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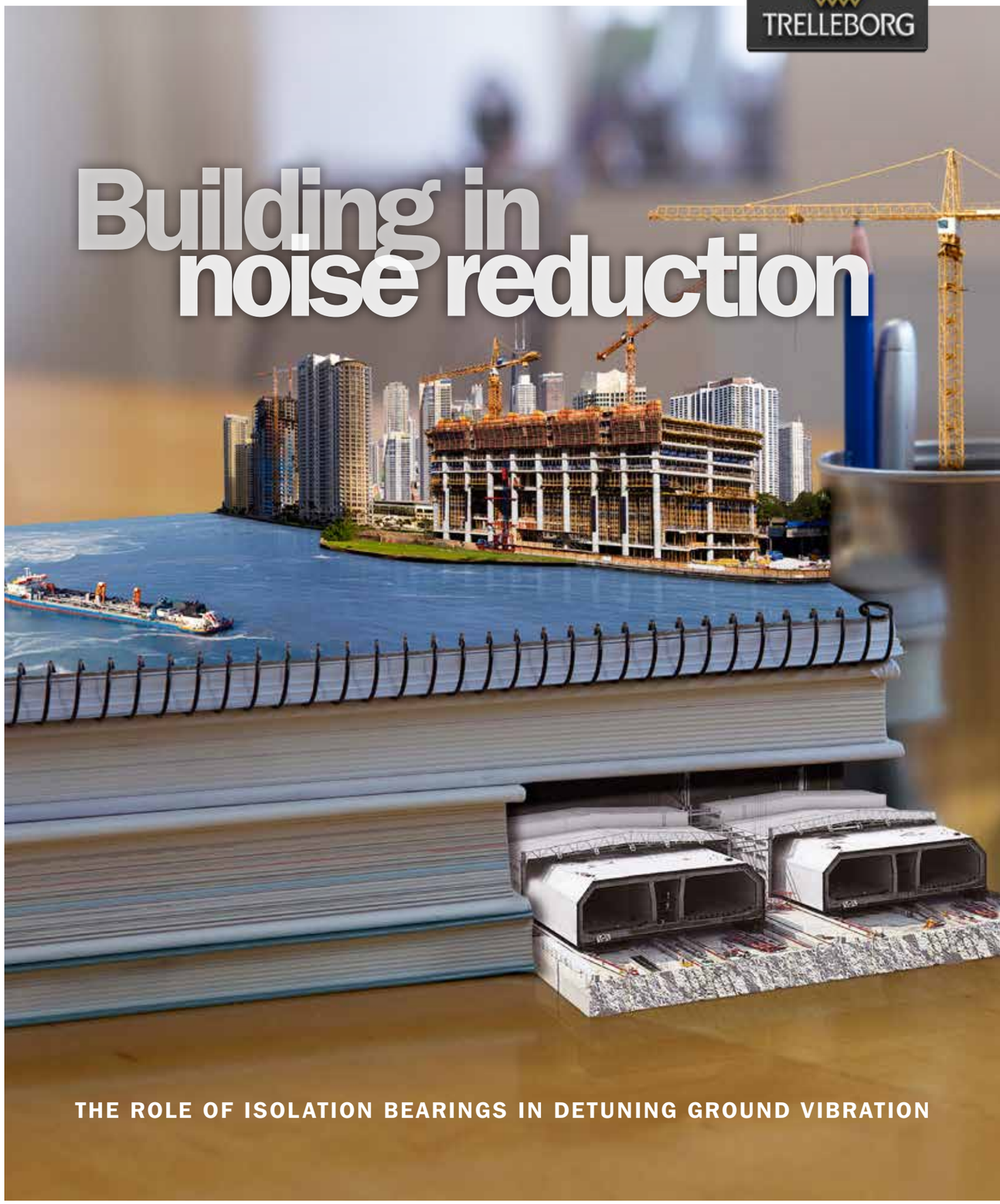
Building in noise reduction



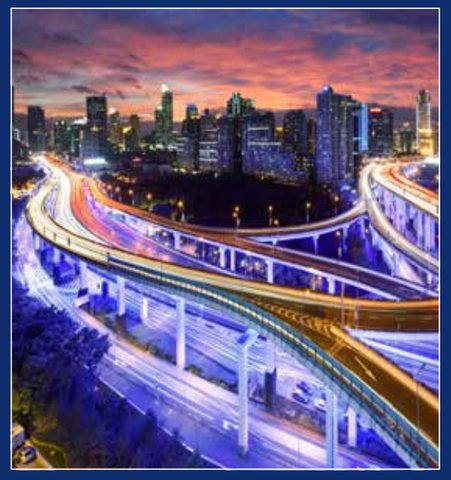
THE ROLE OF ISOLATION BEARINGS IN DETUNING GROUND VIBRATION

Introduction

Dense urbanization and increasing transportation needs of people and goods are resulting in a growing need for noise and vibration isolation strategies in buildings. In addition, more demanding requirements for prestige and premium priced buildings are driving the need for higher performance specifications. This is becoming increasingly important, not only for specialist buildings such as concert venues, but for commercial and residential buildings too.

