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CASE STUDY: FLAWS OF CONCRETE ROADS IN PAKISTAN - POSSIBLE REASONS AND REMEDIAL MEASURES

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1 Project Overview

1.1 Introduction

Pavements are generally classified into asphalt and concrete ones. Contrasted with asphalt pavements, concrete pavements can offer a more sustainable development due to low maintenance cost and durable road network because of high strength of concrete (Sheety et al. 2013). During the construction of rigid pavements, many issues can be expected since this procedure is refined, and includes numerous exercises like concrete placing, spreading, compacting, finishing, texturing, curing, protecting, jointing, testing, and other sub-activities (Mosa et al. 2011). Professionals who have expertise in construction-engineering services concluded that there are constantly adverse outcomes during construction process, which cannot predictable during design experimentation in the laboratories under ideal conditions (ACI 224.1R-07, 2007). Either, it is material quality control or desired construction practice; everything should be in the place as per the design standards.

Any abnormality in these project inputs can harm the functional and primary purpose of the project. On the whole, these issues influence the desirable quality and the underlying construction cost (Stock 1988, Newman 1986). Similarly, development of micro cracks at initial level of concreting later on results into complete fracture (Kumar et al. 2012). These cracks are also responsible for creation of chain and transverse cracking in concrete pavements (Niken et al. 2016). A shrinkage reduction admixture with a dosage of 3.71 l/m3 was effective in reducing these micro cracks up to 30% (Ambrosia et al. 2001). There are many other distresses, among which transverse and longitudinal cracks are mostly found in concrete pavements (Harvey et al. 2000).

The construction of rigid pavements in Pakistan is increasing in the recent decade to facilitate heavy traffic vehicles used for goods transportation. But these pavements are prone to a number of distresses. Distresses like polished aggregates, scaling, transverse cracks, corner breaks, and erosion of sub-base in concrete pavements was found by Suja et al. (2016) in Srilanka. As Pakistan and Srilanka both are Asian countries with same climatic conditions and nearest similar transportation infrastructure. Hence, environmental and traffic loading upon pavements can be relate able. The overall purpose of this project is to find distresses in newly constructed, six months old, five years old and ten years old concrete pavements in Islamabad, to find governing causes behind these identified distresses and to recommend most economical remedial solutions keeping in mind locally available materials and practising construction techniques. To the best of author's knowledge no such study has been conducted in Pakistan and this study can help in suggesting the economical remedial solutions to mitigate the problems of distresses in the concrete pavements and to eliminate uncertainties in future road projects.

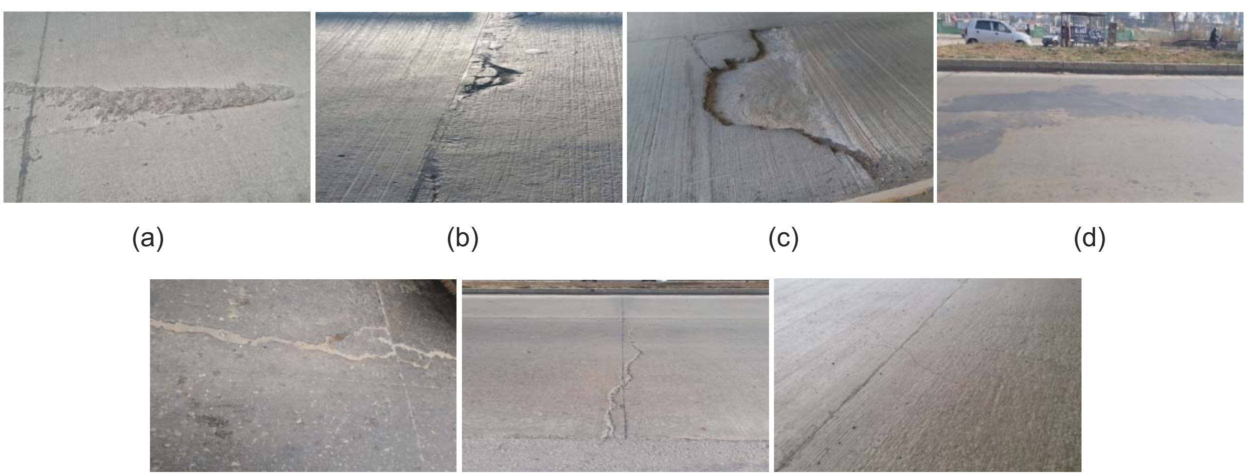
1.2 Methodology

This case study is based on the field surveys of rigid pavements in Pakistan. Kashmir Highway, and Islamabad Express Highway of capital city, was covered in this study. Data regarding reported distresses in the old rigid pavements and their maintenance reports have been collected from “National Highway Authority” to associate with identified flaws. The main objective of the field surveys was to identify the failures occurred in recently constructed, six months old, fiver years old and ten years old rigid pavements. For this purpose, a Performa was developed. The considered parameters were: age of pavement, number of identified distresses individually, categorization of severity level of each distress. Concrete pavement distresses have been identified with the help of this activity. Their possible governing causes have also been identified through field observation. Remedial measures to eliminate these distresses have been proposed keeping in mind the economy, locally available treatment materials and availability of skilled labour as per documentation of local highway body.

2 Innovation

In the recent decade, the demand of concrete pavements has been increased over flexible pavements in Pakistan. Because these provide high strength and durability, which is required by heavily loaded vehicles used for mass transportation of goods countrywide. The transportation infrastructure of Pakistan is evolving by every passing day in the form of various under construction road projects throughout the country. These road schemes are having separate concrete pavement lanes for heavy traffic vehicles. But these pavements are prone to different issues since the beginning of construction to ultimate design life in the form of concrete pavement distresses. These distresses tend to low the serviceability and structural integrity of roads.

