Modern capabilities of research and simulation strength of metalstructures

Współczesne możliwości badania i symulacji nośności konstrukcji metalowych

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The use of modern measurement techniques and computing methods opens up new possibilities for the calculation and testing of metal structures. This article presents research conducted using measuring set MTS to verify the computational model of the structure of the roof protection on industrial buildings.

KEYWORDS: numerical methods, strength tests

Available calculating software and measuring devices open up to the modern engineer new opportunities in the field of metal design and testing. Modern computational systems allow the design and calculation of new solutions based on MES and simulations of construction working under various operating conditions. Each MES computation system requires the introduction of material characteristics of the various components of the structure, interrelation of those parts, execution of a regular and densely mesh of finite elements, and the definition of boundary conditions. The basis for determination of material characteristics is testing, usually performed on strength machines using samples of materials, from which the construction is made. The results of calculations are important, however, depending on the degree of correctness of the discrete design model. The only way to validate these calculations is to investigate the actual construction. These tests determine the actual carrying capacity, displacement and deformation of the structure and confront them with the results of numerical calculations.

This type of research cannot be performed on classic endurance machines. However, such possibilities are created by modern measuring systems, e.g. MTS measuring system. Its basic part is servo-hydraulic servomotors, controlled by a signal from a force sensor, a displacement, or a signal defined by a suitable combination of these magnitudes. The following section presents the validation of the model of discrete roof protection structure using the MTS measuring system as well as testing of samples and finished constructions carried out at the Laboratory of Technical and Humanistic Academy in Bielsko-Biała.

Geometric model and discrete model

The subject of the MES analysis was the construction of roof protection for maintenance workers on the roofs of factory halls. The basic module of this structure, which consists of a steel sheet and an arm with an ear, is attached to the sheet of trapezoidal roofing. Complete security system consists of several dozen basic modules in the amount dependent on the roof area and the number of people working at the same time. Preparing a safe workplace involves pulling the steel rope through the ear of the rope and connecting both ends with a steel clamp. Employees take maintenance work after they have been pinned to a safety rope. The geometrical model of the basic module is shown in fig 1.

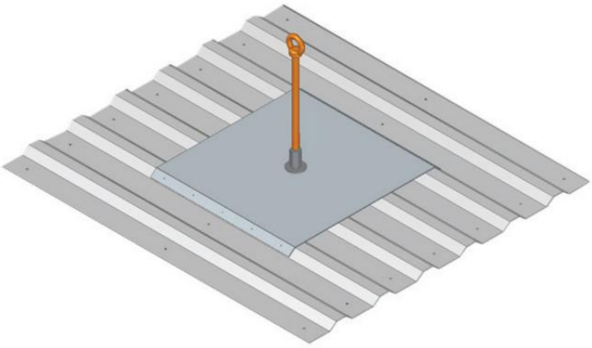

Fig 1. Geometric model of the basic module

The geometric model was divided into parts to obtain a regular hexagonal grid. This division was done in FEMAP v.11 with NX Nastran [1]. The grid of elements is shown in fig. 2.

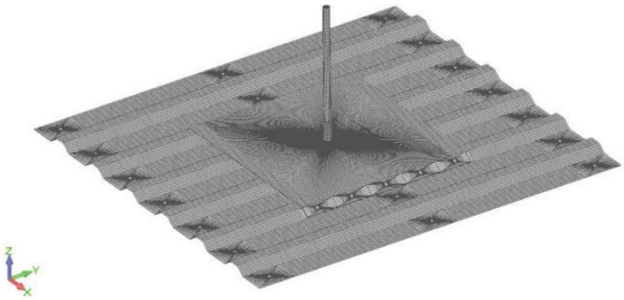

Fig. 2. Discrete model

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41,496 plate elements were used for sheet metal discretization; the rest of the structure was modeled with 4,768 solid elements. The boundary conditions were defined by means of the Rigid type in the nodes corresponding to the locations of the trapezoidal sheet metal fixings to the roof structure and the mounting locations of the structural module sheet to the trapezoidal sheet.

Description of the measuring set for determining the materials constants

For calculations, it is necessary to determine the material constants for the material, from which the construction is made. These constants were determined in a static stretching test using the MTS test set. ATH's measuring set consists of two hydraulic cylinders: a 150 mm servo-hydraulic linear, dynamic and fatigue linear actuator with a nominal force of ±25 kN and a servo-hydraulic linear actuator for static and variable load testing of variable displacement with a stroke of 500 mm. And compression force 160 kN and 90 kN for stretching (fig. 3).

Fig. 3. MTS actuator

The configuration includes a measuring amplifier for programmable selection of the operating mode. The amplifier has auto-zeroing and calibration options for any sensor and measuring range directly by the user. Actuators direct digital multi-channel control to provide feedback control. The complete set is complemented by grooved slabs and a frame construction for fixing the actuators. This design provides the ability to easily move and change the working space. Material constants were determined in a static tensile test on flat steel paddle samples, from which the roof protection structure is made. The test was performed using a smaller set of actuators. A self-made adapter for testing flat samples (fig. 4) was used.

