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Using TRC as an Environmentally Effective Alternative for Subtle Elements of Railway Furniture

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Abstract. This paper presents the possibilities of an innovative and aesthetic solution of furniture from concrete for railway stations. At present, the railways in the Czech Republic undergo significant changes. Due to automation and centralization there is a lot of stations without permanent staff. Thus the need for railway station furniture, that exhibits considerable resistance to damage during the intense operation and deliberate vandalism, is raising. Currently, the most used material is metal. Such equipment is expensive and requires constant maintenance. Current concrete furniture is too massive, heavy and usually has a lack of aesthetic or architectonic appearance. The paper presents some results of research and development of the new, modern solution based on the use of concrete to form aesthetic furniture elements, while saving consumption of concrete and maintaining the required parameters and dealing with deliberate destruction. Reduction of concrete as a second most used material is one of the key factor of this solution focusing sustainability goals. This paper thus also presents the environmental analysis and comparison with standard solution.

1. Introduction

Concrete is the second most used material after water, thus significant environmental impact is associated with its extensive use. The potentials of reduction of concrete use is one of the most recently discussed topics. In the constructions, where the use of concrete is necessary or desirable, the possible approach is to optimize the element shape, concrete mix and reinforcement to reduce the consumption of concrete to a minimum while maintaining the same mechanical parameters.

Textile reinforcement used in TRC is a relatively new material which can replace a steel reinforcement in tension zone of reinforced concrete element. The concrete cover could be thus significantly reduced due to non-corrosive properties of textile rovings. This allows the design of very thin elements. This is why TRC has been used in last few years especially for facade panels [1] and also for shell structures with particular shapes [2, 3] or for the strengthening of different types of structures [4–6].

A few studies contain detailed Life Cycle Assessment (LCA) and describe that structures from TRC or HPC have environmental profiles with significantly reduced environmental impact [7,8] and therefore contribute to the goals of sustainable buildings. Study [9] describes that almost 85% of concrete can be saved using alkali resistant textile reinforcement.

This article describes differences between standard solutions and innovative solution using HPC and lightweight recycled material for thin shelter, but similar approach can be applied to other elements of railway furniture. Three alternatives were compared: ordinary steel reinforced concrete, high performance concrete reinforced by non-corrosive textile reinforcement and optimized lightweight shape with non-corrosive carbon textile reinforcement. Structural assessment for all variants was performed. Thickness of elements was designed as small as possible, but with regard to the standard requirements for concrete structures. Optimized variant has lightening almost 40 %. Basic environmental analysis is also included in this article.

2. Materials used in experiment

2.1. Concrete

In this experiment were compared two types of concrete – ordinary concrete C30/37 and HPC concrete.

*2.1.1. Ordinary concrete***.** Ordinary concrete (OC) used in the specimens consists of gravel, technical silica sand, cement CEM II 32.5 and of one superplasticizer. This mixture has water/cement ratio of 0.43 (Table 1). Compressive strength is 41.5 MPa, tested on 100 mm cubes according to CSN EN 12390-3 standard. [10]

