Improvement of Collapsible Soil Behavior of a Lateritic Soil Using Rice Husk Ash

Article *in* Key Engineering Materials · October 2015

DOI: 10.4028/www.scientific.net/KEM.668.290

7 authors, including:

Jhaber Dahsan Yacoub
São Paulo State University
1 PUBLICATION **1** CITATION
SEE PROFILE

Jose Lollo
São Paulo State University
96 PUBLICATIONS **100** CITATIONS
SEE PROFILE

Jorge LUIS Akasaki
São Paulo State University
66 PUBLICATIONS **295** CITATIONS
SEE PROFILE

Mauro Mitsuuchi Tashima
São Paulo State University
68 PUBLICATIONS **544** CITATIONS
SEE PROFILE

Key Engineering Materials Vol. 668 (2016) pp 290-296
© (2016) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/KEM.668.290

Submitted: 2015-04-08
Accepted: 2015-06-09
Online: 2015-10-13

Improvement of collapsible soil behavior of a lateritic soil using rice husk ash

Luiza P. Fagundes [a*], Jhaber D. Yacoub [b], Andrey C. Lima [c],
Flávia R. Nakatsuchi [d], José A. Lollo [e], Jorge L. Akasaki [f]
and Mauro M. Tashima [g]

UNESP – Univ Estadual Paulista, campus de Ilha Solteira – SP, Brazil.

[a] fagundesluiza94@yahoo.com.br, [b] jhaber.yacoub@gmail.com, [c] andrey_c.lima@hotmail.com,
[d] flavia_naka@hotmail.com, [e] lolloja@dec.feis.unesp.br, [f] akasaki@dec.feis.unesp.br,
[g] maumitta@hotmail.com

Keywords: Lateritic soil, collapsible behavior, rice husk ash.

Abstract. Great areas of Brazil present lateritic soils, such as the northeast and the south. Some of these soils have, as main characteristic, instable structures that can present considerable volumetric deformation in the presence of water. This behavior, also named collapse, is responsible for several problems on the building construction such as cracks and fractures that can damage the safety of structures. The aim of this paper is to assess the possibility of improvement of collapsible behavior of a lateritic soil using rice husk ash (RHA). A previous characterization of soil and RHA was performed in order to assess the combined effect of soil/RHA. The results are so promising, showing a new alternative to reduce the collapsible behavior of soils using an environmental friendly technology.

Introduction

Some type of soils can present significant variation on their volume when submitted to an increment of moisture or when the moisture is increased after an overload. This behavior, also named collapsible behavior, is caused by a suddenly reduction on the void ratio (e) and occurs for soils with metastable structures. This soil behavior can affect the safety of civil constructions producing cracks and stability problems. Collapsible soils can be found in several places of the World such as South Africa, Angola, Argentine, Australia, Brazil, Spain, United States, Israel, etc. In Brazil, great areas of northeast and the south are covered by collapsible soils [1].

The identification of collapsible soils can be performed in situ or through laboratory tests. In situ methods can estimate the collapsible behavior in real scale, mainly for foundation projects. Otherwise, laboratory tests can assess the collapsible behavior of soils using both physical index or by means of strength tests that can simulate a specific condition. Between strength tests laboratory commonly used (axial and tri-axial test), the axial compressive strength associated to an increment on the moisture of specimen for a given load stress is one of the most performed tests in order to assess the collapsible behavior of soils. This test condition, also named simple oedometer test, was first used by Jennings and Knight [2].

In order to assess the collapsible behavior of one lateritic soil located in Ilha Solteira (SP - Brazil), several studies have been conducted [3-8]. Oliveira and Lollo [3] performed a zone mapping for collapsible soil in urban areas of Ilha Solteira, identifying some problems caused by collapsible soil behavior. In 2004, Rodrigues Souza and Lollo [4] measured collapse settlement for different depth and load stress.

