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Escuela Académico Profesional de Ingeniería Ambiental
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Tesis

Analysis of the vicugna pacos (Alpaca) wool fiber in the properties of concrete

Levi Acevedo Villazana
Cristian Starky Mora Altez
Steve Dann Camargo Hinostroza

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Yo: Cristian Starky Mora Altez , con Documento nacional de identidad (DNI) N° 71910165; teléfono 935874123; estudiante de la Escuela Académico Profesional de Ingeniería Civil.

Yo: Steve Dann Camargo Hinostroza, con Documento nacional de identidad (DNI) N° 43979868; teléfono 998998506; estudiante de la Escuela Académico Profesional de Ingeniería Ambiental.

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Fecha: 13/09/2023

DNI: 44530969

Nombre: Cristian Starky Mora Altez

Fecha: 13/09/2023

DNI: 71910165

Nombre: Steve Dann Camargo Hinostroza

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Analysis of the *Vicugna pacos* (Alpaca) Wool Fiber in the Properties of Concrete

Acevedo Villazana Levi[1, a] [0000-0001-8834-151X]*, Mora Altez, Cristian Starky[1, b] [0000-0001-8871-1429] and Camargo Hinostroza Steve[1, c] [0000-0001-6814-9918]

[1] Universidad Continental, Huancayo, Peru
44530969@continental.edu.pe[a], 71910165@continental.edu.pe[b] and scamargo@continental.edu.pe[c]

Abstract. This research aimed to analyze alpaca (*Vicugna pacos*) wool fiber as a reinforcement in the properties of concrete. For this purpose, methodologies such as ASTM (American Society for Testing and Materials), ACI (American Concrete Institute), and Peruvian Technical Standards (NTP) were used; likewise, the experimental design methodology was employed. The sample consisted of 45 specimens; 30 were cylindrical, and 15 were in the form of beams. The alpaca wool fiber was used in percentages of 0%, 0.5%, 1%, 2%, and 4%, with 60 mm length cuts added to the concrete mix. The results showed that the compressive strength in the specimens containing the alpaca wool fiber at 28 days complies with the percentages established by the ACI standard. However, the compressive strength of 33.48% was decreased in the control specimen. As for the tensile strength, compared to the control specimen, an average increase of 1.19% was observed on day 28. Finally, compared to the control specimen, the values obtained in the flexural strength of the alpaca wool fiber specimens showed an average reduction of 19% and 18% on days 14 and 28, respectively. In conclusion, when analyzing the samples containing the alpaca wool fiber, we observed that the tensile strength improved thanks to alpaca wool fibers.

Keywords: Alpaca wool fiber, compressive strength, flexural strength, tensile strength.

1 Introduction

Worldwide, concrete is considered one of the basic construction materials due to its high strength (1). In 2021 the concrete industry increased by 10% and is expected to increase by 5% more by the end of 2022 compared to the previous year (2). However, temperature variation, rainfall, and other pathologies cause the mechanical properties of concrete to decrease significantly (3), and Peru is no exception. According to the National Meteorology and Hydrology Service of Peru, in Junin's Region, during June 2022, the maximum temperature was 32 °C, and the minimum was -4.8 °C. Likewise, the average annual rainfall is 700–2,000 mm (4), thus causing the useful life of concrete to be impaired. Because of this, many industries add inorganic and organic fibers to improve their mechanical properties.

The use of natural animal fibers in construction has many advantages due to their high resistance to abrasion, bending, tenacity, compression, and traction, among others (5). They also mitigate environmental impacts and reduce transportation costs (6). Natural fibers are tiny filaments found in cotton seeds, flax, wool, hair, or silk; and are considered valuable raw materials for construction(5). Alpaca (*Vicugna pacos*) fiber is composed of keratin, whose diameter is approximately 18–27 mm (7). This fiber has the particular characteristic of being more resistant and softer than sheep fiber (8). Recently, research has been carried out on using natural fibers in concrete, as in Alyousef et al. (9), where their objective was to determine the effects of sheep wool fiber on the properties of concrete. For this purpose, they used wool percentages of 0, 0.5, 1, 1.5, 2, 3, 4, and 6 percent, which were added to the concrete. The findings showed improved tensile strength (32.7%) and flexural strength (20.8%). They concluded that concrete with wool fiber improves its effectiveness.

