Journal of Engineering Research and Reports

19(2): 1-15, 2020; Article no.JERR.62167
ISSN: 2582-2926

Influence of Elevated Temperature on Concrete Properties Containing Natural Wastes Treated by Pyrolysis

Manal M. Farag[1*], Magdy El-Yamany[1], A. S. Faried[1] and W. H. Sofi[2]

[1]*Department of Civil Engineering, Faculty of Engineering, Fayoum University, P.O.Box 63514, Fayoum, Egypt.*
[2]*Raw Building Material Research Institute, Housing and Building National Research Center (HBRC), P. O.Box 12622, Cairo, Egypt.*

Authors' contributions

This work was carried out in collaboration among all authors. Author MMF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MEY and ASF managed the analyses of the study. Author WHS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2020/v19i217225
Editor(s):
(1) Dr. Tian-Quan Yun, South China University of Technology, China.
Reviewers:
(1) Afaf Ghais Abadi, University of Technology and Applied Science (UTAS), Oman.
(2) Pavel Kudryavtsev, Israel.
Complete Peer review History: http://www.sdiarticle4.com/review-history/62167

Original Research Article

Received 22 August 2020
Accepted 28 October 2020
Published 27 November 2020

ABSTRACT

Concrete is probably the most extensively used construction material in the world. The modern concept of construction is directed at the use of recycled materials, in particular, various waste products. This solves a number of problems -saving the expensive materials; - decreasing CO_2 emissions by reducing the production of construction materials, so, these can also be used as refractory materials. Plant fibers are the most abundant fiber among all the natural fibers. Bamboo, palm, sisal, jute, date kernel, flax etc. are the commonly known plant fibers. Plant fibers are also called cellulosic fiber and have quite promising tensile strength. Natural Plant fibers treated by pyrolysis in concrete such as additions; determine the effect of these substances and the effect of temperature on the properties of concrete. The natural fibers in concrete are added accordingly with the percentage of 0.5%, 1%, 1.5% and 2% by weight of cement concrete cubes are tested at the age of 7 and 28 days of curing. Natural waste treated by pyrolysis and different additives on

**Corresponding author: Email: mm2830@fayoum.edu.eg.com, mm2830@fayoum.edu.eg;*

concrete behavior to improve its performance in the future to use in Civil Engineering and Construction World. The optimum result for natural fibers was observed at 1.0% for bamboo and date kernel and 1.5% for palm oil of natural fiber.

Keywords: Natural organic waste (cellulosic fiber); pyrolysis treatment; bamboo fiber; palm oil fiber; date kernel fiber.

1. INTRODUCTION

The increase in global population is putting rising demand on the construction industry; Concrete, as an essential material for construction and building industries, is the most consumed man-made material in the world. The Portland cement ”an essential constituent of concrete” leads to the release of a significant amount of CO_2 and other greenhouse gases. It is known that manufacturing 1ton of Portland Cement produces about 1ton of CO_2. When limestone is heated in oven, CO_2 is produced as part of the reaction, accounting for approximately half of the total amount [1]. Environmental consciousness has been increasing and many strategies have been given for the reduction of environmental load produced by discarded waste products. The concept of “zero emission’’ is the idea that has been proposed to reduce environmental impact of waste products. It is becoming more common in the United States like the pyrolysis or carbonization of waste material, mostly from plants. Carbonization is applicable in both developed and developing countries because it is easy to carry out and does not involve highly complex equipment.

Pyrolysis (carbonization) has been proposed as one of several optional technologies for disposing and recycling waste plants as bamboo, rice straw and other materials [2-5].

The scope of the study is investigating the effect of the addition of natural fibers on the mechanical properties of reinforced concrete to get the best result in terms of resistance to Compressive Strength, Splitting Tensile Strength, and Flexural Strength compared with plain concrete and the type of material used and the mixing ratios.

Pyrolysis is defined as” an endothermic process that induces the thermal decomposition of waste materials without the addition of any reactive gases, such as air or oxygen to prevent combustion”. Temperature of process has a major influence to the treatment results. Higher temperatures of pyrolysis provide greater quantity of non-condensable gases like syngas and synthetic gas. Slow Pyrolysis which used in this study is defined as the process of biomass very slow heating (heating rate: 5-7°C/min). Slow pyrolysis typically produces less liquid (30-50% mass) and more char (25-35% mass) than fast pyrolysis [6-8].

Process Control to achieve good yields of high quality products, reaction conditions must be well controlled. The heat generated must be sufficient to dry the fibers and maintain a temperature for efficient carbonization. Burning also must be limited in order to obtain the proper amount of heat to produce quality biochar [9].

The temperature in the reactor is the most important variable to control during pyrolysis. Two ways to control heat conditions of pyrolysis reactors: are (1) to observe the color of vapors produced, the production of steam results in white smoke that indicates the drying of the biomass, whereas a black smoke is typically associated with pyrolysis. After pyrolysis begins, the smoke becomes more transparent as the process continues. Once the carbonization process is completed (no more smoke is produced), and (2) to measure and control the temperature inside the reactor either manually or using standard feedback control systems [9].

2. EXPERIMENTAL WORK

2.1 Material Properties

The cement used for this study was ordinary Portland cement (OPC) provided by Wadi El-Nile Cement Company, Beni-Swif, Egypt, which met the specifications of ASTM* C150. After bringing the cement into the laboratory, it was stored in an airtight plastic container and sealed. This was done to avoid any likely reaction of air moisture with cement, the specific gravity was 3.15 and the physical properties of the cement with the limits of the Egyptian standard specifications are shown in Table 1.

