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Autor: Budjevac, Dragan / Stipanic, Bratislav

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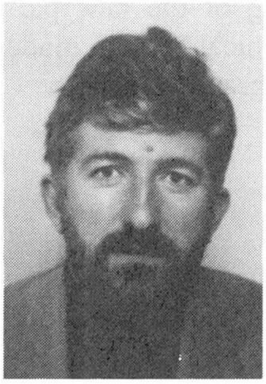
Strengthening and Repair of a Large Industrial Building

Renforcement et réparation d'un large bâtiment industriel

Verstärkung und Reparatur einer grossen Industriehalle

Dragan BUDJEVAC
Associate Professor
Belgrade University
Belgrade



Dragan Budjevac, born 1953, received his civil engineering, M.Sc. and Ph.D. degree at the University of Belgrade. He is author of several books and numerous scientific and technical papers related to steel structures. He is designer, expert and consultant in steel structures.

Bratislav STIPANIC
Associate Professor
Belgrade University
Belgrade

Bratislav Stipanic, born 1949, received his civil engineering, M.Sc. degree and is finishing Ph.D. at the Univ. of Belgrade. He is author of several books and numerous papers related to design of steel structures. He is a designer and consultant for steel bridges and buildings.

SUMMARY

The strengthening and repair of a large industrial building for cold mill plant (over 100'000 m2), built in structural steelwork, is presented. The main columns and crane girders were strengthened because of the increased loading due to the change of plant technology. The structural components of the industrial building were repaired because of damages due to a fire. The applied strengthening and repair interventions are described.

RÉSUMÉ

Le renforcement et la réparation d'un large bâtiment industriel pour une usine de laminage à froid (surface de plus de 100'000 m2), en charpente métallique, sont présentés. Les colonnes principales et les poutres de roulement sont renforcées pour supporter les augmentations de charges, dues aux changements de la technologie. Les éléments structuraux du bâtiment sont réparés pour pallier les détériorations causées par un grand incendie. Les interventions de renforcement et de réparation, appliquées à la charpente métallique du bâtiment, sont décrites brièvement.

ZUSAMMENFASSUNG

Es werden Verstärkungen und Reparaturen einer grossen Industriehalle dargestellt. Die aktuelle Grundrissfläche der Stahlkonstruktion beträgt über 100'000 m2. Zuerst wurden die Hauptstützen und der Krahnbahnträger wegen der Lasterhöhung durch die Produktionsänderung, verstärkt. Dann wurden auch verschiedene Elemente der Tragwerke repariert, diesmal wegen grossen Brandbeschädigungen. Die verwendeten Verstärkungen und Reparaturen werden dargestellt.

1. STRENGTHENING INTERVENTIONS

1.1 Introduction

The multi-bay building for cold rolling mill plant "MKS" in Smederevo (Yugoslavia) was built in steelwork. This industrial building, having original area 60747 sq.m, was constructed twenty years ago according to the applied technological process of that time. Because of the introduction of the new technology, the industrial building was strengthened, reconstructed and enlarged by new useful area of 43.594 sq.m. The new technological process requested the significant increasing of total number of cranes (from 18 to 37) with greater (40-110%) bearing capacities and more intensified working regimes; that resulted in the strengthening of the main columns and crane girders of the original building structure. The strengthening and reconstruction of the original industrial building as well as the building of the new part (second stage) was designed by "Projmetal Belgrade", consulting and technical control made by Institute for materials and structures of Civil Engineering Faculty of Belgrade University.

1.2 Structural Steelwork of the Industrial Building

The plan view and the sections of the industrial building (first stage is shaded part of plan drawing), having unite total useful area of 104.241 sq.m and structural steelwork of total weight 17.000 t, is given in Fig. 1.

