Journal of Building Engineering 9 (2017) 177–191

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

A study on the potential utilization of crumb rubber in cement treated soft clay

J.S. Yadav*, S.K. Tiwari

Civil Engineering Department, Malaviya National Institute of Technology, Jaipur 302017, India

ARTICLE INFO

Keywords:
Cement stabilized clay-rubber mixtures
Compaction
Strength
CBR
Consolidation
Swelling pressure

ABSTRACT

The present study investigates the geotechnical characteristics of cemented clay-crumb rubber mixture through a series of compaction, UCS, STS, CBR, one-dimensional consolidation and swelling pressure tests. Crumb rubber (0.8–2 mm size) and cement content in the mixtures were 0%, 2.5%, 5%, 7.5%, and 10%, and 0%, 3%, and 6% by the dry weight of the specimens, respectively. The results of experimental research indicated that incorporation of crumb rubber in cemented clayey soil decreases the UCS and STS but prosperously able to overcome the brittleness of cemented clay in compression and tension. The CBR values of the composite having 6% cement were found to be propitious for its use as road sub-base with light traffic. It was also noticed that crumb rubber helps in reducing the swelling pressure and compression index of the mixes, which make it is a good candidate for lightweight fill material behind the retaining walls and embankment construction. Incorporation of crumb rubber in uncemented and cement clayey soil potentially reduces the reinforcement cost and deteriorating impact of waste tire disposal on the environment.

1. Introduction

The two arguable problems associated with cohesive soil are its low strength and high compressibility. These problems could be overcome by using well-established techniques of chemical stabilization. However, the addition of chemical stabilizers such as cement or lime leads to a high stiffness and brittle behaviour [1–4]. Incorporating reinforcement (such as polypropylene fibre, polyester fibre, carpet fibre, steel fibre, etc.) inclusions in treated soil can provide an efficient and reliable way to solve the problem of high stiffness and brittle behaviour [2,5–7]. Fatahi et al. [6] reported that the inclusion of polypropylene fibres, carpet fibres and steel fibres in the cement treated kaolinite increases the shear strength, reduces stiffness and changes the brittle behaviour of cemented kaolinite clay to ductile behaviour. The utilization of reinforcement techniques available in the markets are costly and requires trained labour for its application. Therefore, there is eager to probe new reinforcement material, which is cost effective and having durability, strength, resiliency, higher frictional resistance, etc.

The potential utilization of waste tire is nowadays has become a major challenge in front of the engineering community because of its deteriorating impact on the quality of the environment. About 1.5 billion tires are manufactured in the world per annum and 1000 million tires reach the cessation of their subsidiary life every year. This number can gain up to 1200 million tires per year, by the year 2030. In Indian scenario, 112 million discarded tires generated per year [8,9]. These discarded tires are disposed to either landfills, stockpiled or burn off, which causes serious health and ecological problems. The recycling and reuse of these discarded waste tires can only minimize its environmental impacts. Many attempts have been made for its utilization in concrete, asphalt pavement, waterproofing system and membrane liner, etc. However, the knowledge about its utilization in geotechnical engineering is minimal and even scarce especially for cohesive soil.

1.1. Background

Many researchers have utilized the waste tires as reinforcement for soft soils, in the stabilization of slopes, and as a lightweight material for road construction and back filling purposes. The problems of settlement and cracking were faced in the past by the authors [10,11] due to the development of exothermic reaction, when the pure tire shreds were utilized for civil engineering applications. Hence, in the recent years, the research has been directed toward its utilization as partial replacement of soil. Geotechnical properties of sand- rubber tires (different types as classified by ASTM D 6270-98 [12]) mixtures depend on the ratio of scrap tire and sand [13–22], confining pressure in triaxial tests [13,18,20,23,24], normal stress in direct shear tests [14–17,19], unit weight of the sand matrix [14–16,18,19], and aspect

* Corresponding author.
E-mail addresses: jitendershine@gmail.com (J.S. Yadav), sktiwari.ce@mnit.ac.in (S.K. Tiwari).

http://dx.doi.org/10.1016/j.jobe.2017.01.001
Received 26 May 2016; Received in revised form 9 November 2016; Accepted 4 January 2017
Available online 05 January 2017
2352-7102/

ratio of tire shreds or chips [18–20]. The incorporation in waste tires in sand (i) leads to lowering the unit weight of the composite because of the low specific gravity of rubber tire particles; (ii) improves the shear strength and angle of friction because of the development of apparent cohesion due to interlocking of the sand and shredded tires; (iii) results in lesser compressibility because of the elastic behaviour of sand-rubber mixtures. Very few researchers in the past conducted studies on the incorporation of variant types of waste tires in clay at varying percentages along with and without the use of pozzolanic materials.