Table 1. Physical properties of OPC (ASTM* C150)

Properties		Measured values	Specification limits
Surface area of particles		2920 (cm^2/gm.)	More than 2500
Water standard		28%	26%-30%
Volume change		1	<10
Specific gravity		3.15	3.1-3.2
Setting time initial final		145 min	>45 min
		3.1 hr.	<10 hours
Compressive	3 days	18.6	>18 Kg/mm^2
strength	7 days	27.4	>27 Kg/mm^2
	28 days	36.9	>36 Kg/mm^2

(ASTM): Applicability of the standard specifications

Table 2. Physical properties of the sand

Properties	Value
Specific Gravity	2.5
Bulk Density (t/m^3)	1.72
Absorption %	2
Fineness modulus	2.70

Table 3. Crushed stone physical and chemical properties

Property	Test values
% Sulphate of C.A	0.12
Absorption of C.A%	0.8
% Chloride of C.A	0.01
Crushing value of C.A%	19%
Max aggregate size (mm)	12.5
Bulk density (t/m^3)	1.52
Specific gravity	2.85

2.2 Fiber Sampling, Extraction and Treatment

In this research were used Natural waste treated by pyrolysis as additives in concrete mix design natural fiber used with Density bamboo 240, dates kernel 500 and palm of the palm 160. Plain concrete was cast to compare with result of natural fiber in concrete mix design. Fig. 1 shows, the natural fiber (Bamboo, palm, kernel) used for this research were collected locally from local traders, the fibers are usually obtained by manually extracting them from the inner fruit or trees.

The fibers were washed properly (kernel) to remove films of impurities attached to them, after which they were air dried for some few days under ambient temperature [10], Bamboo were collected Then were cut using sharp scissors to 4.0 cm length and bamboo plants having 4.5 m average length were collected. Bamboo culms were prepared through cutting into circles with 1, 2, 4 cm width, Inner and Outer diameter using power saw, below shows electrical aided power saw and the bamboo culm cut into desirable pieces. Then began the process of pyrolysis. Treatment of fiber by thermo- treatment leads to structural and surface changes and there by enhances the mechanical properties of the fibers as shown in Fig. 2 and Table 4, the original process of carbonization is to increase carbon content which works to absorb salt and sugar so resisting the aggressive media attack and Disposal of organic contents, the putrefaction and degradation [11-13].

Pyrolysis at the container used without the addition of any reactive gases such as air or oxygen. The fibers were put in the container for (2) hours and leave the natural pyrolysis fiber cooling (2 hours) after this process without any air inside the container.

The addition of natural pyrolysis fiber can affect the mechanical properties of the concrete remarkably, which is highly dependent on the fiber length and volume fraction and the orientation of the fibers in concrete [14].

a) Bamboo b) Palm oil c) Dates kernel

Fig. 1. Natural fibers before pyrolysis

a) Palm oil fiber b) Bamboo fiber c) Dates kernel fiber

Fig. 2. Natural fibers after pyrolysis

Table 4. Properties of natural fibers

Type of Fiber	Length (cm)	Width (cm)	Density (kg/m^3)
Palm oil (empty fruit bunches)	~4	~0.2	160
Dates Kernel	2	0.5	500
Bamboo	Inner diameter (cm) 2	Outer diameter (cm) 4	240

Table 5 shows, chemical properties of natural fiber have their own significance while selecting fiber for the fabrication of composite. The chemical properties make the basis of predicting the final properties of fiber polymer fabricated composite. The chemical constituents of natural fiber greatly affect the properties [15].

2.3 Mix Proportions

A concrete mixture was formed through the usage of 0.5 water/binder ratio to obtain plain concretes. To produce natural fiber (NF) reinforced concretes, each NF category (BF, DKF, and POF) were formed by the addition to 1, 1.5, 2 and 5% concrete of the total concrete volume. So to test concrete mechanical characteristics of this concrete, 13 samples containing different fiber proportions were prepared. In Table 4 the concrete mixtures details are clarified. According to the different types and natural fibers volume fraction, the concrete mix were named. For example, CP1 code stands for the concrete incorporated with 1% natural fiber type palm oil fiber (CP1).

A layer of natural fiber was spread in the pan, followed by spreading of aggregate, sand and cement. The first layer of fibers was hidden under the dry concrete materials with the help of a spade. Then, another layer of natural fiber followed by layers of aggregate, sand and cement was spread. This process is repeated until the rest materials were put into the mixer pan. Approximately three quarters of the water (according to water/cement ratio which was the same as that of plain concrete) was added and the mixer was rotated for 2 min. The concrete mix were cast into lubricated molds and then compacted on three layers in molds then using dynamic vibrator for several seconds, The concrete samples that were poured then wrapped by plastic cover and placed within the temperature treatment room 21±2°C in it for 24 hours, and then these samples were extracted from the molds and put within placed in the treatment tanks to the age of the final test. The properties like Compressive strength, flexural strength, split tensile strength of concrete using different type of optimum values of natural fibers are studied ACI. Code method of mix design was used for mix design of concrete. Concrete specimens with various percentages of natural fiber were prepared [16-18] as shown in Table 6.

2.4 Test Specimens

High performance concrete was designed by using ACI Standard method. Trial control mixes for concrete with additives of cement by natural fiber in concrete with different addition of natural fibers with different dosages 1%, 1.5%, 2% and 5% respectively. The random distribution of the fibers and their ability to add strength and mitigate crack propagation is more important [19]. They were cast for the plain concrete as well as for the NFRC. A layer of natural fiber was spread in the pan, followed by spreading of aggregate, sand and cement then the water (according to water/cement ratio which was the same as that of plain concrete) was added and the mixer was rotated for 2 min. All the cast specimens were given a 24 hour period to set under ambient temperature in their respective moulds as shown in Fig. 3, before being transferred to a curing tank for the appropriate curing days to their final tests. The properties like compressive strength, flexural strength and split tensile strength of concrete using different type of optimum values of natural fibers are studied according to ACI dimensions of specimens as shown in Table 7.

