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RESPONSE OF SANDY SOILS WITH RUBBER-SAND MIXTURE LAYER USED AT DIFFERENT DEPTHS TO SINGLE PERIOD SINUSOIDAL INPUT GROUND MOTION

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ABSTRACT

Novel protection methods have been proposed by various researchers that recommended placing recycled rubber and rubber/sand mixtures (RSM) as lightweight material below building foundations, for vibration absorption. This paper presents comparable analyses between a baseline case of pure sand soil profile and others in presence of a rubber-sand mixture (RSM) layer at different depths from the foundation level. This study is focusing on the effect of increasing the depth of the utilized layer of RSM, on the ground response during certain input ground motion. Site response analyses were performed by applying simple constant amplitude sinusoidal wave with single predominant period (Tp). Input ground motions were classified according to predominant period (Tp) into two categories. The first category is the low period (high frequency) range which covers periods less than or equal to 0.50 sec. The second category is the high period (low frequency) range which covers periods more than 0.50 sec. In addition, acceleration amplitude of input ground motion was classified into weak and strong amplitude where, if acceleration amplitude is less than or equal to 0.2g, it was classified as weak amplitude and if acceleration amplitude is more than 0.2g it was classified as strong amplitude. Depth of RSM layer is classified also into shallow for depths less than 4.0 m and deep for depths more than or equal 4.0m. It was noted that placing a 2m thickness layer of RSM caused shifting of the maximum spectral acceleration at the top surface towards high periods (low frequencies) zone relative to baseline model of pure sand soil. Increasing the depth of RSM layer or/and acceleration amplitude of input ground motion (G.M.) caused more shifting for the maximum spectral acceleration of the top surface towards high periods (low frequencies). Shifting was accompanied with decreasing in the values of spectral accelerations that led to more reduction in the spectral ratio. In addition, the existence of soft RSM layer between two stiff layers resulted in that the top and bottom layers move out of phase and consequently accelerate damping of top layer movement.

Keywords: granulated tire rubber; Embedded; Seismic response; Finite element

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1. Introduction

Waste materials such as waste tires, rubbers, and plastic materials are normally produced in every society, entering the environment and causing serious problems. These problems may be somehow reduced by finding applications for them in engineering applications. In recent years, many developing and developed countries, have legislated laws concerning the limitation of the disposed tires and the encouragement of recycling and re-use of tires in variant applications. The increased damping capacity of Rubber Sand Mixtures (RSM) encouraged its use as replacement soils in seismic areas to reduce the amplitude of earthquake induced ground motions. Novel infrastructure protection methods have been proposed by various researchers that recommended placing recycled rubber and rubber/sand mixtures (RSM) as lightweight material around building foundations, for vibration absorption. This civil engineering approach has been widely growing over the past decade, because of the high damping capacity of the rubber that permits consideration of granulated rubber/soil mixtures as part of a damping system to reduce vibration. Processed waste tires mixed with soils have been introduced as lightweight fills for slopes, retaining walls, and embankments subjected to seismic loads.

The mechanical properties of the mixture were discussed by [1], [2], [3] and [4], while dynamic properties of granulated rubber-sand mixtures were studied by [5] and [6]. Numerical studies were performed by [7] and [8] on protecting buildings from earthquakes hazards by RSM. The utilization of RSM as replacement soils in seismic areas to reduce the amplitude of earthquake induced ground motions was addressed in earlier work by [9].

The effect of changing the depth of the RSM layer is investigated in the present study. Results are compared for a range of varied amplitude ground motions. Data used in this parametric study is based on a comprehensive set of torsional resonant column tests performed for different dry and saturated specimens of rubber-sand mixture, [1] and [10]. Based on these tests, the shear modulus reduction and damping curves can be generated for the rubber-sand mixture as a function of confining pressure. GeoStudio 2007-QUAKE; [11], module is used to perform the parametric study for the ground response based on one-dimensional finite element analyses by applying an equivalent-linear constitutive model.

2. Material properties

The properties of parent materials for the RSM used in this numerical analysis are based on results of the study were carried out by [6] and [12]. In this study, specimen of dry sand and rubber material were used as parent materials for the rubber-sand mixture (RSM) specimen. The sand is natural of sub-rounded to rounded particles, whereas the rubber is granulated from recycled tire shreds. Properties of the parent materials are indicated in Table (1).

The RSM used in the analyses herein was assumed to contain 35% rubber content (by weight) and a dry unit weight of 12.5 kN/m^3. The modulus reduction and damping curves of dry RSM for different confining pressures (σ'_m) were generated according to [10]. The modulus reduction and damping curves of dry rubber-sand mixture and sand at Confining pressures (σ'_m =50 kPa) are shown in Figure (1). The small strains shear modulii for the sand and RSM are 65.6 MPa and 10.4 MPa, respectively.

