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Analysis of Mechanical Strength Concrete with Addition of Fiber PAMBIL

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Abstract*: In the second decade of the twentieth-century housing still plays a decisive role in the quality of life of the population of the countries in the developing world and it represents the primary investment and the most important assets of middle and low-income families. However, despite acknowledging recognizing its importance, the deficits recorded for the countries of Latin America are more than 25 million housing units (CEPAL, 1995) and to Ecuador, a requirement of 1 million, two hundred thousand solutions. The causes that prevent the provision of accommodation associated with the unequal distribution of wealth, the high costs of building materials, and the dependence on technology and the lack of local research and ingenuity. Currently, the predominant use of concrete has led to the discovery of composite materials, achieved through the addition of fiber to the real matrix, aiming to reduce costs. In this case, the design of concrete performed under the Maximum Density Method and utilized Iriartea deltoidea or Pambil as fiber reinforcement, which is readily available in the province of Zamora Chinchipe, located in the southeastern part of Ecuador. It used in varying percentages of 0.50, 1.50 and 2.5% and whose sizes retained in sieves 4 and 8, placed randomly in the concrete mix. The results obtained show that the addition of fiber elements tested under compression improves the characteristics of the composite. However, about flexion the concrete strength decreases, showing not so encouraging results for the manufacture of composite concrete and fiber pambil. This adverse outcome does not guarantee the success of the composite concrete, which under experimental conditions is technically recommendable, but still does not prove to be economically appropriate solutions.

***Index Terms*— composite materials, organic fibers. Reinforced concrete.**

I. INTRODUCTION

In the second decade of the century, housing and access to basic services still play a decisive role in the quality of life of the population of the developing country, Since they are essential conditions to achieve minimum welfare; even when the first of them represents "the largest investment and most valuable heritage of the families of middle and low income; and in some cases, it is a primary source of income "(Szalachman, 2000). While recognizing the importance of housing, deficits registered for the countries of Latin America are high, a fact confirmed by CEPAL, which reported for 1995 lack of housing units more than 25 million quantities by overall conditions and qualitative.

Overcoming the housing deficit in Latin America would require the approximate sum of 125 billion dollars, which advocates a difficult or almost impossible to solve, in countries with the little economic problem. If extrapolated to the amount indicated for Ecuador, a requirement of 6 billion dollars, which the housing deficit of one million two hundred thousand units would be solved is established.

Moreover, we must recognize that since man began with processes of building his home took for it elements of nature, such as soil and organic fibers, until the development of the technology of cement and steel were displaced and came to dominate the construction.

Market to such an extent that the adoption of concrete, led to a devaluation of materials and old technologies and a rise in costs. Today this trend is reversed when trying to find new raw materials, without returning to the native materials considered, could enable the manufacture of new, minimizing their market value through an appropriate combination thereof, as which gives way to a series of investigations among which studies concrete with fibers are added.

It conducting a historical perspective is that in the early 1900s, asbestos fibers already used in concrete. In the 50s was born the concept of "composite" and "concrete reinforced with fibers," This was one of the topics of greatest interest, especially because the need to find a replacement for asbestos raised (which used in forming concrete and other), once they discovered health risks associated with that substance.

From this knowledge and importance, they started in various parts of the world studies of organic fibers, which has allowed substantial resources for research purpose. However, in the Southern Region of Ecuador, the study on these issues is almost nil, although there are important plant species that provide fiber, which could contribute in the construction area.

In this regard, the National University of Loja considered essential to venture into the issue of housing, through the Masters Program in Civil Construction and Sustainable. Development, Major in Social Housing, to be achieved research and develop materials and construction technologies that enable the construction of housing, with viable solutions for the smaller economy. In this framework, this investigation was raised, identifying the species Iriarte deltoid or Pambil, as a fiber readily available in the southeastern part of Ecuador,

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For the province of Zamora and could be used to incorporate certain characteristics, matrices plain concrete, resulting in a composite material that provides excellent results regarding strength, economy, and durability. In this regard. "Research for alternative materials to conventional reinforced concrete have increased; and in the search for alternatives, fiber reinforced concrete has the characteristics of a solution with technical and economic feasibility. Thus, they have already used steel fibers, glass fibers, carbon fibers, mineral and natural fibers (wood, jute, bamboo, coconut, sisal, asbestos, wool, etc.), polypropylene fibers and many other synthetic fibers as Nylon and Polyester. "(Cepeda, 1997).