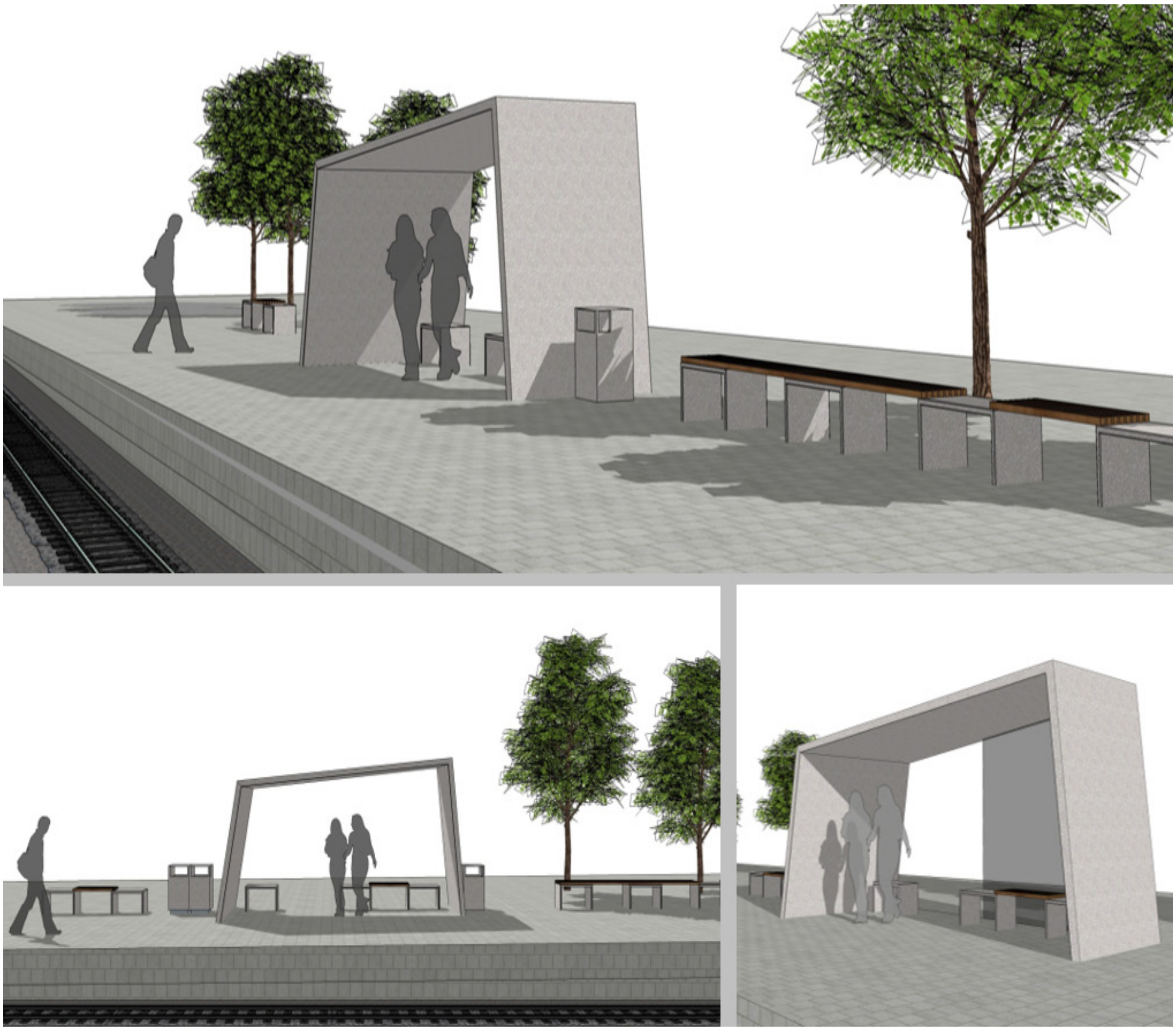

Figure 1. Visualization of railway station with optimized concrete furniture elements

