PROGRESS 2017-2020
PROVISIONS FOR GREATER REUSE OF STEEL STRUCTURES

upt Universitatea Politehnica Timişoara

Research Fund for Coal & Steel

Experiences and Lessons learned from the past

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PROGRESS 2017-2020
PROVISIONS FOR GREATER REUSE OF STEEL STRUCTURES

Reuse scenarios

	In-situ	Same site		Different site	
		Same configuration	Different configuration	Same configuration	Different configuration
Entire primary structure	A	B	C	D	E
Elements of the primary structure	N/A	N/A	F	N/A	G
Individual elements	N/A	N/A	H	N/A	I

Type of product:

- The entire primary structure;
- Elements of the primary structure, e.g. trusses or 2D portal frames;
- Individual structural elements, e.g. the column or rafter.

Location:

- Reuse in-situ, i.e. the primary structure is retained and not deconstructed;
- Reuse on the same site, i.e. the primary structure is deconstructed and re-erected either in the same configuration and/or same or different location;
- Reuse on a different site.

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The reuse of reclaimed steel is limited to:

- Steelwork erected after 1970;
- Steelwork which has not been subject to fatigue, e.g. not reclaimed from bridges;
- Steelwork from structures which have not experienced extreme loads;
- Steelwork which has not been subject to significant strains, e.g. plastic hinges;
- Steelwork without significant loss of sections' dimensions due to corrosion;
- Steelwork which has not been exposed to high temperature.

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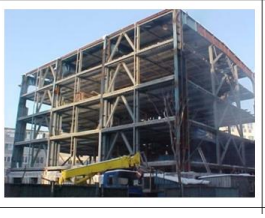
Identification of the cases studies

14 case studies

4

Presentation of the case studies

Scenario	Image	Brief description
G		**NTS building, Thirsk, UK** The original order for the building was cancelled in 2008 and the elements were stored. The new building was erected in 2017 by reusing a quarter of the steelwork of the original building [factsheet 1].
E		**SEGRO warehouse, Slough, UK** The structure was built in 2000 and relocated in a different layout at a new location in 2015 [factsheet 2].
A		**HIDROTIM office, Timisoara, Romania** The building was erected in the 1960s as a single storey industrial hall of steel structural elements with crane and converted into a five-storey office building in 2004 [factsheet 3].

https://www.steelconstruct.com/eu-projects /progress/case-studies/

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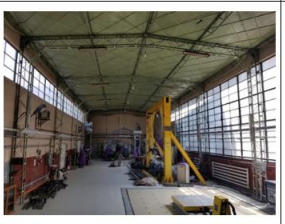
A		**RWTH seminar building, Aachen, Germany** Following the closure of the RWTH heat and power plant in the 1990s, the decision was made to transform it into a seminar building by adapting the structure to meet the new functional requirements [factsheet 4].
A		**UPT Steel Structures Laboratory, Timisoara, Romania** The structure was erected in 1959, consisting of truss elements. Part of the structure was severely damaged in 2017 by a storm. As the structure was designed more than 50 years ago, it needs to be upgraded to fulfil the current codes, operating with higher climatic (snow and wind) and seismic loading than the codes at the time of design [factsheet 5].
E		**MEXX DAY hall, Timisoara, Romania** The structure was designed in 2008 as a ***standard kit*** to be adapted for different locations and applications. It was erected in 2009 and relocated for reuse in 2017 [factsheet 6].

https://www.steelconstruct.com/eu-projects /progress/case-studies/

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D		**Agrocolumna warehouse, Copăceni, Romania** The building was erected in 2004 in Craiova, consisting of a two-storey office building and a warehouse. In 2012, it was moved to Copăceni (227 km east of Craiova) and one more bay was added to the warehouse [factsheet 7].
D		**Bus station Schiphol – Nord, Amsterdam, The Netherlands** The initial use of the structure was a T2 type hangar for the British Royal Air Force during the World War II. After the war, in 1958 this T2 was taken at Zestienhoven airport and used as a hangar until the late nineties. In 2003, the structure was reused as a hangar for seven years by the Rotterdam Detention Center. In 2015, it was reused again as a bus station in Schiphol [factsheet 8].
D		**Metis canopy, Otočcu, Croatia** The original structure was erected in Pula and was relocated for reuse in 2011 in Otočcu, 266 km away [factsheet 9].

