AN OVERVIEW ON THE APPLICATION OF FRC AS A STRUCTURAL MATERIAL IN BRAZIL AND FUTURE TRENDS

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Abstract

The use of FRC as a structural material has gained a greater level of confidence in Brazil in recent years with the publication of technical standards, recommended practices and some emblematic applications. The main applications are still underground projects, such as the tunnels linings and the production of concrete pipes for sanitation works. This meets some of the main infrastructure demands attributed to the country's development stage. Although close to the European philosophy, Brazilian practices have specificities that deserve to be presented. In this sense, it should be emphasized the greater rigor in quality control programs and the differentiation of the requirements required for the material depending on the type of structure to be executed. In addition, there are also innovations in this subject that can guarantee greater reliability in the evaluation process of existing structures and that are being proposed for future publication as technical standard.

1. INTRODUCTION

The evolution of fibres reinforced concrete (FRC) in Brazil is something backward in relation to the observed in other countries. In Europe, FRC has been used for suspended slabs on buildings as the unique reinforcement system [1, 2] ten years ago. On the other hand, in Brazil the used of FRC was, basically, focused in applications of low level structural demand, such the case two industrial pavements and sprayed concrete in the same period [3]. One referential application of FRC in Brazil was the construction of São Paulo Subway Line 4 (Yellow Line) where the segments for TBM (Tunnel Boring Machine) were produced using only steel fibres as reinforcement [4]. Therefore, the main applications are underground projects, such as the tunnels linings and the production of concrete pipes for sanitation works. This meets some of the main infrastructure demands attributed to the country's development stage. In this period, a main problem is the fact that the standardization was restricted to steel fibres specifications of its use for concrete pipes reinforcement [5]. This condition starts to change in recent period with the publications of recommended practices as described in the next item.

2. BRAZILIAN RECOMMENDED PRACTICES

CT 303 is the Technical Committee created in 2011 to produce recommended practices for the use of fibre reinforced concrete for structural purposes. This committee involve the Brazilian Concrete Institute (IBRACON) and the Brazilian Association of Engineering and Structural Consulting (ABECE). Its main objectives were the elaboration of referential documents for the structural application of the FRC with the establishment of guidelines for the design of structures and technological control.

The committee used as reference main the fib Model Code 2010 [6, 7]. The main Brazilian document for design approach of FRC [8] for structural purposes follows completely the philosophy of the fib Model Code 2010 [7] for conventional structures such as buildings. The main difference occurs for structures such as pavements where the FRC residual strength parameters are required in terms of average values instead the characteristic ones.

The innovative contribution of the CT303 is more focused on the recommended practice for controlling the quality of the FRC [9]. In this guideline, it is recommended to carry out a previous homologation study of the FRC in order to certify its structural behavioural characteristics as in conformity with the ones specified in the design. The main parameterization of the FRC in terms of mechanical behaviour to verify its conformity with the design conditions is done through the EN14651 test [10]. However, this test method present difficulties to be performed in routine practice of quality control. In that sense, the CT303 allowed previous studies of correlation with the double punch test, also known as Barcelona test [11,12], to be used in this condition.

Another working front for the establishment of best practices for the use of fibres in structural concretes is starting in the Brazilian Committee of Tunnels (CBT). In this group it is wanted to parameterize the use of FRC designed for tunnel lining. The approach is very close to that adopted by EFNARC [13] but prioritizing the use of the double punch test to perform the quality control of the material and also allow the evaluation of the tunnel coating through extracted cores [14].

3. FUTURE PERSPECTIVES

One of the main current concerns is the analysis of the reliability of the FRC for the fire situation. This concern occurs both for its application in tunnels and for buildings. In the case of tunnels, the concern is in terms of preserving structural safety, avoiding collapse of the structure during and after the fire. This concern is emphasized in Brazil by the fact that there are large numbers of tunnels running on soft soils. For this reason, some researches are being developed in order to parameterize this behaviour [15]. This is particularly important because there are a large number of suppliers of synthetic macrofibres, which are more susceptible to the action of high temperatures. The concern is even greater in the case of use of FRC in building construction, especially in the particular situation of elevated slabs.

Other research and developments have been made aiming to verbalize the use of FRC in pre-cast elements. The concrete pipes are an established application of fibre reinforcement. Currently in Europe and Brazil, the evaluation of pipes made with FRC is more rigorous than the conventional reinforcement [16]. The specific standard, currently being revised, will seek to match the evaluation method and parameters of concrete pipes with different types or reinforcement: steel fibres and rebars. This idea makes the application more reliable in terms of durability and the fibres more competitive to ensure better control of cracking [17].

Another trend that has been studied in Brazil is the use of FRC in mixed structures of concrete and steel [18] as an alternative for conventional reinforcement. In this particular case, there will be advances in terms of elements production which will be facilitated. Other studies are being carried out in order to evaluate the use of fibres to substitute conventional shear reinforcement in precast elements, even when recycled aggregates are used [19].

4. CONCLUDING REMARKS

Technological developments in Brazil tend to focus more on quality control models than on innovative products. This is due to the Brazilian technological tradition that emphasizes the control of concrete mechanical properties. In large part, this tradition is based on the fact that there are no earthquakes in Brazil, which makes the responsibility of concrete strength greater to guarantee the structural stability. Therefore, the great number of researches are aiming at simple tests developments, easy to reproduce and able to evaluate the structural behaviour of the material reliably.

