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EXPERIMENTAL ANALYSIS OF MECHANICAL RESISTANCE IN CONCRETE STRUCTURES WITH FORMATION OF COLD JOINTS INCORPORATED WITH STEEL FIBERS

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ABSTRACT

Cold joints are formed due to the interruption of concreting at the moment of launching and mixing (Torres, 2016). The formation of cold joints besides directly influencing the properties of the hardened concrete represents a common occurrence during the concreting phase in the works. As stated by Harsem (2005), the formation of the cold joints can directly affect the structural performance of the parts, reducing the mechanical characteristics of supported tension, and deformation. For Sampaio (2010) it is fundamental that the surface of the joint is treated properly so that the constructive discontinuity that the joint creates does not translate into structural discontinuity. In this sense, a material that has been widely used in the present day for concrete reinforcement is steel fibers, which can be applied in cases of joint formation. According to Banthia (2007), these fibers can be effective in arresting cracks at both micro and macro levels. Thus, the present article seeks to analyze the influence of cold joints on concrete parts and to evaluate, through an experimental study, the performance of the use of steel fibers in the bonding between concretes of different ages, aiming to improve the adhesion in the region of union among them, as well as to verify possible elevations of their resistance in the areas known as fragile planes. The results of this work show that in some cases CRF can improve its performance by up to 25%. The steel fibers were effective in the relief of pebbles in the joint joints and had a mechanism of rupture in the generalized cases that were used.

KEYWORDS: Cold joints, tilt joints, steel fibers, experimental study.

1. INTRODUCTION

Concrete is characterized by being one of the materials most used in the construction industry. Its wide application is associated with its favorable cost-effectiveness, durability (Choi, 2015) and easy availability (Metha, 1993), which make this component one of the most common materials in the construction of structures, since these characteristics are linked to the high mechanical strengths provided by this compound. However, its production process is influenced by several factors, and its final quality depends almost exclusively on the production workforce (Neville, 2016).

Inadequate execution of the concrete production processes can generate failures that affect its final performance, compromising strength and durability. Roque and Moreno Júnior (2005) declare that it is essential, in order to guarantee the durability of the concrete, that due care is taken in the execution phase, in order to obtain satisfactory levels of quality, especially with regard to launching, and the cure of concrete. In this sense, it is

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ideal that the integral stages of the concrete manufacturing process, such as: transportation, curing, densification and mixing time are carried out satisfactorily, contributing to the proper functioning of the structure, in order to avoid damages to its useful life service.

Thus, one of the main parameters that can measure the quality control of concrete is the existence of pores, which directly affect its durability (Choi, 2015), since these can favor the passage of ions in the structure and cause degradation in the steel contained in reinforced concrete pieces (Legat 2007, Ishida 2003, Maekawa 2003). Among the factors that contribute to the formation of concrete parts are the cold joints. Lima and Siqueira (2010) affirm that the intrinsic causes of concrete joints are associated with human failures during construction.

Cold joints are formed due to the interruption of concreting at the moment of launching and mixing (Torres, 2016). These joints, which may occur due to the delay in the placement of untreated concrete between the new concrete (Yoo, 2016), can affect both corrosion resistance and shear force strength (JSCE 2000, Rathi, 2013, ACI 224.3R-95 2005). As stated by Harsem (2005), the formation of the cold joints can directly affect the structural performance of the parts, reducing the mechanical characteristics of supported tension, and deformation. The following figure exemplifies the formation of a cold joint (Volz, 1997).

Figure 1: Cold joint formation (Volz, 2007).

In recent years, several studies have been carried out on the subject, with different approaches. From the perspective of the composition of the fresh concrete mix, Rathi (2013), approached in his work, a methodology to delay the effect of the handle on the concrete and to avoid the formation of cold joints, obtaining satisfactory results with the use of the tested additive. For the concrete in its hardened state, Yoo (2016) quantitatively investigated the increase of supported stress in concrete pieces with presence of cold joint through the addition of granulated blast furnace slag and evaluated the action of chlorides, which accelerate the corrosion process of the reinforcement, in the region of the cold joints, adding blast furnace slag. Still in this segment, Torres (2016), tested in his work, the resistance of concrete pieces submitted to the formation of cold joints with slopes and in different times of formation, through a theoretical and experimental study.

The formation of cold joints, besides directly influencing the properties of hardened concrete, is a common occurrence during the concreting phase in the works, so it is very important to know the behavior of this phenomenon and its mechanisms of constitution. Marek and Vanderlei (1997) state that the contact region between concretes of different ages is usually the region most susceptible to problems. In addition to being an area with a high risk of segregation of materials, it is also a region where there is a high probability that there will be layers of cement cream, which act as a layer of low resistance and decrease the adhesion between the two concretes.

