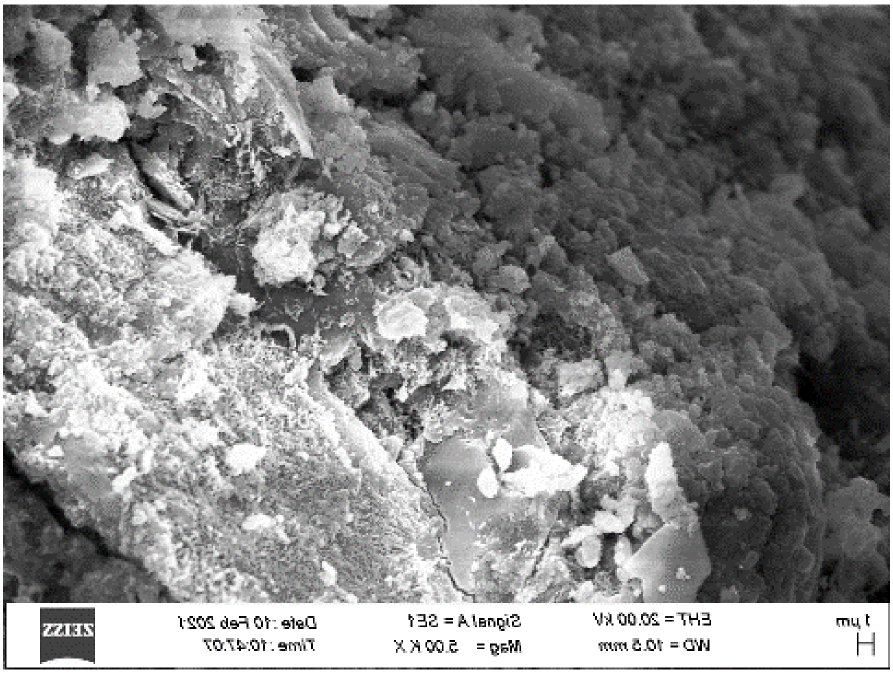

Figure 4-11 SEM of a cross-section of CPB - B05 (5KX)

From SEM images of B01 to B05 cross-sections, the surface of those blocks gradually roughening as to the naked eye. The porosity of the B05 block shows in higher as compared to other SEM images. So due to the loss of workability compaction of concrete has gradually decreased and resulted increase in surface area and surface roughness. SEM images have provided better justification.

4.2 Cost Analysis

4.2.1 Cost Calculation as per Materials Cost

When a new type of CBP is introduced, the cost factor plays a vital role to compete with existing manufacturers of CPBs. To compete in the market a new product should be a performance effective, low-cost product while complying with the standards. When designing concrete for industrial applications, the cost plays a vital role. Hence, a cost calculation was carried out for all trial mixes by considering materials cost and a cost per square foot.

Table 4.8 Unit Prize of Materials

Materials	**Cost per 01 ton/Rs:**
Cement	16410
Fly ash	10530
Wood ash	0.0
Crushed sand	1970
Coarse Aggregate 01	1500
Coarse Aggregate 02	1500
Water	1000
Ecomix® 30	273 (01 Liter)

Here materials cost for 01 ton is provided. These values were taken from Tokyo Super Mix® concrete plant- Peliyagoda. Based on the material costs, the materials cost for each block is calculated. The prizes are subjected to wholesale. So that these values are as low as competing with other suppliers.