Although the results of these investigations have been encouraging, we found some deficiencies regarding its durability; these apparently result from the reaction between the alkalinity of the cement paste and the fibers, besides the attack by microorganisms in the presence of moisture. (Lewis, 1979).

"In compounds of organic origin major degradation agents are the chemical and physical incompatibilities between fibers and matrices, the first given by two circumstances:

• The high alkalinity causes water porosities in the matrix around the fiber where calcium hydroxide with increasing temperature causes a degradation sensitive acceleration accumulates; Y

• When the lignin and hemicellulose decomposed due to the high pH water weakened adhesion with the matrix and transforming the fiber into an inert material within the composite. "(MacVicar, 1999).

To avoid degradation processes of plant fiber in the concrete matrix by effects of alkalinity, and seeking to cement setting is not affected, Beraldo use washing material. (Beraldo, 1997).

The durability of the compound then depends protection having fiber characteristics and activities of the parent impermeability.

The deltoid Iriartea, is a genus of flowering plants, belonging to the palm family (Arecaceae), it is native to the American tropics where they are from southern Nicaragua to Bolivia Which commonly found in Ecuador where it adopts the common name of "Pambil or Chonta" grows in forests without strong interventions, with higher densities on the banks of rivers in very firm soils and rows, which could reflect higher light levels or better drainage. The density of adult individuals (> 10 cm dbh) in a forest in Ecuador ranged from 107 per ha in slope, 44 ha in a creek valley, 13 per hectare alluvial plain.

They are trees that form a canopy or canopy, growing from 15 to 25 meters, the prominent bulge in the center of the trunk easily recognizes it, and roots form a dense cone of up to 1 meter in diameter at the base. The leaves of up to 5 meters long and the fruit is a drupe 2 cm in diameter and primarily dispersed by bats.

In Iriartea, like all palms, density and hardness increase stem tissue from the center to the periphery and they are greater towards the base. According to studies (Rich, 1987) on mechanical properties of stem Iriartea deltoid in Costa Rica, the density of the outer cover increases progressively from the trunk of the palm is about 9 m high until about 18 m; thereafter it continues to increase density, but slightly. Furthermore, as the fibers composing the outer cover stem lignify, tannins give a dark color raising aesthetic possibilities of wood (Anderson, 1998).

The possibility of using fiber reinforcement Iriartea deltoid as suitable for structures, has not been studied, so it is important to start the design of reinforced concrete pambil

II. Methodology

2.1 Methods used during the research process.

For the study of the mechanical strength of concrete with added fibers Pambil, the chosen research design was experimental correct (Hernández, 2003) because it allows you to manipulate treatments, stimuli, influences or interventions (called independent variables) to observe their effects on other variables (dependent) in a control situation. This method adjusted to the investigation as it meets the following requirements:

- Intentional manipulation of one or more independent variables.
- Measuring the effect the independent variable has on the dependent variable.
- Control or internal validity of the experimental situation.

As for the selection of the sample size, the following is considered:

- The standard ACI 214 (6.2) of 2011 establishes the ACI 318 standard that defines an endurance test as the average strength of two or more copies of the same age, made from a sample taken from a single batch of concrete. In the experiment, a universe of three specimens for each of the tests to perform on the various experimental groups, concerning experience studies with other fibers was established.
- The optimal sample size, which depends on the maximum permissible error is set (E), and in addition to its range of variability from the values assigned to variables p and q [p (+, acceptance) was determined → q (-, rejection)].

