IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
June 2020 Vol.:15, Issue:4

Mechanical Characterization of Wooden Panels Using Ultrasonic Waves and Impulse Excitation

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Pizzol, V.D.[1], Krüger, P.V.[2], Rezende, M.A.P.[2], Alves, R.C.[3], Carrasco, E.V.M.[2,*], Mantilla, J.N.R.[4], Smits, M.A.[1]

1- PhD student, School of Engineering, Federal University of Minas Gerais, Belo Horizonte, Brazil

2- Professor, School of Architecture, Federal University of Minas Gerais, Belo Horizonte, Brazil

3- Professor, Department of forestry engineering, Federal University of Espirito Santo, Alegre, Brazil

4- Professor, School of Engineering, Federal University of Minas Gerais, Belo Horizonte, Brazil

Submission: 20 May 2020
Accepted: 28 May 2020
Published: 30 June 2020

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Nondestructive testing, panels of wood, modulus of elasticity, bending test

ABSTRACT

One of the most obvious tendencies in the wood industry is the growth of the production of panels to the wooden base. The MDF is a product that every time gains more stand out in the industry of furniture and the civil construction and its characterization is of abridgment importance to guarantee its correct use and to secure its qualities, being the nondestructive testing a quick form, cheap and promising for his evaluation. The objective of this work is to determine the modulus of elasticity of panels of MDF through nondestructive testing, identifying the best frequency of the ultrasonic transducers, and comparing the ultrasonic method with the excitement method for impulse, from the correlation with the test of static flexing. The results showed that two techniques can be used for the determination of the modulus of elasticity and the excitement for impulse supplies superior correlations.

INTRODUCTION

The reconstituted panels of wood appeared with the purpose of reducing some disadvantages from the massive wood, like for example, anisotropy, heterogeneity, hygroscopicity, dimensional instability and to increase the use of the raw material. These panels can be done from blades, fibers, and particles of wood joined by a sticker under the action of temperature and pressure.

The medium-density fiberboard (MDF) is constituted by fibers, it is a homogeneous panel and stable dimensionally because the fibers are linked to diffuse forms reducing the anisotropy from the wood. They appeared in the United States at the beginning of the 60 years, reached Europe in the middle of the decade of 70 and too late in Brazil in 1997 [1]. Its consumption, in 2005, reached 40 millions of m^3, Asia is responsible for 56 % of the world-wide consumption of this panel, followed by Europe (22 %), by the United States together with Canada (15 %) and the Latin America (7%) [1].

According of data of the Brazilian Association of the Industry of Mechanically Prosecuted Wood [2], as much in absolute terms as relative, the world-wide consumption of MDF passed of 5 % in 1995 for 26 % in 2012. In Brazil, this consumption destines to the furniture manufacture is also used in the civil construction, like the fine floor, baseboard, cushions of doors, partitions, doorposts, and pieces turned in general.

The checking of the characteristics of the plates MDF is done by rigorous quality control. Because owing to the production process, there is the monitoring of the properties of resistance, the proceeding is slow demanding much time and it requires for technicians with specialized training, with the generation of residues, because in the end the used samples are discarded[3,4]. The checking of the mechanical characteristics is done through destructive tests according to the Brazilian standard [5].

An appropriate evaluation can be helped by the use of nondestructive testing (NDT), because these allow to value the self-element, without the necessity of extraction of the sample [6]. The NDT are those carried out in materials to check the existence, or not, of discontinuity or defects, through definite physical beginnings, without altering its physical, chemical, mechanical, or dimensional characteristics, and without interfering in its subsequent use. Inhomogeneous and isotropic materials, the nondestructive evaluation allows detection faults that appeared in processes of manufacture [3]. In the wood, these irregularities take place naturally, because the question is about a material produced by nature. The influence of these irregularities from the wood about the mechanical properties can be valued in the form nondestructive [3, 4, 7].

For the massive wood, studies carried out with the use of equipment for NDT, indicate the possibility to be established correlations with the modulus of elasticity (E) when was obtained through destructive testing [3, 4, 7]. Among the advantages of the application of nondestructive techniques can be detached the possibility of realization of the evaluation of the plates in the production line, with the additional advantage of happens the evaluation of all the plates and not only of samples [3].