Para Sampaio (2008) é fundamental que a superfície da junta seja tratada adequadamente para que a descontinuidade construtiva que a junta cria, não se traduza em descontinuidade estrutural. A NBR 14931:2004 permite a utilização de materiais para melhorar a aderência entre as camadas de concreto em uma junta de concretagem, desde que estes não causem danos ao concreto e seja possível comprovar desempenho pelo menos igual ao dos métodos tradicionalmente utilizados. Vários pesquisadores destacam-se no desenvolvimeto de

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tecnologias para reforçar a junção entre concretos de diferentes idades, dentre eles MATTOCK *et al*. (1972), MATTOCK *et al*. (1975), MATTOCK *et al*.(1976), REINHARDT (1982), MATTOCK *et al.* (1988), WALRAVEN e STROBAND (1993), JANSZE e WALRAVEN (1996), ZILCH eREINECKE (2000).

In this sense, a material that has been widely used, for reinforcement in the concrete are the steel fibers. According to Banthia (2007), these fibers can be effective in arresting cracks at both micro and macro levels. At the micro level, the fibers inhibit the initiation and growth of cracks, and after the micro-cracks coalesce into macro-cracks, the fibers provide mechanisms that decrease their unstable propagation, provide effective bridges, and transmit sources of strength, hardness and ductility gain . The introduction of steel fibers in the concrete matrix characterizes CRFA (Reinforced Concrete with Steel Fiber), which according to Katzer (2006), is nowadays mainly used to overcome the problem of concrete brittleness. Figure 2 illustrates the performance of the fiber in areas subject to cracking (Figueiredo, 2005).

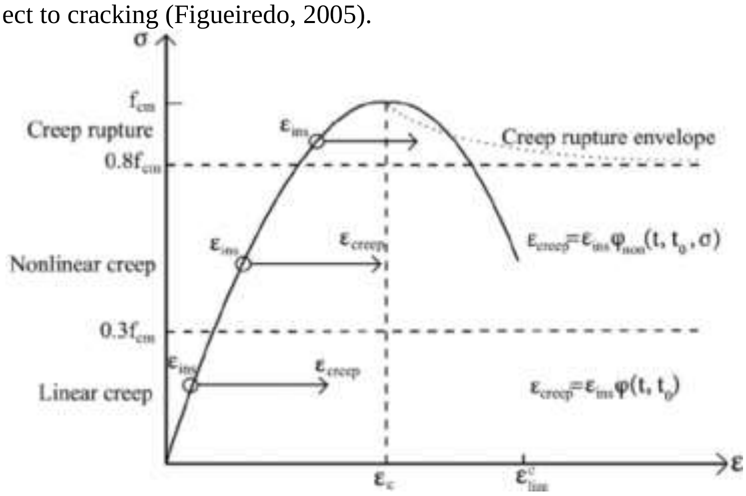

Figure 02. Steel fiber performance in stress relief (Figueiredo, 2005).

In this paper, the aim of this paper is to analyze the influence of cold joints on concrete parts and to evaluate, through an experimental study, the performance of the use of steel fibers in the bonding between concretes of different ages, aiming to improve the adhesion in the region of union between them, as well as verify possible elevations of their resistance in the areas with concrete joints, known as fragile planes. For this, an experimental program based on the test of tensile strength and compression in concrete cylinders with dimensions 100mmx200mm, considering different configurations: a reference without joints, horizontal joints and diagonal joints was set up.

2. MATERIALS AND METHODS

Composite materials

The experimental study allowed to evaluate the tensile strength and compression of concrete elements with the formation of cold joints arranged diagonally and horizontally, with and without the addition of steel fibers. For this, tests of direct compression and diametrical compression were carried out following the recommendations of NBR7222: 2011 and NBR5739: 2007 in cylindrical bodies measuring 100x200 mm. Reference specimens were produced, without the formation of joints, for further analysis and comparison of the results with the other elements. The joints produced on the parts had a 24 hour formation interval and the strength of the parts were tested over 3, 7 and 28 days, except for the steel fiber parts, which were tested only for 28 days.

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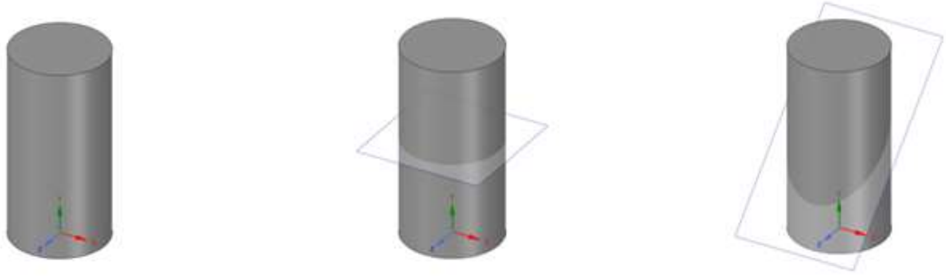

No formation of jointsHorizontal jointsDiagonal seals

Figure 3: ***Configuration of the elements to be tested.***

The concrete used to produce the elements was initially defined and characterized according to the recommendations of the ABCP method for final strength of 25 MPa. This method of measurement is based on aggregate granulometric analysis to determine the modulus of fineness of the aggregate, maximum size of the aggregate, and the specific and compacted mass of both (CURTI, 2009). Defining the trait for the fck adopted, this was maintained during all stages of concreting the elements, to ensure the maintenance of the same mechanical characteristics. The characteristics of the materials used are described below in Figure:

Figura 04: Aggregate characterization tests.

