1. INTRODUCTION

In presently manufactured SIN girders [16] with corrugated (undulated) webs, sinusoidal webs have three elementary thicknesses of $t = 2.0, 2.5$ and $3.0$ mm, and the wave amplitude is $40$ mm. The height of available girders ranges from $333$ to $1500$ mm while the maximum length of the items is up to $20$ m. In long girders, problems are found that concern low shear resistance of webs in the near-support zones. The sheets are pressed using rolling dies that create desired corrugations. The hot-rolled flat sheets have the minimum mill-guaranteed yield strength of $R_{e_{\text{min}}} = 235$ MPa [22]. $R_{e_{\text{min}}}$ is determined merely on the basis of investigations into steel samples that were conducted prior to corrugation. Steel sheets with the yield strength lower than $235$ MPa are rejected. The manufacturer of corrugated webs ensures that the yield strength is $R_e = 215$ MPa [16]. That corresponds to design strength $f_d$ for structural components made of St3SX steel with the thickness below $16$ mm acc. standard [25]. Alternatively, corrugated webs were made of St37-2G steel, acc. German standard DIN [26], in which $R_{e_{\text{min}}}$ was $215$ MPa. The guaranteed yield strength $R_e$ is lower than the yield strength of flat sheet if the advantageous effect of cold rolling in steel sheet corrugation on a change in mechanical properties is disregarded [18]. The guidelines [16] do not account for the beneficial effect of web sheet corrugation. That provides a certain safety margin in the structural reliability of the corrugated web.

Statistical investigations into the strength of structural steel properties were conducted by Sowa, Murzewski, and Mendera [9, 10, 11]. The mechanical properties of thin (0.5–2 mm) steel sheets were examined by Gwóźdź and Machowski in the years 2005–2010 [8]. The authors discussed the yield strength range for thin flat sheets that had thicknesses applicable to the manufacture of corrugated webs.
Based on the investigations, steel yield strength distributions were derived and factors of variation in yield strength \( V_{Re} = D(R_e)/E(R_e) \) were computed, where \( D(R_e) \) denotes standard deviation of yield strength \( R_e \), and \( E(R_e) \) – the mean value of yield strength \( R_e \) (notations in accordance with quantile algebra). On the basis of coefficients of variations \( V_{Re} \), partial factors of the yield strength \( \gamma_m \) were estimated.

Because of the shape and thickness of the corrugated web in SIN girders, numerous phenomena occur that are related to web shear resistance. They are reported in studies [1, 2, 5, 6, 7]. In those phenomena, an important role is played by random variation in the material strength. Currently, for the resistance computations of already corrugated webs, according to recommendations [16] the yield strength of 215 MPa, guaranteed by the web manufacturer is assumed. The work hardening in corrugation that changes parameters of steel strength properties is not taken into account. Corrugated sheet bending along the wave is also disregarded (Fig. 1).

The span of the SIN girder is limited by the shear resistance of the corrugated web. Shear resistance of the thin-walled web depends on corrugation geometry and yield strength of the steel web. Shear resistance of the web depends also on thickness and depth of the web. Consequently, investigations into steel strength and the scatter of sheet thicknesses were conducted.

Yield strength of the corrugated web results from the individual stages of the manufacturing process:
1) in the casting process at the steel mill, the so-called slab, i.e. plate, 220 mm in thickness is produced;
2) the second stage involves rough hot rolling;
3) in the third stage, sheet metal is hot-rolled to the required thicknesses of 2; 2.5, and 3 mm;
4) the fourth stage consists in the cooling of flat sheet metal and winding it onto a coil, the internal diameter of which is 740–760 mm. The consecutive stages include:
5) decoiling
6) cold straightening
7) longitudinal slitting
8) the last stage involves by cold-formed corrugation (Fig. 1).

Due to cold process of thin sheet folding, stress state along the wave occurs, which is shown in Fig. 1.

In European standards [17, 20], the assessment of random strength of the material is based on the method of load coefficients and load bearing capacity coefficients. Partial factor for a material property, also accounting model uncertainties and dimensional variations \( \gamma_m \) calculated from formula (1) were referred to the characteristic values \( R_k \) [20]:

\[
\gamma_M = \frac{R_k}{R_d} = \gamma_m\gamma_{rd}
\]  

where: \( R_k \) – characteristic values (5% fractile at a given level of probability),
\( R_d \) - design values, \( \gamma_m \) – partial factor of the material property acc. standard [20], \( \gamma_{rd} \) - partial factor associated with the uncertainty of the resistance model acc. standard [20].