https://www.steelconstruct.com/eu-projects /progress/case-studies/

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D		**S-Market, Urjala, Finland** The original structure was erected in 1980s in Tampere and was relocated for reuse in 209 in Urjala, 60 km away [factsheet 10].
G		**Fabrication plant, Wuppertal, Germany** The production company has two fabrication sites. Due to growth over the years, this hall was planned to be cleared and populated by modern fabrication buildings afterwards. The owner, however, decided to reuse the original historical steel trusses from the early 1920s [factsheet 11].
G		**Steel industrial kit hall for multiple locations** An existing standard kit structure was used to construct buildings in different locations in Romania between 2008 and 2010. Recently, in 2020, a new complex of buildings reused the elements of one of the existing standard kits [factsheet 12].

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A		**Structural strengthening of a steel structure to enable the removal of 2 columns** The two-storey structure (reinforced concrete columns and steel trusses), built in 2008, located in Târgu Jiu, Romania, and is used as restaurant. In order to reconfigure the upper floor and increase the clear space, two central concrete columns were removed, and consequently the strengthening the steel trusses [factsheet 13].
A		**In-situ rehabilitation of a Water Treatment Plant in Brasov, Romania** The building was used as water treatment plant for a local brewery factory, erected in 2003. In 2015 the owner decided to rehabilitate the building, due to the bad thermal insulation and corrosion of some steel components, keeping the function of the building and not interrupting the activity [factsheet 14].

Case A: 5

Case D: 4

Case E: 2

Case G: 3

	In-situ	Same site		Different site	
		Same configuration	Different configuration	Same configuration	Different configuration
Entire primary structure	A	B[1]	C	D	E
Elements of the primary structure	N/A[2]	N/A	F	N/A	G
Individual elements	N/A	N/A	H	N/A	I

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PROGRESS 2017-2020 PROVISIONS FOR GREATER REUSE OF STEEL STRUCTURES

1) Reuse of the elements of the primary structure

Different site / different configuration

- area of Sibiu / production hall
- 12m span

  Reused New
- 53.5 m (5x3.5m + 6x6m) length

  S235 S355
- existing frames built in 1972 (Germany) / reuse in 2015

!

- change of location (Germany to Romania)

  ⇨ new loading conditions
- evolution of design codes (1972 to 2015)

  (snow, wind, seismic)
- no information about the existing structure

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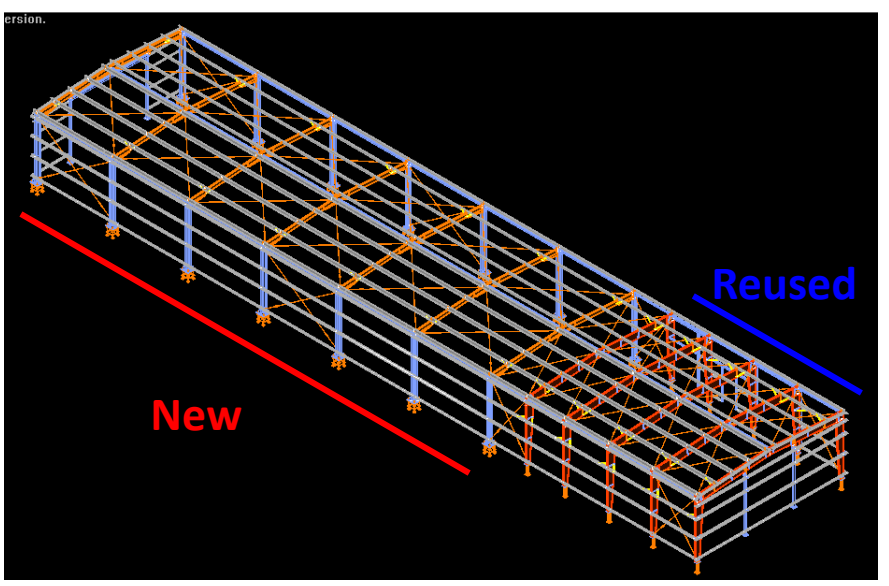