Similarly, Alyousef et al. (10) questioned if sheep wool improves concrete transport properties and strength. For this purpose, they made five mixtures using ordinary cement and sheep wool of 70 mm length, ranging from 0–2.5%. This research showed that adding fibers to the concrete decreased its slump. However, it increased the compressive strength by 30MPa at 90 days after curing. Additionally, they observed that the flexural strength had higher values than the concrete without fiber. The researchers concluded that adding wool fiber improves some properties of concrete.

In their experimental investigation, Ahmad and Rehman [11] used sheep wool to increase the total strength of concrete. They found that the flexural, compressive, and tensile strength increased by 21%, 29%, and 12%, respectively, compared to concrete without adding sheep wool fiber. However, concrete with 5% wool had lower capillary absorption. Al-Kafri et al. (12) determined the effect of sheep wool fiber on the properties of concrete, where the proportion of the concrete mix was 350 kg of cement, 700 kg of sand, 1,050 kg of gravel, and 219.8 kg of water. The specimens had percentages of wool fiber at 0%, 0.09%, 0.12%, and 0.14%. They found that the compressive, flexural, and tensile strength improved after 90 days of curing for all the specimens. However, the elasticity decreased as a higher percentage of fiber was added. They concluded that adding the sheep wool fiber improved the properties of the concrete.

Adding natural sheep fibers to the concrete mix benefits the concrete's properties because the fibers are flexible and cover pore spaces. In all the investigations, researchers followed standardized methods and established concrete designs. Regarding alpaca wool fiber, the study conducted by Quispe et al. (13) in South America identified the existence of more than one million small producers who have alpacas, and about 30% of the fiber is used in their communities. About 10% is waste, and these residues are not used in most cases. Therefore, this work proposes to use alpaca wool fiber to determine if it influences the mechanical properties of concrete, hoping that it can contribute to the reduction of waste and considering that concrete mixed with fibers improves the properties of concrete to a great extent (14).

2 Materials and Methods

2.1 Alpaca Wool Fiber Characteristics

Natural fibers, such as alpaca, are used in different industries, and their importance is immense due to their high elasticity and resistance (15). Peru has the largest alpaca population; it is also the largest producer of alpaca fiber worldwide (16). By 2017, the alpaca population had increased up to 50.2% compared to previous years (17). The main properties of alpaca fiber are high fire resistance, high absorption, high water repellency, thermal resistance, insulation, strong thread, odor absorbing, rot resistance, and vibration control (18). The physical properties of the alpaca fiber from the Huacaya breed are minimally variable (Table 1).

Table 1. Physical properties of alpaca fiber

	Diameter - Micron[mic]	Standar deviatión -SD[mic]	Coefficient of variation-CVD[%]	Confort factor - CF[%]	Finesse Wool-SF(mic)	Staple Len - SL[mm]	Fiber Curvature CRV[Dg/mm]
MWF1	32.9	7.6	23.2	39.1	32.7	95	26.6
MWF2	34.4	7.4	21.5	30.3	33.7	90	24.7
MWF3	33	7.1	21.6	37.1	32.2	100	23.5
MWF4	30.4	7.3	23.9	53.3	30.4	90	27.1
MWF5	29.5	7.2	24.5	59.1	29.5	100	27.2
MWF6	29.7	7.5	25.3	57.9	30.1	90	30.1
Average	31.7	7.4	23.3	46.1	31.4	94.2	26.5

The average diameter of alpaca wool fiber was 31.7 microns (Table 1); likewise, the coefficient of variation of the fiber diameter was 23 microns, which indicates that there is not much difference about the mean. The average fiber length was 94.2 mm. As for the fiber curvature index, on average, it was 26.5 Dg/mm, which indicates that there is no significant difference among the samples.

Table 2. Pearson's correlation between the characteristics of alpaca fiber fleece.

