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Investigating the acceptable quantity of fine aggregate to be replaced with sawdust to obtain strong, light weight, and economical result for HCB production

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ABSTRACT

Hollow concrete blocks are a construction material produced from a mixture of Portland cement (OPC or PPC), Fine aggregates and Water. But the concrete mixture used for blocks has a higher percentage of fine aggregate and a lower percentage of water than the concrete mixtures used for general construction purposes. The construction industry is a rapidly growing industry in the world and hollow concrete blocks are being widely used in the construction of residential buildings, factories, and multi-storied buildings. Due to these, there is a scarcity of good quality fine aggregate due to depletion of resources and restriction due to environmental consideration, to make a hollow concrete block manufacturing to look for suitable alternative fine aggregate. The objective of this experimental study was to investigate the effect of using sawdust as an alternative fine aggregate for hollow concrete block production and to determine an optimum content of sawdust for the replacement of fine aggregate that can be acceptable for the production of hollow concrete blocks, in order to help contribute to the industry in saving the environment, to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using sawdust concrete mixture, and sustain good product performance. The study was a laboratory experimental study conducted by preparing two types of HCB test samples. The first test sample of HCB was produced by using mix proportion 1:2:1:2 of cement, sand, gravel 00 and crushed aggregate respectively as a control group. The second sample PCBs were produced by replacing sand with sawdust in a 4% increment in volume 4%. 8%, 12%, 16%, 20%, and 24%. But the result between 8% and 12% replacement shows high difference therefore 10% replacement is needed to get the intermediate result. According to this study, the HCB without sawdust achieved 5.09Mpa mean compressive strength and the HCB with 10% sawdust achieved 4.01Mpa mean compressive strength and the HCB with 20% sawdust achieved 2.13Mpa. The acceptable replacement was obtained at 10% for the desired class B HCB and at 20% for class C HCB. The result from density and absorption show replacing sand with sawdust 4% in volume can decrease the density by 3.86% and increase the absorption by 2%. The material cost of all HCBs with sawdust was found lower than the HCB without sawdust. Replacing sand with sawdust 4% in volume can decrease the material cost by 3.68birr or 2%. According to the result, a hollow concrete block with sawdust replacement in this study has achieved a better reduction in material cost and density and a smaller increment in absorption also achieved the desired compressive strength by limiting the sawdust replacement percentage. Therefore as a recommendation for contractors, HCB manufacturers, Wood product manufacturing firms, construction industry and another researcher that the benefit of using sawdust as a replacement of fine aggregate has to be considered and deeply investigated. Keywords: Compressive Strengths, fine aggregate, hollow concrete block, sawdust.

Keywords— *Light weight, HCB*

1. INTRODUCTION

The construction industry consumes more natural resources than any other industry. With increasing public awareness of the needs and demands of sustainable development and environmental conservation, no other industry is called on as much as the country's construction and building industry to evolve their practices to satisfy the needs of our current generation, without curtailing the resources of future generations to meet theirs(MEMON , 2016).

The construction industry is rapidly growing industry in the world and hollow concrete blocks are being widely used in construction of residential buildings, factories and multi-storied buildings. Due to this the demand of HCB in the construction industry is increasing. The blocks are made out of mixture of cement, sand and stone chips [Ministry of Housing and Urban Poverty Alleviation 2010]. The culture of using locally available ingredients for the construction materials is very week in

Ethiopia and also the culture of using alternative construction materials other than the conventional one. This culture should be improved by conducting experimental researches on locally available materials. The fine aggregate is one of the predominant contents of concrete mix for hollow block production. Scarcity of good quality fine aggregate due to depletion of resources and restriction due to environmental consideration, to make concrete manufacturing look for suitable alternative fine aggregate.

In Jimma there is no source of quality fine aggregate, therefore the contractor and the supplier are forced to look to another places. Sawdust is a by-product of wood which comes through the activities of wood based industries. As wood is converted and used for different purposes, it produces heaps of sawdust at milling sites. In Jimma there is a high number of wood product manufacturing firms as a result, a high amount of sawdust is available. This paper seeks for ways of utilizing sawdust as a partial replacement of fine aggregate for the hollow block production to minimize disposal problems, environmental pollution and also enhance the economy.

