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A 1d Equivalent-Linear Ground Response Analysis of Sand Mixed with Shredded Tire Chips

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Abstract: This paper presents a comprehensive one-dimensional, equivalent-linear dynamic response analysis of river sand mixed with shredded tire chips, based on a rigorous numerical modelling technique. Due to substantial increase in urbanization and consequent increase in the number of vehicles, a large number of wastetires are accumulated each year. An improper management of the tires generated in this much significant quantity may become hazardous for the environment and therefore, some sustainable techniques to reutilize the waste tires should be given due consideration. In this regard, addition of shredded rubber tires to enhance the dynamic properties of weak or poor soil in seismically prone region may be given due consideration. In the present study, influence of addition of shredded rubber and its consequent impact on the seismic ground response has been studied comprehensively based on a finite element analysis. Results are presented considering different strong ground motion. Parametric study has further been carried out to and results are presented to quantify the influence of significant parameters, such as rubber content (RC), thickness of rubber-sand mixed deposit (H). Acceleration-time history plots are presented at the bottom and top of the rubber-sand deposit. Maximum shear strain and its distribution has also been plotted. The efficacy of addition of rubber on sand to mitigate the seismic hazard has been illustrated.

Keywords: Ground Response Analysis, DEEPSOIL, Rubber mixed sand, Damping ratio, Seismic waves

1. INTRODUCTION

Due to substantial increase in urbanization and consequently, a surge in the demand of public transportation vehicles, large number of tires are being manufactured each year to fulfill the rising demand. Often, these tires are disposed off as municipal waste after completion of its service life. An improper management of discarded tire may eventually become a huge pile of unutilized stock waste and may require huge area of useful land for its storage and consequently imposing a threat to the environment. These wasted tires, when thrown outside, do not decompose thus, promote the contamination of water by discharging leachate. One of the most promising technique of utilizing the huge volume of discarded tires is to use it as a partial replacement of natural soils in geotechnical engineering applications. Earthquake being one of the major natural hazards, results in the loss of building properties and livelihoods thus procuring the challenges before engineers and researchers to find any solution which not only minimize the losses but also set the guide lines for using such waste materials produced worldwide. Due to its high durability as well as low unit weight, it may be mixed with soil and can be used as a backfill materials in retaining walls to reduce the deflection and lateral stress on the wall [1,2,3]. Inclusion of rubber in soil alters the mechanical properties of the soil rubber mix and hence proves to be an excellent material to enhance the properties of problematic soils. Several researchers [4,5,6,7], based on extensive laboratory investigations, have reported a substantial increase in the shear strength of sand mixed with rubber shreds or chips, predominantly due to the alteration in the fabric of soil and due to the reinforcement effect provided by the rubber. Moreover, some studies have shown that soil reinforced with shredded tyre chips reduces the deformation caused by liquefaction.

One of the most promising technique of bulk utilization of rubber waste in geotechnical engineering applications is to use it as a base isolation for superstructures in seismically active zones. Recently researchers have comprehensively investigated on the improvement of geomaterials under static loading by application of stone columns [8,9], addition of cement [10] and several other ground improvement techniques. Base isolation technique, however, based on the mechanism of energy dissipation, reduces the force on structure by reducing the frequency of earthquake waves, thus increases the probability of building and livelihood safety against the damages. Various researchers have investigated on the suitability of addition of rubber in cohesionless soil as a base isolation technique [11,12]. Rubber sand mix exhibits a substantial increase in its energy dissipation characteristics [13] and therefore may yield a sustainable solution of bulk utilization of huge amount of rubber generated each year. The efficacy of rubber sand mix (RSM) as an effective base isolation technique has been investigated by several researchers in the past [14,15,16]. Efficacy of shredded rubber mixed sand as base isolator was investigated thoroughly by [9] based on series of shake table tests in the laboratory. From the laboratory investigations, it was reported that to obtain significant base isolation, rubber content in sand should be more than 50% by weight. However, all the experimental investigations were carried out considering a sinusoidal input motion and the actual earthquake time history analysis has not been carried out.

