Diyala Journal of Engineering Sciences

Journal homepage: https://djes.info/index.php/djes

ISSN: 1999-8716 (Print); 2616-6909 (Online)

An Innovative Method for Damping the Seismic Waves on Pile Foundations Using A Mixture of Rubber-Binder Jacketing

Azzam M. Mohamed[1*], Amer M. Ibrahim[1], Qutaiba G. Majeed[1] and Mohamed H El Ouni[2]

[1]Department of Civil Engineering, University of Diyala, 32001 Diyala, Iraq
[2]Department of Civil Engineering, College of Engineering, King Khalid University, PO Box 394, Abha 61411 Kingdom of Saudi Arabia

ARTICLE INFO

Article history:
Received May 12, 2023
Revised August 11, 2023
Accepted September 29, 2023
Available online December 15, 2023

Keywords:

Single pile
Rubber
Damping
Shaking table
Earthquakes
Sustainability

ABSTRACT

Earthquakes are sudden and unpredictable natural activity that causes severe damage. As a result of the increasing seismic activity in Iraq, it has become necessary to conduct a study on the impact of earthquakes and methods of damping them. Since traditional seismic damping methods for construction are very expensive, alternative solutions are necessary. Therefore, this research proposes a new damping method that depends on surrounding the piles with rubber crumbs, as the rubber works to dampen the seismic force before it reaches the piles before moving to the structure. This method is considered a type of sustainability. The study included a set of variables, including (the thickness of the rubber that surrounds the piles, and the position of placing the rubber that sleeved the piles). The tests were carried out using the shaking table device. The results showed that surrounding the piles with rubber gave distinct results in damping the seismic force and it is considered an easy damping method due to its ease of implementation, as well as its economic feasibility. The results showed for the models that surround the rubber in the upper part of the pile, an increase in the values of the acceleration of the structure and a decrease in the values of the movement speed of the structure, the values of the lateral displacement of the structure. The models in which the rubber surrounds the middle and bottom part of the pile, the results were close to the reference model.

1. Introduction

The term "solid waste" refers to all solids and semi-solids. Improper solid waste management has negative consequences on the environment, which could lead to disease outbreaks and epidemics [1]. The materials used as soil enhancement additives are diverse in terms of their qualities, shapes, and characteristics. Natural soils, synthetic chemicals, and even repurposed waste items are all examples. rubber material is one of these waste items that have been used as a waste material to help enhance sandy soil. Every year, millions of waste tires are taken out of service and dumped in nature all over the world. Two hundred and ninety-nine million waste tires were dumped in the environment in the United States in 2005. In Japan, one hundred and three million waste tires were disposed of, compared to twenty million in South Korea, Twenty-eight million in Canada, and Fourteen million in the United Kingdom [2]. Waste tires pose a risk to the environment, human health, and safety in today's megacities. In India, one waste tire is estimated to be produced per person per year. Compared to the annual stockpiling, the recycling percentage is very low. Rubber is well known for being a good

* Corresponding author.
E-mail address: azammuthana.hp@gmail.com
DOI: 10.24237/djes.2023.160406

damping material [3]. Because traditional building seismic isolation methods are prohibitively expensive, finding alternative solutions becomes necessary. The use and recycling of rubber waste and its use in soil improvement is a form of sustainability. Earthquakes occur naturally and are unpredictable and occur suddenly and because of their violent movement, they have a great ability to cause damage to facilities, such as the settlement of bases under structures or the destruction of sewage networks and roads. Iraq is located in a seismically active zone along with the Arabian Tectonic Plate's north-eastern limits. According to Iraq's seismic history, annual seismic activity of varying magnitudes may occur. Seismic activity is highest in Iraq's north and north-eastern zones, and it decreases dramatically in the south and southwest an example of this is the Halabja earthquake (2017), which was 7.3 degrees on the Richter scale [4]. As a result of the increasing impact of earthquakes, which has recently increased in Iraq, on civil installations of all kinds, such as shallow and deep foundations, it is necessary to research and verify the behaviour of these structures under the seismic influence in order to limit and reduce human and resource losses. Tire waste and recycled rubber have been used as lightweight building materials, fill, drainage, and thermal-isolation materials in numerous geotechnical projects around the world [5-8]. Investigations on this material have been conducted to of protecting buildings from earthquake-induced vibrations [9-11]. This research aims at an experimental study on the effect of using rubber waste with soil mixture to enclose piles at different heights and different diameters on the solutions and the strength of the piles.

2. Materials used

2.1 Soil

The soil used in this research is sandy soil, which was collected from southern Iraq from Karbala governorate. The necessary laboratory test was conducted to deduce the characteristics of the soil. These tests were prepared in the laboratories of the civil department at the University of Diyala - College of Engineering. Soil properties are shown in Table 1.

Table 1: Results obtained from tests for sandy soil

Property	Value	Standard of the test
Specific gravity, Gs	2.63	ASTM D854[12]
The angle of internal friction, φ (°)	36	Direct shear test ASTM D3080/ D3080M-11[13]
Cohesion, c (kPa)	0	ASTM D3080/ D3080M-11[13]
Maximum dry unit weight, γ_{dmax} (kN/m^3)	18.5	ASTM D4253[14]
Minimum dry unit weight, γ_{dmin} (kN/m^3)	16.8	ASTM D4254[15]
The use of dry unit weight, γd (kN/m3)	17.95	
Relative density, Dr (%)	70	

2.1.2 Crumb rubber

The rubber crumbs used in this research are the result of recycling the damaged tire rubber, where the rubber was cut into very small pieces ranging between (2-3) mm and its density is (14.4) kg/m3 as shown in Figure 1.

Figure 1. Crumbs of rubber used in experiments

2.1.3 Binder

In this research, a binder was used to bind the crumb rubber particles with the piles in order to act and behaves as a single unit. The binder used is an Aromatic polyisocyanate-prepolymer binder based on diphenylmethane diisocyanate. This substance is frequently utilized in the production of numerous polyurethane goods, such as adhesives, coatings, and foams. The final product formulation uses this prepolymer as a binding agent or binder to provide the appropriate mechanical and chemical qualities. Because of their adaptability and capacity to produce strong, flexible, and long-lasting materials, polyisocyanate binders and prepolymers are highly prized.

3. Devices and instrumentation

3.1 Piles

Single hollow aluminum substrates of their light weight, square shape, were used in the experiments. The dimensions of the pillars are (1.3 * 1.3) cm, the length of the pillar is 40 cm and the thickness is 2 mm. The depth of the pile is 35 cm.

3.2 Shaking table and sensors

Practical experiments were performed using a vibration table that simulates earthquakes as shown in Figure 2. The vibration table induces an earthquake on the piles embedded in the soil. Similar to the earthquake that occurred in Japan in 1995, known as the Kobe earthquake, the earthquake had a magnitude of 6.9 on the Richter scale. This earthquake killed more than 5,000 people and destroyed more than 102,000 buildings in Kobe.

Figure 2. Describes the device used in simulating earthquakes (Shaking Table)

In order to measure the acceleration at the loaded pile a sensor type (ADXL335 Analog output 3- Axis Accelerometer Module GY-61 Angular Transducer) when used. the sensor was attached at (At the top of the load center) as shown in Figure 3.

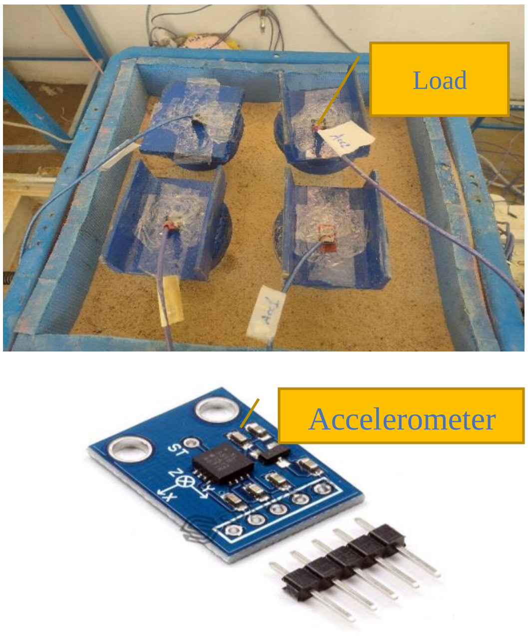


Figure 3. The shape of the acceleration sensor and its location above the load

3.3. Container (soil tank)

The used iron container is square in shape. The dimensions of the container are 50 cm in length and width, and 60 cm in height. The container is covered from the inside with cork, with a thickness of 2 cm so that the seismic wave does not bounce and interfere with each other. The height was divided into five layers, each layer 10 cm so as to control the density of the sand., as shown in Figure 4.

