Research of Meso-pore Structures of Eco-material

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Abstract. A proposed method was introduced to study the meso-pore structures of eco-material in this paper. Firstly, the samples were solidified by using the mixtures of epoxy resin, triethanolamine and blue organic dyestuff. Then, the sections were obtained by cutting the solidified samples and the digital images were gathered by using high resolution camera. At last, the IPP technique was used to analyze the digital images for studying the meso-pore structures. Experimental results show that pore number of eco-material increases with the decrease of pore-size, and the number of pores of pore-size smaller than 0.24 mm is about 30 % of total. Further more, smoother pore number distribution curve indicates more stable structure. With the increase of wet-dry cycles, the total porosity of eco-material of 3 ~ 9 cm depth tends to decrease, while that of 12 ~ 18 cm depth shows a tendency to increase.

Keywords: Eco-material · Meso-pore structures · Sampling depth · Wet-dry cycles

1 Introduction

Pore structures and macro physical mechanics properties of rock and soil are closely linked, and the pore structure is the foundation to carry out the study on relation between macro physical mechanical characteristics and pore structure. With the continuous development of experimental techniques, mercury injection technique and SEM technology were used to study the micro-pore structure of the rock and soil materials and the experiment had become easy (Zhang et al., 2008; Tao et al., 2010). For the study of meso-pore structure, the corresponding experiment is relatively difficult (Skopp et al., 1981; Singh et al., 1991; Tang et al., 1963). Although CT technology has been applied in the study of pore distribution of rock and soil medium in 3D space, the resolution of CT image is low and the precision is not high. In addition, application equipment and expensive testing also limits the CT technology. In soil science, in general, after the sample being solidified using the cured resin, the pore structure is analyzed by the polarizing microscope. A method was put forward to study the meso-pore structure by color photography scanner or high resolution digital camera and the pore distribution data was gained by computer image analysis software (Li et al., 2002; He et al., 2002). Based on the above method, a new method will be presented and applied to the research of the eco-material pore structure.

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2 Materials and Methods

Sample preparation: Referring to the proposed experimental methods (Li et al., 2002; He et al., 2002), a new method to study the meso-pore structure is introduced. The steps of sample preparation and sections cutting are as follows:

(a) Sampling. The light rain weather is very fit for sampling (eco-material humidity is moderate, convenient for sampling). In the field test site of ecological material, a plastic barrel, whose diameter is 11 cm, height is 20 cm and wall thickness is about 2 mm, is slowly put into the eco-materials. Then, the small range of materials near cylinder is hollowed out. In the representative area, 4 samples were made.
(b) Wet-dry cycles. In 4 samples, 3 samples are chosen as the samples of drying and watering cycle.
(c) Specimen impregnation. Before immersion, the specimens were sealed. Then, the samples were put in drying cylinder to dry out, with control temperature at 70°C. In the same time, E44 epoxy resin of a certain volume was heated in the oven until the liquidity achieved to the ideal state. Then, triethanolamine was added into the epoxy resin according to volume ratio of 15 %. Afterward, blue dye of 5 g: 1 L was added. This process took time, so the fluidity of epoxy resin might become worse. Therefore, it need take impregnating agent in the oven for heating, until mobility was in the ideal state. Afterward, impregnating agent was injected slowly into the barrel along the inside. The whole process should be controlled within 30 min.
(d) Specimen solidifying. After completing previous steps, it need continue to heat the samples in the oven, at a temperature about 70°C. In general, samples can be solidified after about 7 h.
(e) Sample cutting. Along the vertical height, each sample was cut at intervals of about 3 cm. Then, 6 representative sections were acquired for each sample and the sections were marked.