E = 0.05 (5%)
p = 0.90 (90% acceptance)
q = 0.10 (10% header)

There are many expressions to evaluate the size de la sample from the above variables; this research uses the following, see equation 1:

$$n= (N·p· q)/ ([(N-1) (E/K) ^2] + (p·q)) \qquad (1)$$

The variable that represents the constant error correction and fixed by (Pazmiño, 2006) a value of K = 2.0 when p. Q = 0.25, while for others it will be the equivalent, in this research p. q = 0.09 K therefore 0.72, see equation (2).

$$n=\frac{(3)(0.90)(0.10)}{(3-1)\left(\frac{0.05}{0.72}\right)^{2}+[(0.90)(0.10)]}=\frac{0.27}{0.090}=2.99\approx 3 \qquad (2)$$

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- Identify the selection range (the following expression evaluated the range selection (F), see equation (3):

$$F = \frac{N}{n} = \frac{3}{3} = 1 \qquad (3)$$

2.1 Experimental design.

Identification of the independent variables

X1: fiber Size

X2: The amount of fiber added pambil

Setting the range of variation of the independent variables

X1: Variation of fiber size

Considering the research for both bagasse fiber, coconut, bamboo and others in which it is stated that these fibers impart significant mechanical properties to the compound, mainly with additions between 0.5 and 2.5% of the total weight of coarse aggregate,

With lengths between 15 and 25 mm which are retained in the sieves No. 4 and 6, in the present investigation using fiber percentages 0.5% arises; 1.5% and 2.5% retained on the screens # 4 and 8.

X11 = Strainer screen 4

X12 = Strainer screen 8

X2: Number of fiber pambil to use.

X21 = 0.5%

X22 = 1.5%

X23 = 2.5%

Selection Technique

The research design included several groups received an experimental treatment all but one of them called standard sample, which was not the subject of any treatment.

In table 1, types of mixtures made regarding the size and the percentage of fiber used and the nomenclature used to identify the same are detailed.

Table 1. Contains the type of mixtures made and the nomenclature used to identify them.

Mixture N°	Fiber size (Sieve)	Fiber Volume (%)	Repeats I	Repeats II	Repeats III
M1	0	0			
M2	4	0,5			
M3	4	1,5			
M4	4	2,5			
M5	8	0,5			
M6	8	1,5			
M7	8	2,5			

Cylinders and beams: For the analysis of the mechanical properties of each mixing two kinds of specimens were prepared.

The cylindrical samples for compression tests in the curing environment until the ages of 7 and 28 days, both witnesses as containing fiber, using the standard A.S.T.M. C-39 (NTE INEN 1573: 2010 1R).

In addition, beams for bending tests in the curing environment until the age of 28 days, using the A.S.T.M C-78.

Fig 1. Equipment utilized in the laboratory: a. for trial compression. b. Bending test. c. Mold compression testing. d. Mold for bending tests and Abrams cone. F. concreter. g. Precision scale. h. Gauge. i. Sieves for fiber preparation.

III. Results

3.1 Analysis of the properties of the reinforcing fiber

• Physical properties of the deltoid Iriartea

Determination of density, moisture content and shrinkage of wood.

In table 2, the results of the tests presented density, moisture content and shrinkage of the test pieces pambil, made in the laboratory and dendrochronology wood anatomy of the National University of Loja.

Table 2. Density moisture content and shrinkage

N° Sample	CH (%)	Density (g/cm³)			CONTRACCIÓN (%)				Relatiónship T/R
		Green	Anhydrous	Basic	Longitudinal	Tangential	Radial	Volumétric	
1	31.37	1.24	1.07	0.94	0.18	6.37	5.43	11.62	1.17
2	29.72	1.18	1.05	0.91	0.15	6.69	6.96	13.32	0.96
3	24.24	1.21	1.09	0.98	0.33	5.46	5.10	10.58	1.07
4	25.36	1.16	1.05	0.92	0.08	6.56	6.17	12.39	1.06
5	23.97	1.17	1.09	0.94	0.20	7.28	6.13	13.14	1.19
6	30.79	1.12	1.01	0.86	0.18	8.74	6.82	15.11	1.28
7	27.43	1.24	1.10	0.97	0.28	6.01	5.71	11.62	1.05
AVERAGE	**27.56**	**1.19**	**1.07**	**0.93**	**0.20**	**6.73**	**6.05**	**12.54**	**1.11**
CLASSIFICATION				Very high		Low	High	Medium	Low