The result for each tests were calculated by take average for 3 samples. Flexural and Splitting tensile strength were examined after 28 curing days while compressive strength was examined after 7 and 28 days as shown in Fig. 4.

2.5 Test Methods

These specimens were tested for each mix 3 cubes for 7 days and 3 cubes for 28 days in compression testing machine, the splitting tensile strength and flexural tensile strength to the beam samples shows in Fig. 5 in each category.

Fig. 3. Cubes, cylinders and beams specimens during casting

Fig. 4. Compressive, splitting and flexural concrete samples during curing

Table 5. Chemical composition of waste plant fiber

Fiber	Cellulose	Hemicellulose	Lignin	Ash
Bamboo	48.2–73.8	12.5–73.3	10.2–21.4	2.3
palm oil (empty fruit bunches)	42.7–65	17.1–33.5	13.2-25.3	1–6

Table 6. Mix proportions of concrete and natural fibers reinforced concretes (kg/m^3)

MIX	W/C	Water	Cement	Fine aggregate	Coarse aggregate	Fiber weight
		(kg/m^3)				
C0	0.5	215	430	828.27	904	0
CP1	0.5	215	430	828.27	904	4.30
CP1.5	0.5	215	430	828.27	904	6.45
CP2	0.5	215	430	828.27	904	8.6
CP5	0.5	215	430	828.27	904	21.5
CB1	0.5	215	430	828.27	904	4.30
CB1.5	0.5	215	430	828.27	904	6.45
CB2	0.5	215	430	828.27	904	8.6
CB5	0.5	215	430	828.27	904	21.5
CK1	0.5	215	430	828.27	904	4.30
CK1.5	0.5	215	430	828.27	904	6.45
CK2	0.5	215	430	828.27	904	8.6
CK5	0.5	215	430	828.27	904	21.5

C0: Control sample, CP: Palme oil, CB: Bamboo and CK: Date kernel

Table 7. Dimensions of specimens

Type	Dimensions (mm)
Cubes	100*100*100
Cylinders	100*200
Beams	100*100*500

(a) (b) (c)

Fig. 5(a, b and c). Compressive, splitting tensile and flexural tests

3. RESULTS AND DISCUSSION

3.1 Mechanical Testing

The results of the concrete mechanical characteristics control specimens and other specimens had various proportions of natural fibers are given in Table 8. The mechanical properties like flexural, splitting tensile and compressive strength [12,20,21,22].

3.1.1 Compressive strength

The average compressive strength values on 3 cubes specimen for the mixes were determined at the age of 7 and 28 days. Compressive Strength Test as shown in Fig. 6 in comparison to the control mix, the compressive strength accompanied by little fiber percent is slightly increased. Concrete mix with 1.5% fiber inclusion for palm oil fiber and with 1.0% fiber for date kernel and bamboo were achieved the best results, this is because of high cohesion among the cement matrix and fibers. Increasing in compressive strength slightly improved with low fiber percent at the fiber content of 1.5%, 1.0%, and 1.0%, were 23.6%, 15.6%, and 9.7% for palm oil fiber, bamboo and date kernel, respectively.

3.1.2 Flexural strength

The average results of flexural strength test values on 3 beams contains a complete mix, 3 mix addition plain concrete for the mixes after 28 days are calculated as shown in Fig. 7, the results for the test of flexural strength which conducted on beam concrete samples (100 x 100 x 500 mm). At the fiber content of 1.5%, 1.0% and 1.0%, the concrete flexural strength increases by 19.8%, 7.6% and 11.36% for palm oil fiber and bamboo and date kernel, respectively. Accompanied by lower fiber percent flexural strength increases.

Table 8. Compressive strength, flexural, splitting tensile values

Mix	Compressive Strength		Flexural strength	Splitting tensile strength	Splitting tensile strength
	(kg/cm^2)				
	7 days	28 days	28 days	7 days	28 days
C0	271	300	17.6	56	80
CP1	286	343	17.9	69	86
CP1.5	312	371	21.1	68	101
CP2	249	286	18.4	85	78
CP5	277.5	284.5	17.2	80	69
CB1	277.5	347	18.95	80	92
CB1.5	176	317	17.2	56	64
CB2	192	298	16.8	50	77
CB5	227	236	11.5	61	63
CK1	295.5	329	19.6	78	98
CK1.5	191	296	18.3	68	94
CK2	211	291	16.5	65	84
CK5	194	282	15.9	53	83

