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Anchorages bonded system in experimental research and their comparison with FEM models

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ABSTRACT

Purpose: The topic of this article is the use of anchors bonded in the outer walls of three-layer large slab panel buildings in Poland.

Design/methodology/approach: Comprehensive laboratory tests of anchoring systems bonded in various configurations were carried out. On this basis, the theoretical load capacity of the new bonded anchorages can be estimated.

Findings: These considerations are the aftermath of the current problem of the former large slab panel buildings in Poland, and more specifically the risk of detachment of the external textured layer in the walls of three-layer large slab panel buildings.

Research limitations/implications: The presented variants of experimental research and their comparison with the MES analysis indicate the directions of conduct in strengthening three-layer walls. It should be remembered that the use of additional reinforcement anchorages is practically a necessity, as the next stage of renewing large slab panel buildings is their thermo-modernization.

Practical implications: This process results in an increase of the load on the external textured layer, and hence also on hangers.

Originality/value: Experimental research is aimed at determining the optimal variant of application of bonded anchors.

Keywords: Buildings, Three-layer walls, Thermo-modernization, Connecting element, Layer

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ANALYSIS AND MODELLING

1. Introduction

The problems of large panel slab buildings in Poland grow with the passage of time. This article discusses the problem of external textured layers in three-layer walls. The risk of detaching the façade of the textured layer, despite different diameters of hangers (8-14 mm), is in any case large. Systems of oblique anchors were proposed at 30°, 45° and 60° angles in single sets and in double systems in cooperation with an anchor perpendicular to the concrete surface.

2. Existing hangers in large slab panel buildings

During the production of three-layer panels in subsequent years, the shape of hangers underwent changes [1]. Checking the load capacity of hangers and pins contains a publication [2]. Stainless steel had a smaller diameter than the ITB guidelines or instructions, Ø6 and Ø8 mm, respectively. However, when using standard steel, diameters Ø12 and Ø14 mm were used. These rods, due to the quality of steel, had to be protected with a zinc protective coating made of aluminium using the "Azulan", asphalt-cement or latex-cement method [3,4,12]. The most common shapes of hangers are presented in Figures 1-4. However, Table 1 lists the steel grades from which the hangers were made.

Table 1.
Steel grades from which hangers were made [1]

Steel grade	Tensile strength	Yield stress	Elongation at break
	MPa	MPa	%
H13N4G9	650	350	35
1H17N4G9	650	310	40
OH18N9	500	200	45

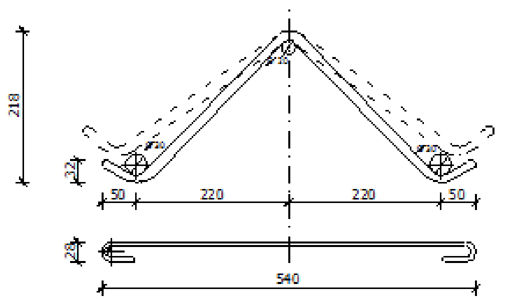


Fig. 1. Hanger type 2.05 used in gable walls in OWT-67 systems [1]

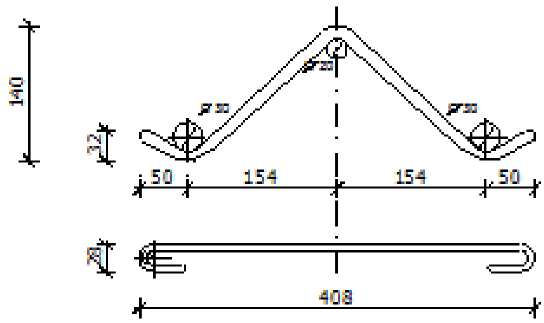


Fig. 2. Hanger type 2.06 used in load-bearing walls in OWT-67 systems [1]

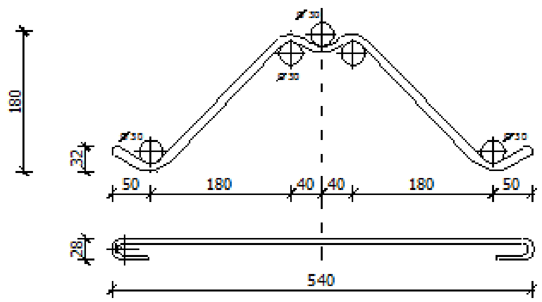


Fig. 3. Hanger type 2.16 used in load-bearing walls in OWT-75 systems [1]

