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EMPLOYMENT OF RECYCLED WOOD WASTE IN LIGHTWEIGHT CONCRETE PRODUCTION

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Abstract: The by-products of wood sawdust and wood fiber are considered to be waste material. It is utilized in the construction of buildings in the form of sawdust concrete or wood fiber concrete. It is used to make lightweight concrete and possesses heat transfer of a long duration. In this study, wood concrete was made at eleven different mix proportions of cement to wood waste by weight, to produce a lightweight concrete aggregate that has the density 1508-2122 kg/m3. The experimental work consists of 330 concrete specimens as 99 cubes (150 * 150 * 150) mm, 165 cylinders (150 * 300) mm, 33 prisms (50 * 100 * 200) mm, and 33 prisms (100 * 100 * 500) mm. Mechanical and thermal properties such as stiffness, workability, compressive strength, static elasticity modulus, flexural forces, splitting tensile strength and density were examined in the specimens after 28 days of 20 oC curing. Also, compressive strength was investigated at 7 and 14 days of curing at 20 oC. The basic observation of the results shows the values with the limitations of ACI and ASTM. Moreover, it is the perfect way to reduce solid wood waste and produce lightweight concrete to be used in industrial construction. It was found that with the increase in the quantity of wood waste, the strength decreased; however, in terms of workability and concrete with a higher quantity of wood waste held very well. Lightweight concrete aggregate is around 25 percent lighter in dead load than standard concrete. Given all the physical and mechanical properties, the study finds that wood concrete can be used in the construction of buildings.

Keywords: Lightweight concrete; Lightweight aggregate concrete; Sawdust; Wood fiber, Wood waste, Normal concrete.

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1. INSTRUCTIONS

More natural materials (like cement, fine aggregate and coarse aggregate) are used in the building industry than any other industry. With a growing population, the construction industry needs more resources for the demands of sustainable development and environmental friendliness. For instance, concrete accounts for the foremost critical building fabric, with trillions of tons created all-inclusive each year. One arrangement for making concrete lighter is for the building industry to offer lightweight concrete.

Lightweight concrete has been made in later a long time because of its potential to lower the dead load. Lightweight concrete density is roughly less than 80 percent of standard concrete weight. Lightweight structural concrete densities regularly extend from 1440 to 1840 kg/m^3, compared to normal weight concrete, with values ranging between 2240 and 2400 kg/m^3 [1-7].

Sawdust concrete has been developing a reputation as a lightweight concrete in development for a long time and has been examined in several nations [8, 9]. The sawdust innovation has been considered and utilized in parts of the contiguous United States of America, Germany, and additionally the zone of Singapore and Malaysia [10] since at least the 1930s. Forest waste within the frame of wood shavings can be joined into wood sand concretes without any preparatory treatment. [11]. Use of sawdust, broadly known as a fractional sand substitution for making sawdust concrete, guarantees that, by and large, the structure is strong and steady without depending on cement filling with sawdust [12]. Sawdust has been utilized in development but not, for the most part, essentially restricted by its low compressive strength. It has serious downsides that must be known; it is utilized. Under these constraints, the advantages of sawdust concrete give significant weight reduction of the structure. It is raising the dead loads transferred to the foundation, the high economy, and the usual weight of the concrete. It also reduces damage and extended shell life due to lower friction, simpler handling, mixing and placing compared to other concrete forms, and improves sound absorption properties because of its high void ratio [13, 14, 15]. Moved forward thermal separator, since it diminishes the thermal properties of concrete wood totals. The reduction in thermal conductivity for concrete sawdust rises from 10 percent to 35 percent for a mass rate of waste wood totals [16]. In recent years the use of sawdust for lightweight concrete production has gained some attention [10, 17]. Globally, interest in this technology revolution and environmental consciousness have been resurgent. Previously unknown uses are being found, and many are centred on the extraordinary physical and mechanical properties, such as the strength of wood [18].

