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INTERFACE SHEAR STRENGTH EVALUATION BETWEEN DIFFERENT CONCRETE TYPES

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Abstract. Composite concrete elements, combining different types of concrete, are widely used in modern infrastructure projects like bridge deck overlays and the reinforcement of existing structures. A critical property for ensuring effective composite action between concrete materials of different ages or types is shear strength, which must be sufficient to prevent excessive slippage or complete separation. This is a fundamental requirement for achieving composite action.

This article presents an experimental study on the shear strength at the interface between two different types of concrete, assessed through a push-off test. This investigation stands directly on earlier research focused on the use of high-performance concrete as lost formwork, providing core protection for concrete with recycled aggregates. The study explored the influence of Recycled Aggregate Concrete with aggregates from bricks (RAC) and High-performance Concrete (HPC), with particular attention to the treatment of the concrete interface and the impact of interface roughness and surface treatment. The findings validated the hypothesis that shear strength at smooth, untreated interfaces is considerably lower than that at rough, treated interfaces.

Keywords: Shear strength, Recycled Aggregate Concrete (RAC), High-performance Concrete (HPC).

1. Introduction

The effective bonding between different types of concrete is crucial for ensuring that composite structures perform as intended. Composite action depends on the shear strength at the interface between two materials, and any separation between them can drastically reduce the overall load-carrying capacity [1]. This study evaluates the shear strength at the interface between high-performance concrete (HPC) and recycled aggregate concrete (RAC), particularly focusing on the role of surface treatment [2–4].

2. Materials

Both of the concrete mixtures used in this experiment was evolved at the Department of Architectural Engineering, Faculty of Civil Engineering CTU in Prague. The average compressive strength of the HPC mixture measured on cubes of the length of the edge 100 mm after 28 days of hardening was 126 MPa. The average compressive strength of the RAC mixture measured on cubes of 100 mm in length of the edge after 28 days of hardening was 23 MPa. The detailed composition of the matrix is described below in Tables 1 and 2.

The samples were prepared as the whole element 350 mm × 150 mm × 80 mm, interface area was 300 mm × 80 mm. All specific dimensions will be shown in the next chapter.

Mix content	**kg m^{-3}**
Cement I 42.5R	650
Technical quartz sand D_{max}=1.2 mm	1 200
Technical quartz powder ST 6	235
Silica fume (microsilica)	75
Superplasticizer based on PCE	18
Water (at 12 °C)	190
Total	2 368

Table 1. HPC mix design.

Mix content	**kg m^{-3}**
Cement I 42.5R	274
Recycled aggregate 0/4	922
Recycled aggregate 4/8	0
Recycled aggregate 8/16	733
Water (at 12 °C)	253
Total	2 200

Table 2. RAC mix design.

3. Experiment

The interface between the HPC and RAC core was subjected to different surface treatments to evaluate the impact of roughness on shear strength. The four variants were as follows:

Reference Type (Smooth Interface): In this case,

Figure 1. Horizontal grooves on the left, vertical grooves on the right.

no surface modification was applied, leaving the concrete in its natural state, with a smooth interface resulting from the formwork.

Bubble Wrap Imprint: A bubble wrap sheet was pressed into the surface of the HPC before casting, leaving an imprint of small, rounded indentations that created a mild roughness on the interface.

Vertical Grooves: Vertical grooves were created by inserting small plastic strips into the formwork before casting the HPC. These strips were removed after casting, leaving a series of vertical grooves across the interface, Figure 1.

Horizontal Grooves: After the HPC was cast and cured, horizontal grooves were milled into the surface using a mechanical tool. This method created a controlled and uniform roughness pattern at the interface, Figure 1.

Each variant was tested with a set of three samples, and the results were used to calculate the average shear strength at the interface.

The shear strength was evaluated using a push-off test, where a compressive load was applied to the upper HPC block while the force required to induce failure at the interface was measured. HPC blocks were on the outer layer and the core was made by RAC. The setup of this first test is shown in the Figure 2.

The second push-off test aimed to examine the effect of concrete shrinkage on the bond between HPC and RAC. In this setup, the concrete samples were enclosed in a steel casing (hollow rectangle pipe) that tightly contained the samples during the curing process. This steel casing was used to restrict lateral shrinkage during the hardening phase, which can otherwise lead to microcracks at the interface [5].

Shrinkage occurs naturally as concrete hardens, but when confined within the steel casing, the concrete was restricted from expanding outward. This allowed for a more controlled curing process, which is expected to maintain the integrity of the interface and improve the shear strength. Setup of the samples were exactly the same with added steel profile outwards [6].

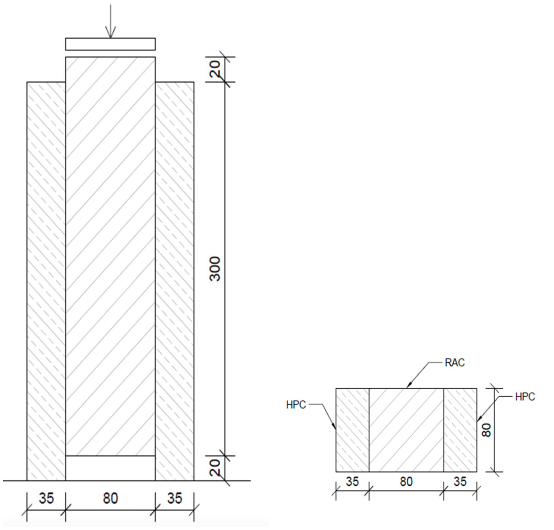

Figure 2. Setup of the push-off test. Vertical section on the left, plan view on the right.