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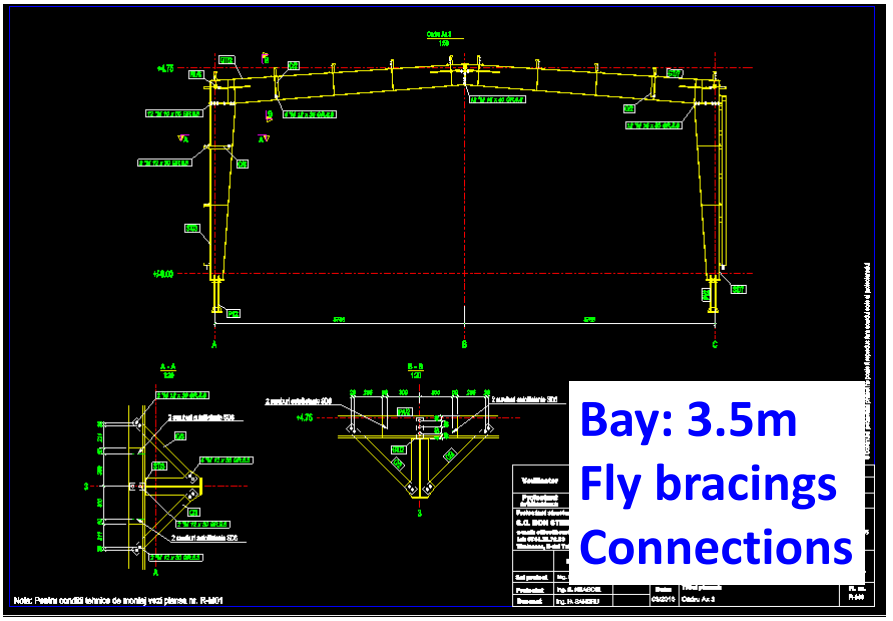

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	Same layout	Different layout Modification/adaptation can be needed due to different individual member loading	
	Relocated reuse Modification/adaptation can be needed due to different external conditions and regulatory requirements.		In-situ reuse
Frames	(A) Deconstruction and re-assembly on a new site.	(B) Several (or all) frames are integrated into the new building layout	
		(C) Reuse of individual elements cut from the frame (e.g. sections) on different site(s)	(D) Reuse of individual elements cut from the frame (e.g. sections) in the new building on the same site
Secondary structure		(E) Reuse of individual elements on different site(s)	(F) Deconstruction and reuse of elements in a different configuration
Envelope			

Degree of reuse ⇨ Main frames ⇨ 100%

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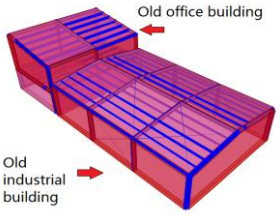
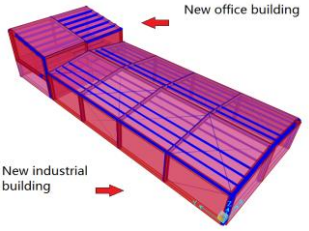
2) Reuse of the entire structure

Different site / same configuration

Model		
Time	2004	2012
Location	Craiova	Bucharest (250 km)
Material	**Office**: cold-formed steel profiles **Industrial building**: welded steel profiles	

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!

- **change of location (Craiova to Bucharest)**
  ⇨new loading conditions (snow, wind, seismic)
- **evolution of design codes (2004 to 2012)**

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COMPARISON OF LOADS
(old vs. new code for industrial building)

Load (Design code)	Characteristic Value (kN/m2)			ULS (kN/m2)		RATE
		OLD	NEW	OLD	NEW	
Permanent load (STAS 10101-1/78) (SR EN 1991-1-1)	Cladding (roof and walls)	0.250	0.250	0.275	0.338	18.5%
	Technological loadings	0.150	0.150	0.165	0.203	18.5%
Snow (STAS 10101/21-92 STAS 10101/0A-77) (CR 1-1-3/2012)	uniform load	1.500	1.600	3.195	2.400	-33.1%
	drifted load	3.000	2.900	6.390	4.350	-46.9%
Wind (STAS 10101/20-90) (CR1-1-4/2012)	transversal	0.704	0.420	0.845	0.630	-34.1%
	longitudinal	0.704	0.560	0.845	0.840	-0.6%

