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Finite Element Analysis of Geotechnical Isolation System Finite-Element Analysis on the Geotechnical Seismic Isolation (GSI) System

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ABSTRACT: *In order to verify the effectiveness of the Geotechnical Seismic Isolation (GSI), a series of finite element parameter studies were carried out. The finite element calculation model of the GSI system and superstructure is established. The finite element analysis conditions consist of two kinds of confining pressures, three kinds of RSM ratios and three kinds of seismic wave inputs, a total of 32 kinds of conditions. Comparing the analysis results of the parameters, it can be seen that the dynamic shear modulus of the RSM sample increases with the increase of the confining pressure, but the degree is affected by the input of seismic waves. The greater the peak value of the input acceleration, the more obvious the isolation effect; As the RSM ratio increases, it decreases, but it is not greatly affected by the input of seismic waves, and the isolation effect remains basically the same. The numerical simulation results verify the isolation effect of GSI, which can be used as a reference for practical engineering applications in the future.*

KEYWORDS: geotechnical seismic isolation, numerical simulation, rubber-sand mixture; seismic wave; seismic isolation

INTRODUCTION

Earthquake disaster is a kind of natural disaster that human beings cannot avoid. In the past half century, the rise and development of seismic design and isolation technology have greatly reduced the harm of earthquakes to human society. However, compared with the mature anti-seismic engineering practice or research in cities, the vast villages and towns in my country are still at a seriously backward and unsafe level, whether it is the structural form adopted by the building or the anti-seismic engineering technology. The economic conditions in villages and towns are lagging behind and the residents' awareness of earthquake resistance is weak. Therefore, only by exploring anti-seismic measures with low cost and simple construction can we truly benefit the rural residents and improve the anti-seismic safety of houses in villages and towns.

The mixture of rubber particles and sand has been widely used in slope, retaining wall, roadbed and runway backfill, but its application in building foundation isolation is relatively rare. Rubber-sand particles have many advantages such as light weight, durability, economy, good shock absorption and isolation effects, and convenient construction. There are already some engineering application examples abroad [1–7]. Scholars at home and abroad have conducted a series of studies on the rock-soil isolation system with rubber-sand mixture as backfill material: Liu Fangcheng et al. A series of experimental studies have been carried out, and the results show that the rubber-sand core composite block has a good shock-isolation effect. Yao Fei et al. [11,12] conducted low-cycle repeated load tests on the steel-asphalt composite isolation layer, and studied the influence of the shear stiffness and horizontal force-displacement curve of the isolation layer on the seismic response. Lu Huaxi et al. [13,14] established a two-dimensional finite element calculation model of the subgrade-raised terrain under the action of trains, and studied the influence of the width, shape, aspect ratio and foundation soil properties of the raised terrain on the vibration of the railway environment.

With the increasing application of rubber-sand particles in engineering, it is foreseeable that this mixture will receive more attention and research. The application of the rubber particle-sand mixture will promote the development of the waste tire recycling industry, and will also provide more help for the shock absorption and isolation problems in the vast economically backward villages and towns.

1. Geotechnical Isolation System Introduction

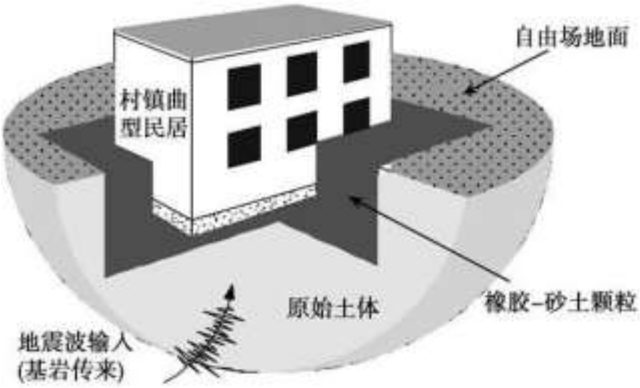

Fig. 1 Schematic diagram of rock-soil isolation system using rubber-sand particles as backfill material

Fig.1 Schematic view of the GSI system using RSM

Starting from improving the seismic fortification capacity of buildings in vast villages and towns, based on soil-structure interaction and nonlinear soil response, a method of using rubber-sand particle mixture as foundation pit backfill material for effective seismic isolation is proposed. The seismic isolation system is called the geotechnical isolation system. Since the rubber-sand particle mixture is backfilled in the foundation pit as a shock-isolation cushion, buildings using geotechnical isolation systems rely on the good hysteretic energy dissipation and low anti-corrosion performance of rubber particles and sand when an earthquake occurs. Lateral stiffness, a considerable part of the seismic energy is consumed and isolated when the seismic wave propagates upward from the bedrock to the rubber-sand particle layer, so that the input of seismic waves at the bottom layer of the building structure is also greatly reduced. Therefore, compared with the traditional seismic isolation measures, the geotechnical isolation system has the following advantages:

(1) The construction process is simple and easy to operate. Because it can reduce the damage to buildings caused by earthquakes, it also has strong robustness. When the earthquake level is small, the shear strain of the soil is small, and the shear deformation is maintained in the elastic stage, so

that it does not affect the superstructure; in the case of a large earthquake, the shear deformation of the rubber particle-sand mixture increases, The soil enters a non-linear stage, and as the seismic intensity increases, the range in which the mixture participates in the deformation also increases, thereby significantly reducing the horizontal acceleration movement response of the upper structure caused by the earthquake excitation, thereby ensuring the stability of the building structure and the safety of internal personnel. Safety.

(2) Economical and cheap, green and environmentally friendly. Waste tires can be turned into fragments or granules through a certain process, and rubber granules are the key material of rock-soil isolation system. Therefore, the use of rubber granules-sand soil mixture for vibration isolation can greatly reduce the utilization rate of waste tires. The low situation makes the use of waste tires more effective. In addition, the production process of the rubber particle-sand mixture is simple, and its cost is relatively low. In addition, the rubber has good elasticity, good wear resistance, superior processing performance and high mechanical strength. After using this mixture for backfilling, it will not The harmful substances are volatilized to ensure that the environment is not damaged.

More than 80% of my country's magnitude 5 earthquakes occur in villages and towns, and the establishment of geotechnical isolation systems can solve the problem of earthquake prevention and disaster reduction for rural houses in a timely manner. Therefore, the study of seismic isolation performance of geotechnical isolation systems has very important practical significance , It will also bring good news to the lives of the majority of village and town residents.

1.0 Finite Element Numerical Analysis

1.1. Assumptions of the Computational Model

The structure of the model is relatively simple, using a frame-type interlayer shear model, and then performing finite element analysis. The following assumptions are made throughout the vibration process:

(1) The connection between the upper structure and the seismic isolation surface of the storey is consolidated, which can be equivalent to complete rigidity because it is absolutely firm and reliable.

(2) The mass of the floor can be simplified as the mass of the mass, and the mass of the mass acts on the floor.

