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PRE-CAST PORTLAND CEMENT CONCRETE APPLICATION IN URBAN ROADS

ElHussein H. Mohamed

Abstract

Cities are concerned about utility cuts performed on roads and consider them a factor that influences the structural integrity and function of municipal roads. This paper discusses a concept for an innovative road design and construction technique based on the use of pre-cast Portland cement concrete (PCC) panels. Reusable panels are designed to withstand traffic and environmental loading and when lifted, provide utility companies with access to buried facilities. These panels could then be placed back and secured in place using special panel-to-panel tying techniques to maintain load transfer efficiency between adjacent panels.

Manufacturing pre-cast PCC panels in factories under controlled environment guarantees that they will achieve the necessary strength (maturity) reducing life cycle cost of roads. Construction operations occupy a smaller space and require less personnel and equipment on the street. Construction time is limited to utility repair, reinstatement of the granular base and placement of the panels. Depending on the size and nature of the utility job, the process could be planned to take place within a short time interval. Since no time is needed for curing the material, traffic may be allowed immediately after securing the panels reducing substantially disruption to businesses and residents.

PCC panels possess the ability to accommodate low construction quality in underlying road layers because of their ability to span over spots with low bearing capacity. Considering difficulties encountered when compacting unbound materials such as in the case of multi-occupancy trenches, the proposed road surfacing technique reduces the potential for premature failure incidents. The pre-cast technology has been tested in many locations in Europe and North America and produced favourable results. However, this paper discusses issues pertaining to the pre-cast option that should be addressed prior to implementation of this road construction technique.

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Background

Aging of buried utility pipes and increasing demands for service connections have put extra burden on city streets. Utility providers require periodic access to buried facilities to maintain, retrofit and/or to provide new connections. Until trenchless technology or utility corridors are established as viable options, utility providers will continue to depend on open cuts to perform their tasks. Settlement due to inadequate or non-uniform compaction of backfill material was identified as the major problem leading to poor performance of restored cuts. Research work revealed that restoration layers in utility cuts are exposed initially to extremely high traffic induced stresses far exceeding those known to exist in the original road. This finding explains observations suggesting that damage in restored utility cuts takes place within the first year of service [1]. Low initial asphalt concrete stiffness and unfavourable stress distribution associated with discontinuities in the road related to cut edges are two factors explaining these high initial stresses. The rush to open the road for traffic immediately after construction when the mat temperature is still relatively high and the AC stiffness is low contributes to damages in the restored cut. Depending on traffic volume and mix, high initial deformations may be acquired and the AC layer inherits low resistance to shear deformations and fatigue. The sand used as pipe bedding and cover is applied in an arbitrary manner and research data revealed that this layer contributed high deformations in a number of cuts when not compacted properly.

Under these circumstances, cities are looking for means to streamline and improve street resurfacing/reconstruction operations by coordinating and scheduling of work between city agencies and the private utilities to reduce disruptions to the affected community associated with road cutting and restoration. This paper discusses an alternative road design and construction technique based on the use of pre-cast Portland cement concrete panels (PCC).

The Pre-cast Concept

Combination of reusable panels could be fabricated using PCC and designed to withstand traffic and environmental loading to function as the road load-bearing layer and as a driving surface. When lifted, panels provide utilities with access to buried facilities. With utility work completed, the panels could then be placed back and secured in place using special panel-to-panel tying techniques to maintain load transfer efficiency between adjacent panels. The proposed approach is expected to reduce life cycle cost and address the concern of cities related to the slowness of the current construction technique and the disruption it causes to communities.

The proposed pre-cast PCC alternative has the following features:
- Panels are manufactured in factories under a controlled environment and following well-defined quality control specifications. This process guarantees that the material will achieve the strength (maturity) necessary for durability. Requirements for assembly in the field are incorporated in the panel with adequate precision.
- Construction operations occupy a smaller space and require less personnel and equipment on the street. Construction time is limited to utility repairs, reinstatement of the granular base and placement of the panels. It will therefore reduce substantially disruption to businesses and residents. Depending on the size and nature of the utility job, the process could be planned to take place within an 8-hour cone-in-cone-out time interval. Traffic may be allowed immediately after securing the panels with no time needed for curing.
- More road sections may be restored using the proposed approach since it is possible to maintain construction operations during all seasons with limited disruption from winter or rainy conditions.