The research focuses on the use of wood waste (sawdust (SD) and coarse sawdust particles (wood fiber)) in normal Portland cement concrete, to find its workability, density, compressive cylinder strength, compressive cube strength, flexural strength, tensile strength, elastic modulus, and thermal properties of sawdust concrete. This work does not incorporate the fetched investigation of utilizing sawdust in concrete but this course does not tend to neglect the study's economy to the setting, but it could be assumed that specialized issues need to be identified and settled right sometime recently the study's financial viewpoint is decided. The scope of the work can be accomplished by carrying out the work according to the methodology and material requirements and standards.
Significance of study: As well as incorporating wood sawdust waste in the field of concrete manufacturing. The main PURPOSE of this research is to implement wood sawdust waste and wood fiber into the field of concrete technology in order to obtain as many advantages as possible, saving both our economy and the environment. The utilization of waste sawdust will not cause harm to the environment but will spare concrete materials. Its claim interface incorporates numerous focal points over ordinary concrete, such as low bulk density, significantly better heat capacity and heat separator properties, decreased natural contamination, etc. Utilizing waste sawdust seems moreover to expand the utilization of straw within the wide open, which may lead to natural salary investment funds. A significantly growing number of the world's population needs greater settlement establishment. Therefore, new technologies and materials for building green buildings should be planned. Lightweight concrete (LWC) may be a profoundly adaptable development fabric that gives a wide run of preferences that maximize and maintain the benefits of innovation, economy, and environment.

2. RESEARCH APPROACH

This study’s applied the method for wood concrete was made at eleven different mix proportions of cement to wood waste by weight. To achieve the proposed objectives, this research employed the approach shown in (Fig. 1). The method is explained in the experimental work. NALYSIS RESULTS

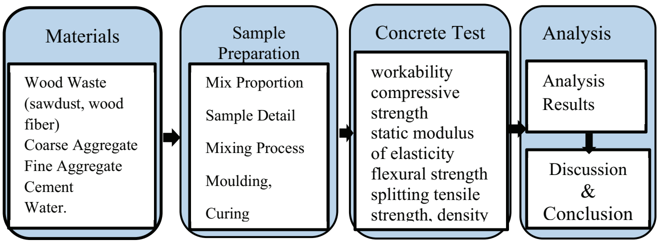


Fig. 1. Overview of Research Methodology

3. EXPERIMENTAL WORK

In this work, an attempt is made to produce structural concrete lightweight aggregates, using wood waste as an aggregate LWA and natural sand as fine aggregate, with cement content ranging from (252 – 400) kg/m^3. This experimental work illustrates the main details of the experimental program, materials used and their characteristics, mixed properties criteria, and methods of testing and controlling admixtures used in this work.

3.1. MATERIALS

- Cement: Over the course of this investigation, customary Portland cement delivered at the northern cement manufacturing plant (Tasluja-Bazian) was utilized. The cement was kept in tight plastic containers so as to mitigate the impact of unfavorable dampness.
- Fine Aggregate: Natural sand Al-Ekhaider of max. 4.75 mm was used as fine aggregates.
- Coarse Aggregate: The ideal coarse aggregate should be clean. 100% crushed aggregate with minimum flat and elongated particles has been used.
- Mixing Water: Use of tap water to cast and cure all the specimens.
- Wood waste (sawdust (SD) and coarse sawdust particles (wood fiber)): Sawdust is also known as wood dust. It is the by-product of cutting or drilling wood with a saw or any other tool; this consists of small wood particles. Sawdust is created as little spasmodic chips or little parts of wood amid the sawing of logs of timber into diverse sizes. Around the sawing handle, the chips stream from the cutting edges of the saw edge to the surface. Two types of wood waste were used: sawdust (SD) is the type (1) and coarse sawdust particles (wood fiber) is the type (2). Recycled wood waste is shown in (Figures 2 and 3), respectively. The shape of type (1) is spherical; the grading of wood waste is shown in Table 1. The shape of type (2) is random, but more flat with different; the grading of wood waste is shown in Table 2. Tables 3 and 4 demonstrate the physical, mechanical, and chemical properties of the two types.


