DOI: 10.2478/v.10169-010-0016-7

EVALUATION OF RESISTANCE OF CORRUGATED SHEETS UNDER BENDING BY A CONCENTRATED LOADS FROM THE LOCAL SUSPENSIONS

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Th This paper presents a simple method of evaluating the load resistance and stiffness of corrugated sheets locally loaded with suspended technical fixtures. As a part of this research, parametric numerical analyses of corrugated sheets of different span, and with differently located concentrated forces, were carried out. Stress distributions in the individual folds in the elastic range and in the ultimate limit state were identified. On their basis, equivalent concentrated load factors for the individual folds in the sheet were determined. The load factors enable analyses of the load resistance and stiffness of corrugated sheets loaded with concentrated forces, which can be helpful in design practice.

Key words: Corrugated sheets, Load resistance, Concentrated load, Finite element method.

1. Introduction

The corrugated sheets used for roofing and cladding are subject to bending moments caused by dead loads (the deadweight and the heat and damp insulations weight) and live loads (snow, wind). The loads are considered to be uniformly distributed. Although the corrugated sheets are loaded as plate girders, due to the large difference in stiffness in both perpendicular directions, the assumed beam model has the form of a repeatable single fold. Time-consuming iterative computations of the effective geometric and strength characteristics (effective cross sectional area A_{eff}, effective moment of inertia I_{eff}, effective section modulus W_{eff}) need to be performed to determine deflections y and the design resistances (moment M_R, shear V_R and bearing pressure F_R). In order to simplify the design process, corrugated sheet manufacturers in their product catalogues include tables specifying the limits of uniformly distributed loads (for single-, two- and multi-span systems). Thus, laborious static-strength computations can be avoided and the optimum cross-sectional properties can be readily determined.

However, technical fixtures are often mounted on the underside of roof corrugated sheets (Fig. 1) by suspending the former from single folds (Fig. 2), whereby local

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concentrated loads are created. This kind of loading is quite different from the (linearly concentrated or evenly distributed over the surface) load acting uniformly on all the folds. In such cases, neither the single-fold beam model nor the manufacturer tables can be used in the strength analysis. The new loading configuration raises the questions: how many adjacent folds are stressed by the suspended load, and what is the resistance and stiffness of the coating plate part of the corrugated sheet?

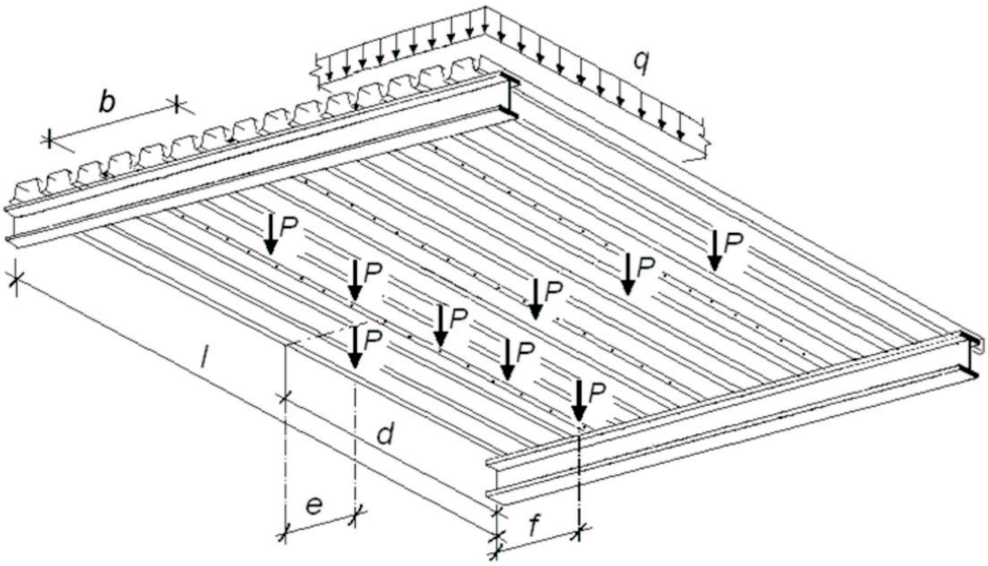


Fig. 1. Scheme of a corrugated sheet loaded by concentrated loads from local suspensions.
Rys. 1. Schemat obciążenia blachy fałdowej siłami skupionymi od lokalnych podwieszeń

