RIADENIE ÚNAVY ŠTÍHLYCH KOMPOZITNÝCH KONŠTRUKCIÍ

FATIGUE CONTROL OF SLENDER COMPOSITE STRUCTURES

Alexander TESÁR, Marek SEDLÁR and Martin KRIŽMA[1]

Abstrakt

Numerické a experimentálne overenia účinnosti novej spojovacej lišty pre riadenie medzného únavového pôsobenia štíhlych kompozitných konštrukcií. Vlnové aproximácie na báze neurónových simulačných modelov so spätnými väzbami sú aplikované pre numerické analýzy problému. Prezentované sú niektoré výsledky numerických a experimentálnych overení daného problému.

Kľúčové slová: Kompozitné konštrukcie, neurónové siete so spätnou väzbou, riadenie únavy, spojovacia lišta.

Abstract

Numerical and experimental assessment of new facility for the fatigue control of modern composite structures is treated in present paper. The wave approach of the back propagation neural network in micromechanical modeling is used for numerical analysis of the problem. Some numerical and experimental results are submitted in order to demonstrate the efficiency of the techniques and facilities suggested.

Keywords: Back propagation neural network, composite structures, connecting strip, fatigue control.

INTRODUCTION

Numerical and experimental research of modern composite structures equipped with facilities for the control of their ultimate fatigue response has recently become the focus of intense efforts in structural engineering. This is because of pressing problems of tuned vibration control and disaster prevention of modern composite structures. Required are new connecting devices containing the facilities for ultimate fatigue control of modern composite structures. It has become increasingly common to connect the concrete slabs to the supporting steel beams by mechanical devices. These eliminate or at least reduce slip at the steel/concrete interface, so that the slab and the steel beam sections act together as a composite unit. For the composite structures made of conventional materials the standards and regulations for the assessment of their ultimate fatigue behavior are available. The situation becomes more complicated if new devices for the behavior control of slender composite structures are required. To ensure the satisfactory composite action between the materials, the shear connectors or strips have to be placed in the areas of concentrated load introduction. The fatigue efficiency of the connecting facility made of the steel strip with geometric configuration as shown in Figs. 1 and 2 is accentuated and verified in this paper.

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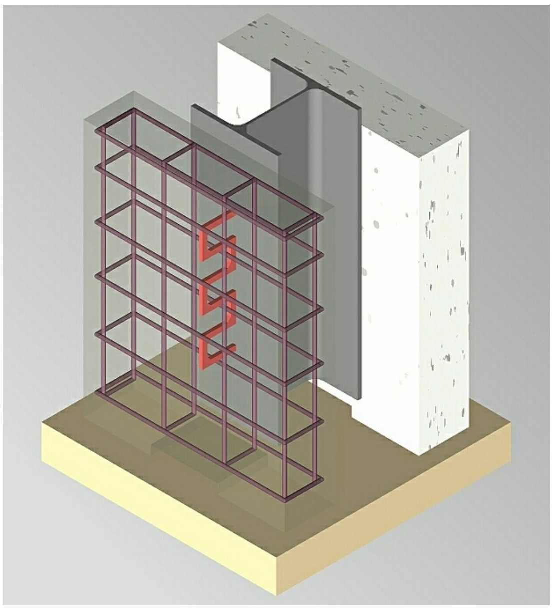

Fig.1 Elevation of connecting strip studied

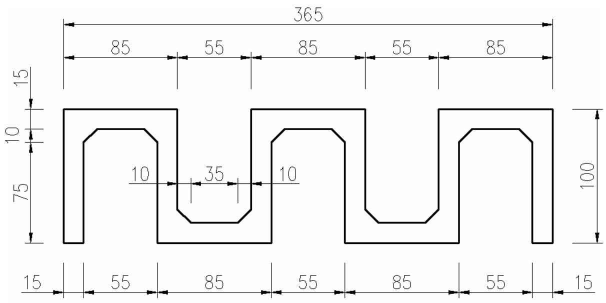

Fig.2 Geometry of connecting strip studied

BACK PROPAGATION NEURAL NETWORK

The neural networks have been developed recently for the solution of some sophisticated problems in structural engineering. Compared to conventional digital computing techniques the neural networks are advantageous because of their special features such as parallel processing, distributed storing information, low error sensitivity and adaptability to new information. The application of the neural network principle in structural engineering first appeared in (Adeli and Yeh, 1989). The back propagation neural network (Wei Lu and Mäkeläinen, 2001) is a multi-layered feed-forward neural network trained by back-propagation algorithm.