Fig. 2. Wood Waste Type (1)


Fig. 3. Wood Waste Type (2)

Table 1. Grading Type (1)

Sieve size	Cumulative % passing
14 mm	100
10 mm	100
5 mm	96.16
2.36 mm	88.42
1.18	73.95
0.6	55.63
0.3	18.02
0.075	3.164

Table 2. Grading Type (2)

Sieve size	Cumulative % passing
14 mm	100
10 mm	99.04
5 mm	59.73
2.36 mm	16.72
1.18	3.66
0.6	2.94
0.3	0.81
0.075	0.11

3.2. MIX DESIGN

Methodology Many trial concrete mixes were made previously. Accordingly, eleven mixes were chosen to cast the specimens used in this study. Details of the chosen mixes are shown in Table 5.

Table 3. Physical Properties

Particulars	Type (1)	Type (2)
Specific Gravity	12	14
Fineness Modulus	2.11	2.89
Water Absorption	1.8%	1.6

Table 4. Chemical Properties

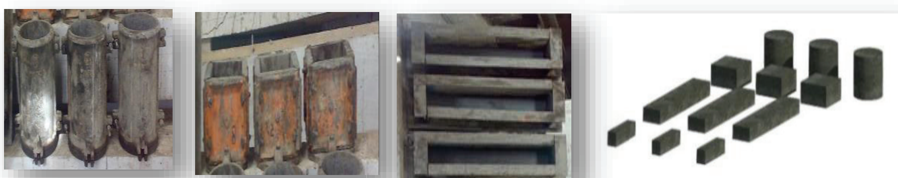
Particulars	Type (1)	Type (2)
CaO	10.2	3.75
SiO_2	66.8	87
Al2O3	4.9	2.5
Fe2O3	3.26	e2.0
MgO	6.1	0.24
Na2O	0.09	0.1
SO2	0.43	0.3
MnO	0.01	0.05
K2O	0.11	0.2
P2O5	0.43	0.3
Loss on Ignition (LOI)	3.88	4.66

Table 5. Composition of Mixtures Used in this Investigation

Mixture No.	Portland Cement (C), (kg/m^3)	Fine sand (F.S) (kg/m^3)	Coarse Aggregate (kg/m^3)	Wood Waste (kg/m^3) Sand Replacement of Wood Waste (%)	Type 1 Sawdust	Type 2 Wood Fiber	Water (w) (kg/m^3)	w/c	Density (kg/m^3)
Group 1	400	600	1200	0	0.0	0.0	200	0.5	2400
Group 2	360	513	1080	5	27	0.0	180	0.5	2160
Group 3	356	507	1068	5	0.0	26	178	0.5	2135
Group 4	326	440	978	10	49	0.0	163	0.5	1956
Group 5	320	432	960	10	0.0	48	160	0.5	1920
Group 6	300	382	900	15	68	0.0	150	0.5	1800
Group 7	298	380	894	15	0.0	67	149	0.5	1788
Group 8	276	331	828	20	83	0.0	138	0.5	1656
Group 9	272	326	816	20	0.0	82	136	0.5	1632
Group10	256	288	768	25	96	0.0	128	0.5	1536
Group11	252	283	756	25	0.0	95	126	0.5	1512

3.3. MOULDS

In each mix, nine (150 * 150 * 150) mm cubes were cast with fifteen (150 * 300) mm cylinder, three (50 * 100 * 200) mm prisms and three (100 * 100 * 500) mm prisms, as shown in (Fig. 4). Specimens were compacted by a table vibrator with a compaction time (2 minutes) for each layer; some of these procedures are explained in (Fig. 5). To determine the corresponding compressive strengths, static modulus of elasticity, flexural strengths, splitting tensile strength and density after (28) days of curing at 20℃. Also, compressive strength was investigated at 7, 14, and 28 days of curing at 20℃.



a. Cylinder b. Cubes c. Prisms d. specimens of lightweight concrete

Fig. 4. Cylinder, Cubes, Prisms and specimens of lightweight concrete.

3.4. TESTING SPECIMENS

Results The test was done at the structure laboratory, College of Engineering, Mustansiryiah University, as shown in (Fig. 6).

