Advances in Engineering Software 72 (2014) 128–133

Contents lists available at SciVerse ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

Dynamic structure response excited by technical seismicity effects

Daniel Makovička [a,*], Daniel Makovička Jr. [b]

[a] Czech Technical University in Prague, Klokner Institute, Šolínova 7, 166 08 Prague 6, Czech Republic
[b] Static and Dynamic Consulting, Šultysova 170, 284 01 Kutná Hora, Czech Republic

ARTICLE INFO

Article history:
Available online 31 May 2013

Keywords:
Building
Dynamic excitation
Transport
Vibro-isolation
Response
Calculation

ABSTRACT

The subject of the solution consists in the design and evaluation of vibro-isolation of the multifunctional reinforced concrete frame structure of a building over the tunnel metro structure, based on analysing its 3D calculation model. Measured vibrations in accelerations from passing metro trains were used as non-periodic excitation of the object on the level of its foundation slab. Results of the dynamic calculation are used to document the nature of the building structure response, and of the reduction/amplification of the vibrations at selected points of individual storeys during the pass of metro trains, including the frequency characteristics of the response. The comparison of the building response without and with vibro-isolation is used to demonstrate the efficiency of using a rubber layer in the footing bottom for reducing the transfer of vibrations from the metro to the building. Measurement of the vibrations when the construction had been finished allowed to compare the vibration prognosis to vibrations actually measured in the finished structure.

1. Introduction

Currently, plots of land are being built up in large cities under which or in whose vicinity metro or railway lines are found. Vibrations that occur when the trains pass propagate as a technical seismicity through the subsoil in the surrounding structures. The nature of these vibrations that load the building structure depends particularly on the mass of the vehicle, driving speed and character of its passage, and on the direction of its movement. The "planarity" of the running track is another parameter, thus equalization of the tracks in terms of direction and height, way in which the rails are fastened, track crossings, composition of base layers, etc. Besides vibration parameters at the source, the magnitude of the vibrations is affected by composition of the environment along the path of the vibrations from the source to the building structure at risk, thus especially the composition of the geological environment and its mechanical properties, namely stiffness, velocity of the wave motion propagation, damping with distance, etc. Finally, the magnitude of vibrations from the subsoil may be amplified or reduced by the building structure itself, by its composition, materials, mass and method of foundation. Sensitivity of the structure to any amplification of vibrations from the subsoil can be evaluated based on the spectrum of its natural frequencies and modes of vibration.

As a rule, vibrations due to traffic do not limit the structure safety of new, properly reinforced structures, and they usually do not lead to the formation of cracks in building structures. A more serious problem is caused by action of the vibrations on persons within such structures. As a rule, vibrations of this type usually exceed safety limits given by hygiene standards much sooner before the structure is damaged by formation of cracks.

Vibro-base isolation is an effective method for reducing the vibration level of the protected structure as a whole with reference to its foundation types (plate, piles, strips, etc.) [1–4]. Base isolation is one of the most powerful passive structural vibration control technologies in earthquake engineering. It is meant to enable a building or some other structure to survive a potentially devastating seismic (or in our case technical seismic) impact through suitable initial design or subsequent modifications. In some cases, the application of base isolation can considerably raise both the seismic performance and the lifetime of a structure. The base isolation system consists of isolation units or isolation layers, where:

(a) Isolation block units are the basic elements of the base isolation system which are intended to provide the decoupling effect for a building or a non-building structure [2,3].
(b) Isolation slab units are plate elements from which the isolation layer is composed [4,5].

The example of a new building structure over a metro tunnel structure is used to analyse the nature of its dynamic response if this building is loaded by vibrations on the foundation base level, and to compare the response of this structure without and with

* Corresponding author.
E-mail addresses: daniel.makovicka@klok.cvut.cz (D. Makovička), d.makovicka@makovicka.cz (D. Makovička Jr.).

0965-9978/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.advengsoft.2013.05.003

vibro-base isolation, and finally to evaluate the efficiency of vibro-isolation based on comparison of vibration measurement before, during and after the building construction.

The measuring set of the firm BMC Messsysteme GmbH was used for vibration measurement in acceleration. The time histories were measured by measuring device, including the acceleration sensors, amplification set on the digital basis and data recording and processing by software NextView.

2. Calculation model of the structure

The calculation model respects with the highest accuracy the geometric design of the structure including the dimensions, mass and stiffness of individual structure elements. The building is designed as a monolithic reinforced concrete structure and has three storeys under ground and five aboveground storeys. Two underground storeys are partially visible in the front facade, due to the steep land, thus seeming to be above the ground. The object itself has in the longitudinal direction the broken form (Fig. 1) and is composed of three parts mutually rotated in modular axes by 30° and 45°. The building has different heights (an open letter U; 30.0 + 30.0 + 36.0 m and width of 18.0 m on average; the basement floors are extended over the ground plan of the part above the ground). The arrangement and structure type of the object are adapted to the purpose of the building, i.e. the storeys above the ground are designed for flats and underground storeys for commercial purposes, for technical facilities and parking.