Table 1.
Properties of sand and granulated rubber (parent materials)

Material	Sand	Granulated rubber
Unit weight, γ (kN/m^3)	16.50	6.50
Specific gravity, G_s	2.67	1.10
Max. particle size, D_{max} (mm)	1.43	5.55
50% passing size, D_{50} (mm)	0.56	2.80
Coefficient of uniformity, C_u	2.76	2.29
Coefficient of curvature, C_c	1.23	1.18

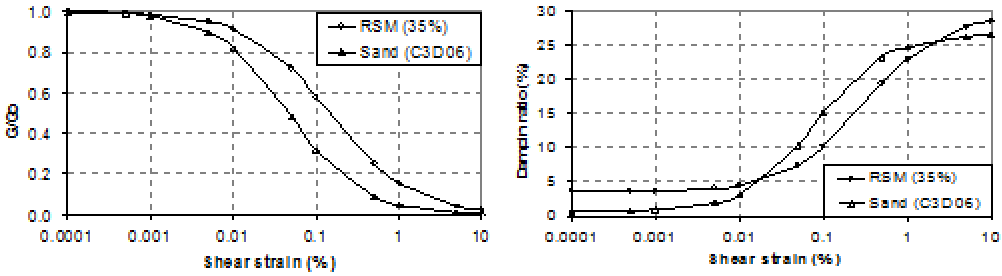
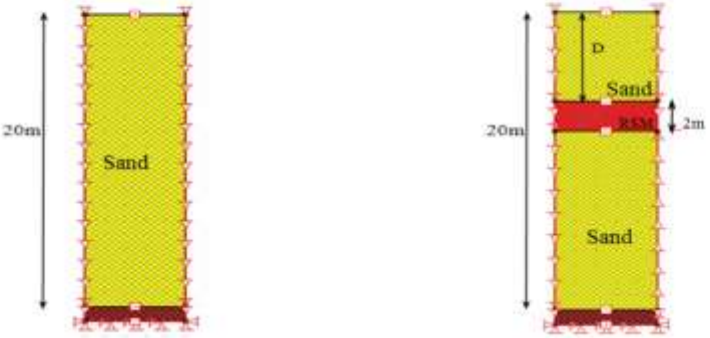


Fig. 1. Shear modulus reduction and damping curves at (σ'_m= 50 kPa)

3. Numerical model

A number of one-dimensional finite element models were built in QUAKE/W software to evaluate the site response during an earthquake. The soil was modeled using an equivalent linear constitutive model; [9]. The baseline model case shown in Figure (2-a), represents the untreated site condition constitutes a 20 m thick layer of sand above bedrock. One additional layer was inserted into the original baseline model to simulate RSM layer in the different numerical analyses, as shown in Figure (2-b). Two meter thick RSM layer was first assumed to be placed at depths of 2m, 4m and 8m. The effect of changing the depth of the RSM layer, from the foundation level, on top layer response during different input ground motions is investigated.



(a) (b)

Fig. 2. The FEM model used in the numerical study
(a) Baseline model (b) Model with RSM layer

4. Model natural period

It is important to specify the model natural period (Tn) that helps in explanation of model response to different input ground motions. To identify natural period for the baseline case empirically, it is important to specify the geotechnical site category. Site period can be obtained depending on the depth and characteristics of the soil deposit after, [13]. Because of the sand soil deposit depth (20m) is greater than 6m and less than 30m, the site is classified as "Shallow Stiff Soil" and the site natural period is around (0.5 sec), i.e. the natural frequency is 2 Hz.

Numerically, the natural period/frequency of the model profile can be obtained by shaking the model with sweep frequencies sinusoidal wave of constant acceleration amplitude, as shown in Figure (3). Swept frequencies of the wave are selected in the range of (1-20 Hz). The acceleration amplitude value of the sweep frequencies wave should be very small, ($5x10^{-5}$g), to simulate free vibration condition. Transfer Function that stated in Equation (1) can be determined as the ratio between Fourier amplitude (FFT) of top surface layer and base rock layer.

$$\text{Transfer Function} = \left(\frac{(FFT)_{\text{Surface layer}}}{(FFT)_{\text{Bedrock layer}}} \right) \tag{1}$$

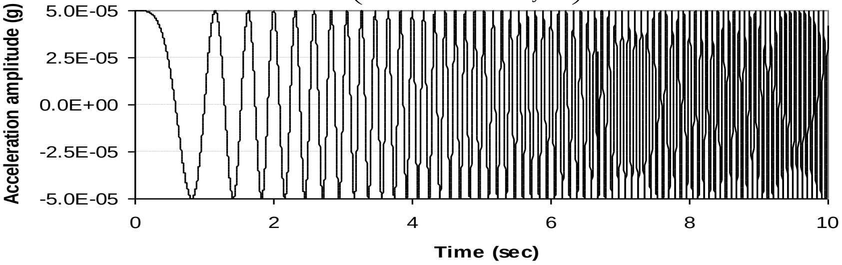


Fig. 3. Sweep frequencies sinusoidal wave of constant acceleration amplitude

The Transfer Function shows how each period/frequency in the bedrock input motion is amplified or deamplified by the soil deposit, [14]. The maximum amplification of the Transfer Function occurs at period/frequency which is very close to the natural period/frequency of the soil profile, [14]. Figure (4) shows that the natural period of the base line model is about (0.47 sec), that was corresponding to the maximum amplitude of transfer function. Figure (4) also shows, natural periods for soil models with RSM layer at depths 2m, 4m, 6m, 8m, 10m, 12m and 14 m, respectively. Natural periods of different RSM depth soil models were plotted against depths of RSM layer, as shown in Figure (5).