2. OBJECTIVE

The general objective of this study is to determine the acceptable quantity of fine aggregate to be replaced with sawdust to obtain strong, light weight, and economical result for HCB production.

3. STUDY DESIGN

The study was an experimental study on hollow concrete blocks in a partial replacement of fine aggregate with sawdust in different proportion. The amount and kind of cement was constant, but the quantity of sawdust, aggregate and water was varied. The study was conducted in different steps. These include material preparation, determining engineering property of materials and production of hollow blocks then compressive strength, density, moisture content, absorption test and production cost calculation were conducted.

3.1 Material preparation

Cement: DANGOTE grade 43.5 ordinary Portland cement
Sand Crushed aggregate (01) (10mm – 2.36mm) and crushed fine aggregate (00) (5mm – 0.15mm)

3.2 Sawdust

For this research the sawdust was collected from wood manufacturing firm found in JIMMA and used without any pre-treatment. The wood manufacturing firm used wanza for manufacturing therefore the sawdust used was the byproduct of wanza and it is a hard wood. There are different size of sawdust, courser and finer but in the study sawdust used was finer sawdust.

3.3 Production of HCB

The HCB produced for the research was class B and has the conventional dimension 40cm*20cm*20cm (L, W and H).

3.4 Cement aggregate ratio

After the materials was prepared, by adopting the proportioning for class B HCB in accordance to ESC D3.301: prepare the materials with cement aggregate ratio of 1:5 by volume.

Class	Proportions by volume of				
	Sand	Gravel 00	Gravel 01	Red ash or pumice	Cement
A	2	1	1		1
	2	1		1	1
B	2	1	2		1
	2	1		2	1
C	3	1	2		1
	3	1		2	1

3.5 Water cement ratio

According to GTZ Low Cost Housing Manual Volume I water cement ratio for hollow concrete block is between (0.49 - 0.55) was recommended. Therefore for this research 0.5 water cement ratio was selected but when the amount of sawdust increase, the amount of water to get the desired workable mix was also increased water cement ratio

%of sawdust	Amount of cement in Kg	Amount of water in Liter	Water cement ratio
0	50	25	0.5
4	50	25.3	0.506
8	50	25.7	0.514
10	50	26.1	0.522
12	50	26.5	0.53
16	50	27	0.54
20	50	27.5	0.55
24	50	28.2	0.564

3.6 Laboratory test

Then after there were laboratory tests within 7th, 14th and 28th days for the compressive strength of HCB and at 28th day such as, density, moisture content and absorption test for the HCB has been carryout then comparison are made between the mixes and with different standards specification.

4. SAMPLING PROCEDURE AND SAMPLE SIZE

The sampling procedure was purposive sampling, therefore the sample size was determined accordingly to the test specimen number required to conduct compressive strength, density, and moisture content and absorption test for HCB. Therefore there were 6 samples for compressive strength and 3 samples for moisture content, absorption and density tests in each % replacement and age

% of sawdust	Number of sample				Total
	For compressive strength test		Density, moisture content and absorption test		
	7th	14th	28th	28th	
0%	6	6	6	3	21
4%	6	6	6	3	21
8%	6	6	6	3	21
10%	6	6	6	3	21
12%	6	6	6	3	21
16%	6	6	6	3	21
20%	6	6	6	3	21
24%	6	6	6	3	21
Total number of sample					168

4.1 Hollow concrete block test result

After the hollow concrete blocks are casted and cured to determine the physical requirement of HCB deferent laboratory tests like, compressive strength, density, absorption and moisture content are carryout that help us to compere the result between different percentage of sawdust and with standard specification.

4.2 Compressive strength

Compressive strength of the 7th, 14th and 28th days of HCB was tested in the laboratory in different age of the HCB. A total of six (6) samples for each age and percentage of sawdust are taken and the results are shown below.