Table 4.9 Materials Cost Calculation of Paving Block Types per 01M^3

Materials	B01/Rs:	B02/Rs:	B03/Rs:	B04/Rs:	B05/Rs:
Cement	4135.32	3958.58	3675.84	3446.10	3216.36
Fly ash	294.84	294.84	294.84	294.84	294.84
Wood ash	0.00	0.00	0.00	0.00	0.00
Crushed sand	1733.60	1733.60	1733.60	1733.60	1733.60
Coarse aggregate01	526.50	526.50	526.50	526.50	526.50
Coarse aggregate02	1098.00	1098.00	1098.00	1098.00	1098.00
Water	174.00	174.00	174.00	174.00	174.00
Ecomix® 30	614.25	614.25	614.25	614.25	614.25
Total cost per 01m^3	**8576.51**	**8346.77**	**8117.03**	**7887.29**	**7657.55**

According to the cost calculation, B05 shows the lowest materials cost while B01 shows the highest materials cost. The cost of cement is the deciding factor of the cost of mix design. Here only considered the materials cost per 01 cubic meter concrete for every block type. The final cost of a block can be calculated by adding labor cost, electricity cost, machine wearing cost, etc.

By replacing wood ash 11% of materials cost can be reduced in B05 type. But it was not performance effective block. In B04 type 8% of materials cost can be reduced, and it is complying with the SLS 1425 standard.

4.2.2 Cost per Square feet

Prize of 01 cubic meter of concrete B01	= 13950+VAT = 15066LKR
Volume of each block	= 1.2L
Approximate blocks per 1000L	= 800
Cost per Block	= 18.83 LKR
Area of one block	= 200*100mm^2 = 0.2152 Ft^2
Blocks per SQFT	= 4.64
Cost per SQFT	= 4.64*18.83 = 87.37 LKR

New modified mix design B04 Cost	= 13330+VAT = 14396.40LKR
Cost per block	= 17.99
Cost per SQFT	= 4.64*17.99 = 83.47 LKR
Cost reduction per SQFT	= 3.90 LKR

By considering materials cost, B05 has the lowest cost but it is deviating from the standard limits. So B04 is the best effective type.

By considering final costs 3.90 LKR can be reduced from 01 Square feet.

This is the finalized mix design as per 15MPa strength class 04.

Table 4.10 Modified Mix Design

Material	**Quantity per 01 Cubic meter/Kg**
OPC	210
Fly Ash	28
Wood Ash	42
Water	174
M – Sand	887
CA 01	353
CA 02	737
Ecomix 30	2250ml

5. CONCLUSIONS

This study focused on manufacturing a cost-effective SLS standard that complies with SLS. Several parameters were analyzed such as workability, dimensions, verification of visual aspects, compressive strength of CPB at 7 and 28 days, the flexural strength of CPB at 7 and 28 days, and total water absorption. Also, SEM images of cross-sections of each and all block types were obtained.

For this concrete paving block trial 15MPa mix design was selected.

Workability was reduced by increasing the wood ash percentage. It means 5%, 10%, 15%, 20% replacement of wood ash showed less workability compared to the control mix (B01). Mix proportions were designed for 150±25mm slump. In the control mix, 175mm slump was observed and 20% wood ash replacement (B05) showed 73.3mm slump. B02, B03, B04 slumps values were within the required limit. So B05 deviated from requirements. Due to the porous structure (figure 3.8 & Figure 3.9) of wood ash water demand was highest in B05. With the same amount of water content slump value has decreased.

Compressive strength was reduced by increasing the wood ash percentage by 5%, 10%, 15%, 20%. This resulted in a gradual decrease in strength when compared to the control mix. In 28 days, the strength of concrete should be at least 15MPa, for the G15 mix design. Here B01, B02, B03, B04 strength values were within the limit while B05 value has deviated from the requirements. Less cementitious properties caused lower strength hence Silica content of fly ash is around 50% but in wood ash 8%, so that wood ash is less reactive than fly ash. Adding more wood ash gradually decrease the cement content so that compressive strength has gradually decreased.

For the flexural strength, no such requirement is mentioned in the standard, however, when the wood ash percentage is increasing, flexural strength was decreased gradually. While B01 showed the highest value and B05 shows the lowest value. The uneven distribution of flaky and angular particles of wood ash may cause the abnormality of flexural strength. High flakiness may cause lower results and properly distributed specimens shows better strength.