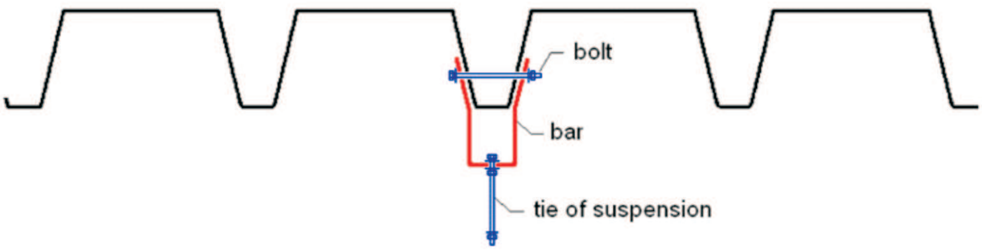


Fig. 2. Example of construction of connected to the corrugated sheet.
Rys. 2. Przykład elementu podwieszającego połączonego z blachą fałdową

The German Standard for corrugated sheets: DIN18807 [5], Part 2, recommends to test the corrugated sheet by applying concentrated loads: 1.2 kN, 1.5 kN and 2.0 kN to a single fold (taking into account its position in the whole unit). This kind of corrugated sheet load resistance evaluation can be used only for provisional calculations, e.g. during assembly. It should be noted that neither the European nor the Polish standards touch on the problem of evaluating the load resistance of corrugated sheets under a concentrated load. This question is also practically unsolved in the literature, although a few simplified methods have been proposed.

In Bahre, Gong [4] the evaluation is based on an analysis of the single-fold beam model on an elastic foundation. The behavior of the adjacent folds is described by the vertical (C_V) and horizontal (C_H) flexibility of the foundation.

In Biegus, Kowal [2] the results of both experimental investigations and theoretical studies of corrugated sheets, subjected to bending by a concentrated load applied to a single fold, were analyzed in the elastic range. The load-deflection dependence was determined from the single-fold beam model having an equivalent stiffness resulting from the interaction of the adjacent folds. An experimental factor of coaction by the adjacent folds (k) for evaluating the load resistance of T55×188×0.75 corrugated sheets was given.

To sum up, there are no normative or literature proposals (even in a rough form) for evaluating the load resistance of corrugated sheets loaded with suspended technical fixtures.

This paper presents a simple method of evaluating the load resistance and stiffness of corrugated sheets locally loaded with suspended technical fixtures.

2. Description of the problem

Let us assume that forces P_i produced by fixtures suspended from a corrugated sheet are regularly (not randomly) located and are accompanied by uniformly distributed dead load q. Each concentrated force P_i is applied to the axis of the bottom flange of the fold.

An example of a design of a suspension from a corrugated sheet is shown in Fig. 2. The load is transmitted to the fold through a horizontal bolt (or screws and one-side rivets) fixed to the webs with a clearance between them and, the nuts to avoid the effect of local bending. Direct suspension from the bottom flange is not recommended since it can weaken the most stressed part of the fold.

Because of the many different parameters involved, the behavior of corrugated sheets loaded with concentrated forces is a very complex problem. The analysis should cover:

- the shape and geometrical proportions of the sheet cross section (e.g. the slenderness and longitudinal stiffening of the walls),
- the sheet's width and number of folds,
- the density of single-point joints between the sheets,
- the static scheme (a single- or multi-span system),

- the span,
- the topology of the concentrated forces on the surface of the covering (the arrangement of the individual suspensions: along the span, across the span, and across the sheet, and the distance between the forces, and the fasteners joining the adjacent sheets).

Experimental tests are an effective way of assessing the load resistance of corrugated sheets locally loaded with concentrated forces, but they are costly and their results are case specific. The behavior and strength of such systems can be examined numerically by FEM, taking into account the geometrical and material nonlinearity. However, due to the complexity of the numerical corrugated sheet model, this method is not recommended for use in design practice.

As part of this research, parametric numerical analyses of corrugated sheets of different span and with differently located concentrated forces were carried out. Stress distributions in the individual folds in the elastic range and in the ultimate limit state were identified. On their basis equivalent concentrated load factors for the individual folds in the sheet were determined. The load factors enable analyses of the load resistance and stiffness of corrugated sheets loaded with concentrated forces, which can be helpful in design practice.

3. NUMERICAL ANALYSES OF CORRUGATED SHEETS LOADED BY CONCENTRATED FORCES

Single-span corrugated sheets T55×188×0.75 with width b = 750 mm and different span: l_j = 1500 mm, 2000 mm, 2500 mm, 3000 mm (Fig. 3) were studied numerically. Concentrated force P_i was applied to the webs of the central fold (P_1) or to the fold before the last one (P_2). The point of application of force P_i was shifted along the fold's axis a_k, assuming a_k/l_j = 0.166, 0.333, 0.500.

