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Research Article

Application of Polymeric Cement Concrete as Food Architecture Overlay Material

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Abstract: This study presents an experience case of applications of Polymer Cement Concrete (PCC) as food architecture overlay materials in China. The material composition of PCC is introduced. PCC was designed according with filling index defined. The compressive and flexural strength were tested at 7 d and 28 d. The field performance tests were done including the compaction degree, texture depths, the British pendulum number. The surface appearance and the field core of PCC were observed. Finally, economic benefits were achieved through comparisons of cost of PCC with other surface food architecture overlay material. The result show that the application of polymer concrete overlays with high-strength, fast-curing characteristics and skid resistance which can result in improved safety and reduced maintenance at a lower cost in comparison to asphalt reconstruction.

Keywords: Construction experience, food architecture overlay materials, polymer cement concrete

INTRODUCTION

The growing attention to road safety worldwide has enabled to highlight that the major problems arise in urban areas and in the secondary rural road network. On the other hand the increase in traffic volumes and loading, together with the budget restrictions, are leading to very poor architecture conditions, mainly in urban areas and on local architectures. There is therefore a strong need for more reliable and durable food architectures for this type of architectures and this is leading to a growing interest towards the use of concrete food architectures.

Concrete food architectures can provide a very valuable solution for this type of architectures as they offer a very good resistance to heavy axle loads and a generally lower maintenance, compared to flexible food architectures. There is also a reduced risk of having a major deterioration, as a depression or a pothole that can be a cause of danger for motorcycles and bicycles.

However, the existing infrastructure has aged to or past the design life of the original architecture design. In many cases, increased commercial traffic is creating the need for additional load carrying capacity, causing state highway engineers to consider new alternatives for rehabilitation of existing surfaces. Alternative surface materials, thicknesses and methods of installation must be identified to meet the needs of individual food architectures and budgets. With overlays being one of the most frequently used rehabilitation alternatives, it is important to learn more about the limitations and potential performance of thin bonded portland cement overlays and subsequent rehabilitation.

Asphaltic concrete and Portland cement concrete overlays were suggested as a rehabilitating method for food architectures subjected to moderate and heavy traffics (Zhang and Li, 2002). Using the HMA (Hot Mix Asphalt) as an food architecture overlay was found the cracks start to appear after three years (Blankenship *et al*., 2004) and HMA overlays was found usually exhibit reflective cracking (Zhou *et al*., 2010), formed due to movements of underlying concrete slab; thus, the architecture serviceability reduces at a rapid rate. Researching on the same area, Hot Mix Asphalt food architecture overlay is the most commonly used rehabilitation technique for such deteriorated concrete food architectures (Shan and Guo, 2011). However, the performance of these HMA overlaid food architectures is mired due to the occurrence of reflective cracking, resulting in significant reduction of architecture serviceability. Various fractured slab techniques, including rubblisation, crack and seat and break and seat are used to minimize reflective cracking by reducing the slab action.

For low volume architectures, every municipality, county and state is facing the same pressures: Do more with fewer tax dollars. So the key word among today's materials specifies is value that delivers more performance for every dollar spent. In road maintenance and repair, everyone recognizes the long

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life and superior performance characteristics of concrete paving. But budget constraints often have stopped specifies from choosing concrete.

Polymer concrete is adopted in thin overlays on old concrete architecture, which may be a cost-effective method. In polymer concrete, thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals. They have provided long-lasting wearing surfaces with many advantages, including high tensile, flexural and compressive strengths, rapid curing at ambient temperatures, shallow depths that eliminate the need for raising approach slabs, ability to transition from overlaid lane to non-overlaid lane during construction, low permeability and good frictional resistance (Fang *et al*., 2009). Doody and Morgan (1994) reported two types of polymer food architecture overlay material thin epoxies an thick polyster. They reported the polymer concrete food architecture overlay in New York appear to meet expectations, showing good performance during their first 5 to7 years. Lee and Kim (2007) reported that the color polymer concrete with a synthetic resin is stronger and less susceptible to moisture than are typical asphalt mixtures. The Thin Polymer Concrete Overlays (TPCOs) consist of a polymer binder and aggregates with a thickness of 25 mm or less was introduced, which have been widely used for providing long-lasting wearing surfaces for bridge decks. Fang *et al*. (2009) suggest that composite architecture structure with roller compacted concrete base layer and polymer modified cement concrete surface layer could meet the requirements of the traffic load by the method of ANSYS finite element numerical simulation.

A polymeric concrete with polyester fiber had been successfully used for thin overlays in China. This study presents some of the experience gained in PCC as food architecture overlay materials on old concrete architecture in China. The selected architecture construction will perform in the 2012-2013 in China. The goal of this study is to share technological innovations made and lessons learned in this construction.