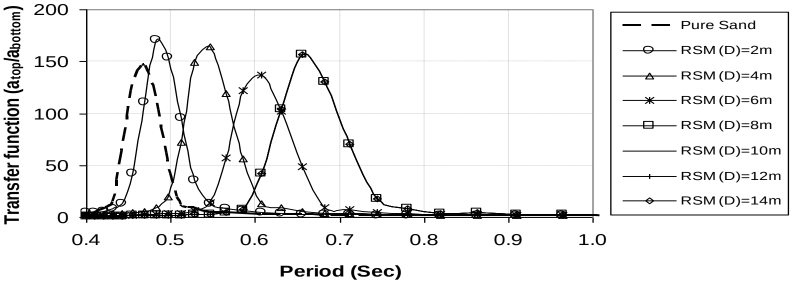


Fig. 4. Natural periods for base line model and models of different depths of RSM layer

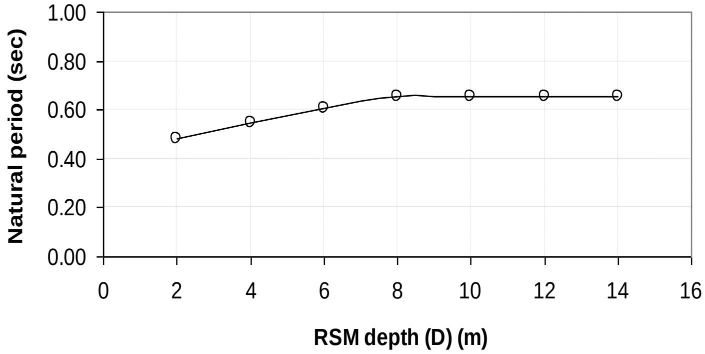


Fig. 5. Change in natural period against RSM layer depth

From Figure (5), it can be noted that placing the RSM layer caused increasing of the soil profile natural period from the value (0.47 sec) of the base line pure sand soil profile to values of 0.48 sec, 0.55 sec, 0.61 sec and 0.66 sec for RSM depths 2m, 4m, 6m and 8m, respectively. No change in the natural period of the soil profile occurred by increasing the RSM depth beyond 8m.

5. Response of soil profiles

Response of base line of pure sand and with RSM layer soil profiles to different input ground motion was investigated. A simple sinusoidal wave of single period/frequency and constant amplitude was applied on the model. In this study it was considered that input ground motions can be classified according to predominant period (Tp) into two categories. The first category is the low period (high frequency) range which covers periods less than or equal to 0.50 sec. The second category is the high period (low frequency) range which covers periods more than 0.50 sec. In addition, acceleration amplitude of input G.M. can be classified into weak amplitude if acceleration amplitude is less than 0.2g where it is classified as strong amplitude if it is more than or equal 0.2g.

Response Spectral Ratio (R.S.R.) stated in Equation (2) can be defined as the difference of spectral acceleration (S_a) between the model with (RSM) layer and base line models, respectively, relative to the spectral acceleration of base line model in percentage. This ratio denotes to amplification in case of positive value of R.S.R. and denotes to reduction in case of negative value of R.S.R.

$$\text{Response Spectral Ratio (R.S.R) (\%)} = \left(\frac{(S_a)_{RSM} - (S_a)_{Sand}}{(S_a)_{Sand}} \right) x100 \qquad (2)$$

Where:

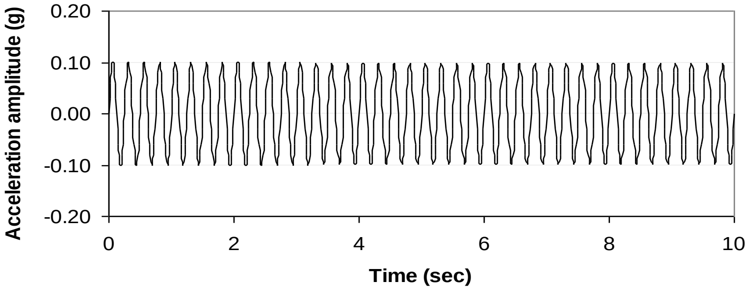
$(S_a)_{RSM}$ = spectral acceleration with (RSM) layer.

$(S_a)_{Sand}$ = spectral acceleration in case of baseline model (pure sand).

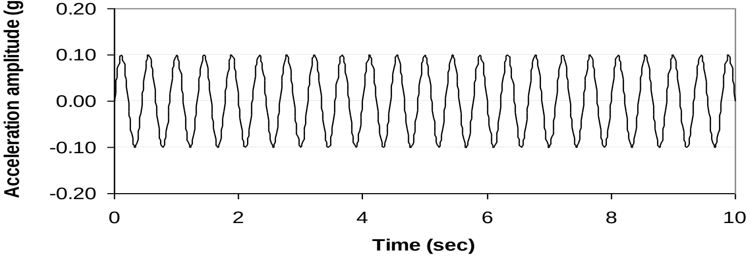
6. Simple sinusoidal wave input motion

In this section, the response of baseline model and with RSM layer soil profile models to single period/frequency and constant amplitude ground motion is investigated. Input ground motions of weak acceleration amplitude (0.1g) and strong acceleration amplitude (0.5g) are used at three different predominant periods (Tp) 0.25 sec, 0.5 sec and 1.0 sec, respectively. Figure (6) shows example of sinusoidal wave time histories of weak amplitude (0.1g) ground motion at three different single predominant periods (Tp) 0.25 sec, 0.5 sec and 1.0 sec, respectively.

