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Análisis del comportamiento del cemento mezclado con fibras de acero
Behavior analysis of concrete mixed with steel fibers

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***Resumen*—En este trabajo se realiza un estudio sobre el fondo de la cuestión de la técnica aplicada a la mejora de la eficiencia. Con este punto de partida podemos profundizar en las claves en el uso de los recursos para la eficiencia energética y concretarlas en un modelo de actuación que ilustra una aproximación sistémica al campo del aprovechamiento de la energía, y que reintegra a la edificación su valor intrínseco como medio eficiente de gestión de la energía y su transformación.**

Palabras clave— Eficiencia energética; rehabilitación; geotermia.

***Abstract*- This paper presents a study on the heart of the matter of the technique applied to improving efficiency is performed. With this starting point we can deepen the keys in the use of resources for energy efficiency and achieve them in a role model illustrating a systemic approach to the field of energy efficiency, and reintegrated into building its intrinsic value as efficient means of energy management and processing.**

Index Terms— Energy efficiency; rehabilitation; geothermal energy.

I. Introduction

Said the famous architect and military engineer Vitruvius in his book "Architectural" which the materials to build must be "strong, useful and beautiful"

These words constitute a treatise on materials, even including the bearing capacity of these in the concept of durability and aggressive response to external agents.

However, a definition more consistent and current with the issue before us is: "A structure is durable if throughout its intended life, fulfills its function with regard to service, strength and stability without considerable loss Utility and without excessive unscheduled maintenance".

Data collected from the work undertaken by the Delegation of Madrid Building on the largest construction group in the country, show that 70% of the structures are formed by

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reinforced concrete frames and unidirectional forged. The buildings for housing are the most numerous and posed greater economic volume within the field of construction.

The materials from which the structural elements constituting the skeleton resistant constructions are basically the concrete and steel running. The executed with reinforced concrete structure are those with a greater number of accomplishments. The most used type is composed of pillars as sustaining element.

The large park HA resolved in existing buildings in Madrid, leads me to finding a material capable of withstanding, more responsive solicitations demanded.

A material from the incorporation of additions allow us to improve the behavior of concrete structures.

Improving the durability of concrete with fibers over conventional concrete is done clearly accepted. Unfortunately, very little research conducted to study in a more concrete level, the processes that lead to the fibers to increase the strength of concrete (EHE-08, 2010).

In addition to its tough from a mechanical point of view, that is, their ability to withstand the stresses caused by the actions applied to the structure capacity, structures must also be able to withstand during its service life the physical and chemical aggressions which they are exposed according to their location and operation (Eurocode 2 EN-2, 1992).

The idea that inspired me to carry out this study was to think about how it might respond to a structural support of reinforced concrete, as the most important in the bearing capacity of a building element when they had built additions steel fibers and from there know their strength capacity residual, with the intention to meet prior information to structural collapse and features that gives us the incorporation of fibers.

The mass concrete is a brittle material with a low tensile strength, and incorporate fibers is to bridge through the cracks that develop, modifying the nonlinear behavior of structural concrete, providing "ductility" (post- cracking) (Abrishamba; Joaquim & Mcf Cunha, 2015) and preventing the opening and crack propagation (Nguyen; Ryu; Koh & Kim, 2014).

The fibers in its structural function cause an increase in the width of the compression struts reducing the amount of conventional armor in regions where a high density of armor they hinder correct concreting of the element is present (Tailhant; Rossi & Daviau-Desnoyers, 2015).

Moreover plasticizing phenomenon does not lead to instability problems in the compressed areas of the concrete section, thus, the plasticization of the fibers improve the performance of concrete in these areas avoiding cracking (Wald; Vodicka & Kohoutkova, 2013).

The structural fibers provide enhanced breaking energy and the mass concrete are an improvement to certain properties such as controlling shrinkage cracking, increasing fire resistance, abrasion, impact and other (Doo-Yeold; Kyung-Hwan; Joo-Haa & Young-Soo, 2014).