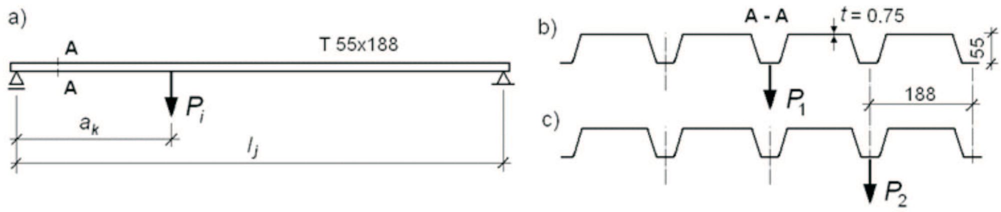


Fig. 3. Scheme of the tested corrugated sheets.
Rys. 3. Schemat badanych blach fałdowych

The ABAQUS 6.5 software was used for the calculations. Four-node finite shell elements S4R were adopted. The geometrical and mechanical properties of the corrugated sheets were experimentally determined assuming a perfect elastoplastic material model.

As regards the density of the division into finite elements, three zones were distinguished in the corrugated sheet unit (Fig. 4). Zone I is characterized by high density of the grid of finite elements, which are 5 mm wide and 10 mm long. In zone II the finite element grid density is low. The elements are 10 mm (the web and the bottom flanges) and 20 mm (the upper flanges) wide and 40 mm long. In zone III the grid represents a gradual transition from zone I to zone II. The curvature of the corrugated sheet's corner was modeled by a single finite element. A concentrated load (P_1 or P_2) was uniformly applied along the web of the corrugated sheet and its value was changed incrementally through displacement.

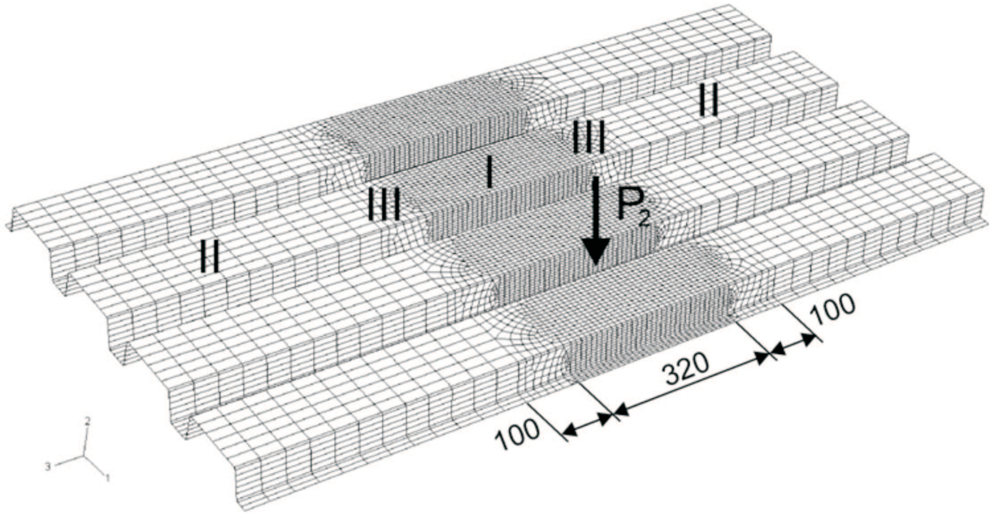


Fig. 4. Partition of finite elements for FEM model.
Rys. 4. Siatka podziału modelu na elementy skończone

Figure 5 shows an exemplary load-displacement relation (LDR) for a corrugated sheet with the following parameters: l_j = 2000 mm, a_k = 333 mm, a_k/l_j = 0.166, loaded by concentrated force P_1. A similar relation was obtained for the rest of tested units. In the stressing, two stages can be distinguished: the first one is in the elastic range (the linear part of LDR), while the second one is nonlinear. The two stages differ in the stress distributions in the individual folds. In the nonlinear part of the system behavior, the coaction between the folds adjacent to the loaded fold increases. The resistance of the sheet decreases once load-bearing capacity $P_{1,ult}$ is reached.

Thanks to the numerical analyses, the distribution of stress in the individual folds of the unit was identified. For the needs of the proposed calculation method, the plate behavior of the corrugated sheet (Fig. a in Table 1 and 2) was represented by fold-beam models loaded by equivalent forces k_iP_i (Fig. b in Table 1 and 2). Coefficients ($k_{el,i}$) of the elastic forces (Table 1) and coefficients (k_{ult}) of the equivalent load-bearing capacity

