Bearing Capacity of Sheet Hanger Connection to the Trapezoidal Metal Sheet

Kateřina Jurdová

Abstract—Hanging to the trapezoidal sheet by decking hanger is a very widespread solution used in civil engineering to lead the distribution of energy, sanitary, air distribution system etc. under the roof or floor structure. The trapezoidal decking hanger is usually a part of the whole installation system for specific distribution medium. The leading companies offer installation systems for each specific distribution e.g. pipe rings, sprinkler systems, installation channels etc. Every specific part is connected to the base connector which is decking hanger. The own connection has three main components: decking hanger, threaded bar with nuts and web of trapezoidal sheet. The aim of this contribution is determinate the failure mechanism of each component in connection. Load bearing capacity of most components in connection could be calculated by formulas in European codes. This contribution is focused on problematic of bearing resistance of threaded bar in web of trapezoidal sheet. This issue is studied by experimental research and numerical modelling. This contribution presented the initial results of experiment which is compared with numerical model of specimen.

Keywords—Decking hanger, concentrated load, connection, load bearing capacity, trapezoidal metal sheet.

I. INTRODUCTION

THIS paper is deal with the issue of suspended load by hangers to the trapezoidal metal sheet.

Nowadays, the trapezoidal metal sheets are often used as roof structures for single-storey or multi-storey buildings. The main function of this structure is carrying the vertical load from the roof deck (roof snow loads, wind loads, etc.) to the rest building structures and after that to the foundations. Another load, which trapezoidal sheets are exposed, are concentrated loads e.g. from installation of air distribution, sanitary distribution, sprinkler system or wiring installation and from hanging advertising posters etc.

These loads are connected directly to the wave of trapezoidal metal sheet by special decking hangers. In European trade are several systems offered by producers of anchoring systems. The widespread system is a hanger in shape of "V" which is anchored to the wave of trapezoidal sheet by threaded bar or spring toggle anchor.

These systems are adapted for common building facilities e.g. air distribution, sprinkler system etc. but the main part – the "V" hanger or spring toggle anchor is still the same. The "V" hanger is connected to the web of wave by threaded bar. The hole for threaded bar is punched by special pliers. The load bearing capacity of these anchors are obtained from the table values given by producers.

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Nowadays in European codes does not exist the unified calculation method for obtain load bearing capacity of this hanger which is connected to the trapezoidal sheet. Load bearing capacity of these hangers is in practice obtained from the load bearing capacity of trapezoidal sheet. This load bearing capacity depends on position of concentrated load.

This paper deals with load bearing capacity of connection "V" hanger to the wave of trapezoidal sheet. The aim of contribution is find a real mechanism of failure of this type of connection and presenting our existing achievements at the field of this activity.

II. PRACTICE

A. Types of Anchors

In this time exist a lot of types of anchoring to the trapezoidal metal sheets, but most widespread anchor is type of "V" hanger (see Fig. 1 (a)), second type is spring toggle anchor (see Fig. 1 (b)) [4], [5].

(a)   (b)

Fig.1(a) Trap. deck.hanger – "V" hanger; (b) Spring toggle anchor

For our research was chosen only one type of trapezoidal sheet hanger, exactly "V" decking hanger.

B. Assembly Instruction

Advantage of this working procedure is fast and simple assembling, which can be used on finished construction. The first step is making holes to the trapezoidal sheet with special pliers. Then follow assembling "V" decking hanger to the correct position and pass threaded bar through the trapezoidal sheet and decking hanger. Then fix position with using the nut. At the bottom of the hanger screw down threaded bar to the correct position and then complete whole anchoring system (see Fig. 2). [6]
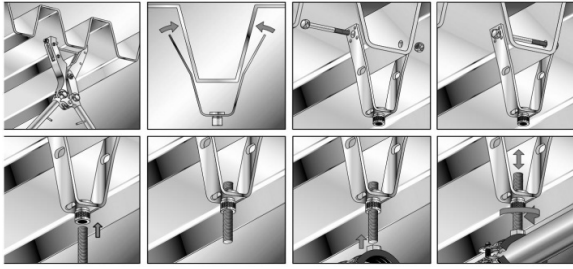
Fig. 2Procedure of assembling