The actual contribution of the fibers increase the toughness of the concrete, the fibers tend to increase the stress at maximum load, and provide a great deal of energy absorption in the post-peak curve of load versus deflection part.

It is established that one of the important properties of the steel fiber in concrete is its resistance to breakage and crack propagation, increasing the extensibility and strength in both the first crack and end of the process, the fibers are able to maintain the concrete matrix and fibers together even after rupture of the element (Hadelwander; Jonas & Riech, 1995).

When the reinforcement is in the form of short size fibers, effectively they act as rigid inclusions in the concrete matrix. The fiber reinforcement steel can not be considered a direct replacement of longitudinal reinforcement in concrete components, but because of the inherent material properties of fiber concrete, the presence improves the resistance of members, backing conventionally cracking (Kim; Lee & Moon, 2015).

On this basis, the aim of this work is to study the effect conferred by incorporating steel fibers to plain concrete structures, compared with commonly used concrete, estimating the bearing capacity of a concrete structure with mass adding steel fibers and comparing concrete structures without fibers.

The behavior of mass concrete structures incorporating adding steel fibers from the point of view of its ability to withstand the loads applied without crack and break, studying their stresses and peak deformation is determined ductility.

The objective of this research is to study the behavior of concrete reinforced steel fibers comparing the behavior of fiber concrete over traditional .

Determining the effect conferred by incorporating steel fibers to concrete structures in mass compared with concrete conventionally used , estimating the bearing capacity of a concrete structure in dough with added steel fibers and comparing concrete structures without fibers.

II. Experimental Procedure

An investigation into the compression fracture behavior in cylindrical specimens (200 mm x 100 mm Ø) concrete mass (HM-25) with 1 dosage is presented 0.5 aggregates no larger than 12 mm comprising adding steel fibers 20 mm long and 0.5 mm thick. These samples are compared with other standard specimens without additions of the same dosage. Fibers were used cold-drawn steel lines (Sika Fiber CHO65 / 35 NB) in 1% and 2% by weight of cement, compressive assayed for the maximum tensile strength and maximum deformation, contrasting the results with a concrete without additions (Aenor AEN/CTN 146, 2004; EN/CTN 83, 2008a

Fig. 1. Behavior compression test on specimens without additions to the catastrophic fracturing.

& AEN/CTN 146,2009a).

12 specimens of the same batch of mass concrete structural strength 25N / mm^2, of which 3 of them contain an addition of 1% of steel fibers and the other 3 2% by weight of cement and the remaining 6 are made with concrete without addition. They were then tested for compression failure UNE-EN 12390-1. Universal press MIB 60 / AM is used as test machine resistance to compression stroke, in order to obtain the data of the computer program and subsequent analysis of force (kN) and stroke (mm), as shown in Figure 1 (Aenor AEN/CTN 83, 2009b; EN/CTN 83, 2009c, AEN/CTN 80,2012 & AEN/CTN 83,2012b) (Rc-08, 2009).

Considering the area of "A_c" section results are treated for "σ_c" strain compressive strength of concrete in N / mm^2 and "e_c" deformation of the concrete and analyze the most representative data from the graphic tension -deformation.

Then catastrophic fracturing of the specimen without addition, where cracks are wide and deep, and even a portion of the crushing of the material itself is observed prior to the structural collapse shown.

III. Results

A plot of stress-strain to study graphically, the most characteristic and significant test and analyze the results is made.

The assay is performed with universal press MIB 60 / AM 9000 that provides data about each specimen, obtaining a graphic model Force (kN) / Run " δ " (mm) of concrete tested in compression, where

F: force (kN).

δ : displacements obtained in the test stroke (mm).

