# THE ROBALL A NEW SEISMIC ISOLATION DEVICE

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### **SUMMARY**

Robinson Seismic's latest developments in seismic isolation includes a new device, the Roball<sup>TM</sup>, for seismically isolating structures during earthquakes.

This advance is a new concept for seismic isolation based on the principle of the inverted pendulum. It consists of 'friction balls' or 'Roballs' moving between upper and lower spherical like cavities or flat plates. The Roballs are filled with a material which is able to provide the friction forces required to absorb the energy from numerous earthquakes while supporting the structure. The Roball technique is expected to enable light and in the future possibly heavy structures to be more economically seismically isolated.

As part of a program to develop a user friendly 'seismic isolation system' a series of full-scale tests have been carried out on a number of possible designs including three approaches for vertical pressures of ~1 MPa resulting in coefficients of friction of ~0.1 to ~0.4.

In this paper we present the preliminary experimental results.

#### INTRODUCTION

The acceptance by the engineering community of the technique of seismic isolation was given a major boost in the 1970s by the introduction of the lead rubber bearing, commonly known as the LRB. The first structure in the world to be seismically isolated with lead rubber bearings was the Toetoe Bridge, completed in 1978, on the main highway linking Wellington and Auckland, New Zealand (Robinson, 1982). In 1981 the William Clayton building in Wellington, New Zealand was completed. This four storey building mounted on 80 LRBs was designed in the late 1970's (Megget, 1978). Based on the state-of-art knowledge for earthquake ground motions at that time a seismic gap of 150 mm around the building basement was deemed adequate. Buffers were provided to restrain the building should the base-isolator displacement exceed 150 mm (Skinner et al. 1993).

In the last 10 years or so, many near source records have been obtained from large earthquakes, for example, the Lucene and Joshua Tree records from the 1992 Landers earthquake (M<sub>w</sub>=7.2) and the Sylmar record from the 1994 Northridge earthquake ( $M_w$ = 6.7). A common feature of several of these records is a long period velocity pulse of very large amplitude. Such a pulse can impose very large displacement demands on intermediate and long period structures, including base isolated buildings (Hall et al. 1995). These results have encouraged design engineers to increase seismic gaps to 300 to 500 mm. This increase in displacement is illustrated by the example of three seismic isolation projects completed in New Zealand during the 1990's, vis: the new Wellington Central Police Station with a gap of 400 mm (Charleson, et al 1987), the old NZ Parliament Buildings retrofit with a seismic gap of 300 mm (Poole & Clendon, 1992) and the new Museum of NZ (Te

Papa) with a seismic gap of 450 mm (Boardman & Kelly, 1993).

The lead rubber bearing has been a very useful isolator but like all rubber bearings it is limited by the behaviour of rubber at high strains. To satisfy the requirements of customers, isolation designers are now requiring strains in the rubber as high as 300 to 400%. In addition designers are asking for non-linear restoring forces together with very large displacements ( $\sim 1$  metre). We believe that the Roball which has no inherent limit to the horizontal displacement can satisfy many of these demands

A method of satisfying the demanding requirements of a very large displacement is to use 'friction device' operating within an 'inverted pendulum' (Zayas, 1995). We have followed this approach with the invention and development of a 'friction ball' or 'Roball' rolling between two spherical like cavities (Robinson, 1998). The Roball rolling between two spherical like surfaces has no inherent displacement limit, provides a constant coefficient of friction and allows greater freedom in the choice of the function describing the restoring force.

# EXPERIMENTAL RESULTS FOR THE ROBALL

The experimental results for the new isolation device, the 'Roball<sup>TM'</sup> (Robinson, 1998, 2000) have proved to be very positive. For commercial reasons, we are not able to present the details of design of the Roball at this stage. We have made a number of prototype Roballs and performed extensive shear tests and compression tests on them. Figure 1 illustrates the set up of a shear test. This is also likely to be the configuration used in seismic isolation applications. The rolling action of the Roball means that the device itself has

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no design displacement limit and so the maximum displacement is limited only by installation requirements. Figure 2 shows a hysteresis loop for the rolling of a prototype Roball with a vertical load of 10 kN resulting in a coefficient of friction,  $\mu$ , of  $\sim 0.1$ . Figure 3 shows the axial force-

displacement relationship in a compression test with loading and unloading for a vertical pressure of up to  $\sim 9.5~kN$  for a Roball with  $\mu \sim 0.3$ . Note that a considerable amount of energy is absorbed in the compression test.

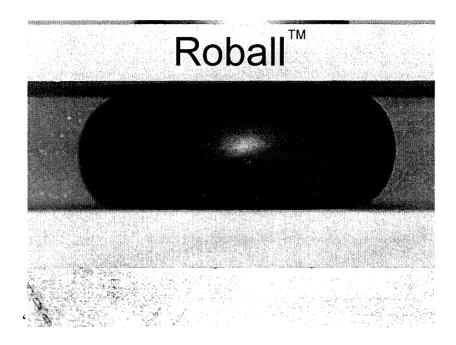


Figure 1: 'Roball' under pressure.