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COMPARISON OF SEISMIC LOADING

	Parameters	OLD	NEW	RATE
Seismic (P100-92) (P100-2013)	Design ground of acceleration	a_g=0.20g	a_g=0.30g	50.0%
	Amplification coefficient	β0=2.5	β0=2.5	0.0%
	Behavior factor	q=1	q=1	0.0%
	Upper limit of the period of the constant spectral acceleration branch	Tc=1.5	Tc=1.6	-

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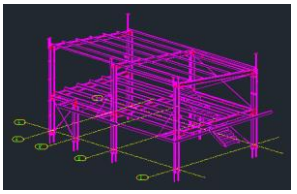
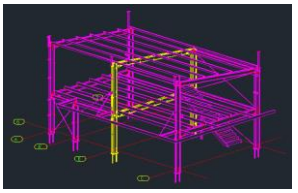
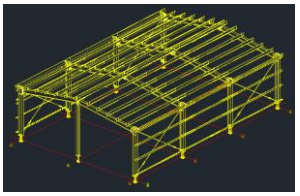
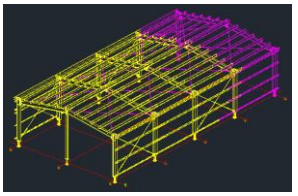
	Old Project	New Project
Office		
		strengthening of intermediate frame
Weight	6436.3kg	6965.58kg
Industrial		
Weight	8799.67kg	11561.7kg

addition of the roof bracing system and addition of a new bay

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	Same layout	Different layout Modification/adaptation can be needed due to different individual member loading	
	Relocated reuse Modification/adaptation can be needed due to different external conditions and regulatory requirements.		In-situ reuse
Frames	(A) Deconstruction and re-assembly on a new site.	(B) Several (or all) frames are integrated into the new building layout	
		(C) Reuse of individual elements cut from the frame (e.g. sections) on different site(s)	(D) Reuse of individual elements cut from the frame (e.g. sections) in the new building on the same site
Secondary structure		(E) Reuse of individual elements on different site(s)	(F) Deconstruction and reuse of elements in a different configuration
Envelope			

Degree of reuse ⇨ whole structure ⇨ 100%

+

strengthening of <u>office</u>'s intermediate frame

<u>industrial</u>: change of the roof bracing system and addition of a new bay

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3) Reuse of the entire primary structure

Different site / same configuration

- area of Timisoara (approx. 60 km)
- 2x35m span
- 84m (14x6m) length
- built in 2008 / reuse in 2017-2018

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History:

- designed in 2008 as a Standard Kit to be adapted for different locations in Romania (low to moderate climatic/seismic conditions) and applications (production, warehouses etc.);
- executed according the Standard Kit design and the mainframe erected in a 30 Km distance area from Timisoara (2009), but never completed;
- project adapted for a "Pasta fabrication" plant, only half-span of the hall intended to be used (2012) - not realized;
- actually, a new owner prepare the exiting structure, using the whole hall, for a Cereals Storage Unit: some functional intervention compared with initial kit appears i.e. a partial mezzanine over two bays for offices and laboratories.

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Necessary interventions for reusing the structure:

- the actual design codes - wind, snow and earthquake have been changed (higher load intensities) compared with initial 2008 design;
- the mezzanine structure has to be inserted in the existing structure;
- consolidations of some structural components were necessary;
- bracing system needs for revision and involve some modifications;
- fire protection requirements for cereals closed storage warehouse need to be ensured.

