LIGHTWEIGHT STRUCTURES in CIVIL ENGINEERING
CONTEMPORARY PROBLEMS
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MEASUREMENT METHODS OF TRAPEZOIDAL SHEETING IMPERFECTIONS

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ABSTRACT: The aim of the paper is to find an alternative method to measure the imperfections of lightweight steel profiles. The 3D laser scanning is a costly way to take precision measures and import them in CAD software. The paper shows how for engineering purposes it is enough taking photos around the structure to obtain a 3D model of it. This method ensures a good precision to measure the imperfections of sheeting profiles and requires only a high-resolution camera and a software to convert the images into a dense points cloud. In the paper the comparison of traditional and digital measurement methods is performed. At first, the specimens are measured using ruler, callipers and, to improve the precision, the shape of edges is sketched on sheets of paper. The same specimens are measured by digital method using special software to correct the distortions due to the perspective, which allowed for making the measure directly on the shape of the edges visible on the photos. Finally, there was used a software to obtain 3D model from the photos taken around the specimens and based on this model, the measures of all the parts of the sheeting profiles can be carried out. The final objective of the research is to find the best way in terms of precision and costs of measures the imperfections of trapezoidal sheeting.

Keywords: Photo-scanning, photogrammetry, imperfections, measures, trapezoidal sheeting, 3D model.

1. INTRODUCTION

The complex geometry of lightweight steel profiles not allow to take precision measures using ruler and callipers. This is due to the rounded corners and the in plane geometrical imperfections of the trapezoidal sheeting. To avoid this problem the comparison of different measuring methods of steel profiles in order to find the best and fastest way to obtain high precision of measure was performed.

In the field of precision measurement exist different solutions. For engineering purpose in case of trapezoidal sheeting it can be used special software to create automatically a 3D model from photos taken 360° around the structure. This method ensures a good precision to measure the imperfections of sheeting profiles and requires only a high-resolution camera and a software to convert the images into a dense points cloud.

2. PROBLEM FORMULATION

To evaluate the measures of the imperfections it was considered two different approach:

1) traditional: by ruler, callipers and by tracing the shape of edges on the paper with graphite and then by measuring them with ruler;

2) digital: by taking photos of the edges and import them on Perspective Rectifier to correct the proportions and setting the scale and by taking photos around the specimen and import them on Autodesk ReCap Photo to obtain the digital model and the mesh of the imperfections.

3. NUMERICAL EXAMPLE

The validation of different methods of measurement of imperfections, was performed on BTR153 trapezoidal steel sheet profile by Balex company (Ref. 1), illustrated in Fig. 1.

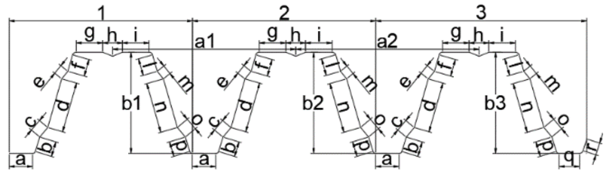
In Fig. 2, it is shown a code describing the information, which was assigned at the different folds and sides of the specimens in order to not lose data, and to not make confusion between the measures for each of these elements.

Fig. 1 BTR153 trapezoidal profile

Fig. 2 Code name for specimens

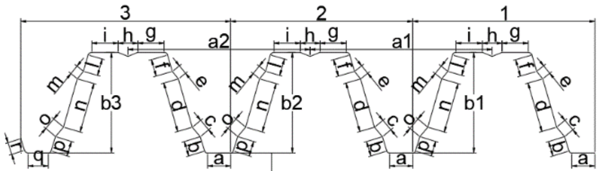
The measurement of imperfections is conducted on 2 specimens with a thickness of 1.5 mm and 2 specimens with the thickness of 0.7 mm.