(3) During the simulation process, the seismic isolation effect of the story isolation surface is equivalently linearized.

1.2. Computational model building

In order to consider the earthquake action and the spatiality of the structure itself, and to reflect the earthquake motion and the three-dimensional characteristics of the structure more truly, this paper takes a two-story I-shaped steel frame structure as an example, and conducts seismic isolation (RSM isolation layer) and non-seismic isolation. 3D seismic response analysis under (fixed foundation) conditions. The three-dimensional finite element models of the non-isolation structure and the

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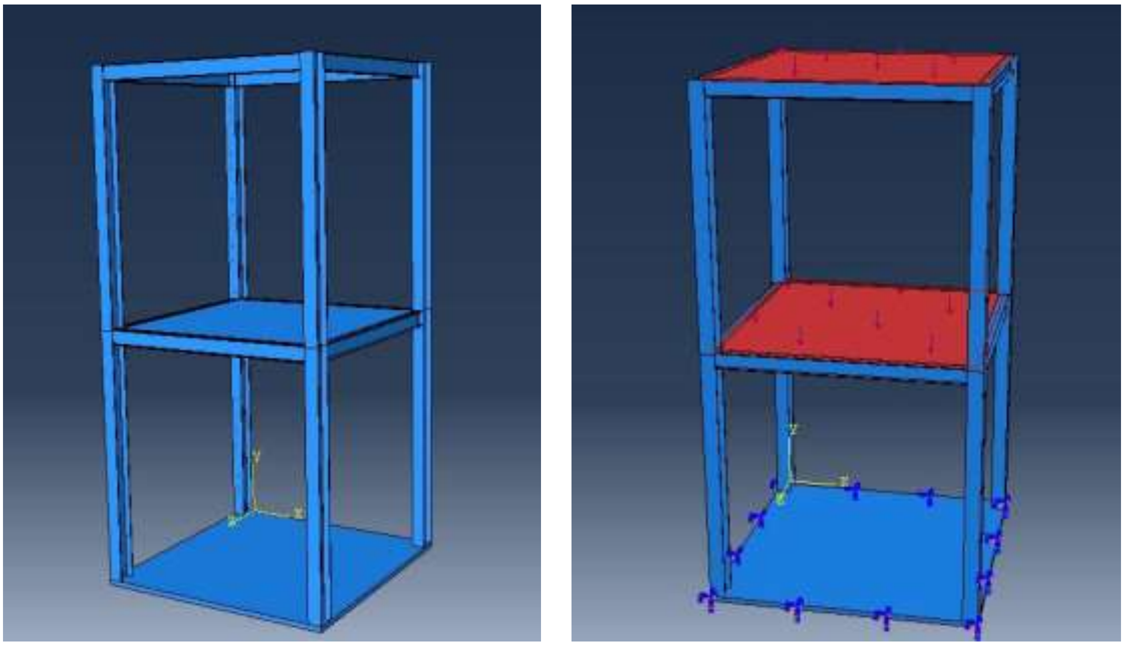
isolation structure with rubber particle sand isolation layer were established according to the relevant codes of building structure design, as shown in Fig. 2. The structure is a steel frame structure with a total building height of 10m, 2 storeys, and a plane size of 5.3m□5.4m; the seismic fortification intensity is 8 degrees, and the design basic seismic acceleration is 0.2g; the columns and beams are all made of I-shaped steel, and the elastic modulus is 2.1□1011 with a density of 7.85□10^3, Poisson's ratio is 0.2; the thickness of the plate is 0.1m; the beams, columns and plates of the structure are all C3D8I units.



(a) Non-seismic isolation structure (b) Seismic isolation structure

Fig. 2 Schematic diagram of finite element modeling of superstructure

Fig.2 FE model of the superstructure

The simulated working conditions are shown in the table below:

Table 1 Numerical simulation analysis conditions

Table 1 Analytical case of the numerical simulation

RSMratio (%)	basic form	Confining pressure (kPa)	Structure layers	seismic wave input
	solid base			CenterWave
0、25、40		50		
	pure sand		two floors	KobeWave
50、75、100		100		
	RSM isolation layer			NorthridgeWave

The finite element analysis working conditions consist of two kinds of confining pressures, three

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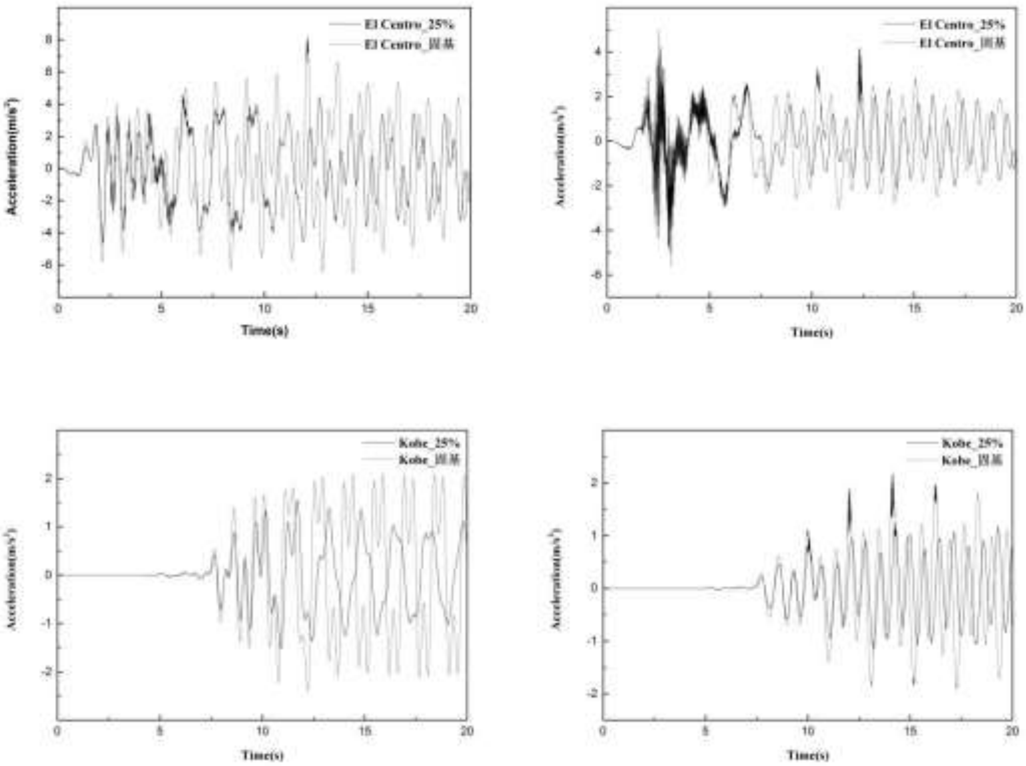
kinds of RSM ratios and three kinds of seismic wave inputs, a total of 32 kinds of working conditions. After summarizing the data with Excel, draw charts for comparison and analysis. The establishment of the finite element analysis model is very critical, which is related to whether the subsequent parameter analysis can be carried out smoothly.

