In-Situ Assessment of Building Isolation Bearings

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ABSTRACT

A sustainable future has driven the increase in public transport options within cities, many of which are rail corridors under or alongside sensitive facilities. Urban development above rail corridors has led to revitalisation of precincts such as the Riverbank Precinct in Adelaide. This has been inspired by the development of the Adelaide Convention Centre, constructed in stages over the main rail corridor into Adelaide since about 1985. The current stage sought to retain building vibration isolators, originally installed in 1985, to support the new Plenary Hall. This paper outlines a novel use of contra-rotating rotary electric vibrators, ordinarily used for materials handling applications, to measure the performance of building isolators in-situ. It also provides a method for estimating the life expectancy of bearings (usually specified as to be no less than 50 years). Finally it provides insight into design aspects of floor structures subject to combined harmonic loads (from crowd dance activities) while needing to adequately isolate structure-borne noise.

Keywords: Building Isolation, Vibration I-INCE Classification of Subjects Number(s): 40, 43, 46

1. NTRODUCTION

The Adelaide Convention Centre has been constructed in stages since about 1985, when the original Adelaide Station and Environs (ASER) project was conceived. This original construction incorporated vibration isolation of the rail bed, and the vibration isolators supporting the plaza level slab housing the plenary hall and exhibition halls. The current development involved an extension of the convention centre further west to Morphett St bridge, and the demolition and construction of a new plenary hall, with the proposed and existing hall shown below in Figure 1.

Figure 1 Proposed and existing Plenary Hall

Portions of the new Stage 2 development are located over the existing railway tracks and platforms, including reuse of the existing Level 05 Plaza slab. A review of the existing structural drawings indicates that parts of this slab are vibration isolated from the supporting columns in the railway station through the use of elastomeric bearings. The purpose of such bearings is to reduce the

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transmission of noise and vibration from train movements in the station, similar to that present in the 2000 redevelopment and in Stage 1 of this project.

A structural assessment of the existing bearings for imposed vertical loads from the new plenary has been undertaken to ensure that they are within the original rated capacity of the bearing. However, it is likely that the existing bearings in the rail corridor have degraded to some extent since their installation as a part of the 1986 construction. The life span of a bearing is based upon the rubber within the bearing degrading over time (getting harder). With the rubber increasing in stiffness with this degradation, the transmission of train vibration through the floor is expected to increase as compared with the original design intent such that the bearing no longer functions as efficiently for vibration isolation.

As the existing bearings are over 35 years old, and the original manufacturer unknown, it is considered that it is a risk to the project to assume that their performance to isolate the new plenary building will be satisfactory for the full life of the new building. This is particularly relevant given the new construction of a new building with vibration-sensitive functionality on top of these bearings which has a design life of around 50 years.

Given the risk of reduced performance, it was initially recommended to replace all of the existing bearings with new to ensure the desired vibration isolation is achieved for as long as possible after the new building is constructed, however this has an estimated cost of approximately $1 million. Given the significant cost of replacement, an assessment in-situ of the existing bearings was carried out to determine:

- The remaining functional life of the existing bearings to review deferral of replacement.
- The vibration isolation performance of the existing bearings for functionality of the Stage 2 plenary floor on the existing Plaza slab.

