Fabrication and erection of the bridge steel structure for highway R1, Beladice-Tekovské Nemce

M. Sventek* and L. Štens

*MONT IRP spol. s r.o., Oceliarska 2, Žilina

Abstract

The aim of this paper is to inform about the fabrication and erection of the bridge load-bearing steel structure, SO205-00. The bridge is located on the 2,097th km over the Majersky creek (Majerský potok). The load-bearing structure of the bridge deck is composed of a composite steel-concrete grate structure acting as a continuous beam over spans of 33 m + 3 x 40 m + 33 m. The steel part of the load-bearing structure is made of welded built-up beams with a constant height of web 1440 mm and, according to the static design requirements, various thickness and width of flanges. The connection of the steel-concrete bridge deck with the steel structure is ensured by means of shear connectors welded to the upper flange. In the paper are listed new standards (STN EN) and rules (TKP 20, MVDRR) valid at production and erection time of the objective bridge load-bearing structure.

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1. Fabrication requirements of the load-bearing structure by the customer

Before the self production of the load-bearing steel structures of the objective bridge SO 205-00 started (for a view over a spatial model of the bridge see fig. 1), it had been required by the customer, that the producer introduces the following documents for acceptance and approval:

a) Necessary qualification and certificates, meaning certificated quality system according to STN EN ISO 3834-2, qualification for production of steel structures according to DIN 18800-7 class E, certified welding procedure qualification reports according to STN EN ISO 15614-1.
b) Technological fabrication procedure of the bridge structure including occupational health and safety (OHS) requirements
c) Fabrication documentation for the bridge steel structure
d) Technological procedure of the erection, including OHS requirements at site

* E-mail address: msventek@montirp.com
According to the accepted project documentation the following was required:

Table 1. The basic material

| Requirement                                                                 | Specification                                                                 |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| the main load-bearing parts of the bridge steel structure                  | S355 NL according to STN EN 10025-3                                             |
| technical delivery conditions                                              | according to STN EN 10025-1                                                     |
| limit dimensions' deflection and the shapes' tolerance                     | quality class B, according to STN EN 10029                                     |
| the surface quality                                                         | class B, subgroup 3, STN EN 10163-2                                            |
| the basic material inspection certificate                                  | supervision certificate 3.2, STN EN 10204                                       |
| flatness tolerance                                                         | class N, according to STN EN 10029                                             |

Table 2. The basic material tests

| Test                                                                 | Description                                                                 |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------|
| tension test according to STN EN 10002-1                             | for all rolled steel elements                                                |
| charpy impact test according to STN EN 10045-1                       | for all rolled steel elements, for plates the minimal required impact energy min. 27 J by - 50°C |
| weld bead bend test according to SEP 1390                            | for steel plates of thickness > 25 mm                                        |
| improved deformation properties perpendicular to the surface of the  | increased requirements Z 25 were applied to the steel plates of a            |
| product test according to STN EN 10164                               | crossbeams                                                                  |
| chemical composition test, determining the carbon equivalent CEV     | to heat, maximal value 0,43 according to STN EN 10025-3                      |
| according to STN EN 10025                                            |                                                                             |
| ultrasonic testing of steel flat products – steel plates of crossbeams' flanges and webs in raster 100 x 100 mm | acceptance class S2, according to STN EN 10160                             |
| ultrasonic testing of steel flat products – other steel plates in raster 200 x 200 mm | acceptance class S1, according to STN EN 10160                             |
| weld edge testing, in width 100 mm (75 mm) from root of a weld edge   | by a double sound according to STN EN 10160                                  |
| shear connectors - pegs                                              | according to STN EN ISO 13918, welding according to STN EN 14555            |

2. Steel load-bearing structures of the bridge and their fabrication

The fabrication of steel load-bearing structures of the bridge SO 205-00 was performed by the company MONT IRP s.r.o. located in Žilina. The company MONT IRP s.r.o. is a holder of all the qualification mentioned in 1a) and followed standards STN 73 2601, TKP20, STN EN 1090-2, STN EN ISO 3834-2 during the production and the pre-production phases.
2.1. Pre-production phase

Material purchase, evidence, storage, documentation.