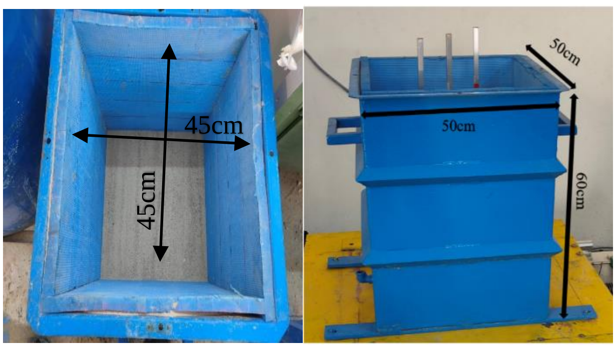


Figure 4. Use of a steel container (soil tank)

4. Models preparation and experimental setup

4.1 Preparing sandy soil for experiments

The soil box was divided into five layers with a thickness of 10 cm, length and width of 45 cm, to ensure the required density of 17.95 kg / m^3 to obtain a relative density of 70%. Through the density equation, the weight required to be placed in one layer was found, which equals (37.05 kg) to be stacked well until it reaches the required layer size by means of an iron hammer as shown in Figure 5. The soil was divided into layers in order to place the piles and control the density of the soil.

Figure 5. Soil box preparation

4.2 Prepare the piles surrounded by rubber

The pile is prepared for examination by surrounding it with rubber. And that is by mixing rubber with the binder at a rate is used for time of 25% of the weight of the rubber and then it is mixed well and placed in cylindrical molds with diameters and lengths specified for examination. The pile is inserted in the center of the mold in the rubber mixture until the rubber hardens and becomes one piece with the pile as shown in Figure 6. Then it is placed in the sandy soil box for examination.

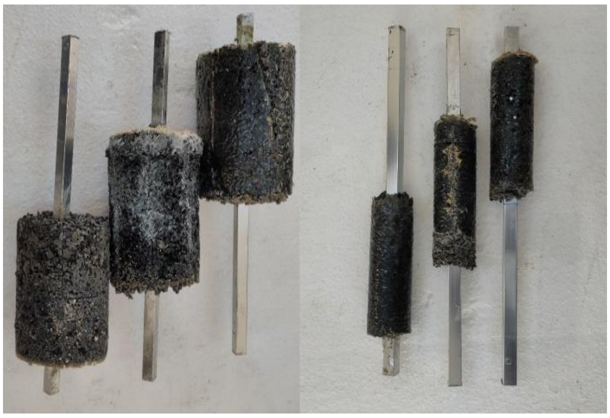


Figure 6. Rubber surrounding piles of different diameters and thicknesses

4.3 Preparing samples for testing

Soil box in which four piles are placed in sandy soil with a relative density of 70%. One of these piles is a reference and not surrounded by rubber, while the other three columns are surrounded by rubber. The length and diameter of the rubber are fixed around the pile, but the location of the rubber from the substrate varies as the rubber is placed at the top, middle and bottom of the mound as shown in Figure 7. Then the load is placed at the top of the pile, the weight of the load was calculated according to the bearing capacity of the pile, which is equal to 5 kg, the acceleration sensors are connected to the top of the load, and the earthquake is loaded onto the inspection model after it is placed on the vibrating table. The length and diameter of the rubber are fixed around the pile are changed in each model that is examined to see the behavior of the pile with the presence of rubber with a train and different lengths and locations of the pile. This method can be implemented in reality through the pile methods, after which the area around the pile is excavated at the depth required to put the rubber in it, and then the pile head is surrounded with rubber and then buried. An earthquake is shed on the samples, data related to the earthquake that occurred in Japan in 1995 were taken in the Kobe region. These data are taken from the Japanese Network for Earthquake Monitoring and Seismology (IMOS), as shown in Figure 8. The data based on the acceleration of the earthquake is used and applied in the form of ground motion through the vibration table to experimental models.

Figure 7. Preparing the sample for testing

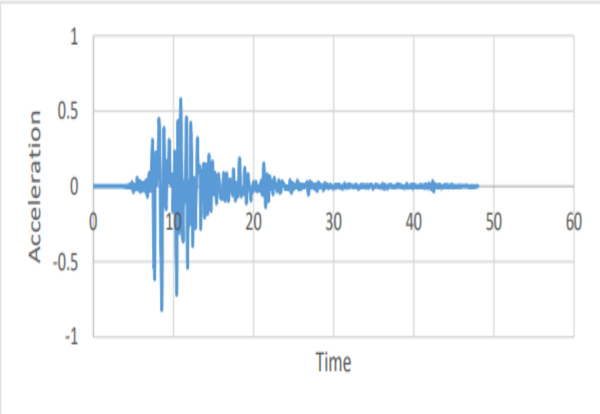


Figure 8. Time history of the Kobe earthquake (Japan Seismic Network at the Japan Meteorological Organization and seismology (IMOS))

5. Results and discussion

5.1 General

This study examines how piles behave when rubber is placed around them while being subjected to earthquakes. Using the results of acceleration, displacement, and velocity of the tested models obtained through the shaking table. In order to conduct sample testing, a number of factors were examined, including the diameter of the rubber encircling the heaps and its placement. In tables and graphs, sample test results show the displacement caused by the movement of structures under the effect of earthquakes, the acceleration of structures under the influence of earthquakes, and the velocity of movement of structures under the influence of seismicity. The experimental findings are also thoroughly explained.

5. 2 The cases study

The first group (7D.15L) consists of four models; the first model serves as a reference and is not surrounded by rubber; the other three models, which are located at the top, middle, and bottom of the pile, are all surrounded by rubber that has a diameter that is seven times greater than the pile's diameter and a length of 15 cm. In this group, the behaviour of the pile and the degree to which the presence of rubber and the various rubber sites of the pile affected it was discussed. For each model, the topics of acceleration, velocity, displacement, the acceleration response spectrum, and specific energy density are discussed. It was discovered that the rubber at the pile's top affects how it responds to seismic loads.

The second group consists of four models; the first is a reference that isn't enclosed in rubber, while the other three models are, with three times the pile's diameter and a length of 15 cm, enclosed in rubber at the top, canter, and bottom of the pile, respectively. Seismic stress was applied when testing the models. In this group, the behaviour of the pile and the degree to which the presence of rubber and the various rubber sites of the pile affected it was discussed. For each model, the topics of acceleration, velocity, displacement, the acceleration response spectrum, and specific energy density were covered. It was discovered that the rubber at the pile's top affects how it responds to seismic loads.

5. 2. 1 Group One (7D.15L)

This group tests four models under seismic load (chronological history analysis). Table 2 provides a list of all model codes studied in this group. Figure 9 shows the details of the Model.

Table 2: Model symbols for the first group (7D.15L) of tests under seismic load

No.	Name of Models	Diameter of rubber	Length of rubber	Location of rubber from the pile
1	RP	-	-	-
2	7D.15L.T	7D	15CM	rubber top
3	7D.15L.M	7D	15CM	rubber medial
4	7D.15L.D	7D	15CM	rubber down

Where RP: The reference pile that is not surrounded by rubber, 7D: The diameter of the rubber that surrounds the pile is seven times the diameter of the pile, 15L: The length of the rubber that surrounds the pile is 15 cm, T, M, and D: The location of the rubber that surrounds the pile (top, middle, down).

When the seismic load is applied to the models using a shaking table, the earthquake acceleration is measured using sensors positioned above the load, which is then placed above the piles. The findings given in Table 3 were obtained by analysing the acceleration measurements using a program (SeismoSignal) that is specifically designed for analysing.