This study presents the results of statistical investigations into random parameters of strength properties of steel from corrugated webs 2, 2.5 and 3 mm in thickness. Investigations were performed for samples randomly collected from twenty SIN girders that were earlier subjected to testing. Based on the investigations, variation coefficients of yield strength \( V_{Re} \) and partial coefficients of yield strength \( \gamma_m \) were obtained. They were compared with the factors found in the investigations into thin flat sheets [6, 7]. It was proposed that the value of yield strength in the computations of strength of SIN girders should be applied in a uniform manner.
Table 1.
Program of investigations

<table>
<thead>
<tr>
<th>Girder</th>
<th>( h_w \times t_w ) [mm]</th>
<th>End Stiffener [mm]</th>
<th>( L ) [mm]</th>
<th>Girder</th>
<th>( h_w \times t_w )</th>
<th>End Stiffener [mm]</th>
<th>( L ) [mm]</th>
</tr>
</thead>
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<tr>
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<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>M 1.11</td>
<td>500x2</td>
<td>300x25</td>
<td>7825</td>
<td>M 1.12</td>
<td>500x2</td>
<td>300x25</td>
<td>6000</td>
</tr>
<tr>
<td>M 1.21</td>
<td>1000x2.5</td>
<td>300x25</td>
<td>7825</td>
<td>M 1.22</td>
<td>1000x2</td>
<td>300x25</td>
<td>6000</td>
</tr>
<tr>
<td>M 1.31</td>
<td>1000x2.5</td>
<td>300x25</td>
<td>7825</td>
<td>M 1.32</td>
<td>1000x2.5</td>
<td>300x25</td>
<td>6000</td>
</tr>
<tr>
<td>M 1.41</td>
<td>1250x2</td>
<td>300x25</td>
<td>7825</td>
<td>M 1.42</td>
<td>1250x2</td>
<td>300x25</td>
<td>6000</td>
</tr>
<tr>
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<td>300x25</td>
<td>7825</td>
<td>M 1.52</td>
<td>1500x2</td>
<td>300x25</td>
<td>6000</td>
</tr>
<tr>
<td>M 2.11</td>
<td>500x2.5</td>
<td>300x25</td>
<td>5825</td>
<td>M 2.12</td>
<td>500x2</td>
<td>300x25</td>
<td>3750</td>
</tr>
<tr>
<td>M 2.21</td>
<td>1000x2</td>
<td>300x25+tee bar</td>
<td>5825</td>
<td>M 2.22</td>
<td>1000x2</td>
<td>300x25</td>
<td>3750</td>
</tr>
<tr>
<td>M 2.31</td>
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<td>300x25+tee bar</td>
<td>5825</td>
<td>M 2.32</td>
<td>1000x2.5</td>
<td>300x25</td>
<td>3750</td>
</tr>
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<td>1000x3</td>
<td>300x25+tee bar</td>
<td>5825</td>
<td>M 2.42</td>
<td>1000x3</td>
<td>300x25</td>
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<td>5825</td>
<td>M 2.52</td>
<td>1500x3</td>
<td>300x25</td>
<td>3750</td>
</tr>
</tbody>
</table>

Figure 2.
Girders with corrugated webs, from which samples used in investigations into strength properties of corrugated webs were collected:
a) with a flexible end stiffener; b) with a rigid end stiffener; c) cantilever girders
Figure 3.
Girders at the test stand a) beam girder M 1.41 WTA 1250/300x15; b) cantilever girder M 152 WTA 1500/300x15
2. INVESTIGATIONS INTO CORRUGATED WEBS OF GIRDERs

The first stage of investigations covered twenty research models of girders with corrugated web, the load diagram of which was that of a simply supported beam, or a simply supported beam with a single cantilever. Three types of beams geometry were distinguished (Table 1): a) girders with a flexible end stiffener (Fig. 2a); b) girders with a rigid end stiffener (Fig. 2b); c) cantilever girders (Fig. 2c).

The girder group under consideration comprised twelve WTA models with the web basic thicknesses of 2 mm, six WTB models having the web thickness of 2.5 mm, and two WTC models with the web thicknesses of 3 mm.

Research models of girders with corrugated webs were designed and produced in accordance with literature data and standards [19, 21]. Corrugated webs of girders were made from flat S235JRG2 steel sheets that were hot-rolled to the thickness of 2; 2.5 and 3 mm, whereas flanges were made from S275JRG2 steel [15]. It should be added that individual girders came from different batches. Each batch was provided with mill certificates indicating the grade of steel products.