In the present study, efficacy of addition of rubber in sand as a base isolation technique has been investigated by considering three different earthquake input motion based on a numerical approach. One dimensional equivalent linear wave propagation analysis has been carried out using DEEPSOIL software. Influence of rubber content (RC in % by weight) and its thickness (H) on the overall ground response has been investigated in details.

2. METHODOLOGY

3.2 Methodology

2.1.1 Properties of the Materials Considered

The properties of the sand and rubber has been adopted from [17]. The adopted values are presented in Table 1. A linear analysis has been carried out for which the input parameters required are the bulk unit weight (γ), thickness (H), shear wave velocity (Vs) and damping ratio (ξ). To model the bedrock, rigid half space has been adopted.

2.1.2 Problem Geometry

Bedrock was assumed to be at a depth of 30m from the ground surface. Schematics of the problem has been presented in Figure 1.

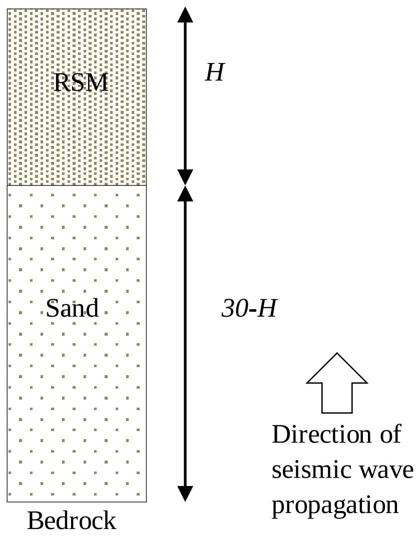


Fig. 1. Schematics of the problem considered in the present study

2.1.3 Details of Input Motion Considered

As previously discussed, three different earthquake input motions are considered in the present study. Details of the three-earthquake input motion are presented in Table 1.

Table 1 Details of different eartquake input motions

	Time and place	Magnitude	Peak acceleration	Casualities	Soil condition
Chichi	21 Sep 1999 Jiji,Nantou, Taiwan	7.3	1.92g	2415 casualities 51711 buildings destroyed 53768 buildings damaged	Fine sand and silt
Kobe	17 Jan 1995 Kobe, Japan	7.3	0.8g	Over 6000 human lives lost 2 Lakh buildings collapsed	Hilly zone, plateau, alluvial low land & reclaimed land

				1 km of Hanshin expressway damaged	
Northridge	17 Jan 1994 Los Angeles, California, US	6.7	1.82g	57 Casualities	Sandy silt