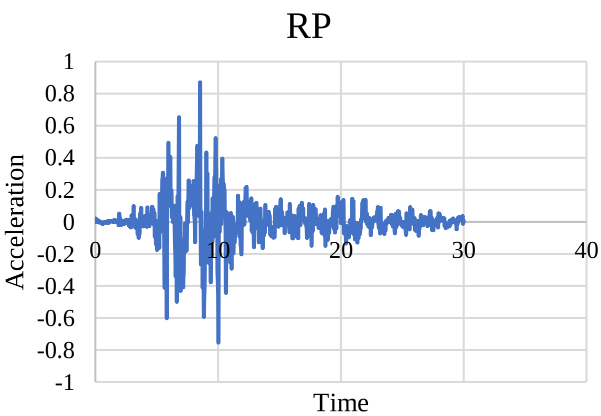
Figure 9. Details of the Sample for Earthquakes Models that Underwent Seismic Load Testing

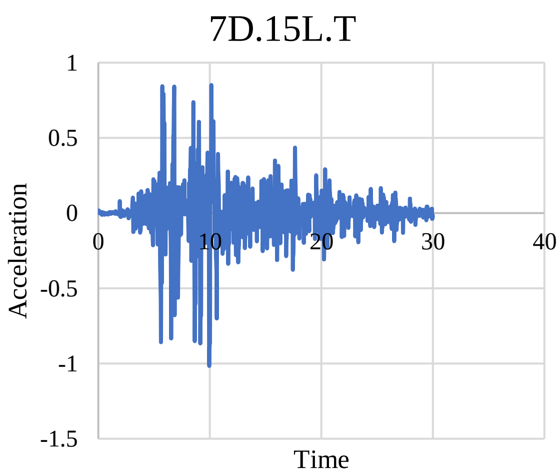
Table 3: The results for Group One (7d.15l) that Tested under Seismic Load

Parameter	RP	7D.15L.T	7D.15L.M	7D.15L.D
Max. Acceleration (g)	0.86977	1.01599	0.84021	0.88996
Time of Max. Acceleration (sec)	8.528	9.945	10.02	8.529
Max. Velocity (cm/sec)	88.82224	62.14307	104.4791	90.95798
Time of Max. Velocity (sec)	8.573	5.719	8.581	7.468
Max. Displacement (cm)	26.82648	11.67856	28.83724	28.43885
Time of Max. Displacement (sec)	7.024	11.132	7.014	7.011
Specific Energy Density (cm2/sec)	12161.28	5053.175	16972.9	12927.7

5. 2. 1.1 Acceleratio

It can be noted from Table 3 that the acceleration values in the model (7D.15LT) increased by 16.5% over the acceleration value of the reference model (RP) as shown in Figure 10. This increase is due to the presence of rubber in the upper part of the mound, where when an earthquake occurs, the structure starts to move and the upper part of the mound close to the surface of the soil starts to move due to the presence of rubber in this area, the rubber works to dampen vibration due to the high elasticity of rubber and its high ability to absorb energy, which leads to an increase in acceleration. It can be noted that the amount of acceleration in models (7D.15L.M) and model (7D.15L.D) is equal to the amounts of acceleration in the reference model (RP), and the reason for this is the presence of rubber in areas where the pile does not move and remains fixed in the soil, so no It shows no effect on the amounts of acceleration.





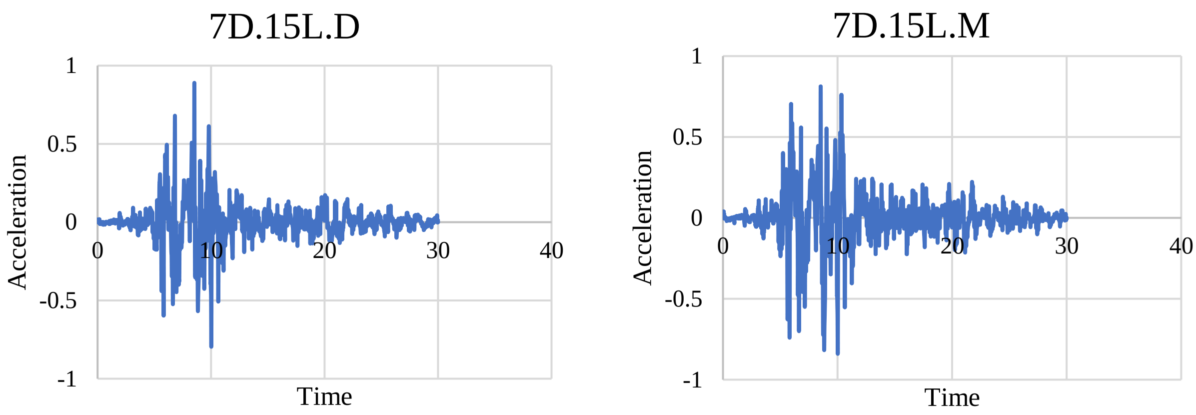


Figure 10. Time history (Acceleration) of the examined models (RP, 7D.15L.T, 7D15L.M, 7D.15L.D)

5. 2. 1. 2 Velocity

Table 3 shows that the speed in the model (7D.15L.T) is 30% lower than the reference model (RP), which is attributable to the rubber's high elasticity and capacity to absorb vibration energy. as the rubber works on Dampening the kinetic energy of the pile leads to a decrease in the speed. It can be noted that the amount of speed in the model (7D.15L.M) (7D.15L.D) is somewhat close to the speed of the reference model (RP) as shown in Figure 10 because the moving portion of the pile is the upper portion Consequently despite the existence of rubber, the velocity estimator does not change in models (7D.15L.M) and (7D.15L.D) since the higher section of the pile is surrounded by sand.

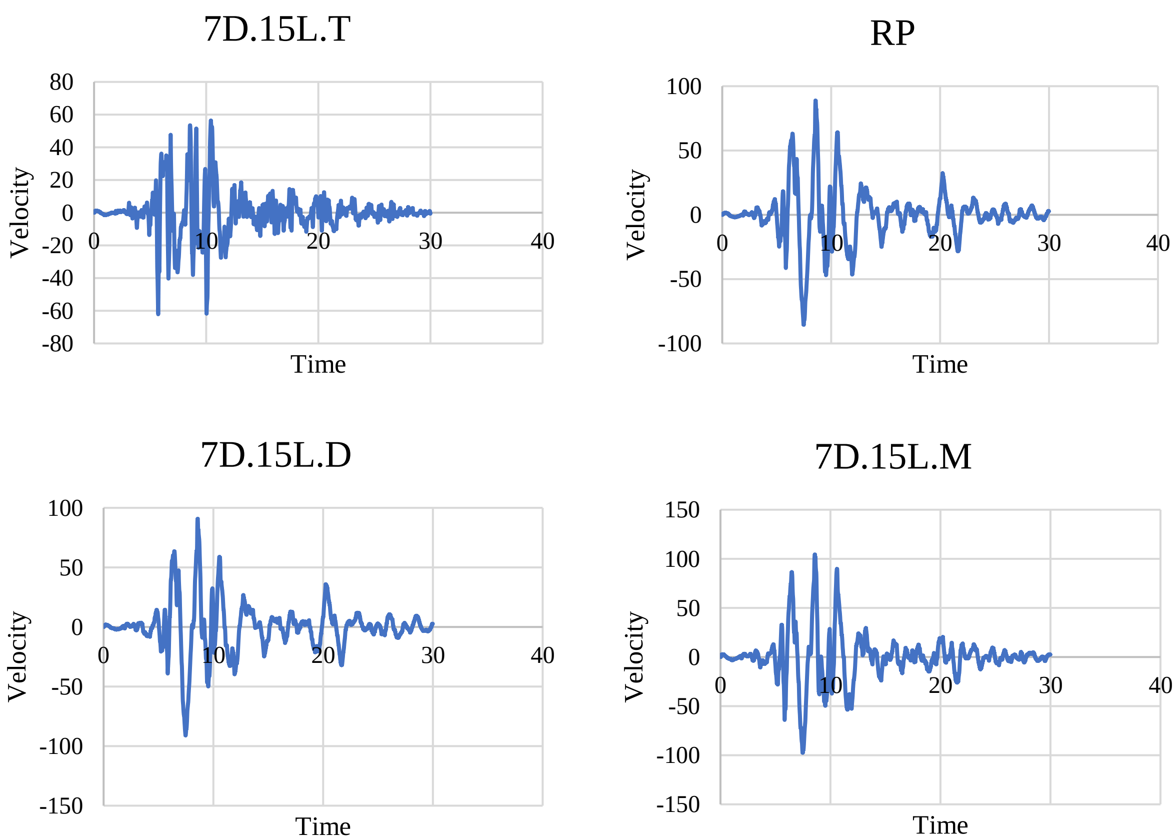


Figure 11. The velocity of the examined models (RP, 7D.15L.T, 7D.15L.M, 7D.15L.D)

5. 2. 1. 3 Displacement

Table 3 shows that the displacement findings are similar across all models, with the exception of the model (5D.15L.T), where the displacement was 56% lower than the reference model (RP), as shown in Figure 12 Rubber's elastic modulus is low, and it can withstand deformation to a significant extent since it has the qualities of flexibility and energy absorption. When compared to the reference model, the sample's bearing capacity was higher because of these characteristics, which allowed the rubber to absorb and lessen the stresses and strains associated with earthquakes (RP). The displacement in models 7D.15L.M and 7D.15L.D is nearly equal to the displacement in the reference model (RP), this is because of the sand that surrounds the top of the pile, which is part of the pile that moves when exposed to an earthquake. That's why the rubber had no effect.