TABLE I
MOST REPRESENTATIVE VALUES OF MAXIMUM AND LAST COMPRESSION TEST ON SPECIMENS WITH 1% AND 2 % BY WEIGHT STEEL FIBER CEMENT

	σ_{max} (N/mm^2)	σ_{ult} (N/mm^2)	ε_{max} x 10^{-3}	ε_{ult} x 10^{-3}	E_{max} x 10^{-2} (N/mm^2)	E_{ult} x 10^{-2} (N/mm^2)
FA1%.1	17,852	12,503	4,294	6,000	4,660	7,324
FA1%.2	22,573	15,809	4,143	5,725	5,690	8,838
FA1%.3	22,840	15,995	4,039	5,500	5,199	8,143
MIDDLE VALUE	**21,088**	**14,769**	**4,159**	**5,742**	**5,183**	**8,102**
FA2%.1	20,510	14,359	3,440	5,226	3,814	6,993
FA2%.2	23,968	16,782	4,070	5,689	5,553	8,915
FA2%.3	21,501	15,055	4,041E-03	5,972	5,141	8,779
MIDDLE VALUE	**21,993**	**15,399**	**2,505**	**5,629**	**4,836**	**8,229**

Really interesting thing is the value of the concrete strength, from the data of the Force in kN and the area of the "A_c" section of the cylindrical specimen in mm^2 and the length of it, the results obtained "σ_c"strain compressive strength of concrete in N/mm^2 and the "e_c" deformation of concrete, dimensionless

$$\sigma_c = F/A_c \qquad \varepsilon_c = \Delta L/L$$

where these stress-strain graph is done and the most representative data, which are analyzed: σ_{max} is maximum concrete stress, ultimate stress σ_{ult} is concrete, ε_{max} is maximum deformation of concrete is ε_{ult} ultimate strain of concrete is density E_{max} maximum power generated deformation during the test (N/mm^2) and is E_{ult} energy density of ultimate strain generated during the test (N/mm^2).

The strain energy density is the energy stored by the cylinder per unit volume, obtained from the expression

$$E = \int_0^{\varepsilon} \sigma \cdot d\varepsilon$$

From the data supplied by the IBERTEST MIB- 60 / AM Wintest software 32 of the universal press for compression breakage tests performed data analysis.

Maximum, average and last values of the stresses, strains and strain energy densities in samples with 1% and 2% by weight steel fiber cement shown in the following table 1.

The test results on specimens compression with 1% and 2% by weight steel fiber cement show that 1% addition of steel fiber , normal values are reached maximum stresses around 21 N/mm^2 thereof so with 2 % addition , whereas the mean value of the maximum deformation "ε_{max}" it is higher in the samples with 1 % compared to 2% , still twice deformation.

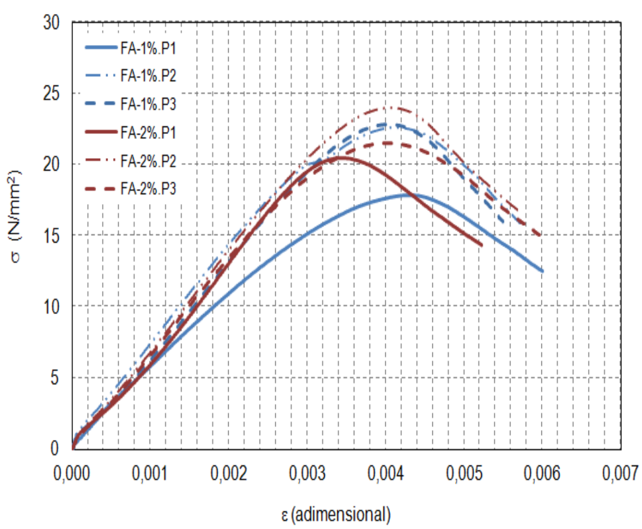

Fig. 2. Comparison of compressive behavior in specimens with 1% and 2 % of steel fibers in cement weight.

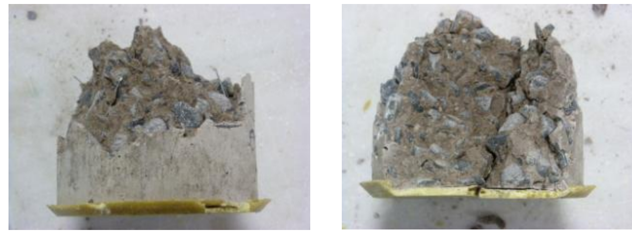

Fig. 3. Compression strain specimens with 1% and 2 % of steel fibers in cement weight.