Table 1. Sample number of eco-material and corresponding sampling depth and wet-dry cycles

Sample number	Sampling depth (cm)	Wet-dry cycles	Sample number	Sampling depth (cm)	Wet-dry cycles
S1-1	3	0	S3-1	3	3
S1-2	6	0	S3-2	6	3
S1-3	9	0	S3-3	9	3
S1-4	12	0	S3-4	12	3
S1-5	15	0	S3-5	15	3
S1-6	18	0	S3-6	18	3
S2-1	3	1	S4-1	3	7
S2-2	6	1	S4-2	6	7
S2-3	9	1	S4-3	9	7
S2-4	12	1	S4-4	12	7
S2-5	15	1	S4-5	15	7
S2-6	18	1	S4-6	18	7

According to the above experimental methods, 4 samples respectively corresponding to 0, 1, 3, 7 wet-dry cycles were solidified, and each sample was cut into 6 representative sections. The relationship between sample number, sampling depth and wet-dry cycles is shown in Table 1.

Image acquisition and processing: A scale mark of 2 cm was put near by the sample section and the high resolution image was acquired for each representative section. Then, by using the IPP software, the color photographs were converted to binary image of black and white. In the processing, threshold adjustment function was chosen to complete pore and particle segmentation in IPP. The binary image of black and white must be compared with the original color image, guaranteeing the black and white image can reflect the actual situation. The same work should be completed by one or more peoples. If the error is within 10 %, it may be a black and white image which can reflect the actual situation.

Figure 1 shows the binary image of eco-material standard sample with 2 cm scale signs nearby. By impregnating liquidity constraints, it will inevitably lead to not fully filled pores, so that pores of color photographs are divided into two kinds, one is dipping agent filled pores with the color of blue; another is not filled with color of black. In binary image of the black and white, black represents pore, and the white represents the particle.

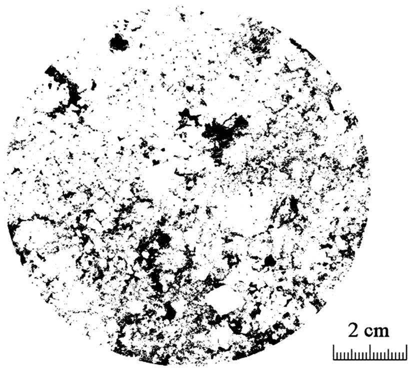

Fig. 1. Binary images of standard samples of eco-material

3 Results and Discussion

Using IPP software, the statistics and analysis work of pore-size distributions of eco-material was completed. Although the sampling barrel diameter is 11 cm, the samples generally have the volume shrinkage, which lead to smaller diameter. To avoid the pore caused by volume shrinkage, 10 cm was chosen as the circular diameter of analysis region.

Pore-size distribution and the porosity: In accordance with the pore-size range, the pore distribution data of IPP software was divided into 13 to 16 pore-size level, the number and pore area corresponding to pore-size level were counted. In particular, according to the resolution of digital cameras, the minimum pore-size is 0.16 mm.

Figure 2 gives pore-size distributions using the porosity for pore-size grade, in which all the abscissa is used in logarithmic form. As you can see from Fig. 2, each pore-size interval porosity distribution is relatively uniform on the whole, the porosity of pore-size smaller than 1 mm is relatively small, and porosity of pore-size larger than 1 mm is relatively big. For part samples, the porosity of pore-size larger than 10 mm presents obvious increasing intend, such as sample 1-1, and there exists a large pore, the corresponding porosity approaches 50 % of total porosity. The reason may be that corresponding sample has loose structure, and that many connected large pores form large pores. These pores should be the main pore water preferential flow, which easily leads to nutrient loss of eco-materials.