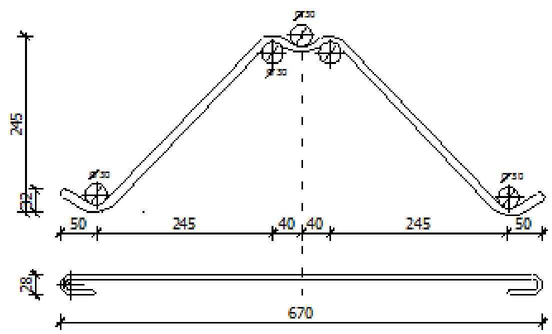


Fig. 4. Hanger type 2.17 used in gable walls in OWT-75 systems [1]

3. Proposed variants of the use of new bonded anchors

Selected variants of anchors were designed based on the observation of the risk of loosening the external textured layer and estimated durability of connections [5,13]. Figure 5 shows schemes of solutions that were tested in experimental studies.

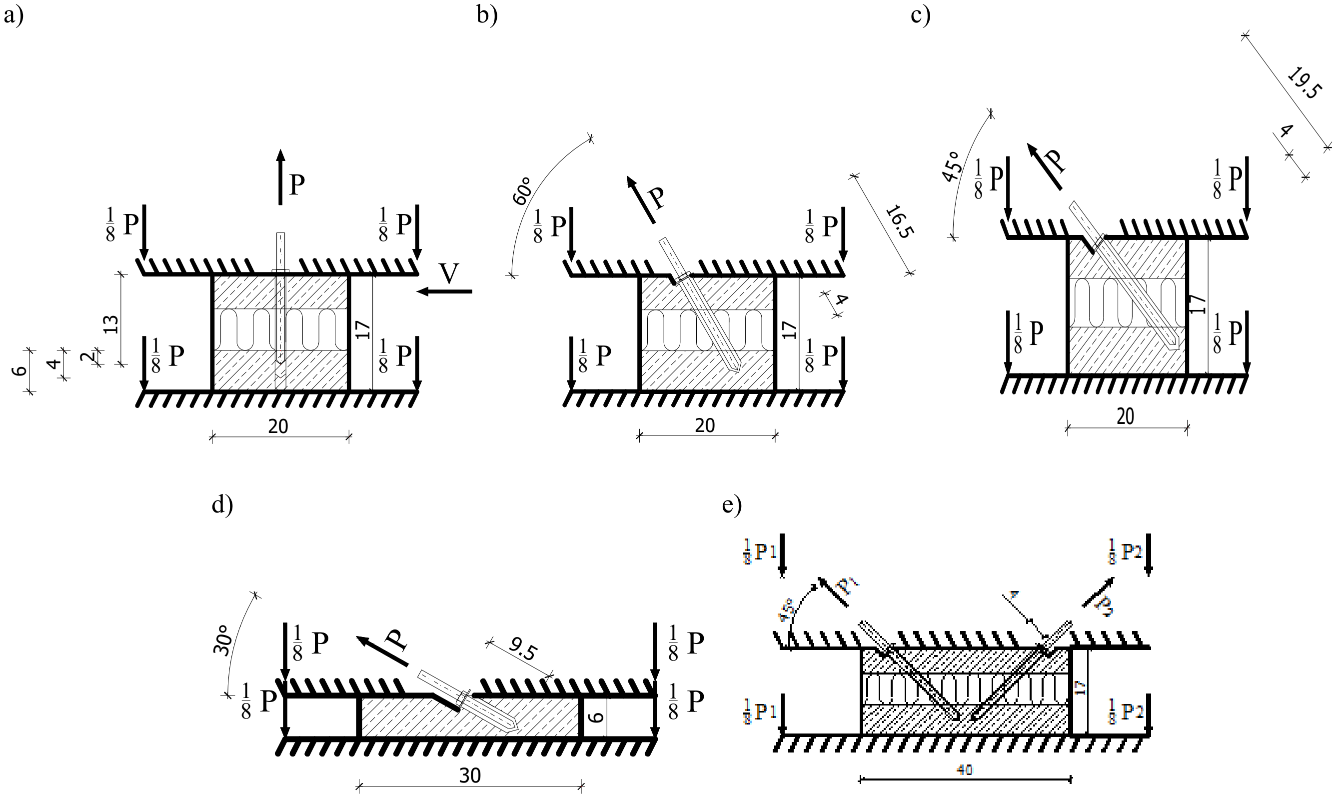


Fig. 5. Anchorage variants tested during experimental research: a) single anchor, mounted vertically, b) single anchor, mounted at an angle of 60 degrees, c) single anchor fixed at an angle of 45 degrees, d) single anchor fixed at an angle of 45 degrees, e) double anchor fixed at an angle of 45 degrees

The proposed variants were aimed at demonstrating the greater effectiveness of the use of diagonal anchorages in relation to the anchor perpendicular to the sample surface (Fig. 5a).