There are several evaluation techniques nondestructive, what they are employed for the evaluation from the wood and from its products, between which it is possible to stand out: ultrasound, resistograph, cross vibration, and waves of tension.

The technique that uses ultrasonic waves began in the decade of 1950, in Europe, being employed initially in concrete investigations. Subsequently, began theoretical studies for the application of the ultrasound in the wood, being found some difficulties due to the anatomical peculiarities of the material. The first experimental results were obtained by Waubke, in1983, in Germany [8, 9].

Currently, several types of research have been developed to prove the validity of the technique of ultrasound in the classification of pieces and products of wood. How, for example, Nogueira and Ballarin [7] in the study with massive wood obtained coefficients of correlation between E and dynamic constant, obtained with a test of ultrasound, varying between 0.76 and 0.89. Gonçalves and Silva [4], applying ultrasonic waves to MDF panels, found that the correlations obtained between the propagation speeds of the ultrasound waves and the modulus of elasticity of the plates, obtained in destructive tests, make it possible to infer the use of NDT. Thus, the excellent correlations with speed were significant for use in the industry, so its determination will be much simpler and more direct than the determination of the dynamic constants.

The excitement technique for impulse is based on the natural vibration frequencies. To suffer a light mechanical impact, the proof body gives out a characteristic sound that depends on its dimensions, mass, and elastic properties. The reduction and the frequencies present in this acoustic answer allow the precise determination of the modulus of elasticity and the deadening [10]. This technique was introduced in the decade of 70 using the equipment Grindosonic, what it is marketed at present with the same resources and functionalities. In the decade of 90, due to the advancement of computer science, the second generation of equipment appeared for the technique of the excitement for impulse [4, 9, 10].

In this context, the objective of this work is to value the job of two techniques nondestructive at panels of MDF, identifying which supplies better correlation with the results obtained by the destructive testing.

1. MATERIALS AND METHODS

There were used samples of commercial panels of MDF of Pinus were withdrawn 16 Test Samples (TS) with dimensions of 5x2x25 cm, what they were rehearsed using the techniques of ultrasound and excitement for impulse and static flexing. The density of the panels was around 0.65 g/cm^3 and the moisture varying from 10.9 % to 13.1 %.

The 16 TS of MDF was tested in an ultrasound appliance of the mark Fakopp, model Ultrasonic Timer, in which they have used three types of transducers one for each frequency, Figure No. 1, that they allowed the measurement of the time of propagation of the wave in the material. The used transducers were of 30 kHz, 54 kHz (exponential) and 150 kHz to identify which one was supplying better correlation, in other words, which one is the ideal frequency for analysis of TS of MDF.

Of possession of the time, there were calculated the speeds of propagation of the waves that are connected with the elastic constants (dynamic constants), they're determined so information correlated to the mechanical behavior of the evaluated material. The MDF can be considered a stratified material or transversely isotropic and the stiffness matrix, in agreement with [4, 9] it is given by Eq. (1). The constitutive law of this material has 5 independent components, in this work, only will be determined the constant that correlates the modulus of elasticity of the material. This dynamic constant of stiffness (CR_{11}=CR) is determined by Eq. (2).

$$\begin{bmatrix} CR_{11} & \cdots & CR_{66} \\ \vdots & \ddots & \vdots \\ CR_{61} & \cdots & CR_{66} \end{bmatrix} \quad (1)$$

$$CR = \frac{\delta . v^2}{g} . 10^{-6} \quad (2)$$

Where: CR is the constant dynamic of stiffness (MPa), δ the apparent density of the sample (kg/m^3), V the speed of propagation of the ultrasonic (m/s), and g the constant of gravity (10 m/s^2).