1.3. Parametric analysis

1.3.1. Confining pressure

The setting of the confining pressure is 50kPa and 100kPa in two situations. The acceleration response time history curves of three types of seismic wave input under the same RSM ratio and two confining pressure conditions were compared and analyzed, and the influence of confining pressure on RSM dynamic shear modulus was summarized and analyzed according to the peak value and fluctuation range of the curves. The left side of the comparison chart below represents the situation of 50kPa confining pressure, and the right side represents the situation of 100kPa confining pressure.



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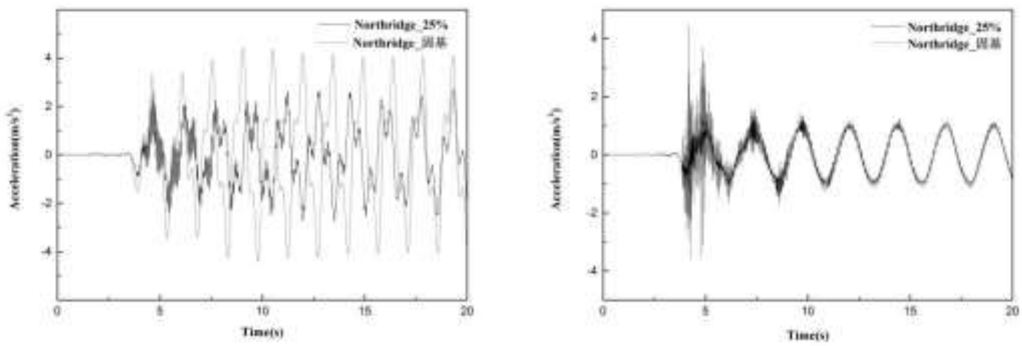
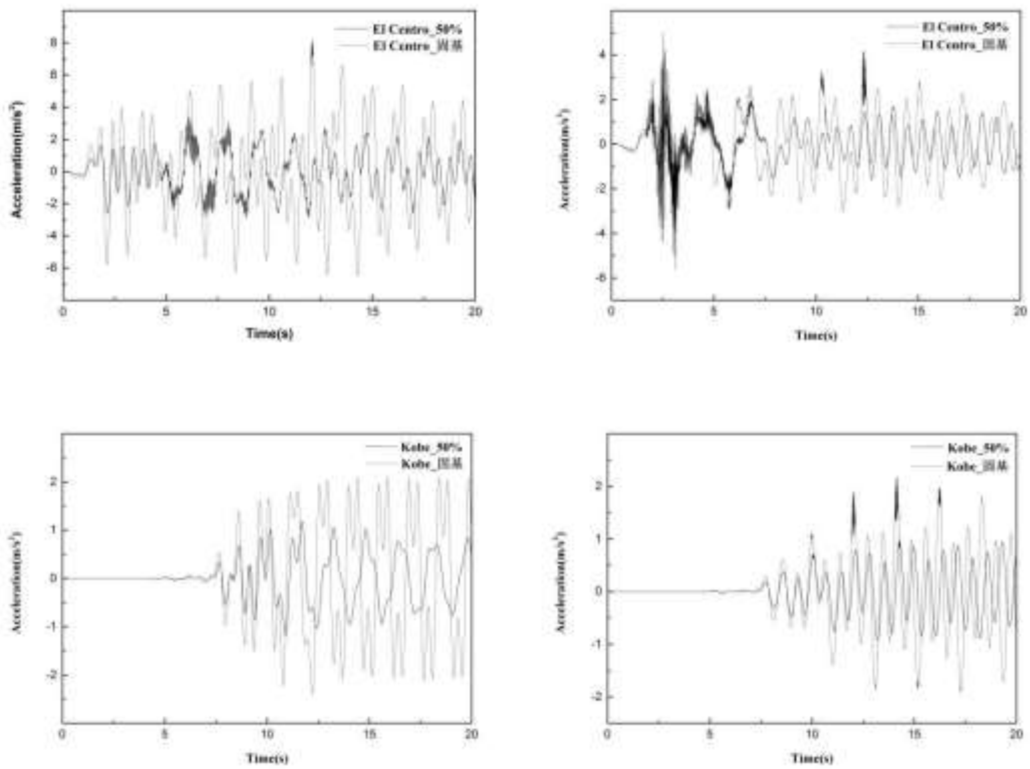


Fig. 3. Comparison of earthquake motion response under different confining pressures with 25% RSM ratio

Fig.3 Response comparison of different consolidation pressure under 25%RSM

Comparing the acceleration responses of the three kinds of seismic wave input, it can be seen that under the same seismic wave input condition, the acceleration time-history curve under 50kPa confining pressure fluctuates more than the curve under 100kPa confining pressure, but the amplitude is not much different, that is to say, 25%RSM Compared with the increase of confining pressure, the effect of seismic isolation is not changed obviously. However, it can be concluded that under the same RSM ratio, the larger the confining pressure, the smaller the ground motion response and the larger the dynamic shear modulus, which is consistent with the previous dynamic triaxial test results.



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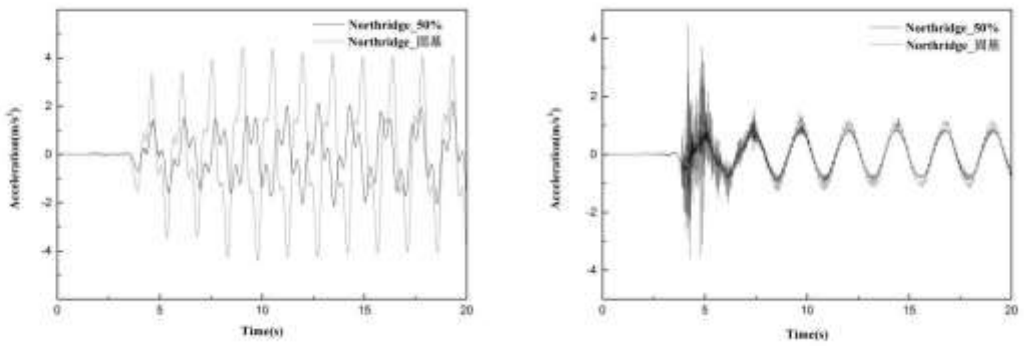
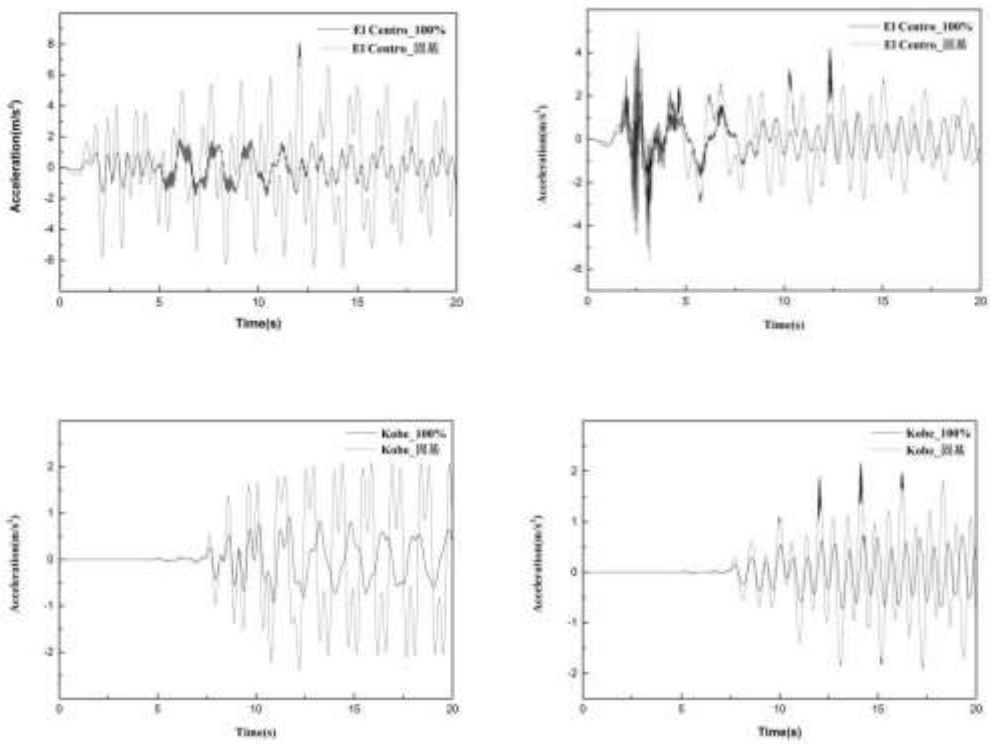