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	Same layout	**Different layout** Modification/adaptation can be needed due to different individual member loading	
	Relocated reuse Modification/adaptation can be needed due to different external conditions and regulatory requirements.		**In-situ reuse**
Frames	(A) Deconstruction and re-assembly on a new site.	(B) Several (or all) frames are integrated into the new building layout	
		(C) Reuse of individual elements cut from the frame (e.g. sections) on different site(s)	(D) Reuse of individual elements cut from the frame (e.g. sections) in the new building on the same site
Secondary structure		(E) Reuse of individual elements on different site(s)	(F) Deconstruction and reuse of elements in a different configuration
Envelope			

Degree of reuse ⇨ main structure ⇨ 100%

+

additional components

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4) "Reuse" of the entire structure

In-situ / same configuration

Name: Beverage Can Plant in Bucharest, Romania
Year of design: 2004
Production started in: 2005

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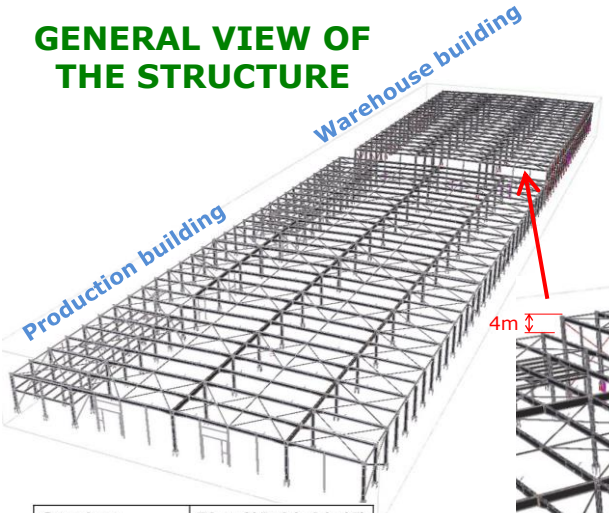
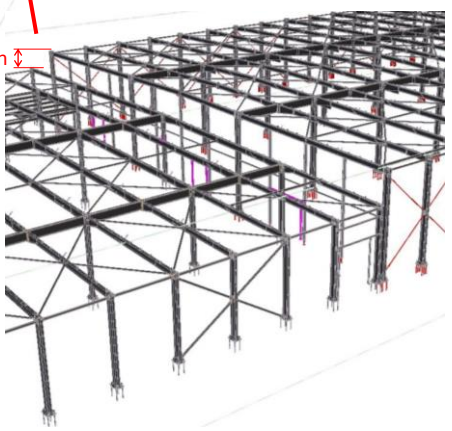
GENERAL VIEW OF THE STRUCTURE



Opening:	72 m (24+24+24)
Bay:	6 m
Number of bay:	20
Length	120 m
Height:	11.8 m
Roof slope:	2%
Roof:	2 slopes



Opening:	78 m (15+24+24+15)
Bay:	6 m
Number of bays:	30
Length	180 m
Height:	8.2 m
Roof slope:	2%
Roof:	2 slopes

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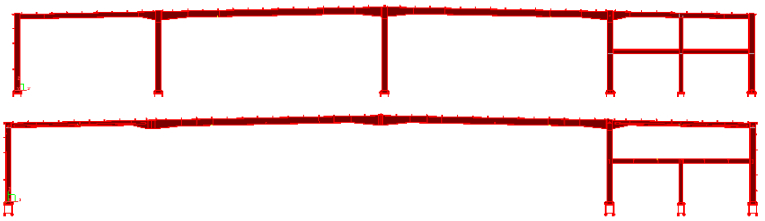
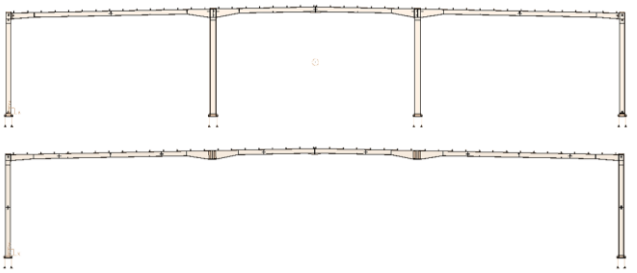
Production building

Current transversal frames



Warehouse building

Current transversal frames



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Technical evaluation

- structural evaluation according with the new technical regulations, necessary for insurance companies (planned);

coincide with

- in February 2010, the structure was affected by strong snow falls and strong winds, producing snow drifts (accumulation up to 4.0m of snow);

⇒ Very large deformations of the roof, purlins and roof panels severely damaged
⇒ Structural collapse prevented.