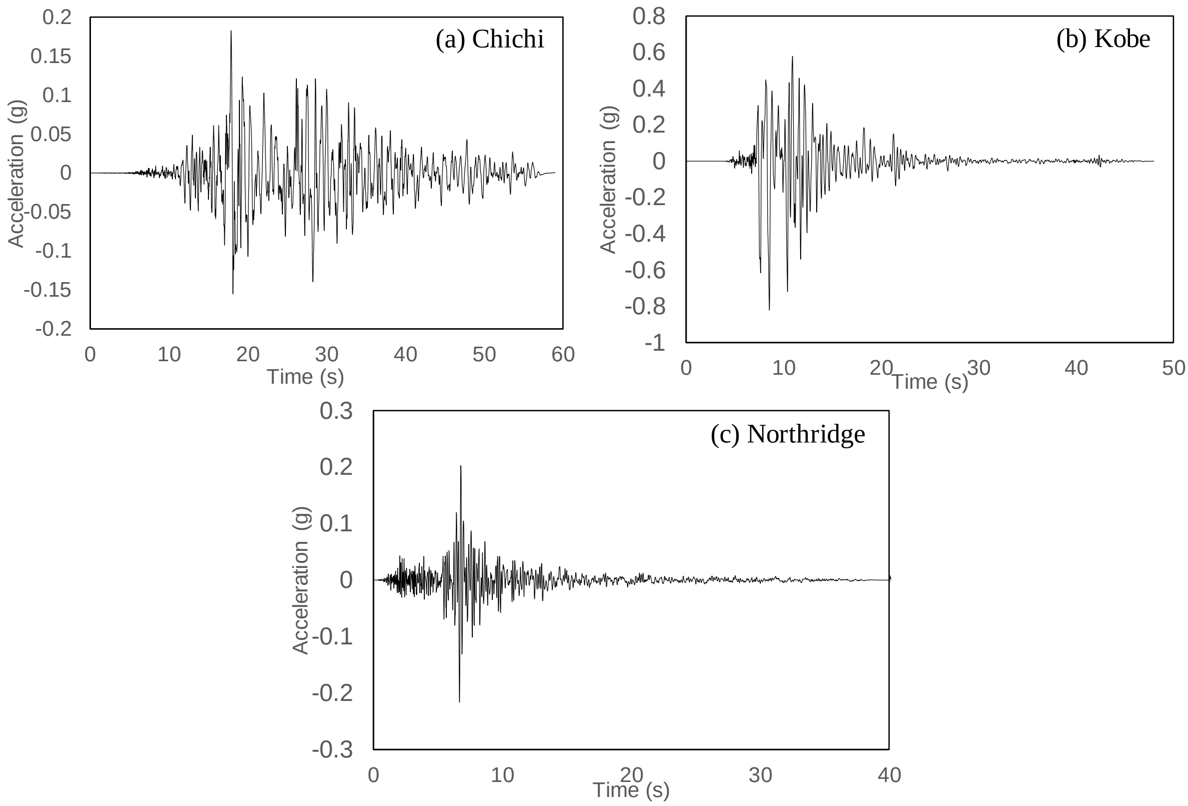
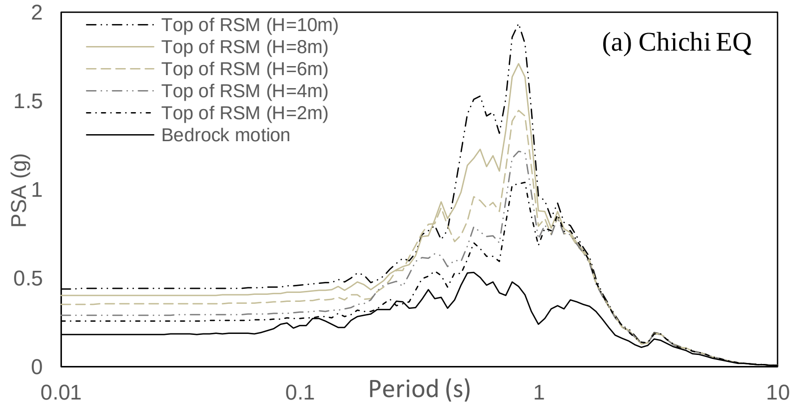


Fig. 2. Time -history of ground motion considered in the present study

3. RESULTS

3.3 Influence of Thickness of RSM layer (H)

To investigate the influence of thickness of RSM on the overall ground response, plot of spectral acceleration with time period were obtained for all the three-earthquake input motion, considering rubber content (RC) as 50%. Analysis were carried out for 5 different thickness (H=2m, 4m, 6m, 8m and10m). The spectral plots obtained for each thickness of RSM layer has been shown in Fig. 3.