Fig. 4. Comparison of ground motion responses under different confining pressures under 50% RSM ratio

Fig.4 Response comparison of different consolidation pressure under 50%RSM

Comparative analysis shows that with the increase of RSM ratio, the impact of confining pressure on the ground motion response becomes more obvious. Compared with the case of 25% RSM ratio, the effect of confining pressure on dynamic shear modulus is also greater. The specific reaction is in the fluctuation range of the acceleration time-history curve. However, it is worth noting that the isolation effect of the RSM isolation layer is not good when the Northridge wave is input under the confining pressure of 100kPa. Except for the short-term effect in the initial state, the acceleration response in most of the time is basically the same as that under the condition of no isolation. .



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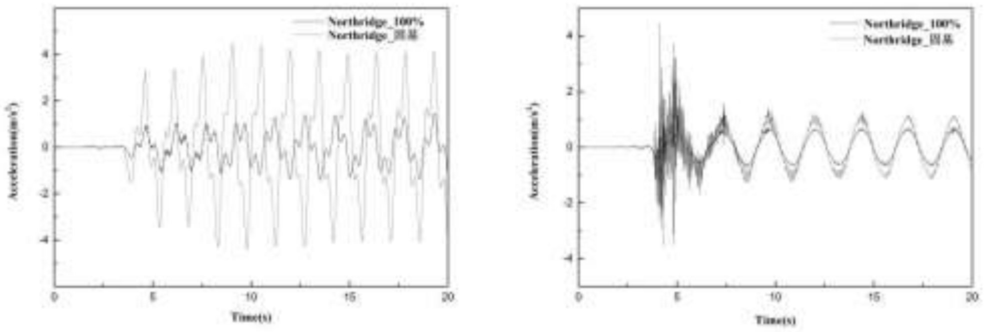
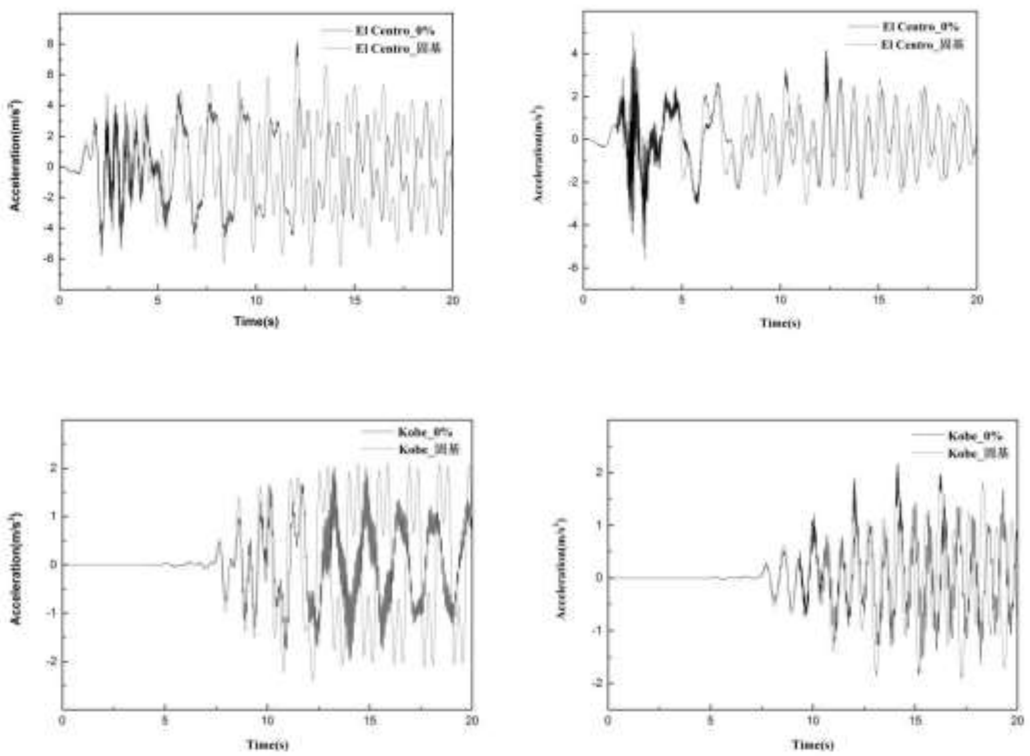


Fig. 5. Comparison of earthquake motion responses under different confining pressures under 100% RSM ratio

Fig.5 Response comparison of different consolidation pressure under 100%RSM



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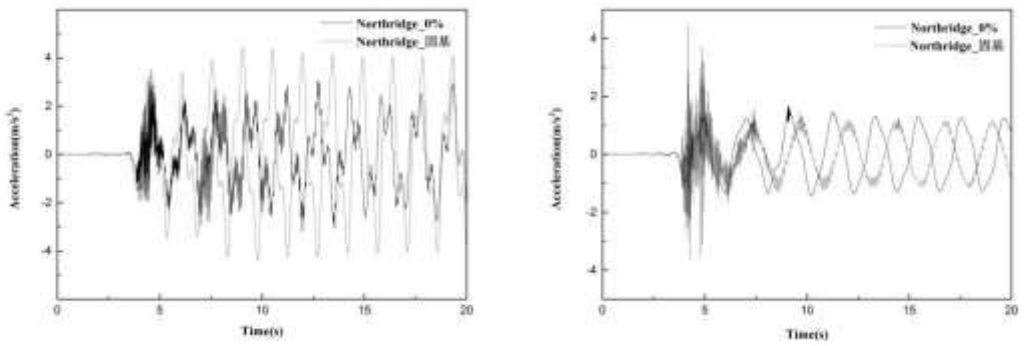