This article focuses on bonded anchors, composed of threaded anchors, the load capacity of which was also compared with the anchors corresponding to the surface shape of the existing hangers [6,11] and the impact of design and construction errors on damage to the used connections of other materials was eliminated [14].

4. Summary of experimental research and the results of FEM

The research was carried out in the hall of the Faculty of Civil and Environmental Engineering at the Bialystok University of Technology in Bialystok in Poland. They were made using the HYSDOZOK [7] hydraulic load system.

Figure 6 presents the programming of the experimental tests, which was carried out according to the following short description.

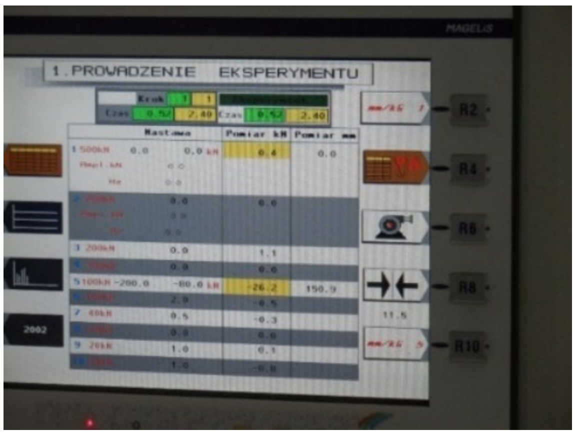


Fig. 6. Setting the parameters of the expected test run and planning the experiment

The maximum (limit) load of the tensile force with the upper range of 80 kN has been programmed with a stroke of 0.5 kN/s in accordance with the PN-EN 12504-3:2006 standard [8]. Figures 7 and 8 show the tests of intermediate anchors at an angle of 45°.

Additionally, in the case of a single anchorage, perpendicular to the specimen surface, and a double-anchor (Fig. 8), the effect of the sheer force of the textured top layer of 1.4 kN was taken into account.

Fig. 7. Test stand during the examination of a single anchor test at an angle of 45° [9,10]

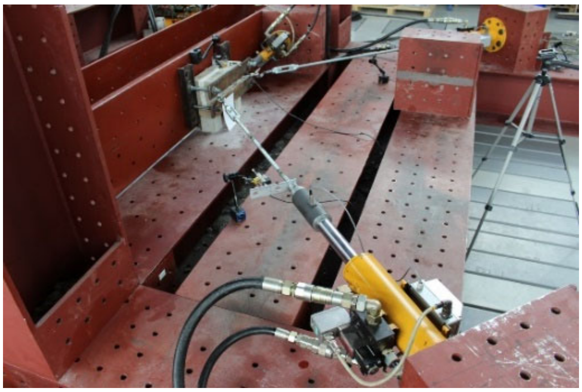
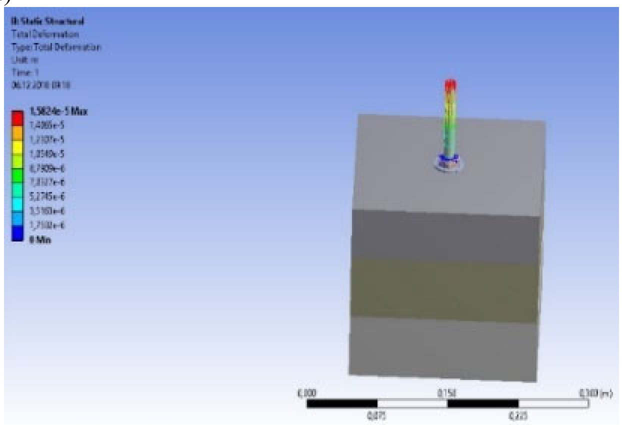


Fig. 8. Test stand during the examination of a double anchor at an angle of 45°

Figure 9 presents the model of the anchor bonded in the concrete solid element with a layer of thermal insulation in the middle with a clear propagation of stresses closer to the anchor tip (Fig. 9a) and a FEM mesh with thickened meshes in the zones of potential propagation of model failure, i.e. in the vicinity of the steel anchor (Fig. 9b).

