About Simulation of Load-Bearing Capacity of Rammed Earth Wall Based on Big Data

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Abstract: The raw-soil structure occupies an important position in the villages and towns in China. It originates from and blends with nature. Although earth constructions are ancient regional building types, their low energy consumption, excellent thermal performance, and green and pollution-free are being favored by more and more modern buildings. However, due to the influence of the wall on the raw-soil, its resistance to earthquake is insufficient and the durability is worse. Therefore, the author first briefly describes the structure of rammed soil, and then experimentally demonstrates the mechanical performance of the rammed earth wall to study the compressive performance of the building under the different mixing ratios, and studies the monotonic horizontal bearing capacity of the rammed earth wall.

Introduction

As a natural geological disaster that human beings have to face, earthquakes will cause serious threats to human living environment and even life safety. The modern science and technology is not enough to ensure that the time of the earthquake can be accurately predicted. People can only infer natural disasters through science and technology and abnormal reactions of animals in nature. However, in fact, the probability of earthquakes in the world is extremely high. According to incomplete statistics, more than 5 million earthquakes occur every year. China itself is surrounded by the Pacific Rim earthquake zone and the Eurasian earthquake zone, and its probability of earthquakes is relatively high. As one of the types of earth constructions, rammed earth buildings have the characteristics of environmental protection and excellent thermal performance. It improves its biggest deficiency, that is poor earthquake resistance, and it can undoubtedly create a more comfortable living environment for human beings.

1. Brief Description of Rammed Earth Structure

Earth constructions have high historical value to China, and are precious legacy left by the Chinese ancestors for all mankind. To a certain extent, earth constructions have recorded the details of human beings from primitive society to modern civilized society. There are various forms of earth constructions, among which the representative buildings include rammed earth buildings, haystack buildings, and cave buildings. The rammed earth building, as a building with a thick wall, has relatively good heat storage capacity and thermal stability. The indoor can maintain a warm winter and cool summer, which is a comfortable living environment for human beings. Rammed earth buildings are more common in the southwest of Shaanxi Province in China. As one of the most important architectural forms of earth constructions, rammed earth buildings have high literary and artistic value since ancient times. The earth buildings of Hakka in Fujian Province is a typical example. As a load-bearing structure, the height of the rammed earth wall can exceed 20 meters. The rammed earth wall is not only the cultural treasure of the Chinese nation, but also the architectural style of the architectural history in Chinese nation.

Rammed earth structure is also recognized by experts and scholars at home and abroad in the 21st century. More and more scholars believe that rammed earth has a lot of its own advantages.

First of all, the structural performance of rammed earth building is ideal, its stability is better from the overall analysis, and the integrity is more ideal. Compared with traditional rammed earth wall, modern rammed earth wall is continuously researched and upgraded and can bear the weight strength of 4-5 MPa, so it can be used in the construction of multi-storey buildings. Secondly, the living environment brought by rammed earth structure is comfortable. The rammed earth material can adjust the indoor humidity, and its good thermal stability can help the rammed earth building keep warm in winter and cool in summer. Thirdly, the load-bearing of rammed earth building structure is to choose the wall, the number of beams and columns is less than that of modern buildings, and the indoor space is relatively larger, so the ventilation performance is ideal. Besides, compared with other traditional construction technology, rammed earth structure can be more convenient to complete the building construction with the help of machinery. Therefore, compared with traditional buildings, rammed earth structure can develop its advantages and avoid its disadvantages with the development of machinery and science and technology, and the proportion of rammed earth materials has increased significantly. More scientific and reasonable means can improve the ramming of rammed earth wall. Compared with the traditional rammed earth walls, the modern rammed earth construction tools such as vibration and impact rammer can better improve the efficiency and obtain more satisfactory results.

2. Experimental Study on Bearing Capacity of Rammed Earth Wall

2.1 Research on Bearing Capacity of Rammed Earth Wall

In the experiment, there are 51 walls in total with four proportions, namely plain-soil wall, plain-soil solidified agent wall, plain-soil machine-made sand cement wall and plain-soil lime wall. The curing time of different proportion walls is also different, and the fiber degree and tamping tools are also different. The curing age varies from 1 day to 30 days, and the walls of each wall will have different curing ages. Some walls will carry out compressive test after 1 day of curing, and some will carry out compressive test after 30 days of curing. In total, 3 of the 51 walls will be made by electric pickaxes, and the remaining 48 will be tamped by vibration and impact rammer. Relevant information is summarized in Table 1.