Girders were assembled from items (Fig. 2) prefabricated at the plant. The items of the girders were butt-connected using High Strength Friction Grip (HSFG) bolts. Girders were tested (Fig. 3) until ultimate resistance was reached, which resulted from the condition for web failure in the span or cantilever part of the girder. The load, considered as a concentrated force P, is transferred from frame (R) by means of the actuator (1) via a dynamometer (2) or a plate (3), to the end plate of the span or cantilever part of the girder (4).

Samples were collected from examined girders to conduct materials tests on web steel, which limits the ultimate resistance of girders.

3. MATERIALS TESTS ON STEEL USED IN THE WEBS OF SIN GIRDERs

Six samples were collected from the web of each examined girder. The samples came from the areas with the lowest stress intensity level. In the first stage, the corrugated web part was cut out of undamaged area (box-marked in Fig. 4).

Then, standard samples were cut out of the plate along the fold (Fig. 6) and machined using a milling
Samples were cut out in such a way so that the contour of the samples was kept away from the edge on which permanent deformations and dislocations occurred.

Web strength parameters change in accordance with a change in the sinusoidal geometry of the web. Yield strength increment is altered, which occurs at the sinusoidal wave crests. At “zero” wave inflection points, yield strength remains almost unaltered. The samples were cut out at the sites near connections to flanges, where the corrugated sheet was under maximum stress (Fig. 5), which was found on the basis of computed yield strength. That was done to obtain more reliable strength estimates.

Investigations into strength properties of steel samples from webs and flanges were carried out acc. standard [24]. Samples were cut out of webs with “tenfold” base (Fig. 6). Geometric dimensions of the samples were measured using Vernier Callipers with 0.1 mm graduation. Altogether, 120 samples were examined, including: 12 x 6 = 72 samples with nominal thickness of 2 mm, 6 x 6 = 36 samples nominal thickness of 2.5 mm and 2 x 6 = 12 samples with nominal thickness of 3 mm.

The results of investigations were influenced by the following: the direction of sheet hot-rolling, the direction of sheet folding, and tensile tests on samples along the fold direction.

Investigations into strength properties were conducted using PUL 400 VEB Werkstoffprüfmaschinen Leipzig testing machine. In the tests, it was tried not to exceed the stress increment rate of 8 MPa/s, which corresponded to the tensile force increment level of 0.4 kN/s. In the tests, tensile force \( F \) and the elongation \( \Delta L(L_0– L) \) of the gauge base of samples \( L_0 \) (Fig. 6) were measured. The results of yield strength \( R_y \), tensile strength \( R_m \), elongation \( A_{10} \) measurements are presented in Table 2.

Anomalies in steel metallurgical structure were not found in any samples of the tested material. The sample fracture was regular and showed uniform structure of the material (Fig. 7).

On the basis of investigations, graphs (Figs. 8 and 9) of the dependence \( F – \Delta L \) and also \( \Delta F \) were plotted. In the graphs, the values of forces \( F_{el} \) and \( F_{el2} \) corresponding to yield strength \( R_y \) and also the values of forces \( F_m \) corresponding to tensile strength \( R_m \) were marked. For a majority of samples, graphs clearly indicated plateau that specify the material’s yield strength. However, due to the corrugated web manufacturing process that involves folding and cold-rolling, the plastic flow zone represented by Lüders-Czernov’s lines was clearly short. A distinct difference between upper and lower yield strength was not
observed (Fig. 8), which is advantageous for the bearing capacity of corrugated sheets.

As regards the graphs of the static tensile test for samples that did not show discontinuities clearly indicating the material yield strength, the conventional yield strength was identified as the one corresponding to 0.2% of the permanent elongation of the samples.

Sheet corrugation produced changes in the material structure, which resulted in the shortening of the plastic flow zone and obscuration of a clear yield

<table>
<thead>
<tr>
<th>Table 2. Parameters of yield strength and tensile strength tests on web samples</th>
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<tbody>
<tr>
<td>Girder number</td>
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<tr>
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</tr>
<tr>
<td>1</td>
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<td>M 1.11</td>
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<td>M 1.51*</td>
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<td>M 1.42*</td>
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<td>M 2.12</td>
</tr>
<tr>
<td>M 2.22</td>
</tr>
<tr>
<td>M 2.52</td>
</tr>
</tbody>
</table>