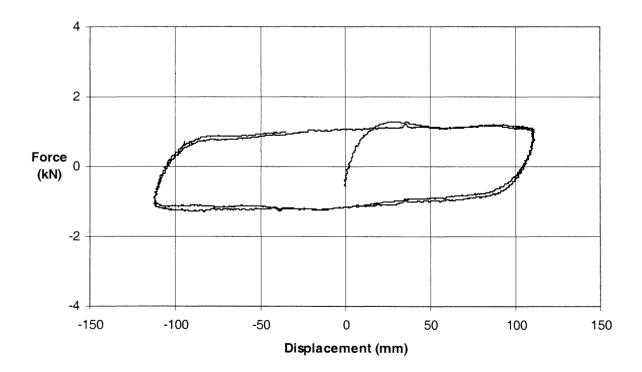


Figure 2: The force-displacement Hysteresis Loop for a 'Roball' with a vertical load of 10 kN,  $\mu \sim 0.1$ .

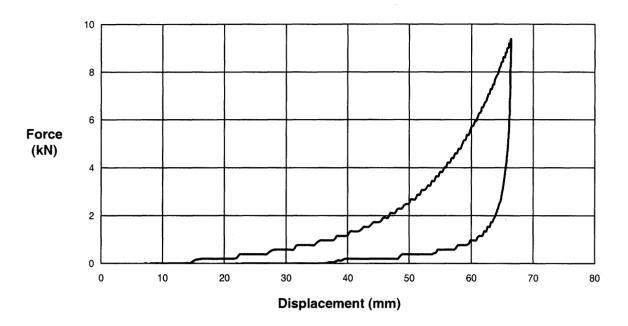


Figure 3: Vertical force verses vertical displacement for a 10 kN Roball with  $\mu \sim 0.3$ .

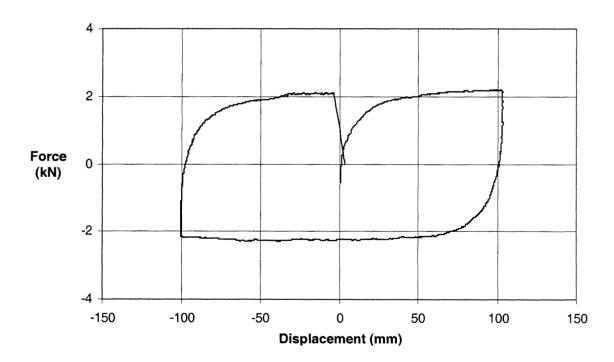


Figure 4: The force-displacement Hysteresis Loop for a 'Roball' with a vertical load of 5 kN,  $\mu \sim 0.4$ .

The dynamic behaviour of the device is independent of both frequency and ambient temperature within ranges that are applicable to most practical installations. The friction coefficient, i.e., the ratio of the nominal yield shear force to the compression force, of the prototypes, is between 0.1 and 0.4. With further development, the friction coefficient of the device is expected to be variable between 0.05 - 0.5 depending on the design.

The range of possible applications for this device is likely to be very wide. At the present stage of the development, the device is ready for protecting light equipment and light structures from mechanically generated or earthquake induced vibrations. We expect that the device will become an economic alternative to rubber or lead rubber bearings for isolating structures and to provide damping needed for structures to resist near-source ground motions.

For an isolated structure located close to an active fault, it is desirable for the building to be buffered so that the isolator displacement can be limited to the maximum design displacements of the bearings. In a recent paper (Zhao & Robinson, 1999) we showed that buffer-structure impact could have a detrimental effect on the building performance if the buffer is not designed properly. For resisting nearsource ground motions with forward directivity effect, it is desirable to have an isolation device that behaves like a conventional isolation device but which also has a gently increasing stiffness at large displacements. This can be easily achieved by using Roballs, with a compression forcedisplacement relationship as shown in Figure 3, as buffers. Such buffers can also absorb seismic energy to assist in providing the required amount of damping at large displacements.

Figure 4 illustrates the force-displacement hysteresis loop for a Roball with vertical load of 5 kN. This hysteresis loop results in an effective coefficient of friction,  $\mu$ , of approximately 0.4.

# **CONCLUSIONS**

The following conclusions can be drawn from this study:

The Roball promises to be an economical alternative to existing seismic isolation devices. It has no inherent displacement limit, provides a constant coefficient of friction, allows greater freedom in the choice of the restoring force and may also be used as a buffer. As a buffer the Roball has two very desirable characteristics: it absorbs energy, and has gently increasing stiffness at large displacement amplitudes. The buffer action may also be useful for reducing the transmission of vertical earthquakes forces to the isolated structure.

At present a number of versions of the Roball have been developed and tested for vertical pressures of  $\sim 1$  MPa with a range of coefficients of friction,  $\mu$ , available ranging from 0.1 to 0.4.

## ACKNOWLEDGEMENT

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