MAIN PROBLEMS OF REPAIRING ARCHITECTURAL ELEMENTS OF A RAILWAY FLYOVER BUILT IN 1905-1914 WITHIN THE CITY OF GORZÓW USING DRY-MIX SHOTCRETE TECHNOLOGY

HAUPTPROBLEME BEI DER REPARATUR VON ARCHITEKTONISCHEN ELEMENTEN EINER EISENBAHNÜBERFÜHRUNG, DIE ZWISCHEN 1905 UND 1914 IN DER STADT GORZÓW UNTER VERWENDUNG VON TROCKENSPRITZBETONTECHNOLOGIE GEBAUT WURDE

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The paper discusses the method of using dry-mix shotcrete technology to repair architectural elements of a railway flyover built in 1905--1914 within the city of Gorzów in Poland. This object was one of four made by Prussian railways in the areas east of the Elbe (also in Berlin, Wrocław and Strzegom). All were designed as modern arch structures made of concrete and brick. The repair technology involved preparing the substrate along with the assembly of the anti-shrink reinforcement and then making C25 / 30 grade shotcrete. The difficulty in carrying out the repair was recreating the architectural elements, including grooving and rustication. Repair works were carried out in the years 2017 - 2019. The investor was Polish Railways, Warsaw.

Der Beitrag diskutiert die Trockenspritzbetontechnologie als Methode zur Reparatur von architektonischen Elementen einer Eisenbahnüberführung, die 1905-1914 in der polnischen Stadt Gorzów gebaut wurde. Dieses Objekt war eines von vier Objekten der preußischen Eisenbahnen in den Gebieten östlich der Elbe (weiter Objekte gibt es in Berlin, Breslau und Strzegom). Alle wurden als moderne Bogenkonstruktionen aus Beton und Ziegeln entworfen. Die Reparaturtechnologie umfasste die Vorbereitung des Untergrunds zusammen mit der Montage der Schwindbewehrung und die anschließende Herstellung von Spritzbeton der Klasse C25 / 30. Die Schwierigkeit bei der Durchführung der Reparatur bestand darin, die architektonischen Elemente, einschließlich Rillen und Bossierungen, wiederherzustellen. Die Reparaturarbeiten wurden in den Jahren 2017 - 2019 durchgeführt. Der Sanierungsinvestor ist die Polnische Eisenbahn, Warschau.

1. Introduction

The analyzed railway flyover from km 295.591 to km 297.707 of route 203 Tczew - Kostrzyn, with a total length of 2116 m, is located on the coastal areas of the Warta River in the center of Gorzów Wielkopolski. The main part of the flyover was built in the years 1905 - 1914. The flyover consists of several sections of retaining walls, brick and concrete spans, steel viaducts, a station flyover with tunnels and platforms as well as a passage under the tracks located in the depot. The same facade finish of all elements was used along the entire length of the foundation. The constituent elements of the structure were made at the place of foundation from concrete castings - artificial stone - terrazzo. The artificial stone consisted of a dark gray cement binder constituting about 30% of the mass and a limestone filler with a carefully developed surface imitating "wild" machining: stone blows, with traces of tool on the surface and grooving on the edges. Individual parts of the architecture were not differentiated in color,

only by the surface texture. The facades are ecru, light cream, while the arcades vaults were built of red brick. The structure of the building consists of 51 open arcades, vaulted with segmental arch supported on pillars reinforced in the lower part with low buttresses (remains of former pylons of different height) with a face from several horizontal rustication, secured from the top with a sloping cap. The elements of the viaducts were constructed of steel elements, rolled, joined with large rivets, span supports with a structure adapted to high loads and vibrations (appropriately flexible), painted with oil paints in various colors as corrosion protection. Reinforcements made of iron elements are visible from below the flat culvert ceilings, also painted with oil paint. Arcade slopes made of earth embankments are strengthened on the surface, laid on lean cement mortar with granite pebbles of uniform size. The vaults of through arcades were built on wooden formwork and were made of red bricks, heavily burned, from lean clay through the addition of ceramic debris. Bricks were connected with cement-lime mortar, grouting flush with the surface of the bricks. A general view of the flyover is shown in Figure 1.