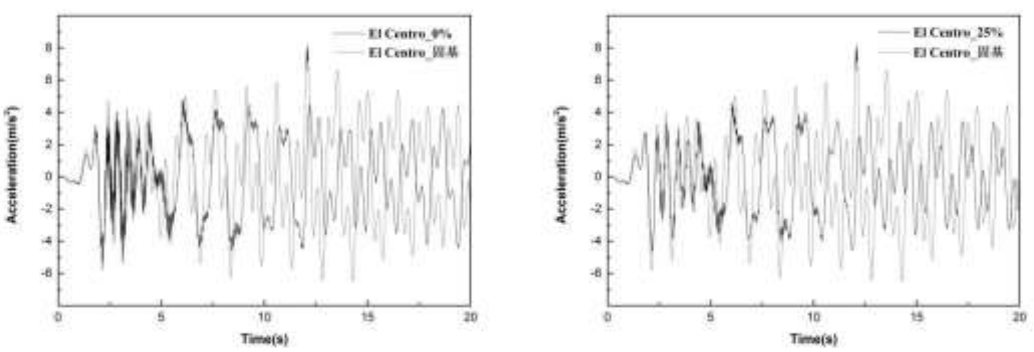
Figure 6 Comparison of earthquake motion responses under different confining pressures at 0% RSM ratio

Fig.6 Response comparison of different consolidation pressure under 0%RSM

Putting the ratio of 0% and 100% together, it is found that for seismic waves with a large input acceleration peak value, the isolation effect is very obvious, while for seismic waves with a small input acceleration peak value, the isolation effect is not obvious or even some "abnormal" Phenomenon. However, in general, the dynamic shear modulus of the RSM sample tends to be proportional to the applied confining pressure, but due to different seismic wave inputs, the final degree of change in the seismic isolation effect is also different.

1.3.2. <u>RSM mix ratio</u>

Slightly different from the dynamic triaxial test, we only take the five RSM ratios of 0%, 25%, 50%, 75% and 100% for analysis, and omit the 30% and 40% cases. The acceleration response time history curves of five different RSM ratios and three kinds of seismic wave input under the same confining pressure were compared and analyzed, and the influence of RSM ratios on the dynamic shear modulus was summarized according to the peak value and fluctuation range of the curves.



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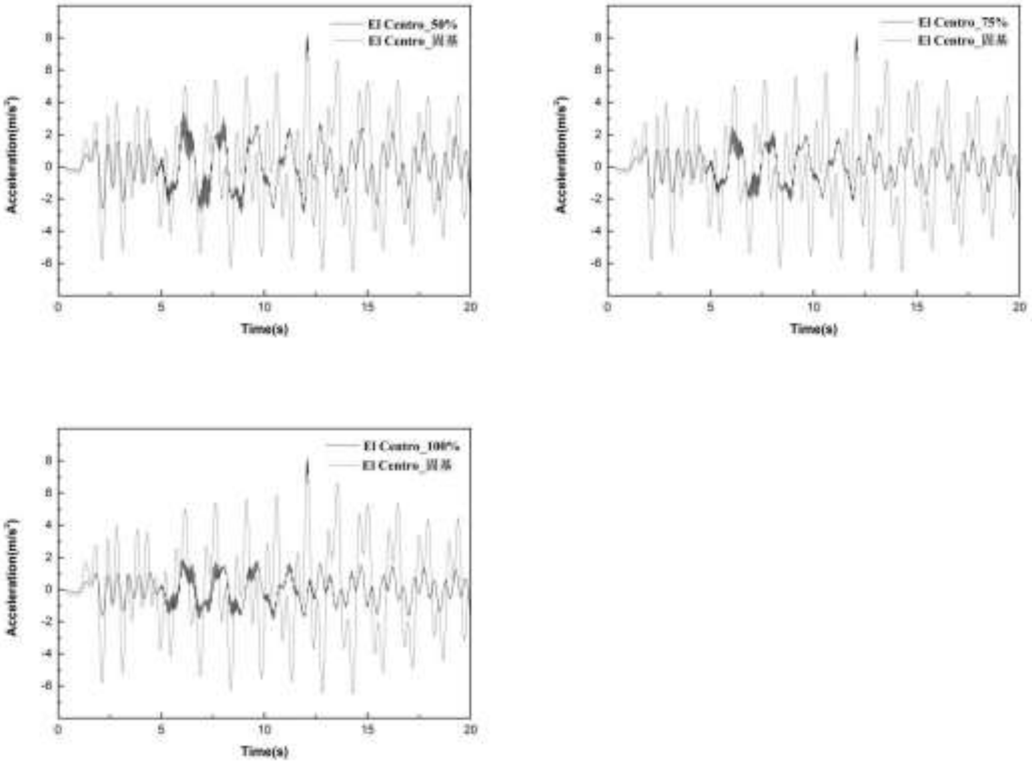
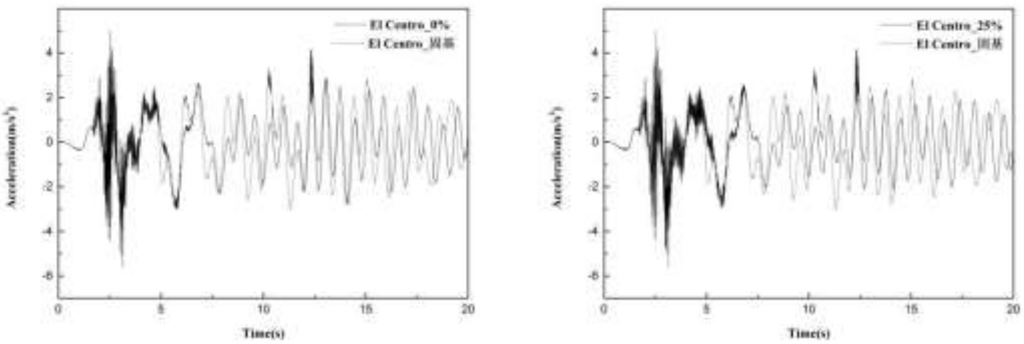


Fig. 7. Comparison of ground motion responses of different RSM ratios under 50kPa confining pressure

Fig.7 Response comparison of different consolidation pressure under 50%RSM

When the El Centro wave is input, it can be clearly seen that with the increase of the RSM ratio, the fluctuation range of the acceleration time-history curve becomes smaller and smaller. The seismic isolation effect is not good, and the difference between 50% and 75% ratios is very small, and the seismic isolation performance of the RSM seismic isolation layer is not significantly improved until 100%.