Dimensions were measured by a digital caliper. From B01 to B04 produced some sort of fare finish of the outer surface of paving blocks. Due to a huge decrease in workability B05 showed a rough outer surface finish product. From B01 to B04 observed acceptable fare outer finish while B05 showed a much rougher finish. It can be concluded visually. SD values of B05 show many deviations when compared to others. Due to the lower workability, this roughest surface was obtained on B05.

As per SLS 1425 total water absorption should be less than 6%. All values of B01 to B04 showed less than 6% and B05 showed 7.1%. It was due to organic matters in wood ash and as well as the higher porosity of it. Here clear pattern was not observed from B01 to B04, it may be due to the uneven distribution of flaky and angular particles.

Finally, SEM images were taken for the finished products of cross-sections of every block type. According to those images surface area and porosity of the structure have gradually increased.

From the technical view B01 – B03 shows good performance, but in cost consideration, they show higher values. In cost consideration, B05 shows the lowest, but its properties exceeded the standard limits. Technical properties are achieved in B04 acceptably and the best cost option after B05 is B04. Therefore, we can recommend B04 as a cost-effective paving block.

Cost calculation as per materials cost shows B05 has the lowest while B01 has the highest. 8% of materials cost can be reduced by introducing a B04 type mix design. From the cost per square feet calculation – it has reduced 3.90 LKR per square feet in modified mix design B04.

6. RECOMMENDATIONS & FURTURE WORK

- This conclusion can be implemented to any CPB manufacturer to increase their profit margin. Also, it would be beneficial by utilizing the industrial byproduct to a new product.
- Further separate study can be carried out to calculate the total cost per cubic meter and also cost per each block by adding labor cost, electricity cost, machine wearing cost, etc.
- This study has revealed only the 15MPa strength class concrete trialing procedure, it can be implemented to 50MPa, 40MPa, 30MPa like other strength classes as well.

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Appendix A

Test Results of Aggregates

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Sieve Analysis of Aggregate

01. Date of Test : 02.01.2020
02. Job No :
03. Client : Tokyo Super Aggregates (pvt) Ltd.
04. Source : M sand
05. Test Method : BS 812 - 103: 1985
06. Test Certificate No :

Step	Reading
Initial weight of oven dried sample /g	1328.3
Weight of oven dried sample after washing on ......75μm...... sieve /g	1258.8
Weight of passing through the......75μm...... sieve /g	69.5
Percentage of material finer than ......75μm...... in fine aggregate / %	5.2

Size(mm)	Weight Retained/g	Retained /%	Passing /%
10.00	0.0	0.00	100.0
5.00	32.4	2.44	97.6
2.36	311.4	23.44	74.1
1.18	235.0	17.69	56.4
0.60	189.6	14.27	42.2
0.30	206.4	15.54	26.6
0.15	173.4	13.05	13.6
0.00	180.1	13.56	0.0
Total	1328.3	100.00	
	Fineness Modulus	290	

Tested & Computed by

Name : HMTM Amarugama

Designation : R.O.

Signature : Au.

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature : [illegible]

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Specific Gravity & Water Absorption of Aggregate

01.	**Date of Test**	: 20.12.2019
02.	**Job No**	:
03.	**Client**	: Tokyo Super Aggregates (pvt) Ltd.
04.	**Source**	: M sand
05.	**Test Method**	: BS 812 - 2: 1995
06.	**Test Certificate No**	:

Step	**Reading**		
Weight of pyknometer with sample and rest filled with water /g	3263.3	3263.7	
Temperature of water /°C	24	24	
Weight of pyknometer fulfilled with water /g	2943.7	2943.7	
Temperature of water /°C	24	24	
Weight of the sample in SSD condition /g	500.0	500.0	
Weight of the oven dried sample/g	498.1	498.3	
Specific gravity (oven dried) (g/l)	2.761	2.768	
Average specific gravity (oven dried) (Mg/m^3)	**2.765**		
Specific gravity (SSD) (g/l)	2.772	2.778	
Average specific gravity (SSD) (Mg/m^3)	**2.775**		
Apparent specific gravity (g/l)	2.790	2.795	
Average apparent specific gravity (Mg/m^3)	**2.793**		
Water absorption (%)	0.381	0.341	
Average water absorption (%)	**0.36**		

Tested & Computed by

Name : HMTM Amarugama

Designation : R.O.