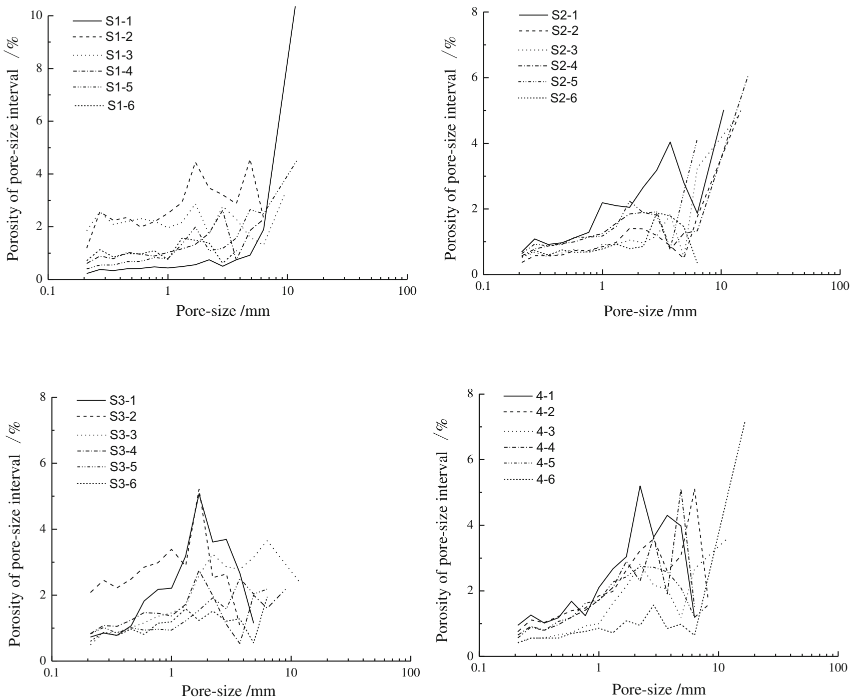

Fig. 2. Pore-size distribution

For the sampling depth, porosity of the same pore-size interval decreases with the increase of sampling depth on the whole. The reason is that, larger action of gravity of deeper eco-material leads to smaller porosity. Due to the pore distribution's variability of eco-materials with space, porosity of pore-size interval of some samples shows the opposite trend, i.e. the porosity increases with the increase of depth. For example, the porosity of small pore-size interval of surface sample 1-1 is smaller than the deeper samples.

Figure 3 shows the changes of cumulative porosity with the pore-size. On the whole, the growth trend of porosity is relatively stable. The reason is that porosity distribution of each pore-size interval is uniform on the whole. However, for individual samples, the growth rate of porosity of pore-size interval shows mutations. For example, the sample 1-1, porosity growth rate of pore-size interval presents significant accelerating trend when pore-size is larger than 8 mm. The reason is that, for the sample 1-1, a bigger proportion of total porosity is occupied by the larger pores, whose porosity shows sudden changes with pore-size.

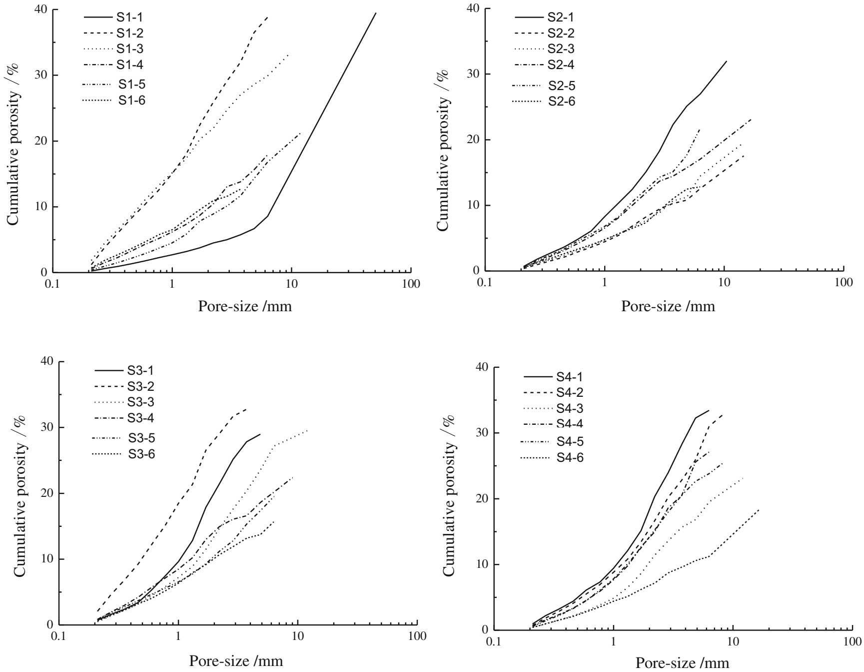

Fig. 3. Cumulative porosity with increasing pore-size

With the depth increases, the total porosity shows an overall decreasing trend. Smaller the total porosity is, more slowly the cumulative porosity increases.