The tables showed in Fig. 3 represent the results of measurements taken by callipers and compared with design values of each part of cross-section. The obtained difference is regarded as the geometrical imperfections. Taking dimensions with the callipers it's more difficult to find the centre of the round corners, so it was preferred to take the dimensions of the flat part of the profile. It leads to under estimation of the real width of the edge (Fig. 4).



I BTR 153 SIDE A thickness: 1,4 mm	a	b	c	d	e	f	g	h	i	l	m	n	o	p
1	32	23	18	74	15	25	37	31	37	27	13	69	16	26
2	33	27	14	73	14	25	38	31	39	27	15	70	15	27
3	33	28	13	74	14	25	38	31	40	25	14	73	15	26
	q	r												
	33	22												

a1	a2	b1	b2	b3
280	285	155	151	152



I BTR 153 SIDE B thickness: 1,4 mm	a	b	c	d	e	f	g	h	i	l	m	n	o	p
1	34	23	17	73	14	27	38	32	40	28	15	73	15	28
2	33	27	16	73	16	27	39	30	38	26	15	71	17	28
3	33	27	16	73	15	26	38	31	39	27	16	73	16	26
	q	r												
	33	25												

a1	a2	b1	b2	b3
285	290	152	152	150

Fig. 3 Results of measurements taken by callipers

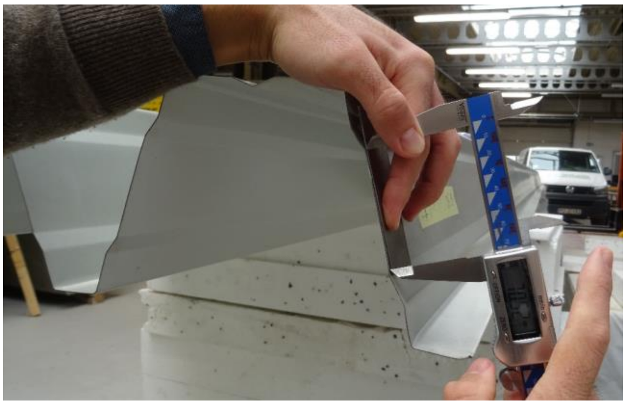


Fig. 4 Measurement technique by callipers

In Fig. 5 it can be visible how to perform the tracks of the folds on the paper sheet (side A of the specimen I) to evaluate the real shape of its edges. Based on this method it is possible to capture the imperfections due manufacturing tolerances on the edge of specimen.

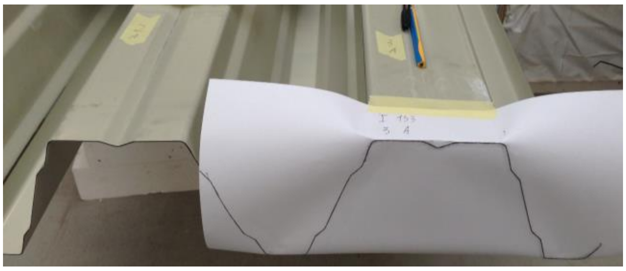


Fig.5 Tracks of edge side A folds 3

The sketch obtained from the tracks of the folds on the paper sheet was scanned and import to AutoCAD and compared with the measures taken by ruler and the exact shape of the specimen given by producer.
In Fig 6 an error of 10% between the shape obtained from the tracks and from the callipers is shown.

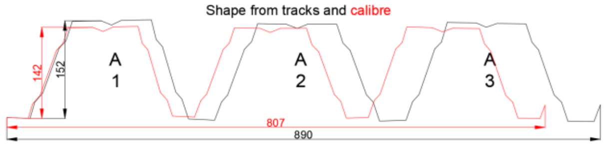


Fig. 6 Differences between tracks and callipers

During the research two computer programmes were used to take measures and analyse the imperfections, in detail, Perspective Rectifier (Ref. 2) and Recap Photo 0.
The first software can be used as an alternative method of the track on the paper. Perspective Rectifier permits to rectify pictures to take measures from digital photos. It is necessary to be careful when the pictures are taken because if the object isn't in the centre of the image or the ruler isn't in the plane of the edge, a different shape of the edge will be obtained from the correction and from the scale of the photo.
In Fig. 7 one can see a completely different proportions of the trapezoidal sheeting if the position of the ruler is in different plane then the edge of specimen. The green, red and magenta sketches illustrate the real shape of the edge obtained from the tracks.

