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Numerical models for the evaluation of natural vibration frequencies of thermo-modernized building walls

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ABSTRACT: As a result of the necessity to improve energy properties of prefabricated buildings, their thermo-modernizations are performed. In the paper various approaches to the modelling of prefabricated load bearing walls before and after thermo-modernization are presented. Simple one layer models with extra mass from ceilings and equivalent stiffness as well as multilayer ones are taken into consideration using the finite element method software. Values of the natural frequencies of the wall horizontal vibrations calculated using the various models, are compared. It was proved that even the very simple model with equivalent stiffness allows to compute natural vibration frequencies of wall with acceptable accuracy for engineering practice.

KEYWORDS: numerical models, thermo-modernized walls, natural vibration frequencies, finite element method

1. Introduction

The group of typical prefabricated buildings (an example is shown in Fig. 1) is very huge among apartment buildings in Poland. They were built in 50's, 60's and 70's of 20th century. Nowadays, because of the new environmental regulations as well as the expectations of current lodgers, they are modernized. Mainly, modernization deals with heat insulation.

This kind of modification brings additional mass to the building, changes its stiffness and, as the result, the dynamic properties of the structure could be changed. Changes in the natural frequencies of vibrations are the most important among them – calculations of these values are necessary especially in the case of objects subjected to paraseismic or seismic excitations [1].

In the paper values of natural vibration frequencies of prefabricated walls before and after thermo-modernization are computed using various approaches to the wall modelling.

Fig. 1. Typical high-rise prefabricated apartment building

2. Analysed wall

Typical high reinforced concrete load bearing wall of WWP prefabricated system [2] (marked in Fig. 1) was considered –10.8m width and 29.7m (11 storeys x 2.7m) height. Each of the prefabricated wall panels have 3 layers: load bearing, thermal insulation and elevation. Extra thermo-modernization part consists of reinforced mortar, styrofoam and glass fibre textile mesh [3].

Wall's layers as well as their thickness are presented in Fig. 2 and Table 1.

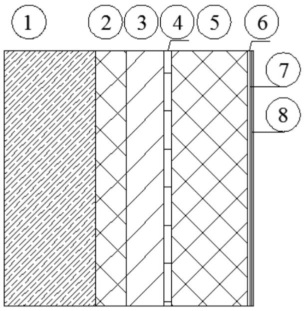

Fig. 2. Layers of the analysed wall

Table 1. Wall layers and their thickness

Layer	Material	Thickness [cm]
1	reinforced concrete	12
2	styrofoam	4
3	concrete	5
4	reinforced mortar	1
5	styrofoam	10
6	reinforced mortar	0.2
7	glass fibre textile mesh	0.1
8	reinforced mortar	0.2

3. Numerical models

Five numerical models have been proposed. The first three models (A, B, C) relate to the wall before thermo-modernization and the two next (D, E) – the wall after insulation.

In model A thickness of the whole wall was reduced to the thickness of load-bearing layer (12cm). Stiffnesses of styrofoam and elevation layer have not been taken into account. However, additional mass from these parts has been included.

In model B thickness of the wall is the same as thickness of prefabricated panel (21cm), but the equivalent (substitute) Young modulus and equivalent (substitute) Poisson's ratio were prepared with the consideration mechanical properties of all of the layers. Equations (1) and (2) were applied for this purpose:

$$E_{eqv} = \frac{\sum_i E_i \cdot d_i}{\sum_i d_i} \qquad (1)$$

$$\nu_{eqv} = \frac{\sum_i \nu_i \cdot d_i}{\sum_i d_i} \qquad (2)$$

where: E_{eqv} , ν_{eqv} – equivalent Young modulus and Poisson's ratio for whole model, E_i , ν_i – Young modulus and Poisson's ratio for particular, subsequent layers and d_i – thickness of the layer.

All actual layers with their real Young modulus and Poisson's ratio were taken into account in model C. So it is the most accurate model of prefabricated wall panel.

