IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

A Comparative Study on Dynamic Response of Buildings Resting on Coir and Rubber mat Reinforced Soil Bed

To cite this article: M V Sreya *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1149** 012012

A Comparative Study on Dynamic Response of Buildings Resting on Coir and Rubber mat Reinforced Soil Bed

Sreya M V [a], B R Jayalekshmi[b] and Katta Venkataramana[c]
[a]Assistant Professor, Department of Civil Engineering, St. Joseph Engineering College, Vamanjoor, Mangalore 575028, India.sreyav@sjec.ac.in (Corresponding author)
[b]Professor, Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore 575025, India. brjaya@nitk.edu.in
[c]Professor, Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore 575025, India. ven.nitk@gmail.com

Abstract. Geotechnical seismic isolation has emerged as an efficient technique for mitigating the severe effects of earthquakes by providing smooth synthetic liners beneath foundations or between soil layers for dissipating seismic energy through sliding. This study investigates the efficacy of using a rubber mat and a natural coir mat as reinforcement materials within the soil to act as a seismic soil-isolation medium. A three-dimensional finite element simulation of five-storey buildings resting on raft foundations in soft soil with and without the soil-isolation mechanism has been performed. The reinforced soil-structure system was exposed to two different earthquake motions, such as the ground motions corresponding to the elastic design spectrum for Zone III as per the Indian standard code (IS 1893 (Part 1): 2016) and the Northridge earthquake (1994). The proposed study deals with the analysis of dynamic responses of buildings when the soil is reinforced with a coir mat and rubber mat under earthquake motions. The findings show that the seismic responses of low-rise buildings are significantly reduced by a novel technique proposed in this work to reinforce the soil with isolation materials in their mat form to reduce the seismic responses under earthquake loads.

Keywords. *Soil isolation-building system, raft foundation, coir mat, rubber mat, finite element modelling*

1. Introduction

Earthquake is one of the major disasters that destroy structures around the world. Buildings need to be built to withstand earthquakes, or their destructive effects need to be mitigated by adopting seismic isolators to provide secure living conditions. When structural isolation is used, the damaging effects of earthquakes on the structure and its building contents can be lessened by creating a sliding or flexible mechanism between the structure and the foundation to separate the lateral movements of the structure from the lateral movements of the soil. However, in soil isolation, soil-reinforced material absorbs seismic energy before it reaches the structure.

A variety of seismic isolation techniques are available from the previous literature in the area of soil isolation. The benefits of using a geosynthetic reinforced isolation system to reduce seismic response during ground vibrations were first studied by Martin, P P; Seed (1982). The provision of rubber sand mix (RSM) surrounding and below the foundation of the structures to act as a cushion [2] and the provision of smooth synthetic liners below the foundation or within the soil at a distance below the footing were explored by researchers [3]. Economical seismic isolation strategies can be useful for nations when there are insufficient resources and/or technology to reduce earthquake severity. Geotechnical isolation refers to seismic isolation techniques that use geotechnical methods, while structural isolation refers to techniques that incorporate structural methods, such as vibrators in superstructures.

Another reinforcement material is coir, which was applied in previous studies in their fibre form in soil to strengthen it and prevent liquefaction [4]. At greater shear strains, where its contribution significantly improves the shear modulus (G), the coir fibre performs better. However, there are some questions about how long the coir material will last. By applying a phenol and bitumen coating on the fibers, the durability can be increased. One method for enhancing the mechanical and durability properties of reinforcing material is chemical treatment [5]. The importance of using natural material as isolation material in their mat form is found to be a novel technique in this scenario. Because isolation materials give better efficiency in soil isolation process when it is provided as mat as compared to fibers.

2. Methodology

Conventional reinforcement materials like natural fibers, rubber tires and geomembranes, strengthen the soil under static loads. Even under the dynamic loads also materials like geomembrane were used in the previous studies. But getting an alternative sustainable material that can act as an isolation material under earthquake loads is a difficult task. Therefore, in this study, an attempt to study the efficacy of materials like rubber and coir in their mat form is used and compared the efficiency of the materials to reduce the seismic responses under the dynamic loads. Due to the large frictional resistance at the interface of soil and foundation the seismic energy transferred from the soil to structure will also be higher when the foundation rests on soil which do not isolated from the earthquake loads.

The seismic response at the top of the structure was simulated in this study using five storey, three-dimensional building for both the isolated and non-isolated states of soil. soft soil was used for the model. The input parameters used for modelling building, soil and structure components are shown in Table 1. A sum total of 4kN/m^3 load was applied on each floor of the building and the self-weight of the structural mass also was considered. Finite element based ANSYS software was used for modeling and studying the soil-structure interaction under dynamic loading. The elements used for modelling the soil-raft-structure components and their details are shown in Table 2.