Pearson's Correlation								
		Micron (mic)	SD (mic)	CVD (%)	CF (%)	SF (mic)	Staple Len (mm)	CRV (Dg/mm)
Micron (mic)	Pearson's correlation	1						
SD (mic)	Pearson's correlation	0.702	1					
		0.120						
CVD (%)	Pearson's correlation	0.411	0.277	1				
		0.419	0.595					
CF (%)	Pearson's correlation	0.204	-0.073	0.936**	1			
		0.699	0.891	0.006				
SF (mic)	Pearson's correlation	-0.061	0.244	-0.863*	-0.985**	1		
		0.909	0.642	0.027	0.000			
Staple Len (mm)	Pearson's correlation	-0.612	-0.598	-0.167	0.014	-0.130	1	
		0.196	0.210	0.752	0.979	0.806		
CRV (Dg/mm)	Pearson's correlation	0.542	0.510	0.948**	0.797	-0.684	-0.416	1
		0.266	0.301	0.004	0.058	0.134	0.412	
	N	6	6	6	6	6	6	6

**. The correlation is significant at level 0.01 (bilateral).
*. The correlation is significant at level 0.05 (bilateral).

The Pearson Correlation of the alpaca fiber characteristics had a high negative correlation (r= -0.612) between Micron and SL, i.e., the lower the micron (finer the fiber), the higher the SL (Table 2). Similarly, the CF has a high negative correlation with SF, so the SF of low value (higher fineness of the fibers) had a higher CF.

2.2 Mix Design Ratio

The determination of the mix design was carried out by the ACI - 211 standard [19]; where the fineness modulus of the coarse aggregate was 6.70, the nominal maximum size was 3.8 cm, the absorption percentage for coarse and fine aggregate was 2.8% and 5.7% respectively; likewise, the moisture percentage of coarse and fine aggregate were 1.7% and 2.5% respectively. Once the calculations were made, the proportion for the mix design was obtained; these values are shown in Table 3. It is worth mentioning that the cement used complied with ASTM C150-16 (19).

Table 3. Mix design for 1m[3] of concrete.

Cement	Fine aggregate	Coarse aggregate	Water
350.8 [Kg]	629.6 [Kg]	1263.1 [Kg]	215.3 [L]
	Design Proportion		
1	1.8	3.6	27 [L]

2.3 Concrete Preparation

Once the design calculations were made, the concrete was prepared to take into account the calculated proportion; these materials were in the mixer as mentioned in ASTM C192-02 (20), then the alpaca wool fibers were added to each beam and cylindrical concrete specimens. For this, the percentage of wool to be added was calculated about the water and cement (0.5) (9). The concrete beams and cylindrical concrete specimens were reinforced with 0%, 0.5%, 1%, 2%, and 4% with cuts of 6 mm in length; these values were chosen because previous research suggests that the percentages should be less than 6% since, if they are higher, they do not have good results in the mechanical properties (10).

Fig. 1. Concrete preparation with the addition of alpaca wool fiber

2.4 Experimental Test

To determine the compressive and tensile strength of concrete, the ASTM C39/C39M-18 standards (21) and the NTP 339.034:2015 (22) were taken into account for cylindrical concrete specimens, where 30 specimens of 15 cm diameter and 30.5 cm height were prepared for evaluation at 7, 14 and 28 days. Likewise, for the flexural strength tests, ASTMC293/C293M-16 standards (23) and NTP 339.079:2012 (revised in 2017) were taken into account (24) where 15 beams of 61 cm long, 15 cm wide, and high were elaborated.

Fig. 2. Specimens Tests

3 Results

3.1 Compressive Strenght Test

At day 28, the compressive strength had values higher than 300 Kg/cm^2 without the addition of the alpaca wool fiber; in addition, in the specimens containing the alpaca wool fiber, they managed to maintain the strength with an average value of 205 Kg/cm^2, 145 Kg/cm^2 and 102 Kg/cm^2 at 28, 14 and 7 days respectively. However, the lowest value obtained was on day 7 with 57 Kg/cm^2 with a fiber percentage of 0.5%. It should be noted that, on day 28 of curing, an average decrease of 33.48% in compressive strength was observed in the specimens containing the fiber compared to the control specimen. When compared with the percentage of resistance according to the ACI 318 standards (25), it was identified that the specimens containing the alpaca wool fiber at 28 days comply with the established standard (100 to 120%) (Fig. 4). On the other hand, the most frequent fractures on day 7 were type III; on day 14, it was type V; on day 28, it was type VI. Therefore, according to ACI standards, adding alpaca wool fiber complies with the compressive strength in the 28 days of evaluation.