C. Simplified Calculation

As was note, in European codes does not exist the analytical methods for obtain load bearing capacity of decking hanger connected to the trapezoidal sheet. So, the structural engineers mostly use own simplified calculations. Engineers recalculate active loads to the area load and this load compare with table values, which are given by producers. This total load, include concentrated load recalculate to the area load. On this total load is designed trapezoidal metal sheet (ULS).

The load bearing capacity of the trapezoidal metal sheet is calculated by (1).

$$M_{c,Rd} = \frac{W_{eff,min}}{\gamma_{Mo}} \cdot f_y \geq M_{Ed} \qquad (1)$$

where M_{Ed} is the design bending moment, $M_{c,Rd}$ is the moment resistance

To determine SLS the engineers mostly use formulas from elastic calculation. [2]

III. MECHANISM OF FAILURE

During the loading can become collapse of component or whole anchoring system. There can become some of next cases:

a. Shear off the threaded bar, when the acting force F is bigger than shear strength by (2):

$$F_{v,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}} \qquad (2)$$

b. Overcome the resistance in tension of the trapezoidal sheet hanger by (3):

$$N_{t,Rd} = \frac{0,9 \cdot A_{net} \cdot f_u}{\gamma_{M2}} \qquad (3)$$

c. Breaking the trapezoidal metal sheet when it is used up the bearing capacity of the sheet

IV. EXPERIMENTAL STUDY OF CONNECTION ON TRAPEZOIDAL SHEET WITH INITIAL STRESS

It was necessary to find a real behaviour of the trapezoidal metal sheet during a loading. At first was done a pilot test, which helped us to determine behaviour of trapezoidal sheet without initial stress.

After the pilot test were optimized whole test equipment, where the initial stress was supplemented(see Fig. 3).
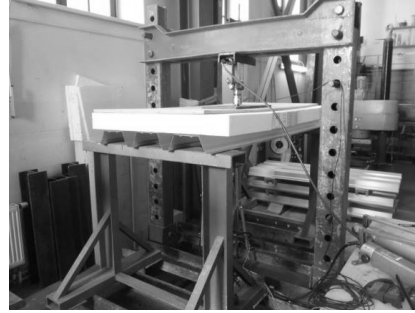

Fig. 3 Test equipment to supplementing initial stress

In the middle of the span were placed measuring instruments (measuring vertical deflection) at the bottom of the wave (see Fig. 4).

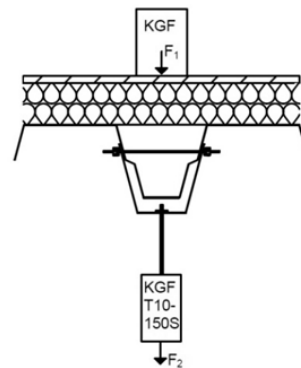

Fig. 4 Measuring instruments to vertical deflection

Fig. 5 Loading schema

According to analytical calculation was define a load bearing capacity in bending of trapezoidal sheet $M_{c,Rd}$by(1). There were chosen three kinds of specimens, where the first one was loaded to 50% of its load bearing capacity, second one was loaded to 70% its load bearing capacity and the last one was loaded to 100% its bearing capacity. For loading initial stress on the top of the system was used pushing

hydraulic cylinder KGF (force F_1). On the bottom of the equipment was used tensile hydraulic cylinder KGF T-series T10-150S to simulate concentrated load (force F_2) (see Fig. 5).

From the point of view of ultimate limit state was the weakest link of whole system the local load bearing capacity of trapezoidal metal sheet.