Figure 05: Molding and curing of the elements.

During the concrete production stage the rebates were observed in the Slump Test test and compared with those described in the design. The curing process was performed by immersion in water and the specimens were kept submerged until approximately 24 hours prior to the breaking tests.

The implementation of steel fibers in the plan of joint formation was one of the objectives of this study. In this way, tests were performed with the addition of fibers in the concrete cylinders, in order to verify the efficiency of this additive in increasing the resistance of the elements. The characteristics of the fiber used fit the recommendations of NBR5589: 82 and provide tensile strength up to 400 MPa. According to NBR15530: 2007, the fiber used is class I type A, with anchoring at the ends of cold drawn wire.

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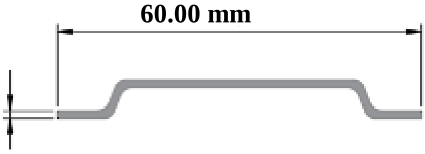

Figure 06: Dimensions and shape of the fiber used.

The fibers were arranged in such a way that the upper and lower faces of the cylinders were orthogonal, acting favorably in the planes with higher tensions. The introduction of fibers into the concrete pieces occurred only in the region of joint formation, dispensing its use in the rest of the body. The volume of fibers used obeyed the formulation below that considers the orientation effects of the fiber (Figueiredo, 2000).

$$V_{f\,crit.} = \frac{\varepsilon_{mu} E_c}{\sigma_{fu} \eta_1} \qquad \text{(EQ.1)}$$

Where ε_mu is the ultimate deformation of the matrix, E_c is the elastic deformation modulus of the matrix, σ_fu is the tensile strength of the fiber and η_1 is the critical volume correction factor as a function of fiber orientation. For a concrete reinforced with steel fibers, the following reference values are adopted: ε_mu = 100.10-6; E_c = 25000 MPa; σ_fu = 1100; η_1 = 0.2; which leads to a value close to 1% (Pasa, 2007). The amount of fiber used considered only 1/3 of the volume of the concrete cylinder, an approximation for the region with the joint forming plane.

Durante o programa experimental foram ensaiadas três amostras de cada elemento para a determinação de um resultado. Ao todo foram confeccionados 72 corpos de prova, divididos em amostras de referência, juntas simples e juntas com fibras. Para identificar os testes realizados e o programa experimental adotado, os elementos foram organizados em uma tabela, onde para cada protótipo foi atribuída uma legenda e designado a idade para rompimento.

Tabela 02: Legenda para elementos ensaiados.

Identificação	Designação	Rompimento
CR	Concrete reference	3, 7, 28 dias
CJHS	Concrete with single horizontal joint	3, 7, 28 dias
CJDS	Concrete with simple diagonal joint	3, 7, 28 dias
CJHRF	Concrete with fiber reinforced horizontal joint	28 dias
CJDRF	Concrete with diagonal reinforcement with fiber	28 dias

The studies carried out were aimed at analyzing, besides the rupture loads, the behavior and mechanism of rupture of the elements, associating them with the stress planes developed in the concrete cylinder. The general plane stress state at one point is represented by the combination of two normal voltage components, σ_x, σ_y, and a shear stress component, τ_xy, which act on the faces of the infinitesimal element. In order to analyze the stresses in the joint formation planes, the main stress and shear stress equations in the plane were studied in the Hibbeler (2010) literature. The boundary conditions imposed with the loading and bonding of the studied model allow to characterize the structure submitted only to main tensions:

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^{\;2}} \qquad \text{(EQ. 2)}$$

$$\tau_{nax} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^{\;2}} \qquad \text{(EQ. 3)}$$

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The voltage transformation equations in the plane are:

$$\sigma_{x\prime} = \frac{\sigma_x+\sigma_y}{2} + \frac{\sigma_x-\sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta \qquad \text{(EQ. 4)}$$

$$\sigma_{Y\prime} = \frac{\sigma_x+\sigma_y}{2} - \frac{\sigma_x-\sigma_y}{2}\cos 2\theta - \tau_{xy}\sin 2\theta \qquad \text{(EQ. 5)}$$