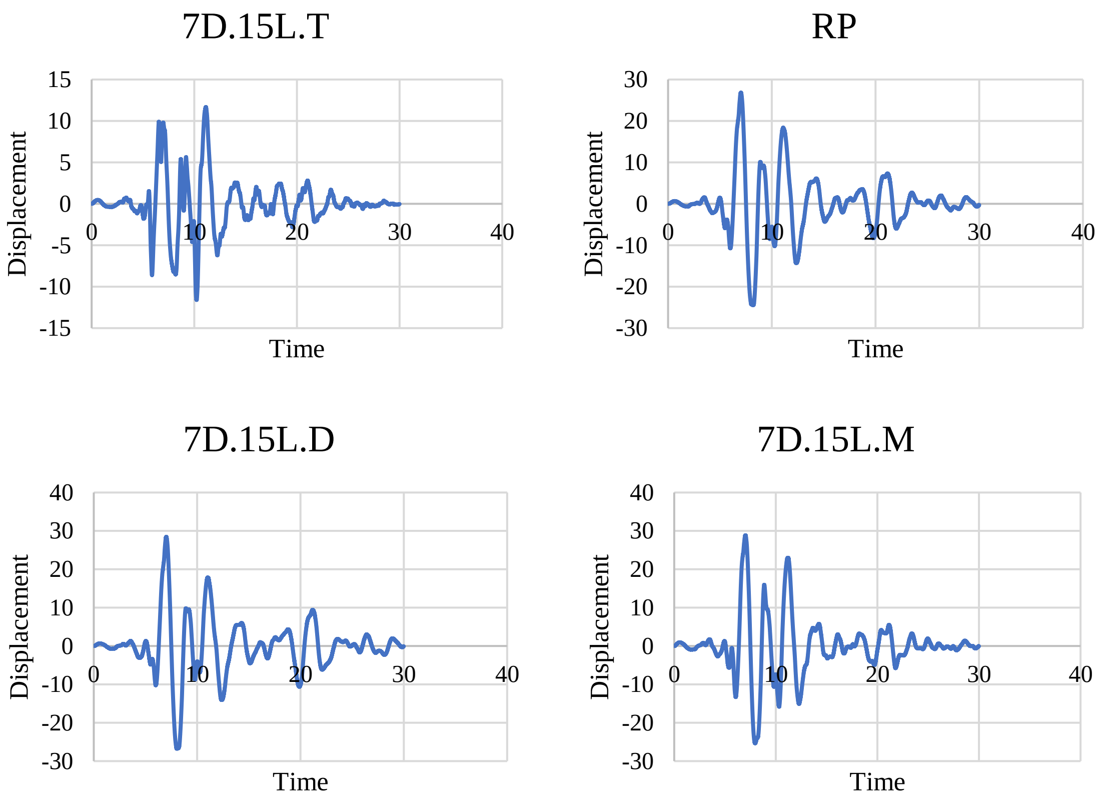


Figure 12. Displacement of the examined models (RP, 7D.15L.T, 7D.15L.M, 7D.15L.D)

5.2.1.4 Acceleration response spectrum

It can be noted the response acceleration in the reference model (RP) and the two models (7D.15L.D) and (7D.15L.M). It starts increasing in the first second and gradually starts to fade until it reaches the tow second when it increases and then fades away. Whereas in the (7D.15L.T) model, It can be noted an increase in response acceleration in the first half of the first second, and it begins to fade rapidly gradually. By comparing the reference model (RP) with the two models (7D.15L.M) and (7D.15L.D), It can be noted that their behavior is somewhat similar. When comparing the reference model (RP) with the model (7D.15L.T) as shown in Figure 13, It can be noted the emergence of the effectiveness of the rubber surrounding the substrate, as it can be noted clear damping through the curves, as the acceleration increases only in the first half of a second and immediately begins to fade rapidly, due to the ability of the rubber High energy absorption and flexibility.

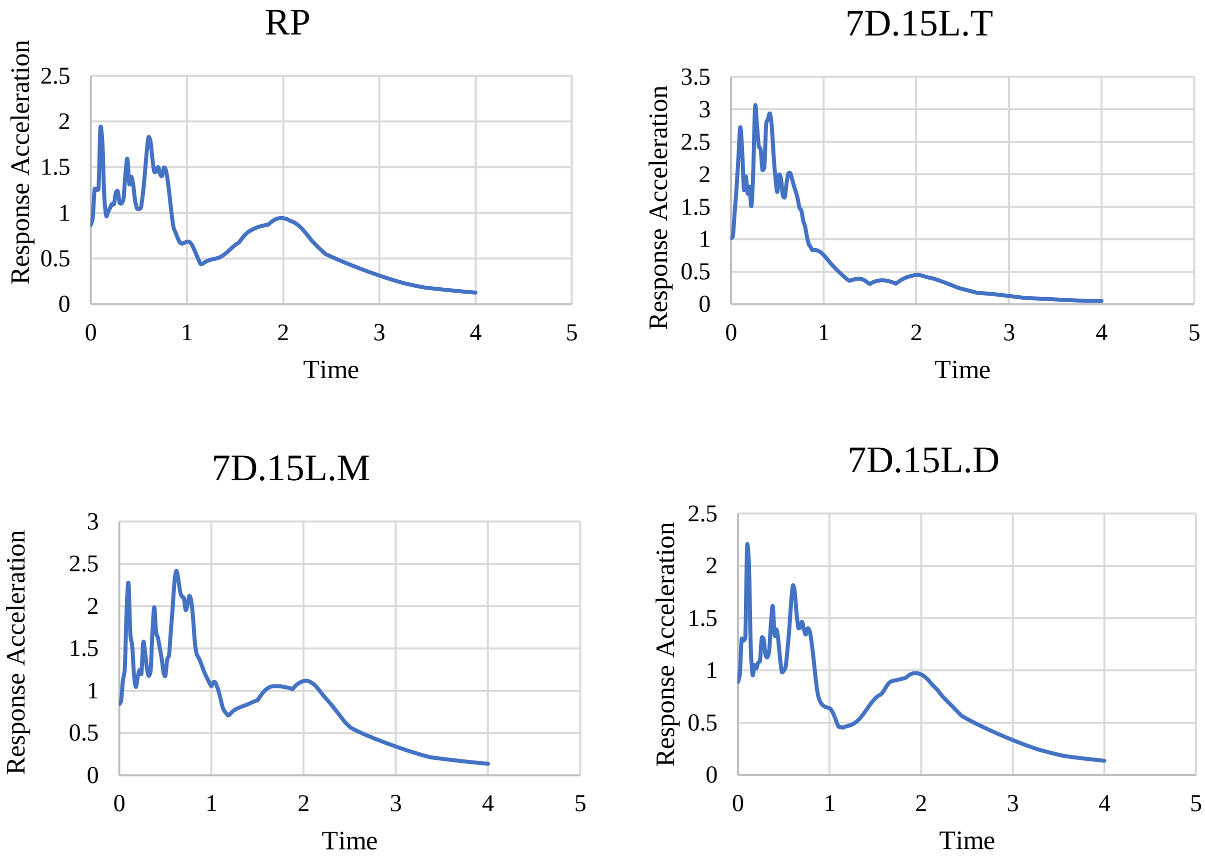


Figure 13. Acceleration response spectrum of the examined models (RP, 7D.15L.T, 7D.15L.M, 7D.15L.D)