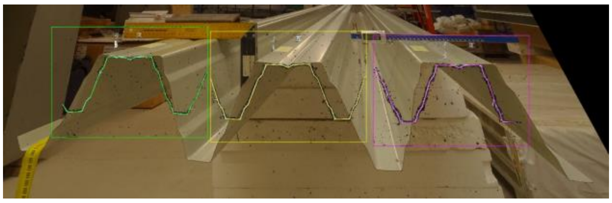


Fig. 7 Errors resulting from incorrect use of Perspective Rectifier

While in Fig. 8 it is shown the correct use of the software.

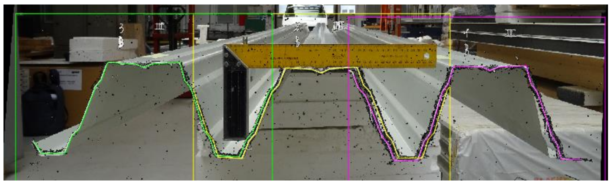


Fig. 8 Correct use of Perspective Rectifier

It is better to take a photo for each folds of the specimen, in this way it's possible to reduce the error due to prospective, visible on the side edges of the specimen. At the right side (Fig. 8) there isn't a good accordance between the overlap of the photo and the track, while in Fig. 9 the agreement is very good because the fold is in the centre of the photo.

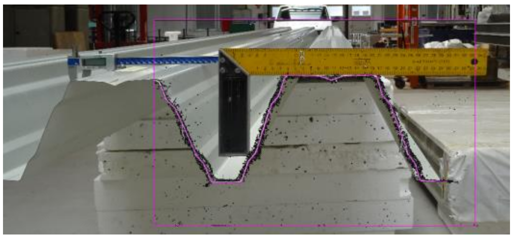


Fig. 9 Correct use of Perspective Rectifier

So, it can be concluded that it was found two ways of performing the measurement with the same accuracy.
In order to import the scans or the photos in CAD ambient and realize the draw with the exact size of the edge the following procedures were carried out. The first one, traditional, by performing the tracks of the folds shape using the calque with carbon pencil on the paper sheet. The second one, digital, by taking the pictures of the edge and use a software to correct prospective and import it into CAD.
In Fig. 10 it is illustrated the perfect match of the position of the imperfection reelevated with traditional and digital method. These kinds of imperfections aren't relevant in terms of calculation, but it was displayed to demonstrate the accuracy of the methods.