From the point of view of serviceability limit state was measured vertical deflection on loaded trapezoidal sheet. After injection an initial stress was note the value of vertical deflection u1 of the trapezoidal metal sheet. There was note a deflection u_2 after the loading of concentrated load in the middle of the trapezoidal sheet.

For example is shown the dependence of deflection u_2 on force F_2 for one specimen thickness of the trapezoidal sheet (see Fig. 6). [3]

.... 50% initial load bearing capacity

———— 70% initial load bearing capacity

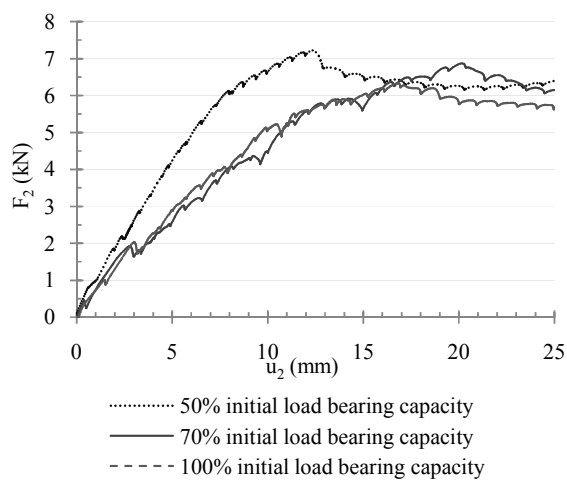- - - - - 100% initial load bearing capacity

Fig. 6 Deflection u_2 depending on force F_2
(Trapezoidal sheet thickness 0.88 mm)

After the end of the testing was done the analytical calculation of deflection with aim to find difference between experimental value of deflection and analytical calculation used in practice in Table I.

TABLE I
COMPARISON OF ANALYTICAL AND EXPERIMENTAL VALUES OF DEFLECTION
(FOR TRAPEZOIDAL SHEET THICKNESS 0.88 MM)

		Experiment	Analytical		Difference (%)
	$u_q =$	3.10	2.72	mm	12
A	$u_{F2} =$	5.65	2.58	mm	54
	$u = u_q + u_{F2} =$	8.75	5.30	mm	39
	$u_q =$	3.80	3.80	mm	0
B	$u_{F2} =$	4.95	2.33	mm	53
	$u = u_q + u_{F2} =$	8.75	6.14	mm	30
	$u_q =$	5.17	5.43	mm	-5
C	$u_{F2} =$	3.58	1.96	mm	45
	$u = u_q + u_{F2} =$	8.75	7.39	mm	16

A = 50% of load bearing capacity, B = 70% of load bearing capacity, C = 100% of load bearing capacity, u_q = deflection by continuous load, u_{F2} = deflection by concentrated load, u = total deflection

These results show how necessary is solve the problematic about local load bearing capacity of the trapezoidal metal

sheet like a discrete problem. This consideration led to do another experiment, which should be more specify to solve local bearing capacity.

V. EXPERIMENTAL DETERMINING THE BEARING RESISTANCE OF THREADED BAR IN WEB OF THE TRAPEZOIDAL METAL SHEET

A. Specimens

For experimental study were prepared two specimens. The first specimen had drilled hole. The second specimen had punched hole by special pliers. There is a difference between drilled hole and punched hole in precision, because the drilled hole has circular hole with exact diameter. Punched hole has not exact diameter and contact area between threaded bar and web of sheet is strengthen by deformed sheet by punching of pliers. The specimens were created in next steps. At first was cut trapezoidal sheet on pieces. There was drilled a hole to the specimen. The hole had 10 mm in diameter. After that were specimens unbended in hydraulic press to the straight form (see Figs. 7 and 8).