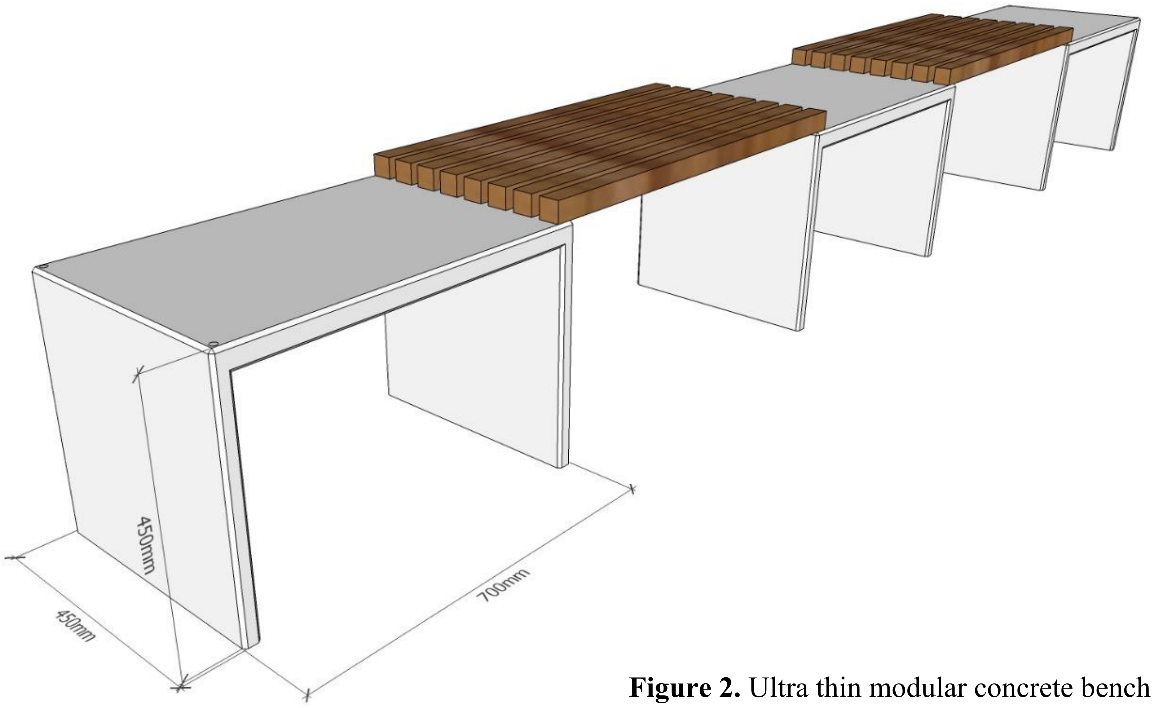

Figure 2. Ultra thin modular concrete bench

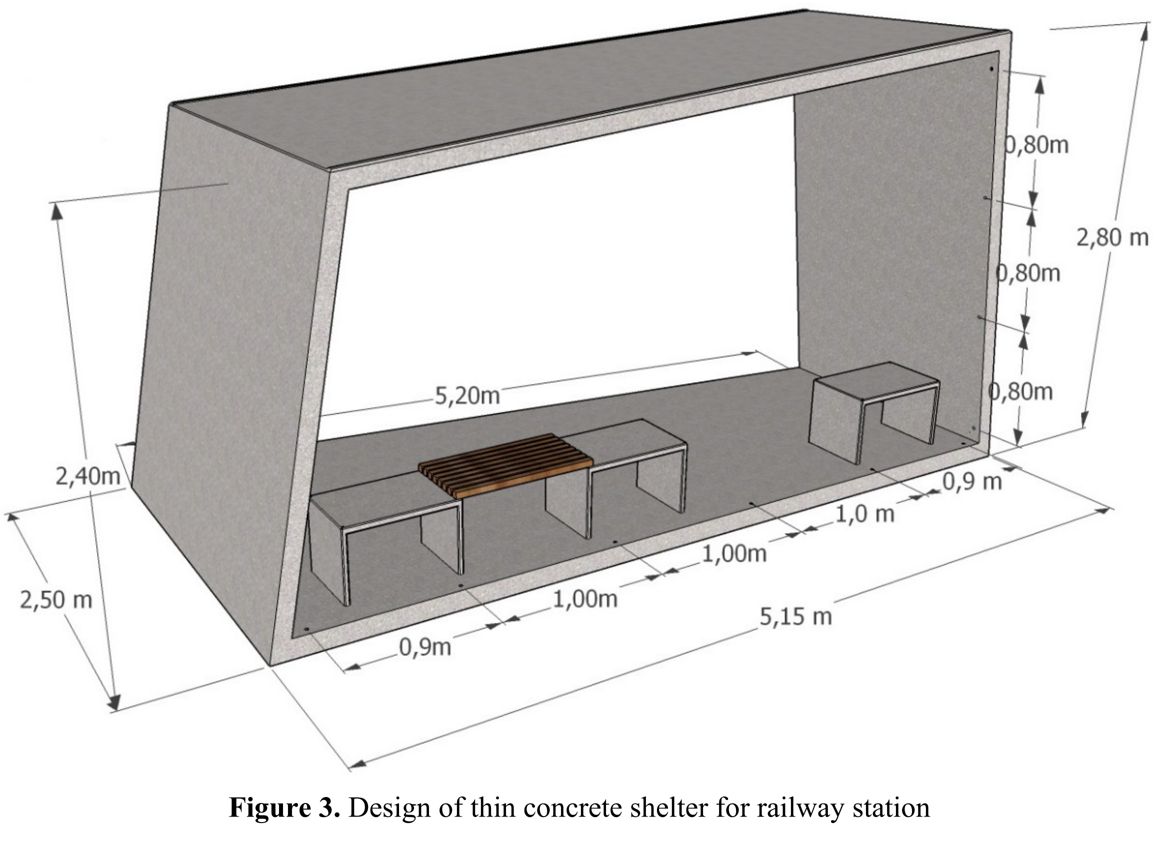

Figure 3. Design of thin concrete shelter for railway station

2.1.2. High performance concrete. The HPC mixture (HPC124) used in experiment was developed and optimized in last few years at CTU Prague. Concrete mixture is presented in Table 1. It is the self-consolidating fine grain concrete without fibres. Developed mixture reduces the amount of water on water/cement ratio only 0.25 and therefore significantly improves the mechanical properties. Direct tensile strength of used HPC is experimentally determined to 5.0 MPa respected the CSN 73 1318 standard. Tensile strength in bending is 14.3 MPa on prisms 40 x 40 x 160 mm with distance between supports 100 mm according to CSN EN 12390-5 standard. Compressive strength is 128 MPa on 100 mm cubes according to CSN EN 12390-3 standard.

Table 1. Concrete mixtures.

HPC mixture		OPC mixture	
mix content	[kg/m^3]	mix content	[kg/m^3]
technical silica sands	960	gravel	810
cement I 42.5R	680	technical silica sand	1150
silica flour	325	cement II 32.5	360
silica fume	175	superplasticizer	2.7
superplasticizers	29	water	155
water	171		
total	2 340	total	2477.7

2.2. Reinforcement

2.2.1. Steel reinforcement. For the comparison, classic steel reinforcement B500, Ø 10 mm was used for this experiment.