Noise and vibration isolation bearings installed within the base and body of a building are a key way to dramatically reduce the effects of ground vibration. This is a primary cause of noise in buildings. However, the industry is currently lacking in specification guidance for these products, as the British Standard (BS 6177:1982) was withdrawn in August 2013. As a result, there is now an absence of regulations in this area.

In order to meet the market's needs in these times of development, it falls to the industry to ensure quality standards are met defining exact specification details so that only the highest performance bearings are used. In order to do this, awareness of the engineering parameters involved needs to be raised. One such parameter which isn't properly considered within the bearing designs is the rate of deflection, which can be significantly affected by the varying weight distribution of a building, impacting on the bearing's performance.



In this whitepaper, Trelleborg will detail the aspects of a bearing's specification which must be considered, in order to ensure optimum performance and safeguard the integrity of buildings.

Developments in our infrastructure

As urbanization and resulting infrastructure continue to grow – especially in built-up, major cities – the development of roads, railways and bridges for example, is bringing more complex environments to build in. Not just in terms of space, access or proximity, but also in the effects this growth has on the behavior of our buildings. Specifically, the vibration caused from traffic and railways, which transfers directly through a building's structure, causing noise discomfort throughout.

Therefore, building designs have to incorporate strategies which meet the change in demands from the environment; isolation bearings are one example of this.

The vibration that passes through the ground and into a building is called a forcing frequency and this vibration will take advantage of any surface, be it a wall or a cupboard, effectively turning it into a speaker to amplify sound. There are specified acceptable levels of disturbance dependant on the function of the building, to ensure that occupant comfort is unaffected and machinery or apparatus works as it should.

So just as insulation or thicker glazed windows might be installed to block out external noises, it is equally as important to install quality bearings at the base and throughout the building, to manage noise transmitted through the ground.

Especially in increasingly popular multi-use buildings, the requirement for vibration isolation strategies is not only increasing, but becoming more complex too. Sophisticated living quarters that sit upon office space or retail outlets, are being sold across major cities at premiums prices. So it is imperative that concerns such as vibration induced noise are negated. Especially stringent specifications for vibration isolation are often required for buildings such as concert halls, theatres and recording studios.

There are many types of vibration isolation bearing, which are built to different specification requirements. Unfortunately, there are also products on the market which are not meeting simple and important performance ideals.

The importance of guidance

The industry was able to take guidance from BS 6177:1982 – albeit that the standard was actually over 30 years old – until it was withdrawn last year. The regulation, titled 'Guide to selection and use of elastomeric bearings for vibration isolation of buildings' included design considerations, acceptable levels of disturbance, type of bearings and testing and identification of bearings. One factor which it covered, though not in prescriptive detail, was the deflection of bearings.

The guidance stated that bearings are often installed at an early stage of construction and deflect progressively as the weight of the structure comes on to them gradually. The overall static deflection of a bearing is always significant (sometimes amounting to 20 mm or more) so it is important that the distribution of weight, both during and after construction, be understood appropriately and due allowance made for changes in the relative levels of any adjacent un-mounted parts of the structure.

Where individual bearings or mounting systems are incorporated at significantly different levels, precautions should be taken to ensure that loading is imposed on both the bearings and the structure in a manner that does not introduce unacceptable stresses.

Allowance should also be made for any additional deflections that may occur due to creep or as a result of wind loading during the life of a bearing. Expansion joints and other building discontinuities require special attention. Pipes and other services that bridge from mounted to un-mounted parts of a building should be capable of accommodating the movements in question and should also be so designed as not to transmit undue vibration.

However, the British Standard failed to go into detail about controlling the bearings' deflection under the weight of the building, leaving the industry to decipher it for themselves. Sometimes with consequences.

Bearing specification and calculations

All buildings and structures are subjected to ground vibration, or forcing frequencies, which cannot be stopped, but can be manipulated. The amount of vibration coming into a building can be controlled but a full understanding of the right processes is required to do this efficiently.

Firstly, an acoustic consultant will assess the site where the building is to be constructed to establish the ground's vibration charateristics and identify if the proposed building would benefit from being constructed on vibration isolation bearings.

The acoustic consultant will specify the bearings' performance in one of two ways. Either by the maximum natural frequency of the bearing (in Hz), or by specifying the level of vibration attenuation / reduction in vibration amplitude (in dB) that's required above a minimum disturbing frequency.

The bearing manufacturer must use this information to ensure that the bearings are designed to meet the specification requirements, to sucessfully reduce the vibration transmission to an acceptable level.

The bearings must confer a natural frequency to the building which is considerably less than the lowest dominant disturburbing frequency.