The reuse of agroindustrial waste materials, especially as construction material has been investigated extensively [9-11]. Rice husk ash (RHA), an agroindustrial waste material generated by burning rice husk for energy production, is one of the most investigated agroindustrial waste material. Frequently, RHA have been disposed in landfill areas or in inappropriate places [12] causing several environmental problems. In the last decades, several studies have been reported the possibility of use RHA as mineral addition in the production of concrete and mortars [13]. According to the obtained results, RHA can improve both mechanical strength and durability aspects of concretes and mortars due a chemical reaction between amorphous SiO_2 present in the RHA and calcium hydroxide released during Portland cement hydration to form hydrated products [14]. Tashima et al. [9-11] performed several studies related to the use of RHA obtained by an uncontrolled burning condition as mineral addition for concrete and mortars. Hence, the aim of this paper is to assess the possibility of improvement collapsible soil behavior using rice husk ash. Soil characterization and oedometer test for soil and soil+RHA are assessed.

Experimental

The experimental processes were conducted in Geotechnic Laboratory at UNESP, Ilha Solteira campus. Confined compression test was performed using an oedometer test machine from Solotest with a metallic ring with 8.7 cm of diameter and 2.0 cm of height. Fine lateritic sand soil assessed in this study was collected in Ilha Solteira (SP) region. In order to avoid soil cementation due the presence of Ca^{+2} ions, distilled water was used for specimens wetting.

At first, lateritic soil was characterized and, so on, compacted specimens were prepared for the confined compression test (oedometer test). 80% of compaction degree was used for specimen´s preparation, similar to the compaction degree previously assessed by Rodrigues [14]. The compaction was conducted in 12.4% of moisture, i.e., the optimum moisture for this soil in Normal Proctor test. A mixture of soil+RHA was also prepared using the same procedure described for soil specimen. For soil+RHA specimen, 8% of RHA replacing soil mass was fixed. Replacing part of the mixture was a strategy for assure the same compaction conditions for pure soil and mixture.

After specimen´s preparation, the simple confined compression test (oedometer test) was performed with optimum moisture until 200 kPa charge and then, specimens were wetted to induce soil collapse at this stage of charge. The 200 kPa charge was chosen because it represents the beginning of pure compression interval for the soil in the test, where the most significant deformations for soils occur. Despite of it, Ilha Solteira code construction does not allows buildings with more than four pavements in urban area, and considering natural geostatic tension summed to the four pavements construction, the maximum stress applied until 10 m deep is 200 kPa. It is considered that until 10 m deep the soil of Ilha Solteira exhibits collapsible behavior.

In the four initial charge stages (6.25; 12.5; 25 e 50 kPa) deformation ceases after about two hours. For 50 to 100 kPa, it occurs among 5 to 8 hours. For 200 kPa to 800 kPa charge stages deformation does not ceases with the same velocity. For these stages, it was adopted the difference of deformation rates between the last three stages of charge as the criteria of stage measurement ending. Whenever the difference of three last measurements was lesser than 10-2 mm, the specimens were submitted to the next charge stage.

Simple confined compression tests were performed until 200 kPa with molding soil moisture, protecting the consolidation cell in order to avoid moisture loss. After the end of specimen deformation at 200 kPa charge, the specimens were wetted and its deformation was measured in this condition until 24 hours. deformation was measured in times of 0:09, 0:16, 0:25, 0:36, 0:49, 1:04, 1:40, 2:01, 2:24, 3:16, 6:40 and 24:00 hours after wetting. With the end of collapse settlement due to wetting, the test was performed in successive stages of charge until 800 kPa. Soil collapse potential was obtained from Jennings e Knight [2]. It is important to state that a plastic device was produced and installed in the oedometer cell in order to reproduce in situ soil condition. Figure 1 shows oedometer test with plastic device.

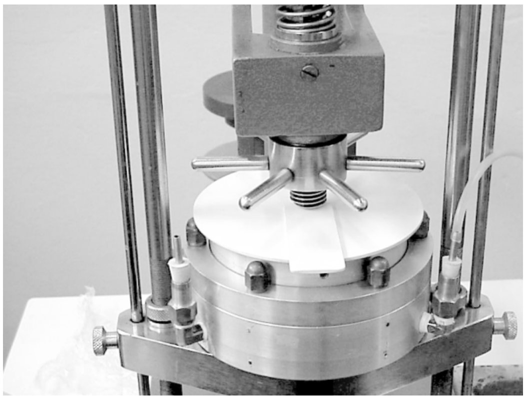

Figure 1 – Oedometric cell adaptation for tests. Source: Rodrigues [8].