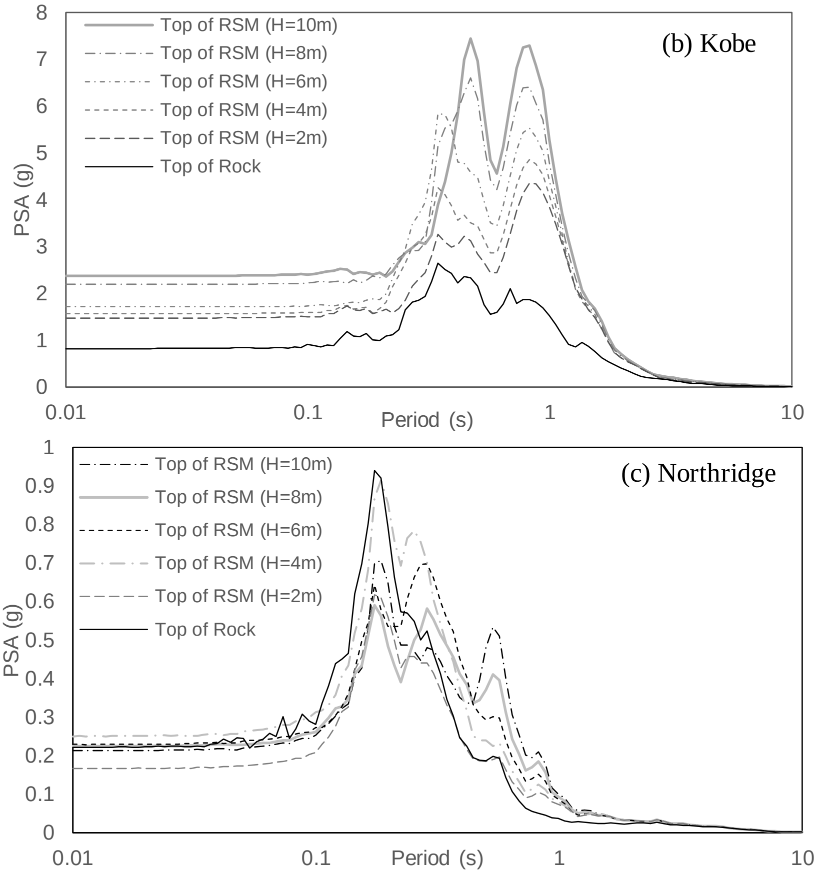
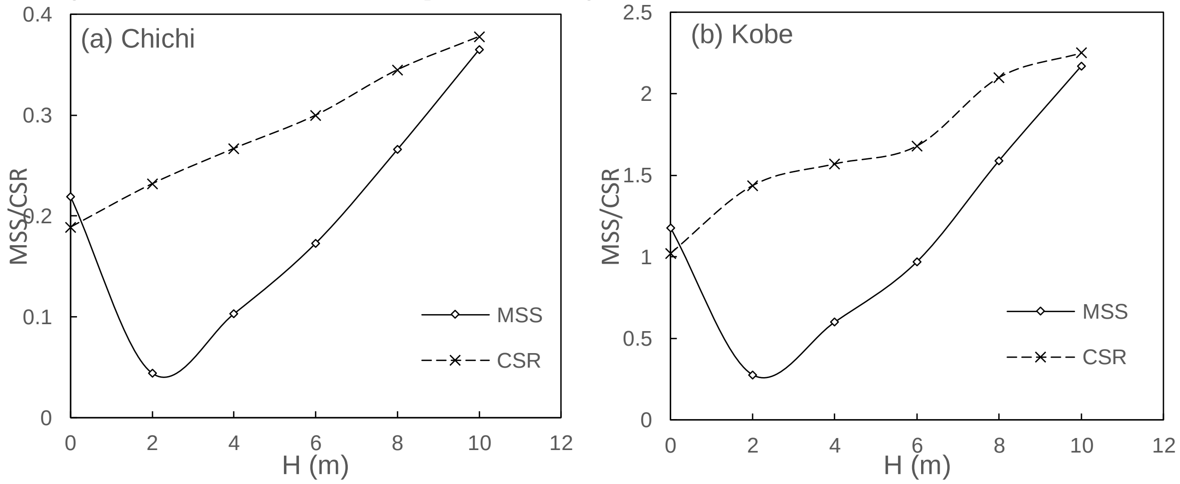


Fig. 3. Spectral acceleration plots for various RSM thickness for earthquake ground motion (a) Chichi (b) Kobe and (c) Northridge

It was seen that except in the case of Northridge earthquake input motions, PSA value was found to be increased with increase in thickness of RSM layer but in the case of Northridge earthquake input motions, PSA value was found to be decreased with increase in layer of RSM thickness. These changes in PSA value might be due to the alteration in Damping ratio of RSM mix. As long as thickness increases, ability of enhancing earthquake waves also increases thus, resulting in higher PSA value. It was also observed that time duration to achieve maximum peak spectral acceleration (PSA) in RSM case was found to be increased, thus increasing the possibilities of waves to slow down and minimize the possible damages.

