STUDY ON THE APPLICABILITY OF TIRE-DERIVED GEOMATERIALS IN THE MARINE LANDFILL SITES

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論 文 名 ： **STUDY ON THE APPLICABILITY OF TIRE-DERIVED GEOMATERIALS IN THE MARINE LANDFILL SITES**
（海面埋立処分場におけるタイヤ由来の地盤材料の適用性に関する研究）

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論 文 内 容 の 要 旨

The number of marine landfills in Japan has increased in the last decade due to the lack of suitable land in coastal metropolises and their important role in the disposal of debris after colossal disasters. In addition, marine landfill sites have a larger waste accumulation capacity as compared to onshore landfill sites. In the construction of marine landfills, the alluvium clay layer generally serves as an impermeable barrier against the seepage of waste leachate at the bottom of the landfill.

To prevent polluted leachate from seeping into the ocean, it is essential to protect this impermeable layer during long-term waste placement operations and consolidation. Furthermore, long-term consolidation of waste may result in a reduction of internal drainage capacity. Therefore, to mitigate the damage to the alluvium clay layer and to improve the leachate collection capability during long-term waste placement, a new low-cost and environmentally friendly technique using tire-derived geomaterials has been developed and proposed in this research.

Here, to overcome the above problems, a coarse-grained gravel-tire chips mixture (GTCM) is used as a horizontal reinforcement and cushioning layer beneath the waste material. This layer will reduce uneven settlement while acting as a cushion against the waste and improving the leachate collection capacity of the landfill.

To evaluate the performance of GTCM as a reinforcement, cushioning, and drainage material, in this research, experimental investigation, theoretical study and numerical simulation were performed. The research mainly consists of the following two parts. For the drainage performance of GTCM, a series of triaxial compression and permeability tests were conducted. Here, the permeability characteristics were evaluated based on the particle size, tire chip content, and different loading conditions. The experimental results confirmed the excellent drainage performance of GTCM. In addition, the effects of transient and long-term cushioning were evaluated by impact loading test, theoretical and numerical analysis respectively.

This thesis is organized into six chapters. The contents of each chapter are briefly summarized as follows:

Chapter 1 presents an introduction to this research, the current problems, and the motivation to conduct this research. Furthermore, the organization of the thesis and original contributions of this research were also presented.

Chapter 2 includes a brief summary of the literature review that has been carried out. This

chapter starts with summarizing leachate collection systems in practice. Next, an overview of the mechanical properties, hydraulic conductivity, aging resistance, and sorption properties of tire-derived geomaterials was presented. It can be concluded that tire-derived geomaterials have significant potential as drainage and reinforcement materials in marine landfills.

Chapter 3 presents the design and development of a new medium-scale triaxial compression and permeability testing apparatus. The inherent nature of GTCM tests required the in-house design of the laboratory testing machine and units and components. Regarding this experimental apparatus, a series of technical issues related to the central axis strength and thickness of the rubber membrane as well as hydrostatic head control were presented, and the corresponding countermeasures were suggested. It was observed that this apparatus is very effective in the testing permeability and compressibility of materials with large particle sizes.

Chapter 4 concentrates on the mechanical and drainage behavior of GTCM using this medium-scale triaxial compression and permeability test apparatus. The effects of MPTC (mass proportion of tire chips), tire chip particle size, and confining pressure on the stress-strain relationship and permeability of GTCM were investigated. For compressibility, it was found that the size of mixed tire chip particles has no effect on shear strength. As for permeability, the nonlinear Forchheimer's law is more acceptable compared to Darcy's law for the GTCM sample. It can be observed that the porosity of GTCM changes only slightly above a certain pressure condition. In this study, the mass fraction and particle size have limited influence on the permeability of GTCM under these loading conditions. In addition, an approximate power function was established between the permeability coefficient and the non-Darcy coefficient. The results showed that GTCM is an excellent drainage material for landfill drainage layers due to the acceptable level of permeability coefficient even under high pressure. Moreover, the hydraulic gradient of GTCM in the non-Darcy state can be easily expressed by the flow velocity and permeability coefficient, and can be easily applied in practice.

Chapter 5 focuses on the transient impact absorption property of GTCM and the reinforcing effect on the horizontal reinforcing cushion to protect the alluvium clay layer over a long period of time. The impact absorption effect of the composite structure of tire chips- gravel was illustrated by the results of impact load tests. In addition, a simple procedure based on the law of conservation of energy was developed to calculate waste penetration depth underwater. Finally, the long-term effectiveness of this technique was discussed using numerical studies. It was found that the performance of maximum impact absorption is 8% higher than in the case of gravel due to the elasticity of tire chips. In the theoretical study of the penetration depth, the calculated results agreed well with the results of the input test. In addition, both the shape and the weight of the waste were considered to influence the penetration depth. The results showed that the effective tire fraction should be less than 20% to ensure sufficient impact resistance of the GTCM. The numerical results confirmed that the GTCM reinforcement can help to limit the soil settlement and to provide bearing support to the vertical load from the waste in the long term. In conclusion, the content of tire chip content has a great influence on the cushioning performance, and content of less than 20 percent is recommended in the design consideration.

Chapter 6 concludes the results and achievements of this study.