4. 2. 1. 5 Specific energy density

It can be noted that the energy flow in the reference model (RP) begins to increase gradually until it reaches (12000) cm^2/sec, while the model (7D.15L.T) begins to increase gradually until it reaches (5000) cm^2/sec, the model (7D.15L. M) starts to increase gradually until it reaches (17000) cm^2/sec, the model (7D.15L.D) starts to increase gradually until it reaches (1300) cm2/sec. By comparing the reference model (RP) with the model (7D.15L.T) as shown in Figure 14, It can be noted that the amount of energy flow decreased by 58%. This is due to the presence of rubber in the upper part of the pillar that moves when an earthquake occurs, and the effectiveness of rubber on damping due to the high ability of rubber to absorb energy and its high flexibility. When comparing the reference model (RP) with the two models (7D.15L.M) (7D.15L.D), It can be noted that the amount of energy flow is close to the reference model or slightly more, despite it being surrounded by rubber, as the effectiveness of the rubber did not appear due to the presence of rubber in the fixed part of the pillar that does not move when an earthquake occurs.

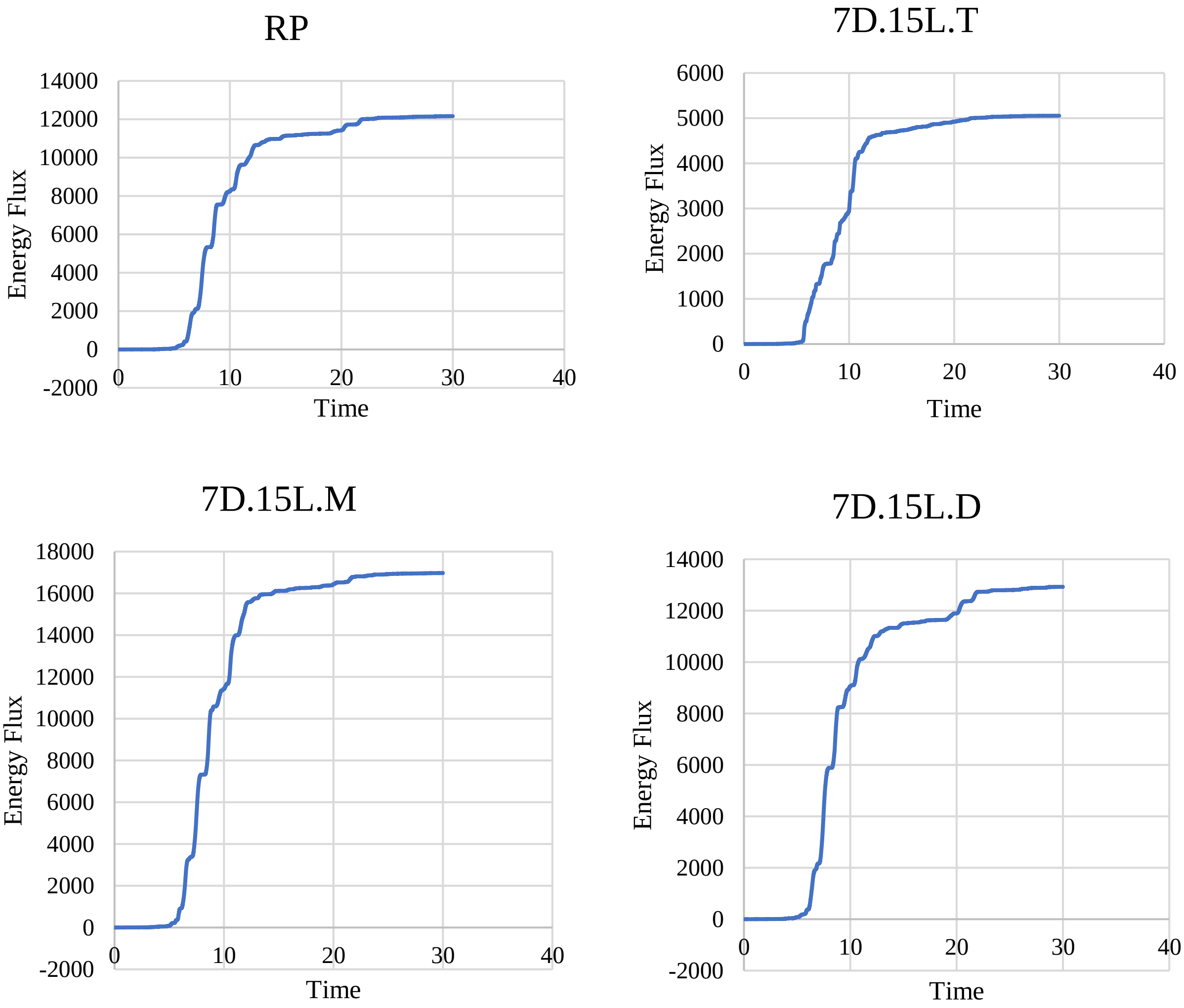


Figure 14. Specific Energy Density of the examined models (RP, 7D.15L.T, 7D.15L.M, 7D.15L.D)

5. 2. 2 Group Two (3D.15L)

This group tests four models under seismic load (chronological history analysis). Table 4 provides a list of all model codes studied in this group. Figure 15 shows the details of the Model. When the seismic load is applied to the models using a shaking table, the earthquake acceleration is measured using sensors positioned above the load, which is then placed above the piles. The findings given in Table ٥ were obtained by analysing the acceleration measurements using a program (SeismoSignal) that is specifically designed for analysing earthquakes.

Table 4: Model symbols for the two groups (3D.15L) of tests under seismic load

NO.	Name of Models	Diameter of rubber	Length of rubber	Location of rubber from the pile
1	RP	-	-	-
2	3D.15L.T	3D	15CM	rubber top
3	3D.15L.M	3D	15CM	rubber medial
4	3D.15L.D	3D	15CM	rubber down

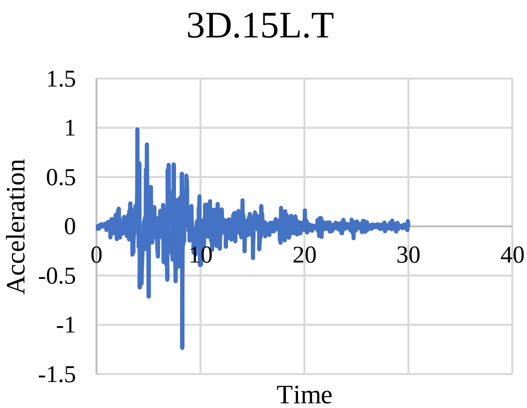
Figure 15. Details of the Sample for Models that Underwent Seismic Load Testing

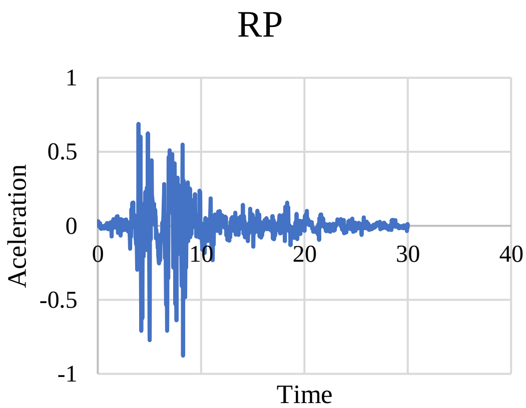
Table 5: The results for Group Two (3d.15l) that Tested under Seismic Load

Parameter	RP	3D.15L.T	3D.15L.M	3D.15L.D
Max. Acceleration (g)	0.87729	1.23621	0.7969	0.84921
Time of Max. Acceleration (sec)	8.252	8.25	8.252	5.026
Max. Velocity (cm/sec)	99.18018	74.1861	89.45857	88.38478
Time of Max. Velocity (sec)	6.838	4.727	6.842	6.837
Max. Displacement (cm)	20.15449	16.33032	20.07552	19.68337
Time of Max. Displacement (sec)	7.113	8.671	7.048	7.022
Specific Energy Density (cm2/sec)	7692.681	6892.292	7318.747	6728.35

5. 2. 2.1 Acceleration

The pace at which speed changes in relation to time is known as acceleration. There are two forms of acceleration (positive acceleration), which is the gradual increase in speed over a period of time, such as the swift acceleration of a car. The second sort of acceleration (negative acceleration) is a slowing down over a period of time, like when an automobile suddenly stops. Both types of acceleration increase the values of acceleration due to the increase in the rate of change of velocity with respect to time. Due to the Existence of rubber, which serves as the car's brakes and raises the rate of change of speed with respect to time, the acceleration in the model (3D.15L.T) is larger than 41% of the acceleration in the reference model (RP), as shown in Figure 17. This is because rubber has excellent elasticity and can absorb energy. from Table 5 the acceleration of the model (3D.15L.M) and (3D.15L.D) is nearly identical to that of the reference model (RP), as can be seen from Figure 16 this is because the rubber location is not inside the pile's range of motion, preventing the rubber's effect from manifesting.