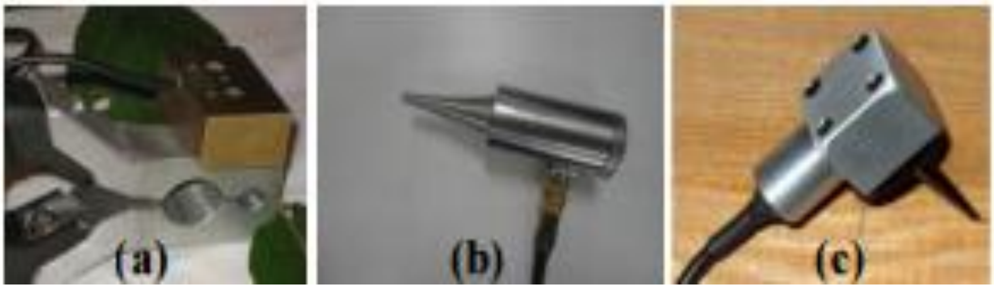


Figure No. 1: Transducers: (a) 30 kHz, (b) 54 kHz (exponential) e (c) 150 kHz

The appliance Sonelastic (excitement by impulse) was used to determine the modulus of elasticity from the natural frequencies of vibration of the samples through excitement for impulse. The principle of functioning of the equipment is based on the excitement through the pulse, follow of the catchment of the acoustic answer by a sensor (frequencies), Figure No. 2. Through the transformed ones of Fourier is obtained the specter of corresponding frequencies and from it, the dynamic elastic module [11] is calculated. For these calculations, it is necessary to supply the geometry, the mass, and the dimensions of the TS, previously measured by a caliper rule and a digital balance, and with the frequency obtained by the equipment, it is determined the E.

Figure No. 2: Test to determine the elasticity module through excitement for impulse

After the NDT, the 16 samples were rehearsed of the agreement the prescriptions of the Brazilian standard [5] is a universal machine of mechanical tests of the mark EMIC and model DL3000, Figure No. 3 equipped with a displacement transducer with 0.001 mm of sensibility. The load applied in the tests was monotonically increased at a rate of 2.5 MPa/min. The mechanical test was the static flexing in three points with which was determined the static elasticity module (E). These values were used to obtain correlations with the values registered by the NDT.

Figure No. 3: Test of static flection in three points.

2. RESULTS AND CONSIDERATIONS

2.1.Identification of the ultrasonic frequency

In Figure no 4 are presented the printers of the correlation between the destructive test and the results obtained by the ultrasound in each frequency. For the 30 kHz frequency, Figure No. 4.a was found a correlation (R^2) of 0.786, however, it is believed that it is a false correlation, because one of the factors that affect the speed of the ultrasonic wave is the length of the sample, and for use a 30 kHz frequency the length of the sample should be bigger than 25 cm [12]. For the 54 kHz frequency, the R^2 was of 0.291 a very low value, Figure No. 4.b. this probably is due to have been used as an exponential transducer which concentrates the waves in only one point.

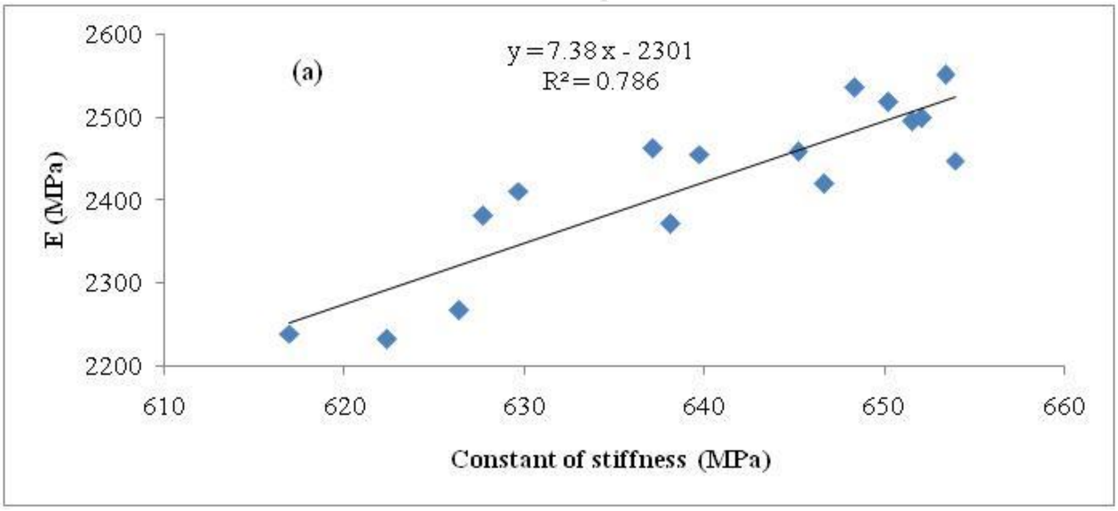
The transducer of 150 kHz shows a correlation of 0.754, Figure No. 4.c, the value that is significant and compatible with the values usually found in the literature, which allows to affirm that the nondestructive method through ultrasound can be used to value the mechanical properties of the MDF and that the 150 kHz frequency is to ideal for these samples dimensions. Several national and international types of research show the viability of the method of ultrasound, through correlations between the modules of elasticity obtained in destructive testing (parallel compression to the fibers and static flexing). The values found in the literature indicate values of the coefficient of determination (R^2) between 0.57 and 0.89 [13-17]. So the Eq. (3), can be used to determine the E of the plates of MDF using a 150 kHz transducer.