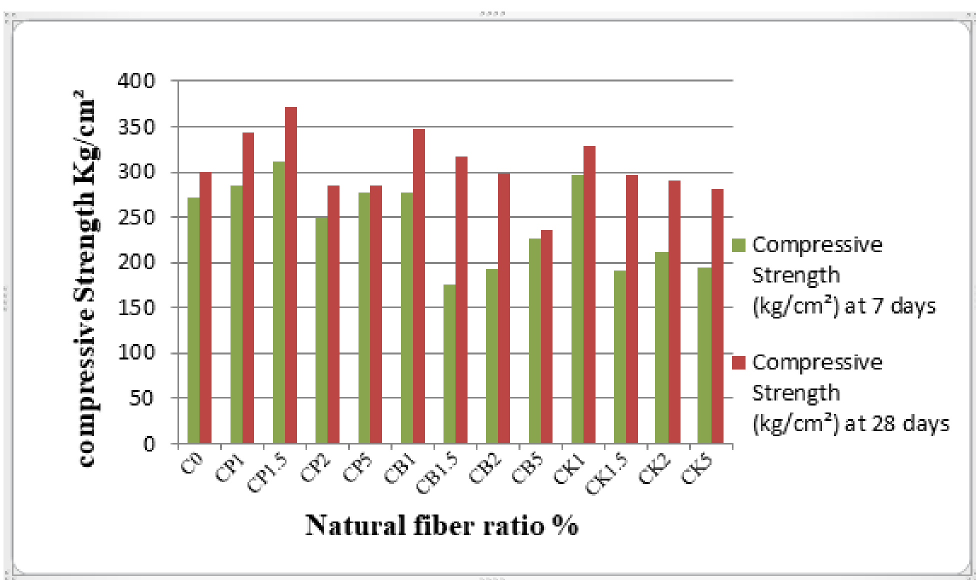


Fig. 6. The compressive strength results with different fibers ratio

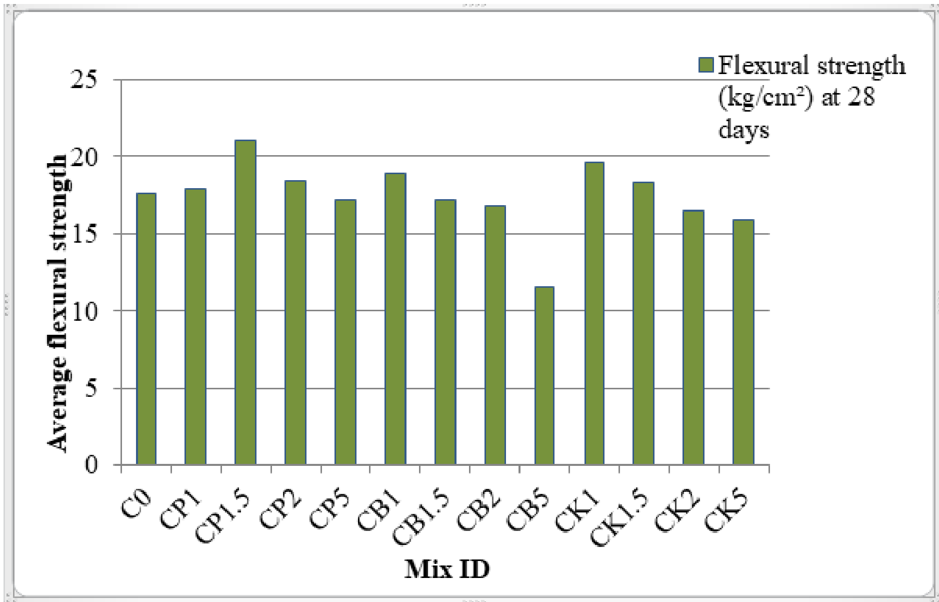


Fig. 7. The flexural strength results with different fibers ratio

3.1.3 Splitting tensile strength

The average splitting tensile strength tested on 3 cylinder specimen for the mixes. The average splitting tensile for 3 cylinders or each mix is calculated after 7 and 28 days as shown in Fig. 8 which in the same direction of compressive strength results.

3.2 Specimens Exposed to High Temperature

Concrete samples were cast control concrete, natural fiber concrete and synthetic fibers concrete (polypropylene) for the determination of different properties of concrete. All specimens were left in the molds for 24 h to set under ambient temperature. Concrete samples removed from the mold and transferred into a curing tank for 28 days then after dried for five days under ambient temperature, This is different from control concrete, natural fiber concrete and synthetic fibers PP when exposed to temperature at 200, 500, 700℃ at oven for two hours then leave all samples cooling in air as shown in Fig. 9. These specimens were tested in compression and splitting testing machine in each category the following results as mentioned in Table 9.

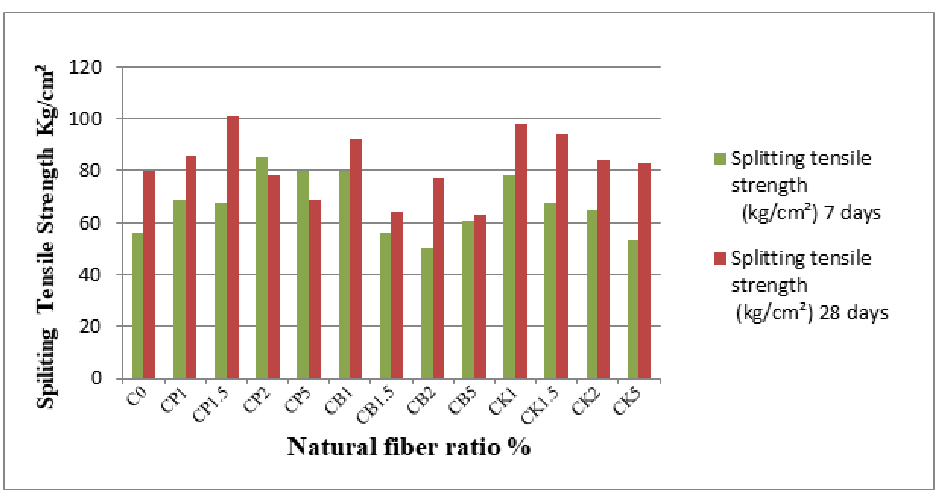


Fig. 8. The Splitting tensile strength results with different fibers ratio

Fig. 9. Specimens exposed to temperature in electric oven drier

Table 9. Specimens exposed to temperature at (a) 200℃ (b) 500℃ (c) 700℃ for two hours

a) At 200℃:

MIX ID	Compressive strength	Tensile strength
C0	334	90
CP1.5	346	96
CB1.5	351	81
CK1.5	313	89
PP 1.5	237	79

b) At 500℃:

MIX ID	Compressive strength	Tensile strength
C0	343	79
CP1.5	368	98
CB1.5	325	78
CK1.5	293	79
PP 1.5	219	66

c) At 700℃:

MIX ID	Compressive strength	Tensile Strength
C0	253	72
CP1.5	279	83
CB1.5	214	69
CK1.5	268	76
PP 1.5	178	65

