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THE LABORATORY TESTING OF “FIBER REINFORCED CONCRETE”

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Abstract: *The use of fiber reinforced concrete (FRC) is becoming a widely accepted solution for reducing the reinforcement for normal concrete structures. This paper presents an experimental procedure for determination of the Elasticity Modulus for fiber reinforced concrete. The experiment determines also the compressive strength for this type of concrete, which determine that a concrete mixture as delivered meets the requirements of the specified strength f'_c, in the job specification. The modulus of elasticity of concrete is a function of the modulus of elasticity of the aggregates and the cement matrix and their relative proportions. The modulus of elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. For the Fiber Reinforced Concrete the Elasticity Modulus depends also of the modulus of elasticity of the Fiber and in conclusion it should have a bigger value for this type of concrete.*
Keywords: *Fiber, concrete, Elasticity Modulus, specified strength.*

1. INTRODUCTION

Concrete is an artificial product which is obtained by strengthening the well homogenized mixtures of binder (in general cement), water and aggregates, possibly additives [2]. The binder and water mixture forms a paste, as a result of physical and chemical processes it becomes a solid matrix which links the aggregate grains, resulting the monolithic nature of concrete. Concrete is highly resistant to compression [2,3,4]. For better tensile strength is usually reinforced with steel bars. In the construction industry, concrete, and especially the reinforced and prestressed concrete is the main construction material used in structures because it has many advantages: durability, performance of construction elements in any form, good resistance to fire, solid character, rigidity and relatively low cost.

In addition to regular concrete, buildings and construction elements subject to special conditions, need special concrete, such as high performance concrete, high-temperature resistant (refractory), antacid concrete, polymer concrete, hydraulic concrete, concrete for roads or concrete reinforced with various types of fiber (FRC).

Conventional fiber reinforced concrete, called FRC, is concrete that has been strengthened by adding shreds of other materials to the wet concrete mix. Concrete is quite brittle; it has very good compressive strength but comparatively little tensile strength, which makes it likely to crack under many conditions. Cracking leads to further damage. Fiber reinforced concrete is less likely to crack than standard concrete.

The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, straw was used in mud bricks. In the early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber-reinforced concrete was one of the topics of interest. By the 1960s, steel (SFRC), glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete, and research into new fiber-reinforced concretes continues today [2].

The fiber reinforced concrete can be used almost at every building type:

[1] Applications for new construction
  a. Bridges ;
  b. Columns;
  c. Industrial floors;
  d. Tunnels (as shotcrete) ;
  e. Equipment foundations.

[2] Repair and rehabilitation applications
  a. Beams;
  b. Slabs;
  c. Roads.

The Fiber Reinforced Concrete can be made with different types of fibers, that have different properties. For example in the Table.1 Are represented some type of fibers with different properties, extracted from "NEW TYPES OF SPECIAL CONCRETE", written by C. Avram, C. Bob.:

Tabel. 1: Types of Fibers used on concrete

Fiber type	Diameter μ	Density ρ_a kg/m^3	Tensile strength KN/mm^2	Elasticity Modulus KN/mm^2	Elongation %	R_t/ρ_a MNm/kg
Asbestos	0,02-20	3200	0,5-3,00	80-150	0,50-2,0	0,15-0,95
Mineral wool	10	2700	0,5-0,8	70-120	0,6	0,18-0,30
Carbon	8-9	1900	1,8-2,6	200-380	0,5-1,0	0,95-1,37
Steel	5-800	7850	1,0-3,0	210	3-4	0,13-0,39
Glass	9-15	2500	1,0-4,0	70-80	1,5-3,5	0,46-1,60
Polycrystalline alumina	500-770	3900	0,65	245	-	0,17
Cotton	-	1500	0,4-0,7	5,0	3-10	0,27-047
Sisol	10-50	1500	0,8	-	3	0,53
Polyethylene	20-200	950	0,7	0,14-0,42	10	0,77
Polypropylene	20-200	900	0,5-0,8	3,5-5,0	20-25	0,55-0,90
Polyesters	20-200	950	0,7-0,9	8,4	11-13	0,74-0,95

2. THE LABORATORY TESTING OF F.R.C.

There are two kinds of tests which are done on hardened concrete. These are non destructive test and destructive tests. In non destructive test, the sample is not destroyed and this test is very useful in determining the strength of existing buildings or structures where as in destructive test a sample is made and then destroyed to find out the strength of concrete. Compression, bending, tensile tests, are the examples of some destructive tests.