Results and discussion

Soil Characterization.

Obtained results of soil characterization showed that soil from Ilha Solteira region present low plasticity (LL = 22.4%, LP = 15.4% and PI = 7.0%). In the same way, mixture of soil+RHA exhibits consistency parameters similar to those found for soil sample: LL = 21.9%, LP = 14.6% and PI = 7,3%. Related to the particle size distribution, soil sample can be classified as fine clayey sand (69% sand, 8% silt, 23% clay). For the mixture of soil+RHA, it is observed an increment on the fine particles: 59% sand, 9% silt and 32% of particles size less than 2 micrometers. Figure 2 and 3 shows the particle size distribution for soil sample and soil+RHA sample, respectively.

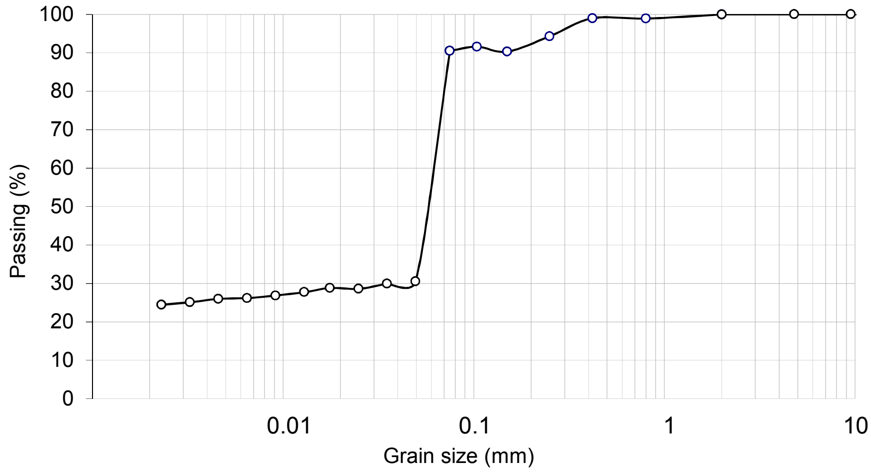

Figure 2 – Soil particle size distribution.

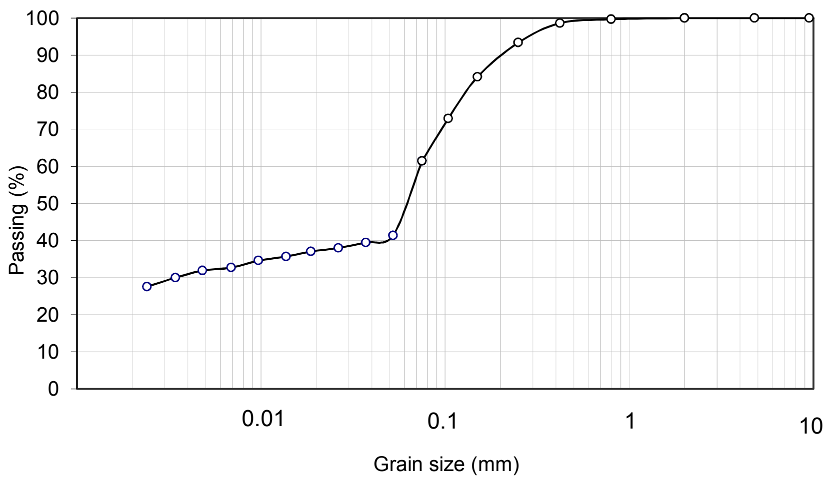

Figure 3 – Soil+RHA particle size distribution.

Confined compression test.

Confined compression curves are presented in logarithmic scale: in horizontal axis is represented the stress data and deformation in vertical axis that is expressed as a fraction of void ratio for a determined stress and initial void ratio (e_i/e_0). Figure 4 shows the obtained results for confined compression test for soil specimen.