Table 1. List of compressive strength test of rammed earth wall under different curing age, process and ratio

Soil types	Fiber content of wall (kg/m^3)	Maintenance age/day		Tamping process
		1	30	
Plain-soil	0.0	3 walls	3 walls	vibration and impact rammer
	1.0	3 walls	3 walls	vibration and impact rammer
Plain-soil: machine-made sand: cement = 50:40:5	0.0	3 walls	3 walls	vibration and impact rammer
	1.0	3 walls	3 walls	vibration and impact rammer
Plain-soil: lime =40:2	0.0	3 walls	3 walls	vibration and impact rammer
	1.0	3 walls	3 walls	vibration and impact rammer
Plain-soil: curing	0.0	3 walls	3 walls	vibration and impact

agent =1m^3:0.25kg				rammer
	1.0	3 walls	3 walls	vibration and impact rammer
Dimensions of walls	Length, width and height are 1.2m, 1.2m and 0.4m respectively			
Soil types	Fiber content	Tamping process: hand-held electric picker		
Plain-soil: machine-made sand: cement =50:40:5	1.0	There are 3 walls in total, and its size is the same as above with the curing age of 30 days.		

The preparation process is selected for all four types of walls. After the soil and admixture (cement, machine-made sand, curing agent, and fiber) are poured into the mixer and stirred evenly, the large pieces of soil are all mixed into loose soil to ensure that there are no large pieces of soil in the soil, otherwise it may affect the final effect on the test. And then the mixture obtained above is poured into the formwork with the depth controlled at about 18cm, and a wooden hammer is used to initially compact the loose soil, and the mixture can also be evenly distributed in the formwork. After that, we choose impact vibration rammer or electric pick to complete the secondary compaction that is an important step. Under the double action of compaction force and gravity, the rammer foot and soil have the effect of making the soil more compact in the reciprocating impact. After the first layer of compaction, we should continue to add the mixture and continue to compact until the design height of the wall is achieved. After that, the formwork shall be removed, the top shall be leveled, an d the bulging part shall be leveled. The experimental loading device is shown in Figure 1.

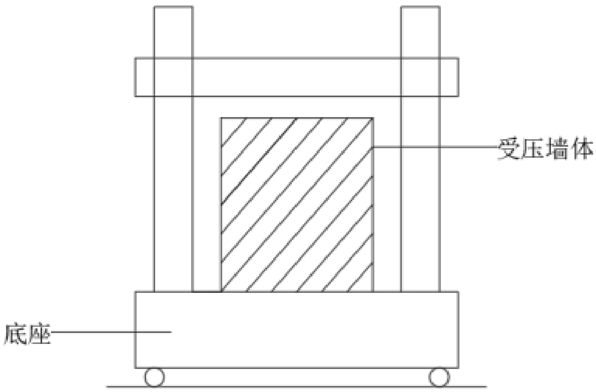

Figure 1. Experimental loading device

The experimental data is summarized to obtain the compressive strength of each wall, and the statistics are listed in Table 2. According to the analysis, the highest compressive strength of the 1-day curing time is plain-soil: machine-made sand: cement wall, and the worst is plain-soil: solidified wall. The best pressure resistance for curing for 30 days is plain-soil: machine-made sand: cement wall, and the worst is plain-soil: lime wall. Under proper conditions, the length of the curing time has a significant effect on the compression resistance strengths. The addition of fibers can also improve the compressive strength of the walls, so the fiber can play a compressive effect on the compressive load carrying capacity of the walls. In terms of different proportions, plain-soil: machine-made sand: cement wall has the best relative bearing capacity, and machine-made sand can make the wall more stable. The vibration compression effect of vibration and impact tamp is better than that of electric pickaxe. It may be affected by working area, the area of electric pick is about 12cm X 12cm, but that of impact rammer can reach 25cm X 25cm.

Table 2. List of compression resistance obtained from various wall experiments

Soil types	Fiber content（kg/m^3）	Compressive strength of earth wall/MPa	
		1 day	30 days
Plain-soil	0.0	0.226, 0.142, 0.203	0.962, 0.921, 0.994
		Median: 0.191	Median: 0.959
	1.0	0.304, 0.252, 0.296	0.927, 1.253, 0.974
		Median: 0.284 Maximum: 0.304	Median: 1.051 Maximum: 1.253
Plain-soil: machine-made sand: cement =50:40:5	0.0	0.298, 0.265, 0.322	1.123, 1.085, 0.923
		Median: 0.295 Maximum: 0.322	Median: 1.044 Maximum: 1.123
	1.0	0.429, 0.459, 0.735	1.598, 1.205, 1.352
		Median: 0.541 Maximum: 0.735	Median: 1.385 Maximum: 1.598
Plain-soil: lime =40:2	0.0	0.218, 0.244, 0.208	0.618, 0.708, 0.69
		Median: 0.223 Maximum: 0.244	Median: 0.672 Maximum: 0.708
	1.0	0.429, 0.459, 0.735	0.853, 0.993, 0.822
		Median: 0.535 Maximum: 0.584	Median: 0.804 Maximum: 0.993
Plain-soil: curing agent =1m^3:0.25kg	0.0	0.178, 0.186, 0.179	0.945, 1.018, 0.951
		Median: 0.181 Maximum: 0.186	Median: 0.972 Maximum: 1.018
	1.0	0.196, 0.195, 0.315	1.131, 1.238, 1.164
		Median: 0.235 Maximum: 0.315	Median: 1.178 Maximum: 1.238
The electric pick with fiber of plain-soil: machine-made sand: cement is 0.655, 0.690, 0.679, and its median value is 0.675 the maximum value is 0.690.			