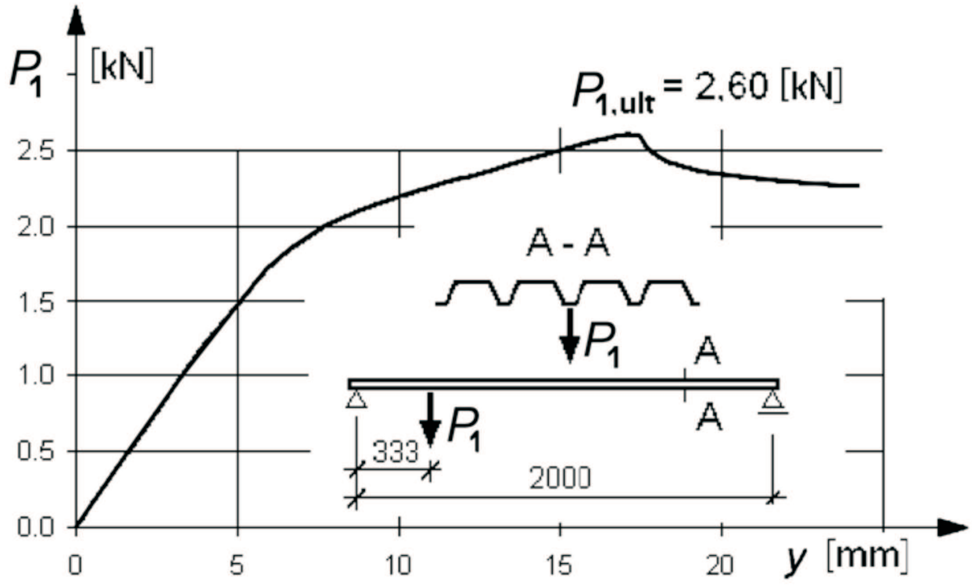


Fig. 5. Load-displacement relationship for a corrugated sheet T 55×188×0.75 under concentrated load P_1.

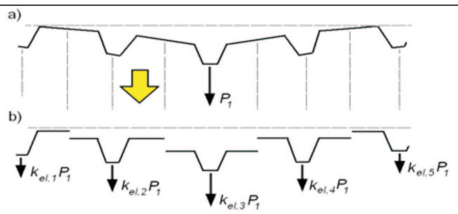
Rys. 5. Ścieżka równowagi statycznej blachy fałdowej T 55×188×0.75, obciążonej siłą skupioną P_1

of the folds (Table 2) represent the level of coaction between the individual folds in the sheet carrying the concentrated force. Hence they are referred to as coefficients of coaction. The coefficients were determined on the basis of a comparative analysis carried out for only (longitudinal) normal stress σ_x in the corners of the bottom flanges of the individual folds for respectively the elastic stress range and the limit state of the system.

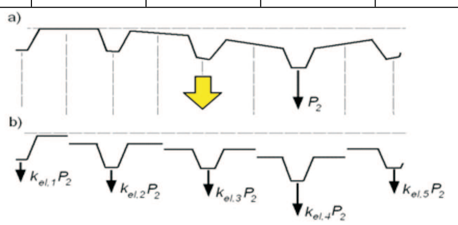
The analyses showed that in the ultimate state of stress the folds bend not only longitudinally. As a result of the deformation of the cross-section in the region of the applied force, local longitudinal $\sigma_{x,i}$ and transverse $\sigma_{y,i}$ stresses are produced. Thus coefficients $k_{ult,i}$ (Table 2) determined on the basis of only longitudinal stresses σ_x, are overestimated. They were introduced to determine the redistribution of stress in the ultimate state. In the considered case, an analysis of reduced stress in the folds according to the Huber-Mises-Hencky hypothesis would be more correct. But then one would face a difficulty connected with the choice of a correct way of determining $k_{ult,i}$ for the fold-beam model representing the plate and nonlinear behavior of the structure. Therefore, the equivalent fold load-bearing coefficients $k_{ult,i}$ were determined through an analysis of the ultimate loads of the corrugated sheets (Table 3).

Table 1

Experimental input data collected in [1].
Wejściowe dane doświadczalne zebrane w [1]



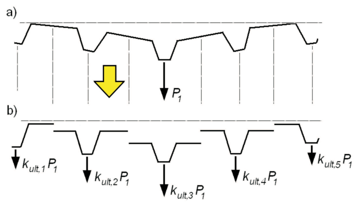
l_j	a_k / l_j	$k_{el,1}$	$k_{el,2}$	$k_{el,3}$	$k_{el,4}$	$k_{el,5}$
1500	0.166	0.01	0.02	0.94	0.02	0.01
	0.333	0.02	0.06	0.83	0.06	0.02
	0.500	0.04	0.10	0.72	0.10	0.04
2000	0.166	0.01	0.04	0.90	0.04	0.01
	0.333	0.02	0.09	0.78	0.09	0.02
	0.500	0.04	0.12	0.67	0.12	0.04
2500	0.166	0.01	0.06	0.87	0.06	0.01
	0.333	0.02	0.11	0.73	0.11	0.02
	0.500	0.04	0.14	0.63	0.14	0.04
3000	0.166	0.01	0.08	0.83	0.08	0.01
	0.333	0.02	0.14	0.68	0.14	0.02
	0.500	0.04	0.16	0.60	0.16	0.04



