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Crushing of non-cohesive soil grains under dynamic loading

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Abstract

Dynamic impact loading may cause gradual crushing of soil grains, especially when soil grains are characterised by weak strength or when the geologic history of the soil has influenced on material fatigue. The aim of the work is to identify the soil crushability during dynamic compaction, as well as the effect of a gradual grain crumbling on changes of the maximum dry density and the uniformity coefficient. All tests were performed for genetically different non-cohesive soils from various Polish areas. In Pleistocene river sands and in the sea sands – repeated compaction does not improve the coefficient of uniformity and does not result in significant changes in the maximum dry density. In the river sands from Holocene alluvial deposits, multiple compaction causes a significant increase in value of $\rho_{d\,max}$. In glaciofluvial sands and gravel multiple compaction increases the maximum dry density and uniformity coefficient of compacted soil. The monomineralic soils was characterised by values of $C_U < 3.0$, and the polymineralic soils – by values of $C_U \geq 3.0$.

Keywords: soil grain crushing, dynamic loading; non-cohesive soil; mineral composition; soil origin

1. Introduction

The strength and stress-strain relation is influenced by the extent to which soil particle breakage appears during loading and deformation. Hardin [1] determined that particle crushing may take place in soil under stress depending on: particle size distribution, particle shape, state of effective stress, effective stress path, void ratio, particle hardness

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Nomenclature

C_U	coefficient of uniformity (–), $C_U = D_{10}/D_{60}$
D_{10}, D_{60}	equivalent grain diameters for which 10% and 60% of the soil by weight is finer (mm)
$\rho_{d\,max}$	maximum dry density at optimum water content by the standard Proctor method (Mg/m^3)

and the presence of water. The effect of moisture on particle crushing depends on particle size [2] – it increases the particle crushing for large grains, and decreases for small one. The change in particle regularity may result in [3]: increase in void ratio and compressibility, decrease in small-strain stiffness, and impact on critical state parameters. Lade et al. [4], having analysed many reference papers on this subject, made a conclusion that soil particle breakage may occur even at relatively low pressure. They described some measures that had been proposed earlier to quantify the amount of particle breaking, more often based on a single particle size or soil grain size distribution. After several high-pressure triaxial compression and extension tests they concluded a lack of a single unifying variable for correlations between them and geotechnical parameters at failure.

Most frequently, the soil is gradually destroyed (crushed) during dynamic compaction at earthworks. In laboratory conditions, a similar process may occur when determining the compaction parameters of soil by the Proctor test. Dynamic interaction may cause gradual crushing of grains in the examined soil, especially when they are characterised by a low strength or when the geologic history of the ground had an impact on material fatigue [5]. By default, it is assumed that changes in particle size, resulting from the process of compaction and crushing of soil grains, always interact favourably – by improving gradation of compacted soil and facilitating compaction [6]. An interesting issue of cognitive and practical point of view, is to recognize what types of soil (i.e. of what genesis and what grain size) are the least vulnerable to crushing in Proctor's mould, and how the effect of a gradual crushing of grains translates into a change of compaction parameters and change of uniformity coefficient (C_U).

The aim of the work is to identify the soil susceptibility to crushing in the Proctor mould, as well as the effect of a gradual grain crumbling on changes of the maximum dry density and the uniformity coefficient. All tests were performed for genetically differential non-cohesive soils, from various Polish areas, with graining of medium sand, and sand and gravel mix.

2. Materials and methods

All tests were performed for non-cohesive, genetically differential soils from various Polish areas, with a grain size of medium sand (MSa) and sand and gravel mix (saGr) – according to EN ISO 14688-2. 2004 [7]: sea sand from the area of beach, river sands from former and present flood plain terraces, and glaciofluvial sands and gravel. The soils were named after the collection site. The characteristics of tested soils are presented in Table 1. The mineral composition of soils has been determined based on an optical microscope studies and on the basis of scanning electron microscopy (SEM) using a microprobe EDS (Energy Dispersive X-ray Spectroscopy). The research was conducted at the Faculty of Geology of University of Warsaw. The mineral composition of soil varies depending on: the fraction of soil, sediment environment and the length of the transport path. A microscopic examination with an optical microscope was performed on separate fractions: 0.5-1.0 mm, 1.0-2.0 mm, and > 2 mm.

Table 1. Tested soil characteristics.

Soil name	Symbol	Place of occurrence	Genesis	Basic mineral composition
Wladyslawowo	MSa	Baltic Sea/beach	Littoral sand	quartz
Bialoleka	MSa	River Vistula’s former flood plain terrace	River sand (Pleistocene)	quartz
Wilanow	MSa	River Vistula’s former flood plain terrace	River sand (Pleistocene)	quartz
Nowa Biala	MSa	River Bialka’s present flood plain terrace	River sand (Holocene)	sandstones, granitoid, quartz
Rudno Jeziorowe	saGr	Mine of gravel and gravel/sand mix	Glaciofluvial soil (Pleistocene)	quartz, feldspars, lithics*
Debinki	saGr	Mine of gravel and gravel/sand mix	Glaciofluvial soil (Pleistocene)	quartz, feldspars, lithics*

Explanations: *lithics – grains: granitoid, gneiss and limestone (smaller amount).