$$E = 1.88CR_{11} - 1872 \ (MPa) \qquad (3)$$

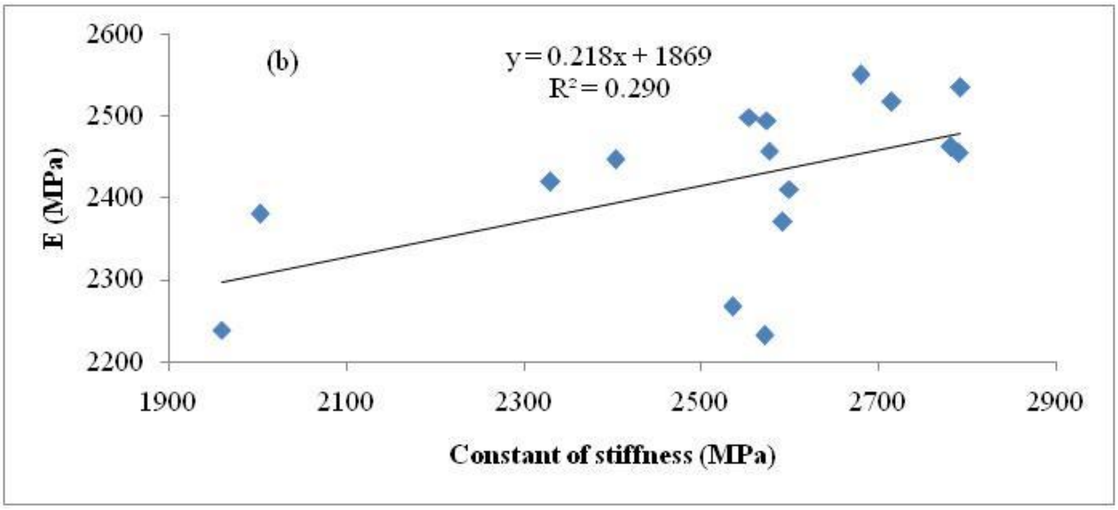
2.2.Correlation between excitement test for impulse and destructive testing.

In Figure No. 5 are the results of the tests of excitement for impulse and the static flexing test, the correlation between both was of 0.923, a high value. Eq. (4) presents this correlation.

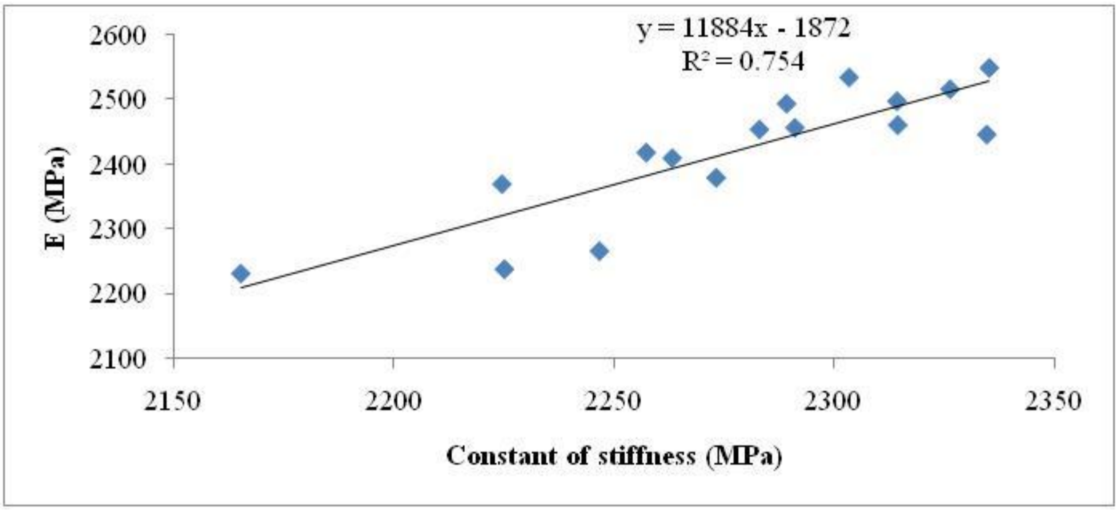
$$E = 0.9811E_{sonelastic} - 785{,}02 \ (MPa) \qquad (4)$$