Mean value for 2 mm samples: 305.1 kN, 404.1 MPa

Mean value for ~2.5 mm samples: 310.2 kN, 430.6 MPa

Mean value for 3 mm samples: 385.7 kN, 483.0 MPa

Mean value for all samples: 310.2 kN, 419.2 MPa

* samples without clear yield plateau

Figure 7. View of an exemplary 2.5 mm thick sample cut out of WTB girder web

Figure 8. Graph $F - \Delta L$ of tension of 3 mm thick steel sample cut out of the web of M 2.42 girder
strength in as many as 25% of samples. Consequently, the elongation range of samples was from 13 to 25%, and it was reduced when compared with steel that was not cold-rolled. In Table 1, the samples that did not show clear yield strength were denoted with *.

4. YIELD STRENGTH FACTORS \( \gamma_m \) ALONG THE FOLD

The guaranteed yield strength of the supplied flat sheets, from which corrugated webs are made is presented as the minimum value specified by the mill on the basis of relevant standards [20, 21] and it is given by the manufacturer as \( R_{em1} = 235 \) MPa. Mill-specified minimum values are determined on the basis of tests on samples of steel sheets as the yield strength of a given batch of products, which is not lower than 235 MPa without specifying the lower quantile.

On the basis of structural analysis, partial factors for material properties \( \gamma_m \) of the steel of corrugated webs were analysed. As regards probability density distribution \( R_e \), the parameters of normal distribution were applied [20]. The variance \( D^2(R_e) \) and standard deviation \( D(R_e) \) of yield strength were determined for the examined samples.

For the determined parameters of normal distribution of yield strength \( R_e \), characteristic values \( R_{ek} \) or 5% fractile recommended by the standard PN-EN 1990 were determined from formula (2):

\[
R_{ek} = E(R_e)(1-1.64V_{Re}) \tag{2}
\]

where: \( E(R_e) \) – the mean value of yield strength \( R_e \), \( V_{Re} \) – coefficients of variations yield strength \( R_e \).

Partial factors for material properties \( \gamma_m \) show the relationship between characteristic and design values of yield strength. They result from the transformation of the design formula for yield strength calculations [20]:

\[
\gamma_m = \frac{R_{ek}}{E(R_e) - 3.04D(R_e)} \tag{3}
\]

where: \( \gamma_m \) – partial factor for material properties \( R_e \), \( D(R_e) \) – standard deviation of yield strength \( R_e \).

To illustrate the level of structural reliability, coefficients of variations of yield strength were estimated. First, the actual coefficients \( V_{Re} \) obtained from materials tests were estimated. The next stage involved comparison of the reliability level obtained from the tests with that declared by the manufacturer of corrugated webs. The coefficients of yield strength variation were compared with the minimum yield strength guaranteed by the steel mill \( R_{em1} = 235 \) MPa, and yield strength guaranteed by the manufacturer \( R_{em2} = 215 \) MPa. In this way, characteristic values of yield strength were substituted with values \( R_{em1} \) and \( R_{em2} \). Coefficients \( V_{Re} \), \( V_{Re235} \) and \( V_{Re215} \) were determined from formula (4):
Then, coefficients of yield strength were determined acc. [8] from formula (5):

\[ V_{Re} = \frac{D(R_e)}{E(R_e)} \quad \text{and} \quad V_{Re235} = \frac{1 - \frac{R_{\text{min},1}}{E(R_e)}}{1.64} \]

\[ V_{Re215} = \frac{1 - \frac{R_{\text{min},2}}{E(R_e)}}{1.64} \quad \text{(4)} \]

Then, coefficients of yield strength \( \gamma_n \): \( \gamma_{n235} \) and \( \gamma_{n215} \) directly showing the level of reliability were referred to the yield strength being used, thus they were estimated for the steel mill guaranteed minimum \( R_{\text{min},1} = 235 \) MPa, and the manufacturer guaranteed yield strength \( R_{\text{min},2} = 215 \) MPa. The coefficients were determined acc. [8] from formula (5):

\[ \gamma_{n,235} = \frac{R_{\text{min},1}}{E(R_e) - 3.04D(R_e)} \]

\[ \gamma_{n,215} = \frac{R_{\text{min},2}}{E(R_e) - 3.04D(R_e)} \quad \text{(5)} \]

Parameters of normal distribution and partial factors of yield strength that were obtained are shown in Table 3.