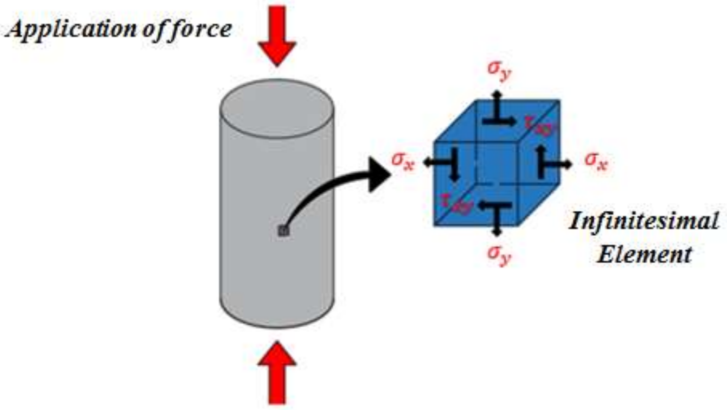

Figure 07:*Orientation of element subjected to the main voltage.*

In this study, stresses developed in the direction normal to the joint forming plane will represent the stresses of ruptures, while the shear stresses will refer to the maximum tension of adhesion in the concrete matrix. Thus, when failure occurs by the maximum shear stress, it will indicate that the concreting joint formed at 45 ° does not favor sufficient adhesion to withstand the loading imposed. Figure 08 illustrates the voltage variation according to the orientation plane (Guerrante, 2015).

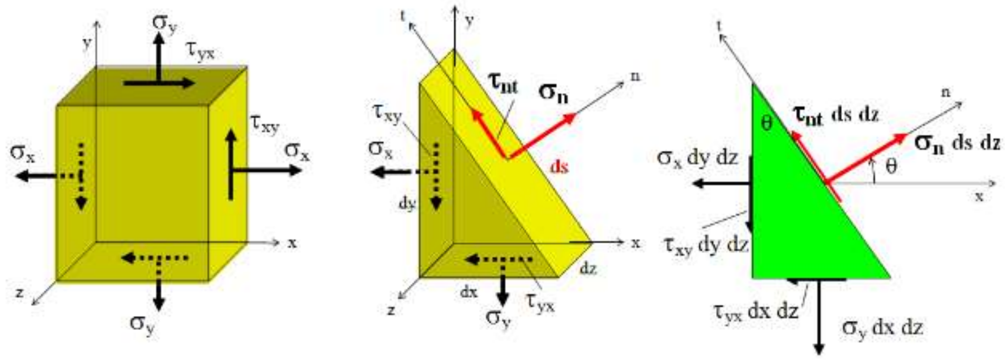

Figure 08:Slope variation in the inclined plane (Guerrante 2015)

Obtaining the failure stress data and analyzing the cold joint rupture mechanism were compared with the results obtained from the non-jointed bodies (Concrete reference), and determined at the percentages of reduction of the bearing capacity of the samples. Another parameter analyzed during the tests refers to the behavior of the stress and deformation of the elements, considering that the specimens increased with fibers tend to have certain stability after the elements rupture, as explained by Lim (1987).

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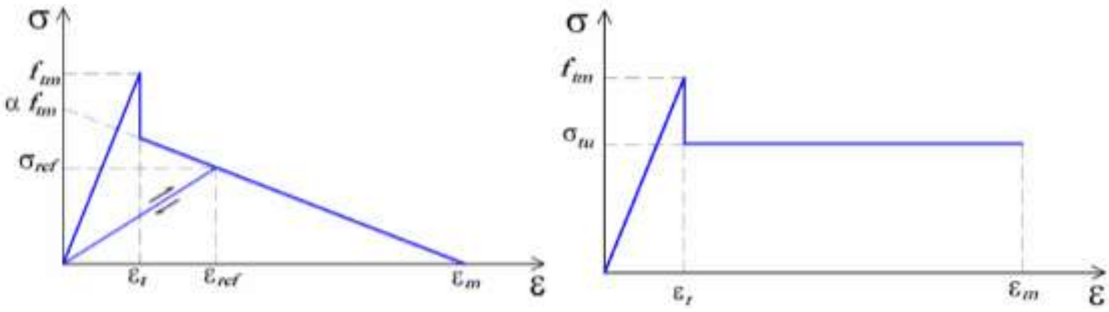

Figure 9: (a) Voltage x Concrete Deformation (b) Voltage x Deformation CRF (Lim, 1987)

3. EXPERIMENTAL PROGRAM

The tests of uniaxial compression and indirect traction applied to the test bodies were performed in a computer controlled electronic universal testing machine. During loading, a table speed of 0.2 mm / minute was maintained, representing an average rate of (specify force application). The data acquisition software of the machine made it possible to record the force x deformation curve, automatically identifying the maximum force supported.

Figure 10: Universal Testing Machine.