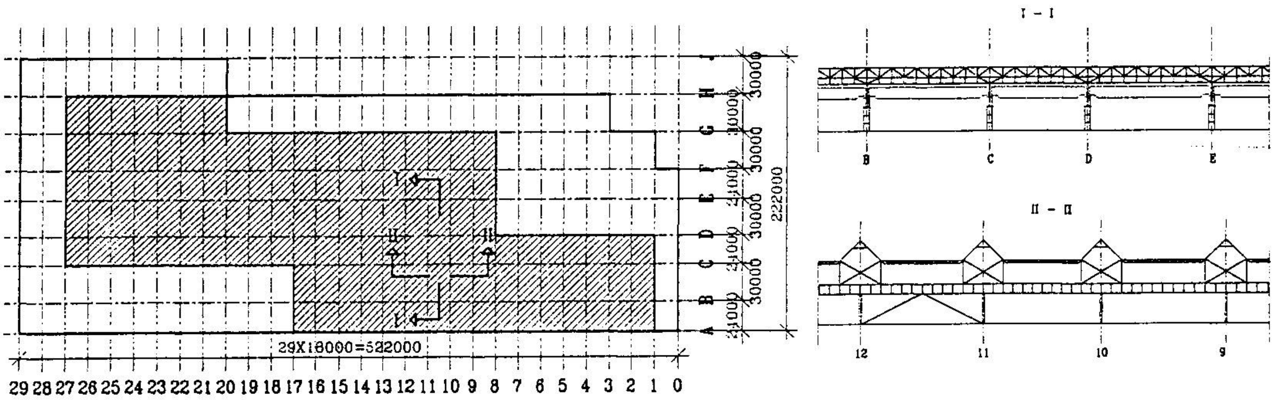


Fig. 1 Plan view and sections of the industrial building

The main columns of the industrial building are spaced on 18,0 x 30,0 m and 18,0 x 24,0 m. Two roof trusses (of span 30,0 m or 24,0 m each), inclined at the angle of 45 °, are coupled forming the transverse lanterns (of width 6,0 m and height 3,0 m) spaced on 18,0 m. The roof trusses are carried by the braced supporting structures, located on the gantry girders; consequently they are not supported directly by the main columns. The purlins, spanning 12,0 m, spacing on 3,0 m, are supported by the roof trusses. The crane girders are constructed as plate girders (depth 2000 m), having static system as continuous beam on n-supports; the distance between the expansion joints defining its length. The entire structure of the industrial building is separated in three parts by the expansion joints, at the column lines 8 and 17.

The roof cladding consisted of profiled sheets, made from aluminum (first stage) and from steel (second stage) combined with the polyurethane insulated panels. The slope of the roof surface (except the pitch-parts with the lanterns) amounted 1,7 % in the drain direction, and it was formed by the longitudinal inclinations of purlins. The wall cladding (second stage) consisted of the "Luxalon" panels, made as aluminum sandwich with foamed polyurethane core as thermal insulator.

1.3 Strengthening of Main Columns

The partial strengthening of main columns F8-F27 as well as the strengthening of column bases (transformation into box section) of main columns D9-D17, E8-E17 were carried out (Fig. 2). The additional longitudinal web stiffeners were welded in all columns. The amount of the additional steel material for the main columns is 44,4 t (i.e. 4,1% more steel in columns).