Fig. 5. Casting Procedure

Fig. 6. Test Instrumentation

4. ANALYSIS RESULTS

4.1. WORKABILITY

Concrete workability is the property of crisply blended concrete which determines how effortlessly and homogeneously it can be blended, situated, solidified and wrapped up. Table 6 displays how sawdust and wood fiber blended concrete droop esteem at distinctive percent substitution.

Table 6. Slump value of wood waste mixed concrete at various % replacement

Mixture No.	Sand Replacement of Wood Waste (%) by weight		Slump value (mm)
	Type 1 - Sawdust	Type 2 - Wood fiber	
Group 1	0.0	0.0	103
Group 2	5	0.0	106
Group 3	0.0	5	108
Group 4	10	0.0	111
Group 5	0.0	10	110
Group 6	15	0.0	107
Group 7	0.0	15	106
Group 8	20	0.0	105
Group 9	0.0	20	104
Group 10	25	0.0	103
Group 11	0.0	25	103

4.2. COMPRESSIVE STRENGTH

Concrete The compressive strength of 7, 14 and 28 days age for several mixes was tested to determine strength development as a function of age. Cube specimens of dimensions (150*150*150) mm and cylindrical specimens of dimensions (150*300) were selected and cast to be tested and compared. Compressive strength of 11 groups of different wood waste mixes, cured in water at 20 ^{o}C for (7, 14 and 28) days, was tested and kept under the dry condition in the laboratory for 24 hours. Then, the specimens were tested and compared with group Normal Weight Aggregate Concrete (NWAC), as shown in Table 7. The results indicate that increasing the weight of wood waste reduces the cylinder compressive strength of Lightweight Aggregate Concrete (LWAC), as shown in (Fig. 7). The cylinder compressive strength increases with density, as shown in (Fig. 8).

The following observations are made after 28 days of curing at 20 ^{o}C:-

1- Average compressive cylinder strength for specimens of group (1) NWAC is 24.88 MPa, the average compressive cube strength for the same group is 30.12 MPa and the ratio between them (f_c'/f_{cu}) is 0.826. The density of concrete is 2360 Kg/m^3. This is the highest compressive strength found in the specimens of a group (1).

2- Average compressive cylinder strength for the specimens of a group (2) is 17.10 MPa, average compressive cube strength is 21.38 MPa and the ratio between them (f_c'/f_{cu}) is 0.799, the density of concrete is 2122 kg/m^3. This is the highest compressive strength for LWAC resulted and is less than NWAC for group (1).

3- Average compressive strength for the rest of the specimens of a group (3 - 11), their values are indirectly proportional with the density of concrete and they varied from (16.88, 13.82, 13.48, 8.68, 8.68, 8.153, 6.29, 6.17, 5.51, and 5.19 MPa) for the cubes and (20.96, 13.45, 13.42, 11.22, 10.69, 8.01, 7.90, 6.48, and 6.44 MPa) for the cylinders.

4- The compressive strength decreases with the decrease in the density of concrete.

Table 7. Values of Compressive Cube Strength f_{cu} (MPa) and Compressive Cylinder Strength f_c' (MPa) for all Mixes at (7, 14 and 28) Days of Curing

Mix. No.	W/C	Average f_{cu} Three Cubes (MPa) 7 days	Average f_{cu} Three Cubes (MPa) 14 days	Average Three f_{cu} Cubes (MPa) 28 days	Average f_c' Three Cylinders (MPa) 7 days	Average Three f_c' Cylinders (MPa) 14 days	Average f_c' Three Cylinders (MPa) 28 days
Group 1	0.5	21.82	26.20	30.12	18.21	21.63	24.88
Group 2	0.5	15.54	19.12	21.38	12.46	15.20	17.10
Group 3	0.5	15.24	18.89	20.96	12.30	15.18	16.88
Group 4	0.5	9.78	11.73	13.45	10.45	12.37	13.82
Group 5	0.5	9.47	11.40	13.42	10.38	12.19	13.48
Group 6	0.5	8.26	9.86	11.22	6.38	7.59	8.68
Group 7	0.5	8.07	9.67	10.69	6.24	7.46	8.153
Group 8	0.5	5.94	6.97	8.01	4.62	5.70	6.29
Group 9	0.5	5.83	6.84	7.90	4.58	5.61	6.17
Group10	0.5	4.80	5.68	6.48	4.05	4.86	5.51
Group11	0.5	4.76	5.79	6.44	4.01	4.78	5.19