• Mechanical properties of the deltoid Iriartea

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Compression parallel to the fiber

In table 3, the results obtained from test parallel to fiber compression presented, which were subjected pambil six specimens in the laboratory of dendrochronology and wood anatomy of the National University of Loja.

Table 3. Results of the parallel compression fiber wing

N° Sample	Proportional limit load		Maximum load		Deformation-limit proportional	L	ELP	MRC	Young's modulus
	kN	(P1) Kg/cm2	(kN)	(P2) Kg/cm2	d (cm)	(cm)	kg/cm2	kg/cm2	Y (kg/cm2)
1	7.608	775.79	12.34	1258.51	0.231	10	124.126	201.362	5.373.422
2	7.920	807.60	13.10	1335.40	0.138	10	129.216	213.664	9.363.506
3	8.560	872.86	12.44	1268.20	0.128	10	139.658	202.912	10.910.790
4	7.336	748.05	12.14	1237.51	0.179	10	119.688	198.001	6.686.498
5	8.136	829.63	13.19	1345.19	0.181	10	132.740	215.230	7.333.727
6	7.192	733.37	11.92	1215.48	0.145	10	117.339	194.477	8.092.339
					AVERAGE		127.128	204.274	7.960.047
					QUALIFICATION		Very Low	Very Low	Very Low

In Figure 2, consist stress-strain curves of the six specimens tested in compression parallel to the fibers.

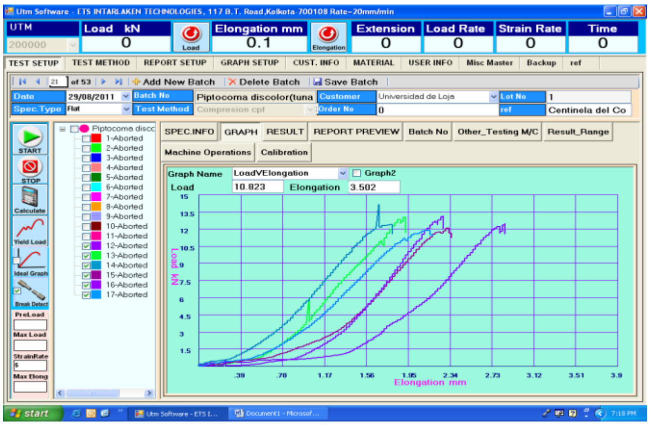

Fig 2. Results of compression parallel to grain

Static bending:

In table 4, the results of static bending test presented, to which they were subjected pambil five specimens in the laboratory of dendrochronology and wood anatomy of the National University of Loja.

Table 4. Results of static bending of the probe Iriartea deltoidea

Nº Sample	Long.	Deflection to limite proporcional (cm)	Proportional limit load	Maximum load	ELP	MOE	MOR
	cm		P1 (kg/cm2)	P2 (kg/cm2)	(kg/cm2)	(kg/cm2)	(kg/cm2)
1	37.2	0.404	62.81	166.82	224.32	51224.83	595.76
2	37.2	0.412	95.44	153.46	340.85	76323.78	548.05
3	37.2	0.431	71.79	134.29	256.37	54875.26	479.59
4	37.2	0.500	77.50	129.20	276.76	51065.17	461.38
5	37.2	0.633	116.65	144.80	416.59	60716.05	517.10
				AVERAGE	302.98	58841.02	520.38
				QUALIFICATION	Very Low	Very Low	Very Low

In Figure 3 shown, Consist stress-strain curves of the five specimens tested in static bending.