Al-Tabbaa et al. [25] noted a decrease in the density, strength, and permeability of different clayey soils mixed with 20% tire. In another study carried out by Al-Tabbaa and Aravinthan [26], clay was mixed with 1–4 mm and 4–8 mm, angular size shredded tire, in the weight percentage between 6% and 15% for its utilization as landfill barrier materials. They concluded that as tire content in the mix increases, the maximum dry density decreases, and optimum moisture content roughly remains the same. They also observed a decrement in unconfined compressive strength and the increment in strain rate corresponding to the maximum stress. Cetin et al. [27] have studied the effect of fine and coarse-grained tire chips on the engineering properties of cohesive soil. Authors suggested that 20% coarse-grained (between 2 and 4.75 mm in size) and 30% fine grained (under 0.425 mm in size) tire chip incorporated with clay can be used as fill materials due to its low dry unit weight, increased shear strength, and increased permeability. It contradicts to work carried out by Al-Tabbaa et al. [25] because of the size of waste used. Özkul and Baykal [28] reported that with the inclusion of 10% rubber fibres (retained between Sieve No. 4 to Sieve No 10.) in kaolinite rich clay gave peak strength greater or comparable to that of clay alone under confining stresses below 200–300 kPa. However, no alterations in the permeability were observed, which is contrary to the other researchers [27]. Akbulut et al. [29] noted a maximum increment in the unconfined compressive strength; shear modulus and damping ratio of clay mixed with 2% rubber fibre of length 10 mm. The test results of Hong and Shahin [30] stated that shredded rubber tires of size 440 µm and 4 mm, varying from 0% to 7% possessed the potential to enhance the ductility of cement-stabilized clay but decreases stiffness and ultimate resistance. Chan [31]studied the use of rubber shreds (< 2 mm thick, 0.425–12 mm in length) varying from 0% to 4% and cement (4%) in the clayey sand. The rubber shred compensates the rigidity and brittleness caused by cementation. Ho et al. [32] scrutinized the influence of rubber tire chips (2–5 mm average size) varying from 0%, 5%, 10%, and 15% on the one-dimensional compressibility characteristics of cemented clay. An increment in vertical effective stress and a reduction in the coefficient of compression and recompression was noticed in the composite. A series of isotropic compression and triaxial consolidation undrained compression tests were carried out by Xin et al. [33] on cemented soil-tire chips mixtures. They concluded that the undrained strength of the composite increases by adding more tire chips whereas compressibility did not change very much by adding 0–60% rubber tire chips. An increase in the hydraulic conductivity and decrease in the swelling pressure was observed by Kalkan [34] while modifying the geotechnical properties of clayey soil using scrap tire rubber fibre of length 5–10 mm varying from 0% to 4% and silica fume (10% and 20%). The maximum improvement in UCS value, cohesion, and angle of internal friction was obtained by adding 20% silica fume and 2% rubber fibre in the mixture. The optimal dose of rubber fibre was found similar as reported by Akbulut et al. [29]. In another research work conducted by Cabalar et al. [35] on stabilization of clay using tire buffing (falling between 0.6 and 4.75 mm size, varying from 0%, 5%, 10%, and 15%) and lime (varying from 0%, 2%, 4%, and 6%) stated that the addition of the tire buffing in the clay markedly reduces the CBR and UCS values. A small quantity of lime up to 4% gave the highest CBR and UCS values for clay treated with/without tire buffing. A significant influence of rubber fibre in the development of cohesion and angle of internal friction was observed by Das and Singh [36] under consolidated drained triaxial test for cohesive soil-fly ash waste tire mixes. Guleria and Dutta [9] examined the effect of treatment of rubber chips (10 mm sizes) on the tensile and compressive behaviour of fly ash+8% lime+0.9% gypsum. The highest improvement in strength and strain was obtained for carbon tetrachloride treated tire chips. Cokca and Yilmaz [37] suggested that fly ash with 10% rubber and bentonite could be as used for the construction of the liner because of increase in hydraulic conductivity and flexibility. The enhancement in the plastic energy capacity, allows the significant deformation at the time of failure. Srivastava et al. [38] reported an improvement in the engineering properties of black cotton soil by the use of shredded waste tires. They concluded that the inclusion of coarse size shredded tire waste (4.75 mm passing –2 mm retaining) was more beneficial for reducing the swell percent, swelling pressure and gave relatively higher undrained cohesion for partially replaced black cotton soil by finer size shredded tire waste (2.00 passing- 75 µm retaining). A similar observation was made by Seda et al. [39] with the addition of 20% waste tire rubber in expansive soil along with the increase in the compressibility. Contrary to this, Wang and Song [40] reported that size of crumb rubber does not make a significant difference in UCS of rubberized cemented soil.

Based on the critical review of the available literature and to the best of our knowledge, very few studies on the cemented clay-crumb rubber mixtures have been carried out. Hence, rigorous research and the systematic experimental investigation are needed to predict the feasibility of the utilization of crumb rubber in the cemented clayey. The proposed composite could be used in low volume road projects and as lightweight backfill materials for retaining walls to accomplish the growing demands for new construction materials and potential utilization of waste tires in sustainable and environmentally friendly approach.

1.2. Scope of present study

In this scenario, a thorough assessment of the potential utilization of crumb rubber in the cemented clayey soil was carried out. The behaviour of the proposed composite was examined thoroughly through a series of compaction, unconfined compressive strength, split tensile strength, California bearing ratio, one-dimensional consolidation, and swelling pressure tests. The crumb rubber was added to the cement stabilized (3% and 6%) clayey soil at ranges of 2.5–10%. This paper presents an overview of the work carried out and the salient conclusions drawn from an application perspective.

2. Materials and experimental program

2.1. Materials

2.1.1. Soil

The soil used in the testing program was Illite clay taken from Kanota, a town near Jaipur, Rajasthan, India. The soil was classified as clay, with low plasticity, CL as per Indian Standard Soil Classification System (IS 1498–1970) [41]. Table 1 shows the geotechnical properties of the soil. It consists of high Illite content with quartz and some kaolinite as indicated in the X-ray diffraction pattern for mineralogical

Table 1
Soil properties.

Soil properties	Values
Specific gravity	2.69
Liquid Limit (%)	34.2
Plastic Limit (%)	24.8
Plasticity Index	9.4
Maximum Dry Unit Weight (kN/m^3)	16.35
Optimum Moisture Content (%)	20.89