IV. Analysis and Discussion

In Figure 2 the compressive strength behavior compared between concrete specimens incorporating 1% and 2 % of steel fibers , the behavior being observed between samples with these percentages of addition is similar.

It is noteworthy that the maximum voltage "σ_{max}" is higher in specimens with 2% FA versus the samples with 1% FA . Furthermore, the maximum deformation "ε_{max}" and maximum energy "E_{max}" give higher values in the samples with 1% FA.

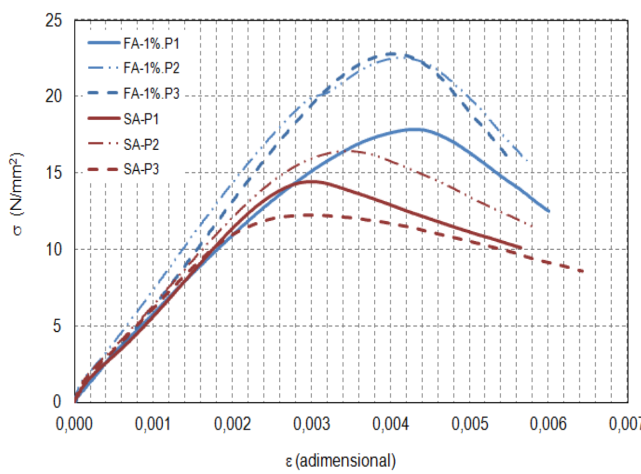

Fig. 4. Comparing compressive behavior in specimens with 1% steel fibers without additions.

In Figure 3 the fragmented specimen after compression test where the arrangement of steel fibers, which reveals how they become a connecting element , conferring greater adhesion to concrete sample is observed . The failure mode corresponds to a truncated laterally compression, which typically occurs in very dry concrete. The break has an angle of approximately 60 degrees, cutting the specimen and remain closed. It seems an unsatisfactory break in cylindrical specimens.

Figures 4 and 5 show a comparison of the behavior of concrete specimens with 1% and 2 % of steel fibers in the specimens without adding compressive strength test , showing that the maximum voltage , maximum power and maximum deformation specimens of concrete with steel fibers are higher than in the samples without addition.

