Exploring Polymer Concrete for Bridge Deck Closures in ABC

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ABSTRACT

Accelerated bridge construction (ABC) techniques are used worldwide to accelerate construction and reduce cost. Precast concrete bridge deck panels are used today as part of ABC to simplify bridge deck construction. When used, bridge deck closure joints are created between the precast panels, as shown in **Figure 1**. Flowable yet very strong concrete with good bond and high shear strengths, such as Ultra-high-performance concrete (UHPC), is necessary to fill the closure joints. This extended abstract examines the use of polymer concrete (PC) as an alternative material for bridge deck closures in ABC (1), as shown in **Figure 1**. PC produced using polymethyl methacrylate (PMMA) and standard aggregate was tested. The low viscosity of PMMA, ease of mixing and relatively very high workability of PMMA-PC are key features for its use for bridge deck closures. We report on test results comparing key mechanical criteria of PC and UHPC showing the superior capability of PC for bridge deck closures compared with UHPC. Development length using pull-out tests, lap splice length and shear strength tests of unreinforced PC were performed. It is demonstrated that PC has a development length of 3.6 times the reinforcing bar diameter that is less than one-half the development length of 12 times the bar diameter recommended with UHPC. PC also showed a shorter splice length for reinforcing bar compared with that reported for UHPC. Finally, unreinforced PC showed shear strength that is twice that of UHPC. It is evident that using PC in bridge deck closures in ABC can improve constructability and performance and provide cost-savings compared with UHPC.

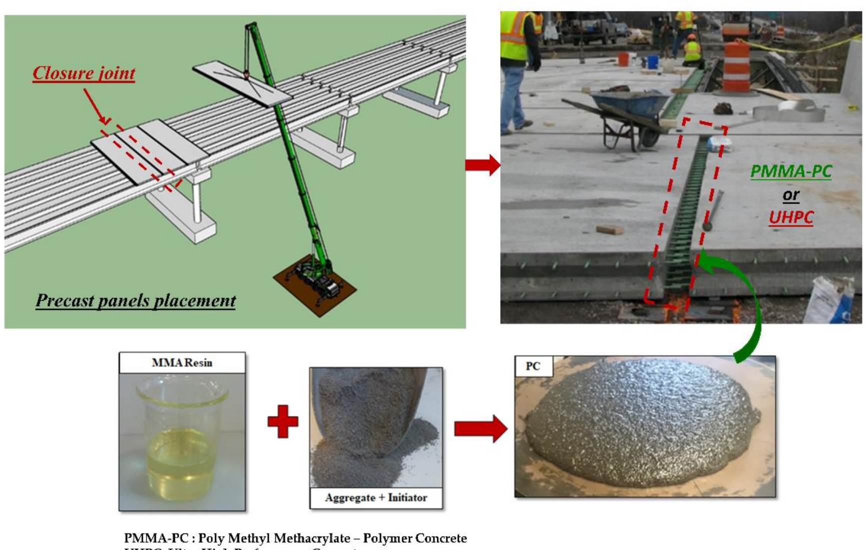

Figure 1. Graphical abstract for the proposed polymer concrete for bridge deck closure joints.

MATERIALS AND METHIODS

This extended abstract highlights the potential use of polymethyl methacrylate (PMMA) polymer concrete denoted here as PMMA-PC as a filling material for ABC closure joints. The low viscosity of PMMA, ease of mixing, and relatively high workability of PMMA-PC are key features for its use for ABC closure joints. Here, the minimum development length of steel reinforcement when spliced in PMMA-PC, lap splice length between bars inside PMMA-PC, and shear strength are determined using pull-out test, lap splice test, and shear test, respectively. Then, the test results are compared with those of UHPC reported in the literature. Mixture proportions and mechanical properties of PMMA-PC are listed in **Table 1**.

Table 1. Mixture proportions and mechanical properties of PMMA-PC

	PMMA-PC	Properties
Mixture	MMA Polymer	159.5 kg/m^3
	Aggregate	2224.6 kg/m^3
Compressive strength		72.6 ±2.1 MPa
Split tensile strength		6.6 ± 0.6 MPa

Pull-out Test

Pull-out test was conducted to determine the minimum development length required for bars sizes #13 (12.7 mm) and #16 (15.9 mm), uncoated ASTM A572 Grade 60 in PMMA-PC. Pull-out tests were conducted for a total of four embedment lengths of $4d_b$, $6d_b$, $8d_b$, and $10d_b$. Three repetitions for each embedment length were tested for each bar size (Total of 24 pull-out specimens). Pull-out specimens were tested at 7 days of age. For specimens with #13 reinforcing bars, all specimens with an embedment length of $4d_b$ failed in bond between the steel bar and PMMA-PC. For specimens with an embedment length of $6d_b$, the failure occurred either due to steel bar rupture or due to failure in bond between the steel bar and PMMA-PC after yielding of the bar. For specimens with an embedment length $8d_b$ and $10d_b$, failure in all specimens was due to steel bar rupture. **Figure 2** shows the median load-displacement curve for specimens with #13 reinforcing bars. For specimens with #16 reinforcing bars, all specimens with an embedment length of $4d_b$ failed in bond between steel rebar from PMMA-PC after yielding of the bar. For specimens with an embedment length $6d_b$, $8d_b$ and $10d_b$, failure occurred due to steel bar rupture after passing the yield strength. The development length for each bar size was calculated as 3.6 times bar diameter for bar #13 and 4.1 times bar diameter for bar #16 compared with 6 times bar diameter as reported for UHPC.