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- Two adjacent buildings
  - 120x80m, 13.0m height
  - 180x80m, 9.5m height
- Snow drifting
- Accumulation up to **4.0m** of snow
- Undrifted snow 1.0m
- Very large deformations of the roof, purlins and roof panels severely damaged
- Structural collapse prevented

- Snow was removed from the roof in the drifted area
- Repairing, upgrading necessary:
  - Purlins will be replaced
  - Panels will be replaced or strengthened
  - Local strengthening at main girders

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Snow drifts between the two adjacent buildings

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Damages

Twisting of the beam from the gable frame

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Supports for the roof

Damages

Supplementary purlins

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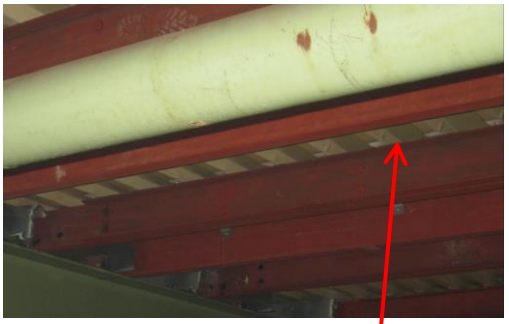

Damages

Web crippling of the corrugated sheet under exceptional snow

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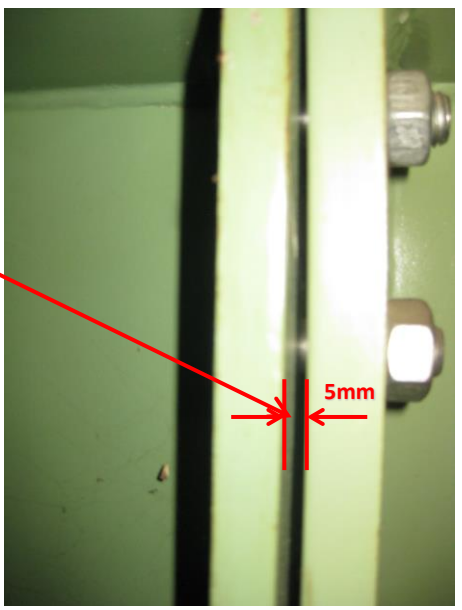
Technical deficiencies:

End connection

⇒ 5mm gap



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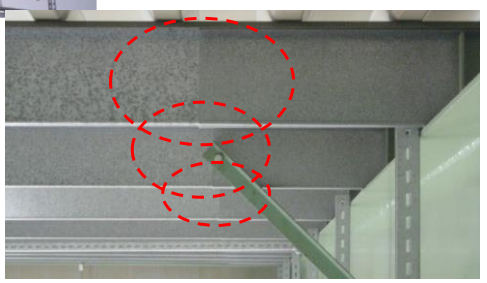
Technical deficiencies:

Lack of bolts which connect purlins at the end of overlaps



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Technical deficiencies:

Self-tapping screws are missing at the connection between purlins and corrugated sheet

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Actions to be done

Based on a visual and non-destructive inspection, followed by structural evaluation according with the new technical regulations:

⇒ Damage identification: critical zones, members, connections

⇒ Repairing of structure due to accidental snow load;

⇒ Structural upgrade of primary and secondary structure.

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The Non-destructive inspection

- Detailed verification of welds and bolts of the beam-to-column connections;
- Ultrasonic investigation of cracks initiation;
- Checking of the lengths of bolts core;
- Special attention will be paid to the first two rows of bolts placed on the tensioned side of the connection (the top side)
- Random investigation of the welded connection along the columns.

The main non-destructive methods used:

- ✓ *visual inspection*;
- ✓ *magnetic particle inspection*;
- ✓ *liquid penetration inspection;*
- ✓ *ultrasonic inspection.*

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The Non-destructive inspection

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The Non-destructive inspection

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The Non-destructive inspection

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The Non-destructive inspection

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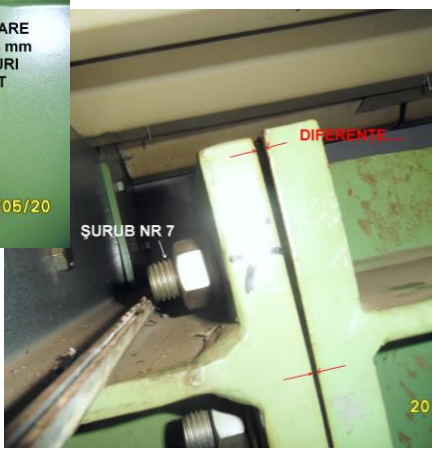
The Non-destructive inspection