(a)



(b)



(c)

Figure No. 4: Correlation between the test with ultrasound using the transducers (a) 30 kHz, (b) 54 kHz, and (c) 150 kHz with the E static obtained in the flexing test.

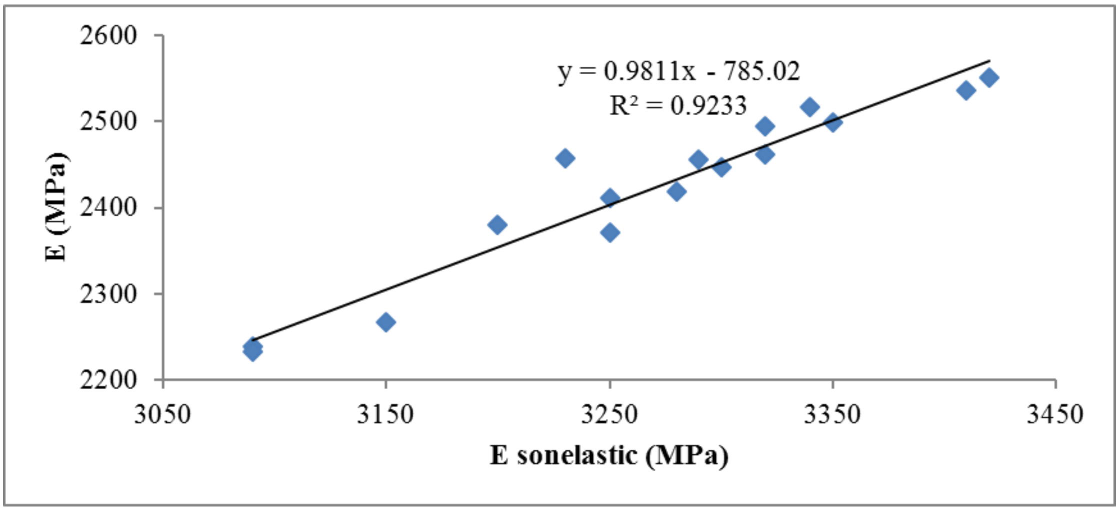


Figure No. 5: Correlation between the excitement test for impulse with the E static.

3. CONCLUSION

The nondestructive method using ultrasonic waves can be used to value the mechanical properties of the MDF and the frequency of 150 kHz is the ideal for the dimensions of the test samples.

The excitement technique for impulse presents a performance better than the technique of ultrasound. However, it can be realized values related, allowing to check that both techniques can be used in the characterization of MDF panels, with the additional advantage of allowing the individual examination of the pieces in the production line.

ACKNOWLEDGMENTS

National Council of Technological and Scientific Development (CNPq) and Foundation for Research Support of the State of Minas Gerais (FAPEMIG), for the financial support given to this research.

REFERENCES

[1] BNDES. Setorial: Painéis de madeira no Brasil: panorama e perspectivas. Rio de Janeiro (Brazil). 2008; (27): 121-156.

[2] Associação Brasileira da Indústria de Madeira Mecanicamente Processada (ABIMCI). Estudo setorial: Madeira processada mecanicamente. Curitiba (Brazil). 2013: 085-100.

[3] Candian M, Sales A. Aplicação das técnicas não destrutivas de ultra-som, vibração transversal e ondas de tensão para avaliação de madeira. Ambiente Construído. 2009; 9(4):83-98.

[4] Gonçalez JC, Vale AT, Costa AF. Estimativas das constantes elásticas da madeira por meio de ondas ultra-sonoras (ultra-som). Cerne. 2001; 7(1):81-92.

[5] Associação Brasileira de Normas Técnicas - NBR 15316-2. Chapas de fibras de média densidade. Parte 2: Requisitos. Rio de janeiro (Brazil). 2006: 25p.