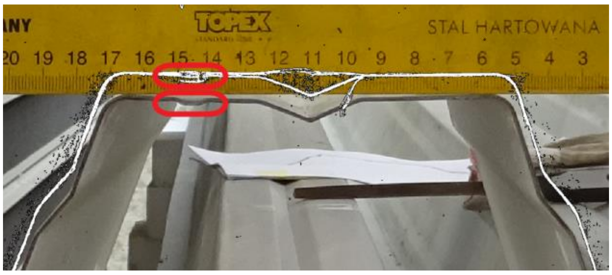


Fig. 10 Detail of edge imperfection

In terms of reliability, the traditional way seems to be better because there are no doubts on the mistakes of the prospective, but, for an experienced researcher it is possible to take good pictures and avoid the problems with prospective. On the other hand, the digital method is faster because there is only a necessity to take few photos and to use a simple software to obtain correct image.
In order to take into account the imperfections of whole trapezoidal sheeting, it is need to know the geometry of whole surface of sheet. If the imperfection are known only at the end edges of the trapezoidal sheeting, it can't be realize a shell element in FEM software. It is because we have two different geometry of the edges, and we can't extrude both of them. Thus we don't know where the line of conjunction of these two different sides is.
It is possible to overcome this problem using a software that create the 3D model of the object through the technic of reverse engineering. It is a technic through is possible to create a 3D model from laser scanning or photogrammetry.
In the next lines we explain how is possible to create a 3D mesh of the trapezoidal sheeting using Recap Photo, a software developed from Autodesk (Ref. 3)0. This software allows to realize 3D model of objects taking photos around 360° of it only. Recap uses the automatic photogrammetry and overlaps the photos with the same objects to understand the position of the, camera and to build the shape of the object.
It's important to take pictures of the object from different views and with the 80% of overlap between each view. The subject, the landscape and the light must stay in the same condition during the whole shooting time, it is necessary because the key of the Recap's method is to locate the points of the same object in the different photos to understand the position of the camera. Fig. 11, Fig. 12 and Fig. 13 show the correct way to take photos and how the photogrammetry method works, (Refs 4, 5).

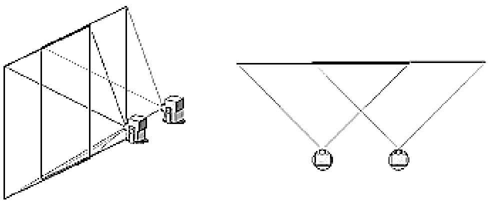


Fig. 11 Overlapping of photos to create dense points cloud

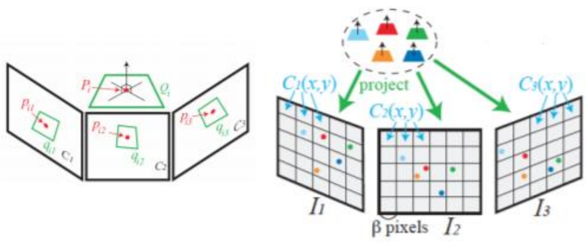


Fig. 12 Different views to create dense points cloud

The element studied in this paper is the steel trapezoidal sheeting and the surface of this object gives different glare under various light conditions and several views. It was a problem, because the software was unable to recognise the points of the steel sheet, and so was impotent to generate the 3D model of the steel surface.

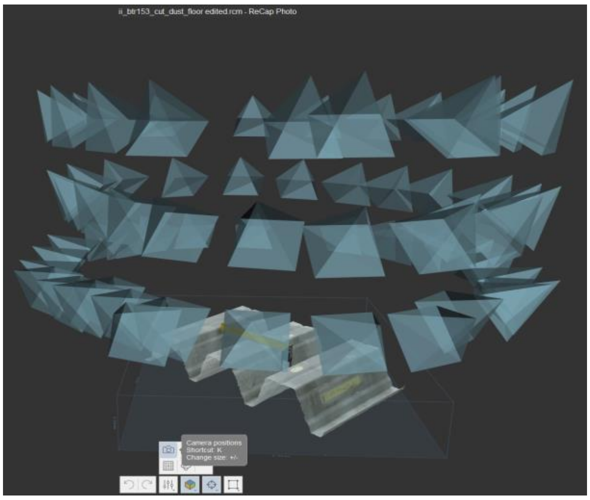


Fig. 13 Camera positions to create 3D model in Recap Photo

The pictures were taken under different lights and different settings of the camera to overcome this drawback, but the results were no satisfying. Next improvement was based on introduction additional lines and reference points on trapezoidal sheeting, but also in this case the results were not good. Finally, in order to avoid the shining of the steel surface, the cement dust and liquid cement was used.
In Fig. 14, it is showed the result after covering the specimen by concrete dust. It is visible that all the shining and reflection effects were removed, and it was possible clearly to see the edge of the web stiffeners.