4.3. STATIC MODULUS OF ELASTICITY

The influence of curing age on the static modulus of elasticity for all types of specimens is presented in Table 8. Measurements of the static modulus of elasticity were made according to ASTM C469 [19] at 40% of the ultimate load, using (150×300mm) concrete cylinders tested in compression. The following observations are made:-

1- The average measured static modulus of elasticity for the NWAC group (1) is 26.10 GPa. It is close to that predicted static modulus of elasticity by ACI 318 and ACI 213 [20, 21] $E = 0.043(w^{1.5})\sqrt{f_c'}$ = 24.59 GPa.

2- The average measured static modulus of elasticity according to ASTM 469-2019 for the rest of the specimens of the mixtures from groups (2-11) is less than the predicted static modulus of elasticity by ACI 318 and ACI 213 [20, 21] $E = 0.043(w^{1.5})\sqrt{f_c'}$. This is due to the lower modulus of wood waste.

3- The values of measured static modulus of elasticity and predicted static modulus of elasticity decrease with the decrease of the density of concrete.

In (Fig. 9), it is shown that for modulus of elasticity, there is a good agreement of results for this work with the ACI 213 [21], in the range of compressive strength f_{cu} (21.38, 20.96, 13.45, 13.42, 11.22, 10.69, 8.01, 7.90, 6.48, and 6.44 MPa) corresponding to the modulus of elasticity values (15.26, 14.78, 14.78, 11.64. 8.04, 7.86, 6.34, 6.23, 5.21 and 5.08 GPa).

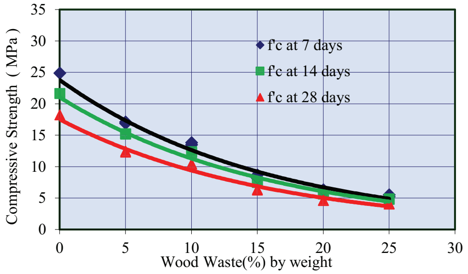


Fig. 7. Cylinder Compressive Strength f_c' (MPa) with the Percentage Weight of Waste Wood for all Mixes with different curing time

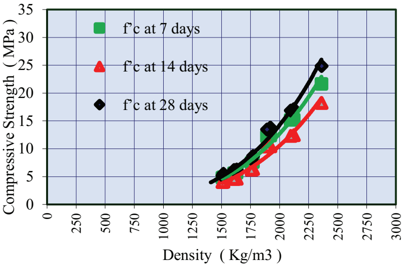


Fig. 8. Cylinder Compressive Strength f_c' (MPa) with the Density for all Mixes with different curing time

4.4. FLEXURAL STRENGTH

The flexural strength for all types of specimens is presented in Table 9. All results are for (28) days of curing. The following observation is made:-

The average modulus of rupture was measured according to ASTM 293 [22] and compared with the predicted modulus of rupture ACI 318 and ACI 213 [20, 21] = $\mathbf{0.62\sqrt{f_c'}}$, as shown in Table 9. The basic observation of the results shows that the values of measured average modulus of rupture and predicted modulus of rupture decrease when the density of concrete decreases. From (Fig. 10) it is shown that for modulus of rupture, there is a good agreement of the results for this work with the ACI 213 [21], in the range of compressive strength $\boldsymbol{f_{cu}}$ (21.38, 20.96, 13.45, 13.42, 11.22, 10.69, 8.01, 7.90, 6.48, and 6.44 MPa) corresponding to the modulus of rupture values (3.01, 2.91, 2.74, 2.64, 2.27, 2.02, 1.78, 1.70, 1.63 and 1.55 MPa).