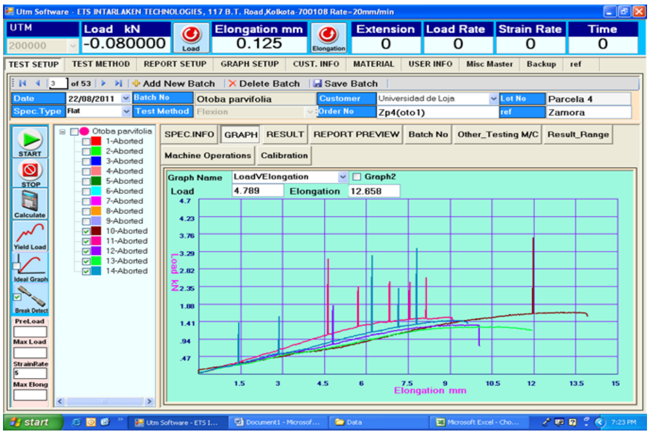

Fig 3. Results of static bending of the probe Iriartea deltoid

• Anatomical characteristics of the fibers

In Figures 4, 5 and 6, the micro captured through the microscope resolution 32 megas of laboratory dendrochronology and wood anatomy, which correspond to the anatomical characteristics of the fibers shown photographs pambil analyzed.

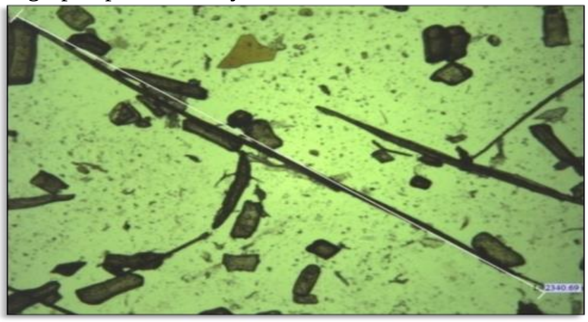

Fig 4. Fiber size fiber Pambil

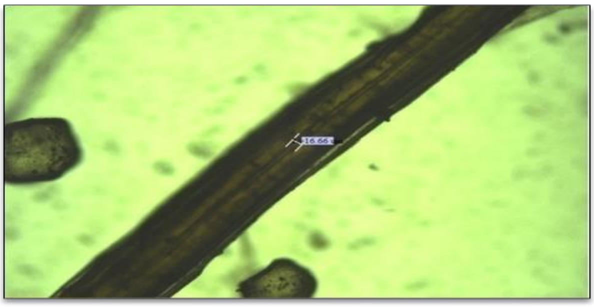

Fig 5. Lumen diameter fiber Pambil.

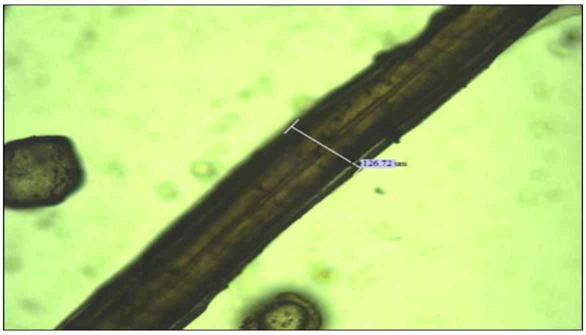

Figure 6. Fiber diameter Pambil.

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In table 5, consist size data, the lumen diameter and fiber diameter pambil.

Table 5. Results of measurements of the anatomical characteristics of the fiber pambil.