**Design and Construction**

The design of the pre-cast slab entails a number of aspects beyond those known for conventional PCC because of special panel handling requirements during fabrication, transportation and construction. The idealized road construction and cut restoration processes are depicted in Figure 1 and 2. Reconstruction of existing PCC or asphalt concrete roads may include removal of damaged surfaces and laying of the pre-cast panels over a compacted granular base or a thin asphalt concrete layer. Special panel-to-panel tying techniques, similar to that shown in Figure 3, are necessary for improving load transfer efficiency across joints. This feature involves post-tensioning strands fed through special opening in the pre-cast panel. Continuous shear keys ensure vertical alignment between adjacent panels and facilitate load transfer mechanism prior to post tensioning. Designing of panels should also take into consideration future rehabilitation requirements associated with restoration of utility cuts. Considering difficulties encountered when compacting unbound materials such as in the case of multi-occupancy trenches, panels may be reinforced during the fabrication process (pre-stressed in the transverse direction). Pre-stressing reduces bending stresses during panels lifting and transportation. Properly designed pre-stressed panels are also capable of reducing the impact of incidents involving low quality cut restoration because of their ability to bridge spots with low bearing capacity such as that associated with poorly compacted backfill.

The reusable pre-cast PCC panels facilitate accessing buried utilities. The road will retain its original structural integrity when the removed panels are placed back and secured to adjacent panels using post-tensioning strands. Reusing these panels is a cost effective approach and requires less technical skill from utility crew limiting the potential for road deterioration in areas experiencing extensive cutting. Even damage associated with unforeseen events could be quickly and easily addressed using readily available standard panels that fit the geometry of the affected road location.

**Applications**

Pre-cast concrete is being tested in highway construction with limited use in urban roads. Some of the completed demonstration projects are listed in Table 1. These projects [2] [3] include reconstruction as well as repair of existing PCC pavements. Panel sizes used
ranged from 6.5 to 13 ft in length, approximately 12 ft width and a thickness of 9 in. Steel reinforcement facilitated the use of thinner slabs in European urban street applications. Grouting was used in some sites as bedding beneath the panel to improve the surface above the granular base. Grout was also used to close opening used for handling panels and for securing post-tensioning strands. Although results of testing this technology in many locations in Europe and North America produced favourable results, there are many issues related to the pre-cast option that need to be addressed. These are issues related to prefabrication and placement of PCC in general and other variables related to local conditions and construction practices.

- Cost control measures are needed. This objective could be achieved in the design and manufacturing processes by adopting standard paneling systems to avoid costs associated with customization. In the presence of steel reinforcement, the design process should maximize slab thickness. Reinforcement is needed to meet requirements of panel handling, load transfer across joints as well as the need to maintain the structural integrity of the road under critical traffic loading conditions.

- The learning curve should target addressing issues that influence road durability and for introducing reliable solutions to problems such as those associated with unevenness of the surface of the prepared base and the presence of iron and concrete enclosures within the pavement structure. Design precision, probably 3D, is needed to address surface drainage requirements especially in spots with complicated road geometry involving multiple curves (combined vertical and horizontal slopes).

Road authorities should examine these issues to make sure that unique resurfacing and reconstruction requirements are adequately met. Specifications developed for this new approach should also be examined by other stakeholders including the pre-cast industry, construction contractors, material suppliers and utility companies to benefit from their expertise and innovations to support the development of practical panel manufacturing specifications and dedicated handling and placement equipment.

**Conclusions and Recommendations**

PCC could be relied upon to produce durable road structures when reusable pre-cast panels are applied as the driving surface. The pre-cast alternative eliminates the majority of conventional cast-in-place PCC problems encountered in the rehabilitation or reconstruction of existing roads. The long life of PCC reusable pre-cast panels compared with asphalt concrete, is also expected to reduce life cycle cost and address concerns of cities related to the disruption to communities observed under the current road rehabilitation practices.