Influence of RSM thickness on the maximum shear strain (MSS) and cyclic stress ratio (CSR) was investigated, and the variation has been presented in Figure 4.



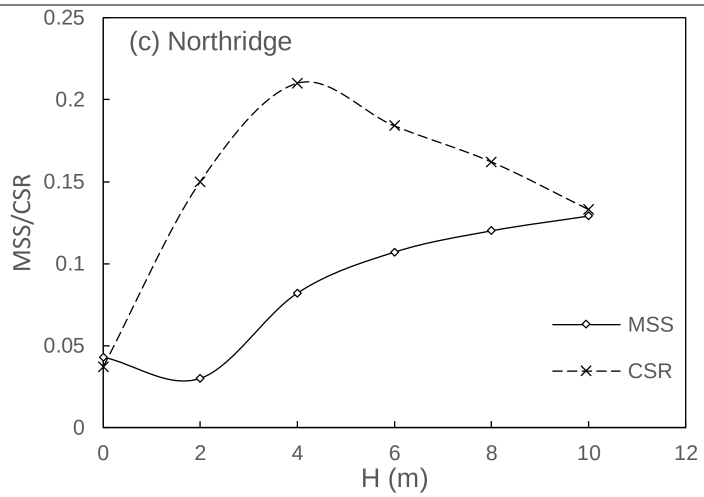
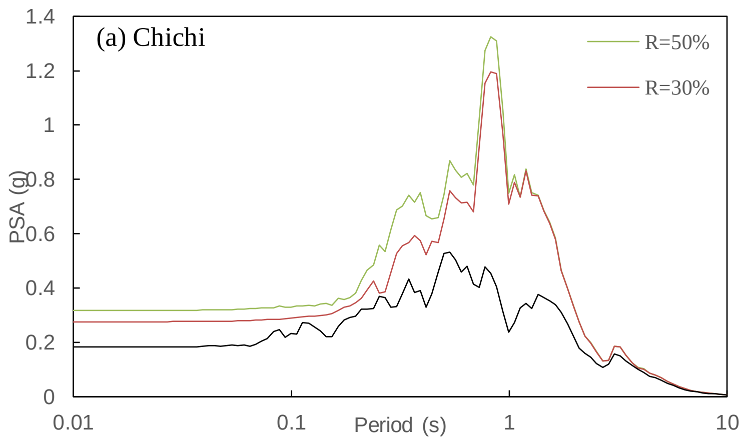


Fig. 4. Variation of MSS and obtained at ground surface for (a) Chichi (b) Kobe and (c) Northridge earthquakes CSR

Figure 4 shows that, with increase in RSM thickness upto 2m, MSS value decreases continuously in Chichi and Kobe earthquake situation while it decreases with flat graph in case of Northridge earthquake situation. Beyond 2 m of RSM thickness, sharp increase in MSS value was observed in first two cases whereas increase with flatter graph was observed in third case. The reason behind all these MSS graph might be due to the heterogeneous behavior of sand-tyre chips mix that imparts friction which increases initially upto 2 m of RSM thickness and then decreases afterwards, resulting in the decrease and increase of MSS value respectively. CSR (a parameter to determine liquefaction potential) value on the other hand was found to be increased constantly with RSM thickness in first two cases but in case of Northridge earthquake, maximum CSR value was obtained at near 4 m RSMthickness. Tyre chips which show good compaction characteristics, might experience more overburden pressure coming from superstructure thus, imparts higher value to the formula of CSR, resulting in the increased value of later. At top of the rock level, CSR value was found to be more than MSS value in all cases.