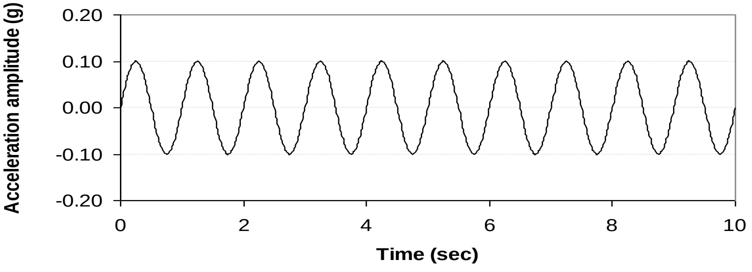
By applying input ground motions on the models, the response of the top surface layer can be obtained and compared for different cases. Figure (7) shows the response spectrum of the top surface layer in case of the pure sand profile model (base line model) for the three input ground motions.



(a) Tp = 0.25 sec

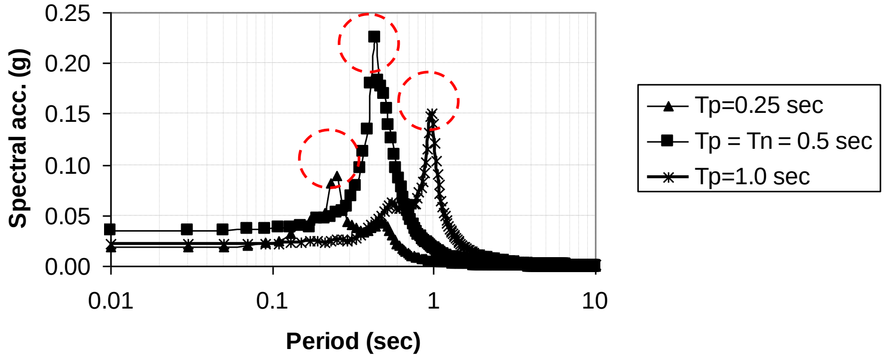


(b) Tp = 0.50 sec

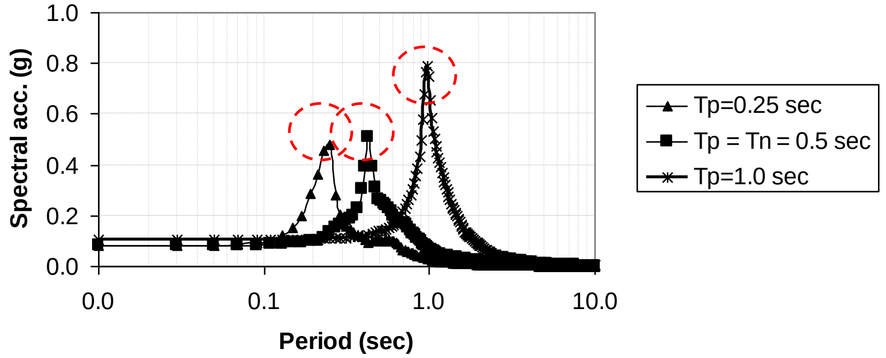


(c) Tp = 1.0 sec

Fig. 6. Time history for constant amplitude-single period sinusoidal wave



(a) Amplitude, A= 0.1g



(b) Amplitude, A = 0.5g

Fig. 7. Response of top surface layer in pure sand soil profile to low and high constant amplitude-single period sinusoidal wave time histories

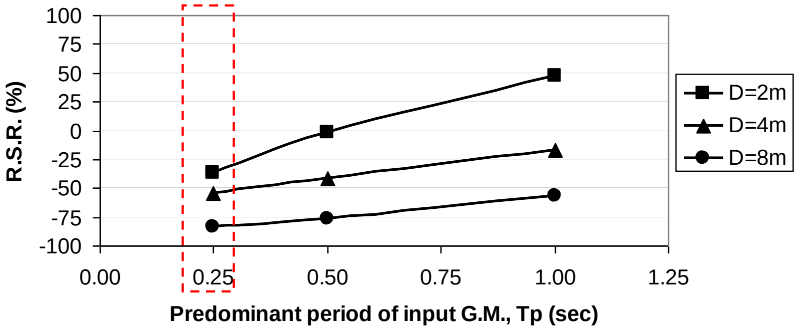
It can be noted clearly from Figure (7-a) that in case of input ground motion of weak acceleration amplitude (0.1g), the maximum response amplitude to 0.25 sec, 0.50 sec and 1.0 sec predominant periods (Tp) are 0.09g, 0.22g and 0.15g respectively. Therefore, the maximum response amplitude occurs when the predominant period (Tp) coincides on the natural period of the site (T_n). On the other hand, in case of input ground motion of strong acceleration amplitude (0.5g) as shown in Figure (7-b) the maximum response amplitude of 0.25 sec, 0.50 sec and 1.0 sec predominant periods (Tp) are 0.48g, 0.51g and 0.79g respectively. Hence, the response amplitude increases as the period increases regardless of the site natural period (T_n). This result can be referred to that in case of weak acceleration amplitude the external force is relatively small. Therefore, soil profile vibration is very close to be free vibration in which the natural period has the most significant contribution in the movement. In case of strong acceleration amplitude, the soil profile is vibrated under a combination of strong external force which dominates its movement and small insignificant contribution of soil profile natural vibration.