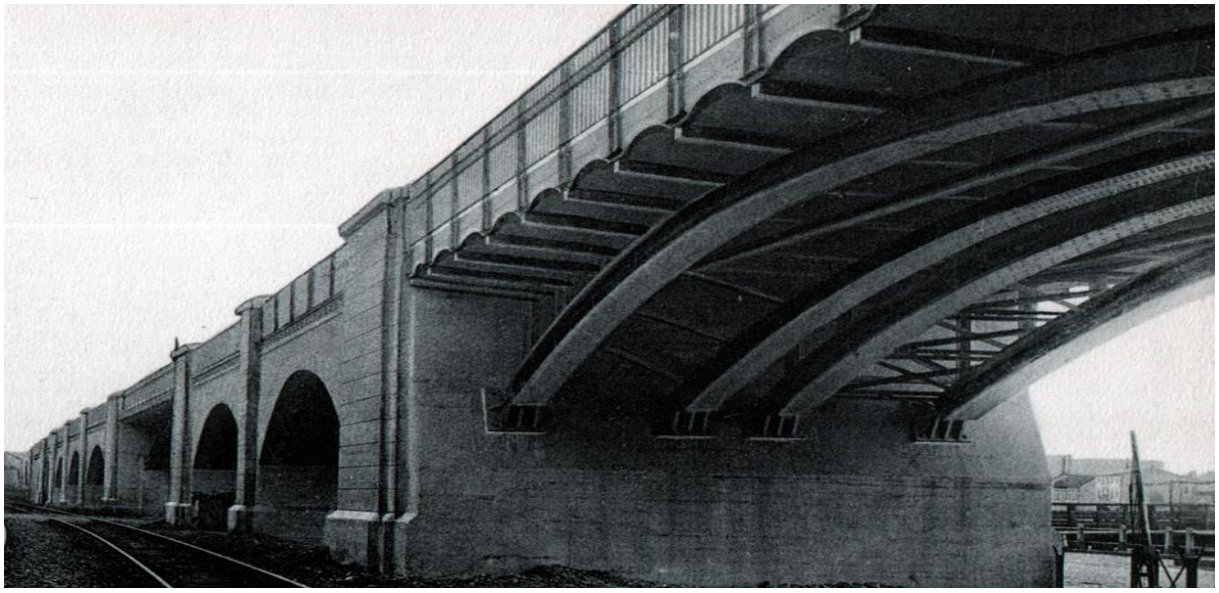

Figure 1. General view of the flyover with concrete and steel brick spans - Photo arch. 1914.

2. The basic structural element of arcades and their technical condition

The subject of detailed analysis are brick-concrete spans created by supports and arches with a total length of 912 m. Arch supports are massive walls 2.2-2.2 m thick and about 9.0 m wide (see Figure 1). Transitions serving as communication between individual arcades are placed in the supports. From the face of the structure on the supports several levels of rustication were formed, usually crowned with a sloping cap. In the case of several supports, the original finish of the supports remained with rustication along the entire height of the walls. The superstructure of the spans are brick vaults with a parabolic span from 10.6 m to 13.3 m. The vaults are made of solid brick with cement and lime mortar in a cross weft and covered with a layer of concrete connected to the side walls. The thickness of the brick vault is variable and amounts to about 0.6 ÷ 0.65 m in the key and 0.85 ÷ 0.95 m in the headboard. The side walls of the vaults are made of concrete and topped with a cornice on which balustrades in various forms have been placed. The side walls of the vaults are about 0.95 ÷ 1.05 m thick. A concrete layer is formed on the brick arches profiling the upper surface of the vaults to drain water. The concrete layer has a thickness of 0.08 ÷ 0.12 m in the key and about 1.60 m above the supports. The concrete layer has two layers of bituminous insulation with protective layers of

concrete and a top layer of insulation. The characteristic dimensions of the indicated structural elements are shown in Figure 2.