Fig 1. Transmissibility response plot for Trelleborg's isolation bearings

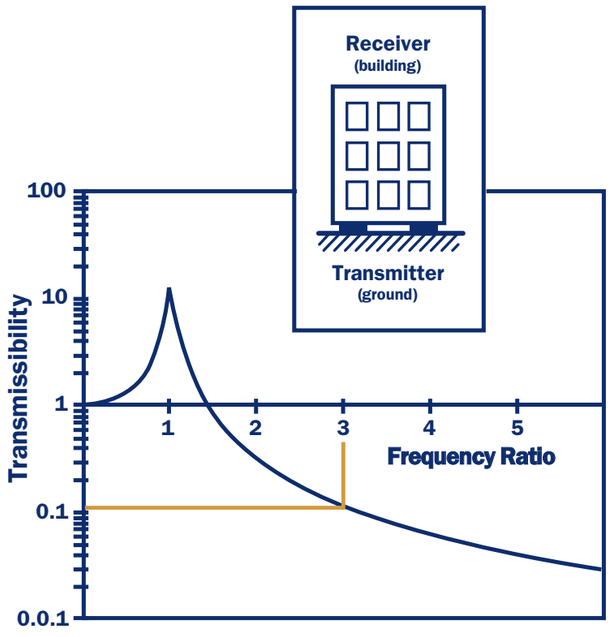
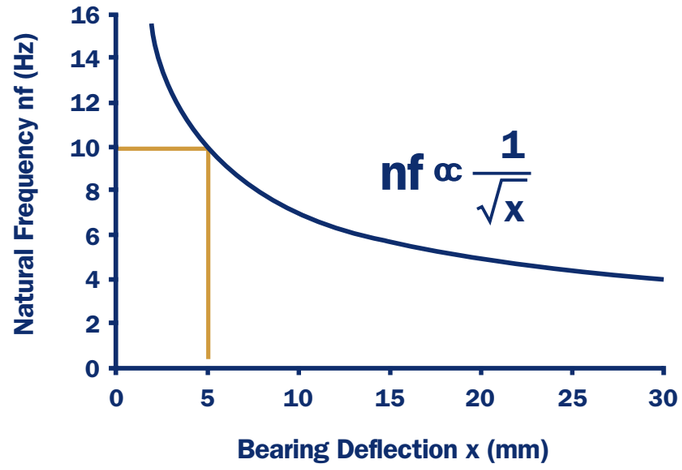


Figure 1 illustrates the transmissibility response of Trelleborg's bearings and their vibration isolation performance. The vertical axis is the ratio of the vibration amplitude received by the building to the vibration amplitude transmitted by the ground. The horizontal axis is the ratio of the ground vibration frequency to the building's natural frequency and is called the frequency ratio.

The example in Figure 1 shows that a frequency ratio of 3 results in a transmissibility of about 0.1. If we consider that the ground has a lowest dominant vibration of 30 Hz a bearing having a natural frequency of 10 Hz will reduce the amplitude of the vibration passing through to the building by 90%.

To achieve the desired natural frequency we must control the bearing deflection, which is the distance by which the bearing is compressed under the weight of the building. Figure 2 shows how the bearing's deflection influences its natural frequency.

Fig 2. Natural frequency versus bearing deflection



In the example below where we are seeking to achieve a natural frequency of 10 Hz, the bearing must deflect by about 5 mm.

We carefully control the deflection by specifying precisely the mass supported by the bearing (determined from the building's weight distribution) and the bearing's spring stiffness.

With this approach to bearing design we ensure that all bearings, irrespective of their acoustic design load, deflect equally thus not causing unnecessary stress to the building's structure.

It is essential to test each bearing to verify its stiffness characteristics and structural integrity, as once it has been installed, it cannot easily be replaced or rectified.

Raising the standards

Once the performance requirements and desired deflection values for the bearings have been established, the bearing design can be tweaked to suit. A rubber bearing, which is designed with steel shim plates inserted within it, will give it structure and strength. Specifically, one to nine layers of steel increases compression stiffness by 49 times. The shear stiffness remains the same. This design allows the manufacturer to tune the block of rubber and influence its behavior, so that the performance can be predicted and the calculations met.

It is only as a result of these processes and techniques, that an isolation bearing will respond the way it is required to when in-situ. And it is this sophistication that enables experienced manufacturers to provide rubber bearings which perform to an optimum and competitive level, every time.

Conclusion

Our environment will continue to evolve and develop. Couple that with more stringent regulations in the construction industry and building designs will have to become even more sophisticated. The nature of our infrastructure is that it is built to last, so we simply cannot allow substandard products and techniques to take hold.

In the instance of vibration isolation bearings, the issue of ground vibrations certainly won't disappear. And given that an installed bearing is extremely difficult to refurbish or replace, it is vital that the industry gets this right first time.

The specification of bearings should not be feared, as the scientific principles are simple enough. A reinstated, valuable guidance which details this, will guarantee best practice amongst manufacturers and assurance for architects, contractors and building owners.