

Rapid Spall Rehabilitation using 3D Printing Technology

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Currently, the partial-depth repair method is most commonly adopted in the field to rehabilitate the spall damage on the surface of concrete pavements. Once the damaged area is separated from the undamaged area with a milling machine, the damaged section is broken up with a chipping machine and the concrete debris is blown away using an air compressor. Concrete is then poured into the cleaned section. To prevent water infiltration, the edges of the repaired area are filled with a waterproof agent. A white-pigmented curing compound is then applied to the repaired area to prevent drying shrinkage or absorb water. The rehabilitated areas by the partial-depth repair method are more stable and last longer than when the spall damage is filled with asphalt. However, it demands a great deal of equipment and time. In addition to time required to fix the spall damage itself, one has to wait until the fresh concrete applied to the spall damage is fully cured. Time needed for the concrete hydration process varies depending on the cement type used, but at least a seven-day detour is required after the white pigmented curing compound is applied to the patch. While the repair process is taking place, the adjacent road needs to be closed to secure the workspace, and it often causes traffic jams. Traffic jams have a negative impact on economy. According to the report from the U.S. Department of Transportation, up to $20,000 loss can be assumed a day. If the road is blocked for seven days for repairing spall damage on a concrete pavement, one can easily assume up to $140,000 loss.

The objective of this research is to see if the 3D printing technology can be used for repairing the spall damage on the concrete pavement. This study proposes the novel spall repair method using 3D printing technology. In detail, the proposed spall repair sequence begins by obtaining a 3D model of a spall damage through photogrammetry. Then print it out using a 3D printer. The output is used as a form to cure fresh concrete. After the epoxy-resin glue has been applied, the spall repair sequence is completed when the hardened concrete fits into the spall. Also, more specifically, this research will examine whether the shear strength development of the bond line between the spall surface and 3D printed concrete segment is strong enough to handle shear stresses generated by the vehicle running over the fixed area. As addressed above, a certain amount of a gap between the spall surface and 3D printed concrete segment is reasonably assumed and the strength development of the glue is affected by the thickness of the glue. This research also plans to investigate the mathematical relationship between the glue thickness and the resisting force of the glued concrete segment against the shear strength applied to the glued layer and verify the mathematical relationship through the slant-shear tests. ASTM C882: Slant-Shear Test is executed with concrete specimens to determine the influence of epoxy-resin type IV adhesive bond line thickness on shear strength and whether or not it is strong enough to handle the applied stresses (federal commercial vehicle maximum standards). This study executed the experiments to identify whether or not bond line thicknesses influence the shear strength development of epoxy-resin glue when glue is applied on the concrete interface. According to the results of tests, the existence of a gap is good to some degree (4 mm) and strong enough to handle the national standard vehicle load. Also, the prefabricated concrete segment is glued on top of the damage without necessity of heavy equipment and long term blocking of the road way. This novel spall repair method can be not only an almost depreciation-free method but also is user-friendly. This study could impact to change the existing concrete road repair practices. It is expected that the spall repair method using 3D printer that suggested in this study can be applied to the actual spall repair project and it will reduce the road blocking time. The immense amount of repair construction costs could be saved by this research in the preventive manner.

Key Words: 3D Printer, Spall Repair, Epoxy-Resin Adhesive