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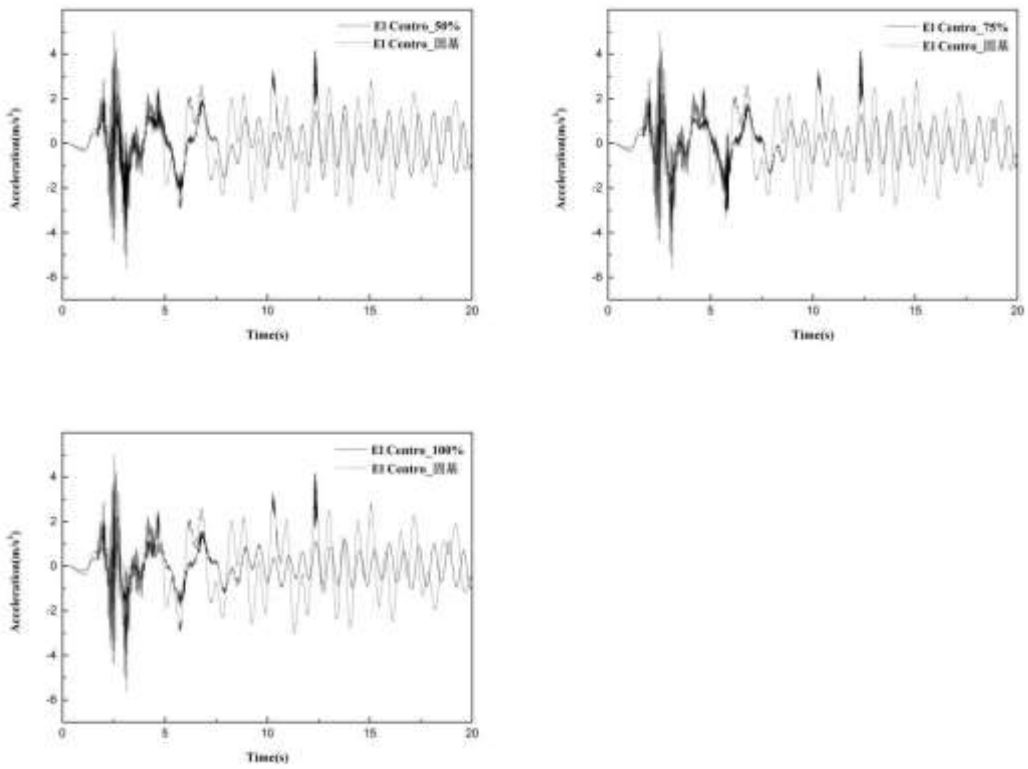
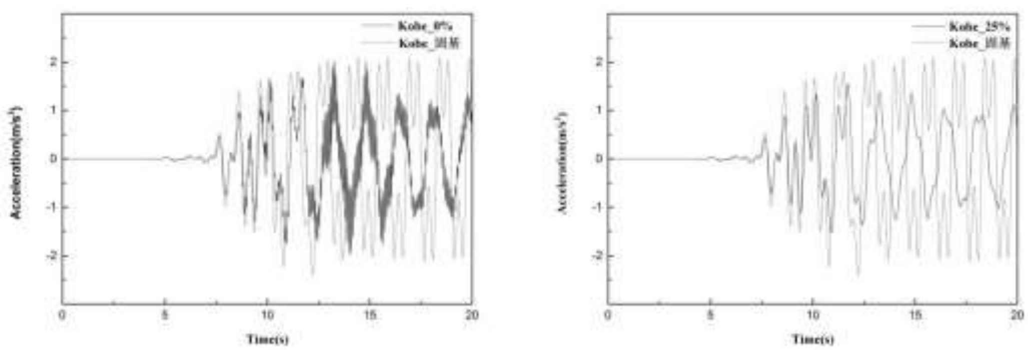


Fig. 8. Comparison of ground motion responses of different RSM ratios under 100kPa confining pressure

Fig.8 Response comparison of different RSM rate under 100kPa consolidation pressure

Compared with the situation of 50kPa confining pressure El Centro wave input, a similar situation occurs at 100kPa confining pressure, the reason may be that the vibration response is not obvious during the dynamic triaxial test, so the fluctuation of the data is not large.

Let's take a look at the input of Kobe wave and Northridge wave. The acceleration response time history curve is shown in the figure below.



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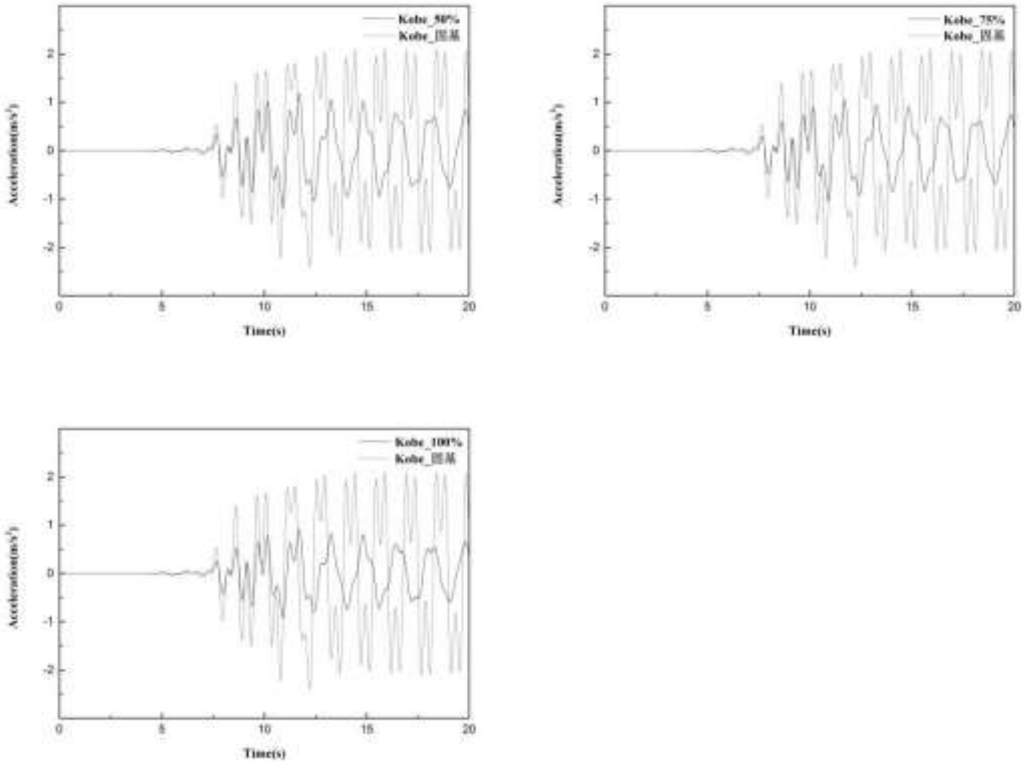
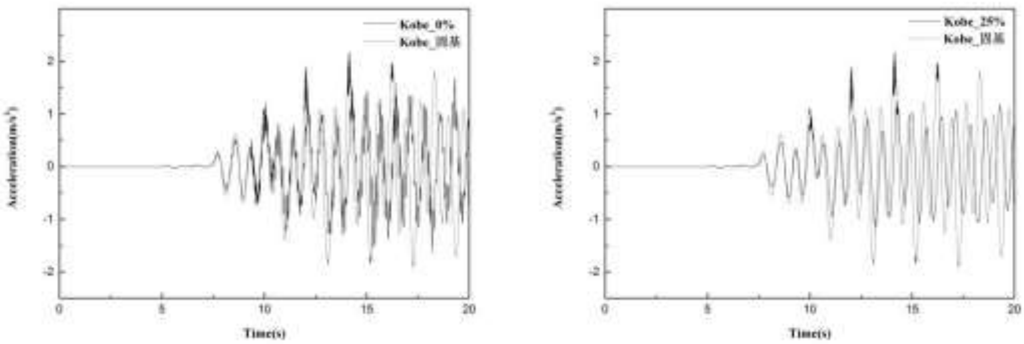