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Load evaluation - Production building
Differences 2004 vs. 2010

Combination	Loads 2004 [kN/m²]	Loads 2010 [kN/m²]	2010 / 2004
C1 – curent (uniform snow)	1.1P + 1.9Z = 1.1·0.55 + 1.9·1.2 = 2.885	1.35P + 1.5Z = 1.35·0.55 + 1.5·1.6 = 3.143	**8.9%**
C1 – drifted snow	1.1P + 1.9Z = 1.1·0.55 + 1.9·2.4 = 5.165	1.35P + 1.5Z = 1.35·0.55 + 1.5·7.0 = 11.243	**117.7%**
Masses for earthquake combinations	P + 0.3Z = 0.55 + 0.3·1.2 = 0.91	P + 0.4Z = 0.55 + 0.4·1.6 = 1.19	**30.8%**
Wind	Partial factor = 1.2 $g_v = 0.55kN/m^2$	Partial factor = 1.5 $g_v = 0.5kN/m^2$	**13.6%**

Snow drift is particularly very dangerous on very large roofs !!!!

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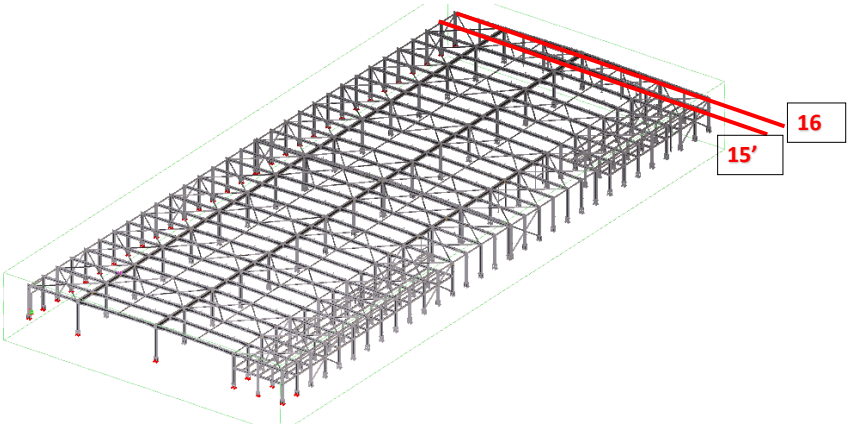
Recommendations
Production building



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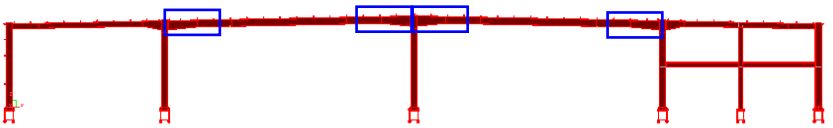
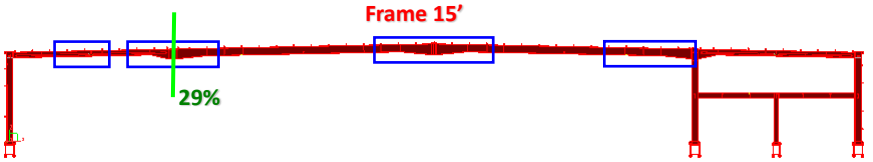
Recommendations - Production building

Frame 16



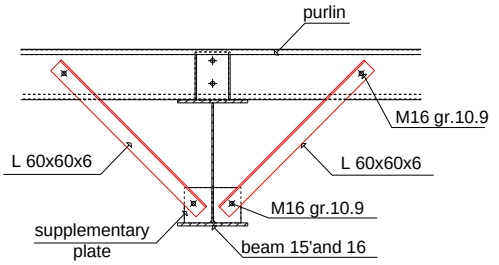
R4 ↗ 11.9% (stability check)

Frame 15'



R1 ↗ 22.1% (stability check)
R4 ↗ 22.7% (stability check)