Pore number distribution: Fig. 4 shows the distribution curves of pore number. As you can see from Fig. 4, pore number increases with the decrease of pore-size, and the number of pores of pore-size smaller than 0.24 mm is about 30 % of total. A few specimens, such as sample 1-2, appear obvious inflection point at about 0.24 mm, and shows decreasing trend for smaller pores.

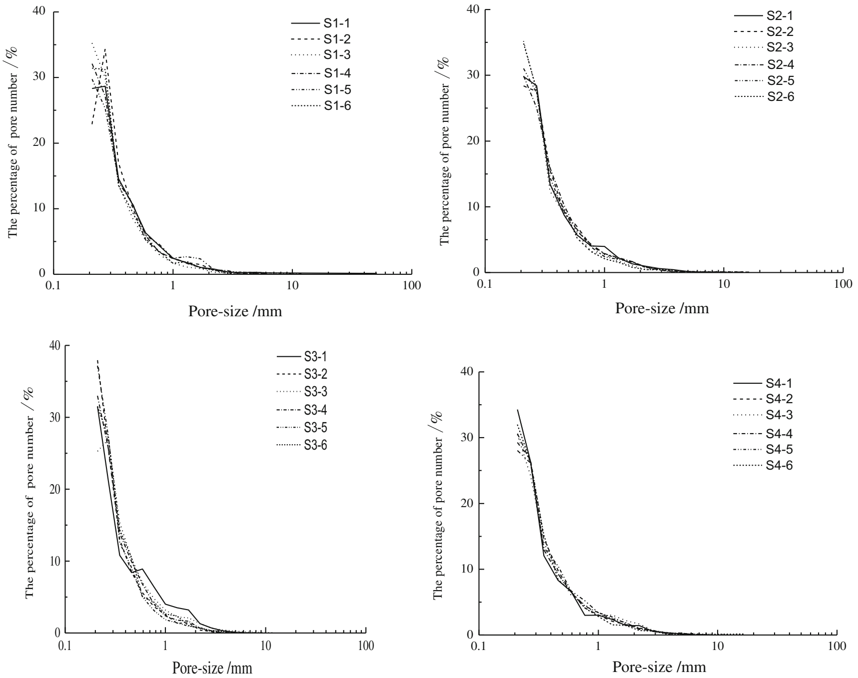

Fig. 4. Distribution of pore number

Pore number distribution curve of surface eco-materials shows large fluctuation. However, the number distribution curves of deeper layers are relatively smooth. The reason may be that the effects of vegetation and soil erosion lead to the discontinuous pore distributions. It can be considered that, smoother pore distribution curves are, more stable the pore structures are.

Figure 5 gives the accumulated number distributions of pores smaller than a certain pore-size. All curves of 24 samples are shown on the corresponding convex, because smaller pore number increases more quickly than larger pores. On the whole, all distribution curves are relatively concentrated. With the increase of depth, the curve tends to be plumper.

For sample 3-1, the curve is not plump, which indicates the structure is most unstable.

The change rule of total porosity: Fig. 6 compares the total porosity of different sampling depths of eco-material. Figure 6 shows that, with the increase of sampling depth, total porosity of eco-material decreases on the whole. This shows that, with increasing sampling depth, eco-material structure becomes tighter. The reason is that, on the one hand, many pores in surface eco-material were produced due to vegetation growth, on the other hand, the deeper eco-material become more compact because of gravity.