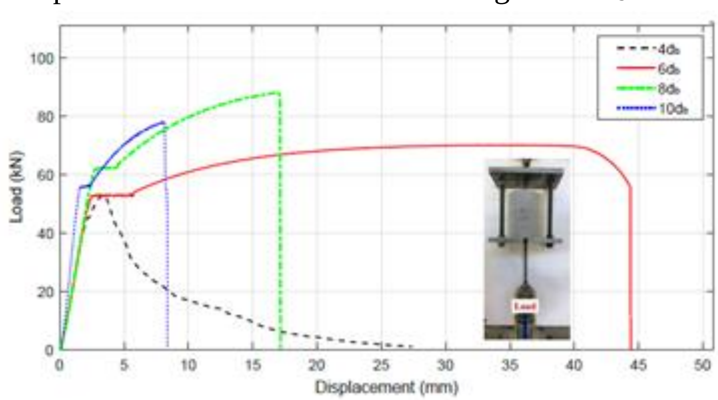

Figure 2. Median load-displacement curve for pull-out test for #13 rebar.

Lap Splice Test.

For lap splice test, a beam with a 660.4 mm span length was loaded using two-point loads at 152.4 mm spacing. The beam is 152.4 mm wide and 152.4 mm deep with a total length of 762 mm and reinforcing bar #13 with a concrete a cover of $3d_b$. The tested splice lengths ranged from $1d_b$ to $7d_b$ with $1d_b$ interval (total of 7 lap splice lengths) in addition to a control beam with straight bars

(Specimen C) and an unreinforced beam (total of 9 different details). Three repetitions were tested for each different detail (Total of 27 specimens). **Figure 3** shows the median force-displacement for splice test specimens. The minimum lap splice length required for uncoated steel bars in PMMA-PC with a concrete cover of $3d_b$ to achieve yield in the rebar was found to be $4.1d_b$. Comparing to UHPC, $4.5d_b$ (typically is taken as 75% of embedment length) is the sufficient lap splice length to observe yielding in the rebar.

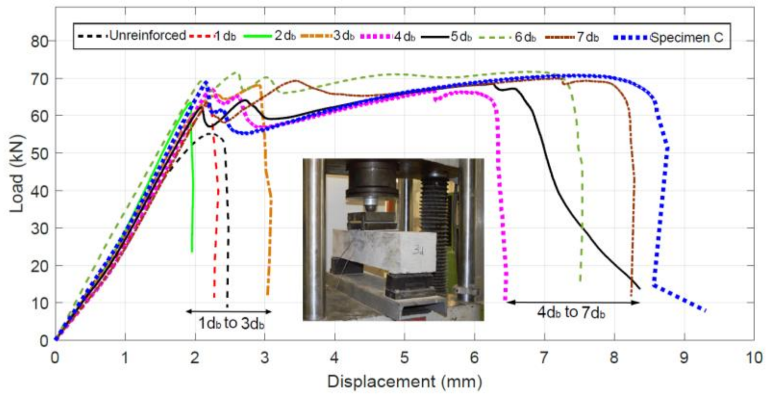

Figure 3. Median load-displacement curve lap splice length.

Shear Test.

A common practice is to use the same material for closure joints between full-depth precast deck panels and between the panels and the top of superstructure girders. Shear strength test was conducted to ensure that PMMA-PC has the necessary shear capacity to provide proper shear transfer and sufficient horizontal shear resistance at haunches between the superstructure girders and precast panels. The shear strength was determined using a 4-point test setup and using short beam specimens with a square section of 153 mm x 153 mm and a span length of 356 mm. UHPC and PMMA-PC were tested (Total of 15 specimens). PMMA-PC shear strength was measured at 7.6 MPa that is 190% and 344% higher than UHPC and normal concrete, respectively.

CONCLUSION

1- The minimum development length required for steel bars embedded in PMMA-PC was found to range between 3.6 and 4.1 times the reinforcing bar diameter. This development length is almost one-half of the minimum development length necessary for UHPC.

2- The minimum lap splice length required for uncoated reinforcing steel bars in PMMA-PC with concrete cover of 3 times the bar diameter was found to be 4.1 times the bar diameter compared with 4.5 times the bar diameter necessary for UHPC.

3- PMMA-PC has shear strength of 7.6 MPa, significantly higher than both normal concrete (+344%) and UHPC (+190%).

4- Closure joints made of PMMA-PC can offer a relatively narrower width and significant cost-savings if compared with UHPC.

REFERENCES

1. Mantawy, I.; Chennareddy, R.; Genedy, M.; Reda Taha, M.M. Polymer Concrete for Bridge Deck Closure Joints in Accelerated Bridge Construction. Infrastructures 2019, 4, 31.