The building is spatially reinforced using three internal staircase cores with elevator wells. On underground storeys, the underground part of structure is circumscribed by using of peripheral reinforced concrete walls, and aboveground part of structure by using of the aluminium circumferential cover, partially glassed. The structure is founded on the base slab and is situated directly above the metro tube, on a protective layer of fills in the thickness of 15.5 m. Metro passes under the building in its central part.

Vibro-base isolation has been designed under the whole ground plan of the object. The foundation structure is designed as a multi-layer sandwich, consisting from upper and lower parts of RC slabs and intermediate elastic layer composed of extruded rubber plates. The rubber plate elements have dimensions of 500 × 500 mm and 50 mm in thickness.

Underground storeys are protected from the sides up to the terrain level using rubber in the thickness of 33 mm on vertical faces and above the ceiling of underground garages that exceed the ground plan of the aboveground part of the building to its sides. The rubber layers are protected by hydro-isolation and protective geotextile on both sides, which prevent the rubber layer from flowing of the water or concrete-milk between the rubber elements, and also provide protection against their mechanical damage. The stiffness of the rubber plate elements were determined by laboratory tests of samples of actual dimensions of the same dimensions as those inserted in the structure. The rubber of selected stiffness classes was distributed in the foundation structure in accordance with its static pre-load given by the structure dead load itself and 50% of live load. The static compression responds to the 10% of the rubber layer height. The rubber distribution on the foundation level is shown in Fig. 2.

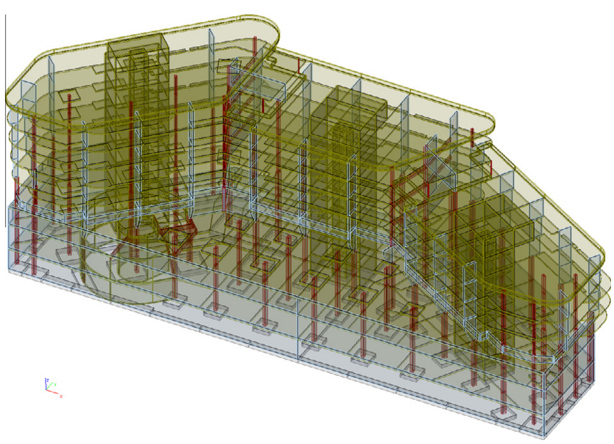

Fig. 1. Calculation model, South-West transparent view.

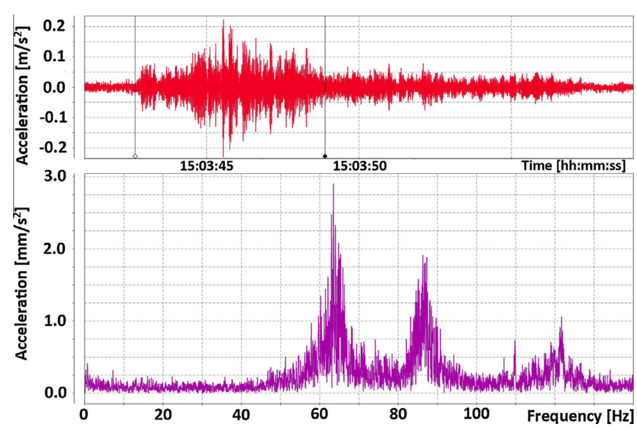

Fig. 3. Structure excitation in vertical direction, the whole record in acceleration and FFT spectrum.

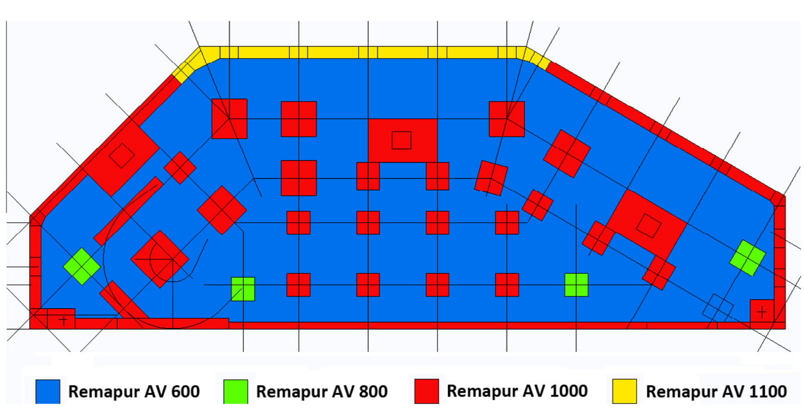

Fig. 2. Distribution of rubber layer on the bottom of foundation plate.