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Carbon Footprints of Ground Improvement Techniques - Case Studies

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ABSTRACT

Geotechnical projects generally consume large quantities of resources and energy and release considerable amounts of CO2 in the atmosphere, and therefore, have a significant impact on the environment. To minimize this effect, sustainable solutions and materials have been proposed and adopted in literature and practice as alternatives to conventional methods wherever applicable. This study reviews and discusses sustainability in geotechnical engineering, in particular, three ground improvement techniques including deep soil mixing (DSM), dynamic compaction, and vibro replacement (VR) compared to the piling method. Three case study projects in Saudi, Egypt, and the UAE were selected for this comparison. Some eco-friendly recommendations are proposed to mitigate the environmental loads of the discussed ground improvement techniques. Moreover, the carbon footprints of three case study projects, each with three alternative solutions (i.e., piling, DSM, and VR), are assessed and compared in two conditions, namely, with and without eco-friendly measures (i.e., substituting new materials with recycled or recovered construction materials or with the by-products of other industries). In the cases studied, the CO2 discharge amounts of DSM and VR were found to be around half and one-tenth of that amount in piling. The CO2 emissions of all three products showed a significant decrease when adopting the eco-measures, with average, of 34, 60, and 14% for piling, DSM, and VR, respectively. Finally, the CO2 emissions of the above cases are presented in functional units.

1. INTRODUCTION

The construction industry is responsible for approximately 40% of the globally consumed energy (Dixit et al., 2010), and consequently significantly contributes to air pollution (Kibert, 2008; Basu et al., 2015). Geotechnical phases of civil projects are no exceptions and can even more directly affect the environment. Hence, improving geotechnical processes environmentally will help in achieving a more sustainable society.

In construction projects -including the geotechnical phases- financial aspects have been typically considered as the main, if not the only, deciding criterion (Basu and Puppala, 2015); however, more recently reducing the CO2 footprint has gained the attention of the researchers in the past years (Fragaszy et al., 2011). More recently and thanks to the increasing awareness regarding sustainable developments, the trend is turning to take the overall cost and environmental impacts as the two key factors of the decision process of projects (Shillaber et al., 2016a). The term "Carbon Critical Design" refers to designs in which carbon emission is considered as a critical parameter (Clarke, 2010).

When it comes to ground engineering, ground improvement techniques are usually known to be less harmful to the environment compared to conventional solutions such as deep or heavy foundations in terms of CO2 emission and energy consumption, subject to the type of technology, design, and other project specific factors (Spaulding et al., 2008; Egan and Slocombe, 2010; Gomes Correia et al., 2016).

2. OBJECTIVES OF THIS STUDY

In this study, first, sustainability in geotechnical engineering is discussed, and then three ground improvement techniques (i.e., vibro replacement, dynamic compaction, and deep soil mixing) are described together with some recommendations to minimize their environmental loads. Next, the environmental impacts of three real projects in Saudi, Egypt, and the UAE, for which various alternative geotechnical solutions were proposed, are analyzed and discussed, and finally, the eco-friendly recommended measures are applied to the studied cases to evaluate their influences. The results of this work, however, should not be generalized to other geotechnical projects unless detailed studies have been carried out.

3. RESULTS

Geotechnical engineers can and should contribute to sustainable designs by adopting environmentally friendly alternative techniques that minimize the use of energy and the production of CO2 (e.g., VR or DSM instead of piling where interchangeable).

The CO2-eq emissions of three real projects, each with three alternative geotechnical techniques, were analyzed using typical and eco-friendly execution procedures. The proposed eco-friendly measures were the substitution of energy-consuming materials (i.e., steel, cement, and aggregate) with more sustainable alternatives (i.e., recycled steel, GGBS, and recycled/recovered aggregate). The use of these materials was proved to have significant impacts on the carbon emission of the projects while keeping the same technical quality of work.