Fig.9 Acceleration response curve when Kobe wave input at 50kPa confining pressure

Fig.9 Acceleration time-history under 50kPa consolidation pressure, Kobe wave



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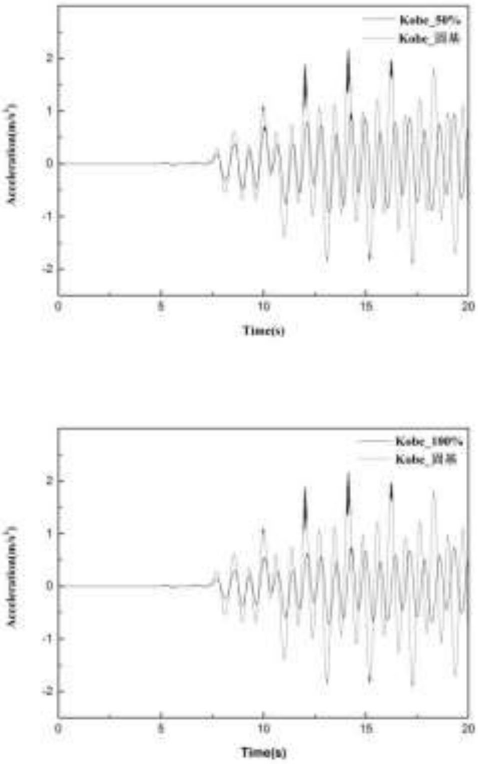
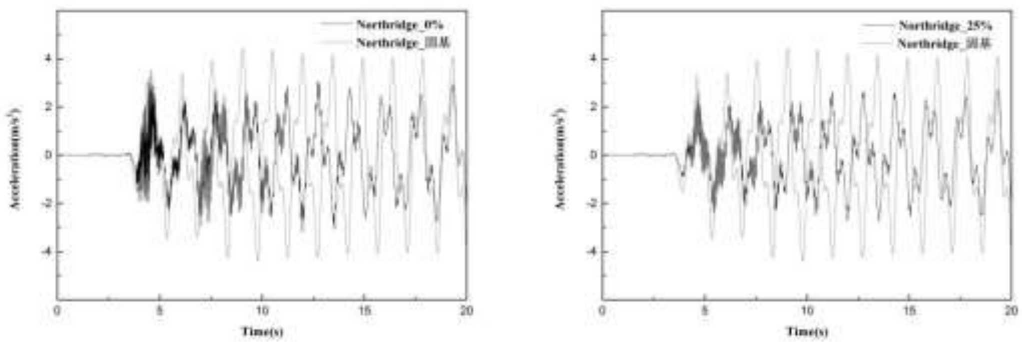


Fig. 10 Acceleration response curve when Kobe wave input at 100kPa confining pressure

Fig.10 Acceleration time-history under 100kPa consolidation pressure, Kobe wave

Different from the situation when the El Centro wave is input, the seismic isolation effect of the RSM seismic isolation layer is more obvious at 50kP confining pressure at 25% ratio, but in the process from 50% to 75%, there is no obvious acceleration response time history curve. The change may also be the same reason as before. But in general, the trend that the higher the RSM ratio, the better the shock isolation performance has not changed.



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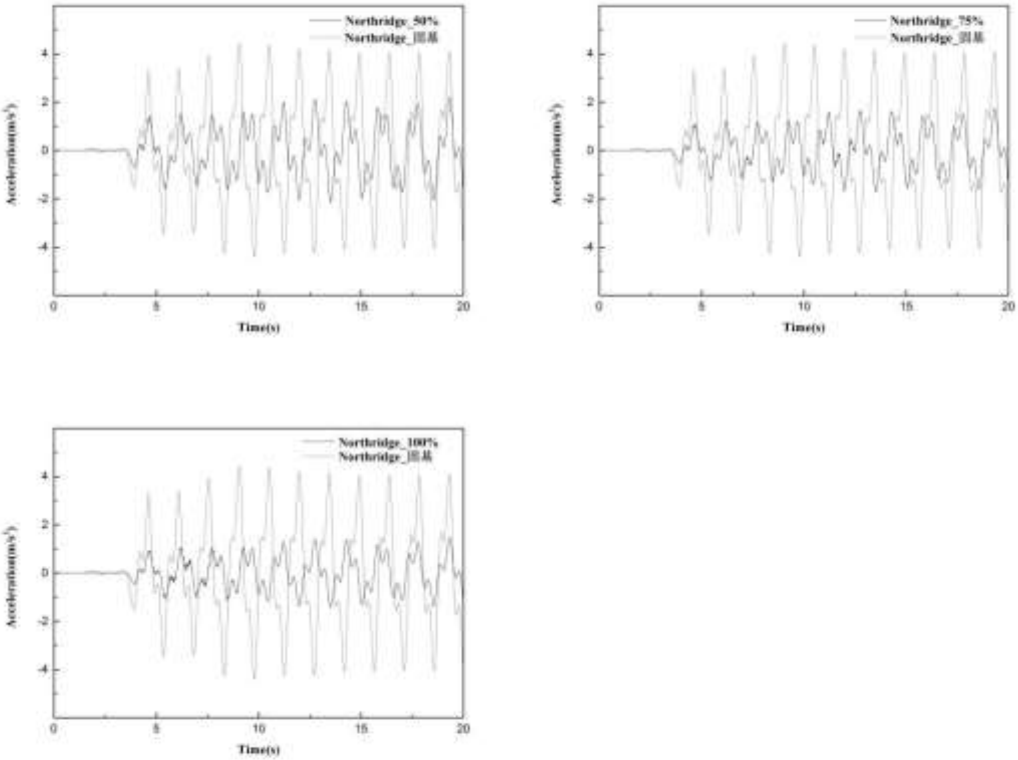
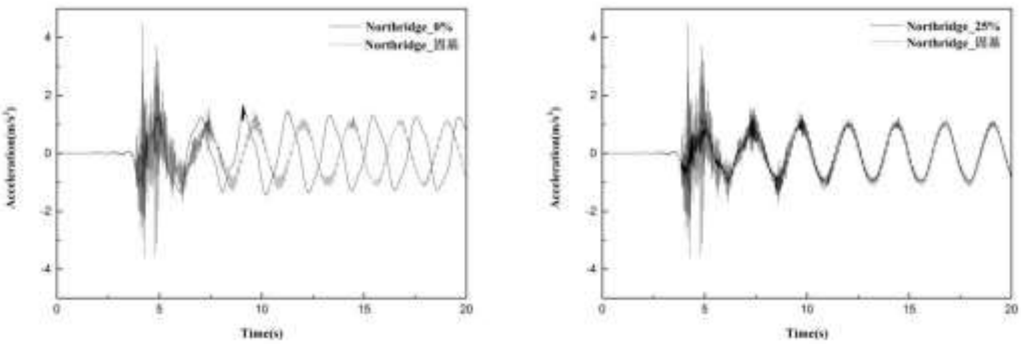