2.2.2. Textile reinforcement. For comparison in this experiment was used carbon reinforcement produced by © Solidian company. Technical fabrics are impregnated by epoxy resin. Grid spacing is 21 mm in both directions. Basic parameters of used carbon roving are: Cross section area of the strands 1.81 mm^2, tensile strength of fibrils more than 4000 MPa. Basic parameters of impregnated reinforcement: Cross section area of the reinforcement 85 mm^2/m for both directions, tensile strength 3300 MPa (characteristic value 2500 MPa) and Young's modulus more than 220 GPa.

2.3. Lightening
For lightening was used recycled material Stered. It is recycled material made of individual textile parts – waste from production of cars, which consists of polypropylene (PP), polyamide (PA), polyester (PET). Supplementary materials may also include polyethylene (PE), and polyurethane foams (PUR).[11]

3. Experimental investigation
Experiment was focused to the possibilities of processing of railway station stops equipped with concrete furniture and shelter as mentioned in the introduction. Three alternatives of reinforcement of shelter were considered and compared from the viewpoint of mechanical parameters and environmental parameters. All data is calculated on the largest surface of this structure, which is the roof. The size of this plate is irregular shape but average is 4.5 m x 2.25 m. All variants have been optimized using a special program and calculated according ČSN EN 1992-1-1 Eurocode 2 to meet load bearing capacity in achieving smaller thicknesses and lower reinforcing. Compression and tensile strength of concrete were performed. Tensile strength tests of TRC elements to verify carbon reinforcement action were also