Figs. 10 & 11 shows, compressive and Tensile strength for Specimens exposed to temperatures 200℃, 500℃ and 700℃ the results for the test at the fiber content of 1.5% for palm oil fiber, date kernel and bamboo in comparison to the control mixtures Concrete mix with 1.5% fiber inclusion for palm oil fiber achieved the best results, this is because of high cohesion. As the natural fibers with temperature, the percolation of fibers in the matrix is critical for resisting thermal. This is different from natural fiber with synthetic fibers like polypropylene, The key for this is the thermal mismatch between embedded fibers and matrix as a result of the expansion of PP fibers with temperature they oppose the mechanism of thermal spalling resistance established for synthetic fibers in where a significant but Natural fibers swell by absorbing water and shrink upon exposure to warm and high temperatures. The deswelling of natural fibers at high temperatures creates spaces between fibers and matrix [23], which could influence permeability at those temperatures. Adding natural fibers increased permeability at high temperatures due to the shrinkage of fibers, which created interfacial gaps between the fibers and cement matrix. The findings suggest that biochar from plant waste can be applied as a sustainable admixture and alternative to improve compressive strength and durability of structure exposed to high temperature. Nevertheless, this can be also an effective means to valorize lignocellulosic waste for high value construction applications.

3.3 Microstructure Examinations

Scanning Electron Micrograph XRD technique and SEM were used to observe the physical formation of natural fibers. The SEM photograph of bunch of fibers surface of fibers and cross-section of fibers.

3.3.1 XRD analysis

The first XRD styles of cellulose fibers had been generated. The goal of X-ray diffraction approaches is the recording and assessment of the scattering path and depth or radiation diffracted through atom planes a hard and fast distance aside, in step with the well-known Bragg's law, $\lambda = 2d \sin\theta$, where λ is the wavelength of the radiation, d is the distance among parallel planes, θ is the perspective of occurrence and mirrored image of X-rays Fig. 12 depict the XRD-patterns of samples of concrete mix at the fiber content of 1.5% for Bamboo and palm curing at 28 days then dried for 5 days in air beneath ambient temperature. The concrete samples were grinded and tested with powder samples to known the components of them.

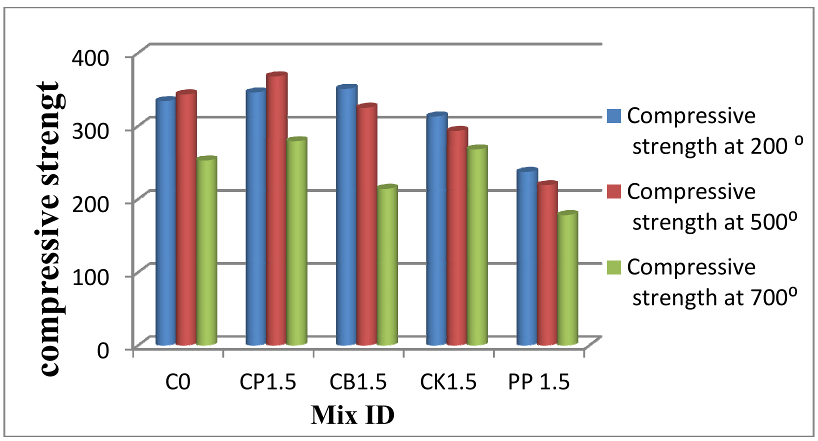


Fig. 10. Compressive strength for specimens exposed to temperature

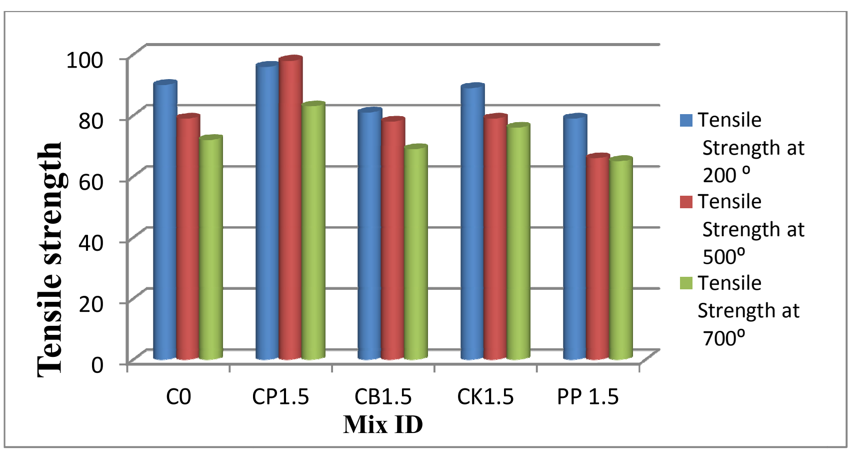


Fig. 11. Tensile strength for specimens exposed to temperature

3.3.2 SEM microscopy

Fig.14. a) it has been observed that the fiber generally looked at an open eyes is eventually attached with single fibers, This carbon tubes this happen when make removal for organic cells from cellulose and this form like finger print for each plant, the diameters of the fibers, are very different from one botanical species to another. The bamboo pyrolysis fibers have elliptical cross-sections.

