第Ⅴ部門　　Nonlinear Analysis for UHPC-NC Bond Strength

神戸大学　学生会員　○Elham Mahmoud
神戸大学　正会員　　三木　朋広

1. Introduction

Changes in services conditions such as increasing traffic volume makes the need for upgrading aging bridges essential. Effectiveness of overlay depend on the bond between overlay and substrate material. Using normal concrete (NC) as repair material has weak bond with NC as (substrate). Due to limited dead loads available to use, advanced material with high mechanical properties is needed as a repair one. Ultra-high-performance concrete (UHPC) is one of the advanced materials. ACI 239R (ACI 2018) defines it as a fiber- reinforced concrete that has a minimum compressive strength of 150 MPa with “specified durability tensile ductility and toughness requirements”. Using fibers improve the material properties by control its flexural cracking. It helps to have light, small cross section. This paper puts highlight on experimental investigation used slant shear test, using finite element models to represent the interface bond strength behavior between NC- UHPC, to represent the bond behavior at the interface between NC-UHPC slab, that need to upgrading; reinforcement concrete (RC) bridge slab with 20 cm thickness, steel fiber RC overlay (SFRC) about 5 cm thickness. As it seen in Figure.1 the bridge deck had damaged, with cracks, separation between NC and SF layer, no asphalt layer.

Figure 1　RC bridge deck with SFRC overlay

2. Analytical program

For the analysis 3D model for Madani et al. (2022), used slant shear test to evaluate NC-UHPC bond strength with different NC surface roughness; sandblasting (SB), drill hall (DH), as cast (AC) for different curing conditions (W for water, H for heating, N for laboratory environment, R for wet-dry and heat-cool cycles). The specimen was cylinder of 75 x150 mm with repair angle 30º Figure 2. The normal concrete material modeled with a total strain-based crack model, with parabolic model with compressive strength of 60 MPa and elastic modulus of 36 GPa. The UHPC material modeled with a total strain-based crack model, with parabolic model with compressive strength of 156 MPa and elastic modulus of 54 GPa. The analysis used Regular Newton- Raphson method with energy convergence criterion of 0.09, the element size to NC, and UHPC was 10 mm, and maximum number of iterations was 10. The load was applied as distributed force 3 N/mm^2 at the loading location. The connection type between NC and UHPC was interface, while the normal stiffness module was 36000N/mm^3, and shear stiffness module 900, 200, 40 N/mm^3.

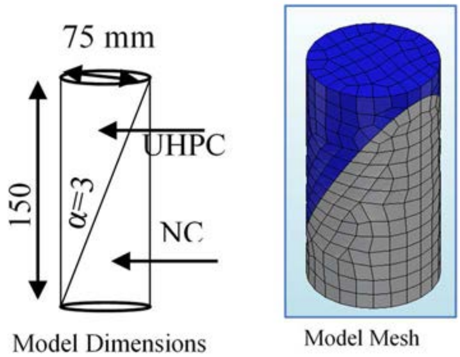

Figure 2　Cylinder for slant shear test

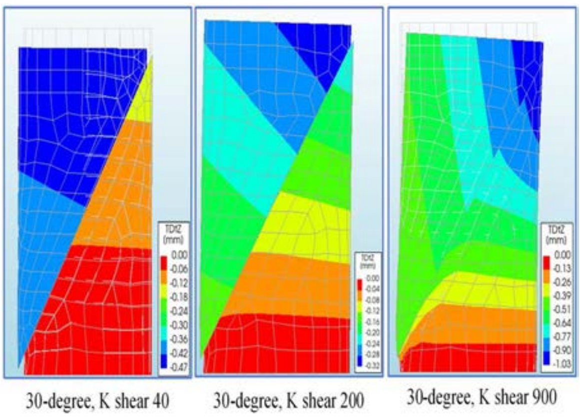

Figure 3　Deformation shape in the cylinder for slant shear test with different interface shear stiffnesses

Elham Mahmoud and Tomohiro MIKI
mikitomo@port.kobe-u.ac.jp

3. Results of bond strength modelling

Interface model was used to simulate the interfacial bond strength between UHPC-NC with different shear stiffness module 900, 200, and 40 N/mm^3, the following points are observed from FEM results. The deformation at the failure load in the analysis is shown in Figure 3. For shear stiffness 900 N/mm^3 FEM shows that the failure occurred at concrete, while for 40 N/mm^3 it was smooth moving between NC, and UHPC surfaces, and for 200 N/mm^3 the failure was at interface too but with a resistance than in smooth case.