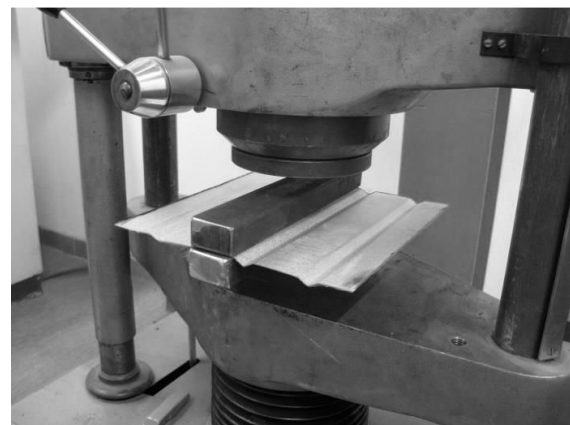Fig. 7 Preparation the test specimen

Fig. 8 Final treatment in hydraulic press

On prepared specimens were fixed the tensiometers HBM for measuring a strain around the hole for threaded bar (see Fig. 7). Then was the specimen placed to the test equipment.

The vertical local force was substitute by hydraulic press. On the threaded bar was placed dial indicator for measuring vertical deflection (see Fig. 8).
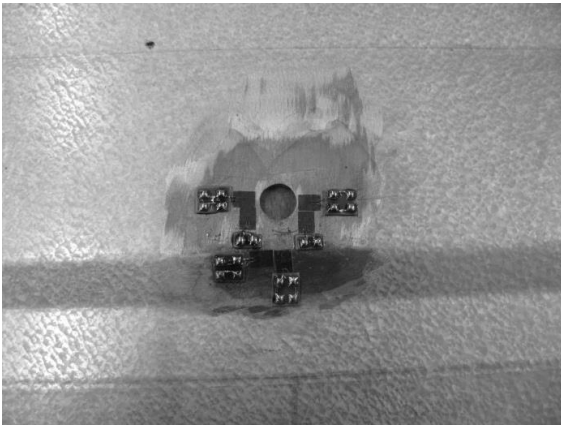

Fig. 9 Tensiometers HBM – type 1-LY11-1.5/120

Fig. 10 Testing equipment

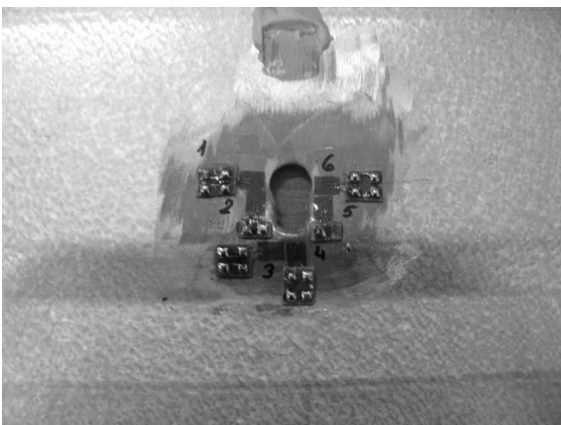During the loading was the specimen loaded over itsbearingresistance (see Figs. 11 (a), (b)).

Fig. 11(a) Specimen after loading – view from the front

Fig. 11 (b) Specimen after loading – back view

B. Results of Experiment

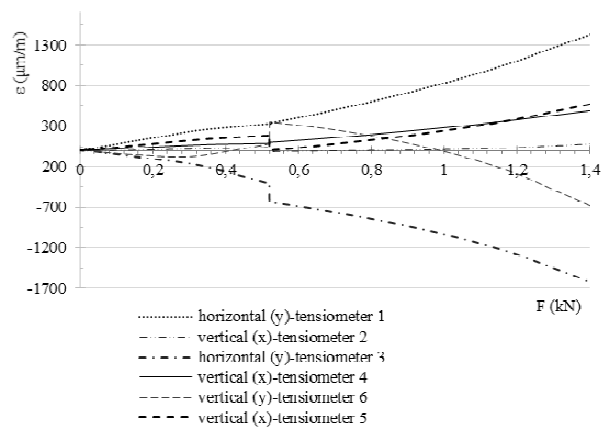Dependence of force and strain is shown in graph (see Fig. 12).