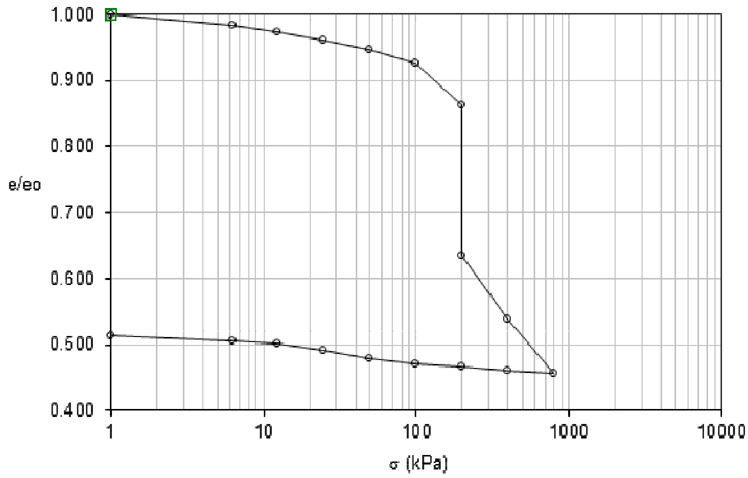

Figure 4 – Confined compression curve for soil specimen.

The confined compression curve for soil+RHA is depicted in Figure 5. Comparing both curves, the first significant result is the difference of total deformation between soil and soil+RHA specimen. While soil specimen presented the final e/e0 about 0.456, soil+RHA specimen showed about 0.585, representing about 12.9% of reduction on the total deformation for soil+RHA specimen.

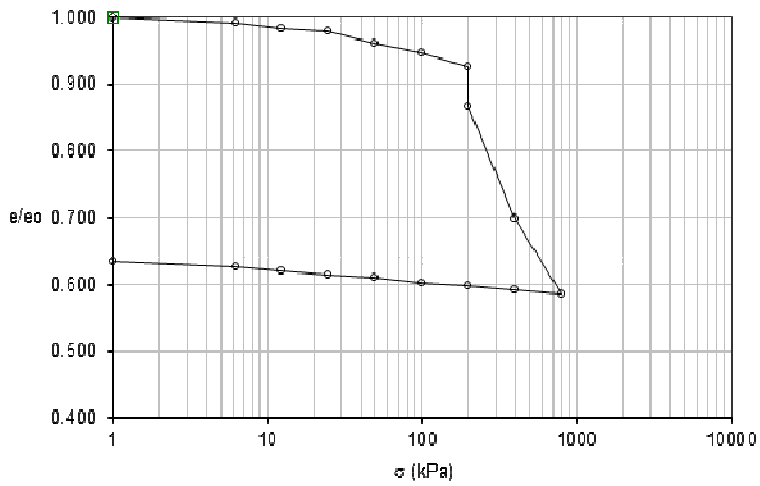

Figure 5 – Confined compression curve for soil+RHAspecimen.

In terms of collapse settlement associated to 200 kPa tension in wetting condition, the deformation measured for soil specimen was about 0.227. Soil+RHA specimen presented for the same test condition just 0.058 of deformation (e/e0), representing a reduction of 74.4% in the collapse settlement due the use of RHA. The compression curves obtained from confined compression tests shows three intervals in terms of material behavior: (1) recompression (the applied stress is smaller than preconsolidation stress of soil – interval between 1 and 100 kPa for the materials investigated); (2) pure compression interval (the applied stress is greater than preconsolidation stress – 200 to 800 kPa in the analyzed tests); and (3) discharge interval (800 to 1 kPa stages of charge). For each of these intervals, the coefficient expressing the deformation ratio for soil in that condition of stress application can be obtained. The general expression for this relationship is showed as follows:

$$C_i = \frac{\frac{e_i - e_f}{e_0}}{log\frac{\sigma_f}{\sigma_i}} \ . \quad (1)$$

In Eq. 1: "ci" is the coefficient expressing deformation ratio in the interval (Cr – recompression, Cc – compression, and Cd – discharge); "ei – ef" express the variation in terms of void ratio in the interval; and "log (σf/σi)" is the variation in applied stress in the interval. Computing these coefficients for the tests performed for both specimens, the obtained data are showed in Table 1.

Table 1 – Deformation coefficients for confined consolidation tests intervals.