N°	Largo (µ)	Ancho (µ)	Lumen (µ)	Pared (µ)
1	2149,22	54,05	6,93	23,56
2	2145,93	45,32	5,2	20,06
3	2533,25	27,41	4,9	11,26
4	2519,08	93,65	9,67	41,99
5	2576,74	48,97	7,1	20,94
6	1584,51	126,72	16,66	55,03
7	2566,09	35,4	4,74	15,33
8	2599,51	56,08	8,77	23,66
9	2515,74	84,81	6,6	39,11
10	2513,93	86,41	9,5	38,46
11	2164,14	65,41	7,38	29,02
12	2563,41	134,24	16,06	59,09
13	2540,39	124,57	11,59	56,49
14	3316,73	78,32	8,96	34,68
15	1935,48	87,97	5,22	41,38
16	2947,39	101,78	9,71	46,04
17	2103,96	80,84	8,97	35,94
18	2520,39	116,55	13,91	51,32

In table 6 show, the statistical analysis includes data size, the lumen diameter and fiber diameter pambil.

Table 6. Statistical analysis of the anatomical characteristics of pambil

	Statistic analysis			
	Long (µ)	Width (µ)	Lumen (µ)	Wall (µ)
Half	2391,37	68,17	6,63	30,77
Typical error	94,52	3,91	0,45	1,78
Median	2363,63	66,84	5,95	30,59
Fashion statist	#N/A	#N/A	7,38	#N/A
Standard devia	668,35	27,66	3,17	12,59
Sample varian	446689,29	765,21	10,06	158,6
kurtosis	2,32	-0,26	2,26	-0,49
Skewness	1,15	0,45	1,3	0,36
Rank	3206,35	111,38	14,54	48,72
Minimum	1290,42	22,86	2,12	10,37
Maximum	4496,77	134,24	16,66	59,09
Sum	119568,4	3408,38	331,52	1538,43
Bill	50	50	50	50
Confidence le	189,94	7,86	0,9	3,58

3.2 Results of experimentation

Compressive strength

In tables, 7 show the results of tests carried out to determine the compressive power of the cylindrical specimens tested at 7 days of curing, for which the standard used A.S.T.M. C-39 (NTE INEN 1573: 2010 1R).

Table 7. Test results of the compression cylinder 7 days cure

MIXTURE	FIBER SIZE	FIBER VOLUME	Reps			Average	DEVIATION
Nro.	(Sieve)	%	I	II	III	Mpa	STANDARD
M1	0,00	0,00	16,48	15,93	15,78	16,06	0,37
M2	T4	0,50	14,71	15,43	15,15	15,10	0,36
M3	T4	1,50	18,42	17,71	19,05	18,39	0,67
M4	T4	2,50	16,69	16,02	15,75	16,15	0,48
M5	T8	0,50	20,82	21,24	21,04	21,03	0,21
M6	T8	1,50	18,92	17,44	18,54	17,99	0,77
M7	T8	2,50	24,89	22,37	24,04	23,77	1,28

In Figure 7, recording the results of the tests cylinder compression tested to 7 days

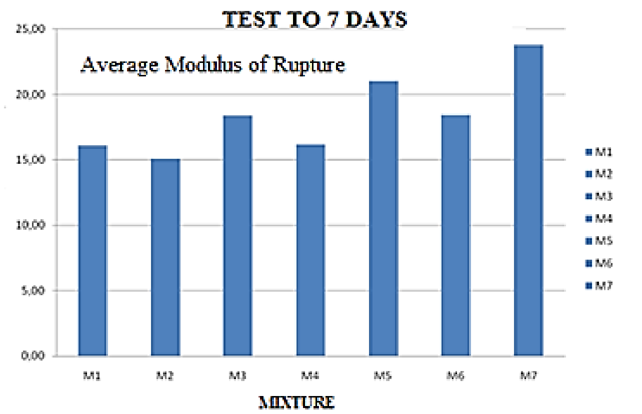

Fig. 7 Test results of the compression cylinders tested at 7 days.

In table 8 show, the results of tests carried out to determine the compressive power of the cylindrical specimens tested at 28 days of curing, for which the standard used A.S.T.M. C-39 (NTE INEN 1573: 2010 1R).