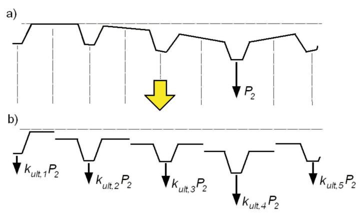
l_j	a_k / l_j	$k_{el,1}$	$k_{el,2}$	$k_{el,3}$	$k_{el,4}$	$k_{el,5}$
1500	0.166	0.01	0.02	0.04	0.91	.02
	0.333	0.02	0.05	0.08	0.81	0.04
	0.500	0.04	0.08	0.11	0.71	0.06
2000	0.166	0.01	0.02	0.05	0.89	0.03
	0.333	0.03	0.05	0.09	0.79	0.05
	0.500	0.04	0.09	0.12	0.69	0.07
2500	0.166	0.01	0.02	0.06	0.87	0.03
	0.333	0.03	0.05	0.11	0.76	0.06
	0.500	0.04	0.09	0.13	0.66	0.07
3000	0.166	0.01	0.02	0.07	0.85	0.04
	0.333	0.03	0.05	0.12	0.73	0.07
	0.500	0.04	0.09	0.15	0.64	0.08

Table 2

Coefficients k_{ult} of ultimate joint co-action of corrugated sheets under concentrated load.
Współczynniki $k_{ult,i}$ fałd blach fałdowych obciążonych siłą skupioną P_i



l_j	a_k / l_j	$k_{ult,1}$	$k_{ult,2}$	$k_{ult,3}$	$k_{ult,4}$	$k_{ult,5}$
1500	0.166	0.01	0.07	0.84	0.07	0.01
	0.333	0.03	0.13	0.68	0.13	0.03
	0.500	0.04	0.19	0.54	0.19	0.04
2000	0.166	0.01	0.19	0.62	0.19	0.01
	0.333	0.02	0.17	0.60	0.17	0.02
	0.500	0.04	0.18	0.56	0.18	0.04
2500	0.166	0.01	0.19	0.60	0.19	0.01
	0.333	0.02	0.20	0.55	0.20	0.02
	0.500	0.04	0.21	0.51	0.21	0.04
3000	0.166	0.02	0.21	0.54	0.21	0.02
	0.333	0.03	0.22	0.50	0.22	0.03
	0.500	0.04	0.23	0.47	0.23	0.04



l_j	a_k / l_j	$k_{ult,1}$	$k_{ult,2}$	$k_{ult,3}$	$k_{ult,4}$	$k_{ult,5}$
1500	0.166	0.01	0.02	0.04	0.88	0.05
	0.333	0.03	0.06	0.11	0.67	0.14
	0.500	0.04	0.09	0.16	0.58	0.13
2000	0.166	0.01	0.02	0.12	0.67	0.18
	0.333	0.03	0.05	0.13	0.64	0.15
	0.500	0.04	0.08	0.17	0.57	0.14
2500	0.166	0.01	0.02	0.13	0.66	0.17
	0.333	0.02	0.05	0.15	0.61	0.17
	0.500	0.04	0.07	0.16	0.56	0.17
3000	0.166	0.01	0.03	0.19	0.62	0.15
	0.333	0.02	0.05	0.17	0.56	0.21
	0.500	0.03	0.07	0.20	0.56	0.15

The corrugated sheets (with parameters P_i, l_j, a_k) were subjected to loading up to load-bearing capacity $P^{j,k}_{i,ult}$. The total bending moments in the ultimate state, shown in Table 3, were calculated from the formula

$$M_P = M^{j,k}_{R,i} = P^{j,k}_{i,ult} \frac{a_k(l_j - a_k)}{l_j}. \tag{3.1}$$

Also uniform bearing load q_{ult} was calculated, and on this basis the bending moment resistance for one fold (Table 3) was calculated from the equation

$$M_{R,1} = M^{j}_{R,q} = 0.125 q^{j}_{ult} l^2_j. \tag{3.2}$$

Table 3 contains also equivalent concentrated load coefficients for a directly loaded single fold in the limit state, calculated from the formula

$$k_{ult} = \frac{M^{j}_{R,q}}{M^{j,k}_{R,i}}. \tag{3.3}$$

Coefficient k_{ult} is the measure of coaction between the folds adjacent to the loaded fold. A low value of k_{ult} indicates a high degree of coaction. In order to compare the stresses in the elastic state and in the ultimate state in the considered folds, elastic coefficient k_{el} of the equivalent concentrated load acting on the fold to which the load was applied is given in Table 3.

Table 3

Coefficients of the both equivalent elastic load (k_{el}) and ultimate load (k_{ult}) of a corrugated sheet under concentrated load P_i.