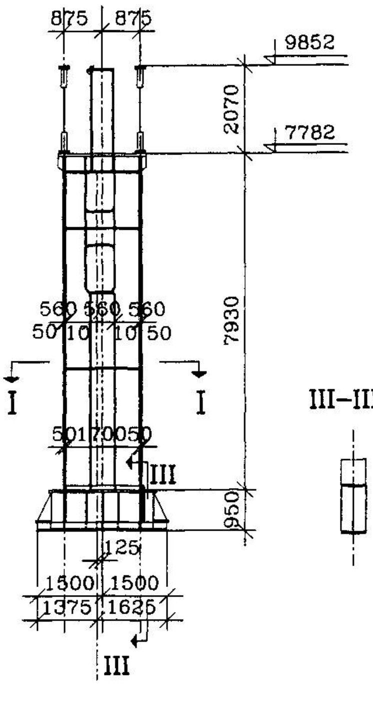


Fig. 2 Strengthened main column

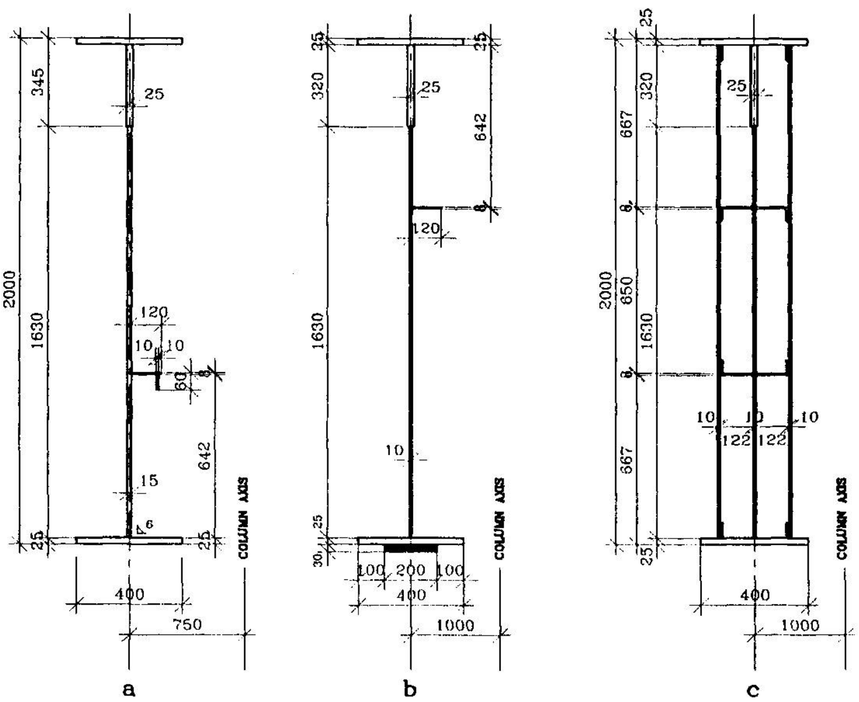


Fig. 3 Strengthened crane girders

1.4 Strengthening of Crane Girders

The numerous different types (31) of the crane girders (total number 502), were applied in the original building. Thus the crane girders were classified in three types, concerning the strengthening works. The type "a" represented the crane girders (411 pieces) where the additional elements were put in for the longitudinal web stiffeners; the crane girders of type "b" required the additional plate to be welded on the bottom flange; the transformation of plate girder into box girder was applied to the crane girders (81 pieces) of type "c" (Fig. 3). The expansion joints of crane girders were strengthened as well. The additional steel material for the strengthening of crane girders amounts 256,1 t (i.e. 10,0% more steel in crane girders).

1.5 Conclusion Remarks

The all strengthening and reconstruction works were carried out practically without any interruption of the current plant production. Having applied the adequate methods of design and optimal constructing procedures, the effective solution in the functional, technical and cost benefit aspect was attained.

2. REPAIR INTERVENTIONS

2.1 Damages of the Building Caused by Fire

The second building stage, was about to finish when the fire accident occurred and caused a lot of damages of structural steelwork and equipment as well. Next day after the fire accident the special technical commission for building rehabilitation was formed by team of experts (including the co-authors of the paper). The detailed geodesic measurements were carried out in order to determine exactly the actual state of the structural steelwork. The special photogrametric method from air (by plane) was used as well.