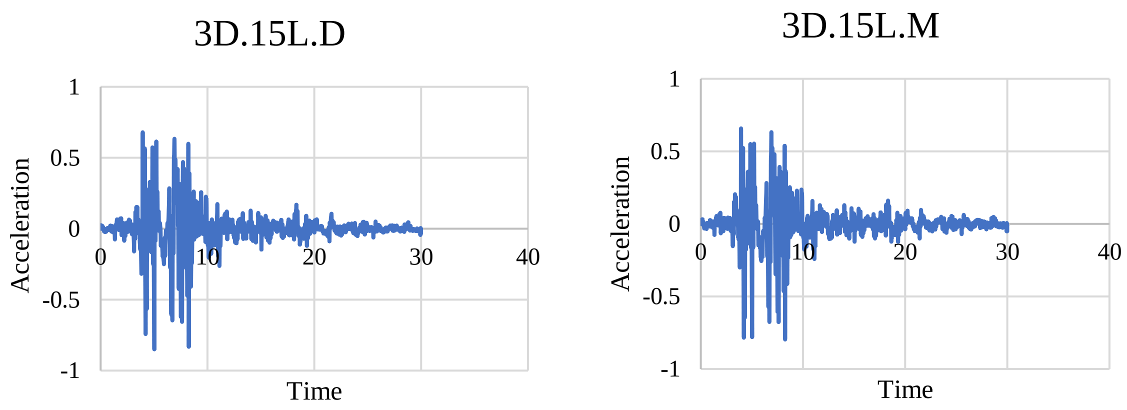


Figure 16. Time history (Acceleration) of the examined models (RP, 3D.15L.T, 3D.15L.M, 3D.15L.D)

5. 2. 2. 2 Velocity

When comparing the velocity results of the model (3D.15L.T) with the reference model (RP) as shown in Table 5, we note that the velocity estimator decreased by 25%. This is due to the presence of rubber around the pile in the upper part, which moves when an earthquake occurs, the rubber works to dampen the movement of the pile and absorb the energy of the earthquake due to its high flexibility as shown in Figure 17. Therefore, it can be noted that the speed of the models (3D.15L.M) and (3D.15L.D) is close to the reference model (RP) due to the presence of rubber at the bottom and canter of the substrate. No effect of rubber appears due to the fact that this area is fixed and no movement occurs in it.

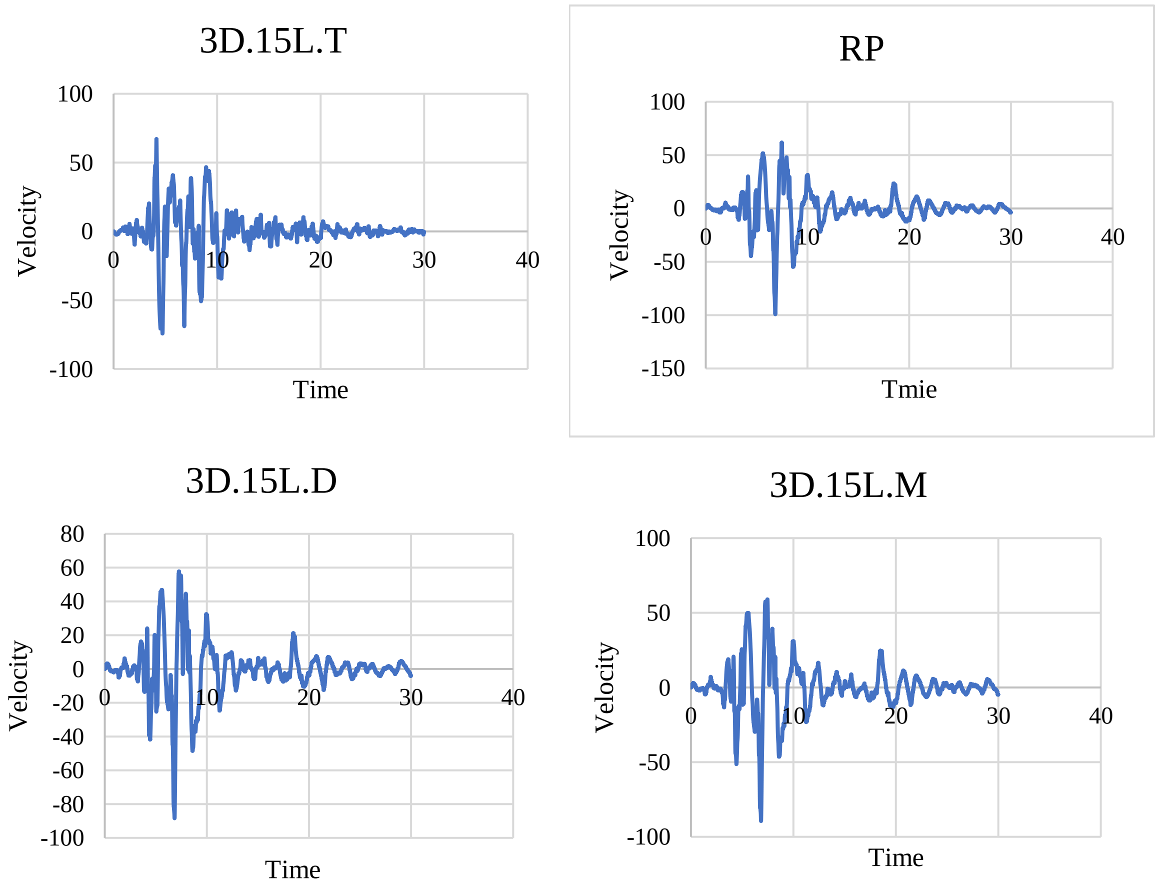


Figure 17. The velocity of the examined models (RP, 3D.15L.T, 3D.15L.M, 3D.15L.D)

5. 2. 2. 3 Displacement

The presence of rubber in the upper portion of the pile, which moves when an earthquake occurs, caused the estimated displacement to decrease by 19%, as shown in Figure 15 when comparing the displacement results of the model (3D.15L.T) with the reference model (RP), as shown in table 5 and figure 18. Whereas rubber's great degree of flexibility causes it to absorb energy and slow down the pile's motion reducing displacement. It can be noted that the displacement in the two models (3D.15L.M) and (3D.15L.D) is nearly equal to the displacement in the reference model (RP), this is because the top of the pile is surrounded by sand, which moves when subjected to earthquakes. For this reason, the rubber had no impact because it was located at the bottom and middle of the pile.