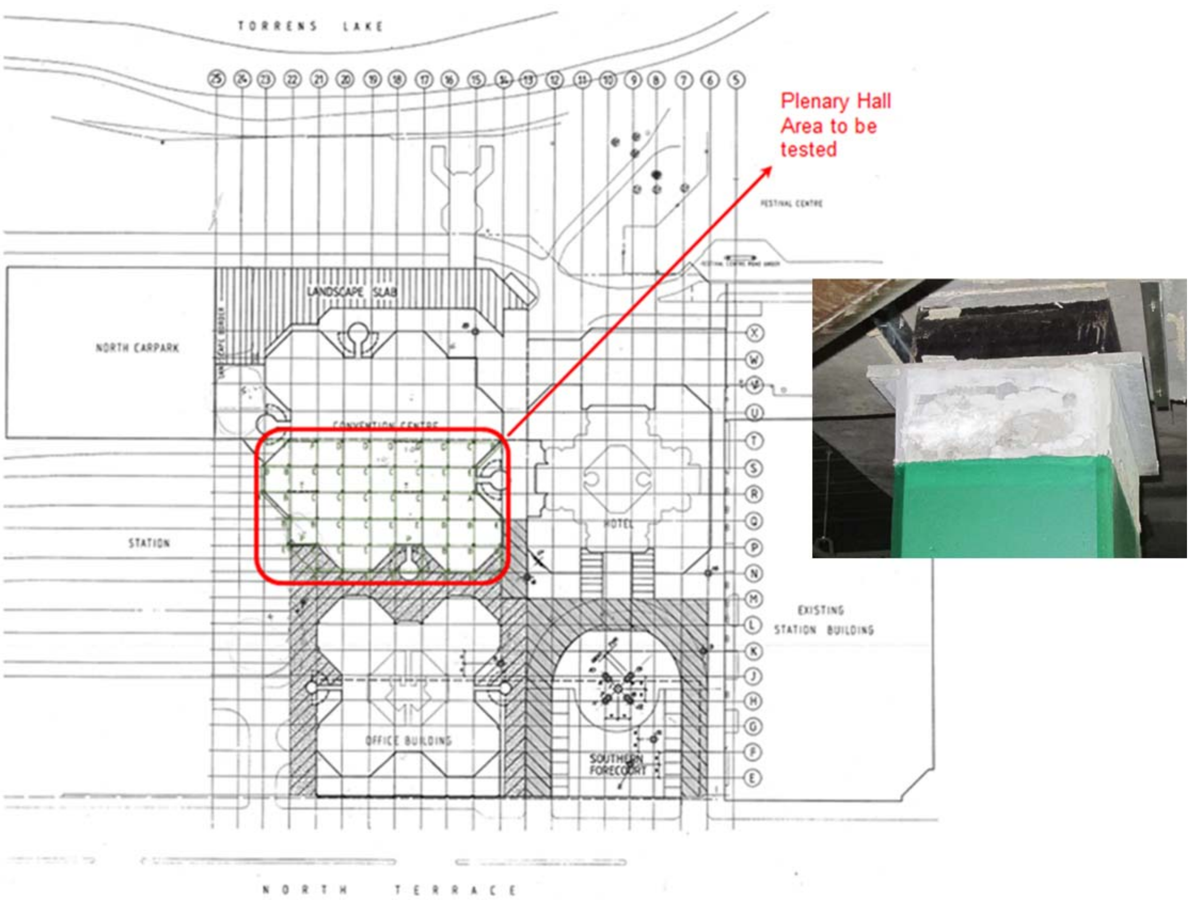


Figure 2 Existing vibration isolators to be retained

2. BUILDING ISOLATOR DESIGN ISSUES

The method of assessing the dynamic performance of the bearings is to use a rotating eccentric mass to excite the dynamic system through resonance as shown in Figure 3. As shown, subject to inherent damping of the isolator, vibration of the floor will be amplified at resonance, allowing the stiffness and damping characteristics of the isolator to be determined.