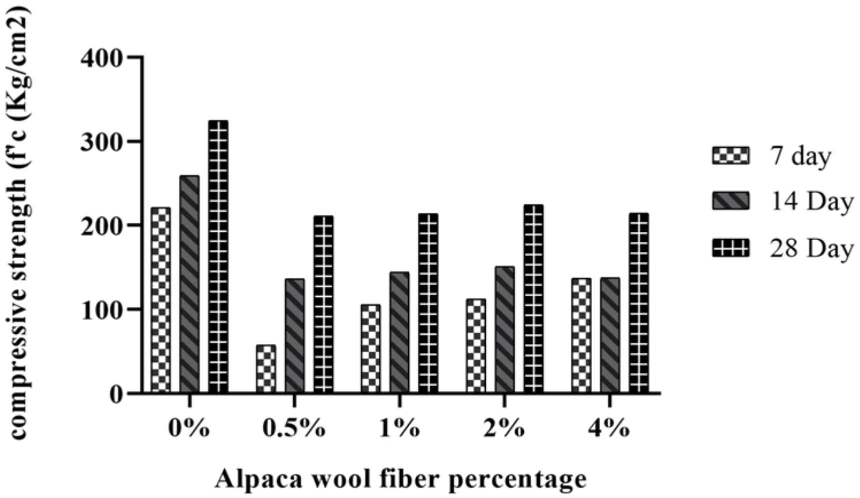

Fig. 3. Compressive strength test on the specimens

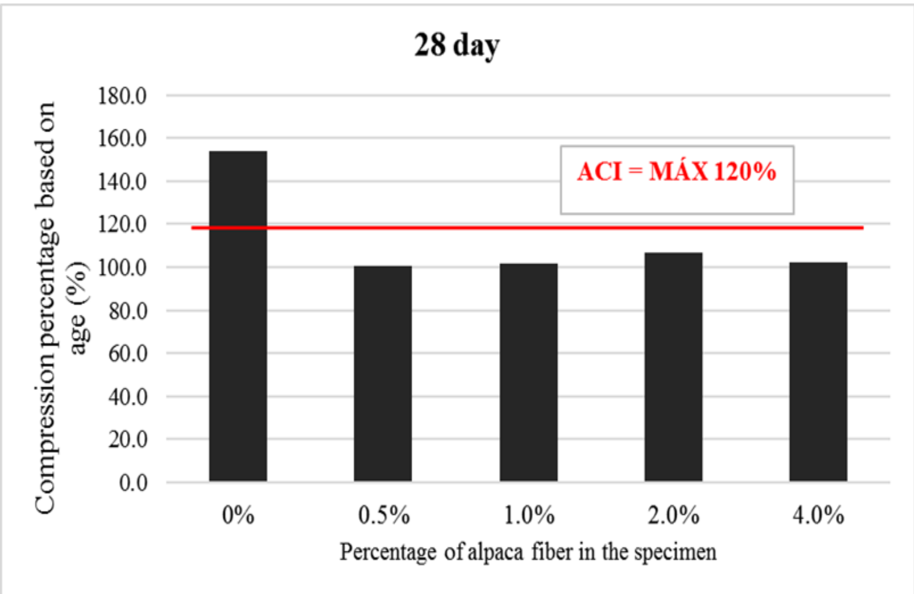

Fig. 4. Concrete strength as a function of age according to ACI standards

3.2 Tensile Strength Test

The control specimen had a resistance factor of 190 Kg/cm^2, 235 Kg/cm^2, and 294 Kg/cm^2 on days 7, 14, and 28, respectively; likewise, the specimen with 4% alpaca wool fiber had higher values regarding the other models containing percentages of wool fiber, where the results were: 208 Kg/cm^2, 248 Kg/cm^2 and 307 Kg/cm^2, for days 7, 14 and 28 days of age respectively. Regarding the percentage of tensile strength compared to the control specimen, an average increase of 1.19% was observed on day 28. Also, it was evidenced that the most common types of fracture in the samples on days 7, 14, and 28 were type III. On the other hand, when comparing the strength of concrete as a function of age, according to the ACI-318 standards (25), it can be seen that in all the specimens containing the alpaca wool fiber, as well as the control specimen, they exceed the recommendation of this standard, whose maximum suggested value is 120% (Fig. 6).

