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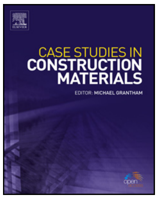

Implementing a fast, practical, and rational quality control technique at a soil mixture production plant, based on a continuous and quantitative classification of materials: A case study

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ABSTRACT

This study analyzed the variability in the production of batches of a soil mix prepared from cohesive and granular material, in an improved materials production plant. For soil analysis, a non-dimensional number known as characteristic factor was used, in order to provide a quantitative and continuous classification for the mix; in addition, it was sought to link this non-dimensional number to particle size-analysis and liquid limit of soils obtained from the same geological formation. This study shows that with the use of a quantitative and continuous classification, quality control was optimized not only during production at the production plant but also at the construction site. It is also shown that if the characteristic factor of the soil mixture is close to the predefined characteristic factor, there is a high probability that the mechanical response of the material measured at the production plant will be close to the mechanical response evaluated at the construction site, as long as the conditions of water content and dry unit weight are close to the optimum value of the compaction curve's laboratory.

1. Introduction

Soil improvement by mixing two materials is a common technique used in construction of roadways [1]. This technique is especially used when cohesive material is involved, because construction standards set a specific range of values for the liquid limit, the plasticity index, and the bearing capacity (i.e. California Bearing Ratio, also known by CBR), and because, in general, in cohesive soils these values do not fall within the required range [2]. The problems with the mechanical and plasticity properties of cohesive soils have promoted the development of technology for soil improvement; such techniques often involve mixing soils with polymers, chemical products, cement, and other materials ([3–6]).

The mixture of granular material and cohesive material is preferred over any other soil improvement technique, as long as both materials are readily available in quantity and quality [1].

Regarding soil improvement techniques, it is frequent to find in the literature investigations in which soil improvement is carried out in the laboratory, where the investigator controls variables at will, and where the working material is dry, the

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weight is dosed, particle grain size is controlled, and environmental temperature and relative humidity are controlled [2]. In contrast, at civil construction sites, conditions are hardly controlled: aggregates are wet, the dose generally is done by volume, the grain size is affected by changes in geological formation, etc. [7].

In production plants of soil mixtures, soil batches are frequently accepted if they possess a certain particle grain size, if they fall within consistency limits, and if they meet the qualitative classification ASTM D3282 [8]. This qualitative classification can lead to erroneous “false-positive” acceptance of a batch of material; for example, a material classified as A-4 with a 1% variation above the liquid limit and above the plasticity index can be erroneously classified as A-7 [8]. This abrupt leap in the qualitative classification of soils can be solved through the use of a quantitative and continuous soil classification criterion [9], such a criterion would be especially useful in production and quality control projects, in which a minimum difference in particle grain size and consistency limit can lead to a precipitated decision to reject or accept a batch of improved material, entailing economic losses and waste of time for construction companies.

In 2002 Sánchez-Leal and collaborators published RAMCODES, an acronym of Rational Methodology for Compacted Geomaterial’s Density and Strength Analysis [10], a methodology which essentially deals with most aspects of design and quality control of compacted soils. In subsequent publications, Sánchez-Leal and collaborators included into RAMCODES various methodological techniques related to the optimization of aggregates for asphaltic mixtures (gradation chart) [11], to the optimization of binding in asphaltic mixes (polyvoid) [12], to the design of compacted materials based on performance criteria [13], and to quality control of asphalt mixtures and compacted soils using resistance maps that are based on statistical techniques and multifactorial experiments [14].

The RAMCODES methodology defined the “characteristic factor” (Fp) as a non-dimensional number in which particle grain size and plasticity properties are involved, in order to provide a quantitative and continuous classification of soils [9,10,13]. In addition, because the RAMCODES methodology proposed a characteristic factor for asphaltic mixes, the characteristic factor for soils mixtures provides a quasi-linear relation between basic material properties (i.e. particle grain size and liquid limit) and density potential (i.e. maximum dry unit weight and optimum water content) for soils from the same geological region [11].

The characteristic factor (Eq. (1)) for soils containing granular and cohesive particles (soil mixes) is given by:

$$F_p = (1 + w_L)\frac{F}{1+G} \tag{1}$$

where w_L represents the liquid limit of the material, F represents the fraction of the material which passes sieve N°200, and G represents the fraction of the material retained in the sieve N°4; each of these values is expressed in decimal form.

According to the quantitative and continuous classification of soils, for a given characteristic factor value, the mechanical response of a material remains relatively constant, when the proportion of fine particles and the liquid limit are varied independently or in combination [10].

This study presents a case study in which the characteristic factor was used for analysis of the variability in the production of batches of soil mixtures in a production plant in Urubó, Bolivia. In addition, the variability in the mechanical properties of a soil resulting from mixing cohesive soil and granular soil was analyzed, which will be used as base course for hydraulic concrete pavement and its response in quality control tests at a civil construction site.

2. Methodology

2.1. Origin of materials

Granular soil was obtained from bank storage of materials located on the banks of the Piray River; the cohesive soil was obtained from the site called *Colinas del Urubó*; both sites are located to the west of Santa Cruz city, Bolivia. Materials were not submitted to any treatment before the mixing process.

2.2. Experimental methodology

Representatives samples of the material were taken from stockpiled materials laying on the work esplanade of the Urubó mixtures production plant, located in *Colinas del Urubó*. Samples were transported for characterization to the laboratory of soil mechanics.

At the production plant, materials were descriptively classified as granular and cohesive, and submitted to particle size-analysis [15], submitted to analysis of specific gravity of soil solids [16], and submitted to compaction test in laboratory [17]. In addition, consistency limits of the cohesive soil were analyzed [18]. Granular and cohesive soils were also classified according to RAMCODES methodology, as well as to standard ASTM D3282 [8] for the classification of materials for highway construction purposes.

The material resulting from a mixture whose properties were pre-established by the engineers in the materials production plant (see Fig. 1a and b) was used for analysis of particle size [15], of consistency limits [18], and for laboratory compaction test [17] (see Fig. 2a and b). This material was also tested for bearing capacity in the laboratory; CBR was thus assessed at maximum dry unit weight and optimum water content [19]. The soil was classified according to RAMCODES methodology for compacted soils (Eq. 1) [10], and according to the qualitative classification of soils suggested by ASTM D3282 [8].