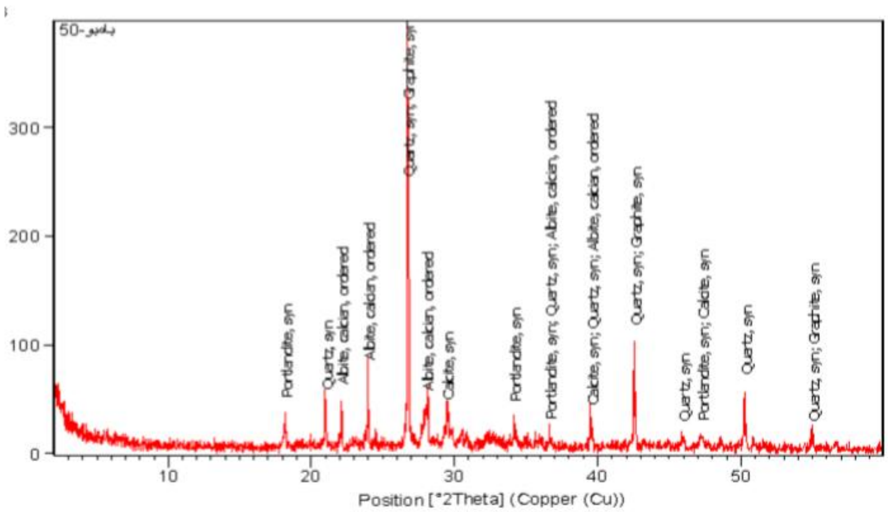


Fig. 12. XRD-patterns for bamboo

Bamboo

Peak number	Pos. [2θ.]	d-spacing [A]	Height *[CTS]	FWHM Left [2θ.]	Rel. Int. [%]
1	18.1667	4.88334	29.70	0.1181	7.52
2	21.0051	4.22942	37.71	0.0787	9.56
3	22.0943	4.02333	42.39	0.1181	10.74
4	23.9381	3.71745	63.06	0.0787	15.98
5	26.7320	3.33492	394.66	0.0984	100.00
6	28.0539	3.18072	33.83	0.3936	8.57
7	29.4614	3.03189	25.74	0.2362	6.52
8	34.1935	2.62236	25.44	0.1181	6.45
9	36.6608	2.45134	10.08	0.2362	2.55
10	39.5198	2.28035	24.77	0.2362	6.28
11	42.5465	2.12487	98.05	0.0590	24.84
12	45.9411	1.97546	8.53	0.2362	2.16
13	47.2801	1.92259	9.60	0.6298	2.43
14	50.2495	1.81422	52.67	0.0720	13.35
15	54.9696	1.67045	10.67	0.2362	2.70

Ref. Code	Mineral Name	Chemical Formula	Semi Quant [%]
01-072-0156	Portlandite	$Ca(OH)_2$	5
01-085-1108	Calcite	$CaCO_3$	5
01-074-3485	Quartz	SiO_2	60
00-041-1480	Albite, calcian	$(NaAlSi_3O_8), (CaO)$	10
00-025-0284	Graphite	C	20

**CTS:computerized tomography scan; this parameter for explain the character of device*

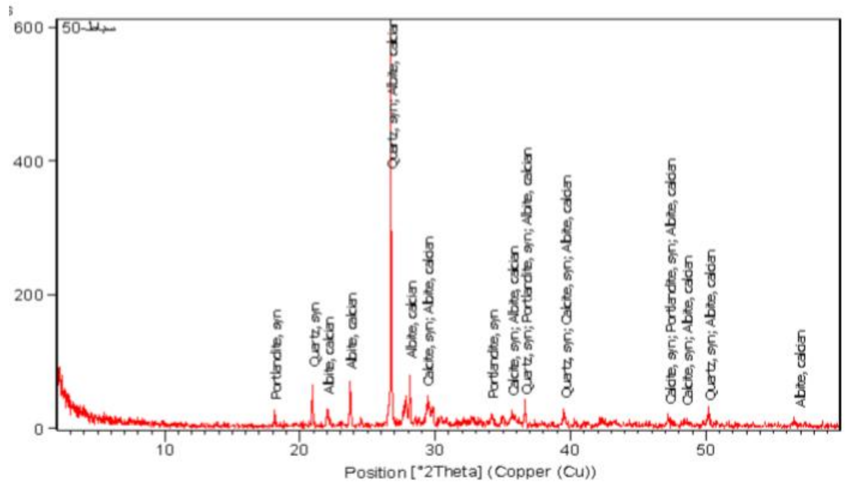


Fig. 13. XRD-patterns for palm

Palm

Peak number	Pos. [2θ.]	d-spacing [A]	Height *[CTS]	FWHM Left [2θ.]	Rel. Int. [%]
1	18.1028	4.90043	15.95	0.1181	2.72
2	20.8896	4.25255	64.33	0.1181	10.96
3	22.0293	4.03505	22.64	0.1181	3.86
4	23.7224	3.75076	58.62	0.0787	9.99
5	26.7061	3.33810	586.98	0.0787	100.00
6	28.0902	3.17669	72.65	0.0590	12.38
7	29.4255	3.03551	32.01	0.1574	5.45
8	34.1795	2.62340	14.15	0.2362	2.41
9	35.6904	2.51573	16.59	0.3149	2.83
10	36.6359	2.45295	18.67	0.1574	3.18
11	39.5406	2.27919	16.97	0.3149	2.89
12	47.3174	1.92116	7.97	0.6298	1.36
13	48.5209	1.87628	7.22	0.4723	1.23
14	50.2176	1.81680	14.06	0.2362	2.40
15	56.8867	1.61863	2.67	0.9446	0.45

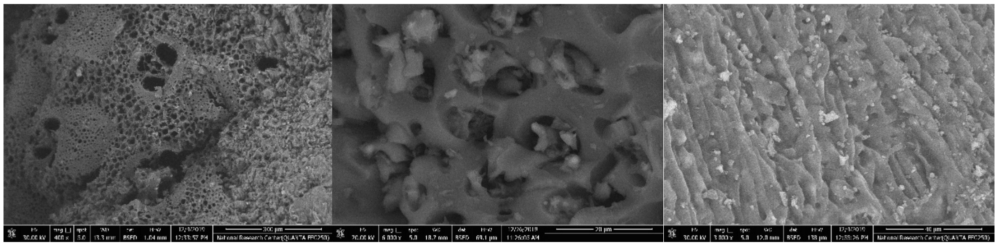
Ref. Code	Mineral Name	Chemical Formula	Semi Quant%
01-085-0865	Quartz	$Si\ O_2$	75
01-071-3699	Calcite	$Ca\ (C\ O_3)$	5
01-070-5492	Portlandite	$Ca\ (O\ H\ )_2$	3
01-079-1148	Albite, calcian	$(Na\ Al\ Si_3\ O_8),\ (Ca\ O)$	15
00-001-0640	Graphite	C	2