4.5. SPLITTING TENSILE STRENGTH

The influence of curing age 28 days on the flexural strength for all types of specimens is presented in Table 10. The following observations are made:-

1-The measured splitting tensile strength was made according to ASTM C496 [23]; their values are greater than the predicted splitting tensile strength ACI 318 [20] $=0.556\sqrt{f_c'}$.

2-The values of measured average splitting tensile strength and predicted splitting tensile strength decrease with the decrease of the density of concrete.

4.6. DENSITY

Air-dry densities **for** all mixes are shown in Table 11.

Table 8. Values of Modulus of Elasticity for all Mix after (28) Days of Curing

Mixture No.	W/C	Average modulus of Elasticity (GPa) (after 28 days)	Predicted Static Modulus of Elasticity (ACI 318-2019) and (ACI 213R-2014) $E = 0.043(w^{1.5})\sqrt{f_c'}$GPa
Group 1	0.5	26.10	24.59
Group 2	0.5	15.26	17.38
Group 3	0.5	14.78	16.95
Group 4	0.5	11.64	13.45
Group 5	0.5	11.46	12.9
Group 6	0.5	8.04	9.44
Group 7	0.5	7.86	9.05
Group 8	0.5	6.34	7.09
Group 9	0.5	6.23	6.88
Group10	0.5	5.21	5.96
Group11	0.5	5.08	5.74

Table 9. Values of Modulus of Rupture for all Mixes after (28) Days of Curing

Mixture No.	W/C	Average Modulus of Rupture (MPa) (after 28 days)	Predicted Modulus of Rupture (ACI 318-2019) and (ACI 213R-2014)$=0.62\sqrt{f_c'}$ (MPa)
Group 1	0.5	3.91	3.09
Group 2	0.5	3.01	2.56
Group 3	0.5	2.91	2.55
Group 4	0.5	2.74	2.30
Group 5	0.5	2.64	2.27
Group 6	0.5	2.27	1.82
Group 7	0.5	2.02	1.77
Group 8	0.5	1.78	1.55
Group 9	0.5	1.70	1.54
Group 10	0.5	1.63	1.45
Group 11	0.5	1.55	1.41

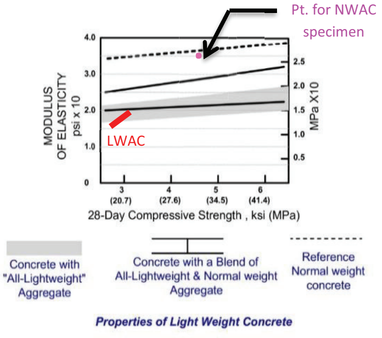


Fig. 10. Relation of Modulus of Rupture of of Concrete to Compressive Strength f_{cu} (MPa) **[20]**

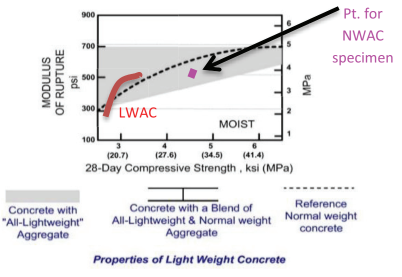


Fig. 9. Relation of Modulus of Elasticity Concrete to Compressive Strength f_{cu} (MPa) **[20]**

Table 10 Values of the Splitting tensile strength for all Mixes after (28) Days of Curing

Mixture No.	W/C	Average Splitting Tensile Strength (MPa) (after 28 days)	Predicted Splitting tensile strength (ACI 318-2019) =0.556$\sqrt{f_c'}$ (MPa)
Group1	0.5	2.38	2.77
Group 2	0.5	2.06	2.29
Group 3	0.5	2.01	2.28
Group 4	0.5	1.98	2.06
Group 5	0.5	1.95	2.04
Group 6	0.5	1.56	1.63
Group 7	0.5	1.54	1.59
Group 8	0.5	1.26	1.39
Group 9	0.5	1.24	1.38
Group 10	0.5	1.23	1.3
Group 11	0.5	1.19	1.27