Współczynniki zastępczego obciążenia sprężystego (k_{el}) oraz granicznego (k_{ult}) fałdy bezpośrednio obciążonej siłą skupioną P_i

P_i c	l_j	M_P [kNm]			$M_{R,1}$ [kNm]	$k_{ult} = M_{R,1}/M_P$			k_{el}		
		a_k/l_j				a_k/l_j					
		0.166	0.333	0.500		0.166	0.333	0.500	0.166	0.333	0.500
P_1	1500	1.16	1.48	1.52	0.775	0.67	0.52	0.51	0.94	0.83	0.72
	2000	1.45	1.56	1.62	0.775	0.54	0.50	0.48	0.90	0.78	0.67
	2500	1.54	1.66	1.73	0.775	0.50	0.47	0.45	0.87	0.73	0.63
	3000	1.54	1.71	1.79	0.775	0.50	0.45	0.43	0.83	0.68	0.60
P_2	1500	1.07	1.43	1.46	0.775	0.73	0.54	0.53	0.91	0.81	0.71
	2000	1.38	1.47	1.50	0.775	0.56	0.53	0.52	0.89	0.79	0.69
	2500	1.43	1.49	1.53	0.775	0.54	0.52	0.51	0.87	0.76	0.66
	3000	1.46	1.51	1.55	0.775	0.53	0.51	0.50	0.85	0.73	0.64

The analysis of stress distribution in the individual folds shows that the directly loaded folds take over as much as 94% of the concentrated load P_i. in the elastic range

(Table 1) and up to 67% in the limit state (Table 3). A comparison of the corrugated sheets loaded by concentrated forces P_1 and P_2 shows a difference of less than 6% in stressing for the directly loaded folds (in both the elastic range and the ultimate state). In the case of the models loaded by force P_2, the stressing of the fold situated along the sheet's side does not exceed 8% of P_2 in the elastic range.

The numerical analyses show that load-displacement relations for the tested corrugated sheets (Fig. 5) are nonlinear as load increases, so does the coaction of the folds adjacent to the loaded fold (Table 3). This means that in comparison with the adjacent folds, the part of the load which is carried by the directly loaded fold is larger in the elastic range than in the ultimate state. This is shown in Figs 6 and 7, where elastic coefficient k_{el} and ultimate k_{ult} coefficient of the equivalent load of the fold are compared. For instance, the corrugated sheet with parameters P_1, l_2 = 2000 mm, a_k/l_j = 0.500 carries 0.67 P_1 in the elastic range and 0.48 P_1 in the ultimate state.

In both stages, the interaction between the individual folds decreases when the concentrated force is located closer to the supporting zone (Table 1 and 2, Figs 6 and 7). The highest degree of coaction between the adjacent folds is observed when the concentrated force is applied in the midspan of the corrugated sheet (then the equivalent load coefficients for the directly loaded fold are the lowest). The larger the corrugated sheet span, the higher the degree of coaction between the directly loaded fold and the adjacent folds (in both the elastic range and the ultimate state – Figs 6 and 7).

4. Evaluation of ultimate limit state of corrugated sheets subjected to bending by concentrated force

Experimental investigations (Biegus, Kowal [2]) and the numerical FEM analyses have shown that the main part of concentrated load P_i (0.94-0.60P in the elastic range and 0.88-0.47 P in the ultimate state) is carried by the directly loaded fold. The adjacent folds carry 0.02-0.16P in the elastic range and 0.04-0.23P in the ultimate state. The coaction in concentrated load carrying between the adjacent folds and the directly loaded fold is an evidence of the plate behavior of the corrugated sheets (despite the considerable differences in bending stiffness in the two perpendicular directions). Moreover, this means that the directly loaded fold carries only a part of the concentrated force.

The coefficient of the equivalent concentrated load carried by the directly loaded fold was calculated from

$$k = \frac{M_{R,1}}{M_P}, \tag{4.1}$$

where:

$M_{R,1}$ – the bending moment resistance of the fold's cross section,

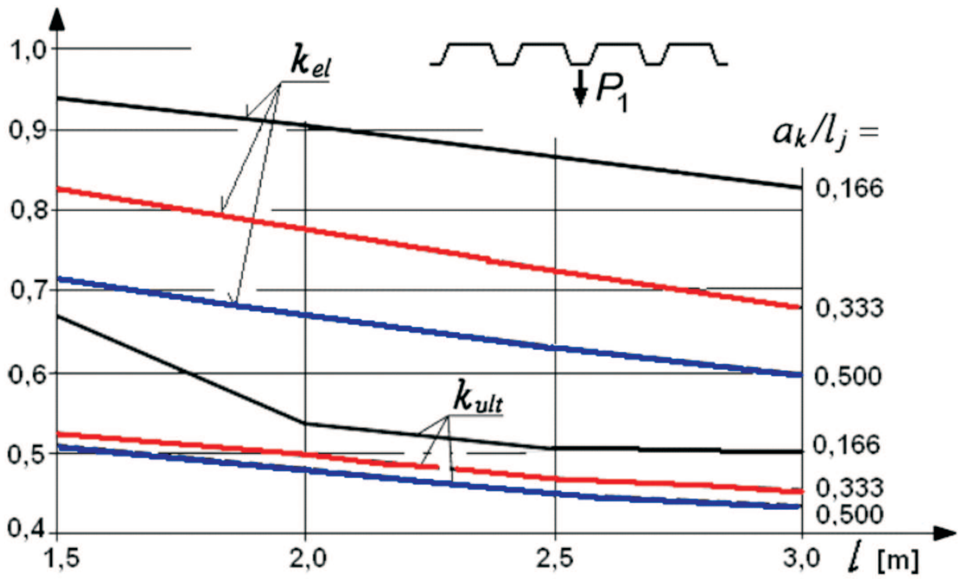


Fig. 6. Coefficients k_{el}, k_{ult} for a fold under concentrated load P_1 as functions of a span.
Rys. 6. Współczynniki k_{el} i k_{ult} fałdy obciążonej siłą P_1 w funkcji rozpiętości przęsła $l$oraz a_k/l_j

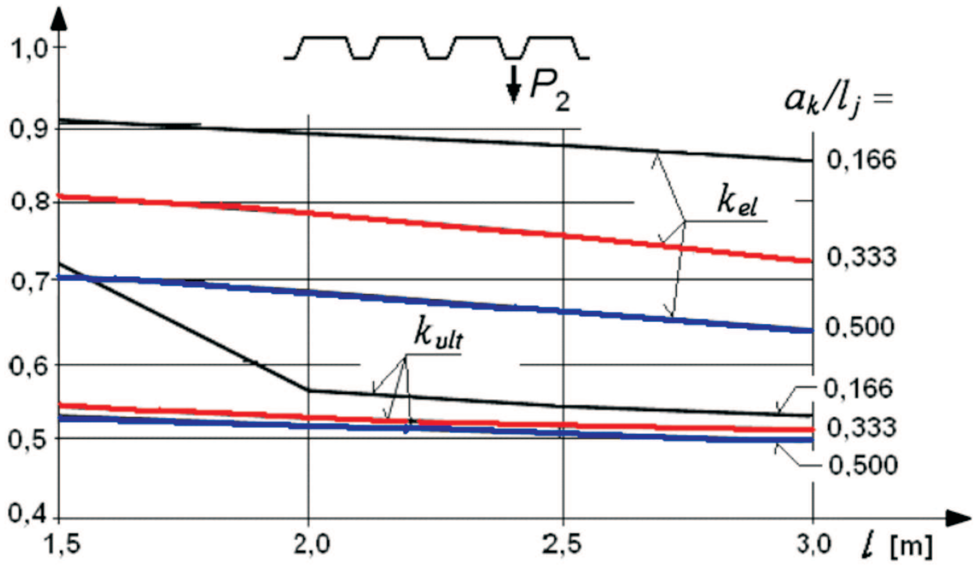


Fig. 7. Coefficients k_{el}, k_{ult} for a fold under concentrated load P_2 as functions of a span.
Rys. 7. Współczynniki k_{el} i k_{ult} fałdy obciążonej siłą P_2 w funkcji rozpiętości przęsła $l$oraz a_k/l_j

M_P – the bending moment resistance of the entire corrugated sheet.

This coefficient can be determined experimentally or numerically by FEM. The coefficients (k_{el} and k_{ult}. for respectively the elastic range and the ultimate state) of the equivalent concentrated load per one fold, determined by the parametric FEM analyses, are shown in Table 3.

Thanks to the proposed method, the load resistance of a corrugated sheet subjected to bending by a concentrated force can be evaluated on the basis of an analysis of a single fold loaded by an equivalent concentrated force calculated from

$$P_z = kP. \tag{4.2}$$

The load bearing capacity of a single corrugated-sheet fold loaded uniformly by q and by concentrated force P should be verified by analyzing the stress level in the critical cross sections (i) of the system (for instance, at the support or in the mid-span), according to the formula

$$M_{q,1} + M_{Pz} \leqslant M_{R,1,i}, \tag{4.3}$$

where:

$M_{q},_{1}$ – the bending moment generated by uniformly distributed load q, for a single fold;

M_{Pz} – the bending moment in a single fold, caused by equivalent concentrated load P_z, Eq. (4.2);

$M_{R},_{1,i}$ – the moment resistance in cross section i for a single fold at the support or in the mid-span.

Thanks to the simplicity of the adopted model, the proposed method of evaluating the load resistance of corrugated sheets locally, loaded by concentrated forces, originating from suspended technical fixtures, is simple and useful for design purposes. However, in order to be commonly used in practice, equivalent coefficients k of the concentrated forces for the directly loaded fold need to be (numerically or experimentally) determined and included in the manufacturer catalogues. Moment resistances $M_{R},_{1,i}$ for the cross section of a single corrugated sheet fold are usually given in the catalogues.

