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3. EXPERIMENTAL PROGRAM AND ANALYTICAL ANALYSIS

Based on the extensive literature review, an experimental test program was established, aiming to identify the mechanical properties of masonry and its components. Based on the obtained results, the effects of variable wall geometry and precompression level were considered on the performance of the unreinforced and jacketed masonry walls, tested in real scale and subjected to alternating cyclic in-plane forces. The analytical models for reinforced masonry were used to investigate the capacity of the jacketed masonry due to the similarity of both structural materials and the similar behaviour when exposed to horizontal actions. The effectiveness of the strengthening method was verified experimentally and an increase in the seismic resistance of the strengthened masonry walls was obtained when compared to the resistance of the reference unreinforced walls. However, the ductility performance was not improved.

An analytical model for evaluation of RC jacketed masonry walls was proposed, based on the contribution of the masonry and the horizontal reinforcement. The contribution of the vertical reinforcement to the resistance of the walls was ignored, because the tests were performed without anchorage of the vertical reinforcement in the top and bottom beams. This approach was used in order to study the behaviour of the strengthening structural material, rather than to investigate the behaviour of a strengthened structural element - wall. Based on the obtained results, the proposed method for evaluation of the seismic performance of jacketed masonry walls was used to study the strengthening effects on an existing building.

4. NUMERICAL ANALYSIS

The elasto-plastic force-deformation relations for unreinforced and strengthened masonry walls, based on the experimental results, were implemented in a displacement-based analysis software, through a newly developed analysis module. The capacity spectrum method was applied to validate the efficiency of the strengthened material and to assess the seismic resistance of the building.

The research presented in the paper follows the concept of the new generation of design codes for masonry buildings. The obtained results enable application of the analytical approach for design of masonry buildings in cases of strengthened masonry buildings.

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Nonlinear stability analysis of the frame structures

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ABSTRACT. In this doctoral thesis the nonlinear stability analysis of frame structures is presented. Numerical analysis was performed by the finite element method. Stiffness matrices were derived using the trigonometric shape functions related to exact solution of the differential equation of bending according to the second order theory. When the buckling of structure occurs in plastic domain, it is necessary to replace the constant modulus of elasticity E with the tangent modulus Et that is stress dependent function and takes into account the changes of the member stiffness in the inelastic range. For the purposes of numerical investigation in this thesis, the computer program ALIN was created. This program is developed in the C++ programming language. In this thesis, the algorithm for the calculation of buckling lengths of compressed columns of the frames was established. The algorithm is based on the calculation of the global stability analysis of frame structures. Results obtained using this algorithm were compared with the approximate solutions from the European (EC3) and national (JUS) standards for the steel structures. By the presented procedure it is also possible to follow the behavior of the plane frames in plastic domain and to calculate the real critical load in that domain.

KEYWORDS. Stability of structures, nonlinear elasto-plastic analysis, finite element method, tangent modulus, buckling lenght

The usual approach for the stability analysis of frame structures is based upon the analysis of compressed structural elements isolated from the structure as a whole. This approach has been used for the formation of national and European standards. In this thesis it is shown that such concept of the stability analysis of structures in engineering practice may lead to substantial errors and it should be replaced by more accurate method.

In the presented analysis the global stability analysis of whole frame structure is suggested, and in first step, determination of the critical load for the structure as a whole. Then, the critical load and effective buckling length of each member can be found. The proposed method is not unknown, but the way how it is formulated and implemented here has not been applied in any of the commercial programs that deal with the stability of frames. In available commercial programs, stability analysis is based upon the geometric stiffness matrix as a part of the tangent stiffness matrix. Interpolation functions are the cubic polynomials, because they are derived from the solution of the differential equation of bending of a beam according to the linear theory. So, it is an approximate solution, because bifurcation stability problem is essentially geometrically nonlinear problem and it requires the second order theory analysis. Consequently, in order to obtain acceptably accurate results related to the global critical loads and the corresponding buckling modes, sufficient number of finite elements must be adopted along each column or beam of considered frame. However, in this thesis the calculation where interpolation functions are derived from the exact solution of the differential equation of bending according to the second order theory is proposed. Such interpolation polynomials are obtained as trigonometric or hyperbolic functions of the axial force of each element, sometimes known as the stability functions. The advantage of such an approach, which is applied in the program ALIN, is in the fact that only one finite element is needed for each beam or column, so the total number of finite elements is significantly less than in the usual approach based on the geometric stiffness matrix.