The HCBs are produced according to Ethiopian standard ESC D3. 301 from a mix ratio of **1:5** (cement to aggregate ratio) or **1:2:1:2** of (cement, sand, crushed fine aggregate (5mm – 0.15mm) and crushed aggregate (10mm – 2.36mm))to produce **class B** HCB with a mean compressive strength of **4.0MPa.** According to Ethiopian Standard ESC .D3. 301. Desired strength of class B HCB at the 28th day

Types of HCB	Class	Minimum compressive strength (N/mm2)	
		Average of 6 units	Individual unit
Load bearing	A	5.5	5
	B	4	3.2
Non load bearing	C	2	1.8

28th day compressive strength test result

% of sawdust	Mean compressive strength in MPa (average of six(6) HCB)		
	7th day	14th day	28th day
0	2.6	3.71	5.09
4	2.44	3.5	4.76
8	2.27	3.4	4.5
10	2.2	3.33	4.01
12	1.92	2.99	3.58
16	1.74	2.17	2.73
20	1.67	1.98	2.13
24	1.21	1.42	1.69

From the above table we can see that, the maximum compressive strength was gained at 0% replacement and we can achieve the desired class B HCB (4MPa) strength by replacing sand with sawdust up to 10% in volume also we can achieve class C HCB (2MPa) strength by replacing sand with sawdust up to 20% in volume.

The result shows that HCB with sawdust has low strength than the HCB with the conventional materials and in case of replacement, when the percentage of sawdust replacement increases it can lower the compressive strength of HCB. The reason behind this effect of sawdust that found during the study was discussed below.

a) Naturally sawdust has low strength
b) Due to high amount of water in the mix.
c) In the process of mixing, when the percentage of sawdust increase, the amount of water to get the desired workable mix was also increased and it leads to the presence of high amount of water in the mix. The relation sheep between strength and water cement ratio is inversely proportional therefore, when the amount of sawdust replacement increase the compressive strength of the HCB had decreased.
d) Due to low bonding characteristics of sawdust with other materials.

4.3 Moisture content, Absorption and Density

According to Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units ASTM C140 laboratory test was conducted to determine the moisture content, absorption and density of HCB. There were three (3) samples in each percentage replacement and the results are described below.

% of sawdust	Moisture content, % of total absorption	Absorption		Average density in Kg/M^3
		in %	in Kg/M^3	
0	61.94	8.8	175.6	2000.05
4	60.12	11.1	213.3	1921.54
8	58.6	13.1	240.25	1829.13
10	57.33	16.2	282.05	1743.41
12	56.34	19	312.5	1657.76
16	55.55	22.9	353.65	1549.09
20	54.87	27.3	392.85	1452.65
24	54.3	36	455.55	1309.04

Absorption requirements of load bearing HCB [ASTM C90-70

Grade	Water absorption max(kg/m3)			
	Oven dry weight classification (kg/m3)			
	Light weight		Medium weight	Normal weight
	>1362 (kg/m3)	1362 - 1682 (kg/m3)	1682 - 2002 (kg/m3)	<2002 (kg/m3)
N-I & II	-	290	240	210
S-I & II	320	-	-	-

On the other hand Ethiopian standard [ES 596:2001] specify water absorption 290 kg/m3 (25%) for load bearing hollow concrete block and 320 kg/m3 (30%) for non-load bearing hollow concrete block but Indian standard recommended 10 percent.
Density classification of hollow concrete block [ASTM C90-70]

GRADE	oven dry density classification (kg/m3)		
	Light weight	Medium weight	Normal weight
N-I & II	1362 - 1682 (kg/m3)	1682 - 2002 (kg/m3)	<2002 (kg/m3)
S-I & II	>1362 (kg/m3)	-	-

4.4 Production cost comparison

The production cost for both type of HCB contain direct and indirect cost and in the direct cost there are material cost, labor cost and equipment cost. In indirect cost there is an overhead cost. The major cost that makes deference in my study was the material cost but both labor and equipment costs are remain constant because the replacing of sand with sawdust didn't affect both labor cost and equipment cost only affect material cost.