5. Evaluation of serviceability limit state of corrugated sheets subjected to bending by concentrated force

Besides the deflection of the corrugated sheet under uniform load q, also the local increase in displacement in the region of concentrated load action should be evaluated. The deflections produced by concentrated loads can be calculated from basic strength formulas. All the calculations should be done for the characteristic (unfactored) equivalent concentrated load (Eq. (4.2)) and for the effective moment of inertia of the fold-beam; a single- or multi-span scheme should be considered.

It should be observed that large differences between the deflections of the individual folds are observed in corrugated sheets locally loaded by a concentrated force. This can adversely affect the serviceability limit state and cause such damage to the roof covering as:

- damage to the water insulation,
- gaps between corrugated sheets and the (heat and water) insulation,
- damage to insulation bonding,
- local depressions on the roof – water retention.

6. VERIFICATION OF LOAD RESISTANCE OF JOINT BETWEEN CORRUGATED SHEET AND SUSPENSION

Because of possible ovalization of the hole or tearing of the sheet, the design resistance of the fasteners joining the suspension bar (with thickness t_1) to the webs of the corrugated sheet needs to be calculated from the formula

$$S_{Rb} = \alpha_i \frac{t d f_u}{\gamma_{M2}} \tag{6.1}$$

where:

t – corrugated sheet thickness ($t < t_1$),
d – the diameter of the fastener body,
f_u – the tensile strength of the corrugated sheet steel,
$\gamma_{M2} = 1.25$ – a partial factor of load resistance,
$\alpha_i = 2.5$ for bolts,
$\alpha_i = 3.2\sqrt{\frac{t}{d}} \leq 2.1$ for one-side rivets or screws.

7. CONCLUSIONS

Technical fixtures are often mounted on the underside of roof corrugated sheets (Fig. 1) by suspending the former from single folds (Fig. 2), whereby local concentrated loads are created. In such cases, neither the single-fold beam model nor the manufacturer tables can be used in the strength analysis. The new loading configuration raises the questions: how many adjacent folds are stressed by the suspended load, and what is the resistance and stiffness of the coating plate part of the corrugated sheet?

The analyses have shown that in the ultimate state of stress, not only longitudinal bending of the folds occurs. As a result of the deformation of the cross section in the region of the applied force, local longitudinal $\sigma_{x,i}$ and transverse $\sigma_{y,i}$ stresses are produced.

In a corrugated sheet loaded by a concentrated force one can distinguish two stages of stressing: the first one is in the elastic range (the linear part of LDR) while the second one is nonlinear. The two stages differ in the stress distributions in the individual folds. In the nonlinear part of the system behavior, the coaction between the folds adjacent to the loaded fold increases.

The main part of concentrated load P_i (0.94-0.60P in the elastic range and 0.88-0.47 P in the ultimate state) is carried by the directly loaded fold. The adjacent folds carry 0.02-0.16P in the elastic range and 0.04-0.23P in the ultimate state. The coaction in concentrated load carrying between the adjacent folds and the directly loaded fold is an evidence of the plate behavior of the corrugated sheets.

The interaction between the individual folds decreases when the concentrated force is located closer to the supporting zone. The highest degree of coaction between the adjacent folds is observed when the concentrated force is applied in the mid-span of the corrugated sheet. The larger the corrugated sheet span, the higher the degree of coaction between the directly loaded fold and the adjacent folds.

Thanks to the proposed method, the load resistance of a corrugated sheet subjected to bending by a concentrated force can be evaluated on the basis of an analysis of a single fold loaded by an equivalent concentrated force. Owing to the simplicity of the adopted model, the proposed method of evaluating the load resistance of corrugated sheets locally loaded by concentrated forces originating from suspended technical fixtures is simple and useful for design purposes.

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OCENA NOŚNOŚCI GRANICZNEJ BLACH FAŁDOWYCH ZGINANYCH SIŁĄ SKUPIONĄ OD LOKALNYCH PODWIESZEŃ

S t r e s z c z e n i e

Przedmiotem pracy jest analiza nośności i sztywności blach fałdowych wytężonych obciążeniem skupionym od lokalnych podwieszeń np. „instalacji". Wykonano parametryczne badania numeryczne MES blach fałdowych o zmiennych rozpiętościach i zmiennym usytuowaniu sił skupionych na długości i szerokości arkusza. Przeanalizowano 24 modele blach fałdowych. Zidentyfikowano rozkłady wytężeń poszczególnych fałd w fazie sprężystej i w stanie granicznym nośności ustrojów. Na ich podstawie wyznaczono współczynniki zastępczych obciążeń skupionych poszczególnych fałd ustroju. Umożliwiają one analizę nośności i sztywności blach fałdowych obciążonych siłami skupionymi, która jest przydatna w projektowaniu.

Remarks on the paper should be sent to the Editorial Office no later than March 30, 2011

Received December 16, 2009 revised version December 18, 2010