The construction applications, although still very focused on conventional uses, are beginning to show innovation trends in terms of increasing the use of FRC in precast elements. This is because fibres turn out to be advantageous in more industrialized systems where there is greater control of production, reducing time production and costs.

REFERENCES

[1] DESTRÉE, X. Steel-fibre-only reinforced concrete in free suspended elevated slabs. Concrete Engineering International. Spring, 2009. pp 47-.9

[2] BARROS, J.A.O., SALEHIAN, H., PIRES, N.M.M.A., GONÇALVES, D.M.F. Design and testing elevated steel fibre reinforced self-compacting concrete slabs. In: Eighth RILEM International Symposium on Fibre Reinforced Concrete (BEFIB 2012), 2012, Guimarães. Fibre Reinforced Concrete: challenges and opportunities. Bagneux: RILEM Publications SARL, 2012.

[3] FIGUEIREDO, A. D. Concreto Reforçado com Fibras. São Paulo, 2011. 247p. Thesis (for Associate Professor examination). Escola Politécnica, University of São Paulo (in Portuguese). (http://www.teses.usp.br/teses/disponiveis/livredocencia/3/tde-18052012-112833/pt-br.php).

[4] TELLES, R. C. D.; FIGUEIREDO, A. D. Possibilidades de incorporação de novas tecnologias em anel de concreto pré-fabricado para túneis com tuneladora. Concreto & Construção, São Paulo, v. XXXIII, n.41, p. 30-35, 2006.

[5] FIGUEIREDO, A. D., CHAMA NETO, P. J., FARIA, H. M. A nova normalização brasileira sobre fibras de aço. Concreto e Construção. v. XXXVI. IBRACON. p.67 - 76, 2008.

[6] di PRISCO, M.; PLIZZARI, G.; VANDEWALLE, L. Fibre reinforced concrete: new design perspectives. Material and Structures, v. 42, p. 1261-1281, 2009.

[7] FÉDÉRATION INTERNATIONALE DU BÉTON – FIB. Fib Model Code for Concrete Structures 2010. Swtizerland, 2013. 402p.

[8] IBRACON/ABECE. Estruturas de concreto reforçado com fibras – Recomendações para projeto. Prática Recomendada, 2016.

[9] IBRACON/ABECE. Controle da qualidade do concreto reforçado com fibras: Práticas Recomendadas, São Paulo, 2017.

[10] EN 14651. Test method for metallic fibre concrete - Measuring the flexural tensile strength (limit of proportionality residual). European Standard. 2007.

[11] ASOCIACIÓN ESPAÑOLA DE NORMALIZACIÓN Y CERTIFICACIÓN. **UNE 83515**. Hormigones con fibras. Determinación de la resistencia a fisuración, tenacidad y resistencia residual a tracción. Método Barcelona. Barcelona, 2010. 10p.

[12] GALOBARDES, I.; FIGUEIREDO, A. D. Correlation between beam and Barcelona tests for FRC quality control for structural applications. In: 8th International Conference on Fibre Concrete, 2015, Prague. Fibre Concrete 2015. Prague: Czech Technical University in Prague, 2015.

[13] EFNARC. European Specification for Sprayed Concrete. European Federation of Producers and Applicators of Specialist Products for Structures (EFNARC), Hampshire, UK, 1996. 30p.

[14] ESTRADA, A. R. C.; SANTOS, F. P.; FIGUEIREDO, A. D. Parâmetros para especificação e controle do concreto projetado com fibras aplicado como revestimento de túneis. CONCRETO & CONTRUÇÃO, v. 88, p. 79-85, 2017.

[15] RAMBO, D. A. S.; BLANCO, A.; FIGUEIREDO, A. D.; SANTOS, E. R. F.; TOLEDO FILHO, R. D.; GOMES, O. F. M. Study of temperature effect on macro-synthetic fiber reinforced concretes by means of Barcelona tests: An approach focused on tunnels assessment. CONSTRUCTION AND BUILDING MATERIALS, v. 158, p. 443-453, 2018.

[16] FIGUEIREDO, A. D.; de la FUENTE, A.; MOLINS, C.; AGUADO, A. A new approach on crushing strength test for fibre reinforced concrete pipes. In: Eighth RILEM International Symposium on Fibre Reinforced Concrete (BEFIB 2012), 2012, Guimarães. Fibre Reinforced Concrete: challenges and opportunities. Bagneux: RILEM Publications SARL, 2012.

[17] FIGUEIREDO, A. D.; de la FUENTE, A.; AGUADO, A.; MOLINS, C.; CHAMA NETO, P. J. Steel fiber reinforced concrete pipes: part 1: technological analysis of the mechanical behavior. Revista IBRACON de Estruturas e Materiais, v. 5, p. 1-11, 2012.

[18] PEREIRA, M. F.; De NARDIN, S.; El DEBS, A. L. H. Uso de fibras de aço em pilares mistos parcialmente revestidos de concreto. REVISTA DA ESTRUTURA DE AÇO, v. 5, p. 99-115, 2016.

[19] GAO, D., ZHANG, L., NOKKEN, M. Mechanical behavior of recycled coarse aggregate concrete reinforced with steel fibers under direct shear. Cement and Concrete Composites 79 (2017). P. 1-8.