Table 8. Test results of the compression cylinder 28 days cure

MIXTURE	FIBER SIZE	FIBER VOLUME	Reps			Average	DEVIATION
Nro.	(Sieve)	%	I	II	III	Mpa	STANDARD
M1	0,00	0,00	20,54	18,18	19,27	19,33	1,18
M2	T4	0,50	20,03	21,59	22,24	21,29	1,14
M3	T4	1,50	22,62	22,68	21,18	22,16	0,85
M4	T4	2,50	27,63	29,20	28,36	28,4	0,79
M5	T8	0,50	23,23	21,16	24,36	22,92	1,62
M6	T8	1,50	22,09	24,15	25,12	23,79	1,55
M7	T8	2,50	27,83	32,25	29,84	29,97	2,21

In Figure 8, recording the results of the tests compression cylinders tested at 28 days

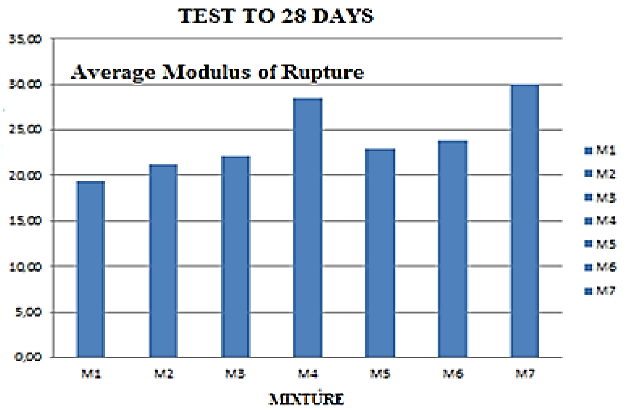

Fig.8.Test results of the compression cylinders tested at 28 days.

Flexural strength

Table 9 shows the results of tests carried out to determine the flexural strength of the prismatic specimens tested at 28 days of curing is shown, for which the standard is used A.S.T.M. C-78.

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Table 9. Test results bending of prismatic specimens to 28 days cure

MIXTURE	FIBER SIZE	FIBER VOLUME	Reps			Average	DEVIATION
Nro.	(Sieve)	%	I	II	III	Mpa	STANDARD
M1	0,00	0,00	4,58	4,60	4,54	4,57	0,03
M2	T4	0,50	4,35	4,06	4,24	4,22	0,15
M3	T4	1,50	4,44	3,95	4,25	4,21	0,25
M4	T4	2,50	3,73	3,57	4,04	3,78	0,24
M5	T8	0,50	3,85	3,75	4,09	3,90	0,17
M6	T8	1,50	4,17	3,78	3,72	3,89	0,24
M7	T8	2,50	3,58	3,64	3,71	3,64	0,07

In Figure 9, comprise the test results flexural beams tested at 28 days

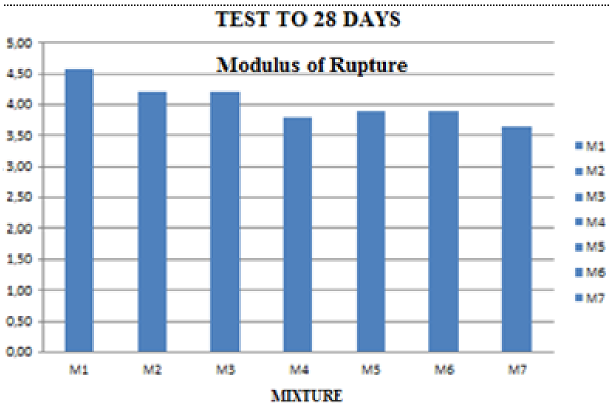

Fig. 9 Test results of the flexural beams tested at 28 days.

3.3 Analysis and interpretation of results of plain concrete with added fiber

The results obtained after conducted research mainly focuses on deducing the influence of the addition of fibers pambil in the behavior of the composite matrix of concrete with Portland cement, in what has to do with the mechanical properties.

- A compression:

By the provisions of the Methodology, it has proceeded compression test cylindrical samples whose ages were 7 curing and 28 days.

Mixtures presents better characteristics of resistance to compression at 7 days of curing are M5 (consisting of fiber retained on the sieve 8 with 0.50% fiber).

