Study on dynamic properties and micro-structure of exceeding lean RCC

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Abstract. In recent years, exceeding lean RCC has been widely used in the quality structure of hydraulic buildings due to its advantages of low cost and environmental friendliness. In order to study the dynamic characteristics of exceeding lean RCC under seismic action, cyclic loading test is carried out. According to the test results, the elasticity of the stress-strain relationship was determined by cyclic loading test under the condition that the maximum compressive stress did not exceed the linear range of the hard packing. On this basis, the linear range of cyclic load exceeding the limit of lean concrete is analyzed. In addition, the reaction products of each sample were tested, and it was found that ettringite with typical acicular structure was produced after adding cement. The micro-structure of exceeding lean RCC was studied by SEM and EDS.

1. Introduction

Exceeding lean RCC (Roller Compacted Concrete) is a new kind of structural material, which can be considered as a kind of fine RCC in a loose sense. Exceeding lean RCC was first proposed in 1992[1] as a "hard-filled" material. It has the advantages of low cost, simple and quick construction and environmental friendliness. In recent years, this material has been widely used in quality structures such as airports, runways, ports, wharves and highway subgrade projects, especially in water conservancy projects structure [2]. China is a famous earthquake country in the world. Therefore, important civil engineering structures must have sufficient seismic performance. Especially, the hydraulic structure is very important, and its safety must be guaranteed in seismic design. The structure, stress analysis and dynamic characteristics of exceeding lean RCC fillers determined by cyclic loading test are introduced. The results show that the stress-strain curve of exceeding lean RCC fillers is obviously nonlinear compared with that of concrete. Under the condition that the maximum compressive stress does not exceed the linear range of exceeding lean RCC, the elasticity of its stress-strain relationship is determined by cyclic loading test. The purpose of this study is to investigate the dynamic characteristics of exceeding lean RCC structures, and to provide reference for the seismic performance evaluation of exceeding lean RCC structures.

Faced with urgent demands for high safety, protection of the natural environment and low cost, the future hydraulic construction must be better than the past [3]. Exceeding lean RCC is a material made by simply mixing cement and water into readily available riverbed gravel or foundation pit surrounding rocks near the dam site. As a quarry, aggregate plant and turbid water treatment facility, the use of exceeding lean RCC can be greatly reduced, thus reducing the cost of dam construction projects and achieving the purpose of protecting and protecting the environment. A typical lean RCC production process is shown in Figure 1[4].
Figure 1. Exceeding lean RCC production process

The mechanical properties of exceeding lean RCC are affected by the grain size distribution curves of cement content, raw material and water content. The basic properties of exceeding lean RCC, such as elastic modulus, compressive strength, tensile strength and stress-strain curve, are obtained through laboratory tests. The stress-strain curve of typical exceeding lean RCC uniaxial compression test is shown in figure 2. Because the stress-strain curve of exceeding lean RCC is nonlinear, it is considered that exceeding lean RCC is an elasto-plastic material.

As shown in figure 3, a typical exceeding lean RCC dam is a new type of dam. The dam not only has the advantages of CFRD and RCCD [5], but also has its own advantages of high safety, good environmental protection performance, low cost and short construction period.

2. Dynamic test of exceeding lean RCC

2.1. Test conditions

In order to investigate dynamic properties of exceeding lean RCC under earthquake conditions, cyclic loading tests of exceeding lean RCC were carrying out by the uniaxial compression test in a laboratory. Figure 4 shows the uniaxial compression instrument used for tests. The sizes of exceeding lean RCC test specimen were 300mm in height and 150mm in diameter (shown in Figure 5). Exceeding lean RCC test specimen was made by mixing the raw material with cement (80kg/m³) and water (105-135kg/m³), and compacted by hand vibrator[6]. Figure 6 and Figure 7 show the patterns of cyclic loadings.
2.2. Results of cyclic loading tests
Figure 8 and figure 9 shows the results of cyclic loading tests.
According to results, the linearity of stress-strain relationship was observed when the maximum compressive load did not exceed the linear limit strength (σ_L). The linearity of stress-strain relationship was also confirmed by the result of Case 3, shown in figure 8, even if the number of loading cycles increased. In Case 4, peak loads were increased by cycles and exceeded the linear limit strength (σ_L). From the result of this case, it is observed that the elasto-plasticity was clearly appeared in the stress-strain curve and the residual strain increases cumulatively when a cyclic load exceeded the linear range of exceeding lean RCC.

3. Micro-structure of exceeding lean RCC

In this study, the type and distribution of hydration products on the surface of samples were detected by scanning electron microscope (SEM) [7]-[8]. Its composition is analyzed by energy dispersion spectrum. Energy spectrum is an analytical technique for analyzing the elements or chemical characteristics of a sample. Figure 10 shows the microstructure of the sample. As shown in the figure, cement hydration in exceeding lean RCC produces some results. SEM results show that the higher the cement content is, the higher the output of acicular ettringite will be.

![Figure 10. EDS spectra of the exceeding lean RCC materials (φ 150 mm, cement content 10%)](image)

As mentioned above, hydration products are proportional to the volume of cement, indicating that hydration products may be one of the parameters influencing the compressive strength of materials. In addition, more acicular ettringite was observed in larger samples, making the relationship between hydration and sample size more comprehensive. Figure 11 shows EDS [9] results of sample 150mm (cement content 10%). As can be seen from the figure, the main components of the first two samples are O and Si. At the same time, the sample (treasure 150mm) is mainly composed of O and Ca. In
addition, Si, C and S were also found in the third specimen. In particular, sulfur is assumed to be ettringite. Small amounts of aluminum (Al) were also detected.

Figure 11. EDS spectra of the exceeding lean RCC materials (φ 150 mm, cement content 10%)

4. Conclusions
In this paper, the dynamic material properties of hard packing were studied by laboratory experiments, and the microstructure of hard packing was studied by SEM and EDS.

Compared with the conventional concrete dam, the trapezoidal exceeding lean RCC dam has less stress. The maximum stress decreases proportionally with the increase of slope. The dynamic performance of exceeding lean RCC is verified by cyclic loading test. When the maximum compressive load does not exceed the linear ultimate strength of exceeding lean RCC, the linear relationship of stress-strain curve is verified. In addition, when the cyclic load exceeds the ultimate strength, the elastoplastic performance of exceeding lean RCC lining is obvious.

SEM results show that the greater the cement content is, the greater the formation of acicular ettringite will be. In the basic design of exceeding lean RCC dam, the strength and elastic modulus within the linear range should be taken as the material performance indexes. Therefore, even in the case of a sudden earthquake, the exceeding lean RCC dam body has a wide plastic range and the load beyond the linear ultimate strength will have an effect on the dam body. Exceeding lean RCC dams are less prone to brittle failure. This means that exceeding lean RCC dams have enough safety margin to withstand severe earthquakes.

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