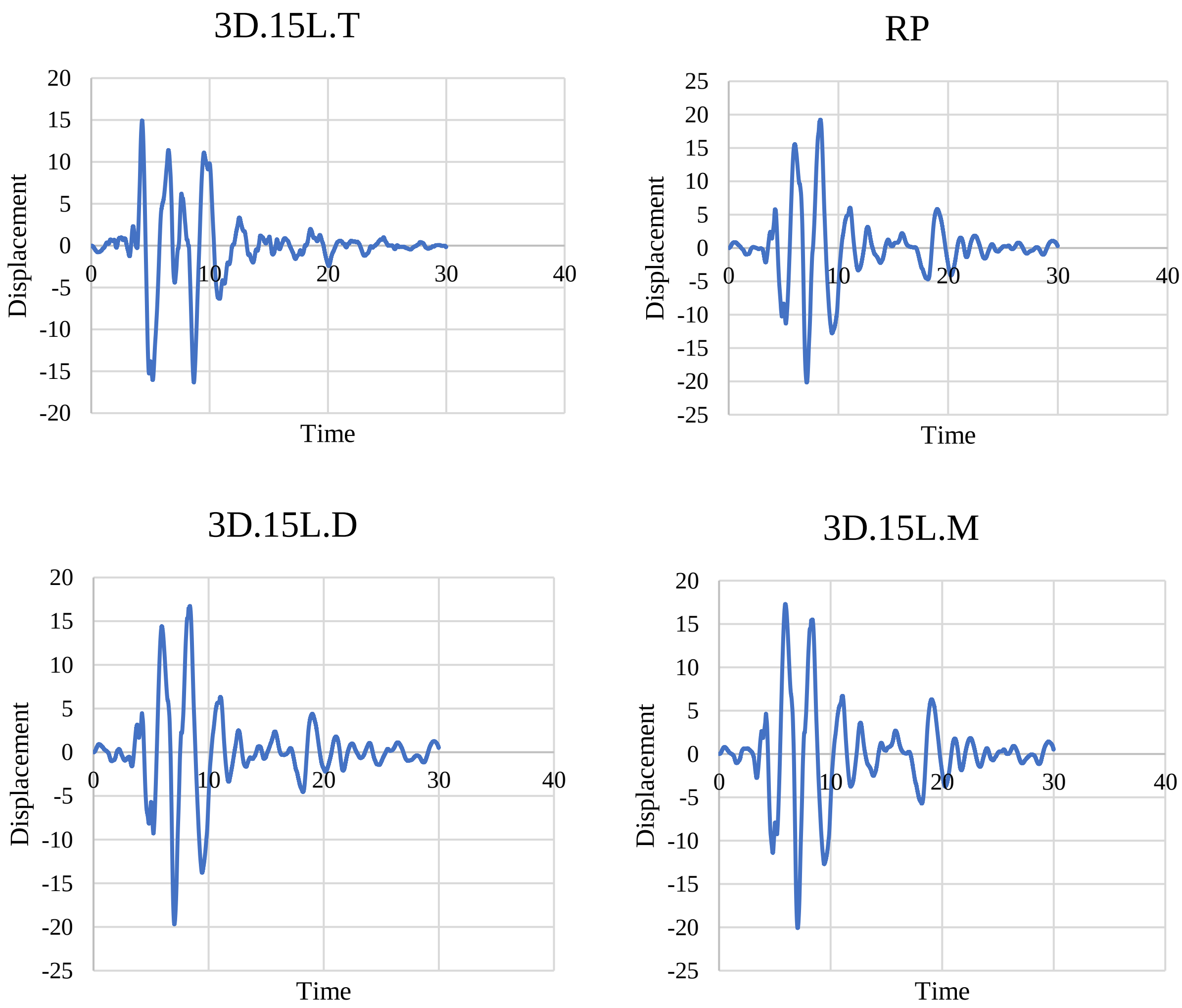


Figure 18. Displacement of the examined models (RP, 3D.15L.T, 3D.15L.M, 3D.15L.D)

5. 2. 2. 4 Acceleration response spectrum

It can be noted the acceleration of the response in the reference model (RP) and the two models (3D.15L.D) and (3D.15L.M). It starts increasing in the first second and gradually starts to fade until it reaches the second when it increases and then fades away. The (3D.15L.T) model, it can be noted an increase in the acceleration of the response in the first second, and it begins to fade rapidly gradually. By comparing the reference model (RP) with models (3D.15L.M) and (3D.15L.D), we note that their behaviour is somewhat similar. While comparing the reference model (RP) with the model (3D.15L.T) as shown in Figure 19, It can be noted the appearance of the effectiveness of the rubber surrounding the substrate, as It can be noted clear damping through the curves, as the acceleration increases in the first second and immediately begins to fading, due to rubber's high energy absorption and resilience.

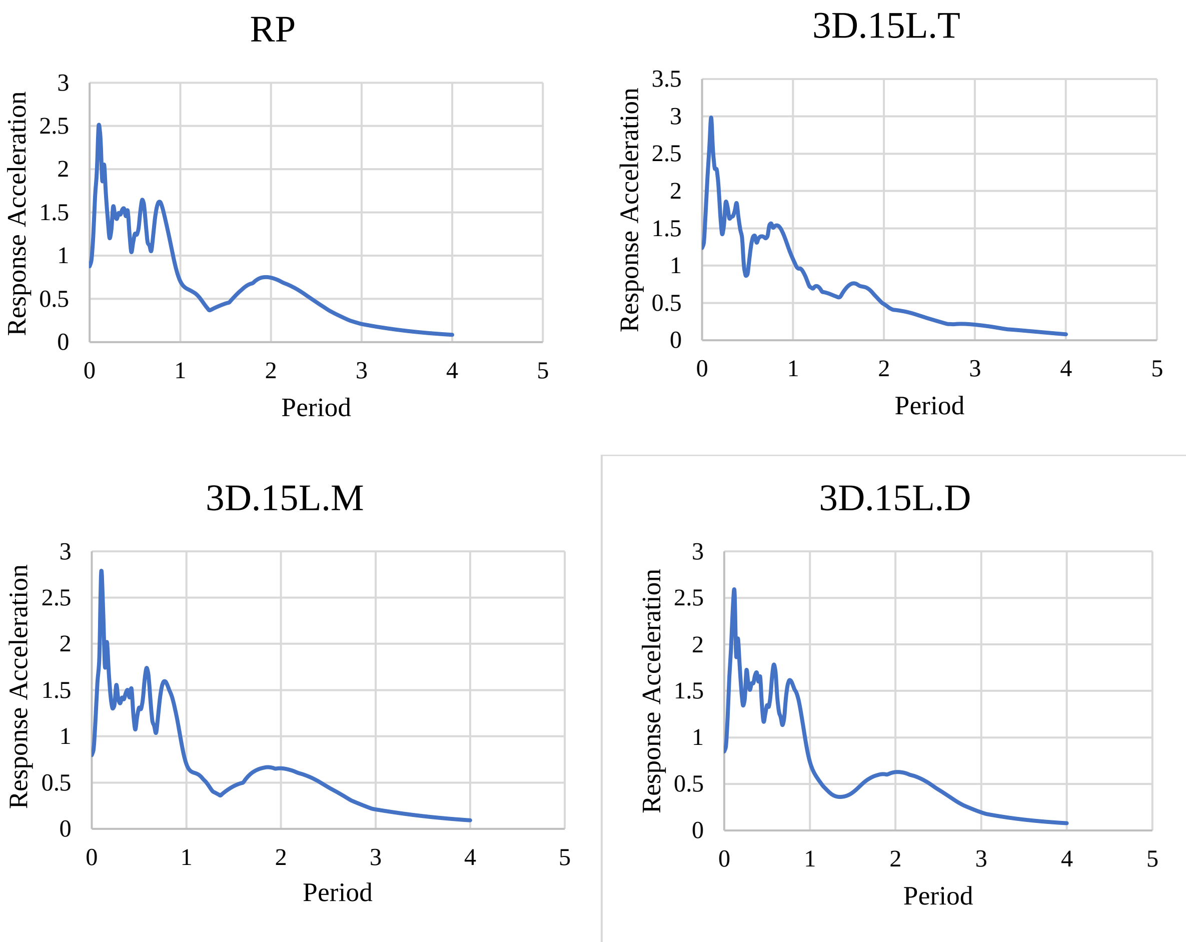


Figure 19. Acceleration Response Spectrum of the examined models (RP, 3D.15L.T, 3D.15L.M, 3D.15L.D)

5. 2. 2. 5 Specific energy density

It can be noted that the energy flow in the reference model (RP) begins to increase gradually until it reaches (7700) cm^2/sec, while the model (3D.15L.T) begins to increase gradually until it reaches (6800) cm^2/sec, while the model (3D.15L. M) starts to increase gradually until it reaches (7300) cm^2/sec, while the model (3D.15L.D) starts to increase gradually until it reaches (6700) cm^2/sec. By comparing the reference model (RP) with the model (3D.15L.T) as shown in Figure 20, It can be noted that the amount of energy flow decreased by 11.6%. When comparing the reference model (RP) with the two models (3D.15L.M), It can be noted that the amount of energy flow decreased by 5%. When comparing the reference model (RP) with the two models (3D.15L.D), It can be noted that the amount of energy flow decreased by 13%.