The elements submitted to the uniaxial compression test were properly centered in the axis of application of the load and supported with Neoprene discs on the compressed faces. The constant loading of 0.2 mm / min that was maintained until the pieces broke, simulated the condition of static forces in the concrete cylinders. The tensile strength of the elements was tested on all prototypes.

The indirect traction experiment was applied to the elements with and without cold joints, being carried out with speed rate equal to (INDICATE). The contact between the load application cell and the curved face of the cylinder was made by inserting a sufficiently rigid steel disc. The positioning of the piece was carried out in such a way that the cold joint simulated the most common condition of its formation at the construction sites, where the CJD (Concrete Joint Diagonal) simulated beams and slabs and the CJH (Concrete Horizontal Joint) pillars.

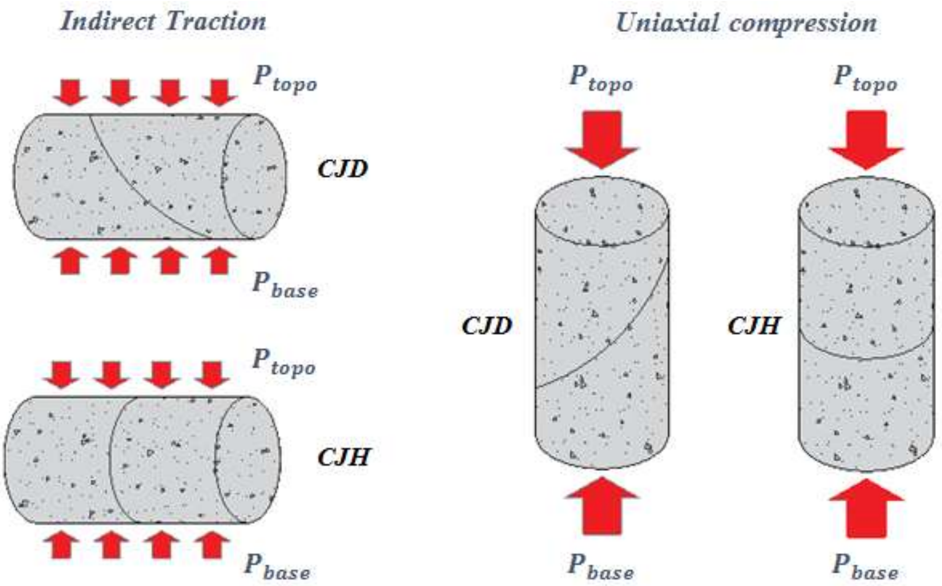

Figure 11:Positioning of the elements.

The confection of the elements with concreting joints was made with the same cylindrical molds used for the manufacture of the reference threads. The faces of the pieces with cold joints simulated the conditions imposed on construction sites, in which the roughness of the aggregates was maintained on the contact surface. Both halves of joint elements were densified in the same way, with a metal rod. Diagonal joints were produced from the inclination of the molds during the period in which the concrete of the first part was in the fresh period. In order to launch the second blend, only a wetting of the contact surface was performed. Figure 9 shows the positioning of the concreting molds.

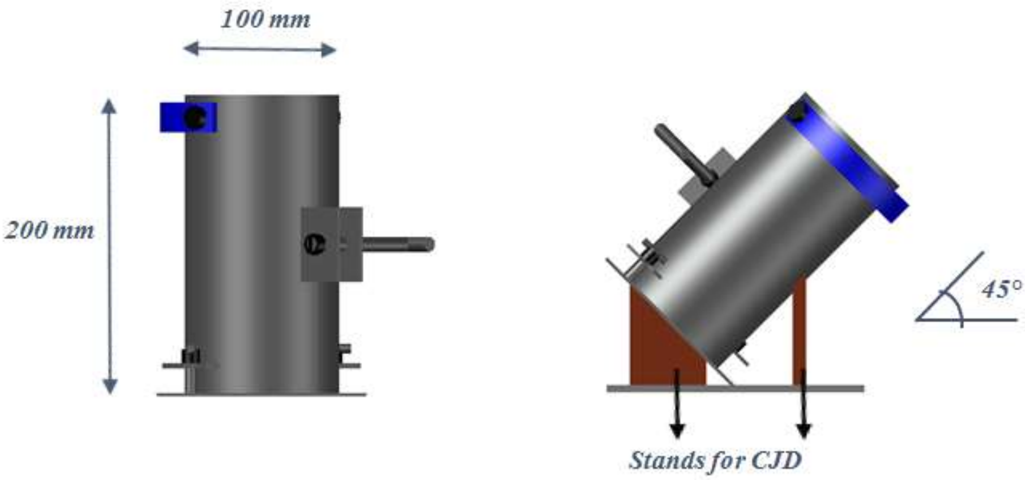

Figure 12: Detail and positioning of molds.