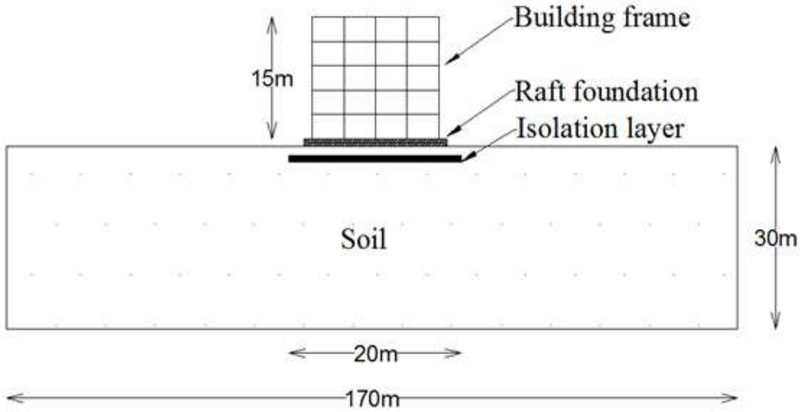

Fig. 1 Schematic illustration of the model

In order to replicate the infinite behavior of soil viscous boundaries were provided on the lateral sides of soil stratum so that no waves will reflect back once it goes from the soil to lateral boundaries. At the bottom of soil both horizontal and vertical translations are prevented and act as a rock surface.

The entire soil-structure system was subjected to an external input motion to study the response under earthquake motion. Input motions used are the accelerogram recorded corresponding to the elastic design spectrum for Zone III as per the Indian standard code (IS 1893 (Part 1): 2016) and the scaled Northridge earthquake (1994) having 0.3g peak ground acceleration. Seismic response of both soil-structure system incorporating both reinforced and unreinforced cases of soil are analyzed. Coir mat and rubber mat were placed at 1m below the foundation in soil, which is the optimum value of placement [6]. Absolute deflection of the roof mass is the main response structural quantity to assess the performance of isolation system, since it is proportional to the bending moment and shear force that exerted at the bottom of the superstructure.

IOP Conf. Series: Earth and Environmental Science 1149 (2023) 012012 doi:10.1088/1755-1315/1149/1/012012

Table 1. Properties of building components and isolation materials

Specification	Dimension	Young's Modulus of Elasticity (MPa)	Poisson's ratio	Unit weight (γ_d) (kN/m^3)
RC Beam (BxDxL)	0.3mx0.3mx4m	25x10^3	0.15	25
RC Column (BxDxL)	0.5mx0.5mx3m	25x10^3	0.15	25
Raft foundation (BxDxL)	18mx18mx1m	25x10^3	0.15	25
Rubber mat (BxW)	20mx20m	100	0.49	15
Coir mat (BxW)	20mx20m	4100	0.3	15
Soft soil	170mx170mx30m	65	0.4	16

Table 2. Elements and details used for modelling in ANSYS

Component	Element	Details
Soil	SOLID 185	8-noded first order linear brick reduced integration element.
Raft foundation		Good for convergence in contact analysis
Building	BEAM188	2-noded beam element with linear behavior
Coir mat/ Rubber mat	SOLSH190	3D finite strain 190 element having negligible bending stiffness

3. Results and discussions

The peak roof deflection responses of building under seismic loading were estimated. Fig. 2 represents the maximum value of roof deflection observed for the isolated conditions of soil, i.e. with coir mat and rubber mat placed at its optimum thickness (1m) and for conventional soil in the present study. Compared to the unreinforced soil bed, the reinforced soil bed shows reduced building responses under seismic loading. Deflection shown by the building resting on soil reinforced with coir mat is less than that observed with rubber mat. This shows that the material, coir mat is better in absorbing the vibration energy before it reaches to the structure from soil.

Base shear ratio (F') for the five storey building was calculated using Eq^n, F'= F/W, where, w is the weight of the superstructure and F is the total shear force calculated at the ground floor.

The base shear ratio obtained for the models considered for the analysis shows that the soil reinforcement isolation mats such as coir mat and rubber mat considerable reduces the seismic base shear and the coir mat shows much better isolation efficiency over rubber mat. Fig. 3(a) and Fig. 3(b) show the base shear ratio and the percentage reduction in the seismic base shear ratio respectively for different soil-structure system considered.