4. Results

The first were tested unrestrained concrete samples in the four mentioned variants. Results of maximal loads and the average shear strength are described in the Tables 3– 6.

F_{max} [kN]	τ [MPa]	øτ [MPa]
26.46	0.551	0.592
28.59	0.596	
30.14	0.628	

Table 3. No surface treatment.

F_{max} [kN]	τ [MPa]	øτ [MPa]
20.79	0.434	0.439
21.14	0.443	

Table 4. Foil (imprint of bubble wrap).

F_{max} [kN]	τ [MPa]	øτ [MPa]
84.67	1.771	1.961
98.19	2.048	
98.75	2.064	

Table 5. Vertical grooves.

F_{max} [kN]	τ [MPa]	øτ [MPa]
96.28	1.995	1.945
92.91	1.926	
91.30	1.914	

Table 6. Horizontal grooves.

These results indicated that the smooth surface (reference type) exhibited kind of low shear strength, while the textured surfaces (vertical and horizontal grooves) displayed a significant increase in shear strength. The bubble wrap imprint, which created mild surface roughness, showed a lower shear strength than the smooth interface.

The smooth interface's lower strength can be attributed to the lack of mechanical interlocking between the two materials. In contrast, the textured surfaces allowed for greater bonding due to the increased surface area and better mechanical interlocking. The similarity in the performance of the vertical and horizontal grooves suggests that both types of surface treatments created effective roughness that enhanced the shear strength [7].

Concrete samples with steel casing were tested subsequently in two surface treatment variants possible for casting in the steel profile – smooth interface and vertical grooves. Detailed results are visible in the Table 7 and 8 and are presented as a compression tests results due to form of fracture.

$\mathbf{F_{max}}$ [kN]	$\mathbf{f_c}$ [MPa]	$\mathbf{øf_c}$ [MPa]
149.7	30.248	26.635
128.5	25.672	
118.7	23.984	

Table 7. Smooth interface.

$\mathbf{F_{max}}$ [kN]	$\mathbf{f_c}$ [MPa]	$\mathbf{øf_c}$ [MPa]
149.7	30.248	26.635
128.5	25.672	
118.7	23.984	

Table 8. Vertical grooves.

During the tests, the load primarily concentrated on the RAC segment of the composite sample. The applied force crushed the RAC at its upper surface, causing failure in this region, Figure 3. This localized crushing at the top of the RAC core limited the ability of the test to engage the interface fully in shear or even in distributed compression across the interface area. Consequently, the lower part of the interface remained underutilized, further confirming that the test primarily reflected a compressive failure mechanism of the RAC rather than the intended shear interaction between HPC and RAC.

The steel casing successfully mitigated shrinkage-related cracking, maintaining better compressive integrity. Nevertheless, the inability of this test setup to simulate shear stresses limits its applicability for evaluating interfacial bond behavior under composite action.

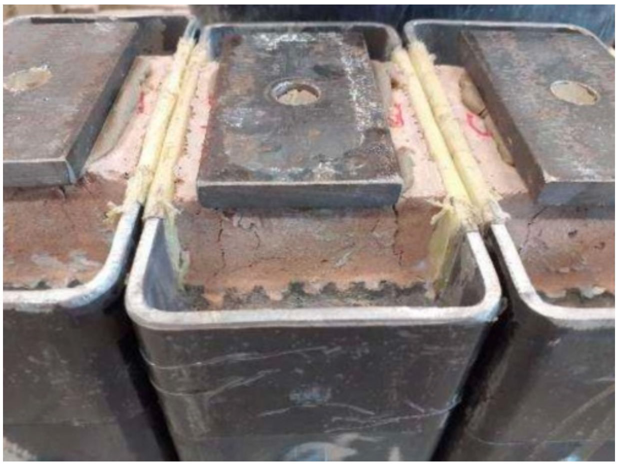

Figure 3. Steel-cased samples after testing.

5. Conclusion

This study investigated the interface shear strength between HPC and RACB using two distinct push-off test configurations. The findings underscore the critical role of surface treatment in improving interface performance but also highlight the limitations of certain test setups in replicating real-world conditions. The first standard pus-off tests provided a clear assessment of shear strength, demonstrating the effectiveness of grooves in enhancing interfacial bond strength. The results confirmed that roughened surfaces significantly outperformed smooth interfaces, emphasizing the importance of mechanical interlock in resisting slippage. While intended to simulate the effects of shrinkage constraints, the steel-cased tests primarily measured compressive resistance due to the load path bypassing the interface. The crushing of the RAC core revealed that this setup was unsuitable for evaluating shear performance and highlighted the impact of material incompatibility on load distribution.

The study reaffirms that surface treatment is essential for optimizing interfacial bond strength, particularly in applications requiring composite action under shear. However, the significant strength disparity between HPC and RAC underscores the need for careful consideration of material selection and test configurations to ensure meaningful assessments. Future research should focus on test setups that accurately replicate shear loading conditions, as well as strategies for mitigating material incompatibility to enhance the overall performance of composite concrete systems.

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