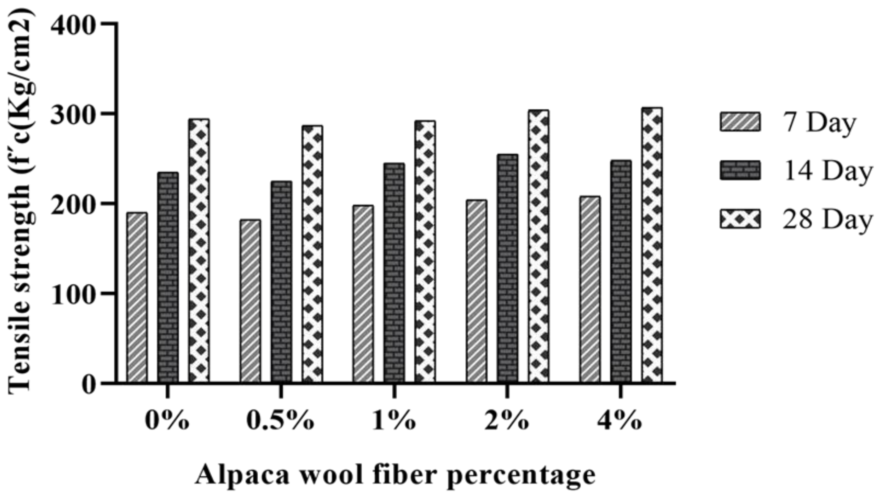

Fig. 5. Tensile strength test of the specimens.

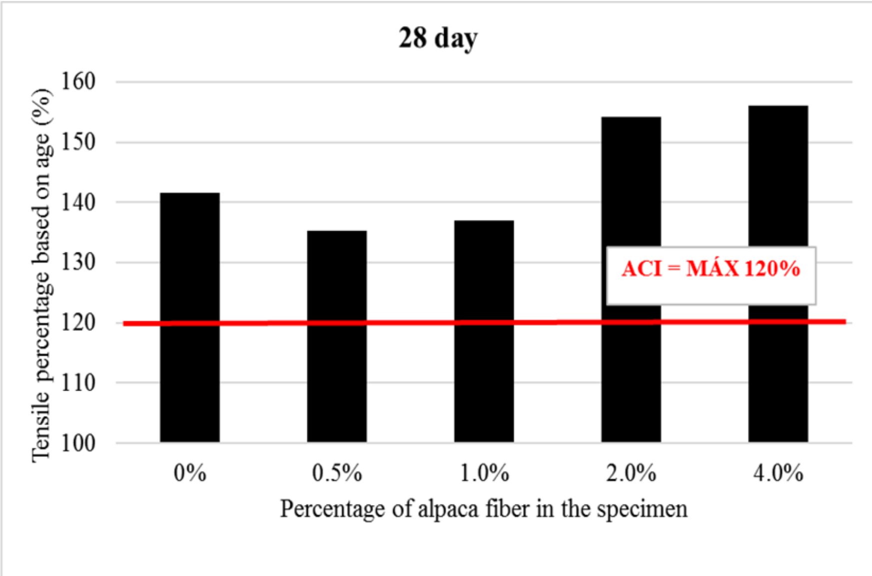

Fig. 6. Tensile strength as a function of age according to ACI standards.

3.3 Flexural Strength Test

At 28 days, the flexural strength in the control sample had a maximum value of 51.7 Kg/cm^2; at 14 days, the specimen with 0.5% of alpaca wool fiber had its highest value of 41.4 Kg/cm^2; at 28 days, the specimen with 1% wool fiber recorded a maximum value of 43 Kg/cm^2; the specimen with 2% fiber on day 28 recorded a maximum value of 45 Kg/cm^2; finally, the specimen with 4% fiber had the highest value recorded on day 28 with 42 Kg/cm^2. As for the flexural strength compared to the control specimen, there was an average reduction of 19% and 18% on days 14 and 28, respectively. It is worth mentioning that as the percentage of alpaca wool fiber in the concrete increases, the flexural strength decreases since the average variation of the flexural strength was 5 Kg/cm^2.