3.4 Influence of Rubber Content (RC)

As already discussed, to understand the influence of relative percentage of rubber content on the ground response analysis, two different rubber contents (RC); 30 and 50 (% by weight) has been considered in the present study. To quantify the influence of % RC on the overall ground response analysis, RSM layer of thickness (H) of 5m has been considered.



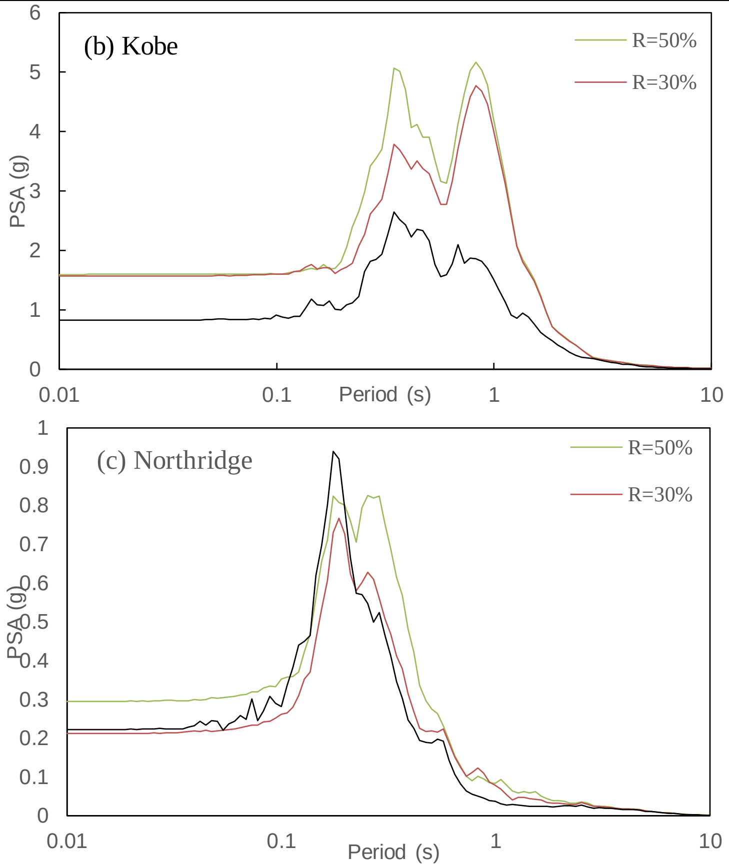
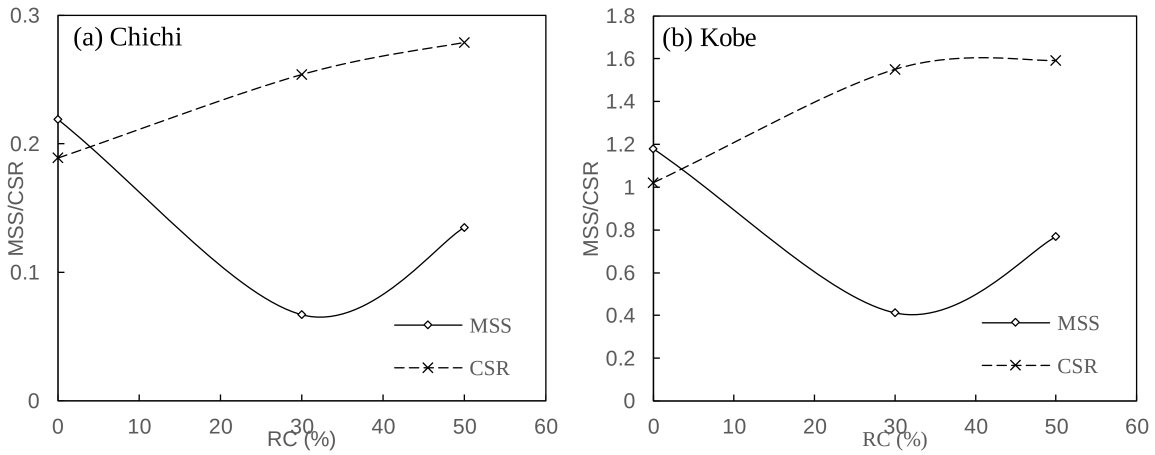


