Base isolation using waste tyre rubber

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Abstract - **The idea that a building can be uncoupled from the damaging effects of the ground movement produced by a strong earthquake has appealed to inventors and engineers for more than a century. Many ingenious devices have been proposed to achieve this result, but very few have been implemented and the concept now referred to as base isolation or seismic isolation has yet to be generally accepted by the engineering profession. Although most of the proposed systems are unacceptably complicated, in recent years a few practical systems have been developed and implemented[1]. While some of these systems have been tested on large-scale shaking tables, none have to date been tested as-built by a strong earth tremor. The shake table testing and related static testing of full-scale components such as isolation bearings, however, has led to a certain degree of acceptance by the profession and it is possible that the number of practical implementations of base isolation will increase quite dramatically in the next few years. This project describes implementations of base isolation and describes an approximate linear theory of isolation which can be used for the design of base isolation systems that use multilayer waste tyre rubber.**

Keywords: isolation bearing, shaking table test, base isolation, ground movement, uncoupled.

I. INTRODUCTION

All of the engineered structures should satisfy the basic equation[2] below -

Capacity > demand

In conventional earthquake resistant design method, the engineer can obtain the solution of Equation 1 either by: Increasing the capacity of the structure or limiting the demand by considering the ductility of the structure.

The first solution above requires enlargement of the structural member sizes to increase the capacity of the structure, which is not an economical way to solve the problem. Thus, the conventional design codes prefer latter option, which is a more economical solution.

The conventional design codes assume that, in cases of small and medium ground motions, the structure stays in elastic range. However, in case of a strong ground motion, it is accepted that the structure passes beyond the elastic limit. If the structural members have enough ductility, the structure shows high level of displacements and does not collapse and survives a severe earthquake. Hence, the conventional codes give ductility requirements for the designer to obey. The high levels of displacements cause considerable damage on structural [4] and non- structural members of a building. The building may not be functional after a strong earthquake because of the damage observed on structural members. Furthermore, large inter-story drifts may create significant damage on non-structural members such as infill walls and windows. Seismic base isolation takes a different approach to the earthquake resistant design problem. Instead of increasing the capacity of the structure or detailing for the ductility of the structural system, it rather attempts to reduce the seismic demand by modifying the dynamic response of the structure. Seismic base isolation is simply composed of laterally flexible system located under the isolated superstructure. Hence, the structural members of the isolated building do not suffer any damage during a strong ground motion. After the event, even non-structural elements of the isolated buildings continue to perform their functions without any corruption.

II. LITERATURE REVIEW

Development of Seismic Base Isolation Systems:-

A medical doctor named J.A. Calanterients, in 1909, proposed the first seismic base isolation method. His isolation system was totally based on sliding. Mr. Calanterients claimed that if a structure is built on a fine material such as sand, mica, or talc, this fine soil would let the superstructure to slide during an earthquake. Hence, the horizontal force transmitted to the building would be reduced and the structure would survive the event. Although the isolation system that Mr. Calanterients proposed was a primitive earthquake resistant design, the basic idea behind his method is same with the philosophy of seismic base isolation today. SREI samples used under buildings are too heavy because of steel plates inside the isolators[6]. This heaviness makes both production and construction of elastomeric isolators difficult. This causes significant increase in the cost of the system. In order to achieve this problem, Kelly et al. tried to use lightweight fiber reinforcement inside the elastomeric isolators. Fibre-reinforced elastomeric isolators are a newly introduced concept in the field of seismic base isolation. Kang et al. searched for hole and lead plug effect on fibre reinforced elastomeric isolators. The elasticity of the fibre material is a factor affecting the compression modulus of fibre reinforced elastomeric isolators. Tsai, Kelly and Takhirov conducted admirable experimental and analytical studies on compression behaviour of fibre reinforced elastomeric isolators.

III. METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study.

1 PREPARATION OF WTP SPECIMENS

Waste tyres are old used car tyres (Figure a). The existence of waste tyres on rubbish areas is an earnest threat for the health of both community and environment. Tyre ring is the part that touches ground (tread) after the sidewalls of the tyre is removed by cutting off (Figure b). Tyre band is the same part after cutting the ring in transverse direction (Figure c). Tyre layers are 20cm long pieces of waste tyre band (Figure d). Waste tyre pad (WTP) is formed when a set of waste tyre layers are placed on each other (Figure 15e). However, they may just be put on each other since the frictional force between tyre layers would be high enough to maintain the stability of WTP layers.

Figure a

Figure b

Figure c

Figure d

IV. EXPERIMENT SETUP

The objective of this experiment was to obtain the behaviour of WTP and available SREI specimens under compression. The specimens were tested in Universal testing machine for Rubber under gradually increasing load . Vertical load applied and corresponding vertical displacement was recorded simultaneously. The results are presented as graphical data in the following pages. The results of WTP specimens were compared with the results of the SREI specimen.

WTP specimens experimented in compression machine were produced from four well-known tyre brands, which will be referred by letters G, M, P, and L here. The trademarks of the specimens will not be mentioned in the manuscript. The SREI specimen was a standard 150mm x 150mm x 40mm elastomeric bridge bearing with a single layer of 3mm steel reinforcement.

UNIVERSAL TESTING MACHINE FOR RUBBER

The experiment setup given above is composed of a Universal testing machine for Rubber with 500 kg vertical load capacity, four displacement transducers and a calibrated pressure gage (load cell) for measurement of axial load, which are connected to a 16 channel data acquisition system. The data was simultaneously collected at 0.10 second intervals at a speed of 8 Hz. WTP specimens were tested under compression as four tyre layers which were placed on top of each other. G-WTP was also tested with 6 layers in addition to 4 layers to search for the effect of tyre layer number on the vertical stiffness of WTP specimens.

V. RESULT

The specimens were tested under cyclic axial load with gradual increments. The measured responses are shown in Figure 12 to Figure 16. Strength and instantaneous compression modulus of specimens are given in Table 1. Since WTPs failed between strains of 0.20 and 0.25, the compression modulus values are calculated at strain levels of $\varepsilon = 0.1$ and $\varepsilon = 0.15$.

The WTPs failure is initiated by series of snapping sounds at about 8MPa axial stress level. The bridge bearing tested here has a vertical strength of 40MPa. The sounds heard from WTPs came from failing mesh wire strands inside the tyres. The compression modulus and axial load capacity of G-WTPs are remained constant for 4 and 6 tyre layers. Each identical tyre layer of STP samples has its own steel mesh causing the total behavior of STP remains similar regardless of the tyre layer numbers: the STP behaves as a spring in series.