a)



b)

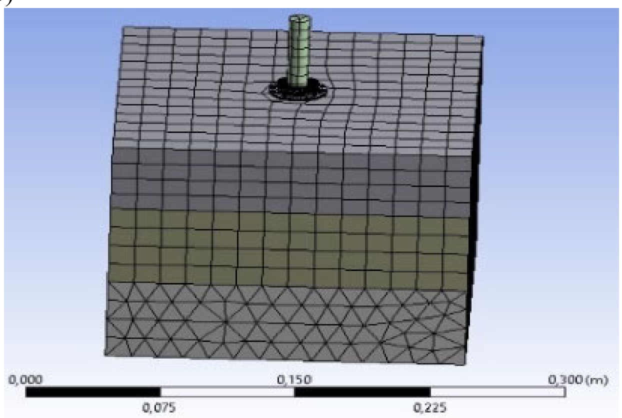


Fig. 9. Generation from the total deformation program and FEM model for a single anchorage at an angle of 90°

In Figure 10 presents the directional vectors of the destruction potentials in the modelled solid element (Fig. 10a) together with the discretization of the mesh, its compaction in concrete layers and the simple FEM mesh in the thermal insulation layer, i.e. in the so-called weak layer, where no adhesion stresses occur.

Figure 11 presents the vector directions of possible model destruction (Fig. 11a) and the FEM mesh for this model (Fig. 11b).

a) b)

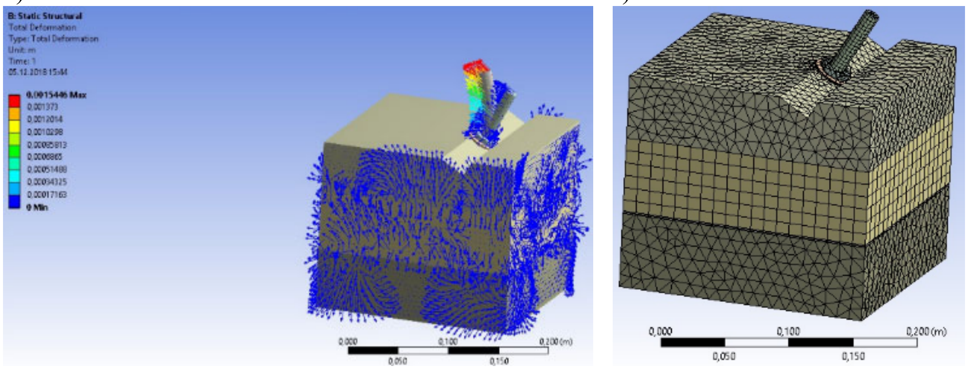


Fig. 10. Generation from the total deformation program and FEM model for a single anchorage at an angle of 60°

a) b)

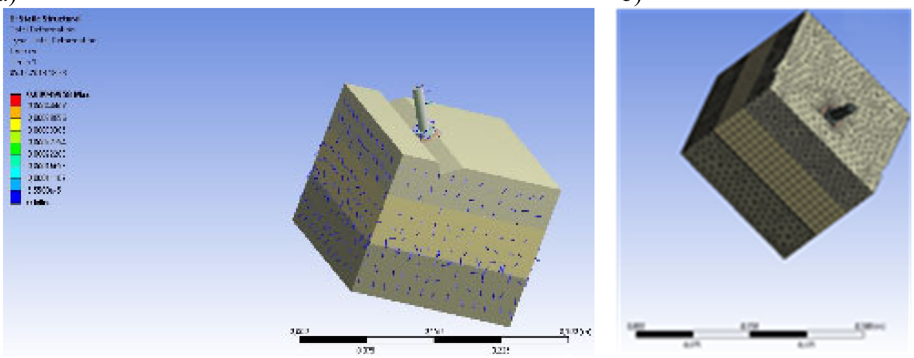


Fig. 11. Generation from the total deformation program and FEM model for a single anchorage at an angle of 45°

a) b)