Figure 10 shows exemplary normal distributions of yield strength obtained for samples of corrugated webs of M 2.12 and M 1.31 models. Mean \( E(R_e) \) yield strength and design yield strength \( f_y \) were marked (acc. formula (2) i.e.
According to investigations, mean coefficients of variation $V_{Re}$ that illustrate the structural reliability level range $0.01 < V_{Re} < 0.03$. In reference to the standard [23], coefficients of variation range $0.06 < V_{Re} < 0.22$. Then, in reference to yield strength stated by the manufacturer, coefficients of variation are found in the range $0.10 < V_{Re} < 0.31$. They are overestimated 2 to 10 times relative to coefficients of variation $V_{Re}$ obtained from investigations. All those measures result in increased, surplus structural reliability. They, however, do not solve the problem of shear resistance of large-span girders that require enhanced shear resistance of webs.

Coefficients of variation mentioned above indicate great caution exercised by both the steel mills and manufacturers of corrugated webs, who adopt reduced mean yield strength $E(Re)$.

That is confirmed by the obtained values of partial factors of yield strength $\gamma_m$, which are marked in Fig.11. The boundary of partial factor of yield strength, which separates the characteristic value of yield strength from the design one is represented as a continuous line.

The obtained values of coefficients $\gamma_{m235}$ and $\gamma_{m215}$ are lower than 1.0, i.e. the value recommended in the standards [17, 20]. They do not correspond to coefficients $\gamma_m = 1.01 – 1.04$ from the investigations. Conversely, yield strength coefficients $m$ from the experimental tests are slightly lower than coefficients $\gamma_m = 1.04 – 1.14$ presented in large-scale statistical investigations [8, 9, 10, 11].

The obtained values of coefficients $\gamma_{m215}$ that are much lower than 1.0 (column (11), Table 3) indicate that the adopted design values [16] of steel yield strength of 215 MPa in manufactured corrugated webs is not statistically justified for a broadly understood representative sample. In addition, the assumed value of the corrugated web steel yield strength of 235 MPa does correspond to the reported investigations, either.

Corrugated web yield strength for the convex part of the wave, where increase in yield strength of cold-formed elements is enhanced, is also given in standard [18] on the basis of formula (6):

$$f_y = f_{y0} + (f_u - f_{y0})k \frac{t_w^2}{s}.$$  \hspace{1cm} (6)

where: $f_{y0}$ – yield strength of the starting material 235 MPa, $f_u$ – tensile strength of the starting material 360 MPa, $n$ = 1 number of folds (one fold per corrugation), $k$ = 7 coefficient dependent on profile type, $s$ = 77.5 length of waveform segment, $t_w$ – web thickness.

When corrugated web is treated as an element with one inflection point, for the yield strength of the starting material 235 MPa, the design yield strength is obtained depending on the web thickness given in Table 4.

| Table 4. Steel yield strength that accounts for the impact of cold rolling acc. (6) [18]: |
|-----------------|-------------------|-------------------|
| web thickness | Design yield strength $f_y$ [MPa] |
| 2 mm | 2.5 mm | 2 mm |
| 2 mm | 254.7 | 259.6 | 264.5 |
However, as many as 25% of the results for samples did not reach the values resulting from formula (6) \[18\]. The reason is the fact that different steel grades were used for the manufacture of corrugated webs. Yet, in the certificate, the manufacturer gave only one steel grade, namely S235JR G2. This fact illustrates the range of variation in normal distribution derived for the entire group of examined samples:

![Gaussian distribution of yield strength in all examined steel samples cut out of corrugated webs](Image)

Table 5. Parameters of normal distribution of geometric dimensions of steel samples from corrugated webs and of resistance obtained according to formulae (7) and (8)

<table>
<thead>
<tr>
<th>Model</th>
<th>( \bar{b}_0 )</th>
<th>( \bar{a}_0 )</th>
<th>( \bar{s}_0 )</th>
<th>( D^2(A) )</th>
<th>( D(A) )</th>
<th>( V_A )</th>
<th>( D^2(N) )</th>
<th>( D(N) )</th>
<th>( V_N )</th>
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<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>mm²</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value for 2 mm samples</td>
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<td>19.98</td>
<td>39.95</td>
<td>0.030</td>
<td>0.170</td>
<td>0.004</td>
<td>0.057</td>
<td>0.217</td>
<td>0.018</td>
</tr>
<tr>
<td>Mean value for 2.5 mm samples</td>
<td>2.57</td>
<td>19.92</td>
<td>51.18</td>
<td>1.111</td>
<td>1.054</td>
<td>0.021</td>
<td>0.209</td>
<td>0.457</td>
<td>0.030</td>
</tr>
<tr>
<td>Mean value for 3 mm samples</td>
<td>3.0</td>
<td>20.0</td>
<td>60.0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.462</td>
<td>0.680</td>
<td>0.029</td>
</tr>
</tbody>
</table>

where: \( N_k \) – fractile of resistance of tension member.