4. RESULTS

At first, it was tried to determine the modulus of elasticity of each material tested according to mechanical resistance to compression at 28 days of age, in order to identify the differences regarding this mechanical property of CR, CJHS, CJDS, CJHRF, CJDRF. Subsequently, the stress and strain behavior of these elements and their respective load capacities are analyzed.

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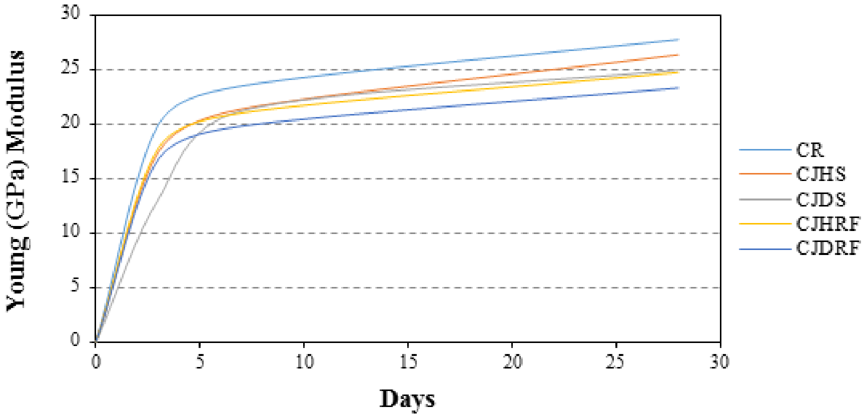

Figure 13: Modulus of elasticity

The mechanical strength of the samples was adopted as the arithmetic mean of the elements tested at the age of 28 days. Graphs 1 and 2 indicate the resistance obtained in the tests of uniaxial compression and indirect traction of the concrete cylinders, in the graphical representation the axis of the ordinates refers to the type of element tested, and the axis of the abscissa is the characteristic value of the resistance.

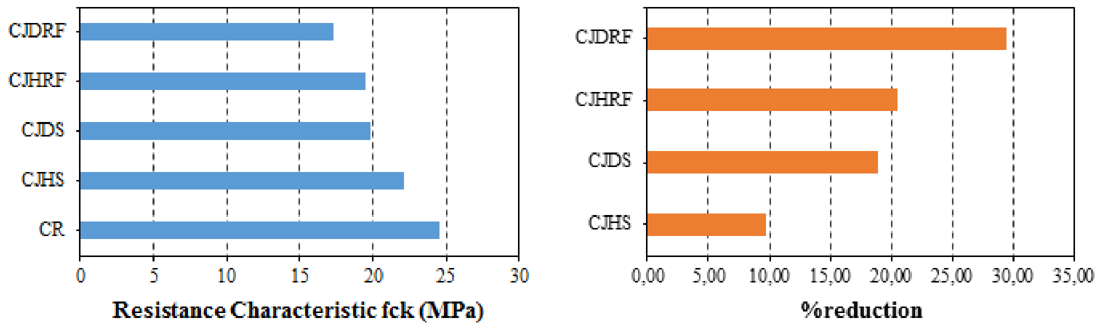

Figure 14: Compression test

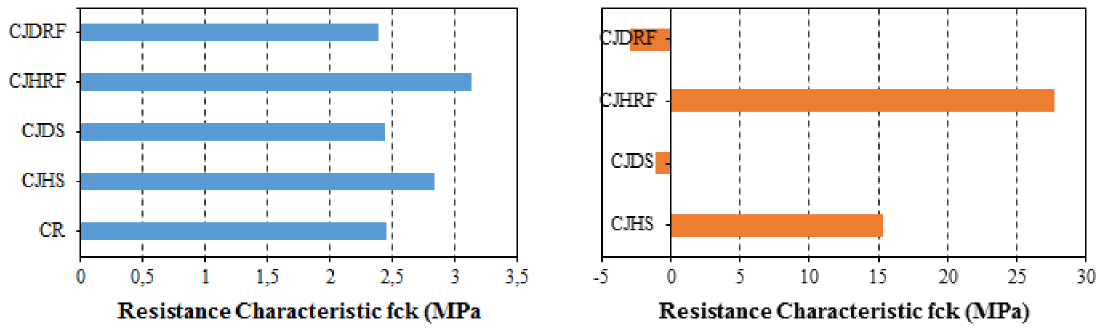

Figure 15: Tensile test

Analyzing the previous graphs, it was observed that in the compression tests, there was a reduction in the bearing capacity of the pieces formed with concreting jute, proving that this constitutes an aggravating factor in the mechanical characteristics in concrete elements. The tests with CJHS presented better results than those performed with CJDS, this can be explained by the fact that the maximum shear stresses are identified in the plane of 45 °, the same plane of joint formation in the CJDS. With respect to the compressive strength in the elements implemented with fiber, it was noticed a reduction in the support capacity in both plans of formation of

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the joints, compared with the elements without fibers. This fact can be explained by the inadequate fiber volume, leading to the formation of voids inside the concrete matrix, considering that in the compression tests equivalent results were expected. With respect to the reference concrete the reductions in the compressive strength of the CJHS, CJDS, CJHRF and CJDRF, were respectively 9.75%; 18.92%, 20.48% and 29.37% respectively.

