INCREASE OF SPAN OF THE GANTRY CRANE OWNED BY COMPANY PUT INŽENJERING NIŠ

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UDK: 621.875.5(497.11)

DOI: 10.14415/konferencijaGFS2014.126

Summary: *By changing the purpose of the gantry crane originally owned by mining and construction company Knjazevac from Knjazevac, and now being used by company Put Inzenjering from Niš, it was necessary to increase the span of main girders . This paper analyzes influence of increasing the span of two main girders on stability, bearing capacity and deformability of the gantry crane. Obtained results for original and newly desgined state of the structure are presented, as well as the recommended reinforcement measures.*

Keywords: *Gantry crane, lateral-torsional stability, reinforcement*

1. INTRODUCTION

The main task in the design process of the supporting structure of gantry crane is to determine optimal cross-sectional dimensions of main girders. Choosing the optimal shape and geometric parameters that affect costs is the subject of research of many authors [1],[2]. Optimisation can be done by analytical methods or by finite elements method. Finite elements method is more convenient method, because of the fact that many parameters can be varied. Advantage of analytical methods is that they provide functional relations of the optimisation results, so that by simple analysis influence of each parameter on reducing the mass of used steel, can be obtained[3],[4],[5]. This paper analyzes options for increasing the stability of main steel girders of modified gantry crane structure owned by company Put Inženjering from Niš. Crane was originally designed in 1975. for the needs of mining and construction company Knjaževac from Knjaževac. Original geometry of crane (L=6+12+6m, figure 1 – left) was designed for 20t load bearing capacity. After purchasing the crane in 2013, company Put Inženjering from Niš changed the purpose of the crane and modified the geometry (L=22.4m, figure

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1 – right). The structure of the crane consists of supporting frames of squared, hollow cross-section and main girders of I cross-section. Whole structure was formed by welding, while all field splices are formed as bolted connection. Longitudinal movement of the crane is by railway, and transverse movement is provided by the hoist and trolley that move along the main girders. Crane mechanism is with electric drive.

Figure 1. Original state of the crane (left) and newly constructed state (right)

During the testing period of the crane, series of functional defects were detected. That indicated on necessary expert's examination of the structure, conducting control designs and taking reinforcement measures. By preliminary visual examination of the steel structure state, some defects and lacks were determined. Compared to original structural analysis, static scheme was changed. Originally designed static scheme was frame with three pinned joints, i.e. connection between main girders and supporting frames was predicted to be pinned on one side, and rigid on the other side. It was determined that both connections were constructed in the same way, i.e. as rigid connections (figure 2 – left), but with no specific construction details for strengthening the joint connection which would provide more significant degree of rigidity. Connections were assembled the same way when crane was originally constructed, contrary to model for structural analysis. By increasing the span, bolted field splice, which is located in the middle of the span, found itself in the critical section, i.e. in the least favorable place, and apart from that, it was determined that web splice plates were constructed combining two different methods, as bolted and as welded contrary to valid standards for steel structures figure 2.

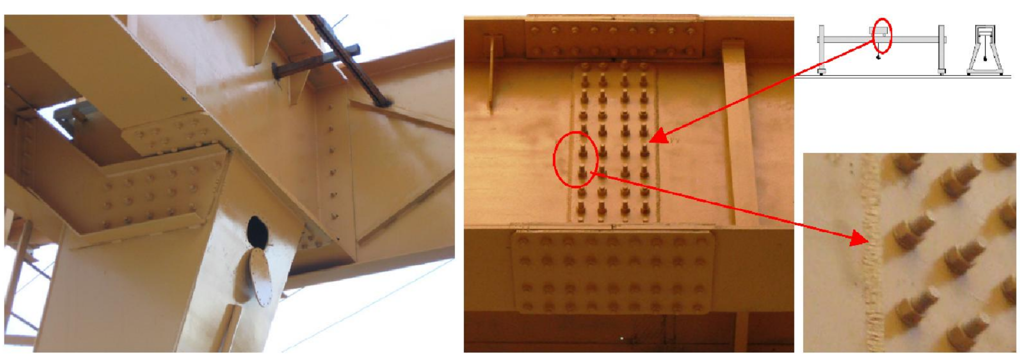

Figure 2. Connection between main girder and supporting frame and field splice

Cross-section of main girders at the location of original supports now have different stress state (bending moment altered its sign), so flange reinforcement for preventing lateral buckling are no longer functional. Flanges remained with net area, i.e. area reduced by holes for fasteners for connecting main and supporting girders. Inspection of box girders of supporting frames indicated that they are filled with various steel waste and cast with concrete up to approximate height from the base of 1-1,50m. This modification indicates on bad dynamic response of the crane structure during the previous exploitation. The most probable reason for that is concentrating the mass close to supporting joints, in order to increase stability of crane subjected to dynamic actions. All previously mentioned defects, although not negligible, do not significantly contribute to decrease of bearing capacity. Increase of span is not limiting factor, considering sufficient stress capacity in main girders. The main limiting factor is problem of lateral torsional stability. Altering the sign of bending moment caused the necessity for lateral stabilization of upper zone, because according to original static scheme stability of lower zone was provided by the revision path structure.