From FEM with different shear stiffness 900, 200, 40 N/mm^3, the shear strength bond, τ were calculated as 25.3, 20.8, 15.2 N/mm^2 respectively. A comparison between the shear strength experimental and FEM results is shown at Figure 4. The FE results shows good matching with experimental failure modes, for example as cast samples the failure modes were pure interface failure, and at SB was at the concrete substrate. As for the shear strength bond FE model shows good predicted with the experimental results such as, the NC sandblasting surface roughness gets 25.3 N/mm^2 while at experimental results were 26.0, 25,77, 25.23 N/mm^2, and FEM for NC as cast surface roughness (AC) shows 15.2 N/mm^2 while experimental were 20.29, 18.86, 15.83 N/mm^2, respectively. It was observer that with increasing in shear stiffness the max load is increase too, which it effects on the shear bond strength to NC-UHPC interface. From stress- strain figure 5 it shown the slope line for FE shear stiffness 200, 40 N/mm^3 less than young's modulus of concrete which it shows that the failure occurred at interface bond, but at shear stiffness 900 N/mm^3 stiffness was 38600 MPa, with compressive strength 60 MPa. At Figure 6 shown the relative displacement at the interface surface, and it shows that for 900N/mm^3 model the failure occurred at the NC part.

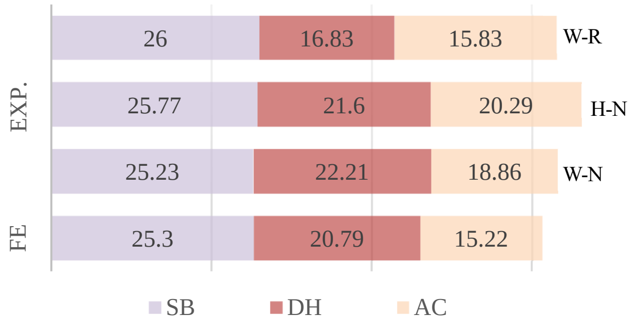

Figure 4 Comparison between experimental and analytical results

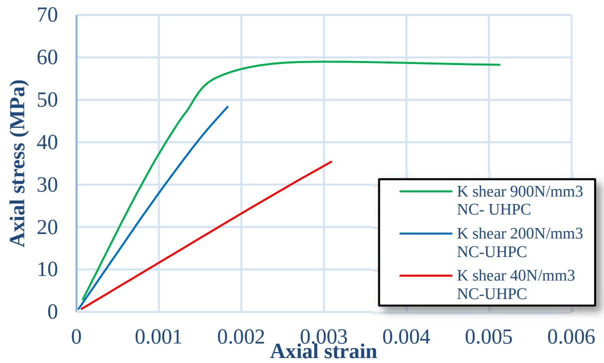

Figure 5 Stress-strain relationship

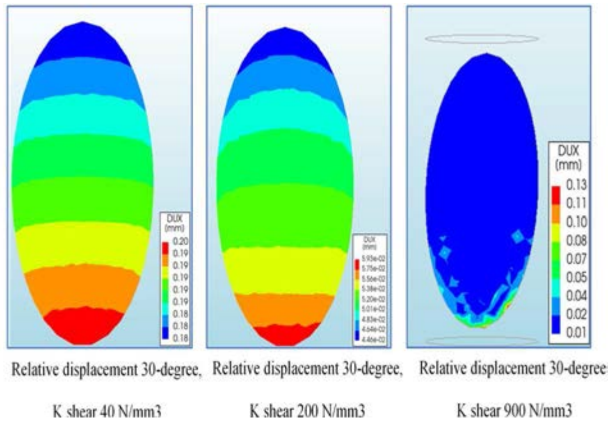

Figure 6 Relative displacement of interface element for UHPC-NC boundary

4. Summary and conclusions

In this paper, used Madani et al. slant shear test for UHPC-NC bond strength of UHPC-NC experimental results using Diana 10.6 software model. FE model shows good predication to failure modes, and shear bond strength with different NC surface roughness. Simulation interface between NC and UHPC results could be used as the interface bond re-preventive, with changes in the normal and shear stiffness modulus according to surface roughness. Data presented in this article should be viewed with other research on the range of simple beam, or slab to understand the behavior of NC-UHPC in the site structure.

Reference

1) Al-Madani, Mohammed K., et al. "Interfacial bond behavior between ultra-high-performance concrete and normal concrete substrates." Construction and Building Materials 320 (2022): 126229.