5. DISCUSSIONS AND CONCLUSIONS

The present work represents different physical models for normal concrete and lightweight concrete to study the behaviour of used wood waste aggregate mixture. The results of the different types of concrete were compared with experimentally work data carried out during the study. The main objective of the present work is to investigate the effect of wood waste on the performance of lightweight concrete that is carried out through two types of wood waste added to the different mixtures of concrete. In this context, the following conclusions were drawn on the basis of the results obtained from the experimental work:

- The average compressive strength for the specimens of lightweight aggregate concrete (LWAC) with the wood waste aggregate mixture, are directly proportional to the density of concrete. Also, wood waste can be used in lightweight concrete production in different areas of industrial construction. The density and the compressive strength are approximately (2122, 2096, 1920, 1892, 1771, 1758, 1630, 1608, 1517, and 1508 kg/m^3) and (21.38, 20.96, 13.45, 13.42, 11.22, 10.69, 8.01, 7.90, 6.48, and 6.44 MPa) respectively. The basic observation of the results of compressive strength and density of concrete shows that the values with the limitations of ACI and ASTM.
- The average measured static modulus of elasticity for LWAC according to ASTM 469-2019, are (15.26, 14.78, 14.78, 11.64. 8.04, 7.86, 6.34, 6.23, 5.21 and 5.08 GPa) which are less than the predicted static modulus of elasticity that is (17.38, 16.95, 13.45, 12.9, 9.44, 9.05, 7.09, 6.88, 5.96, and 5.74 GPa) (ACI Code 318-2019 and ACI 213R-2014) $E = 0.043(w^{1.5})\sqrt{f_c'}$. This is due to the characteristics of LWAC, which contain wood waste that makes the panels

of high ductility. The results of static modulus of elasticity shows that the values are within the limitations of ACI and ASTM.

- The measured average modulus of rupture according to ASTM 293-2019 are (3.01, 2.91, 2.74, 2.64, 2.27, 2.02, 1.78, 1.70, 1.63 and 1.55 MPa), which are more than the predicted modulus of rupture that is (3.09, 2.56, 2.55, 2.30, 2.27, 1.82, 1.77, 1.55, 1.54, 1.45, and 1.41 MPa) (ACI Code 318-2019 and ACI 213R-2014)= $0.62\sqrt{f_c'}$. All results of modulus of rupture of concrete show that the values are within the limitations of ACI and ASTM.
- The measured splitting tensile strength according to ASTM C496-2019, are (2.06 2.01, 1.98, 1.95, 1.56, 1.54, 1.26, 1.24, 1.23 and 1.19 MPa), which are more than the predicted splitting tensile strength that is (2.29, 2.28, 2.06, 2.04, 1.63, 1.59, 1.39, 1.38, 1.3 and 1.27) (ACI 318-2019) =$0.556\sqrt{f_c'}$. The results for splitting tensile strength shows that the values are within the limitations of ACI and ASTM.
- LWAC is about 25% lighter than normal concrete in dead load.

Wood sawdust and wood fiber are considered as waste material and can use to make lightweight concrete and which possesses heat transfer of a long duration. Moreover, it is the perfect way to reduce sold wood waste and produce lightweight concrete to be used in industrial construction. The limitations persist and hence future research is required in the area. More study should extend to other parts of building (beams, columns and slabs).

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REFERENCES

1. Kivrak, S., Tuncan, M., Onur, M. I., Arslan, G., and Arioz, O. (2006). An Economic Perspective of Advantages of Using Lightweight Concrete in Construction. *Paper presented at the 31st Conference on Our World In Concrete & Structures.,* Singapore.
2. Chiad, S.S., (2013). Shear Stresses of Hollow Concrete Beams. *Journal of Applied Sciences Research,* 9(4), .2880-2889.
3. Al-hafiz, A.M., Chiad, S.S. and Farhan, M.S. (2013). Flexural strength of reinforced concrete one-way opened slabs with and without strengthening. Australian *Journal of Basic and Applied Sciences,* 7(6),.642-651.
4. Dadzie, D. K., Dokyi, G. Q., and Niakoh, N. (2018). Comparative Study of the Properties of Sandcrete Blocks Produced with Sawdust as Partial Replacement of Sand. *International Journal of Scientific & Engineering Research,* 9(3), 2229-5518.
5. Hameed, A. M., & Ahmed, B. A. F. (2019). Employment the plastic waste to produce the Lightweight concrete. *Energy Procedia,* 157, 30-38.
6. Omaran, S.M., Alghamdi, A.A., Alharishawi, S.C. and Hains, D.B. (2019). Integrating BIM and Game Engine for Simulation Interactive Life Cycle Analysis Visualization. In Computing in Civil Engineering. *Visualization, Information Modeling, and Simulation. Reston, VA: American Society of Civil Engineers. (120-128).*