2.1 Tensile testing of F.R.C.

Tensile behavior of fiber reinforced concrete, in general case depends on the percentage of reinforcement fiber and other fiber characteristics such as tensile strength, elongation at break, modulus of elasticity, strength of the link between fiber and matrix, the Poisson's coefficient, geometric ratio, texture, shape and surface fibers, and of course, the type of concrete used. The determination of tensile behavior can be done with several methods, for example direct tensile test, stretch from bending or stretch from splitting.

2.1.1 Direct tensile test

This test method covers the determination of the direct tensile strength of cylindrical or prismatic specimen made of concrete. For the determination is necessary to have a stretching stand, with two base plates. Horizontal or vertical stand can be use with the plates linked at the stand by ball joints. The ball joints (pin) are needed to prevent a possible failure of the specimen from bending. In figure 1 is presented one horizontal stand.
If the load cell registers the force aplied at the other end at the failure moment we can write a simple eqation for determination of the tensile inside the F.R.C.:

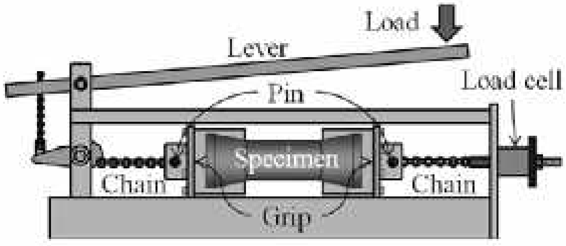

Figure 1: Direct tension test (horizontal stand)

$$R_t = \frac{F}{A_c} \qquad [N/mm^2] \qquad \textbf{(1)}$$

For the results to be correct the tear if the specimen should take place in the central part of the specimen (not in the end zones-1/8).

2.1.2 Tensile from bending

Represents one of the most used methode for determination of the tensile strength. This method uses generaly a prismatic specimen with the dimensions 150x150x600 kept in standard conditions till the testing day. The specimen must be aranged in the press afther one of the scheme showen in the Figure 2.:

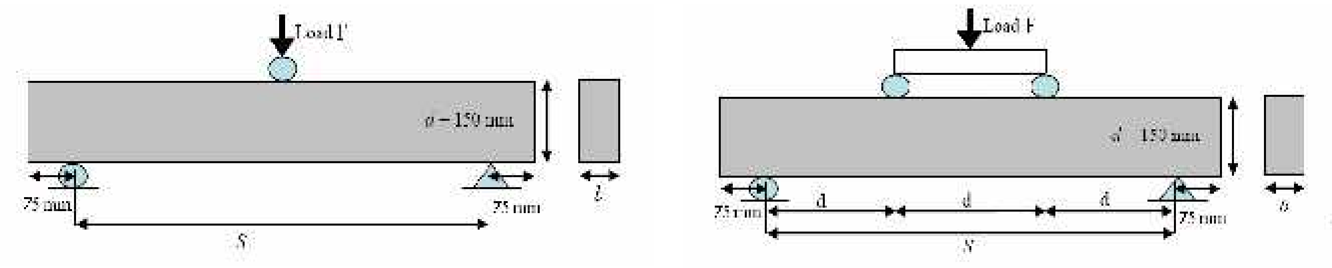

Figure 2: Bending stands (3 points bending and 4 points bending) [1]

The specimens will always be arranged in the stand with the pouring face on one side, never on top or bottom. The force is applied continuously until the cracks appear in the mid zone of the specimen. The tensile value is different for a 3 point bending scheme then for a 4 point bending scheme.

$$R_{ti} = \frac{3F}{d^2} \qquad [N/mm^2] \qquad \text{-3 point bending} \qquad \textbf{(2)}$$

$$R_{ti} = \frac{4,5F}{d^2} \qquad [N/mm^2] \qquad \text{-4 point bending} \qquad \textbf{(3)}$$

Between the direct tensile and the bending tensile is not an univocally relation but we can write an approximate relationship:

$$R_{ti} = 1,00...1,40 * R_t \quad [N/mm^2] \qquad \textbf{(4)}$$

2.1.3 Tensile from splitting

The splitting test used for F.R.C. represents an indirect determination of the concrete tensile. This method seems to have a greater connection with the direct tensile test then the bending test. It is obtained from a compression test made by the median area of a cube or by the generator of a cylinder. In most cases is recommended to use a cylinder because it can be mounted between the plates of the compression press without using other parts. For a cube to be mounted in a press for determining the tensile from splitting is necessary to put between the plates and the cube two wood belts(hardboard pad) with the dimensions: width: 15mm height: 4mm length: the same as the cube. The test is considered to be finished when the compressive load produces a transverse tensile stress and the cylinder or cube will split in half along the line of application of the force. The tensile value is the lowest tensile reached in the specimen as in Figure 3:
If the maximum force needed for splitting the specimen is F then the value of the tensile is:

$$R_{td} = \frac{2F}{\pi l d} \qquad [N/mm^2] \qquad \textbf{(5)}$$

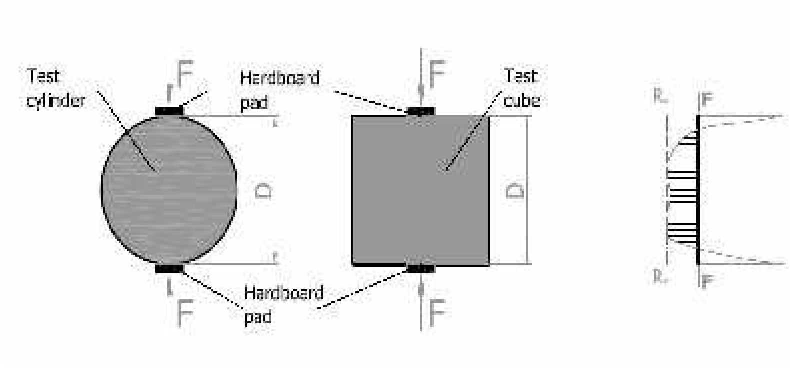

Figure 3: Tensile from splitting stand

Between the direct tensile and the splitting tensile exists an univocally relation that can be write like these:

$$R_t = 0,85 * R_{td}\ [N/mm^2] \qquad \textbf{(6)}$$

2.2 The compression test and determination of the Elasticity modulus

An element made of concrete that sustains a load is due to deform under that load. We are interested to determine how much an element deformed under some loads. For concrete we can speak about two types of deformations: the modification of length and the modification of volume (witch is composed by the modification of length and angles). In this conditions we can extract the linear elongation (7) and the volume elongation (8).

$$\varepsilon = \frac{\Delta l}{l_0} \qquad \textbf{(7)} \qquad \varepsilon_V = \frac{\Delta V}{V_0} \qquad \textbf{(8)}$$

For measuring the concrete deformations different methods can be use but a simple and efficient method is to use displacement transducers (resistive electric method). In the middle part of the specimen two transducers are placed, one vertical (for the transversal deformation) and one horizontal (for the longitudinal deformation) Figure 4.
From this type of test two concrete characteristics can be determined: one is the compression resistance and the second one is the static modulus of elasticity. In the elasticity theory the modulus of elasticity is defined as the tangent to the characteristic curve σ–ε, for a perfect elastic material:

$$E_A = \left(\frac{d\sigma}{d\varepsilon}\right)_A \qquad \textbf{(9)}$$

For the concrete modulus of elasticity the situation is a little different from this theory because the concrete is not an elastic material. From this reason at concrete the literature speaks about more than one modulus, for example: the tangent modulus, the secant modulus, the unloading modulus etc. In practice one modulus is currently used and this is the Conventional Elasticity Modulus E_c, defined:

$$E_c = \frac{d\sigma}{d\varepsilon} \qquad [N/mm^2] \qquad \textbf{(10)}$$

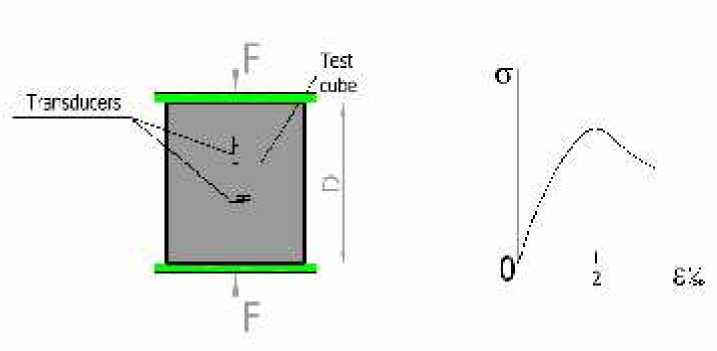

Figure 4: The determination of deformation for F.R.C.

3. CONCLUSION

If for a normal concrete many of it's characteristics are well known, like the modulus of elasticity, the compression resistance or the elongation for fiber reinforced concrete this characteristics need to be determined for every type and quantity of fibers used. All this characteristics are very important for the study and usage of Fiber reinforced concrete.

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