2. STABILITY OF STRUCTURE

Main girders of I cross section are used for shorter spans and smaller loads of cranes. For longer spans of cranes, with heavy operating mode, generally I cross sections should be avoided. Priority should be given to box sections (squared, rectangular or trapezoidal) due to the higher torsional stiffness. I cross sections require additional measures for stabilization of compression zone for out-of-plane buckling. It is recommended that compression zone is reinforced or combined with additional profile which carries the rail [6]. Disadvantage of box profiles are high stress state due to welding (fixed joints, accumulation of joints), which makes their forming more complicated. By original configuration of construction elements for considered crane, very rigid and laterally stable structure was achieved. Revision path was correctly placed in the lower zone of main girders, providing that way lateral stability. By increasing the span and ratio span – stiffness, revision path carriers lose capability of taking over design load. Revision paths become ballast to main girders and apply additional torsional load (figure 3).

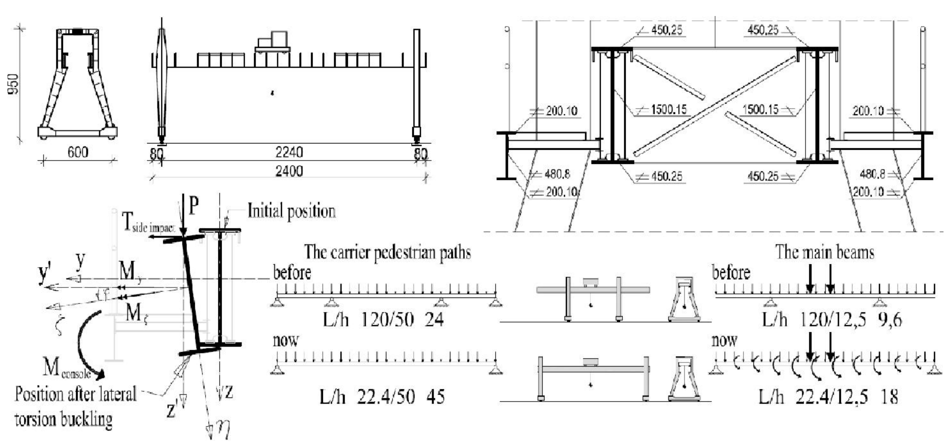

Figure 3. Disposition of crane, static schemes and load types of main girders

3. OPTIONAL REINFORCEMENT SOLUTIONS

When lateral-torsional buckling problem is present, it is necessary to increase moment of inertia about weaker, vertical axis. Options for solving the problem are: decrease of bearing capacity, which in this case was not an option due to the investor requirements, reinforcement of top flange with additional profile or plate or relocating the revision path from lower to upper zone. Main girders of gantry crane are subjected to dynamic actions which induce bi-axial bending combined with torsion as a consequence of horizontal force from side impact in the upper edge of rail level.
Static analysis is the most common method for crane design, assuming that load is applied instantly, and neglecting dynamic effects od system interaction: crane structure, mobile hoist and trolley and cargo. This approach easily provide analytical relations ideal for optimization methods due to clear affect of each factor on stability and deformability of girder [7],[8],[9]. Simplified calculation methods assign entire lateral horizontal force to the top flange or horizontal bracing beneath the revision path. This approach has many disadvantages and does not provide complete overview for behaving of the structure during the exploitation phase. This paper contains complex static and dynamic 3D modelling of the crane structure using the software SAP2000 v.15.1.0. All girders were modeled on a micro-level. Plates of all girders, flanges, webs, walls of box sections as well as transverse stiffening plates are modeled using shell elements. Considering the fact that vertical and horizontal deflections of main girders was considered, as well as the stability of upper zone, dynamic model was simplified compared to the ideal one [10]. Hoist and trolley structure was not modeled. Load was applied to main girders directly as the hoist wheel reaction. Influence of transverse contraction of cables was neglected in dynamic analysis, as well as their non-linear behaviour at the moment when force enters the system (moment of lifting the cargo from the ground). Figure 4 represents the response of the crane structure when fully loaded, up until the 20t limit, and then instant unloading, and to dynamic effect of side impact. The results obtained for phases before and after the increase of span were compared, as well as the influence of possible reinforcement measures.