7. Khairuddin, S.A.A., Rahman, N.A., Jamaluddin, N., Jaini, Z.M., Elamin, A. and Rum, R.H.M. (2020). Bond Strength of Concrete-Filled Hollow Section with Modified Fibrous Foamed Concrete. *Archives of Civil Engineering*, pp.97-108..
8. Adebakin, I., and Adeyemi, A., (2012). Uses of Sawdust as Admixture in Production of Lowcost and Lightweight Hollow Sandcrete Blocks. *American Journal of Scientific and Industrial Research,* 3(.6), 458-463.
9. Mageswari M. and Vidivelli B. (2010). The Use of Sawdust Ash as Fine Aggregate Replacement in Concrete. *Journal of Environment Research and Development,* 3 (3), 720 – 726.
10. Paramasivam, P., and Loke, Y. O. (1980). Study-of-sawdust-concrete. International-Journal-of-Cement-Composites-and-Lightweight-Concrete. *The International Journal of Lightweight Concrete.,* 2(1), 57-61.
11. Sales, A. S., Santos, F.R., Zimer, and W. M. (2010). Lightweight composite concrete produced with water treatment sludge and sawdust: Thermal properties and potential application. *Construction and Building Materials,* 24(12), 2446-2453.
12. Jian, H. (2014). The Implementation of Waste Sawdust in Concrete. *Advanced Materials Research,* 941-944, 849-853. doi: 10.4028/www.scientific.net/AMR.941-944.849
13. Aberdeen. (1971). Waste Materials in Concrete - Can concrete be made from broken glass? sawdust? plastics? mine wastes? garbage frit? Concrete Construction.
14. Ansari, F., Maher, A., Luke, A., Yong Zhang, G., and Szary, P. (2000). Recycled Materials in Portland Cement Concrete. *Final Report. Federal Highway Administration* U.S, 11-37.
15. Bdeir, L. M. H. (2012). Study Some Mechanical Properties of Mortar with Sawdust as a Partially Replacement of Sand. *Anbar Journal for Engineering Sciences,* 5(1), 22-30.
16. Taoukil, D., bouardi, A. E., Ezbakhe, H., and Ajzoul, T. (2011). Thermal Proprieties of Concrete Lightened by Wood Aggregates. *Research Journal of Applied Sciences, Engineering and Technology.*
17. Felix, F., Udoeyo., and Dashibil, P. U. (2002). Sawdust Ash as Concrete Material. *Journal of materials in civil engineering,* 14, 173-176. doi: 10.1061//asce/0899-1561/14:2/173.
18. Ganiron, T., Jr. (2014). Effect of Sawdust as Fine Aggregate in Concrete Mixture for Building Construction. *International Journal of Advanced Science and Technology,* 63, 73-82. doi: 10.14257/ijast.63.07
19. ASTM C469. (2014). Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression, *ASTM International.*
20. ACI Code 318. (2019). Building Code Requirements for Structural Concrete*, American Concrete Institute..*
21. ACI Code Committee 213R. (2019). Guide for Structural Lightweight-Aggregate Concrete. *American Concrete Institute.*
22. ASTM 293. (2016). Flexural Strength of concrete (Using simple beam with centre – point loading). *Annual Book of ASTM Standards,* 4(2).
23. ASTM C496. (2017). Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. *Annual Book of ASTM Standards,* 4(2).

LIST OF FIGURES AND TABLES:

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