Figures (8), (9) and (10) show the effect of increasing the depth of RSM layer (D) relative to the base line case (Pure sand) on the response of the top layer at periods 0.25 sec, 0.50 sec and 1.0 sec for both weak and strong input ground motion amplitude.

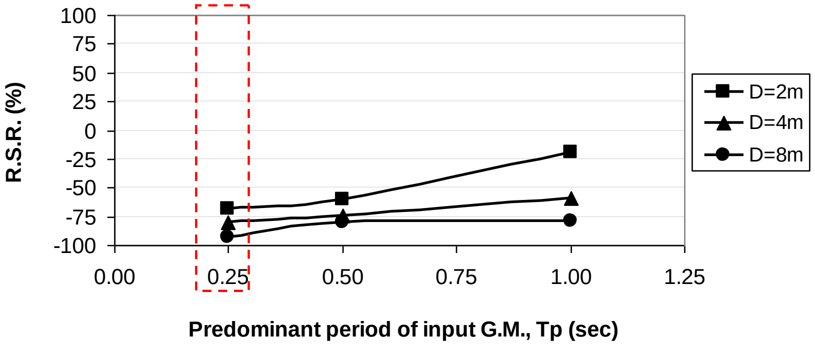
From Figure (8-a), at the period (0.25 sec), it can be noted that placing RSM layer at shallow depth (2m) within sandy soil profile and applying input ground motion (G.M.) of weak amplitude, (A= 0.1g), caused 36% reduction in the value of response spectral ratio

(R.S.R.) in case of G.M. predominant period equals (0.25sec), i.e. matching to the studied period. However, at Tp = 1.0 sec, an amplification in response spectral ratio (R.S.R.) equals to 47% occurred, while no significant changes occurred at Tp = 0.5 sec. Increasing the depth (D) of RSM layer to 4m with the same weak G.M. amplitude, (A= 0.1g), caused overall reduction in (R.S.R.) values in all cases of G.M. predominant periods (Tp) where, reduction values were 54% and 41% for 0.25sec and 0.5sec G.M. predominant periods, respectively as well as 17% reduction occurred at (Tp = 1.0sec) instead of the previous amplification. The more increase in RSM depth caused more increase in the reduction values of (R.S.R.) where values were 83%, 76% and 56% at G.M. predominant periods 0.25 sec, 0.5 sec and 1.0 sec respectively.

In case of applying by a strong amplitude input G.M., (A=0.5g); as shown in Figure (8-b), it can be noted that, no amplification occurred at any depth of RSM layer and the reduction values were more than those in case of weak amplitude input G.M. It is clear that reduction values in case of (D=2m) are 69%, 60% and 20% for G.M. predominant periods 0.25 sec, 0.5 sec and 1.0 sec respectively, and these values increased by increasing RSM depth where they are 80%, 74% and 58% and 93%, 81% and 79% in case of RSM depth 4m and 8m respectively.



(a) At amplitude, A= 0.1g

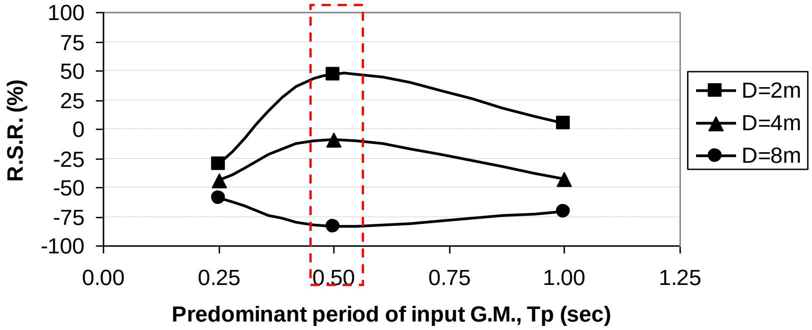


(b) At amplitude, A= 0.5g

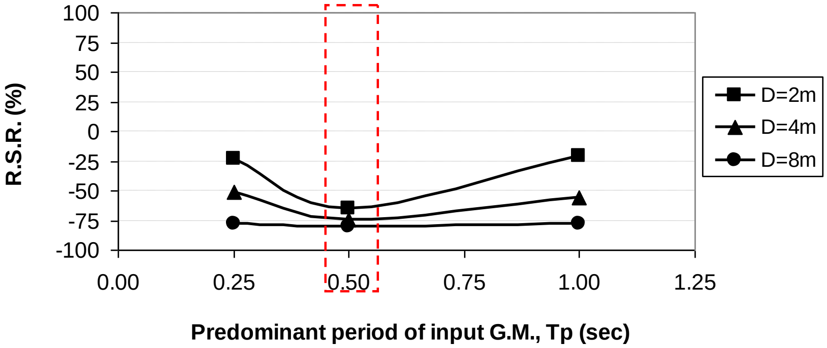
Fig.8. The change in the response of top layer in soil profile due to use of RSM layer, at periods 0.25 sec

From Figure (9-a), at the period (0.50 sec), it can be noted that placing RSM layer at shallow depth (2m) within sandy soil profile and applying by input ground motion (G.M.) of weak amplitude, (A= 0.1g), caused a significant amplifications by 47% in case of input G.M. predominant period (0.5 sec), i.e. when Tp of input G.M. was matching to the site natural period (Tn) and low amplification by 5% at (Tp = 1.0). However, a reduction by