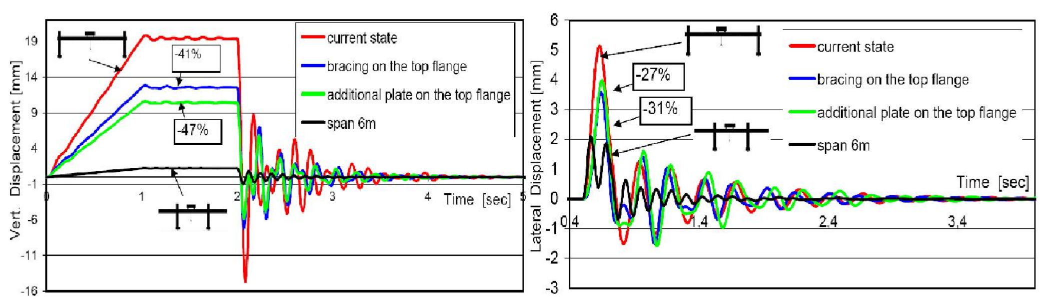

Figure 4. Stability check of compression zone for lateral buckling according to [10]

With the span increased, deflection capacity was completely exhausted as it reached the value of L/1000. Increase of vertical displacement is more than ten times greater. Stress state in critical cross section in the middle of the span is raised from 3.5kN/cm^2 to 19.2 kN/cm^2 and it is well over allowed values. Reinforcement measures are necessary and would comprise adding the plate ≠500x20mm to the top flange and relocating the revision path from lower zone to upper zone plane. With partial reinforcement, which implies only adding the plates to the top flange, it is possible to achieve the maximum span of 21.0m, reducing the vertical deflection for 47%.

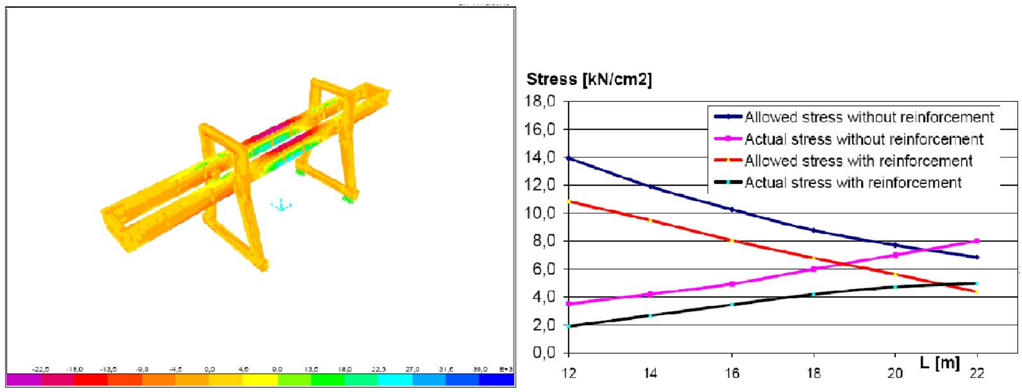

Figure 5. Von Misses' stresses for maximum loading (left); allowed and actual stresses after (SRPS U.E7.101) with and without reinforcement (right)

Lateral displacement of upper zone is efficiently reduced by adding the bracing. Simultaneous action of these measures provide completely satisfactory results. Lateral buckling stability checking of girders was conducted according to Serbian standards. Dependence of maximum possible span as a function of stress is presented on figure 5. Stability of compression zone with and without reinforcement, i.e. allowed and actual stresses for both cases are obtained after SRPS U.E7.101 [11].

4. CONCLUSION

All gantry and rotating cranes, apart from mechanical and electrical examinations require periodic structural examinations. Considering low industrial and economic activity in construction industry, heavy and steel industry, cranes are rarely being used in Serbia. As a consequence, accidental situations are not common, which is not the case around the world where collapses are more frequent because most of the cranes work in the heavy operating mode. Actions on crane structures are mostly dynamic, so they are subjected to more rigorous criteria when being designed and constructed, compared to other structures. As for reinforcement measures, purpose was to obtain optimal solutions considering mass of additional material and simplicity of constructing methods. Advantage of the presented solution lies in simplicity, and disadvantage may represent complex welding (because of the large thickness, preheating is necessary).

ACKNOWLEDGEMENT

This research is supported by the Ministry of Science and Technological Development of the Republic of Serbia, within the framework of the Technological Development project TR36016 for project cycle 2011-2014, "Experimental and theoretical investigation of frames and plates with semi-rigid connections from the view of the second order theory and stability analysis" and TR36028 for project cycle 2011-2014, "Development and improvement of methods for analyses of soil-structure interaction based on theoretical and experimental research" of the research organization The faculty of civil engineering and architecture of University of Nis.

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ПОВЕЋАЊЕ РАСПОНА ПОРТАЛНОГ КРАНА ПРЕДУЗЕЋА ПУТ ИНЖЕЊЕРИНГ НИШ

Резиме: *Променом намене порталног крана рударско-грађевинског предузећа Књажевац iz Књажевца и његовом употребом у предузећу Пут Инжењеринг Ниш јавила се потреба за повећањем распона главних носача. У раду се разматра утицај повећања распона главних двогредних I носача на стабилност, носивост и деформабилност порталног крана. Приказани су добијени резултати за првобитно и новопројектовано стање конструкције као и предложене мере ојачања.*

Кључне речи: *Портални кран, бочна торзиона стабилност, ојачање.*