学 位 論 文 要 旨

Study on resistance to erosion of irrigation facilities by using cement mixed soils
(セメント混合土を用いた灌漑施設のエロージョン抵抗性に関する研究)

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In most developing countries, earth irrigation facilities are commonly found due to the low construction cost. However, most earth irrigation structures are so sensitive to heavy rainfalls and soil erosion. Surface erosion, one type of erosion involving the detachment of surface soil particles and water flowing on the surface, is one of the main causes of embankment failures. Using the high erodible soil materials to construct earth embankments, the occurrence of erosion has increased. The eroded soils from embankments and deposition of sediment in irrigation systems frequently reduce the capacity of irrigation, block irrigation channels and shorten the lifespan of irrigation systems resulted in most irrigation schemes damage. In Cambodia, most irrigation structures are earthworks. The surface erosion occurred on earth embankments usually caused big concerns for irrigation rehabilitation work. Silt is usually found in irrigation systems, and it is the most sensitive soil to erosion. Therefore, the aims of this study were: (1) to investigate the field situation and eroded earth irrigation facilities in Cambodia, (2) to determine the physical, mechanical and hydraulic properties of soil treated with cement and (3) to assess the resistance of soil treated with cement to surface erosion under rain erosion resistance test. The results of field investigations in Cambodia showed that surface erosion was commonly found on earth embankment and the compaction degree of embankment D values existed within 81-88% indicated as a loose condition. One attempt of the use of cemented soils has been conducted to prevent surface erosion. DL clay, a non-plastic silt, was used to mix with normal Portland cement for experimental study in the laboratory. The consolidated drained triaxial compression test (CD test) was used to clarify the mechanical properties of soil cement. Thirty specimens with 3 confining pressures: 50, 100 and 200 kPa, 4 cement contents: 0, 3, 5 and 7% by dry weight of the soil, and 3 curing times: 7, 14 and 28 days were investigated in triaxial compression tests. The dry density of soil specimens in triaxial compression tests were 1.3g/cm^3; water content was 17%.

From the triaxial compression tests, it was found that the shear strength of the soil cement increased with an increase in cement contents and curing times. The strain softening and dilation behaviour of cemented specimens was found when confining pressure σ_3 = 50 kPa was applied. However, the softening behaviour started to disappear with an increase in confining pressure. The cohesion values could be reasonably evaluated by using the test results. It was found that the cemented soils with 3 and 5% of cement content have sufficient shear strength values and they may be suitable for erosion protection.

The rain erosion resistance tests were carried out to assess the effectiveness of soil slope covered with soil cement response to rainfall and surface flow by using the slope adjustable equipment. The angle 20-degree (about 36% slope) of this equipment was assigned to this experimental test. Two rainfall intensities, 50 and 100 mm h^{-1}, were applied on six soil slopes, two of soil slopes are untreated soil and other four soil slopes were cemented soils with 3% and 5% of cement content on 10-cm thick top layer. The curing time for soil slopes in the rain erosion resistance test was 7 days. The pore water pressure transducers were inserted into the soil slopes. The results of the rain erosion resistance tests showed the slope model of 0% have a tremendous soil erosion on the surface soil slope. It was 8 times and 60 times larger than soil cement 3% and 5% under rainfall intensity 50 mm h^{-1}. The deepest erosion was found 10 cm and 30 cm in case of 50 mm h^{-1} and 100 mm h^{-1}. However, the surface soil cement remaining in a good condition from 1 to 3 cm of surface crusts was observed. Adding low cement contents to improve soil shear strength, it possibly reduces the soil detachment and soil erosion from the surface soil slopes. Due to the hardened surface of the soil cement, a strong soil detachment was reduced. The soil slope of 0% cement content showed a very large amount of surface runoff compared with soil cement 3% and 5%. The hydraulic conductivity of the soil cement was increased and enhanced the infiltration capacity of the soil cement. The pore water pressure distribution showed that the rain water infiltrated into soil cement slopes faster than 0%, which reduced the surface runoff on the soil surface as well as soil losses. The flow vectors of three soil slopes showed the unsteady and non-uniformity under 100 mm h^{-1}. The direction of flow vectors moved upward indicating the swelling occur in case of soil cement 3% and 5%. From the element and slope model test results, it indicated that the surface soil detachment and erosion could be prevented at the low cement contents, 3 and 5%. The 3% of cement content performed a better resistance in soil detachment and less eroded soils.