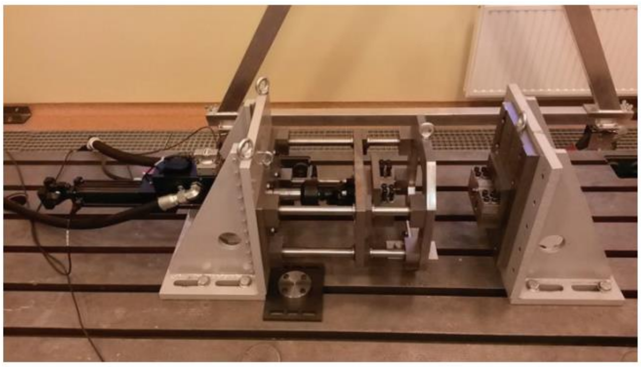

Fig. 4. Test stand with flat-plate test adapter

The material parameters were determined using a 25 mm MTS-based extensometer (fig. 5).

Fig. 5. Sample with extensometer MTS

The test procedure, which performed the stretch test according to [2], was prepared in the MTS TestSuite programming environment [3]. The value of material constants recorded during the test is listed in the table.

TABLE. Material constants

Young's module E, MPa	206767,84
Arbitrary limit of elasticity R_{005}, MPa	177,92
Arbitrary limit of plasticity R_{02}, MPa	188,32
Tensile strength R_m, MPa	321,54

Construction calculations

Based on the MES calculation software, the structure for two load schemes was analyzed - along the trapezoidal sheet metal (*y* direction) and in the lateral direction (*x* direction). The force of 188 MPa value was chosen to produce a reduced stress in the structure, which corresponds to the empirically determined yield point. For the force acting in the *x*-axis, this value is 140 N. It corresponds to a displacement of the arm end of 19.56 mm. The reduced stress distribution in the plates obtained from the calculations is shown in fig. 6.

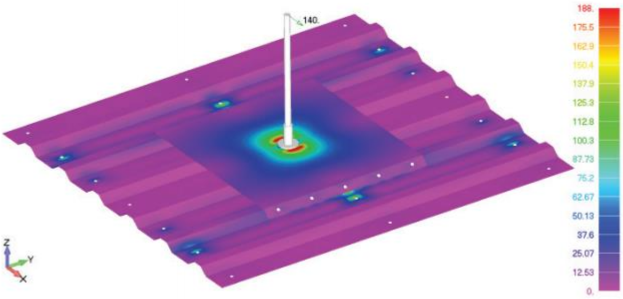

Fig. 6. Contours of reduced stresses in plate elements for load in the transverse direction to the cracks

For a force acting in the *y*-axis direction, this value is 120 N. It corresponds to a displacement of the arm end of 20.39 mm. The reduced stress distribution in the plates obtained from the calculations is shown in fig. 7.

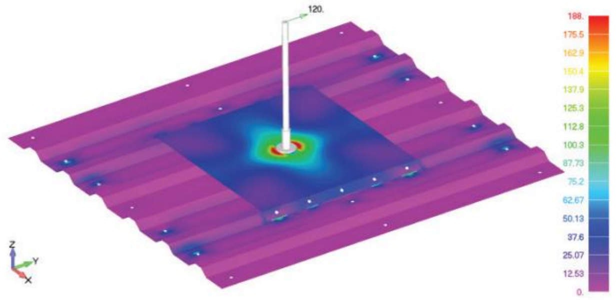

Fig. 7. Contours of reduced stresses in plate elements for load in the direction along the cracks

Validation of discrete model

The displacement values of the arm end caused by the forces under consideration were used to verify the correctness of the discrete model. The calculated displacement values were assumed as the limit values of the displacement of the MTS in the load test of the actual construction. The correctness of the discrete model was verified by corresponding displacement of the load value recorded by the force sensor.

For the test, a frame structure corresponding to the roof support was constructed. A trapezoidal sheet has been attached to this structure with security. The tests were carried out in two mutually perpendicular directions on two copies of the structure (fig. 8 and 9). The test procedure was prepared in an MTS TestSuite environment.

Fig. 8. Study of the construction in a direction perpendicular to the trapezoidal sheet piles

Fig. 9. Study of the construction in parallel direction to the trapezoidal sheet piles

For a load running perpendicular to trapezoidal sheet traverses, the displacement of the 19.56 mm actuator corresponded to a load of 145 N, so the relative percentage error in relation to the setpoint force in numerical calculations is 3.45%.

For a load running parallel to trapezoidal sheet traverses, the displacement of the 20.39 mm actuator corresponded to a force of 128 N, which, in relation to the value of force assumed in the calculation, results in an error of 6.25%.

Magnesium casting capacity test

An example of metal construction research conducted at the ATH laboratory is to check the capacity of magnesium castings produced for the automotive industry by Shiloh Industries in Bielsko-Biała. A 1500 mm cast was subjected to a tensile test with a rated force of 90 kN (fig. 10).

Fig. 10. Magnesium cast on the test bench

A batch of 10 castings achieved an average tensile strength of 50.72 kN at a standard deviation of 1.4. The average maximum elongation was 26.28 mm. Cracks in all castings were in the same zone.

Location of the cracking site allowed the casting manufacturer to verify the casting parameters. Hence, any technological modifications or changes made during the casting process are regularly tested on an MTS before the product is put into mass production.

Conclusions

A slight divergence between the force applied in numerical simulations and the value recorded in tests for the given displacement indicates the correct execution of the numerical model. Positive verification of the discrete model allows it to be used to perform reliable simulations to estimate the load capacity of the structure depending on the roofing material, type of trapezoidal sheet pile and various load combinations, or to modify the structure to increase its carrying capacity.

This unique feedback between numerical simulations and experimental studies of construction plays an increasingly important role as the development of computational tools and modern precision measurement systems evolve. More and more important is the concept of the sample. It is no longer just an object of small dimensions adapted to the handles of a classic endurance machine, but a large-scale structure, behavior of which under various factors can be precisely investigated.

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