- The majority of technical issues related to the pre-cast approach have been resolved using effective design solutions. Panels could be pre-tensioned to reduce bending stresses during lifting and transportation and to bridge weak spots in the road with low load bearing capacity such as sections of the road on top of utility cuts. Post-tensioning strands are proposed as mechanism for maintaining high load transfer efficiency across joints.
Demonstration projects are necessary for developing local specifications with participation from all stakeholders including the road authority, construction contractors, pre-cast panel fabricators and utility companies. This combined effort is necessary for developing cost control measures, practical panel manufacturing techniques and dedicated handling and placement equipment.
Figure 1: Panel combination forming the road surface

Figure 2: Lifting panels to reach buried pipes

Figure 3: Post-tensioned strands positioned across joints
<table>
<thead>
<tr>
<th>Project Location</th>
<th>Construction Year</th>
<th>Sponsors</th>
<th>Paved Area (sq ft)</th>
<th>Special Features</th>
<th>Remarks - Demonstrated Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>US-175 Dallas, USA 2006</td>
<td>Concrete Pavement Technology Program (CPTP) of FHWA</td>
<td>17,500</td>
<td>- Expedite weigh-in-motion scales installation and application</td>
<td></td>
<td></td>
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<tr>
<td>Interstate-90 Albany, New York, USA - 2005</td>
<td></td>
<td>56,400</td>
<td>- Single plane slabs</td>
<td>- Different standard slab sizes - slabs slightly thinner</td>
<td></td>
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<tr>
<td>Interstate-57 Silkeston, Missouri, USA - 2005</td>
<td>Concrete Pavement Technology Program (CPTP) of FHWA</td>
<td>38,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway 427 Toronto, Ontario, CANADA 2004</td>
<td>Ministry of Transportation Ontario (MTO)</td>
<td>235/943/235</td>
<td>- Single plane slabs</td>
<td>- dowel bar slots critical to performance - base preparation to meet surface tolerances</td>
<td></td>
</tr>
<tr>
<td>Interstate-10 El Monte, California, USA 2004</td>
<td>California Department of Transportation (CalTrans), FHWA</td>
<td>9,250</td>
<td></td>
<td>- Higher cost than cast-in-place (conventional vs experimental) - longer design life expected</td>
<td></td>
</tr>
<tr>
<td>Port Jefferson, (New York, New York, USA) 2004</td>
<td>Port Authority of New York and New Jersey</td>
<td>8,285</td>
<td>- Single plane slabs</td>
<td></td>
<td></td>
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<tr>
<td>Interstate-25 (Mead, Colorado, USA) 2003</td>
<td>Colorado Department of Transport (CDOT)</td>
<td>25,300</td>
<td>- 21 port holes/slab for post-placement levelling - 1/4”x5”x36” fibreglass stitch tied panels together</td>
<td></td>
<td></td>
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<tr>
<td>Korean Parkway, (Staten Island, New York, USA) 2003</td>
<td></td>
<td>8,850</td>
<td>- Single plane slabs</td>
<td>- 20% of slabs with low severity cracks in fibreglass stitch area</td>
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<tr>
<td>Belt Parkway, (Jamaica, New York, USA) 2003</td>
<td></td>
<td>16,030</td>
<td>- Warped slabs</td>
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<td></td>
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</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Sponsors</th>
<th>Paved Area (sq ft)</th>
<th>Special Features</th>
<th>Remarks - Demonstrated Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lincoln Tunnel, New Jersey, USA</td>
<td>- Single plane slabs</td>
<td>8,100</td>
<td>-</td>
<td>FWD test revealed 94.1% load transfer efficiency</td>
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<tr>
<td>9A Ramp, (Tarrytown, New York, USA) 2003</td>
<td>- Warped slabs</td>
<td>15,750</td>
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<tr>
<td>Interstate-196 / Interstate-94-BL / Interstate-675</td>
<td>Michigan Department of Transport (MDOT), Concrete Pavement Technology Program (CPTP) of FHWA</td>
<td>1,512 (I-94)</td>
<td>-</td>
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<tr>
<td>Interstate 35 (Georgetown, Texas, USA - 2001)</td>
<td>Texas Department of Transport (TexDOT), Concrete Pavement Technology Program (CPTP) of FHWA</td>
<td>82,800</td>
<td>Pre-stressed, post-tensioned pre-cast installation</td>
<td></td>
</tr>
</tbody>
</table>

References