Increasing by 30.94% compared to concrete without adding texture and M7 (composed of fiber retained on the sieve 8 with 2.50% fiber) in a 47.97%; on the mixture M1 (pattern or without added fiber)

Mixtures having better characteristics to compression after 28 days curing are M4 (composed of fiber retained in the sieve 4, with 2.50% fiber) increasing by 46.90% compared to concrete without adding fiber and M7 (consisting of fiber retained on the sieve 8 with 2.50% fiber) in a 55.06%;

M1 on the mixture (without added fiber pattern) instead M5 mixture (consisting of fiber retained on the sieve 8 with 0.50% fiber) initially for seven days showed a high resistance, it reached 18.57% at this age, not achieving improvements characteristics at the end.

The analysis provides that cylinders with the addition of fibers subjected to compressive stresses increase the strength of concrete which has no fiber, and the best results were obtained from samples analyzed at 28 days with the fiber 2, 50% for fiber size retained on the sieves 4 and 8.

- A bending:

Bending beams tested at an age of 28 days cure

The use of fiber Iriarte deltoid as reinforcement in concrete decreased flexural strength, as detailed in the chart above so that for mixtures compressive best results were obtained such as the M4 (formed by fiber retained in the sieve 4, with 2.50% fiber) 11.1% decreased.

Compared to the mixture without addition or pattern M1 and M7 fiber (consisting of fiber retained on the sieve 8 with 2.50% fiber) reduced by 18.28%.

From the results obtained it is established that any of the tested mixtures showed better flexural characteristics M1 (pattern or without added fiber) and more amount of fiber it decreases the most.

IV. Conclusions

- Using pambil fibers, used as reinforcement in a concrete matrix made with portl and cement, allows obtaining high compression strengths, compared with concrete without fiber addition.
- Mixtures have better characteristic compressive strength at 7 days of curing, on the standard blend, they are:
  - ✓ The shaped fiber retained by the sieve 8 with 0.50% fiber, an increase of 30.94%.
  - ✓ The shaped by retained on the sieve 8 with 2.50% fibers in a 47.97% fibers.
- Mixtures exhibiting superior compressive, about the standard mix, at 28 days of curing are:
  - ✓ The fiber comprised retained in the sieve 4, with 2.50% fibers, increasing by 46.90%.
  - ✓ The shaped by retained on the sieve 8 with 2.50% fiber, 55.06% on a fiber; on the standard mixture.
- None of the tested mixtures flexural presented better characteristics than the norm blend; also observed that most fiber, this decreases its qualities in greater quantity. After that, it concluded that the use of fiber reinforcement Iriarte deltoid as concrete decreases its flexural strength. It presumed that these results are related to the high content of this fiber has parenchyma.
- The ready-mixed concrete used in elements that require resisting compressive and bending performance in the tests performed, which is not met with one of the two requirements; therefore, the use of this fiber structural concrete is not recommended.
- This investigation established the need for studies on the behavior at the microscopic level of the organic fibers within the matrix, to deepen the knowledge of these materials.
- One of the objectives of this research was the realization of economic feasibility studies about the use of fibers Pambil in the development of reinforced concrete construction; however, according to the results obtained in this investigation, it is not consider necessary to perform this analysis, since the hypothesis never confirmed.

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V. RECOMMENDATIONS

• Expand research or studies to determine the mechanical characteristics of the fiber pambil and if the high content of parenchyma causes the flexural strength decreases.

• It is necessary to investigate the modulus of elasticity and tensile strength of composites by a Portland cement matrix and vegetable fiber.

• Provide greater experimentation with fibers from other plants in the region, which allows us to have data that can compared, allowing a better understanding of the composite materials of organic origin.

• Conduct studies on the behavior at the microscopic level of the natural fibers within the matrix, to deepen the knowledge of these materials.

• The need to overcome the technological dependence is necessary to continue investigating alternative materials, which can be employed organic fibers that are readily available in the Southern Region of Ecuador.

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