**CTS:computerized tomography scan this parameter for explain the character of device*

b) Showed the Palm pyrolysis fibers are more elongated in one direction and the single fiber it has been observed that the fiber generally looked at longitude thin fiber and it is like very thin needles in concrete matrix so it is like this form. The surface of fiber is not smooth became rougher and textured. The rough surface improves the interlocking between the fibers and concrete resulting in improved adhesion between concrete and the fiber and can make strong bond with other materials.

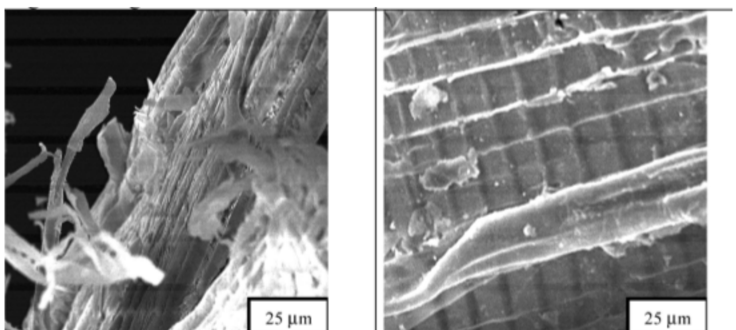
Fig.15. showed cross section of untreated natural fiber that the presence of hemicellulose, lignin, and other non-cellulosic content on the surface of untreated natural Palm, these non-cellulosic contents are responsible for hydrophilic nature of fiber, which causes the poor interfacial bonding with the hydrophobic fiber [24].

Fig. 16 shows the concrete mix SEM micrographs which cured up to 28 days. The images first showed an increase and abundance in the natural fibers gradually with the mixtures. Secondly, it was observed that the treated fibers are intact as they are inside the concrete mortar of the concrete. The appearance of C-S-H gel resulting from cement hydrate reaction, it is clear evidence that the hydration process is carried out naturally without any negative impact on natural fibers presence within mortar concrete.



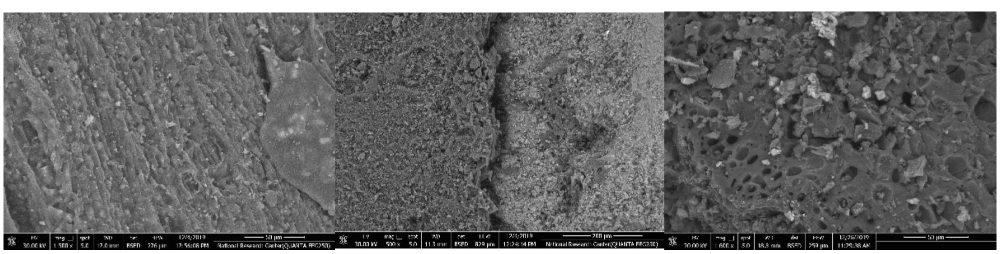
A) bamboo b) kernel c) Palm oil fiber

Fig. 14. SEM images of treated pyrolysis palm oil and bamboo fibers



a) Untreated bagasse fiber x 800 e) Untreated banana trunk fiber x 800

Fig. 15. SEM images of untreated natural fibers



a) 1.5 % palm oil fiber b) 1.5 % bamboo fiber c) 1.5 % date kernel fiber

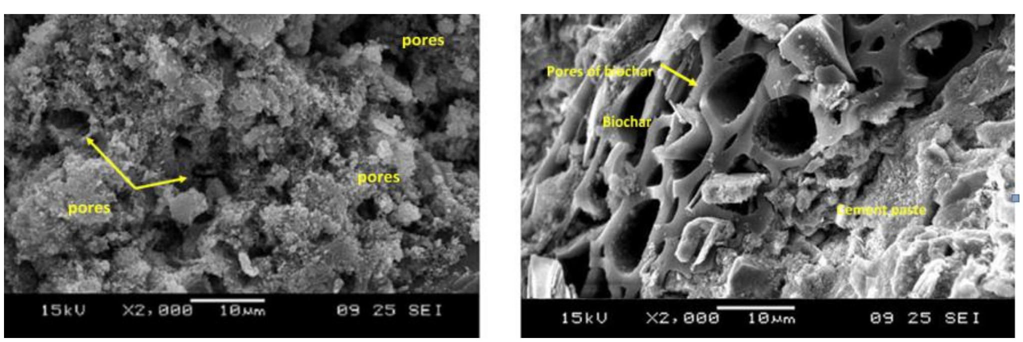


Fig. 16. SEM micrograph of concrete containing different types of treated pyrolysis fibers

4. CONCLUSIONS

In this research, study the impact of using various percentages of different natural fibers on the mechanical properties of concrete to get the best result in terms of resistance Compressive Strength, Splitting Tensile Strength and Flexural Strength compared with plain concrete. From analysis of findings and observations, the following conclusions can be reached:

- The compressive strength result with different % of natural fibers was improved with 1% fiber-concrete ratio and little increase for 1.5% of fiber-concrete ratio compared to control. But the compressive strength was reduced with 2% of fiber-concrete ratio.
- The unexpected and brittle failure of concrete specimens was withstand with the % of natural fibers is increased.
- Increasing of fiber-concrete ratio with compacted concrete samples is leading to increase in void, that due to this is due to the poor bonding between the concrete materials and the increase in natural pyrolysis fibers.
- In all concrete compressive strength mixtures decreased with natural pyrolysis fibers volume proportion increasing.
- SEM images illustrated that, there were less crack width and crack developments number with different natural pyrolysis fibers reinforced concrete; accordingly, it is considered a good alternative for use in the field of construction in different proportions, lengths and shapes.
- Properties of biochar-concrete composite under normal and elevated temperature, biochar may be a sustainable alternative material to conventional micro-fillers in concrete.
- The findings strongly suggested that optimal dosage of biochar, typically between 1 and 2 wt. % of cement depending on preparation conditions, would lead to improved water tightness and compressive strength of concrete under normal condition, and mitigate loss in durability during exposure to elevated temperature conditions.
- At the fiber content of 1.5% the concrete compressive strength increases by 28.33%, 21.33% and 18% for palm oil fiber and date kernel and bamboo, respectively.
- At the fiber content of 1.5% the concrete flexural strength increases by 26.25%, 17.5% and 10.0% for palm oil fiber and date kernel and bamboo, respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Libo Yan, Nawawi Chouw. Sustainable concrete and structures with natural fiber reinforcements. OMICS Group e-Books 731 Gull Ave, Foster City. CA 94404, USA Department of Civil and Environmental Engineering, and Technology; 2014.
2. Várhegi G, Antal MJ, Jr, Jakab E, Szabó P. Kinetic modelling of biomass pyrolysis. Journal of Analytical and Applied Pyrolysis. 1997;42:73–87.
3. Mani T, Murugan P, Mahinpey N. Pyrolysis of oat straw and the comparison of the product yield to wheat and flax straw pyrolysis energy fuels. Department of Chemical and Petroleum Engineering, Canada. 2011;25:2803–2807.
4. Maheshwar Sharon, et al. Hydrogen storage by carbon fibers synthesized by pyrolysis of cotton fibers. 2011;39-43.
5. Ramakrishna G, Sundararajan T. Studies on the durability of natural fibers and the effect of corroded fibers on the strength of mortar. Cement Concrete Composites. 2005;27(5):575-657.
6. Bentur A, Mindness S. Modern concrete technology. Oxford, UK Second Edition. 2007;15:601.
7. Filho RDT, Joseph K, Ghawami K, England GL. Revista Brasileira de Engenharia Agrı´cola e Ambiental. 1999;3(2):245–256.
8. Yurtseven AE. Department of Civil Engineering, Middle East Technical University. Ankara, Turkey; 2004.
9. Methods for producing biochar and advanced biofuels in Washington State Part 1: Literature Review of Pyrolysis Reactors, Ecology Publication Number 11-07-017; 2011.
10. Arsène M, et al. Treatments of non-wood plant fibres used as reinforcement in composite materials. Department of Civil Engineering, Materials Research, January 15, CP 23, CEP 13635-900, Brazil; 2013.
11. Shanmugapriya T, et al. Effects of natural fibers in high strength concrete. International Journal of Engineering

Research and Modern Education. 2017;201-207. ISSN: 2455 – 4200.
12. Nilraj Y. Patne, et al Comparative strength of natural, artificial and combination fiber reinforced concrete. International Journal of Engineering Research. 2015;4. ISSN: 22780181. Available:www.ijert.orgIJERTV4IS030763
13. Li Z, Wang L, Wang X. Cement composites reinforced with surface modified coir fibres. Journal of Composite Materials. 2007;41(12):1445-1502.
14. Ghosh R, Reena G, Krishna A, Raju B. Effect of fiber volume fraction on the tensile strength of banana fiber reinforced vinyl ester resin composites. International Journal of Advanced Engineering Sciences and Technologies. 2011;4(1):89-91.
15. Lalit R, Mayank P, Ankur K. Natural fibers and biopolymers characterization: A future potential composite material. Journal of Mechanical Engineering. 2018;68(1):33–50.
16. Sailesh A, et al. Review on recent developments in natural fiber composites. International Journal of Engineering Research & Technology (IJERT). 2013;2:9. ISSN: 2278-0181.
17. Ranakoti L, et al. Natural fibers and biopolymers characterization; A future potential composite material. Journal of Mechanical Engineering – Strojnícky Časopis. 2018;68(1):33–50.
18. Yazıcı S, Inan G, Tabak V. Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC. Construction and Building Materials. 2007;21(6):1250-1253.
19. Liu B, Gao R, Xu Z. Fabrication of super-hydrophobic surfaces utilizing pyrolysis of waste printed circuit boards. Journal of Cleaner Production. 2020;244:118727.
20. Arsène M-A, Okwo A, Bilba K, Soboyejo ABO, Soboyejo WO. Chemically and thermally treated vegetable fibers for reinforcement of cement-based composites. Materials and Manufacturing Processes. 2007;22:214–227. ISSN: 1042-6914 print/1532-2475 online.
21. Thomas J, Ramaswamy A. Mechanical properties of steel fiber-reinforced concrete. Journal of Materials in Civil Engineering. 2007;19(5):385-392.
22. Tobbala DE. Effect of nano-ferrite addition on mechanical properties and gamma ray attenuation coefficient of steel fiber reinforced heavy weight concrete. Construction and Building Materials. 2019;207:48-58.
23. Gupta S, Wei K, Dai P. Effect of biochar on mechanical and permeability properties of concrete exposed to elevated temperature. Construction and Building Materials. 2020;234:117338.
24. Baruah OP, Talukdar SA. A comparative study of compressive, flexural, tensile and shear strength of concrete with fibers of different origins. Indian Concrete Journal. 2007;81(7):17-24.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/62167