Fig. 5. Spectral acceleration plots for various rubber content (RC) for earthquake ground motion (a) Chichi (b) Kobe and (c) Northridge

Figure 5 shows that the higher PSA value in RC30 and RC50 was obtained in Chichi and Kobe earthquake situation while it showed lower PSA value in Northridge earthquake situation as compared to the bed rock motion. This alteration in PSA value in above three cases reveals that the technique of enhancing wave motions are well affected and controlled by the amount of tyre chips used as well as by the local ground condition of sites.

Influence of rubber content on MSS value and CSR value was investigated and has been shown in Fig. 6.



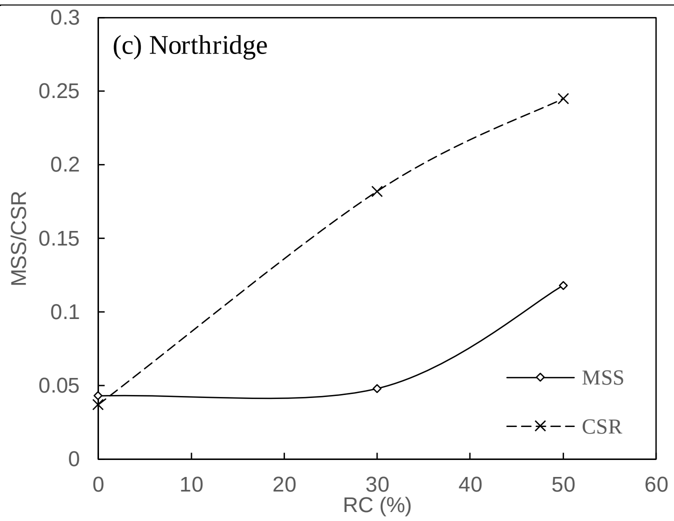


Fig. 6. Variation of MSS andCSR obtained at ground surface including various rubber contents for (a) Chichi (b) Kobe and (c) Northridge earthquakes

It can be seen from the above graph that with the increase in percentage tyre chips in sand, MSS value decreases upto 30% of Tyre chips and then further flourishes. In third case i.e. in Northridge earthquake situation, MSS graph is showing constant value till 30% tyre chips and then flourishes further. This decrease and increase in MSS value might be the result of alteration in frictional force due to mixing of different percentage of tyre chips in sand. As long as the amount of tyre chips in sand is increased, friction is increased and hence MSS value goes on decreasing. After mixing 30 percent of tyre chips, MSS value flourishes which might be due to the poor binding of sand with tyre chips.

Cyclic Stress Ratio (CSR) value was found to be constantly increasing with increase in percentage tyre chips thus reveals a fact that mixing shredded tyre chips in sand must enhances the earthquake waves which further results in increased value of PSA, showing the higher value of CSR.

4. SUMMARY AND CONCLUSIONS

Linear ground response analysis of Sand mixed with shredded tyre chips was performed using DEEPSOIL software considering actual input motions occurred during Chichi, Kobe & Northridge earthquake. Prime focus was to study the effect of thickness and percentage tyre chips on ground response analysis. Graph for MSS & CSR value was drawn and was found that on mixing tyre chips upto 30 percent having 2 m thickness shows the least MSS value. It was also found out that sand-tire chip mixture enhances/ amplifies the earthquake waves in Chichi and Kobe earthquake while diminishes the waves in case of Northridge earthquake. After addition of 30 percent Tyre chips, PSA value was obtained least and was found to be reduced by approximately 0.8 times than that obtained in case of bed rock level thus placing before the idea of using Tire chips with sand to reduce the damages caused by Earthquakes.

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