Specimens	Cr	Cc	Cd
Soil	0.04	0.67	0.027
Soil+RHA	0.05	0.46	0.017

Assessing the obtained data from Table1, it can be noted negligible differences in the recompression (Cr) and discharge process (Cd). Nevertheless, a noticed difference can be observed in the compression interval (Cc). This difference, that is about 45%, indicates that deformation ratio in pure compression was smaller for soil+RHA than soil specimen.

Conclusions

The use of rice husk ash looks like an environmental friendly alternative to reduce landfills areas, besides reducing the collapsible soil behavior. In this way, the improvement manifests itself in terms of smaller total deformation, showing a significant increase on the resistance of soil+RHA mixture, less plastic behavior in the compression interval and smaller collapse settlement.

Acknowledgements

Authors would like to thanks to PROPe – Pró-reitoria de Pesquisa da UNESP and to FUNDUNESP (processo n° 0382/001/14).

References

[1] J.A. Lollo, Solos Colapsíveis: identificação, comportamento, impactos, riscos e soluções tecnológicas, first ed., Cultura Acadêmica, São Paulo 2007 (in portuguese).

[2] J.E. Jennings, K. Knight, A guide to construction on or with materials exhibiting additional settlement due to “collapse” of grain structure, Proceedings of VII REG. Conference for Africa on soil mechanics and foundation engineering, 1, (1975) 99-105.

[3] C.M.G. Oliveira, J.A. Lollo, Uso da Avaliação do Terreno para o zoneamento de solos colapsíveis na área urbana de Ilha Solteira (SP). In: Simpósio Brasileiro de Cartografia Geotécnica (2001) CD-ROM (in portuguese).

[4] R.A. Rodrigues, A. Souza, J.A. Lollo, Estudo da colapsibilidade dos solos de Ilha Solteira (SP) para projetos de fundações rasas e profundas. In: Congresso Brasileiro de Mecânica dos Solos e Engenharia Geotécnica 12 (2002) CD-ROM (in portuguese).

[5] R.A. Rodrigues, Modelação das deformações por colapso devidas à ascensão do lençol freático. Tese (Doutorado), Escola de Engenharia de São Carlos, Universidade de São Paulo (2007) (in portuguese).

[6] R.A. Rodrigues, J.A. Lollo, Influence of domestic sewage leakage on the collapse of tropical soils. Bull. Eng. Geol. Environ. 66 (2007) 215-223.

[7] J.A. Lollo, R.A. Rodrigues, V.R. Elis, R. Prado, Use of electrical resistivity to identify collapsible soils in Brazil. Bull. Eng. Geol. Environ. 66 (2011) 299-307.

[8] R.A. Rodrigues, . A influência do esgoto doméstico como fluido de saturação no colapso de um solo arenoso. Dissertação (Mestrado), UNESP – Campus de Ilha Solteira (2003) (in portuguese).

[9] M.M. Tashima, C.A.R. Silva, J.L. Akasaki, M.B. Barbosa, The possibility of adding rice husk ash (RHA) to the concrete. In: Conference on the use of recycled materials in the building and structures (2004).

[10] M.M. Tashima, Cinza de Casca de Arroz altamente reativa: método de produção, caracterização físico-química e comportamento em matrizes de cimento Portland. Dissertação (Mestrado), UNESP – Campus de Ilha Solteira (2006) (in portuguese).

[11] M.M. Tashima, C.F. Fioriti, J.L. Akasaki, J. Payá, L.C. Souza, J.L.P. Melges, Cinza de casca de arroz (CCA) altamente reativa método de produção e atividade pozolânica. Ambiente Construído (Online), 12 (2012) 151-163 (in portuguese).

[12] J.R.S Rêgo, As cinza de casca de arroz (CCAs) amorfa e cristalina como adição mineral ao cimento – aspecto da microestrutura das pastas. Tese (Doutorado), Universidade de Brasília (2004) (in Portuguese).

[13] J. Torkoman, A. Ashori, A.S. Momtazi, Using wood fiber waste, rice husk ash, and limestone powder waste as cement replacement materials for lightweight concrete blocks. Constr. Build. Mater. 50 (2014) 432-436.

[14] J. Payá, La transmutación sostenible de los residuos para nuevas materias primas en el ámbito del concreto. Dyna, edición especial (2012), 38-47.