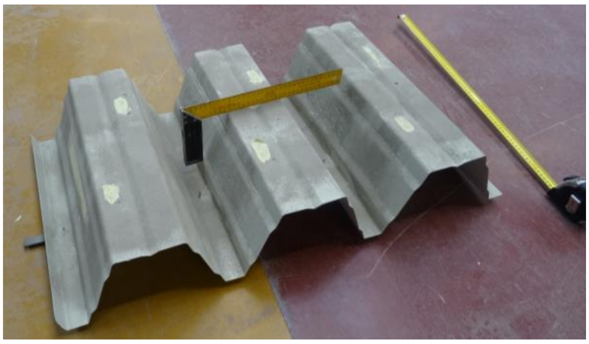


Fig. 14 Trapezoidal sheeting covered by concrete dust

While in the Fig. 15 the specimen is showed after the painting phase by liquid cement.

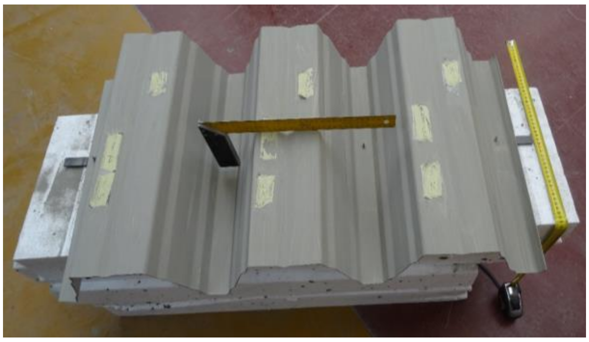


Fig. 15 Trapezoidal sheeting painted with liquid cement

In the follow's pictures, there are showed the screens of the 3D model generated by Recap to illustrate the potential and the precision of this software.
In detail, in Fig. 16 the textured mesh is showed: it shows the model including any textures but does not show the edges of the mesh faces.

Fig. 16 Textured mesh of BTR153 covered by cement dust

Textured with wireframe display (Fig. 17) includes both texture of the mesh faces and their edges.

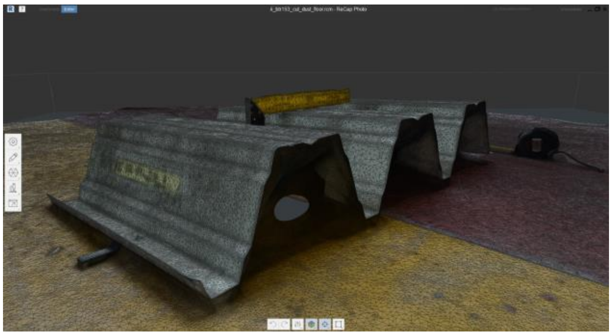


Fig. 17 Textured mesh with wireframe of BTR153 covered by cement dust

If we want to use Recap Photo to measures the specimen only, we can use the ruler in the main page, but, if we want to use the 3D model to import it in CAD ambient or into a FEM software, we need to clean the model and remove the parts outside the sample (Fig. 18).

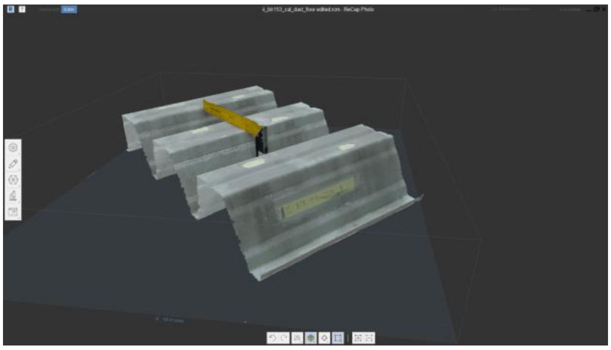


Fig. 18 Textured mesh of BTR153 covered by cement dust

Solid display (Fig.19) shows the mesh as a solid model removing the display of any textures the model might have.