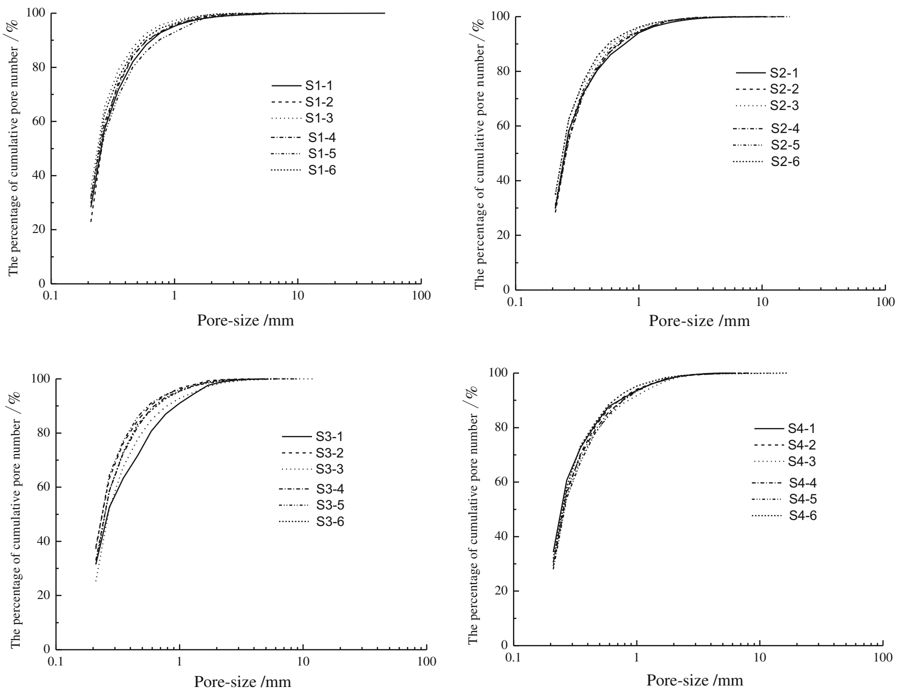

Fig. 5. Cumulative percentage of pore number

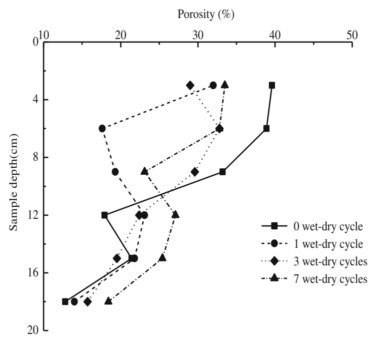

Fig. 6. Variation law of porosity with sampling depth

The total porosity of eco-material of different wet-dry cycles is compared in Fig. 7. It is shown that, with the increase of wet-dry cycles, the total porosity of eco-material of 3 ~ 9 cm depth tends to decrease, and that of 12 ~ 18 cm depth shows a tendency to increase. The reason is that, on the one hand, due to the existing of some large pores, structure collapse phenomenon happens in superficial layer in cyclic wet-dry conditions, so that the total porosity decreases; on the other hand, the wet volume expansion is larger than dry volume shrinkage for deeper eco-material, so that the total porosity increases with increase of wet-dry cycles.

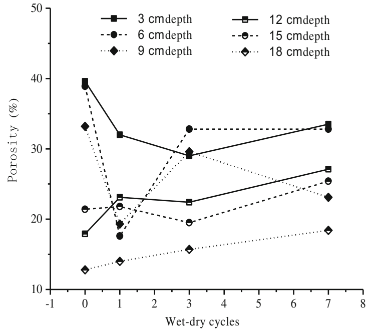

Fig. 7. Variation law of porosity with wet-dry cycles

4 Conclusion

Experimental results show that the proposed approach is perfect for the research of meso-pore structures of soils. Pore number of eco-material increases with the decrease of pore-size, and the number of pores of pore-size smaller than 0.24 mm is about 30 % of total. Further more, Smoother pore number distribution curve indicates more stable structure. With the increase of sampling depth, total porosity of eco-material decreases on the whole. With the increase of wet-dry cycles, the total porosity of eco-material of 3 ~ 9 cm depth tends to decrease, and that of 12 ~ 18 cm depth shows a tendency to increase.

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