Signature :

Checked by

Name : GKMIR Kaviraj

Designation : Manager product testing

Signature :

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Sieve Analysis of Aggregate

01.	Date of Test	: 03.01.2020
02.	Job No	:
03.	Client	:
04.	Source	: 5-13mm
05.	Test Method	: BS 812 - 103:1985
06.	Test Certificate No	:

Step	Reading
Initial weight of oven dried sample /g	2570.4
Weight of oven dried sample after washing on ....75 μm........sieve /g	2566.4
Weight of passing through the..........75 μm.... sieve /g	4.0
Percentage of material finer than ....75 μm...... in coarse aggregate / %	0.2

Size(mm)	Weight Retained/g	Retained /%	Passing /%
37.500	0.0	0.00	100.00
20.000	0.0	0.00	100.00
14.000	25.1	0.98	99.02
10.000	1565.8	60.92	38.11
5.000	968.5	37.68	0.43
2.36	2.5	0.10	0.33
0.00	8.5	0.33	0.00
Total	2570.4	100.00	
	10 mm size passing / %	38.1	

Tested & Computed by

Name : HMTM Amarugama

Designation : R.O.

Signature : Ay.

Checked by

Name : GGMJR Kumara

Designation : Manager - Test

Signature : Jumara

TOKYO CEMENT COMPANY (LANKA) PLC
Construction Research Center

Test Results

Flakiness Index of Coarse Aggregate

01.	**Date of Test**	: 03.01.2020
02.	**Job No**	:
03.	**Client**	: Tokyo Super Aggregates (pvt) Ltd.
04.	**Source**	: 5-13mm
05.	**Test Method**	: BS 812 - 105.1:1989
06.	**Test Certificate No**	:

Step	Reading									
Passing sieves	28	20	14	10						
Retained sieves	20	14	10	6.3						
Retaining weight fraction /g	0.0	25.1	1565.8	940.5						
Total weight retaining on test sieve/g	2531.4									
Retaining weight percentage/%	0.0	1.0	61.9	37.2						
Total weight after descard (5% or less)/g	2506.3									
Specific flakiness / Bar sieve	14.4	10.2	7.2	4.9						
Passing weight through flakiness or bar sieve /g	0.0	15.7	240.5	113.3						
Total passing weight through flakiness or bar sieves /g	369.5									
Total passing weight through flakiness or bar sieves after descard (5% or less)/g	353.8									
Flakiness index value /%	**14.1**									

Tested & Computed by

Name : HMTM Amarasgima

Designation : R.O.

Signature : Am

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature : Jangr

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Impact Value of Coarse Aggregate

01.	**Date of Test**	: 03.01.2020
02.	**Job No**	:
03.	**Client**	: Tokyo Super Aggregates (pvt) Ltd.
04.	**Source**	: 5-13mm
05.	**Test Method**	: BS 812-112.1990
06.	**Test Certificate No**	:

Step	**Reading**		
Passing sieve(mm)	14	14	14
Retained sieve(mm)	10	10	10
Weight of total wet sample /g	352.0	352.0	352.0
No of hammer blows	15	15	15
Weight of total dried sample /g	349.9	349.6	349.9
Testing sieve(mm)	2.36	2.36	2.36
Passing weight through testing sieve /g	83.6	84.8	79.5
Retained weight on testing sieve /g	266.3	264.8	270.4
Passing percentage / %	23.89	24.26	22.72
Aggregate impact value	23.89	24.26	22.72
Average aggregate impact value	**23.6**		

Tested & Computed by

Name : HMTM Amunugama

Designation : R.O.