Fig. 11 Acceleration response curve when Northridge wave input at 50kPa confining pressure

Fig.11 Acceleration time-history under 50kPa consolidation pressure, Northridge wave



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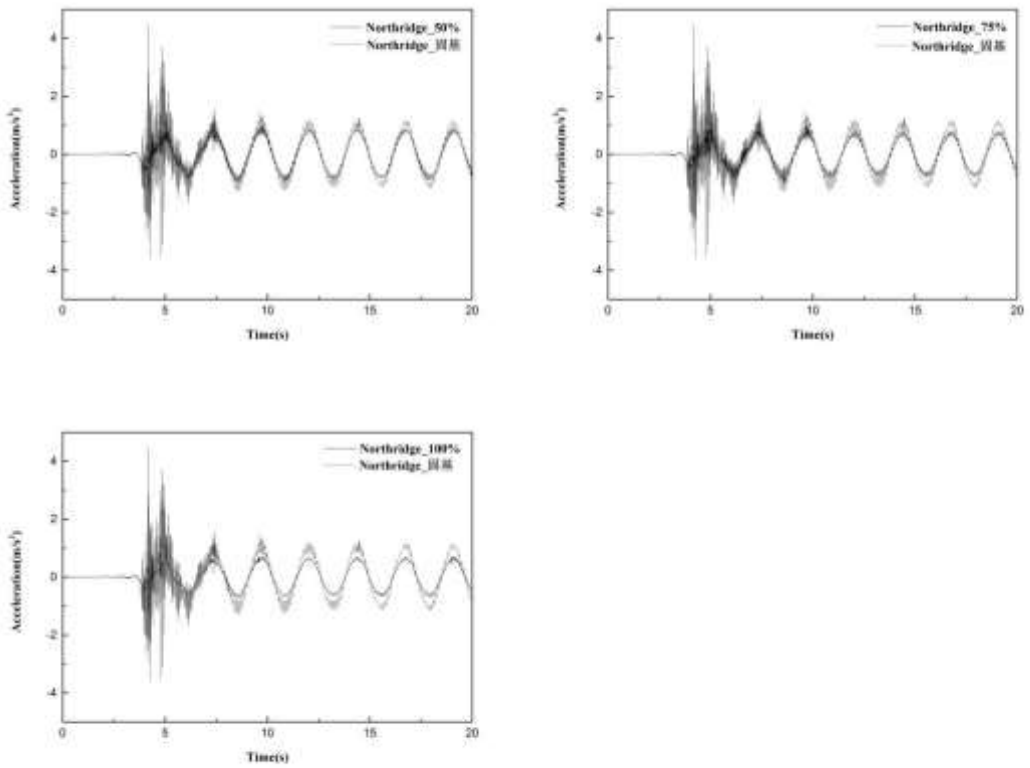

Fig. 12 Acceleration response curve when Northridge wave input at 100kPa confining pressure

Fig.12 Acceleration time-history under 100kPa consolidation pressure, Northridge wave

When the Northridge wave is input, the seismic isolation effect of RSM is relatively obvious when the ratio is 25% under 50kPa confining pressure, and the seismic isolation effect is more obvious when the ratio is 75% to 50%; while the pure sand foundation is under 100kPa confining pressure The curve is "abnormal", and the increase in the isolation effect of the RSM ratio is much smaller than that of all previous working conditions. The reason may be that the thickness of the RSM isolation layer has changed when the Northridge wave is input. Changes, resulting in the final isolation effect is not obvious.

1.3.3. seismic wave input

For different seismic wave inputs, the following table can be obtained by comparing and analyzing the seismic response curves of the fixed foundation and the seismic isolation cushion with RSM ratio of 20% and 50%:

Table 2 Comparison of peak acceleration between different cushions and fixed foundation (m/s^2)

Table 2 Acceleration amplitude comparison of different RSM layers and solid foundation (m/s^2)

Seismic wave pattern	Seismic azimuth	bottom pressure	solid base	pure sand	25%RSM	50%RSM	100%RSM
Center	East-West	50kpa	8.15	5.40	4.64	3.39	1.88
		100kpa	5.61	5.61	4.70	3.65	1.65
Kobe	East-West	50kpa	2.38	2.03	1.55	1.18	0.91
		100kpa	2.17	1.67	1.26	0.99	0.73
Northridge	East-West	50kpa	4.42	3.52	2.74	2.20	1.46
		100kpa	4.45	1.67	1.70	0.97	0.71

Through the comparison and analysis of the above acceleration peak data, it can be seen that under different bottom pressures and three different seismic wave inputs, the final improvement in the isolation effect is different. It is worth noting that under the Northridge seismic wave input, the seismic isolation effect of the pure sand cushion is even slightly better than that of the 25% RSM seismic isolation cushion. Although it can reduce the horizontal acceleration under the wave, its effect is not as obvious as that of the pure sand cushion.

CONCLUSION

In summary, the comparison of the parameter analysis results shows that the dynamic shear modulus of the RSM sample increases with the increase of the confining pressure, which is a proportional relationship, but this degree is affected by the input of seismic waves, and the greater the peak value of the input acceleration , the reflected trend becomes more obvious, that is, the seismic isolation effect will be more obvious; and the dynamic shear modulus of the RSM sample decreases with the increase of the RSM ratio, which is inversely proportional to the relationship, but this trend is affected by the seismic wave input The effect of is not big, and the isolation effect is basically the same. Of course, due to the existence of some uncontrollable factors in the process of data processing and some simplifications in modeling, the final numerical analysis results will be somewhat different from the results of the dynamic triaxial experiment, but they are all within the allowable range. Therefore, the conclusions obtained are also reliable, which further confirms the feasibility of the RSM shock-isolation cushion.

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