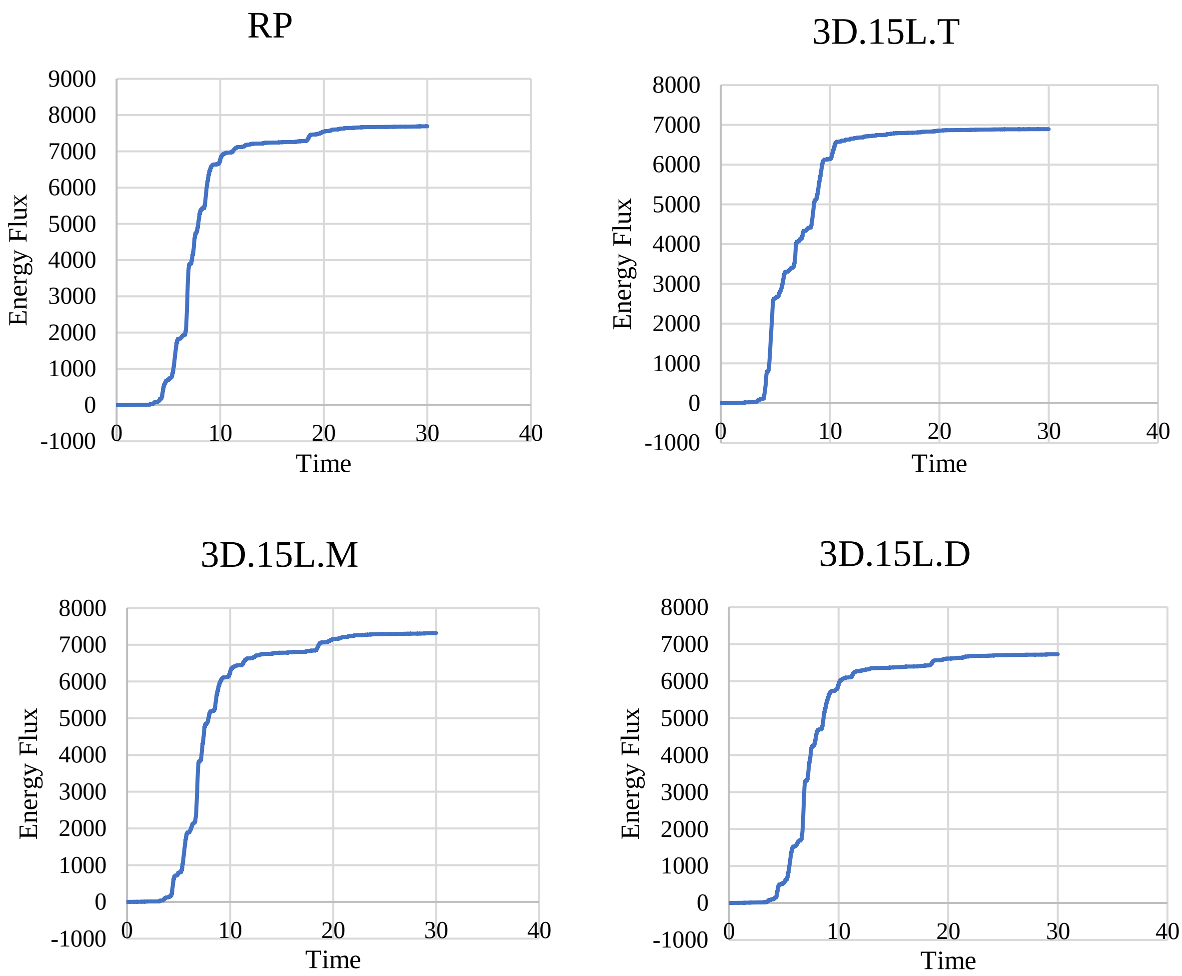


Figure 20. Specific Energy Density of the examined models (RP, 3D.15L.T, 3D.15L.M, 3D.15L.D).

4. Conclusion and summary

After conducting the tests and applying the earthquake on the piles surrounded by rubber of different diameters and different locations and studying the effect of the presence of rubber around the pile on the acceleration, speed and displacement of the facilities, we summarize the following.

1- Significant increase in body acceleration when the outriggers are surrounded by rubber in the upper part. There is no effect of the presence of rubber around the pile in the middle and bottom of the pile on the acceleration of the structure.
2- Decreased rate of movement speed of the structure when the pillars are surrounded by rubber in the upper part. There is no effect of the presence of rubber around the pile in the middle and bottom of the pile on the speed of movement of the structure.
3- Low displacement of the structure resulting from movement when an earthquake occurs when the pillars are surrounded by rubber in the upper part. There is no effect of the presence of rubber around the pile in the middle and bottom of the pile on the displacement of the structure.
4- The effect of rubber increases as the diameter of the rubber surrounding the pile increases.
5- The piles are surrounded by rubber in the upper part, earthquake damping occurs. When the piles are surrounded by rubber in the canter and bottom of the pile, earthquake damping does not occur.

References

[1] Abdel-Mohti, A., & Khodair, Y. (2014). Analytical investigation of pile–soil interaction in sand under axial and lateral loads. *International Journal of Advanced Structural Engineering (IJASE)*, *6*, 1-16.

[2] Andersen, K. H., Puech, A. A., & Jardine, R. J. (2013, September). Design for cycling loading: Piles and other foundations. In *Proceedings of 18th International Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE), Paris, France* (Vol. 26).

[3] Roy, S., Chattopadhyay, B. C., & Sahu, R. B. (2013). Pile behavior under inclined compressive loads–a model study. *Electronic Journal of Geotechnical Engineering*, *18*, 2187-2205.

[4] Zhang, L. M., McVay, M. C., Han, S. J., Lai, P. W., & Gardner, R. (2002). Effects of dead loads on the lateral response of battered pile groups. *Canadian Geotechnical Journal*, *39*(3), 561-575.

[5] Hussien, M. N., Tobita, T., Iai, S., & Rollins, K. M. (2012). Vertical loads effect on the lateral pile group resistance in sand. *Geomechanics and Geoengineering*, *7*(4), 263-282.

[6] Hussien, M. N., Tobita, T., Iai, S., & Karray, M. (2014). On the influence of vertical loads on the lateral response of pile foundation. *Computers and Geotechnics*, *55*, 392-403.

[7] Karthigeyan, S., Ramakrishna, V. V. G. S. T., & Rajagopal, K. (2006). Influence of vertical load on the lateral response of piles in sand. *Computers and geotechnics*, *33*(2), 121-131.

[8] Ni, S. H., Huang, Y. H., & Lo, K. F. (2012). Numerical investigation of the scouring effect on the lateral response of piles in sand. *Journal of Performance of Constructed Facilities*, *26*(3), 320-325.

[9] Raongjant, W., & Jing, M. (2017). Cyclic lateral response of model pile groups for wind turbines in clay soil. *GEOMATE Journal*, *12*(32), 76-81.

[10] Kahribt, M. A., & Abbas, J. M. (2018). Lateral response of a single pile under combined axial and lateral cyclic loading in sandy soil. *Civil Engineering Journal*, *4*(9), 1996-2010.

[11] Saleh, W. A. (2020). Effect of spacing and cross-sectional shape on piled raft system subjected to lateral cyclic loading. *Diyala Journal of Engineering Sciences*, *13*(3), 114-122.

[12] Daher, R., & Abbas, J. M. (2021). The behavior of pile group under inclined static load with different angle of inclination in sandy soil. *Diyala Journal of Engineering Sciences*, *14*(2), 52-61.

[13] Broms, B. B. (1964). Lateral resistance of piles in cohesionless soils. *Journal of the soil mechanics and foundations division*, *90*(3), 123-156.

[14] Poulos, H. G. (1982). Single pile response to cyclic lateral load. *Journal of the Geotechnical Engineering Division*, *108*(3), 355-375.