Random impacts of geometry and yield strength sum up in accordance with the principles of quantile algebra. The impact of random cross-sectional area and yield strength on the cumulative result is expressed by formula (8):

\[
N_k = E(N) - 3.04D(N) = E(N)\left(1 - 3.04\frac{D(N)}{E(N)}\right), \quad \text{(8)}
\]

where: \( N_k \) – fractile of resistance of tension member. Table 5 shows parameters of normal distribution of geometric dimensions of steel samples from corrugated webs, and of member resistance.

Estimated coefficient of variation \( V_A \) in sample cross-section indicates a substantial impact of cross-sectional area on the resistance of members made from web having the basic thickness of 2.5 mm. As regards 2 and 3 mm thick sheets, the influence of the cross-sectional area scatter is low enough to be disregarded. However, it should be emphasised that the number of samples with different thickness varied significantly. Therefore, mean values, especially standard deviation adopted for the evaluation of partial factors, are fractions with different probability level.

On the other hand, resistance variation factor \( V_N = D(N)/E(N) \) for steels used in the manufacture of corrugated webs should follow a clearly specified procedure. That could be done if the manufacturer gives the description of the steel used in cold forming process of sheet folding.

The investigations conducted for the study indicate that when dimensioning structures made of girders with corrugated web, it is possible to apply the design yield strength \( f_y \) obtained in the tests (see Table 3), which is equal to 242 MPa. It should be added that investigations concerned the samples collected from undamaged locations in girders that were tested beforehand.
5. CONCLUSIONS

General conclusion:
The span of plate girders with corrugated web is limited by web shear resistance. The latter is affected by the quantile of the product of yield strength and random cross-sectional area of corrugated the web.

With respect to yield strength, the following should be stated:

1) The investigations indicate that when dimensioning girders with corrugated web, it is possible to apply the design yield strength \( f_y = 240 \) MPa.

2) For the manufacture of corrugated webs, steels that have clearly different yield strengths are used.

3) Yield strengths of prefabricated corrugated webs, separately from each girder, are characterised by high congruence of results and low scatter.

4) Yield strengths put together from different batches show considerable scatter of results and have values that are higher than those given by manufacturers of corrugated webs. The values are also higher than the recommended ones. That may result in a situation in which structural members delivered to the construction site differ substantially in strength parameters.

5) The analysis of variation coefficients \( V_{0,0} \) and partial coefficients of yield strength shows that cold rolling phenomenon was not accounted for in the quoted parameters of yield strength in finished webs. Variation coefficients referred to yield strength declared by the manufacturer \( R_{\text{min},2} = 215 \) MPa are overestimated, from 2 to 4 times, relative to variation coefficients \( V_{0,0} \) obtained from investigations.

6) Due to the fact that the variation in resistance of girders with corrugated web is substantially affected by yield strength of steel of corrugated webs, the manufactured structural elements should be provided with the results of the materials tests for the web. They would show actual distributions of yield strength in steel webs and prove the reliability of structural members.

7) The direction of hot rolling, coiling and cold rolling of steel sheet intended for corrugated web of SIN girders is always perpendicular to the wave being formed. That is significant for the corrugated web dimensioning.

8) When yield strength of finished corrugated webs is given, it is recommended that the relation should be specified between the design yield strength and its mean value having the form:

\[
f_y = E(R_e) - 3.04D(R_e)\tag{9}
\]

Concerning the cross-section, the following should be stated:

1) In the tests conducted by mills, random scatter of the thickness of sample section is not accounted for.

2) Estimated coefficient of variations \( V_A \) for sample sections show substantial cross section impact on the resistance of elements made from web steel having a basic thickness of 2.5 mm. For 2 and 3 mm thick sheets, the influence of the scatter of cross-sectional area on the member resistance is small.

Regardless of the comments above, it should be noted that despite underestimating of the actual yield strength of steel used for the manufacture of corrugated webs, shear resistance of webs puts a limit on the span of SIN girders. Maintaining shear resistance of the web is possible by using tension diagonal braces in the near-support zones of the girders [3, 4], in which the shear load is greater than the web shear resistance.

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