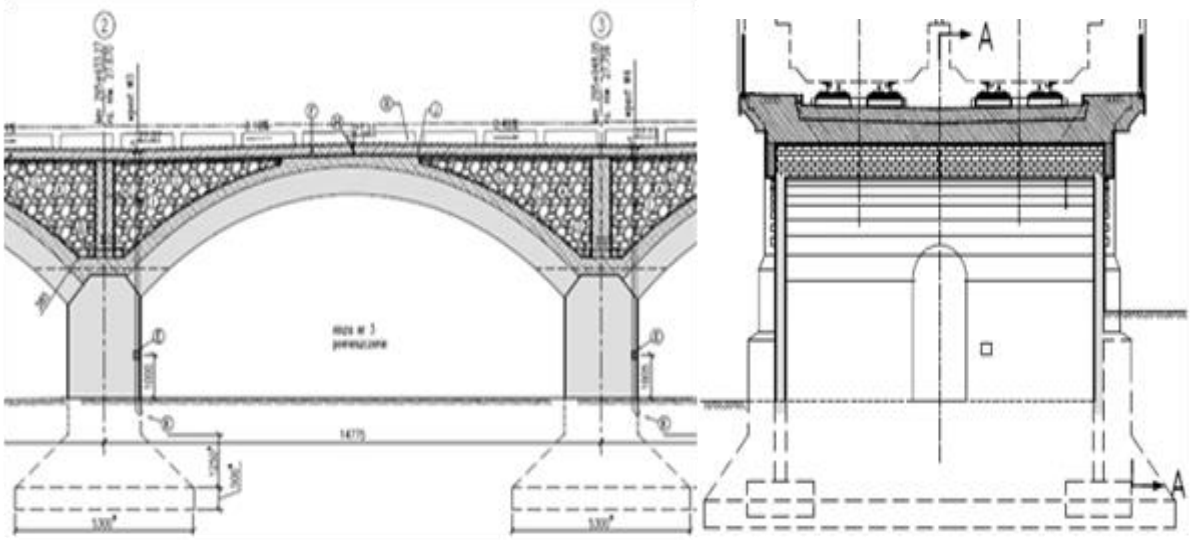

Figure 2: Cross section A-A through a typical span and typical support. Reinforced concrete parts and darkened brick masonry

The condition of most elements of the flyover and the station has been determined in the technical expertise developed over the past years as very bad, and sometimes in emergency. This applies to both structural components and finishes that determine the aesthetics of the entire premise. This paper refers to the state of these finishing elements - facade of walls and arcades, arcade vault surfaces, platform and tunnel finishing elements. These are the primary elements constituting, equally with their construction, the historical and aesthetic value of the object. Selected solutions and their technical condition are shown in Figures 3, 4 and 5. Numerous stains on the facade and salt efflorescence on the stone vault as well as material defects and scratches of both the concrete arch and the brick vault are visible. Rustication on supports is cracked, wet and often on large, detached surfaces from the wall.

Figure 3: View of a typical open brick-concrete bay and the original railway track with a cornice and steel railing

Figure 4: Cracks in the brick and concrete arch and supporting elements

Figure 5: Brick vault and concrete arch end (bottom view). Leaks, efflorescence, defects in bricks and concrete, cracks on a concrete arch

3. Methods for repairing and enhancing the basic brick-concrete flyover elements

The scope of repair work covered the entire brick and concrete structure of the facility, support bodies, drainage systems and track insulation and replacement of the railway surface as well as threshold sections (transition zones) with backfills. The total repaired concrete surface is 13,500 m^2. A basic conservation recommendation was adopted to reproduce the original texture of the concrete and the original forms and surfaces (corrugation) of walls and cornices, and to preserve the light yellow (ecru) color of shotcrete selected after cleaning the original face, recommending, if necessary, coloring with mineral pigments. The mortar should be prepared at the factory, with crushed limestone filler as in the original, which will maintain its unchanging color, composition and properties guaranteed by the manufacturer throughout the entire period of work.

The preparatory works included the following activities: removal of corroded layers of concrete to a depth of 0.06 - 0.08 m; cleaning the concrete surface from water, dust, loose sand and other impurities; replacement of downpipes and making new inspection holes with their closure; filling any concrete defects in existing support structures (and decorative rustication) with PCC mixtures; injection of scratches with an opening larger than 0.2 mm with synthetic PC resins; protection of the support surface against shotcreting by deep, non-injection water-tight sealing that binds pores and capillaries, like "Xypex" or "Hydrostop".

Figure 6: View of the spans after removal of old concrete and mounting of reinforcing mesh

The prepared substrate was covered with mesh of Ø8 mm rods with 100x100 mm mesh width, fixed to the surface of supports and concrete vaults with Ø12 mm anchors glued in to 14 mm holes with a spacing of 0.3x0.3 m. Preparation is illustrated in Figs. 6, 7, 8, 9 and 10 (left). On all exposed concrete surfaces, after preparing the substrate in the manner described earlier a dry-mix sprayed layer was applied at least 0.06 - 0.08 m thick from ready-mixed mixtures of min. C25 / 30 class of concrete. Shotcrete was made in dry-mix technology using the ALIVA 246 machine. The shotcrete mixture was designed with quartz aggregates 0 – 4 mm, Portland cement CEM I 42.5 R, a small amount of fly ash, active silica fume SiO_2 and a small amount of Sika's non-alkaline Sigunit 49 AF setting accelerator. Samples for determining the compressive strength of concrete were made on 600 x 600 mm panels and sent to the laboratory. All of them met the strength criterion.