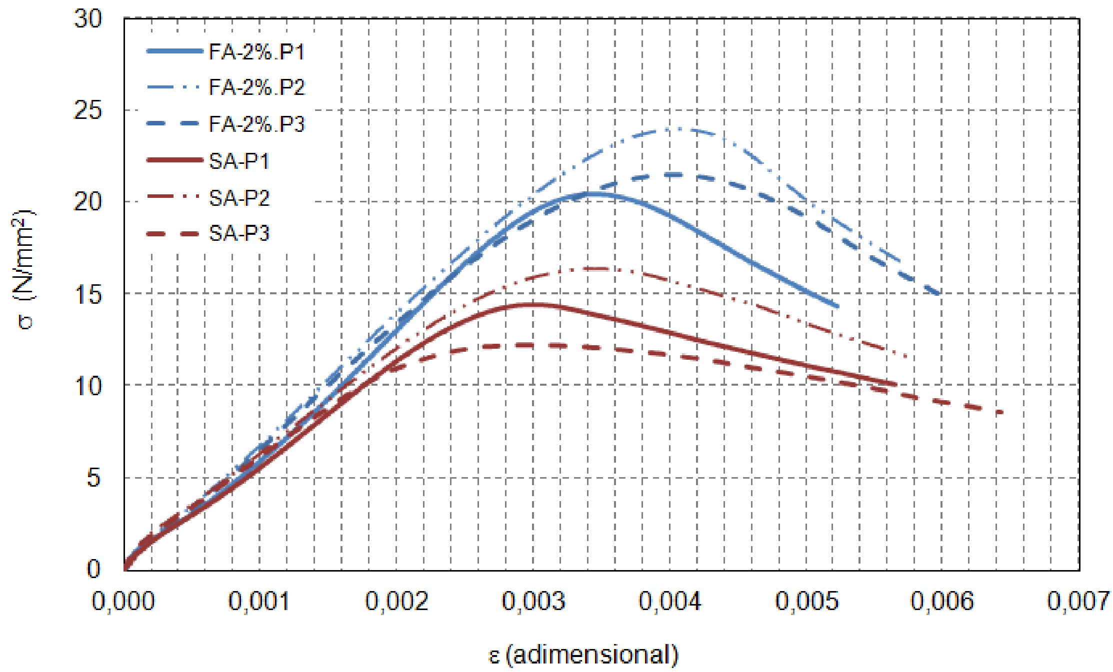

Fig. 5. Comparing compressive behavior in specimens with 2% steel fibers without additions.

Slope on the descending branch of the curve is more pronounced in samples with 1% and 2 % FA regarding the specimens without addition.

Figure 6 shows the values of maximum stresses achieved by steel fiber specimens 1% and 2 % and no additions. It can be seen that the presence of 1 % of steel fibers in the concrete mass increases the resistance to traditional concrete without addition. It also notes that increasing the percentage of adding up to 2% continue to reach higher voltages with respect to concrete without addition, but only significant changes when compared with 1% of steel fibers.

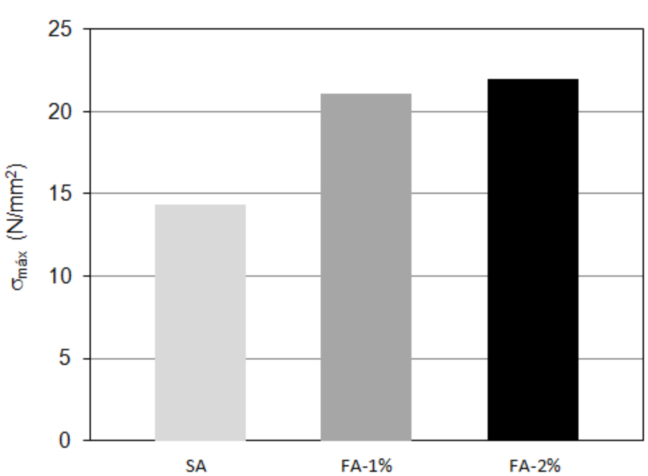

Fig. 6. Evolution of average values corresponding to the maximum stresses.

V. CONCLUSIONS

Table 2 shows the stress ratio between mass concrete specimens without addition steel and additions shown. As can be seen, with additions concrete support higher tensions specimens without additions , producing the best behavior when adding 2% steel fiber cement weight. Adding fiber percentage 2% has no relevance to 1%, being a substantially similar result. The addition of fibers improves the strength of the concrete specimen mass , increasing its resistance at higher rates relative to their homologous probe without fibers, when the concrete is at room temperature.

TABLE II
RELATIONSHIP BETWEEN RESISTORS, IN PERCENT, BASED ON THE TYPE AND ADDITION RATE BEFORE AND AFTER THE FIRE ASSAY

References	Compression test: SA	FA-1%	FA-2%
SA	-----	46.7	53.0
FA-1%	-31.8	------	4.3
FA-2%	-34.7	-4.1	------

The concrete specimens mass percentages of 1% and 2% by weight steel fiber concrete, the support further tensions incorporating 2% addition. La presence of steel fibers in the concrete mass, enter improves adhesion the component materials with percentages of 1% and 2% by weight of steel fibers in concrete specimens. Las mass percentages of 1% and 2% of steel fibers by weight of cement, are tougher and running best percentages of 1% steel. The fiber concrete with additions of polypropylene fibers and steel fibers in percentages of 1% to 2% weight in cement, concrete withstand higher voltages without addition but lose ductility after reaching maximum voltage incorporation of polypropylene fibers is a very good alternative to traditional concrete, because it improves its resistance and its behavior in case of fire, while the incorporation of steel fibers also provides advantages over traditional concrete, but cannot reaching benefits obtained by incorporating polypropylene fibers.

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