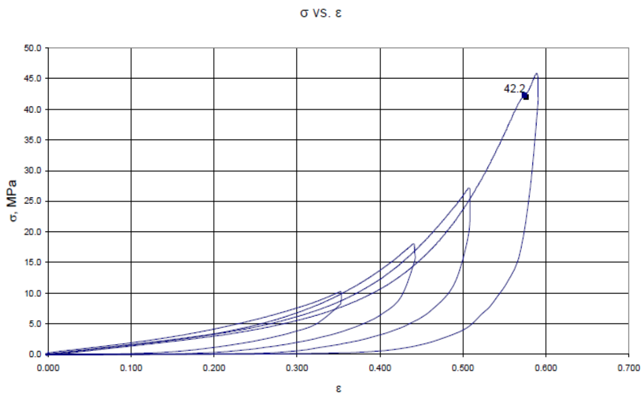

Figure 12: σ ~ ε Curve of SREI

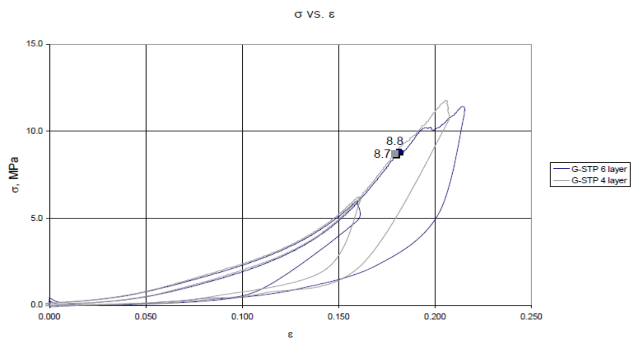

Figure 13: σ ~ ε Curve of G-STP composed of 4 and 6 layers

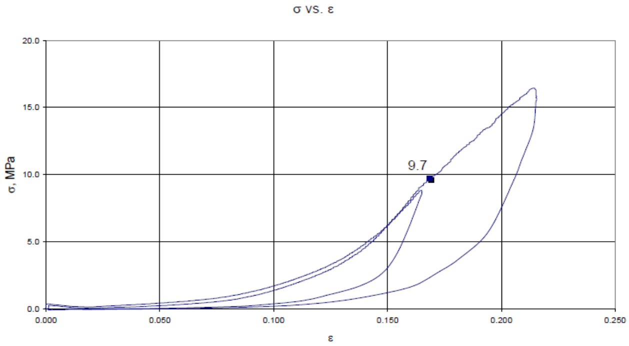

Figure 14: σ ~ ε Curve of M-STP

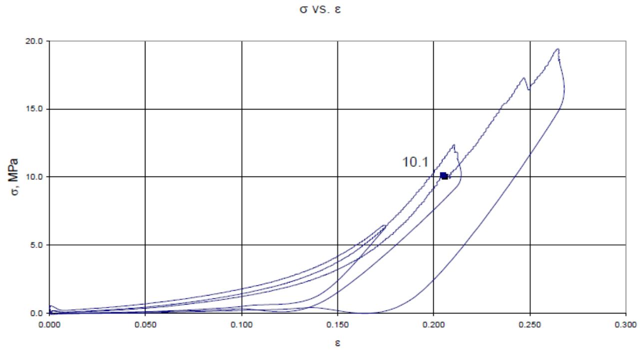

Figure 15: σ ~ ε Curve of P-STP

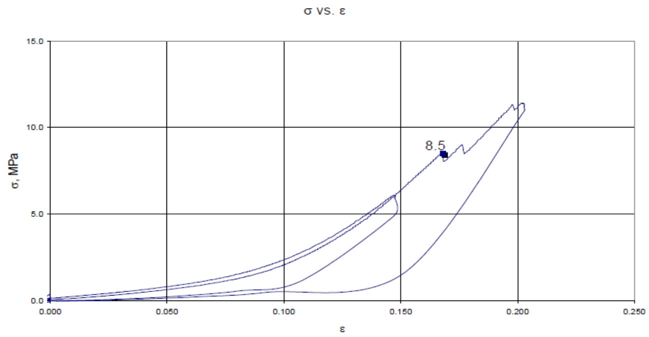

Figure 16: σ ~ ε Curve of L-STP

Table 1: Compression experiment results

Specimen Types	Dimensions (mm)	Number of Layers	Strength (MPa)	Compression Modulus (MPa) (ε=0.10)	Compression Modulus (MPa) (ε=0.15)
SREI	150 x 150 x 40	-	42.2	25	25
G-STP	200 x 180 x 46	4	8.7	33	95
G-STP	200 x 180 x 69	6	8.8	34	94
M-STP	200 x 190 x 46	4	9.7	50	181
P-STP	200 x 175 x 40	4	10.1	30	74
L-STP	200 x 180 x 50	4	8.5	55	124

VI. CONCLUSION

In this project, the experiments have been carried out to investigate the development of low-cost seismic base isolation pads using scrap automobile tyres. Within the scope of the work, axial compression test was conducted.

Compression tests reveal that the axial load capacities of WTPs are around 8 MPa level. An allowable vertical stress of about 4 MPa is recommended for STP design. The compression modulus values of WTPs are found to be 1.2 to 2.0 times the value of SREI sample. The low vertical strength is associated with small amount of steel wire mesh available in scrap tyres and additional steel plates may be used between tyre layers to significantly improve the axial load capacity of WTPs [25](which would also increase the compression modulus). The STP reinforced with steel plate layers under compression is expected to lose steel wire mesh at a certain load capacity, but steel plates would still continue to function generating a bilinear load-deflection curve.

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