30% occurred at (Tp = 0.25 sec). The increase of RSM layer depth to be 4m caused overall reduction by 45%, 9% and 43% at input G.M. predominant periods 0.25 sec, 0.5 sec and 1.0 sec respectively. This means that although a reduction occurred at (Tp = 0.5 sec) which is matching to the site natural period (Tn) due to the increase of RSM depth but it was still minimum relative to those corresponding to other predominant periods 0.25 sec and 0.5 sec. If RSM depth is increased to be 8m, reduction values increased relative to those obtained at RSM depth (4m) and it can be seen clearly that the maximum reduction value was 84% occurred at the predominant period which was matching to the site natural period (0.5 sec). The occurred reduction values at predominant periods 0.25 sec and 1.0 sec were 60% and 71%, respectively. A significant reduction in R.S.R. values could be obtained by applying input G.M. of strong amplitude, (A= 0.5g); as shown in Figure (9-b), where it can be seen that the maximum reduction values occurred at (Tp = 0.5 sec) were 65%, 75% and 80% at RSM depths 2m, 4m and 8m respectively.



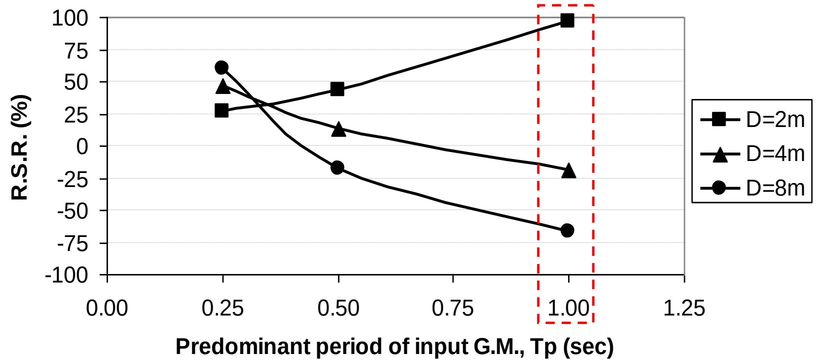
(a) At amplitude, A= 0.1g



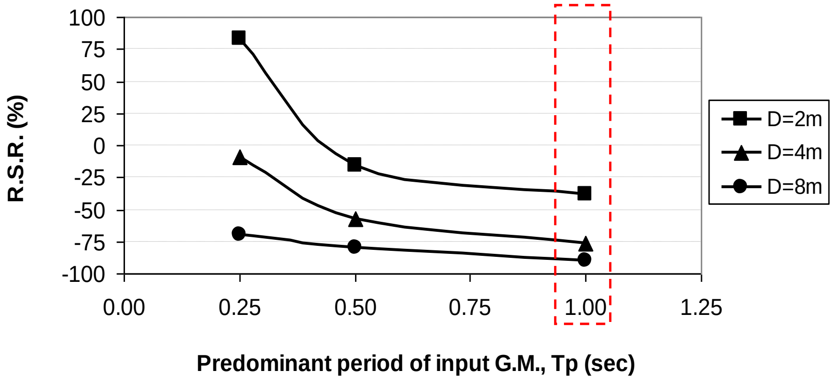
(b) At amplitude, A= 0.5g

Fig. 9. The change in the response of top layer in soil profile due to use of RSM layer, at periods 0.50 sec

From Figure (10-a), at the period (1.0 sec), it can be noted that placing RSM layer at shallow depth (2m) within sandy soil profile and applying input ground motion of week amplitude, (A= 0.1g), caused overall amplification at all predominant periods where the maximum amplification in (R.S.R.) values was 97% and occurred at (Tp = 1.0), i.e. at the period which is matching to the studied period. Amplification values at predominant periods 0.25sec and 0.50sec were 27% and 44% respectively. The increase of RSM depth to 4m caused increase in amplification at (Tp = 0.25 sec) where it was 46% and caused decrease in R.S.R. amplification values in case of (Tp = 0.5 sec) to become 13%, while a mild reduction by 19% started to appear at (Tp = 1.0 sec). When RSM depth increased to 8m, caused increase in amplification at (Tp = 0.25 sec) to become 60% and caused reduction by 18% started to appear at (Tp = 0.5 sec). The reduction increased at (Tp = 1.0 sec) to become 66%.



(a) At amplitude, A= 0.1g



(b) At amplitude, A= 0.5g

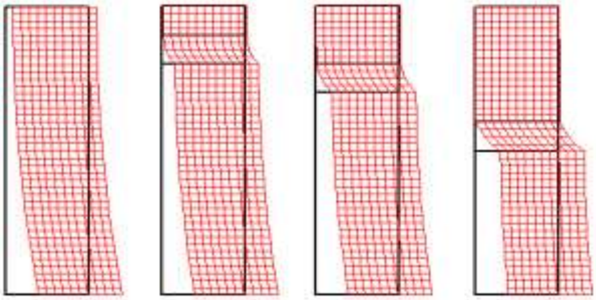
Fig. 10. The change in the response of top layer in soil profile due to use of RSM layer, at periods 1.0 sec

In case of applying a strong amplitude input G.M. (A=0.5g); as shown in Figure (10-b), it can be noted that, no amplification occurred at predominant periods 0.5 sec and 1.0 sec at any depth of RSM. Reduction values at (D = 2m) were 16% and 38%, at (D = 4m) were 57% and 76% and at (D = 8m) were 80% and 90% in case of predominant periods 0.5 sec and 1.0 sec respectively. The only amplification by 83% occurred at (Tp = 0.25 sec) in case of shallow depth of RSM layer (D = 2m) where it was converted to be reduction in (R.S.R.) values by 9% and 69% when the RSM layer depth increased to be 4m and 8m respectively.