MATERIALS PROPERTIES AND MIXTURE DESIGN

Cement: Cement used in this study is the P.O42.5 grade bulk cement from Qilianshan cement factory, its physical and mechanical performance indicators are all in line with regulatory requirements after the laboratory testing and it is initial setting time is 115 min and the final setting time was 205 min.

Aggregate: The aggregate used in this study was crushed limestone aggregates, the aggregates are divided in three types that is 9.5-4.5, 4.5-2.36 and 2.36-0 mm, respectively. The aggregate was dried, riffled and bagged with sieve analysis achieved in accordance with JTG E42-2005 (Chinese Standard Institution, 2005).

Polymer emulsion: Through economic benefit analysis, SD623 (barrel) is recommended in this study. Styrofan SD623 is a carboxylic styrene butadiene latex produced by Shanghai Gaoqiao BASF for special polymer cement mortar modified. It can be used in the construction industry and all grade cement mix. The basic properties of SD623 are shown in Table 1.

Polyester fibers: Polyester fibers have a low modulus, good tensile properties and relatively easy dispersion in PCC polymer modified cement concrete. It can also improve the durability of polymer modified cement concrete. Polyester fiber is selected to prevent concrete architecture cracking. Its technical parameters are shown in Table 2.

Aqueous carbon black paste: In order to make PCC architecture has the same color with asphalt architecture, aqueous carbon carbon black paste is filled in PCC mix. The main physical and chemical properties are shown in Table 3.

Table 1: The Basic properties of SD623

Chemical property	Carboxylic styrene butadiene latex	
Product standards	Total solids (percent) (ISO 1625)	50-52%
	PH (ISO976)	7.8-10
	Viscosity 25°C	35-150 mPa.s
	Density	1.01 g/cm^3
	Particle size (micrometer)	150 nm
	Glass state temperature	13°C
	Surface tension	30~48 mN/m
	Freezing resistance	Cold intolerance

Table 2: Technical parameters of polyester fiber

Product name		Polyester fiber	Standard number
Series number	Item	The standard value	Test value
1	Length, mm	6±1.5	6
2	Diameter, mm	0.020±0.005	0.022
3	specific gravity (g/m^3)	1.36±0.04	1.36
6	Elongation rate %	50%	50
7	Tensile strength/MPa	≥510MPa	669
9	Loss of tensile strength after aging (210°C, 2 h) %	≤20	12

Table 3: Physical and chemical properties of aqueous carbon back paste

Properties	Value
Appearance	Black liquid
Main ingredient	Carbon black
Proportion (thin film 20°C)	1.20±0.02
PH	6-10

Mixture design: Nominal diameter of PCC mixture aggregate is 9.5 mm and the largest diameter is less than 13.2 mm. The graduation was determined based on Fuller Curve, which mathematical expression is shown in Eq. (1):

$$p_d = [d / D]^{0.5} \quad (1)$$

where,
d = Mesh size (mm)
D = The largest diameter (mm)
P_d = The percent passing of mesh size d

Theory graduation and measured graduation of PCC mixture was calculated based on Fuller Curve which is shown in Table 4.

Filling index D_P was defined in this study to characterize condition of PCC mixture, if the value of D_P is equal to 1, its means skeleton dense structure. The D_P is shown in Eq. (2):

$$D_P = {V_m}/{V_a} \quad (2)$$

In Eq. (2), V_m express the volume of polymer emulsion, V_a express porosity of aggregation. Mix proportion of PCC was calculated based on filling index D_P, which is listed in Table 5.

RESULTS AND DİSCUSSİON

Laboratory characteristics of PCC: The compressive and flexural strength of PCC mix were texted in accordance with JTG E42-2005. The test results are shown in Table 6.

As can be seen from Table 6, PCC mixes have high compressive and flexural strength, compared with ordinary cement concrete, the ratio of flexural strength and compressive strength increases significantly.

Field performance tests and observations: Compaction degree is one of the important indicators of construction quality in the PCC architecture. Compaction degree field tests of architecture section were conducted in accordance with the relevant regulations. The results were shown in Table 7. Results could be concluded through the compaction degree test that all the PCC surface compaction of observation point were greater than 98%, it could completely meet the PCC surface compaction degree requirements.

Texture Depths (MTD) of PCC architecture section were tested by Sand patch method. Sand patch testing is the most commonly used technique for estimating architecture macrotexture. Following T0961-1995, this technique was used in this experiment and test results as shown in Table 8. It can be found from Table 3 that the texture depths of the 6 points are greater than 0.70 mm which can meet the depth of structure regulations of highway architecture. It does not need grooving anti-skid construction process for concrete architecture.

The British Pendulum Number (BPN) was used to measure architecture friction. Test results are shown in Table 9. From the table it can be found that text points of PCC architecture surface in wet conditions have high BPN values and good skid resistance.