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performed. Based on the test results of small specimens, several variants were calculated. Option 1 (steel reinforced ordinary concrete) was designed and calculated with steel reinforcement Ø10 and with overall thickness 120 mm of specimens. Option 2 (high performance concrete reinforced by carbon textile) was designed and calculated with carbon textile reinforcement Solidian, mentioned above. Overall thickness of this second variant was calculated 100 mm with one layer of reinforcement. Option 3 is optimized variant with HPC and carbon reinforcement with lightening from Stered. Its thickness is also 100 mm. This variant is more than 40 % lighter and has better environmental profile.

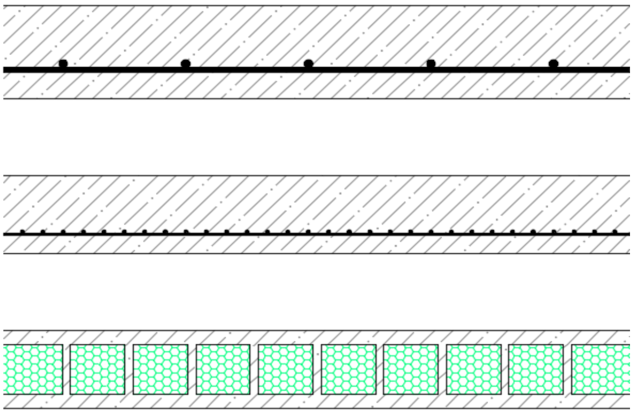

Figure 4 Cross section (a) Option 1: OPC+steel, (b) Option 2: HPC + C, (c) Option 3: HPC+C+Stered

4. Environmental analysis

Three groups of specimens mentioned above were compared in term of basic environmental aspects. Comparison was focused on four main environmental criteria: primary energy consumption (PEC), global warming potential (GWP), acidification potential (AP) and the formation of ground-level ozone (POCP). Material amounts and quantity of reinforcements were calculated for specific volumes of specimens. Data source from Institut Bauen und Umwelt e.V. EPD and iCF⌂concrete LCATool 2.0 GB and the average indicators according to ReCiPe methodology 1.08 (H) were used in the analysis and results are presented in graphs on Figs. 3, 4, 5 and 6. Data is counted for raw material supply, transport and manufacturing. Use, maintenance and lifetime is not part of the calculation. The gate of recycling plant was considered as a system boundary for recycled materials used in option 3. The environmental impact is associated with the production process of recycled material.

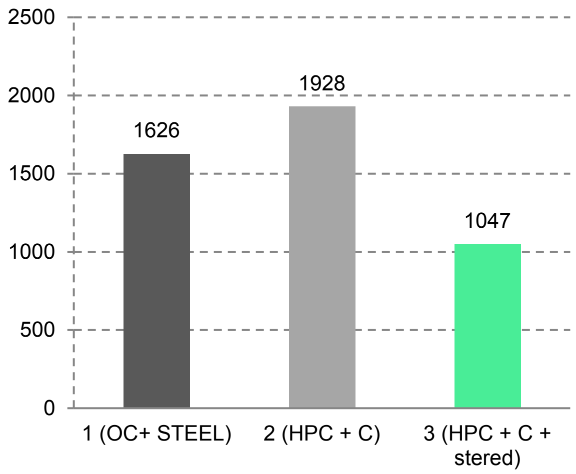

Figure 5. Acidification Potential – AP [gSO_2eq.]