With intention that this thesis has a greater practical importance in engineering practice, for the first time in our literature the accuracy of the solutions given in JUS and EC3 standards was investigated in details, related to the effective buckling length determination. One floor and multi floor sway and non-sway frames were analyzed. The effect of the various parameters to the critical load value, such as different supports and loads, frame geometry, etc. was investigated. Applying the proposed method it was shown that substantial errors are made when the approximate solutions from the codes are used. That means that there is a need for the innovation of these standards in the part where the effective length of frame columns is considered. It can be done, for example, in the way as it is proposed herein. It should be emphasized that some steps have already been taken in EC3 standards, in the part related to the complex deformable structures which require the calculation according to second order theory, however, no more details are given in EC3.

The proposed calculation method has been used also for the elasto-plastic analysis when the geometrically non-linear process is followed by development of the material nonlinearity as well. The generally accepted approach applied to this problem is the tangent modulus concept. It is based on the observation that the load-shortening relationship, for a section made of a material such as structural steel, is affected by the residual stresses that result inevitably form the manufacturing process. So, in this research elastic modulus is be replaced by the tangent modulus (E_t) to represent the distributed plasticity along the length of the member due to yielding caused by the axial force. Stiffness matrices are derived using the tangent modulus which is stress dependant and that follows changes of the member stiffness in the inelastic field. These matrices have been implemented in the computer code ALIN.

One of the main goals of this analysis was to develop the corresponding C++ computer program ALIN that can be used for the nonlinear, i.e. elasto-plastic stability analysis of frame structures. This code enables the complex linear analysis of the plane and space frames. The basic possibilities of this program are analysis according to the first and the second order theory, dynamic analysis and stability analysis, i.e. calculation of the critical load in the elastic and inelastic domains.

In this thesis is shown that by applying this computer code it is possible to calculate the buckling curves in inelastic range, which are used for determining the load bearing capacity of the member. It should be mentioned that in the analyzed standards, a critical force in the plastic domain is determined by the approximate calculation. First, the critical load is calculated when the buckling occurs in elastic domain. Then, using the buckling curves that are defined through the approximate (empirical) expressions, the critical load in plastic domain is determined. The contribution of this thesis is based upon the calculation algorithm implemented in code ALIN. This algorithm introduces more accurate calculation of buckling in plastic domain. It allows monitoring of the phenomena of stability loss of the frame structure in the plastic domain and direct determination of the critical force at the moment of buckling.

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Architectonic – structural design of steel and aluminium façade systems

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ABSTRACT. Curtain walls are a specific façade construction which is defined as light cladding construction which is hung on bearing construction and they are made of industrially manufactured elements, mostly of glass and metal. As they are light and thin, acting loads are numerous and various, heights may be considerable, wind and seismic zones different. For these reasons, even though they have been around for quite a long time, the curtain walls are still a challenge for designers considering design and construction.

KEYWORDS. Light – weight facade, curtain wall, aluminium, steel, wind, CFD, mullion, transom, stability.

The subject of investigation are light-weight facades, important and final part of the buildings. Also called "the faces of the buildings", they represent the synthesis of architectural and structural design and often dominate in the final impression of the building. Curtain walls are a specific façade construction which is defined as light cladding construction which is hung on bearing construction and they are made of industrially manufactured elements, mostly of glass and metal. A transparent envelope is made in front of the bearing construction of the structure. Curtain wall concentrate all essential protective shield functions of a building envelope in a light – weight, thin, impermeable, and sometimes vulnerable shell, many times thinner than the respective load bearing walls, and include individual components responsible for performing dedicated functions [1].

Regarding the fact that the cost of the façade can amount to as much as 25% of the total cost of the building, they represent a subject of permanent theoretical and experimental research.

The construction of curtain wall consists of vertical bearing elements, mullions and horizontal bearing elements, transoms. The curtain wall construction has to absorb, transfer but also to withstand all loads (weight, wind, seismics, temperature, ice, impact load, etc.) through mullions and transoms.

The curtain wall construction and load – bearing construction are different in terms of material, loading, structural systems, connections between these parts and general concept, but they have to work and "behave" together.

Steel and aluminum, owing to their mechanical properties, have been used for construction of curtain wall structures. Aluminum alloys, as metals considerably differ from the steel. Undeniably, there are similarities, so in all the research, the comparison with steel, in all kinds of aspects, is unavoidable. Also, all the technical regulations are similar both in form and philosophical approach.

One of considerable loads for the light-weight façade structures is wind load [2,3]. Wind loading is different for different building heights, due to the effects of terrain roughness and influence of environment. It is the fact that the structures with such type of the façade have increasing heights, and they are also very frequent in the areas where high speed winds prevail. An additional challenge associated