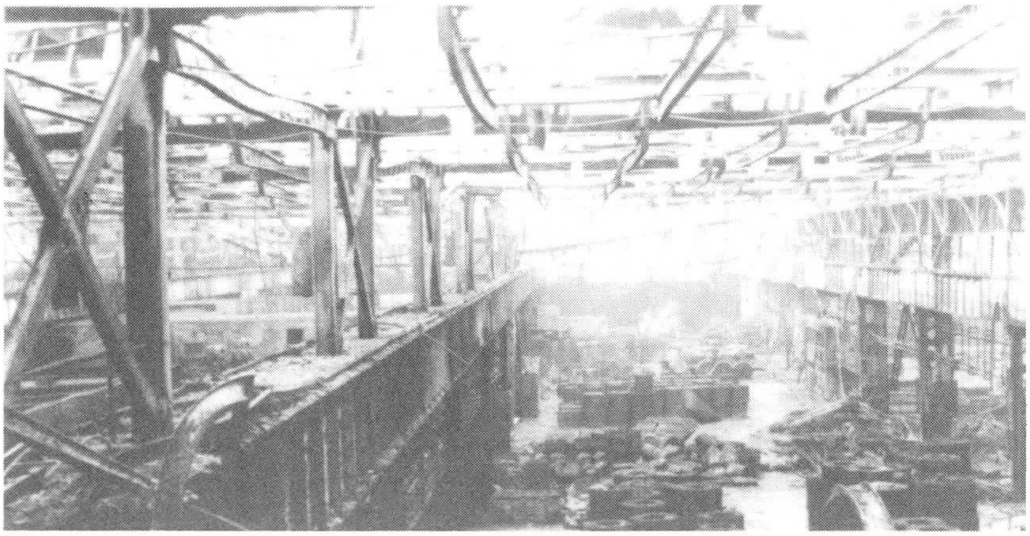


Fig. 4 Building structure damaged by fire

The following damages were noted:
- Roof cladding is either completely destroyed (aluminum profiled sheets), or partly damaged remaining on the roof (steel profiled sheets).
- More than 90% of purlins are largely deformed and they should be changed.
- About 50% of roof trusses and supporting roof structures were significantly deformed (Fig 4.). The roof trusses in the zone of the greatest damages (bays: D-E, E-F and F-G between the columns 20 - 28) fell down.
- The global and local deformations of the main columns were noticed, especially large deformations were present in the column row F, where the crane girders were located on different levels, with the presence of the column twisting consequently.
- The crane girders underwent the significant global and local deformations. The expansion joints were open excessively, some of them even more than 500 mm.

- The brake bracing structures, especially in the field 21-22, got excessive deformations, that somewhere resulted in the member ruptures.
- The wall cladding was damaged in the large area of external walls.

2.2 Repair of Roof Structure

Based on the analysis of test results concerning fire resistance, spread of flame and propagation of harmful gases, the new roof cladding (sandwich made from profiled steel sheets and "vunisol JM" insulated panels), having less self weight is applied. The retained old purlins were repaired and reconstructed (Fig. 5a). The destroyed purlins were replaced by the new type of purlins (Fig. 5b). These new types of purlins enabled the transformation into pitch-roof surfaces (of slope 10%) between the lanterns (having other pitch-roof transparent surfaces of slope 45 °), that improved the drainage from the roof.

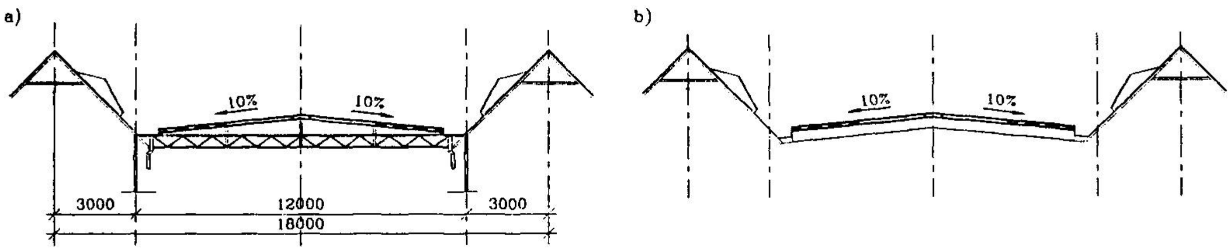


Fig. 5 Rehabilitation of purlins

The increased tolerances concerning the out-of-straightness were specified for the members of roof trusses. The additional flexural moments (with respect to weak bending axis) were introduced for stress control, because of the specified tolerances. All compression members that could not sustain the specified limit eccentricity ($e<L/500$) were strengthened by welding the additional plates. Where the greater eccentricities ($e>L/500$) were registrated, the member were straightened or replaced. The limit eccentricity of L/100 was specified for all tension members for stress verification, and the members with greater values of eccentricities were either straightened or strengthened. The repaired roof structures were tested.

2.3 Repair of Main Columns

The repair treatments were defined after the detailed inspection and geodesic measurements. The main columns were classified into two categories:

a) Main columns where the damaged crane girders are disassembled - " free columns ",
b) Main columns carrying the crane girders -"linked columns".