In the producer’s technological procedure of fabrication (TP) was elaborated a procedure of the material evidence and inspection in compliance with the requirements in technical report. All delivered material had been associated with the material certificates STN EN 10204 including steel plates’ numbers and heats. The steel plates dimensions were specially ordered, organized into the flame cutting patterns so, that by cutting the material there is minimal number of transversal welds and minimal waste.

Table 3. An example of material evidence

| flame cutting pattern | dimensions [mm] | weight [kg] | Qty. [pieces] | quality | EN 10204 Attest no. | heat | plates | TÜV EN 10204 – 3.2 |
|-----------------------|----------------|------------|---------------|---------|---------------------|------|--------|-------------------|
| PL254                 | 25             | 1 980      | 9 560         | 29 718  | S355NL              | 4022/2010 | 15615Y | 504986            |
| PL254                 | 25             | 1 980      | 9 560         | 7       | S355NL              | 36816Y | 503978 | 503978            |
| PL254                 | 25             | 1 980      | 9 560         | S355NL  | 4781/2010           | 36823Y | 50394  | 50394             |

2.2. Production phase

2.2.1. Cutting of materials

All material processing was performed in accordance with the requirements of STN EN 1090-2 [1]. Cutting planes were elaborated for each plate pattern. Flame cutting was performed by the use of NC machines (plasma cutting for steel plates of thickness up to 20 mm, oxygen-acetylene cutting for steel plates of thickness more than 20 mm). For each plate number were registered cut items during production, so that each item has assigned plate no., heat no. and certificate no. All the items were marked immediately after cutting by means of stamping and markers. Items had already assigned edge preparation for weld connection; the edge preparation was performed for thicker plates by burning and grinding and for thinner plates by mechanical machining.

2.2.2. Workshop welding of the steel structures

Before welding the load-bearing bridge steel structures, see point 1., company MONT IRP s.r.o. had prepared technological fabrication procedures in accordance with the requirements listed in STN EN 1090-2 and certified welding procedure qualification reports according to STN EN ISO 15614-1[2] for range of performed welds considering the weld dimensions, the welding positions, type of a weld, etc. Consequently, welding procedure specifications (WPS) were prepared acc.to STN EN ISO 15609-1[3] for all the welds performed on the bridge steel structure with the listed non-destructive testing (NDT). For individual beams were developed procedures for connecting the particular items of the beam together with the evidence of the items, attests, welders, and NDT reports (quality level B acc.to EN ISO 5817 [4] and B+ acc. to EN 1090-2 [1]). The welders met the qualification in accordance with STN EN 287-1 [5]. Fillet welds (FW) on the beams were performed by the use of automatized welding (carts BUG-GY – also with performed WPQR) (see fig. 2. (a)). Butt welds (BW) on the flanges were performed manually with use of inlet and outlet plates (see fig. 2. (b)). The bottom and upper flanges were designed of a variant thickness to be done in continuous change in the ratio ¼. (see fig. 2. (c)). After welding, inspection and NDT, the welds were threatred so that no notch damage occurs, grinding the weld’s surface to plane level with the basic material.
2.2.3. Production assembly – the bridge structure sections assembly

For the manufactory joining of each assembly block, the drawing documentation with the required dimensions and the particular level and directional points was prepared. System of marking and the geodetic nodes was listed in each drawing (the evidence of fabrication assembly was listed even in the production diary). The measurement was done by a geodesist and for each measurement of the bridge structure there was elaborated an inspection protocol with the coordinate system drawing used for erection on site.

2.2.4. Assembly and measurement of a wedge plate

An experimental placing and measurement of wedge plates was realized in the workshop. There was an inclination of the wedge plate in both directions, because crossbeams were inclined both (in the longitudinal and transversal direction related to the plane), so each wedge plate was unique with different dimensions. (see fig. 3 (a), (b)). Bearing surfaces of the wedge plates and the bottom flange of the crossbeam were controlled by the use of a feeler gauger. Inclination of the wedge plates was controlled by the use of a digital water-level. Machining of the wedge plates were performed by grinding. The wedge plates were marked on their face together with orientation direction.

2.2.5. Sheer connectors, welding method 781

Appropriate tests for sheer connectors welding according to STN EN ISO 14555 [6] were performed. Operators have certification according to EN 1418. Sheer connectors Ø 19 x 150 made of steel S235J2G3 + C450 according to EN ISO 13918 [7] were used. Before each of sheer connectors welding, there has been performed an operating test by welding 10 pieces of pegs, which were visually controlled and were tested by
bending angle over 60°. Testing of shear connectors welding was registered in the book of operating supervision for bolts welding. Consequently there was a macro-structure test performed (see fig. 4 (c)).