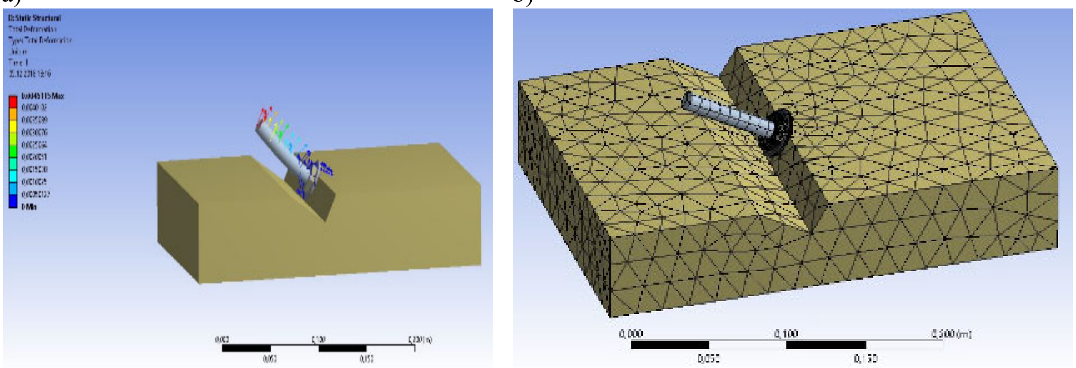


Fig. 12. Generation from the total deformation program and FEM model for a single anchorage at an angle of 30°

Figure 12 is a single-layer solid model due to the steep angle of the anchor. However, it corresponds to the adopted assumptions for the design of bonded anchorages, as the effective anchorage depth is precisely in the lower concrete (structural) layer.

Figure 13 presents the composite model in the form of two diagonal anchors. The numerical procedure is analogous to the previous models. Such tests will be helpful in calculating the load capacity of anchor groups in various systems and configurations with the possibility of adapting

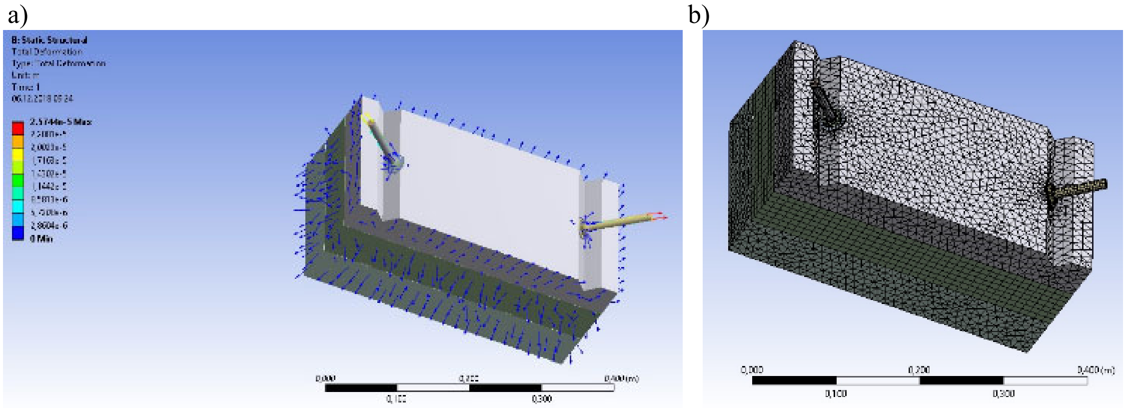


Fig. 13. Generation from the total deformation program and FEM model for double anchorage at an angle of 45°

Table 2.
Steel grades from which hangers were made

Type of sample	Experimental research	Ansys Workbench	Difference
	kN	kN	%
One anchor 90°	6.00	6.00	0
One anchor 60°	11.25	9.74	13.42
One anchor 45°	3.50	3.03	13.43
One anchor 30	10.60	9.18	13.40
Left anchor	5.90	4.17	29.32
Two anchor 45° Right anchor	7.90	5.59	29.24

to the thickness of vertical partitions and the technical possibilities of using a given anchor.

Experimental research was compared with the numerical analysis performed in the Ansys program, in the Ansys Workbench work environment and summarized in Table 2.

5. Conclusions

Work aimed at reinforcing, and hence increasing the durability of attaching the façade of the textured layer in external three-layer walls in large panel slab buildings in Poland is a necessity. The conducted research shows the possibility of using anchors bonded in different systems and adjusting them depending on the thickness of the wall. The results of the conducted research drew attention to the reproducibility of the results.

Differences between experimental studies and FEM calculations are at the level of 13%, which is not a big difference. One should also pay attention to the results of the two anchor test in which the difference doubled to about 29%.

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