The geometry of the "free columns" was adjusted up to the increased tolerances (1.5 times grater than the allowable values), concerning the deviation of column axis from the vertical. The "linked columns" were submitted to straightening up to the specified tolerances, or if it is not possible the columns were strengthened. The correction of column geometry was done by heat treatment only. The strengthening concept comprised the transformation of the column from I - section to box section (Fig. 6).

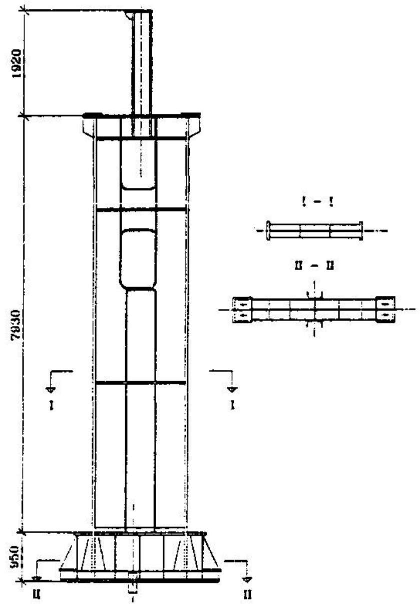


Fig. 6 Repaired main column

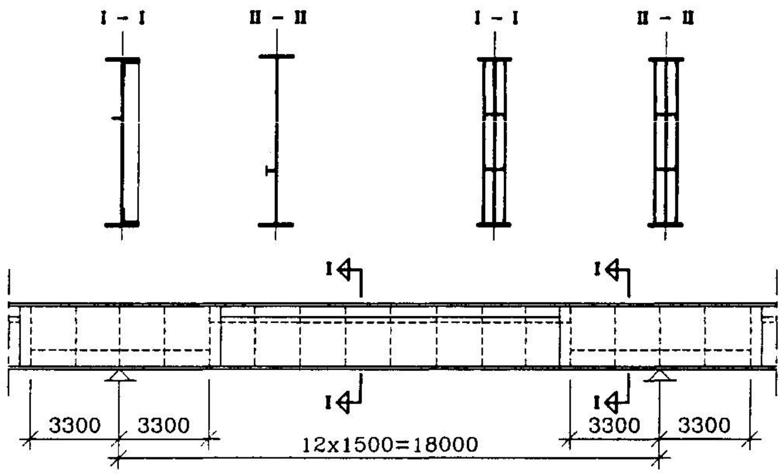


Fig. 7 Repaired crane girder

2.4 Repair of Crane Girders

The tolerances for crane girders were specified in the following increased amounts: - L/50, i.e. 36 mm, concerning the out-of-straigthness in horizontal or vertical direction, - b/200, i.e. 7 mm, concerning the web buckling. The other tolerances, including the deviations of distances and levels between the rails, were taken according to the code. The detailed geodesic measurements were done (measurement spacing in L/4), concerning the following registrations: the axis distance between the rails, the out-of straightness of upper flange in horizontal plane, the deviation of crane girder in vertical sense, the local deformation of the web (out-of-plane displacements) and the relative deviation of upper flange with respect to lower flange. Based on the geodesic measurements, it was tried to adjust the crane girders (to the position that fulfill the prescribed tolerances) by the heat treatment and by the transversal movements at the supports. If it was not possible, and where the excessive measured eccentricities required the strengthening of section due to stress or stability reasons, the I-section was transformed into box section by adding the vertical plates (Fig. 7). The unrepairibly damaged crane girders (42%) were replaced. The expansion joints, open after fire, were repaired. The repaired crane girders were tested by static and dynamic loads.

2.5 Conclusion Remarks

The rates of the rebuilt, repaired and retained components of main structural steelwork are:
- purlins (94% rebuilt, 6% retained), roof trusses (25% rebuilt, 42% repaired, 33% retained)
- main columns (28% repaired, 72% retained),
- crane girders (42% rebuilt, 25% repaired, 33% retained).

The overall rehabilitation works can be illustrated by the following data:
- 5.000 t of ex-steel elements disassembled and the same quantity of new steel structural elements rebuilt and reassembled, 3.000 t of steel structural elements repaired and reerected,
- 70.000 sq.m of new roof, i.e. 25.000 sq.m of new wall steel sandwich panels built and erected.

The all repair and rehabilitation works were carried out simultaneously in due time.