Table 4: Aggregate gradation for PCC

Sieve size (D) mm	13.2	9.5	4.75	2.36	1.18	0.6	0.075
Theoretical graduation	100	84.8	60	42.3	29.9	21.3	7.5
Measured graduation	100	96.7	59.6	36.2	24.4	16.5	5.0

Table 5: Mix proportion of PCC (kg/m^3)

						Aggregate (mm)		
Cement	Water	SD623	Polyester fiber	Aqueous carbon black paste	Super plasticizer	4.75-9.5	2.36-4.75	0-2.36
360	90	90	2	3	5.4	936	312	832

Table 6: PCC strength test results

	7d		28 d	
Specimen shape	Flexural strength/MPa	Compressive strength/MPa	Flexural strength/MPa	Compressive strength/MPa
15×15×55cm	4.76	22.8	5.92	41.2
	4.54	20.7	6.5	40.2
	4.84	22.9	6.0	39.5
Average	4.71	22.1	6.14	40.3
Stdev	0.15	1.2	0.31	0.9

Table 7: Compaction degree test results of PCC architecture

Series number	1#	2#	3#	4#	5#	Average	S.D.
Compaction degree/%	98.2	97.8	98.9	98	98.5	98.3	0.4

S.D.: Standard Deviation

Table 8: MTD test results of PCC architecture

Series number	1#	2#	3#	4#	5#	6#	Average	S.D.
MTD/mm	0.86	0.88	0.87	0.91	0.76	0.91	0.87	0.06

S.D.: Standard Deviation

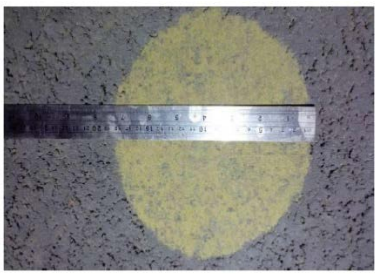
Table 9: BPN test results of PCC architecture

Series number	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#	Average	S.D.
BPN	66	67	66	67	68	70	68	68	67	67	67.4	1.2

S.D.: Standard Deviation

Table 10: The cost of typical architecture overlay

Architecture structure types	Structure layer	Budget price (Yuan/m^2)
Asphalt concrete architecture structure	AC13 above layer (4 cm)	48
	Adhesive layer	4.48
Cement concrete architecture structure	Cement concrete architecture (26 cm)	94
PCC architecture structure	PCC layer (4 cm)	67
	PIC interface bonding layer (0.5 cm)	10
Others	SMA13 above layer (5 cm)	110



(a) Surface appearance of PCC pavement

(b) Filed cores of PCC pavement

Fig. 1: Surface appearance and filed cores of PCC after construction

The PCC architecture actual effects were observed after test sections have been completed. Figure 1a presents the surface appearance of PCC. The PCC surface roughness is superior. Architecture color is uniform and has uniform distribution texture depth. Figure 1b presents the field core of PCC. PCC layer bonds well with old concrete architecture. There haven't any broken slabs in PCC surface core samples. The cross-section is smooth and flat and its interior is dense and homogeneous. It can be seen from the cross section that the aggregates closely squeezed to each other.

Cost of applying PCC: The cost of some typical food architecture overlay in architecture structure is listed in Table 10.

PCC architecture's cost is between asphalt concrete architecture and SMA13 architecture, but PCC mixture doesn't need heating before construction and don't need compaction during construction, which will improve construction efficiency and economic benefits significantly. Besides, PCC architecture's maintenance costs are one-third of the cost of asphalt architecture and PCC architecture's service life is two times longer than asphalt architecture.

The cost of PCC architecture is lower than cement concrete architecture 17 Yuan/m^2 and PCC architecture don't need compaction and vibratory during construction, which will reduce the cost and improve the construction. Besides, the color of PCC architecture is black which could avoid reflective from architecture and improve the comfortableness of driving. Besides, PCC architecture has the advantage of high strength, good abrasion resistance, durability and good waterproof, this will reduce maintenance cost during the post-operation process.

Generally, PCC architecture could effectively solve the cement architecture diseases. Besides, PCC mixture could be constructed with asphalt paver, which will improve construction efficiency and economic benefits significantly.

CONCLUSİON

Research has been conducted on the construction of polymeric concrete with polyester fiber in China. Laboratory mixture characterization and field performance testing and observation were conducted to evaluate the performance of PCC food architectures. Construction process has been studied by the test road. Following observations were drawn based on the analysis of the results:

- The polymeric concrete can be used in food architecture overlay on old concrete architecture.
- The mixture of PCC should be designed by the methods of material volume which is similar to asphalt mixture design. The PCC has a good mechanic performance.

- Field evaluation can be performed with reference to the construction site of the asphalt architecture. The field results show that PCC as food architecture overlay has not only a good architecture performance but also skid resistance.
- Generally, the application of PCC as food architecture overlay materials significantly decreased the construction cost of food architecture overlay on old concrete architecture.

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