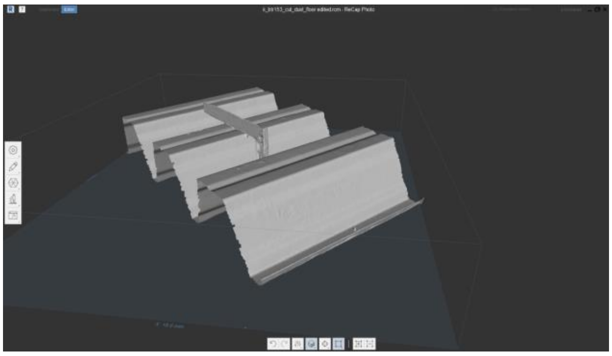


Fig. 19 Solid mesh of BTR153 covered by cement dust

Textured and solid with wireframe display (Figs 20, 21) shows the faces and the edges of the mesh removing the display of any texture the model might have.

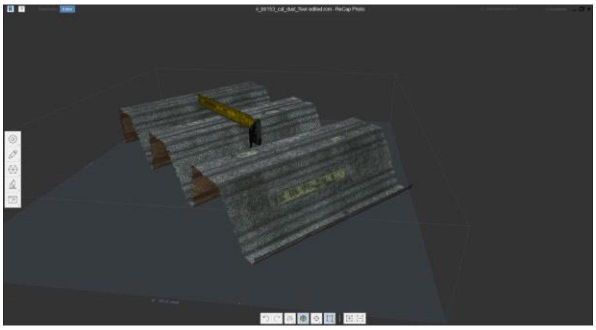


Fig. 20 Textured mesh with wireframe of trapezoidal sheeting covered by cement dust

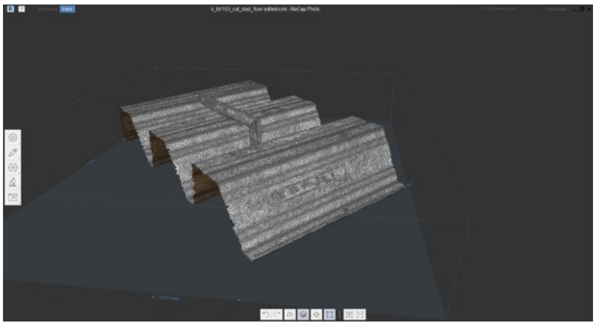


Fig. 21 Solid mesh with wireframe of BTR153 covered by cement dust

After the creation of the 3D model it's possible to export it in different 3D editing software, in the detail we tried to export the model in Rhinoceros to create an open *polysurface* through the command *nurb* ready to be imported into a FEM software, for example Abaqus, this attempt is ended with good result.

4. CONCLUSIONS AND REMARKS

In the paper an alternative methods of measurement of the imperfections of lightweight steel profiles were discussed. The comparison was carried out on measures made by rule, callipers, by tracing the shape on the paper and by using the digital method such as taking photos of the edges and import them into Perspective Rectifier or into Autodesk ReCap Photo.

It was found that the traditional methods give a good result, but refer only to the edge of trapezoidal sheeting. On the other hand, the digital method was assumed to be faster and easier because there was only a necessity to take few photos and get 3D image. But in order to obtain correct results the researcher should be very careful due to mistakes which follow form incorrect use of Perspective Rectifier.

Moreover, in case of creation 3D model in Recap Photo an additional problem has been encountered. Namely, because of the shiny surfaces of the steel sheets software was unable to recognise the points and generate the 3D model. In order to overcome this problem author proposed easy and cheap method of removing the reflection and thus receive a very good image that can be import into a FEM software.

REFERENCES

1. Trapezoidal profiles from Balex https://old.balex.eu/en/trapezoidal-profiles/profile.
2. RectifierSoft.com http://www.rectifiersoft.com/index.htm.
3. Autodesk Inc. http://help.autodesk.com/view/RECAP/2019/ENU/?guid=RealityCapture_Photo_product_overview_html.
4. "Misure, rilievo, progetto per Costruzioni, ambiente e territorio" - Renato Cannarozzo Lanfranco Cucchiarini William Meschieri. Quinta edizione, 2017.
5. CVPR 2017 https://demuc.de/tutorials/cvpr2017/.