- beam-to-column connections capacities exceeded (23%);



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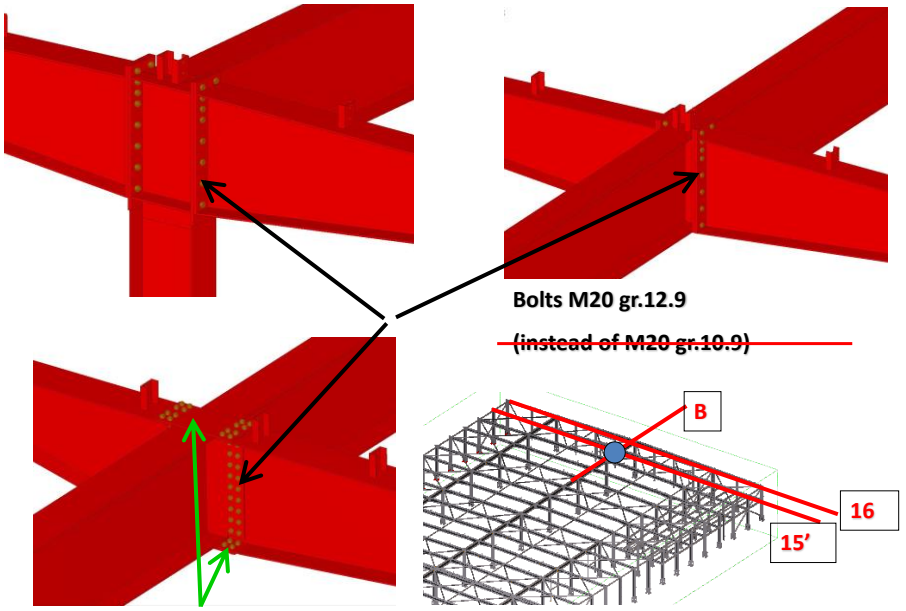
Beam–to–beam and beam–to–column connections
increase the bearing capacity of connections



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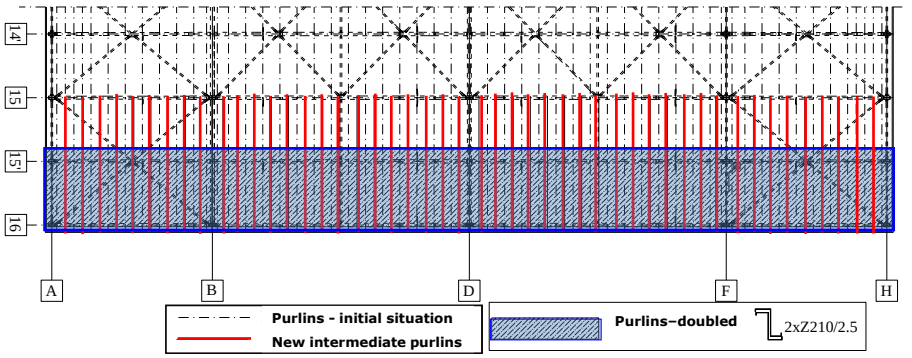
Secondary structure – Purlins
Strengthening solutions

The capacities of purlins and corrugated sheets, between axes 15'-16, are not on the safety range both at ULS and SLS

Increase the capacity of roof structure (bays 15-15' and 15'-16) :

- To introduce intermediate purlins Z210/2.5 between the existing ones for the first two bays and to double ones in the first bay (2xZ210/2.5)



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Comments

1. By applying the repairing and strengthening solutions the initial capacity of both main and secondary structures has been recovered and increased in the regions were this was necessary.
2. The initial design lifetime of the structures can be considered after these interventions to be unaffected.
3. It is important to underlined the intervention can be done without interrupting the current activities inside the buildings.

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General conclusions

- The case studies proved the reuse of existing steel structure is feasible;
- In most of the case studies the entire primary structure was reused (degree of reutilization 80-100%);
- The dismantling process is easier in the case of structures using bolted connections;
- The reused steel structures need to be strengthened by the addition or change of some structural components;
- The reuse process is easier when the original project and material certificates are available;
- Information about the loading history, interventions, any possible incident in the building/area (fire, earthquakes, …) is important to be recorded.

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