Fig. 12 Dependence ε (μm/m) on force F (kN)

VI. NUMERICAL MODEL

According to specimen with drilled hole was created numerical FEM model. For better validation of numerical model was chosen specimen with drilled hole; because, web of sheet had clean edge around circuit after drilling. The numerical model was created in software RFEM by Dlubal Company. The model was created by 2D elements. On the top of the specimen was used fixed support, like simulation of the clamping jaw. The bottom edge of the modelled specimen was not supported, like a real specimen. The load was apply continuously to the half circuit of hole. Calculation was done as nonlinear by Newton-Raphson method [1],[7].

A. Specimens

Numerical model was loaded by equivalent of vertical load with value F= 1 kN. The behavior of strain ε_y is shown in Fig. 13. The behavior of strain ε_y is shown in Fig. 14.
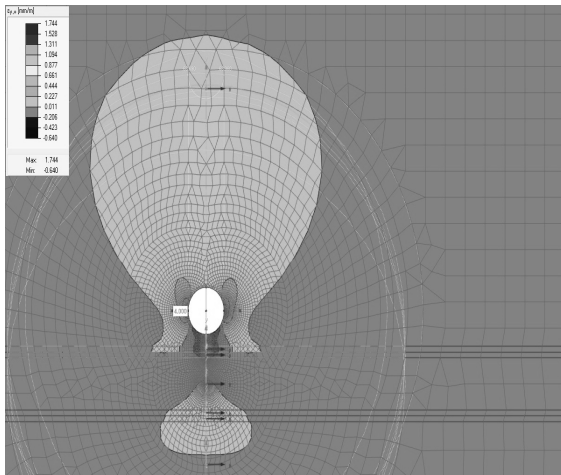
Fig. 13 Numerical model – strain ε_y
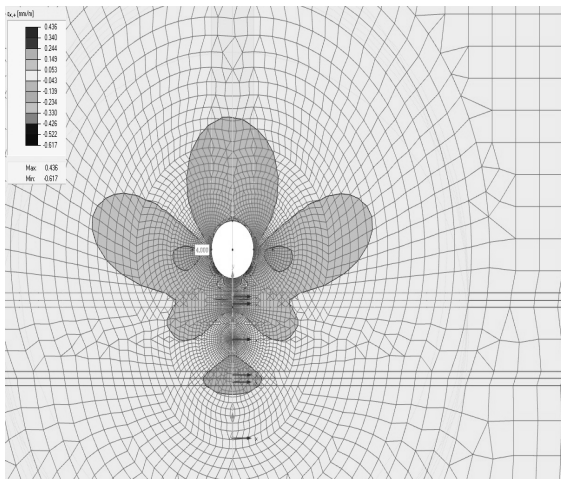
Fig. 14 Numerical model – strain ε_x

VII. CONCLUSION

This contribution is deal with initial study of bearing resistance of threaded bar in web of trapezoidal sheet. The aim of study was comparison of experimental and numerical results. Research was done on specimen with drilled hole and on corresponding numerical model.

The comparison between values of strain given by experiment and by numerical model is shown in Table II.

TABLE II
COMPARISON OF EXPERIMENTAL AND NUMERICAL VALUES OF STRAIN E (MM/M)

Tensiometer	1	2	3	4	5	6
Experiment	0.823	0.016	-1.027	0.278	0.238	0.079
Num. model	0.624	0.011	-0.864	0.205	0.211	0.050

The values of strain according to intensity of load 1 kN.

The results by numerical modelling and by experimental analysis have accordance in 75%.

In next phase of experimental study will be compare the specimen with punched hole. For better accordance between results given by numerical modelling and by experiment will be modified used type of tensiometers. The multiaxial stresstensiometers will be probably more suitable.

Presented results given by initial experiment will be used to improve the numerical model. The improved numerical model will be used for further experiment study.

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