The concrete mix was applied in two stages: first, a layer of shotcrete for embedding reinforcement was sprayed and then a second layer of shotcrete to obtain a reinforcement cover of 30 mm. The adhesion of the applied layers to the substrate by the "pull-off" method was also checked. Results obtained in the range of 1.0 - 1.5 MPa, which is consistent with the requirements of *PN-EN 1504: Products and systems for the protection and repair of concrete structures*.

Figure 7: Spraying the second layer of shotcrete (reinforcement cover 3 cm). In the right the ALIVA 246 machine

Figure 8: Preparation and reinforcement of the surface in the area of support of the flyover arch with damaged rustication. Visible green template used to imprint the arch in the fresh concrete

Figure 9: Grooving the lower part of the arch - steel sheath with vertical cuts and manual line profiling

The concrete surface was finished with the "cut and flash" technique, obtaining an incised texture, similar to natural stone blocks. Span arches and rustication of supports were also processed. Concrete external surfaces were protected with sprayed hydrophobic coatings and light yellow anti-graffiti coatings.

Repair of brick arches constituted a separate technological line and included: removal of the insulation layer together with layers of protective concrete over the arches; injection of cracks and scratches with an opening greater than 0.2 mm, bonding of detached concrete side walls from brick vaults (see Figure 5) by means of injection; joining of brick arches with a concrete jacket by means of Ø 12 mm rods glued onto the resin; supplementing defects in the vaults with brick identical in terms of dimensions, surface appearance and shape with bricks embedded on a cement-lime mortar with a grain size of 0-4 mm; pointing of repaired vaults. Minor defects of bricks were masked with a properly selected mineral putty imitating the surface of bricks and artificial stone veneers in primary colors.

Figure 10: Damaged rustication of the support before and after repair. Visible brick vault repair

Figure 11: View of repaired flyover

In this paper, due to the conference profile – Spritzbeton -Tagung - the implementation of very interesting reconstruction of girders and other steel components of the flyover, reconstruction of missing fragments of track balustrades using locksmith method from appropriate bars and flat bars according to the original modernist pattern from the 1930s, reconstruction of the station itself was not discussed (Fig. 11), hence the recommended visit to Gorzów Wielkopolski.

4. Conclusions

Shotcrete is concrete which offers many advantages over other methods of placing concrete but without extensive structural formwork and complex application by hands. Rich technical literature describes many traditional applications connected with the rehabilitation of concrete [3,5], but also points to new trends such as sprayable fire-protective layers in traffic tunnels [4]. Shotcrete may also be used for shaping architectural space ([Skatepark Project [6]) as well as large surface architectural concrete elements [2]. Similarly to the publication [2], the authors of this work showed another, innovative application of shotcrete, this time to strengthen and renovate the historic railway flyover, over a hundred years old, with artificial stone facades in light yellow. The contractors gained another interesting experience and showed similar companies new opportunities for shotcrete.

5. References

[1] Technical documentation:
Modernization of railway flyover in Gorzów Wielkopolski, Brick and concrete spans flyovers km 295,897 ÷ 296,809. Bridge industry. Made by: Design Office: Transprojekt Gdańsk Sp. z o. o. 80-254 Gdańsk, ul. Partyzantów 72a. 2013.

[2] Jasiczak J., Majchrzak W., Czajka, W.:
Construction of Undulating Walls Using Dry-Mix Shotcrete. Concrete International. Volume**:** 37. Issue**:** 6 , pp.31-35. 6/1/2015.

[3] Kusterle, W.:
Development and practical experience of new ecologically desirable sprayed concrete. Proceedings Tunnelling `97, IMM, London 1997.
[4] Kusterle, W.:
Sprayable fire-protective layers in traffic tunnels. In: Proc. of the third International Conference on Engineering Developments in Shotcrete, Queenstown, 15-17 March, 2010, Bernard, E.S. (ed.) Shotcrete: Elements of a System. CRC Press/Balkema, Taylor & Francis, London 2010, p.159-172.
[5] Lukas, W.; Kusterle, W.; Pichler, W.:
Neue Tendenzen in der Spritzbeton- Technologie - Probleme, Grenzen und Möglichkeiten. In: IBK-Bau-Fachtagung 186: Tunnel- und Stollenbauwerke - Neubau und Sanierung, Hannover, 26.+27. 9.94, Institut für das Bauen mit Kunststoffen, Darmstadt, 1994.
[6] Youkhana, D.:
The North Burlington Skatepark Project. Magazine of the American Shotcrete Association. Vol.15, No1, Winter 2013, p.46-47.

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