[6] Associação Brasileira de Ensaios não Destrutivos. [Internet]. Jul 15, 2016. Available from: http://www.abende.org.br/analise_vibracoes.html.

[7] Pizzol VD, Mantilla JNR, Carrasco EVM. Elastic characterization of plywood used and reused in forms through impulse excitation. Revista Matéria. 2017; suplemento, e-11928.

[8] Sandoz JL. Grading of Construction Timber by Ultrasound. Wood Science and Technology. 1989; 23(2):95-108.

[9] Bucur V. Nondestructive Characterization and Imaging of Wood. Nova York: Springer-Verlag, 2003.

[10] Cossolino LC, Pereira AHA. Módulos elásticos: visão geral e métodos de caracterização. ITC-ME/ATCP. 2010. ATCP Engenharia Física. https://www.atcp.com.br/.

[11] Otani LB, Pereira AHA. Guia de caracterização dos módulos elásticos e do amortecimento de madeiras e derivados utilizando as soluções Sonelastic. GC 02-ATCP. 2013. ATCP Engenharia Física. https://www.atcp.com.br/.

[12] Associação Brasileira de Normas Técnicas - NBR 15521. Ensaios não destrutivos - Ultra-som - Classificação mecânica de madeira serrada de dicotiledôneas. Rio de janeiro (Brazil), 2007, 15 p.

[13] Bartholomeu A. Classificação de peças Estruturais de Madeira Através do Ultra-Som. Ciências e Engenharia de Materiais, Honours [Doctoral thesis]. Campinas (SP, Brazil): Universidade Estadual de Campinas, Campinas; 2001.

[14] Nogueira M. Determinação de Módulos de Elasticidade à Compressão de Madeira de *Pinus taeda* L. com o Uso de Ultra-Som. 2003. Ciências Agronômicas, Honours [Master's thesis]. Botucatu (SP, Brazil): Universidade Estadual Paulista, Botucatu, 2003.

[15] Oliveira FGR. Contribuição ao Estabelecimento de Parâmetros para Ensaios Não-Destrutivos em Madeira Serrada por Meio de Ondas de Ultra-Som. 2005. Honours [Doctoral thesis]. São Carlos (SP, Brazil): Universidade de São Paulo, São Carlos, 2005.

[16] Ross RJ, Pellerin RF. NDE of Green Material with Stress Waves: preliminary results using dimension lumber. Forest Products Journal. 1991, 41(6): 57-59.

[17] Ross RJ, Pellerin RF. Nondestructive testing for assessing wood members in structures: a review. Madison: US Department of Agriculture, USA, 1994.

 Author -1	***Carrasco, E. V. M. – Corresponding Author*** *Full professor, Department of Technology of Architecture and Urbanism, School of Architecture, Federal University of Minas Gerais.* *Rua Paraíba, 697, Funcionários, Belo Horizonte, MG, Brazil.*
 Author -2	***Pizzol, V. D.*** *PhD, Associate Researcher, Department of Structural Engineering, School of Engineering, Federal University of Minas Gerais.* *Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte, MG, Brazil*
 Author -3	***Krüger, P. G. V.*** *Full professor, Department of Technology of Architecture and Urbanism, School of Architecture, Federal University of Minas Gerais.* *Rua Paraíba, 697, Funcionários, Belo Horizonte, MG, Brazil.*
 Author -4	***Rezende, M. A. P.*** *Full professor, Department of Technology of Architecture and Urbanism, School of Architecture, Federal University of Minas Gerais.* *Rua Paraíba, 697, Funcionários, Belo Horizonte, MG, Brazil.*
 Author -5	***Alves, R. C.*** *Adjunct professor, Department of Forest and Wood Sciences, Federal University of Espírito Santo.* *Av. Gov. Lindemberg, 316, Centro, Jerônimo Monteiro, Espírito Santo, Jerônimo Monteiro, ES, Brazil*

 Author -6	***Mantilla, J. N. R.*** *Retired associate professor, School of Engineering, Federal University of Minas Gerais.* *Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte, MG, Brazil*
 Author -7	***Smits, M. A. C. G.*** *PhD, Associate Researcher, Department of Structural Engineering, School of Engineering, Federal University of Minas Gerais.* *Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte, MG, Brazil*