The fundamental element of the network is called the artificial node and consists of a set of connecting dead-weight strings. The string tendons touching the artificial node instead of conventional links contain all physical data, material properties, strength, elasticity, plasticity and dynamics of the composite material studied. All data are contained in the database of the back propagation neural network established. The topology of the network contains the input and output layers as well as one or several hidden layers, an adder used to sum the weighted input, an activation function used to decrease the magnitude of the output as well as the threshold for the activation function adopted.

The back propagation algorithm starts with randomly initialized weights. Using the calculation rule for one node, the input vector is feed-forwarded from layer to layer until the output vector is obtained.

The calculation rule for one basic node is given by

$$Y = f\,(net) = f\,(\sum w_i\, x_i - \Theta) \quad , \tag{1}$$

where x_i is i-th component of the input vector, w_i is the i-th component of the weight vector, Θ is the threshold, f is the activation function, y is the output of the node and t_i is the i-th component of the target vector being the desired output concerning the input vector. The output vector is compared with the target vector and the error in the output layer is calculated using

$$\delta_{pk} = (t_{pk} - o_{pk})\, f_k\, (1 - f_k) \quad , \tag{2}$$

with t_{pk} and o_{pk} representing the target and output values of the k-th node in the output layer corresponding to the p-th training pattern and f_k is the activation function for the k-th node.

When a composite consists of densely packed inclusions within a matrix, the interaction effects play a dominant role in the macroscopic ultimate response of the resulting continuum. The concept of transformation strain can be used when an elastic medium contains periodically distributed inclusions or voids. Adopting the above approach, the calculation of the ultimate behavior of the composite is given by following operations:

1. Micro- and macro-mechanical modeling of the material and structural configurations of the composite in space, temperature and time.
2. Updated calculation of the stress and strain states in structural response in all elements of the model adopted, for each step of the forcing process of the composite structure studied.
3. Automatic comparison with the ultimate strength of the composite material adopted.
4. Initiation of the cracks in all micro-mechanical elements trespassing the ultimate strength.
5. Repeated calculation of the updated deformation process with further development and propagation of cracks until the total fatigue destruction of the composite structure studied.

NUMERICAL AND EXPERIMENTAL ASSESSMENT

Above approaches were adopted for numerical and experimental assessments of the behavior of the connecting strip as shown in Figs. 1 and 2. The geometry and dimensions of the laboratory model studied are submitted in Fig. 3.