4.5 Material cost

The HCBs are produced by using a mix ratio of 1:2:1:2 of cement, sand, crushed sand, crushed aggregate therefor for one bag of cement the material needed is shown below in the table.

% of sawdust	Total material cost	Individual material cost
0	190.12	12.67
4	186.44	12.42
8	182.76	12.18
10	179.08	11.93
12	175.4	11.69
16	171.72	11.44
20	168.04	11.2
24	164.36	10.95

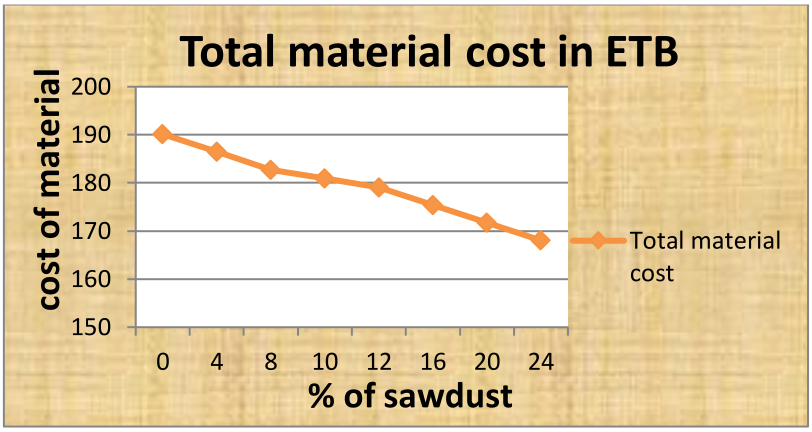

Fig. 1: Total material cost graph

5. CONCLUSION

The main objective of the study was to determine the optimum quantity of fine aggregate to be replaced with sawdust to obtain maximum strength and economical result for HCB production. And from the result gain, the optimum quantity of sawdust can be replaced without affecting the desired class B standard HCB strength by replacing sand with sawdust up to 10% in volume for one mix. And we can achieve class C standard HCB strength by replacing sand with sawdust up to 20% in volume for one mix. The standard strength is according to Ethiopian Standard ES C D3 301.

From the study the effects of using sawdust as a partial replacement of natural sand for the production of HCB are clearly identified and these effects are discussed. Replacing of sand with sawdust to produce HCB can increase the water cement ratio due too high moisture absorption properties of sawdust, can increases the absorption capacity of classB and class C HCB 7%-16% respectively, can decrease the required strength of HCB due to low compressive strength properties of sawdust, due to high water cement ratio and low bonding characteristics of sawdust, can decreases the density of class B and class C HCB 12%-26% respectively due to the low unit weight property of sawdust, also can decreases the material cost of the class B and class C HCB 5%-10% respectively due to the availability of sawdust.

The compressive strength results were compared with ETHIOPIAN STANDARD ESC D3 301 and the result fulfill class B HCB up to 10% sawdust and class C HCB up to 20% sawdust replacement and when the replacement percentage was greater than 20% the strength result doesn't fulfill the standard. The moisture content, absorption and density of the 28th day HCB result also fulfill the standard specification ASTM C 90-70 and ASTM C 129 for both class B and C HCB.

The economic benefit of using sawdust as fine aggregate for HCB production was analyzed and the results shows that by replacing sand with sawdust by 10% in volume we can save 11.04 birr or 5% of total material cost in one mix for class B HCB and by replacing sawdust up to 20% in volume we can save 18.4 birr or 10% of total material cost in one mix for class C HCB.
In general replacing of sand with sawdust for the production of Hollow Concrete Block can be applicable and the replacement can give us low cost and light weight product without compromising the desired strength but the replacement percentage should not be greater than 10% in volume for class B HCB and should not be greater than 20% in volume for class C HCB.

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