Non-Conventional Materials and Technologies for Sustainable Development
10.4028/www.scientific.net/KEM.668

Improvement of Collapsible Soil Behavior of a Lateritic Soil Using Rice Husk Ash
10.4028/www.scientific.net/KEM.668.290

DOI References

[6] R.A. Rodrigues, J.A. Lollo, Influence of domestic sewage leakage on the collapse of tropical soils. Bull. Eng. Geol. Environ. 66 (2007) 215-223.
10.1007/s10064-006-0065-y
[5] R.A. Rodrigues, Modelação das deformações por colapso devidas à ascensão do lençol freático. Tese (Doutorado), Escola de Engenharia de São Carlos, Universidade de São Paulo (2007) (in portuguese).
10.14393/19834071.2014.26852
[4] R.A. Rodrigues, A. Souza, J.A. Lollo, Estudo da colapsibilidade dos solos de Ilha Solteira (SP) para projetos de fundações rasas e profundas. In: Congresso Brasileiro de Mecânica dos Solos e Engenharia Geotécnica 12 (2002) CD-ROM (in portuguese).
10.5585/exacta.v4i1.670
[3] C.M.G. Oliveira, J.A. Lollo, Uso da Avaliação do Terreno para o zoneamento de solos colapsíveis na área urbana de Ilha Solteira (SP). In: Simpósio Brasileiro de Cartografia Geotécnica (2001) CD-ROM (in portuguese).
10.1590/s0100-69162010000500019
[2] J.E. Jennings, K. Knight, A guide to construction on or with materials exhibiting additional settlement due to collapse, of grain structure, Proceedings of VII REG. Conference for Africa on soil mechanics and foundation engineering, 1, (1975).
10.1016/0148-9062(75)91203-6
[1] J.A. Lollo, Solos Colapsíveis: identificação, comportamento, impactos, riscos e soluções tecnológicas, first ed., Cultura Acadêmica, São Paulo 2007 (in portuguese).
10.11606/issn.2238-6149.v18i1p22-29
[14] J. Payá, La transmutación sostenible de los residuos para nuevas materias primas en el ámbito del concreto. Dyna, edición especial (2012), 38-47.
10.1787/888933091049
[13] J. Torkoman, A. Ashori, A.S. Momtazi, Using wood fiber waste, rice husk ash, and limestone powder waste as cement replacement materials for lightweight concrete blocks. Constr. Build. Mater. 50 (2014) 432-436.
10.1016/j.conbuildmat.2013.09.044
[12] J.R. S Rêgo, As cinza de casca de arroz (CCAs) amorfa e cristalina como adição mineral ao cimento - aspecto da microestrutura das pastas. Tese (Doutorado), Universidade de Brasília (2004) (in Portuguese).
10.1590/s0100-69162008000200002
[11] M.M. Tashima, C.F. Fioriti, J.L. Akasaki, J. Payá, L.C. Souza, J.L.P. Melges, Cinza de casca de arroz (CCA) altamente reativa método de produção e atividade pozolânica. Ambiente Construído (Online), 12 (2012) 151-163 (in portuguese).
10.1590/s1678-86212012000200010
[10] M.M. Tashima, Cinza de Casca de Arroz altamente reativa: método de produção, caracterização físico-química e comportamento em matrizes de cimento Portland. Dissertação (Mestrado), UNESP - Campus de Ilha Solteira (2006) (in portuguese).

10.1590/s1678-86212012000200010
[9] M.M. Tashima, C.A.R. Silva, J.L. Akasaki, M.B. Barbosa, The possibility of adding rice husk ash (RHA) to the concrete. In: Conference on the use of recycled materials in the building and structures (2004).
10.1590/s1983-41952013000500007
[8] R.A. Rodrigues, . A influência do esgoto doméstico como fluido de saturação no colapso de um solo arenoso. Dissertação (Mestrado), UNESP - Campus de Ilha Solteira (2003) (in portuguese).
10.1590/s1413-41522010000100004
[7] J.A. Lollo, R.A. Rodrigues, V.R. Elis, R. Prado, Use of electrical resistivity to identify collapsible soils in Brazil. Bull. Eng. Geol. Environ. 66 (2011) 299-307.
10.1007/s10064-011-0357-8