

A Tribute to Fernando L. L. B. Carneiro (1913 – 2001) Engineer and Scientist who invented the Brazilian Test

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Professor Fernando L. L. B. Carneiro making a speech to express his thanks for the tribute paid to him by the city of Rio de Janeiro in 2000.

The engineering mechanics and concrete materials community lost one of its great contributors: Professor Fernando L. L. B. Carneiro, the inventor of the splitting tension test for measuring the tensile strength of concrete, also known as the Brazilian test. He died on November 15th 2001 at the age of 87.

The long and distinguished career of Professor Carneiro included 32 years of work, from the 1930s to the 1960s, at the Brazilian National Institute of Techno-

logy (INT) in Rio de Janeiro, where he spearheaded research in Engineering Science and Technology of concrete. In the early 1940s, when Brazil went to World War II, the application of concrete airport pavements required determination of the concrete tensile strength. Given its operational difficulties, the direct tensile test had turned out to be not adapted for this purpose, and the three- or four-point bending tests were largely employed all over the world, including by Carneiro's team at INT. Carneiro, however, knew the limitations of structural tests to assess a sensitive material property as the tensile strength. In the absence of modern fracture mechanics theory and scaling laws, he had tried – without success – to establish a correlation between compressive strength and flexural tensile strength.

A challenging engineering problem inspired Carneiro to develop a new test method that is known as the Brazilian test: a baroque church was located in the axis of a new avenue to be built in Rio de Janeiro. The engineering solution that was found to avoid the demolition of the church was to displace it on concrete rollers (the production of steel was directed to the war effort). Carneiro was in charge of testing the cylindrical concrete rolls. He observed that concrete fracture developed almost strictly in a vertical plane connecting the line of contact between the cylindrical specimen and the compression plates. This observation brought about the development of a test for the tensile strength that could be performed on normalized cylinders defined by the Brazilian standards for compressive tests ($\Phi = 150 \text{ mm}$; $L = 300 \text{ mm}$). The test rig was very simple,

and for the sake of uniformity, Carneiro proposed the use of a load distributing strip placed between the specimen and the loading plate, with a dimension of 0.1Φ (see Fig. 1).

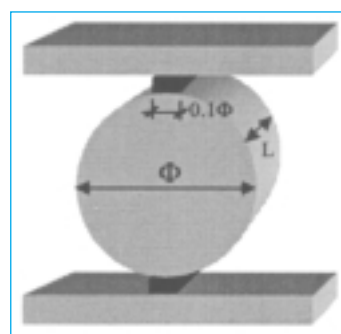


Fig. 1 – The Brazilian test.

Using simple formulas based on elasticity theory, Carneiro evaluated the tensile strength from the elastic tensile strength limit:

$$f_{ct} = \frac{2P}{\pi\Phi L} \quad (1)$$

where P is the applied load at failure.

The method was presented, in September 1943, at the 5th meeting of the Brazilian Association for Technical Rules (ABNT) [3]. It is curious that, almost at the same time (two months later), a similar method was independently presented in Japan by Akazawa [1], without any communication between the researchers (Brazil and Japan were on opposite sides in World War II).

In 1947, Carneiro's test method was internationally presented at the International Meeting of Materials Testing Laboratories, in Paris, during which RILEM was founded [4, 2, 11], of which he would become president later on. Ever since, the indirect tensile test, *i.e.* the Brazilian test, has been the subject of many studies in many countries, and its great impact can be evaluated by its inclusion in several testing standards and recommendations all over the world.

In 1968, after a sabbatical leave to France at Centre d'Études et de Recherches du Bâtiment et des Travaux Publics (CEBTP), Carneiro joined the faculty of the newly created graduate school for engineering (COPPE) at the Federal University of Rio de Janeiro, in charge of developing the Department of Civil Engineering. Carneiro faced this challenge with enthusiasm, and under his leadership the Department emerged as a graduate Institute for civil engineering research that is today the most important research and education center in Latin America. By that time, while continuing to take an active part in the concrete research community, collaborating with RILEM, CEB and FIP [16, 13], his main research focus changed to the establishment of the scientific and technological basis that should make it possible to explore the enormous offshore oil fields in the Brazilian continental platform. Carneiro's close cooperation with the Brazilian oil industry positively impacted the development of offshore engineering (see, for instance the proceedings of ten International Conferences held at Rio de Janeiro from 1977 to



Prof. Carneiro at the Laboratory preparing a cylinder for the Brazilian Test.

1997 [12]; and the renown of Brazil's advanced technology for oil exploration in deep waters to 2000 m depth, owes much to Carneiro's vision of engineering science and engineering development.

The passion for history of science, in particular for the work of Galileo, accompanied Carneiro throughout his career [5, 7, 9]. This brought him naturally to the study of dimensional analysis and similarity theory, and its application to Engineering problems. As an educator, his doctoral course "Dimensional Analysis and Similarity Theory" at COPPE, which he had taught since 1981, and still some months before his passing in 2001, marked more than one generation of engineers and researchers in Latin America. His lecture notes, published in 1993 in Portuguese [8] are a scientific bestseller in Brazil. They will be published in English in 2003.

On the research front, Carneiro developed the theoretical basis for the design of offshore structures based on reduced models [6] – the first reduced models of hydroelastic structures reported in the open literature [14, 15]. Carneiro never stopped his research in similarity theory. In his last contribution published by the Brazilian Academy of Sciences [10], Carneiro revisited by means of modern dimensional analysis Albert Einstein's treatment of three problems of physics of solids: the characteristic frequency of the atom of a solid as a function of the coefficient of compressibility; the relationship between the melting point of solid bodies and the characteristic frequency of the atoms and the thermal conductivity of crystalline insulators.

Carneiro received many national and international honors and awards for his contributions to engineering sciences and engineering practice, among which the Bernado A. Housaay Award from the Organization of the American States in 1984. But he was not only a great scientist and engineer, but also a great Brazilian, a profound humanist and citizen of the world. Besides the international impact of his research, his work was driven by the conviction that the improvement of the scientific and technological capacities in his country has the promise to fundamentally impact the social and ecological balance through science and engineering.

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