2.2 Horizontal Monotonic Load-Bearing Test of Rammed Earth Wall

The study of horizontal monotonic load-bearing experiment of rammed earth wall is also the study of average shear stress under different technology and different proportion. The design parameters of the rammed earth wall are still developed with reference to table 1. The study of the electric pick cancels the step without adding fibers. The size of the wall is selected as 1.6m X 0.8m X 0.4m, and all the maintenance time is 30 days, and the other steps are the same. The displacement layout of relevant load loading can be seen in Figure 2.

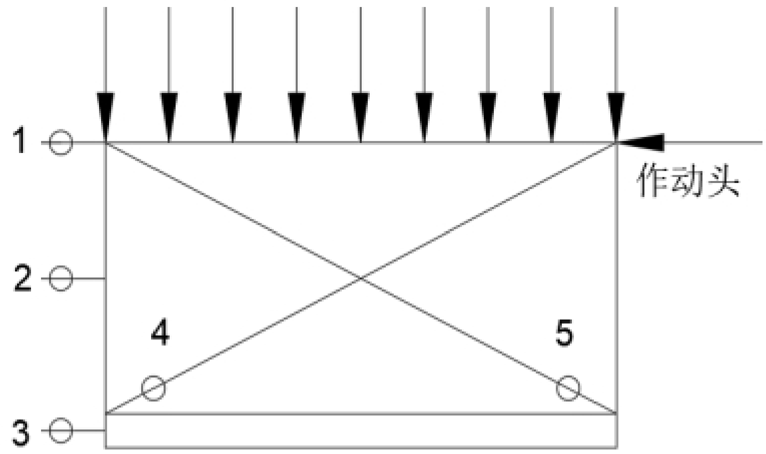

Figure 2. Displacement layout of relevant load loading

In the manufacturing process, the soil material needs to be wetted with water before the wall is compacted. The production steps are the same as above. The maintenance stage is carried out according to the concrete standard of our country. It is found that the bearing capacity and cracking time of the wall are prolonged before and after adding polypropylene fiber. The damage of cement formulation of plain-soil: machine-made sand: cement is light, and that of pure plain-soil is the most serious.

From the analysis of the experimental results, the cracking load of plain-soil is 48KN, and the ultimate load is 78.37KN; that of plain-soil with fiber is 70KN, and the ultimate load is 102.12KN; that of plain-soil: machine-made sand and cement is 95KN, and the ultimate load is 115KN; that of plain soil: machine-made sand and cement with fiber is 118KN, and the ultimate load is 133.12KN.

The yield displacement of plain-soil is 10mm, and the ultimate displacement is 22mm; that of plain-soil fiber is 13mm, and the ultimate displacement is 28mm; that of plain-soil: machine-made sand and cement is 18mm, and the ultimate displacement is 35mm; that of plain soil: machine-made sand and cement with fiber is 20mm, and the ultimate displacement is 39mm.

It can be seen from above that the strength and ductility of plain-soil are relatively the worst. Compared with other groups, the cracking load and ultimate load of plain-soil: machine-made sand: cement with fiber is highest, which may be caused by cement and machine-made sand. The addition of fiber can improve the cracking degree of wall.

Conclusion

From the study of the mechanical properties of the rammed earth wall of the raw -oil structure, it can be found that the addition of an admixture to the walls can help improve the compression resistance capacity and degeneration ability of material to a certain extent. Compared with the traditional plain rammed earth wall, the addition of machine-made sand, cement or curing agent can greatly improve the compression resistance. The wall of plain-soil: machine-made sand and cement can get the maximum compression resistance. The addition of polypropylene fibers can improve the compression resistance to a certain extent, and can improve the ductility of the wall. In the study of monotonous horizontal load-bearing, the admixture can also help improve the bearing capacity, and the wall deformation capacity is better improved, which will be helpful for further use in the future.

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