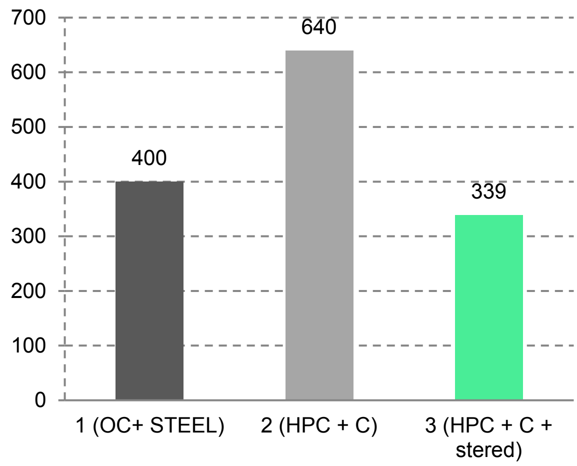

Figure 6. Global Warming Potential – GWP [kgCO_2eq.]

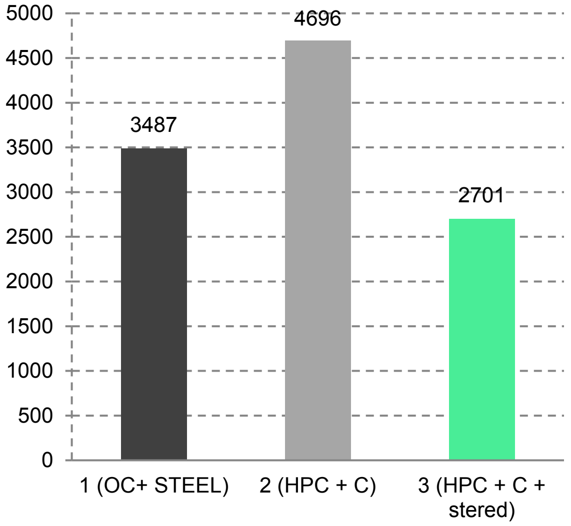

Figure 7. Primary Energy Consumption – PEC [MJ]

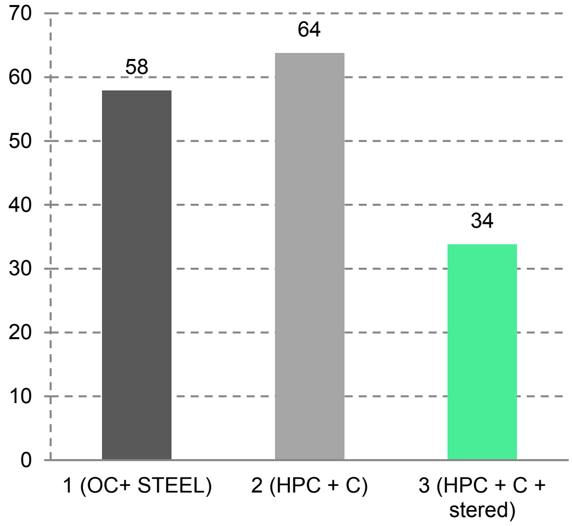

Figure 8. Photochemical Ozone Creation Potential – POCP [$gC_2H_4eq.$]

5. Results, discussion and conclusion

A positive effect of lightening specimen with Stered compared to solid element from ordinary concrete and HPC concrete is evident from the results of environmental impacts. Environmental profiles all of these alternatives (Figure 3-6) show that the values of optimized alternative (Option 3) are the lowest in all analysed categories of environmental impacts. It is due to the fact that the amount of used material is lower than in OC and also than in HPC due to shaping and due to using a lightweight aggregate from recycled material. If we take into account only the raw material supply, transport and manufacturing without maintenance, lifetime etc., it is evident that the UHPC itself using alternative reinforcements does not have as good environmental parameters as ordinary concrete. But if we use appropriate shaping by optimization of the cross-section, we can create elements that have the appropriate mechanical parameters for the purpose and which are environmentally friendly. Taking into account also the durability and lifetime of HPC constructions, which is at least 1.5 time longer, the results compared to conventional concrete would prove better and even great for lighter cross section. Shaped TRC cross sections are a very interesting option for concrete construction of railway furniture and other small buildings.

Acknowledgments

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