The characteristic values of the traction test presented maximum results for the CJHRF elements, surpassing the CR value by 27.76%; the increase of the resistance observed in this case comes from the relief of the tensions in the plane due to the contribution of the fiber in the combat to the tensile stresses. Regarding the CJDRF elements, no improvement of resistance was observed with fiber implementation. However, it is observed that the orientation of the fiber in the concrete matrix was not favorable to combat tensile stresses, presenting results similar to the CJDS.

During the tensile tests performed on the cylinders of all specificities, the tensile stresses inherent to each associated strain were recorded, and the graph of figure 16 was assembled. As discussed by Pisa (2007) in figure 09, the effect of the stability of the supported load was identified in the composite of test with fiber, revealing the efficiency of the fibers in the combat of tensile forces.

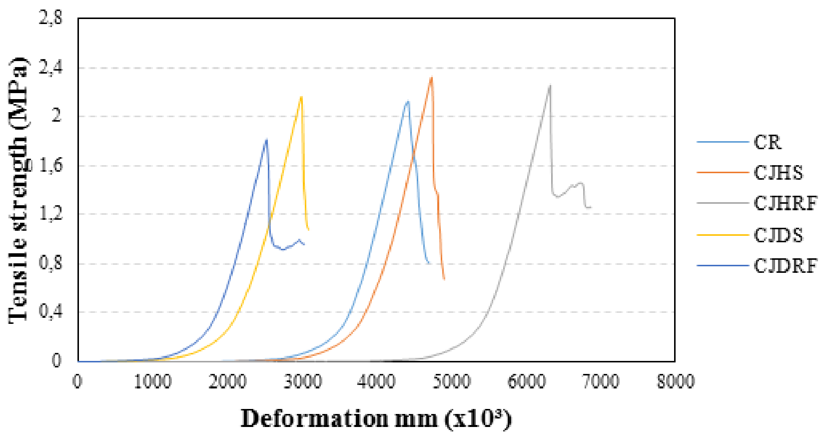

Figure 16: Relation of the tension and deformation of the bodies.

According to the tensions developed and the plan of formation of the joints two mechanisms of rupture of the specimens were observed: generalized rupture or monolithic rupture, and cracking in the concreting joint. The first type of failure was observed when there were fissures outside the concreting joint formation plane, even if the aggregate rupture occurred, the second case was associated to faults occurring at the joint formation site. The latter mechanism is associated with poor adherence between concrete mixtures at 24-hour intervals. The normal and tangential stresses considered were calculated using the equation presented in 2, 3 and 4. Table 03 summarizes the supported average tensions and the tension tension associated with shear stress τnt shown in figure 08.

Tabela 03: Comparison of results

Identificação	Inclination	Mean stress rupture (MPa)		
	θ	σy	σn	τnt
CR	0°	24,50	24,50	0,00
CJHS	0°	22,11	22,11	0,00
CJHRF	0°	19,48	19,48	0,00
CJDS	45°	19,86	9,93	9,93
CJDRF	45°	17,30	8,65	8,65

The adhesion stresses shown in Table 3 and the rupture mechanism in Table 4 indicate that in the elements implemented with steel fiber the rupture was monolithic, while in the CJHS and CJDS fracture rupture was observed in the joint region. The compression rupture mechanism is illustrated in Figures 17 to 19.

Figure 17:CR rupture compression test

Figure 18:CJHS rupture compression test

Figure 19:CJDS rupture compression test

5. CONCLUSIONS

Considering the results presented, it is possible to affirm that the formation of cold joints in concrete pieces can reduce their ultimate tensile strength to values close to 30%. Another important consideration is that the inclination of the joint forming plane directly influences the mechanical strength of the part, with the worst results being observed with its formation at 45 ° from the plane of action of the load.

The increase of fibers in the region of joint formation allowed to evaluate that in the compression tests the addition of these decreased the resistance of the part, however, in tests of traction there was a substantial improvement of its resistance, especially in the elements CJHF. The addition of oriented fibers in the direction of maximum stresses should be a factor taken into account in the reinforcement of concrete pieces, since the quantity used in concrete of different ages can cause the formation of internal voids. It was observed that the use of fibers confirmed the stability of the parts as to the voltage acting after the collapse of the parts, as Pisa (2007) had already determined.