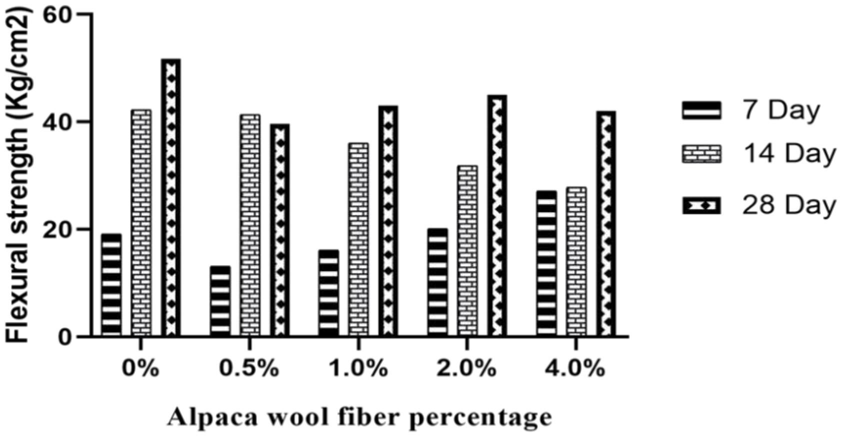

Fig. 7. Flexure strength test of the specimens.

4 Discussions

This research showed that the specimens containing the alpaca wool fiber caused the compressive strength to decrease. However, the percentage of compression at the age of 28 days in these specimens complied with the ACI- 318 standards (25). Regarding the tensile strength, an improvement could be detected at day 28 in all the specimens with alpaca wool fiber; likewise, the flexural had no significant difference in curing at day 28, compared to the control specimen. The findings of this study agree with Alyousef et al. (9) when determining that adding sheep wool fiber improves tensile and flexural strength at 28 days of curing. It also agrees with Gadgihalli et al. (26) when adding sheep wool fiber improved the compressive and flexural strength of concrete;. However, as the cement grade was increased, the strength percentage gradually decreased. Similarly, it agrees with Galema et al. (27) when finding that compressive, flexural, and split tensile strength improved with the addition of sheep wool fiber in the concrete, especially the higher flexural strength with 1.5% fiber. Likewise, Ahmad and Rehman [11] determined that workability was reduced; flexural and tensile strength increased, this thanks to the addition of sheep wool fibers in concrete. Although research shows the importance of sheep wool fiber in concrete reinforcement, not much exists about alpaca wool fiber, mostly simple descriptions of properties and characteristics. This study was able to analyze the attributes of alpaca wool fibers where the high fineness of the thread was evidenced, results that agree with Paucar et al. (17) when identifying the negative correlation between the average diameter of the fiber and the length of the thread; thus determining its high fineness. Likewise, the effects of the alpaca wool fiber on the compressive, tensile and flexural properties of hardened concrete were analyzed, where the thread improved tensile strength and decreased compressively and flexure strengths, on day 28 of curing.