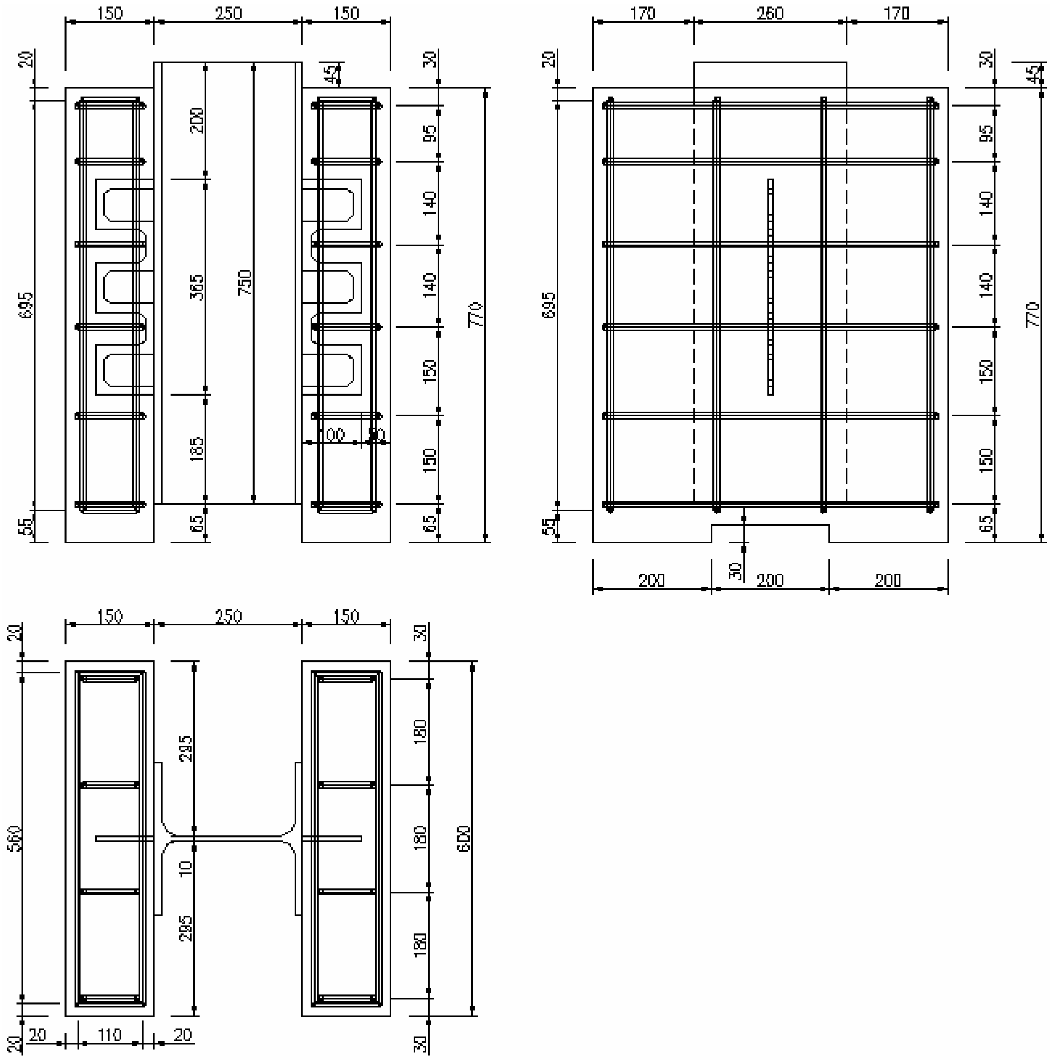

Fig.3 Geometry and dimensions of the laboratory model tested

For the fatigue testing was adopted the pulsator with capacity of 1000 kN as shown in Fig.4. The testing specimen was subjected to cyclic load with middle value 550 kN and with the amplitude 150 kN. Above cyclic forcing was continued until the total collapse of the specimen. The collapse occurred at the cycle Nr. 1 490 330, in the weld between connecting strip and steel profile. Corresponding value calculated by adoption of approaches referenced in [Tesar and Fillo, 1988] and [Tesar and Svolik, 1993] was 1 475 455 cycles.

Fig.4 The pulsator adopted

In the location D (see Fig. 4) was applied the measurement target. The results of fatigue testing are submitted in Fig. 5. In the first step the specimen was loaded on the level 500 kN, with following decrease of the load. In the second step the load was increased on the level 700 kN. In advance the specimen was cyclic loaded in the scope described above. After each 50000 cycle there were measured the slips of connected materials. At the last two measurements the number of period was increased on the level 100 000. The frequency of the loads was 19 Hz.

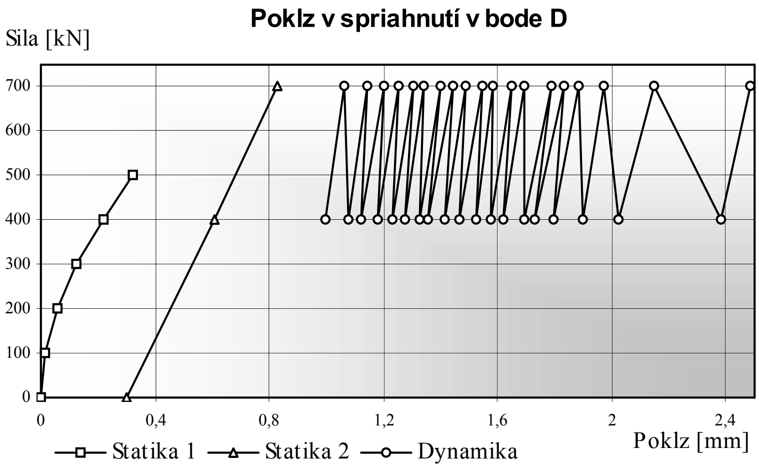

Fig.5 Displacements in ultimate fatigue (with original laboratory comments in Slovak)

CONCLUSIONS WITH DISCUSSION

Theoretical approach and the numerical results sampled up in present paper submit some image on the ultimate response of the composites provided with tuned behavior control strip developed. Experimental verifications of the numerical results obtained are submitted.

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