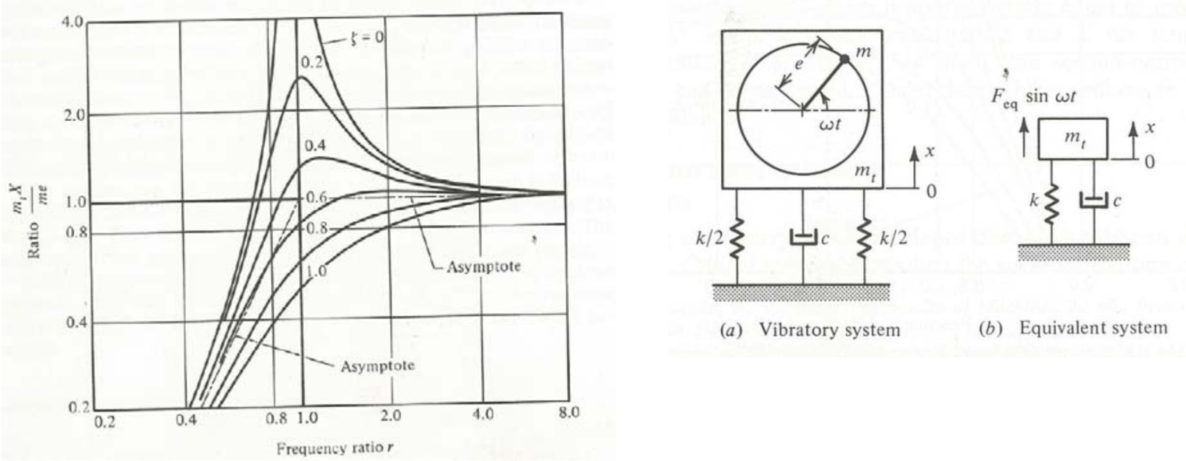


Figure 3 Vibration performance testing using a rotating eccentric mass

However the response of the floor on isolators is complicated by the inherent dynamic characteristics of the floor itself. Dunkerly's method is used to combine multiple modes of systems with more than one-degree of freedom, similar to that shown in Figure 4.

Estimates of the dynamic performance of the isolators based on the previous specifications suggest a natural frequency of about 8Hz. The natural frequency of the floor is likely to be between 6-8Hz.The response of the structure is likely to show two modes either side of that of the system if the floor were infinitely stiff. This is shown below in Figure 5.

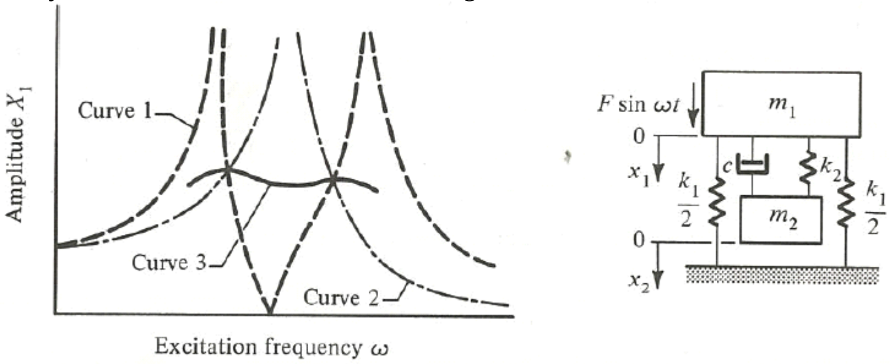


Figure 4 Two degree of freedom system

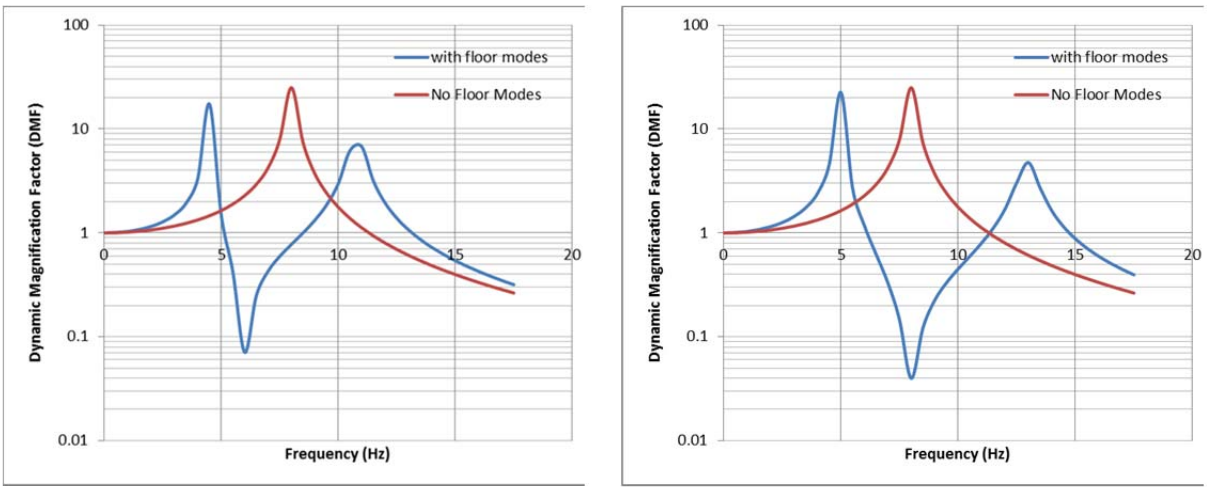


Figure 5 Response of the floor with and without modes at 6Hz (LHS) and 8Hz (RHS)