References

1. Bag of concrete. Why is concrete important. https://bagofconcrete.com/why-is-concrete-important/. last accessed 2022/06/03
2. The Economist. The concrete industry grows 10% in 2021 and forecasts a rise of 5% in 2022.https://www.eleconomista.es/empresas-finanzas/noticias/11627315/02/22/La-industria-del-hormigon-crece-un. last accessed 2022/06/03
3. Ghadzali, N., Ibrahim, M., Mohd Sani, M., Jamaludin N, Desa, M., Misri, Z. Properties of concrete containing different type of waste materials as aggregate replacement exposed to elevated temperature – A review. In IOP CONFERENCE SERIES: earth and environmental Science; 2018; Pahang.
4. National Service of Meteorology and Hydrology of Peru. current weather conditions. https://www.senamhi.gob.pe/main.php?dp=junin&p=condiciones-climaticas#. last accessed 2022/06/03
5. Boumaaza, M., Belaadi, A., Bourchak, M., Systematic Review on Reinforcing Mortars with Natural Fibers: Challenges of Environment-Friendly Option. Journal of Natural Fibers 17(4), 12-15. (2022)
6. Kathib, J., Machaka, M., Elkordi, A.: Manual of Sustainable Management of Concrete ansd Industrial Waste New York: Elsevier; 2021.
7. Mcgregor B. Physical, chemical, and tensile properties of cashmere, mohair, alpaca, and other rare animal fibers. ScienceDirect 105-136. (2018)
8. Vaca-Cárdenas, M., Oleas. M., Vaca-Cárdenas, M., Velasco, A.: Characterization of the Physical - Mechanical Properties of Alpaca Fiber (Vicugna pacos) at the Tunshi Experimental Station. The Ecuadorian Journal of S.T.E.A.M. 1(1) 29-56. (2020)
9. Alyousef, H., Alanduljabbar, H., Mohammahosseini, H.: Utilization of sheep wool as potential fibrous materials in the production of concrete composites. Elsevier 2356(7102), 101-216. (2020)
10. Alyousef, H., Mohammasdhosseini, A., Khalek, A.: An Integrated Approach to Using Sheep Wool as a Fibrous Material for Enhancing Strength and Transport Properties of Concrete Composites. Journal Materials. 2022; 15(1688): p. 1-20.
11. Ahmad, I., Rehman, K.: Experimental investigation on using sheep wool as fiber reinforcement in concrete giving increment in overall strength. ScienceDirect 45(6), 4405-4409 (2021)
12. Al-Kafri, A.: Effect of Natural Fiber (Sheep's Wool) on Properties of Fresh and Hardened Concrete. In THIRD INTERNATIONAL CONFERENCE ON TECHNICAL SCIENCES (ICST2020); 2020; Tripoli. p. 28-30.
13. Quispe, E., Rodriguez, T., Iñiguez, R., Mueller, P.: Producción de fibra de alpaca, llama, vicuña y guanaco en Sudamérica. Animal Genetic Resources Information. 2009; 45(2): p. 1-14.

14. Ahmed, M., Hoque, M., Shaid, A.: A Comparative Study of the Mechanical Properties of Jute Fiber and Yarn Reinforced Concrete Composites. Journal of Natural Fibers. 2018; 17(5): p. 676-687.
15. Jankowska, Wyrostek, A., Patkowska, S., Czyż.: Comparison of Physico-mechanical Properties of Fibre and Yarn Made of Alpaca, Sheep, and Goat Wool. Journal of Natural Fibers. 2019; 18(10): p. 1512-1517.
16. National Institute of Statistics and Informatics. National Agricultural Census 2012. Lima:; 2012.
17. Paucar, R., Ruiz, A., Lafraya, S., Mendoza, G., Alvarado, F.: Características textiles de la fibra de alpacas Huacaya (Vicugna pacos). Scientia Agropecuraria. 2019; 10(3): p. 1-14.
18. Agrarian University of La Molina. Directed technical assistance in characterization and classification of alpaca fiber. Huancavelica:; 2012.
19. American Society for Testing and Materials. Standard Specification for portland cement ASTM C150. New York:; 2016.
20. American Society for Testing and Materials. Preparation and Curing of Concrete Test Specimens in the Laboratory ASTM C192-02. New York:; 2018.
21. American Society for Testing and Materials International. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens1 ASTM C39/C39M-18. New York:; 2018.
22. Technical Standards Peruvian. Concrete. Standard test method for determination of the compressive strength of concrete in cylindrical samples. Lima:; 2015.
23. American Society for Testing and Materials International. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading), ATSM ASTMC293/C293M-16. New York:; 2018.
24. Peruvian technical standard. Concrete. Standard test method for flexural strength of concrete (using simple beam with center-point loading). Lima:; 2017.
25. American Concrete Institute Standar. Regulation Requirements for Structural Concrete (ACI 318S-05) and Comment (ACI 318SR-05). New York:; 2015.
26. Gadgihalli, V., Meena, Y., Chandana, R., Ha, R.: Analysis of properties of concrte using sheep wool dipping in salt water as fibre reinforcement admixture. International journal of research Granthaalayah. 2017; 5(11): p. 1-3.
27. Galena, D., Kebede, G., Feleke, L. Investigation on effects of sheep wool fiber on properties of C-25 concrete. Saudi Journal of Civil Engineering. 2019; 1(1): p. 1-28.