Model D was created in the same way as B – all the eight layers were reduced to one layer with parameters obtained using Equations (1) and (2).

Model E is an analogous version to C model, but including all the eight layers.

In each of models three variants of additional mass from cooperating ceilings were also considered (I – no extra mass, II – from the strip 1m, III – from the strip 2.7m).

Numerical calculations were carried out in Finite Element Method System Ansys [4] using 8-node multi-layer structural shell element SHELL281 [4]. All materials were modelled as isotropic and linear elastic. Their parameters are summarized in Table 2.

Table 2. Material parameters [5, 6]

Material	E [GPa]	ν [-]	ρ [kg/m^3]
concrete	20	0.2	2500
styrofoam	0.003	0.07	13
reinforced mortar	20	0.2	2000
glass fibre textile mesh	66	0.23	2550

4. Results

To illustrate the results obtained using the proposed various models, the first and the second natural horizontal vibration frequencies (f_1, f_2) of the modelled building wall were compared. As an example, natural horizontal vibration modes of model C are presented in Fig. 3.

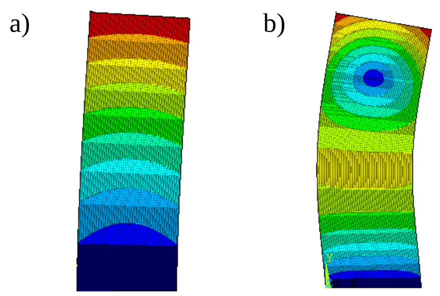

Fig. 3. Model C – natural horizontal vibration modes related to: a) f_1, b) f_2

In Fig. 4 the comparison of the influence of A, B, C load bearing wall modeling (without additional thermal insulation) on f_1 is shown. The similar relations in plots regarding the case of f_2 were obtained. It is visible that taking into account stiffness of all three layers results in an increase of values of the analysed vibration frequencies f_1, f_2. Additionally, the difference between the results obtained with using the simple model B and the multilayered C is negligible.

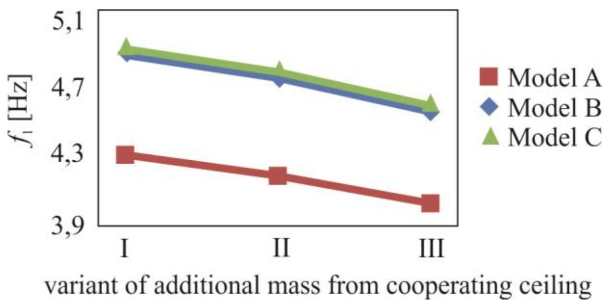

Fig. 4. Comparison of the influence of load bearing wall modeling on the f_1

Furthermore, looking at Fig. 5 it is visible that the thermo-modernization of building walls (mass and stiffness of thermal insulation layers addition) causes changes of the values of wall natural vibration frequencies.

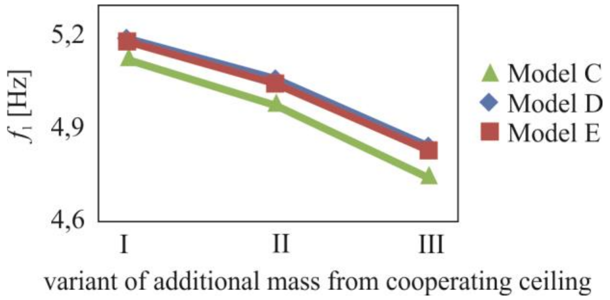

Fig. 5. Comparison of f_1 values for models of wall with and without thermo-modernization

5. Conclusions

In the paper various approaches to the modelling of prefabricated load bearing walls before and after thermo-modernization were presented.

The numerical results show that:

1) thermo-modernization can change values of natural horizontal vibration frequencies of prefabricated walls,
2) application of the simple model reducing multilayer panel to one layer panel with equivalent Young modulus and Poisson's ratio allows to receive results with good accuracy,
3) then the reduction of a numerical effort is possible, which is especially important in the cases of large structure models.

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