Finite element modelling of the multi-degree of freedom system has also been carried out to qualify this result. A simple beam on vibration isolators was modelled, with the modal frequencies of each system shown in Table 1 below. It is expected two dominant modes to be present in the results, being a combination of the fundamental floor mode and the isolator mode.

Table 1 Modal frequencies of multi-degree of freedom system

Mode	Simply Supported flexible Beam	Extremely stiff beam on Springs	Flexible beam on Springs
1	8.5Hz	8.0Hz	5.3Hz
2	34Hz	14Hz	13Hz
3	76Hz	270Hz	23Hz

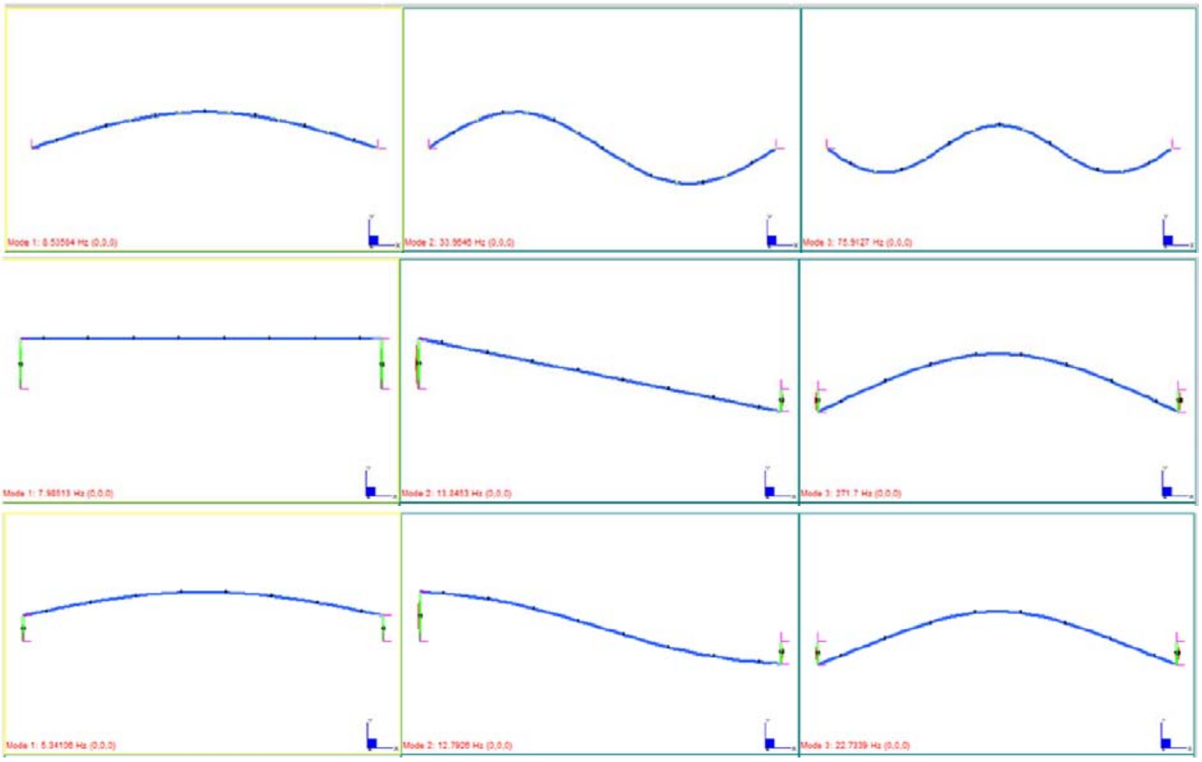


Figure 6 Mode shapes of a simply supported flexible beam (top row), infinitely stiff beam on springs (middle row) and flexible beam on springs (bottom row)