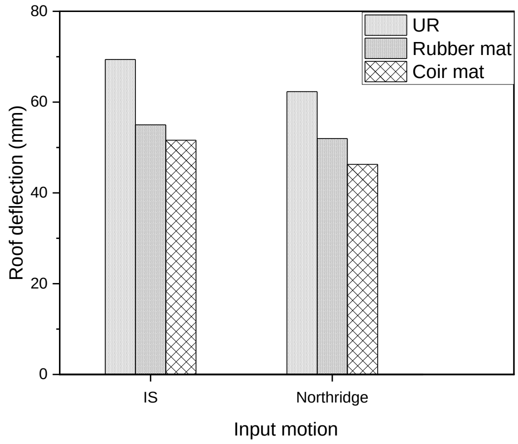

Fig. 2 Roof deflection for soil reinforced with coir mat and rubber mat under different earthquake input motions

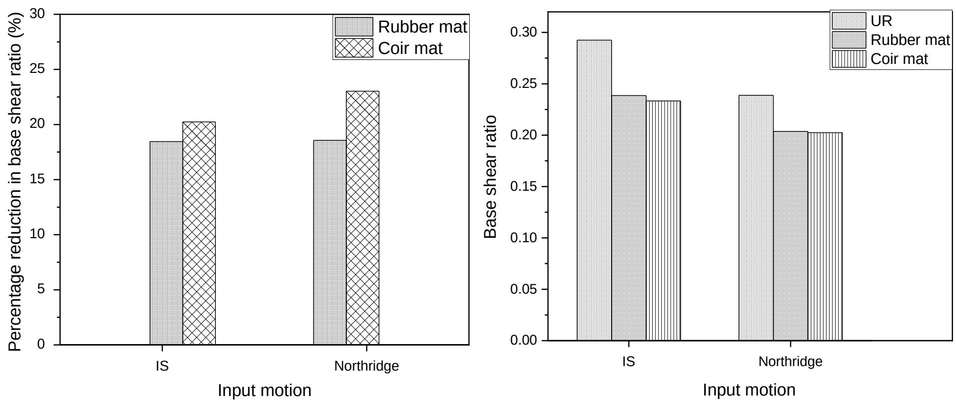

Fig. 3 (a) Seismic base shear ratio of building on reinforced soil with various mats (b) Percentage reduction in the seismic base shear ratio

4. Conclusions

The isolation efficacy of the coir mat and rubber mat in reducing the seismic response of building, those positioned under the foundation, is explored in the current numerical analysis. The following are the conclusions arrived:

1. The soil reinforced with coir mat and rubber mat could considerably reduce the seismic building responses as compared to a conventional building.
2. Maximum attenuation in deflection at roof of buildings occurred by reinforcing soil with coir mat i.e. 28% and at the same time rubber mat could reduce 22% of seismic deflection compared to unreinforced soil case.

3. Seismic base shear is found to be less when soil reinforced with coir mat and it shows 24% reduction in seismic base shear ratio.
4. Materials show same isolation efficiency under both the input motions considered. Which shows that the frequency of input motions which matches with the fundamental frequency of soil-structure system considered was abundant.
5. Seismic isolation with coir/rubber mat was found to be a simple and alternative technique to reduce earthquake severity than the available traditional base-isolation methods.

References

[1] H. B. Martin, P P; Seed. Rock and Soil Improvement Techniques. p. 836288, 1982.

[2] M. K. Yegian and M. Catan. Soil Isolation for Seismic Protection Using a Smooth Synthetic Liner. *J. Geotech. Geoenvironmental Eng.*, vol. 130, no. 11, pp. 1131–1139, 2004, doi: 10.1061/(asce)1090-0241(2004)130:11(1131).

[3] T. H. Ho. Geotechnical seismic isolation. *Earthq. Eng. New Res.*, no. January 2011, pp. 55–87, 2011.

[4] A. Boominathan and S. Hari. Liquefaction strength of fly ash reinforced with randomly distributed fibers. *Soil Dyn. Earthq. Eng.*, vol. 22, no. 9–12, pp. 1027–1033, 2002, doi: 10.1016/S0267-7261(02)00127-6.

[5] A. Kumar and D. Gupta. Behavior of cement-stabilized fiber-reinforced pond ash, rice husk ash-soil mixtures. *Geotext. Geomembranes*, vol. 44, no. 3, pp. 466–474, 2016, doi: 10.1016/j.geotexmem.2015.07.010.

[6] M. V Sreya, B. R. Jayalekshmi, and K. Venkataramana. A study on seismic response of buildings on coir mat reinforced sand bed. *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1114, no. 1, p. 012018, Mar. 2021, doi: 10.1088/1757-899x/1114/1/012018.