Signature : Au

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature : Jaws

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Sieve Analysis of Aggregate

01.	**Date of Test**	: 20.12.2019
02.	**Job No**	:
03.	**Client**	: Tokyo Super Aggregates (pvt) Ltd.
04.	**Source**	: 14-20mm
05.	**Test Method**	: BS 812 - 103:1985
06.	**Test Certificate No**	:

Step	**Reading**
Initial weight of oven dried sample /g	2637.7
Weight of oven dried sample after washing on ......75 µm........ sieve /g	2623.7
Weight of passing through the ....75 µm.......... sieve /g	14.0
Percentage of material finer than ....75 µm........ in coarse aggregate / %	**0.5**

Size(mm)	**Weight Retained/g**	**Retained /%**	**Passing /%**
37.500	0.0	0.00	100.00
20.000	81.9	3.10	96.90
14.000	1868.7	70.85	26.05
10.000	619.5	23.49	2.56
5.000	45.2	1.71	0.85
0.00	22.4	0.85	0.00
Total	**2637.7**	**100.00**	
	10 mm size passing / %	**2.56**	

Tested & Computed by

Name : HMTM Amarugama

Designation : R.O.

Signature : Ay

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature : Jauku

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Center

Test Results

Flakiness Index of Coarse Aggregate

01.	Date of Test	: 20.12.2019
02.	Job No	:
03.	Client	: Tokyo Super Aggregates (pvt) Ltd.
04.	Source	: 14-20mm
05.	Test Method	: BS 812 - 105.1:1989
06.	Test Certificate No	:

Step	Reading									
Passing sieves	28	20	14	10						
Retained sieves	20	14	10	6.3						
Retaining weight fraction /g	81.9	1868.7	619.5	45.2						
Total weight retaining on test sieve/g	2615.3									
Retaining weight percentage/%	3.1	71.5	23.7	1.7						
Total weight after descard (5% or less)/g	2488.2									
Specific flakiness / Bar sieve	14.4	10.2	7.2	4.9						
Passing weight through flakiness or bar sieve /g	0.0	175.4	109.6	5.1						
Total passing weight through flakiness or bar sieves /g	290.1									
Total passing weight through flakiness or bar sieves after descard (5% or less)/g	285.0									
Flakiness index value /%	**11.5**									

Tested & Computed by

Name : HMTM Amunugama

Designation : R.O.

Signature :

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature :

TOKYO CEMENT COMPANY (LANKA) PLC

Construction Research Centre

Test Results

Impact Value of Coarse Aggregate

01.	**Date of Test**	: 20.12.2019
02.	**Job No**	:
03.	**Client**	: Tokyo Super Aggregates (pvt) Ltd.
04.	**Source**	: 14-20mm
05.	**Test Method**	: BS 812-112.1990
06.	**Test Certificate No**	:

Step	**Reading**		
Passing sieve(mm)	14	14	14
Retained sieve(mm)	10	10	10
Weight of total wet sample /g	356.4	356.4	356.4
No of hammer blows	15	15	15
Weight of total dried sample /g	354.0	354	354
Testing sieve(mm)	2.36	2.36	2.36
Passing weight through testing sieve /g	92.2	81.2	85.7
Retained weight on testing sieve /g	261.8	272.8	268.3
Passing percentage / %	26.05	22.94	24.21
Aggregate impact value	26.05	22.94	24.21
Average aggregate impact value	**24.4**		

Tested & Computed by

Name : HMTM Amaragama

Designation : R.O.

Signature :

Checked by

Name : GKMJR Kaviraj

Designation : Manager-Product testing

Signature :

Appendix B

Test Results of Cement

cement report - 2019.12.pdf

Appendix C

Grade 15 Mix Design

mix design G15 paving block.pdf

Appendix D

Technical Details of Ecomix® 30

DESCRIPTION-EC30.pdf

Appendix E

- BSEN 12350-2
- SLS 1425 – 1
- SLS 1425 – 2