7. Discussion

To illustrate the above results one should understand the main concept of using RSM layer. The purpose of using RSM layer is to create partial or complete separation (isolation) between bottom layer and top foundation layer. This can be achieved by insertion of soft layer of a highly damping characteristic between two rigid layers. When the bottom layer moves under input motion force, shear waves propagate upwards till approaching the soft layer. When shear waves go through the soft layer, higher deformation occur in this layer due to its low shear stiffness relative to bottom and top layers. These deformations cause dissipation of the shear wave energy resulting in filtering for higher frequencies and damping for strong amplitudes. The output waves from the soft layer (RSM) have only low frequencies (high periods) and damped (weak) amplitudes. These output waves are considered the input waves to the top foundation layer; therefore, the top layer will move under low frequency and weak amplitude shear waves. As a result, acceleration at the top layer has lower amplitude in case of using the soft layer (RSM) comparing to that of baseline pure sand.

Figure (11) shows deformed shapes of soil profiles in the base line and with RSM layer at depths 2m, 4m and 8m; respectively, at certain time step. It is clear that the bottom layer moved to right side under the effect of input ground motion while the top layer still fixed and it can be noted the higher deformation in RSM layer. Hence, deformations in RSM layer retarded the reach of shear waves to the top layer. The time gap between the movement of bottom and top layers caused that two layers move with phase shifting or may be out of phasing that leads to accelerate damping of the top layer movement.

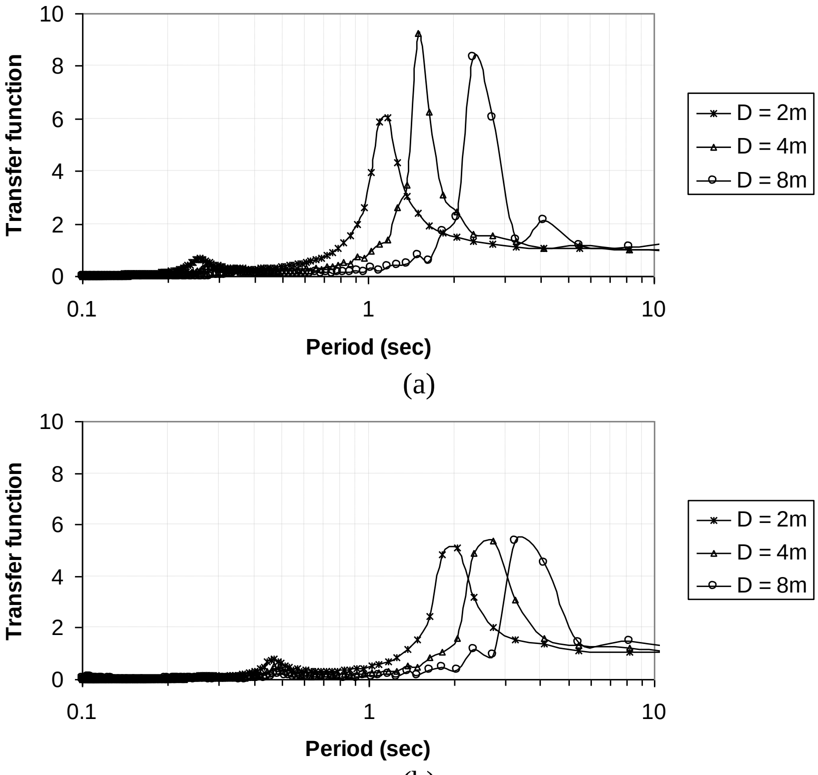


(a) (b) (c) (d)

Fig. 11. Deformed shapes for models of baseline and with RSM at different depths:
(a) pure sand (b) D = 2m (c) D = 4m (d) D = 8m

To confirm the above conclusions, a constant acceleration amplitude sinusoidal wave of sweep frequencies in the range (1-20 Hz) was applied to the model of deferent depths of RSM layer. Then, the transfer functions between the bottom and top surfaces of RSM (soft) layer were computed from Equation (1) and plotted against period in a semi log scale as shown in Figure (12). It is clear that the output wave predominant period was shifted to high periods range (low frequencies) where the low periods (high frequencies) have been highly damped. It should be note also that the range of shifting the output predominant period was affected by increasing RSM layer depth (D) and by increasing the amplitude (A) of input ground motion.

From Figure (12-a), in case of weak acceleration amplitude (0.1g) of input G.M., it is clear that damping occurred in the range of periods from 0.1sec to 0.7 sec in case of RSM depth of 2m. This range of damping expanded in the cases of RSM depths 4m and 8m to cover up to periods of 1.0 sec and 1.6 sec, respectively. From Figure (12-b), in case of strong acceleration amplitude (0.5g) of input G.M., it can be noted that the damping range expanded more than that in case of weak amplitude acceleration (0.1g) of input G.M. where it reached periods of 1.5 sec, 1.60 sec and 2.73 sec for RSM depths of 2m, 4m and 8m respectively. This can be referred to that the increase of RSM layer depth (D) caused increase of the normal stress on RSM layer increased and produced high axial deformation during shaking; therefore, the total deformation in RSM layer increase resulting in damping increase and shifting of predominant period towards higher periods side.