3. Workshop acceptance

In the workshop acceptance the specified section of the bridge steel structure was assembled in workshop, finished without the surface treatment (see fig. 4 (a), (b)). Acceptance was performed in compliance with the requirements of the customer and TKP20 with registered report. After the successful acceptance of the steel structure two layers of anti-corrosion protection were realized according to the customer requirements and the technological procedure specification for the paint-coat system.

![Fig. 4. (a) (b) View over the bridge section assembly at the workshop acceptance (c)The shear connectors bending test](image)

4. The erection

The assembly of bridge load-bearing structures was realized in compliance with the accepted technological procedure of the erection. The erection was set to be started from pillars in axis no. 3. Placing the beams of the bridge structure was performed step by step in the direction of Zvolen (to axis no. 6) and then from pillar no. 3 in the direction of Nitra (to axis no. 1). First the left bridge (direction Zvolen) had been assembled and after it had been welded up completely, the same procedure was applied for the right bridge (direction Nitra).

| Table 4. The basis of erection procedure |
|-----------------------------------------|
| 1. First the bridge bearings on pillar no. 3 were performed (the bridge bearings were “freely” placed to the prepared gap on the top of the pillar) and afterwards “on-pillar beams” were placed on the bridge bearings and PIZMO temporary supports. |
| 2. Joining the beams by erection reinforcement and their geodetic fixation was performed. |
| 3. After the satisfying measurement results and their acceptance by the customer, the assembly connections were realized. After the welded connections had been realized, all the NDT tests of the welded connections were performed. |
| 4. After a geodetic fixation, the assembly continued by adding another structural part. Its geodetic fixation was performed; relevant modification of weld edges and the assembly connections were adjusted. |
| 5. Consequently adding the “between-pillar beams” on PIZMO supports was performed and the structural parts were connected by an assembly reinforcement step by step as the beams were being added. |
| 6. The same procedure was applied by realizing the other parts of the steel load-bearing structures of the bridge – first the “on-pillar beams” were welded in axis no. 4 and after this the assembly connections of these structural parts to the “between-pillar beams” were welded. The welded joints were sandblasted and painted with primer and middle layer. |
| 7. The bolted fixation of the bridge bearings to the structure was realized in the required position and after the customer’s acceptation, the embedding of bearings and their activation was performed. |
| 8. After the bridge bearings activation, disassembly of the supporting structure (PIZMO) was performed. |
| 9. The next step was realization of the composite steel-concrete deck. |
| 10. Following a written appeal by the performer of the civil works in the Erection diary, the erection reinforcement was removed. |
Next, the top paint-coat was applied by the use of assembly platforms.

Fig. 5. (a) The scheme of bridge erection, (b) The assembling supports of the bridge, (c) View over the bridge deck after the concreting, (d) Side view over the finished bridge, (e) Bottom view over the finished bridge

5. Conclusion

In the paper is briefly explained the process of bridge load-bearing steel structure production and erection. The bridge structure of SO205-00 on highway R1 was set in production group Aa according to STN 732601, but handover was made according to EN 1090-2, so both standards were respected. High requirements were applied to quality of welding and raw material, smooth surface with no fatigue stress concentration, designed shape with tight geometrical tolerances, exact material evidence as by pressure equipment and surface protection with durability of 15 years.

References:

[1] EN 1090-2, Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures (EN 1090-2:2008)
[2] EN ISO 15614-1, Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc and gas welding of steels and arc welding of nickel and nickel alloys (EN ISO 15614-1:2004)
[3] EN ISO 15609-1, Specification and qualification of welding procedures for metallic materials. Welding procedure specification. Arc welding (EN ISO 15609-1:2004)
[4] EN ISO 5817, Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections (EN ISO 5817:2007)
[5] EN 287-1, Qualification test of welders. Fusion welding. Steels (EN 287-1:2011)
[6] EN ISO 14555, Welding. Arc stud welding of metallic materials (EN ISO 14555:2006)
[7] EN ISO 13918, Welding. Studs and ceramic ferrules for arc stud welding (EN ISO 13918:2008)