Thus, it is concluded that the addition of steel fibers can improve the performance of cold-formed concrete parts, especially in the combat of tensile forces, however their application requires more detailed studies on the ideal volume in the composition of the mixture , so as not to negatively influence other mechanical properties of

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concrete parts. In later works we intend to analyze the ideal fiber volume for the concrete traces adopted, as well as to construct computational and numerical models to describe the behavior of structures on a larger scale.

6. ACKNOWLEDGEMENTS

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REFERENCES

[1] BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. NBR 5589/82. Low carbon wires. Diameters, tolerances and weights. Rio de Janeiro, 1982.
[2] BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. NBR. 15530.(2007). Concrete Steel Fibers-Specifications. Rio de Janeiro, (2007).
[3] BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. NBR 14931: Execution of concrete structures - Procedure. Rio de Janeiro: Abnt, 2004. 53 p.
[4] ACI 224.3R-95, Joints in Concrete Construction, American Concrete Institute, USA, 2001. 389
[5] Reapproved. *Harsem T. (2005),* Design of reinforced concrete structures, p. 50, Lima: Pontificia Universidad Católica del Perú.
[6] A. Legat, “Monitoring of steel corrosion in concrete by electrode arrays and electrical resistance probes,” *Electrochimica Acta*, vol. 52, no. 27, pp. 7590–7598, 2007.
[7] Banthia N, Sappakittipakorn M. Toughness enhancement in steel fiber reinforced concrete through fiber hybridization. Cem Concr Res 2007;37(9):1366–72.
[8] CÁNOVAS, M. F. Patologia y Terapéutica Del Hormigon Armado. Editorial Dossat, Madrid, 1984.
[9] Choi, S. J.; Kang, S. P.; Kim, S. C.; Kwon, S. J. Analysis technique on water permeability in concrete with cold joint considering micro pore structure and mineral admixture. // Advances in Materials Science and Engineering. 2015, (2015), pp. 1-10. https://doi.org/10.1155/2015/610428
[10] FIGUEIREDO, A. D. Concrete with Fibers. Concrete Teaching, Research and Achievements, Ibracon, v. 2. São Paulo: Ipisis Gráfica e Editora, 2005. Cap.39,p.1195-1225.
[11] FIGUEIREDO, A. D. Concrete with Steel Fibers, 2000. 69 p. Boletim Técnico, Série BT/PCC/260-Escola Politécnica da Universidade de São Paulo, São Paulo.
[12] Hibbeler, R. C. (2010). Resistência dos materiais . Pearson Educación.
[13] T. Ishida and K.Maekawa, “Modeling of durability performance of cementitious materials and structures based on thermohygro physics,” in Proceedings of the 2nd International RILEM Workshop on Life Prediction and AgingManagement of Concrete
[14] VOLZ, Jeffery S. et al. Are They Pour Lines Or Cold Joints?. Concrete Construction Magazine,(Publication No C970369), 1997.
[15] V. R. Rathi and P. K. Kolase, “Effect of cold joint on strength of concrete,” International Journal of Innovative Research in Science, Engineering and Technology, vol. 2, pp. 4671–4679, 2013.
[16] WALRAVEN, J. C., STROBAND, J. “Shear friction in high-strength concrete”. ACI−Conference, High-Strength Concrete, Singapore, 1993.
[17] YOO, Sung-Won; KWON, Seung-Jun. Effects of cold joint and loading conditions on chloride diffusion in concrete containing GGBFS. Construction and Building Materials, v. 115, p. 247-255, 2016
[18] ZILCH, K., REINECKE, R. “Capacity of shear joints between high-strength precast elements and normal cast-in-place decks”. In: International Symposium on high-performance concrete – The economical solution for durable bridges and transportation structures, PCI/FHWA/FIB, Precast/Prestressed Concrete Institute, USA, Orlando, 2000.
[19] Cook, R. D., Malkus, D. S.; Plesha, M. E. E Witt, R. J., (2001), Concepts and Applications of Finite Element Analysis. 4th Edition, John Wiley & Sons.
[20] Crisfield, M. A., (1991), Non-linear Finite Element Analysis of Solids and Structures, vol. 1, John Wiley and Sons.
[21] Jones, R. M., (1999), Mechanics of Composite Materials. 2 ed. Philadelphia: Taylor & Francis.

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[22] Martha, L. F.; Parente Jr., E. (2002), An Object-Oriented Framework for Finite Element Programming. Proceedings of Fifth World Congress on Computational Mechanics (WCCM V), Vienna: 2002, pp. 1–10.
[23] Reddy, J. N., (1996), Mechanics of Laminated Composite Plates – Theory and Analysis. New York: CRC Press.
[24] Vasiliev, V. V.; Morozov, E. V., (2001). Mechanics and Analysis of Composite Materials, Elsevier Science Ltd.
[25] Zienkiewicz, O. C.; Taylor, R. L., (2000), The Finite Element Method. 5ª ed. Butterworth-Heinemann.

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