3. METHOD FOR IN-SITU TESTING OF BEARING LIFE

Two contra-rotating eccentric mass shakers were selected to use on site to maximise the applied force yet enable the equipment to be man-handled. Specifically two MVE 900/075 external vibrators were selected, each weighing 71kg with an eccentric torque or working moment of 187kgcm, each delivering a maximum centrifugal force of 589kg each (over 10kN total). Maximum run speed is 750rpm for 50Hz input, or 12.5Hz. The drive motors are rated at 650W, drawing about 2 Amps per phase. Each REV (rotary electric vibrator) could be lifted by two people with difficulty with the eccentric masses fitted, and relatively easily without. A variable speed drive was fitted to enable the frequency to be increased periodically from start to maximum speed. The centrifugal force is calculated as shown in Table 2 below.

The installation on site is shown in Table 3. The work was coordinated with Baulderstone (now Lend Lease), with a template for the machine mounting holes provided, the locations for each test scanned to identify reinforcement or embedded services, and holes pre-drilled. Boa-Bolts were used to anchor the REVs given their capacity with limited embedment and ease of removal with limited surface damage.

After the shakers were fixed to the floor directly above the isolators, the test method involved running the shakers from 5Hz to 12Hz through the resonance of the floor/isolator system. As shown in Table 3, the force increases exponentially with run speed, hence the measured response (by an accelerometer mounted between the shakers) was normalised by the force providing a measure of the mobility (velocity relative to force).

Table 2 Definition of imposed load by rotary vibrators (eccentric mass)

Formulae for circular vibrations eccentric torque

= Po x ro

Po = eccentric weight (kg)

ro = rotation radius = distance between centre of gravity and rotation axis (cm)

Mo = eccentric torque (kg x cm)

Centrifugal force

$$Fc = \frac{Mo}{100} \times \left(\frac{2\pi n}{60}\right)^2$$

n = frequency (r.p.m.)

Fc = centrifugal force (N)

Working moment

Mt = 2 x Mo

Mt = working moment (kg x cm)

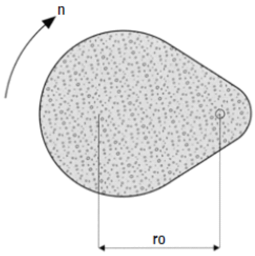
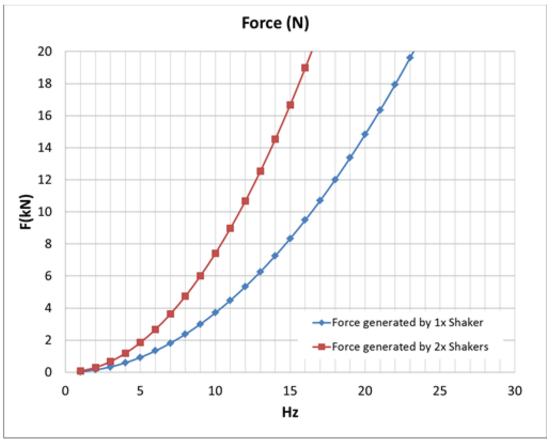


Table 3 Site installation and Force Generated



4. ASSESSMENT

The results are shown below for two types (sizes) of bearings, type C (nominally 480mm diameter x 157mm height) and D (nominally 400mm diameter x 119mm height). The response for Type C bearings is more significant than those for type D, with the weight of the raised floors and operable walls resting on the slab resulting in significant damping of vibration, reducing the isolation performance. Notwithstanding this, the dominant frequency is between 10-13Hz, with a secondary peak at about 7-9Hz. This is consistent with the results expected given the bearings original performance and the dynamic characteristics of the floor structure.

Despite an extensive search of records from previous suppliers, the original test data for the bearings were not found, hence determination of the life of the bearings was made primarily by visual inspection and isolation performance relative to design criteria for structure borne sound and perceptible vibration from train movements in the rail corridor below.

During demolition of the plaza slab, it is intended that bearings to be replaced as a result of inadequate capacity to withstand increased loads, will be tested in a laboratory to confirm their performance and life expectancy.