(a)

(b)

Fig. 12. The transfer function of input G.M. through RSM layer at amplitudes:
(a) A= 0.1g (b) A = 0.5g

From the above illustration, at low periods it is expected that reduction of R.S.R. occurred in case of all input ground motion predominant periods at deeper RSM layer and/or at both week and strong acceleration amplitudes. Amplification is most likely occurred at shallow depths of RSM layer in case of weak acceleration amplitude. At higher periods, it is expected that reduction of R.S.R. occurs in case of high input G.M. predominant periods at deeper RSM layer and/or at both weak and strong acceleration amplitudes. On the contrast, the chance of amplification occurrence increases at shallow depths of RSM layer at high periods.

8. Conclusions

General conclusions can be extracted from the above analyses performed on the base line model and models with RSM layer at different depths. These conclusions can be summarized as the following:

- Placing of RSM layer causes shifting of the input G.M. predominant period towards high periods range (low frequencies) as well as it causes high damping at low periods (high frequencies).
- The range of predominant period shifting is affected by increasing RSM layer depth (D) and also by increasing the amplitude (A) of input ground motion.

- The increase of RSM layer depth causes more shifting of predominant period towards high period's range that causes increase of reduction in R.S.R. value or at least decrease of the occurred amplification if any.
- At low periods, reduction in R.S.R. is found in both cases of shallow and deep RSM layer due to applying input ground motion of low predominant period (Tp).
- At low periods, amplification in R.S.R. is found in case of shallow depth of RSM layer and weak acceleration amplitude of input ground motion.
- At high periods, amplification in R.S.R. is found in case of shallow depth of RSM layer for both weak and strong acceleration amplitude of input G.M..
- At high periods, reduction in R.S.R. is found in case of deeper RSM layer for both weak and strong acceleration amplitude of input G.M..

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تجاوب التربة الرملية المزوده بطبقة من خليط المطاط والرمل والمستخدمة على أعماق مختلفة للحركة الأرضية الجيبيه وحيدة الزمن الدورى

الملخص العربى:

من الوسائل الحديثة لحماية البنية التحتية المقترحة والموصى بها بواسطة العديد من الباحثين هى وضع المطاط المعاد تدويره والمطاط المخلوط بالرمل (RSM) كمواد ذات أوزان خفيفة حول أساسات المنشآت لامتصاص الاهتزازات . هذه الورقة البحثية تقدم تحليلات مقارنة بين حالة أساسية من طبقة واحدة من الرمل النقى مع حالات أخرى يتم فيها إستخدام طبقة من المطاط المخلوط بالرمل موضوعة على أعماق مختلفة من سطح الارض داخل طبقة الرمل الاساسية . كما تركز هذه الدراسة على تأثير زيادة عمق طبقة المطاط المخلوط بالرمل على إستجابة الطبقة السطحية أثناء حركة أرضية معينة .تم إجراء مجموعة من تحليلات الاستجابة بإستخدام موجه جيبية ثابتة السعة ووحيدة الزمن الدورى.

وقد تم تصنف الحركات الأرضية المدخله طبقاً للزمن الدورى لكل منها إلى قسمين. القسم الاول يمثل المدى المنخفض للازمنة الدورية للأزمنة الدورية (المدى العالى للترددات) والذى يغطى الأزمنه الدورية الأقل من أو تساوى 0,5 ثانية بينما يمثل القسم الثانى المدى العالى للأزمنة الدورية (المدى المنخفض للترددات) والذى يغطى الأزمنة الدورية الأعلى من 0,5 ثانية. كما تم تصنيف سعة العجله للحركة الأرضيه إلى سعة ضعيفه وسعة قوية. فإذا كانت سعة العجلة للحركة الأرضيه أقل من أو تساوى (0.2g) يتم تصنيفها على أنها سعة عجلة ضعيفة وأما إذا كانت كانت سعة العجلة للحركة الأرضيه أكبر من (0.2g) فإنه يتم تصنيفها على أنها سعة عجلة قوية.

وقد لوحظ أن وضع طبقة خليط المطاط والرمل (RSM) يسبب ترحيل للقيمة العظمى للعجلة الطيفية للطبقة السطحية ناحية منطقة الأزمنة الدورية المرتفعة (الترددات المنخفضة) مقارنة بالحالة الأساسية للتربة الرملية. كما لوحظ أن زيادة عمق طبقة خليط المطاط والرمل (RSM) مع أو بدون زيادة سعة العجلة للحرك الأرضية يسبب زيادة فى هذا الترحيل ناحية منطقة الأزمنة الدورية المرتفعة (الترددات المنخفضة). هذا الترحيل مصحوب بنقص فى قيم العجلات الطيفية مما يؤدى إلى تخفيض أكثر فى النسبة الطيفية. بالإضافة إلى ذلك فإن وجود طبقة مرنة من خليط المطاط والرمل (RSM) بين طبقتين جاسئتين ينتج عنه أن الطبقتين العلويه والسفلية يتحركان فى طور مختلف مما يسرع من إخماد حركة الطبقة العلوية.