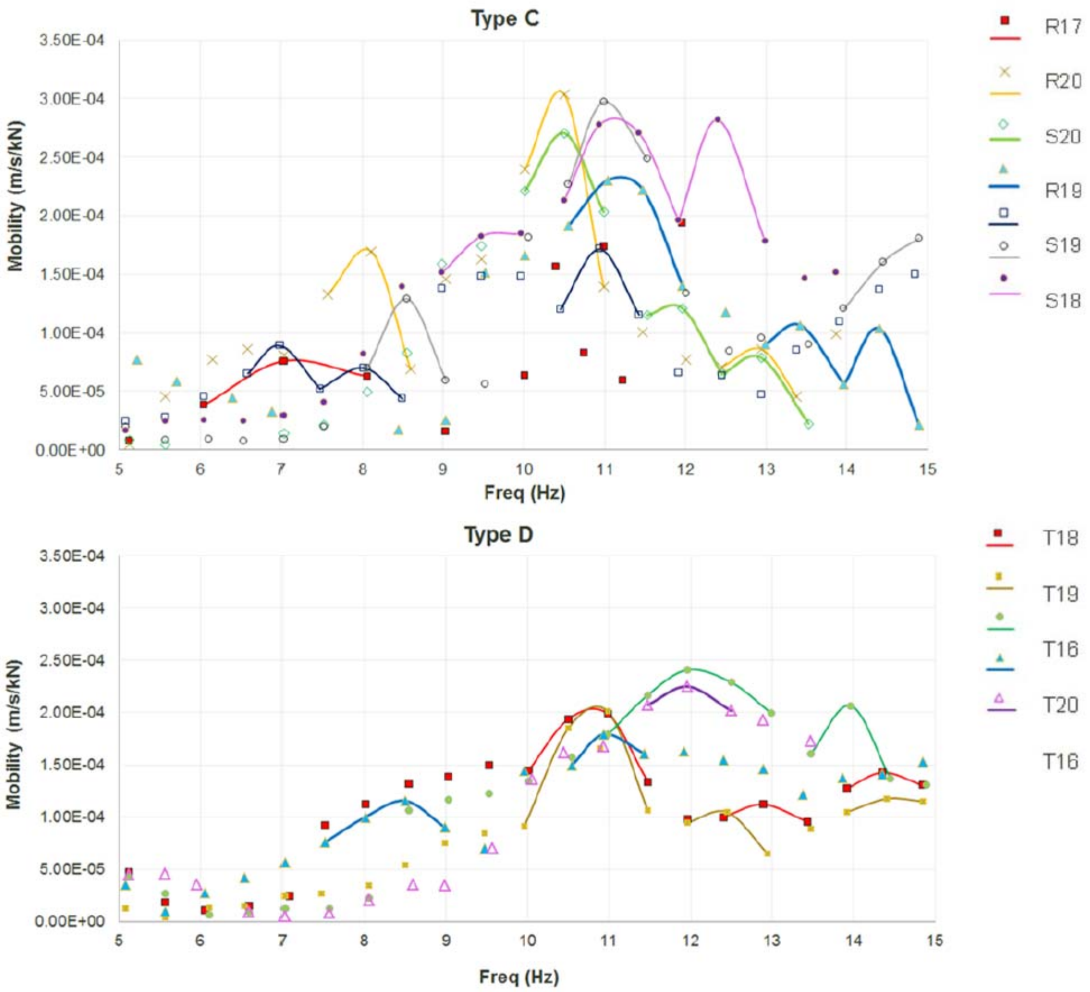


Figure 7 Mobility measurements carried out in-situ.

5. CONCLUSIONS

A low cost method of measuring the mobility of a structure supported on building isolators has been demonstrated, with the ability to determine the potential life of the building isolator based on an assessment of isolator performance over time. Measurements revealed the combined dynamic response of the bearings and floor structure comply with the expected response given assumptions regarding the original dynamic characteristics of the bearings. The response of the structure was well damped potentially resulting in a reduced performance than that presumably originally expected. Ideally imposed loads from operable floors and walls should be located on the static floor which should ideally have an isolation joint separating it from the floating floor. Final confirmation of the bearing performance will be obtained by laboratory tests on bearings to be removed and replaced due to increased loads.

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