In this case study, distresses associated with concrete pavements has been identified through field surveys in the newly constructed, six months old, five years old and ten years old concrete pavements of Islamabad city as shown in the Figure 1. Based on observed site conditions the possible causes behind these distresses are found as: - 1) Poor durability of used aggregates in the form of freeze thaw effect. 2) Freeze thaw effect of aggregates in combination with heavy traffic loading. 3) Formation of cement paste layer due to concrete bleeding and repeated tensile stresses. 4) Improper rehabilitation techniques adopted during maintenance work. 5) Excessive temperature gradient due to adverse climatic conditions. 6) Absence of transverse joints between the slab panels i.e., deviation from design standards. 7) Volumetric changes in concrete within the curing period and improper curing techniques. Table 1 illustrates the statistics of each flaw found in the respective pavement with severity level and recommended possible solution.



(a) (b) (c) (d)

(e) (f) (g)

Figure 1: Distresses identified during surveys (a) Pop outs (b) Durability cracking (c) Surface deterioration (d) Punch outs (e) Longitudinal cracking (f) Transverse cracking (g) Shrinkage cracking

Table 1: Statistics of identified distresses and their remedial solutions

Sr. No	Distresses	Newly constructed			Six months old			Five years old			Ten years old		
	Location	***Kashmir Highway Interchange at Golra Road towards GT Road Interchange***			***Islamabad Expressway in front of Naval Anchorage & Gulberg Greens***			***Kashmir Highway from Zero point to Golra Road Interchange***			***Islamabad Expressway from Kaak Bridge to Faizabad Interchange***		
	Length	**2 KM**			**2.5 KM**			**15 KM**			**15 KM**		
1	Pop outs	**Severity low, moderate and intense (diameter of observed pop outs)**											
		Low (in.)	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**
		1-4	5-12	>12	1-4	5-12	>12	1-4	5-12	>12	1-4	5-12	>12
		Number of identified flaws											
		-	-	-	145	13	-	55	12	3	-	76	42
		Remedial solution*: Partial depth repair for low severity pop outs and full depth repair for moderate and intense pop outs is recommended*											
2	Durability Cracking	**Severity (Distance of observed hairline cracks, cracks without surface disintegration and cracks with disintegration from joint)**											
		Hairline (in.)	**Without Disintegration (in.)**	**With Disintegration (in.)**	**Hairline (in.)**	**Without Disintegration (in.)**	**With Disintegration (in.)**	**Hairline (in.)**	**Without Disintegration (in.)**	**With Disintegration (in.)**	**Hairline (in.)**	**Without Disintegration (in.)**	**With Disintegration (in.)**
		<6	6-12	>12	<6	6-12	>12	<6	6-12	>12	<6	6-12	>12
		Number of identified flaws											
		-	-	-	-	-	-	28	17	2	12	15	26
		Remedial solution*: For hairlines cracks, crack sealant is workable but for intense cases with or without surface disintegration cement paste overlay is recommended*											
3	Surface Deterioration	**Severity low, moderate and intense (Area of punch outs)**											
		Low (ft^2)	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**
		<1	1-3	>3	<1	1-3	>3	<1	1-3	>3	<1	1-3	>3
		Number of identified flaws											
		-	-	-	-	-	-	16	4	-	34	8	6
		Remedial solution*: Asphaltic overlay is the most economical available solution for this flaw from low to intense severity level*											
4	Punch outs	**Severity low, moderate and intense (Area of punch outs)**											
		Low (ft^2)	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**	**Low (ft^2)**	**Moderate (ft^2)**	**Intense (ft^2)**
		<1	1-3	>3	<1	1-3	>3	<1	1-3	>3	<1	1-3	>3
		Number of identified flaws											
		-	-	-	-	-	-	-	12	-	4	7	2
		Remedial solution*: Full depth repair is only possible solution for any kind of punch out, but the root cause of failure of punched area should be indentified and treated firstly*											
5	Longitudinal cracking	**Severity low, moderate and intense (Width of cracks)**											
		Low (in.)	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**
		<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6
		Number of identified flaws											
		-	-	-	8	6	-	115	86	4	335	168	12
		Remedial solution*: For low and moderate severity cracks, crack sealant is applicable, while partial depth repair is suggested for intense cracking*											
6	Transverse cracking	**Severity low, moderate and intense (Width of cracks)**											
		Low (in.)	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**
		<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6
		Number of identified flaws											
		-	-	-	10	4	-	218	154	36	288	54	12
		Remedial solution*: For low and moderate severity cracks, crack sealant is applicable, while partial depth repair is suggested for intense cracking*											
7	Shrinkage Cracking	**Severity low, moderate and intense (Width of cracks)**											
		Low (in.)	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**	**Low (in.)**	**Moderate (in.)**	**Intense (in.)**
		<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6	<0.2	0.2-0.6	>0.6
		Number of identified flaws											
		23	3	-	16	5	-	28	11	8	-	46	21
		Remedial solution: *Usage of locally available crack sealant for all severity levels of shrinkage cracking is workable*											

2.1 Lessons Learned

Transportation officials of Pakistan are widely adopting the development of concrete pavements in the road networks. But it has been learned from this study that there is gap between designed and implemented construction work. As a result of which, these distresses produce. Observed distresses and their possible causes can be categorized into three different kinds:- 1) Distresses due to usage of poor quality construction materials i.e., pop outs & durability cracking. 2) Distresses due to improper construction techniques i.e., surface deterioration, punch outs and shrinkage cracking. 3) Distresses due to variance of construction work from design standards i.e., transverse cracking and longitudinal cracking. It has been analyzed from this study, that distresses found in concrete pavements are not just due to a single factor. Poor drainage conditions, improper material usage and negligence in construction quality control act as a whole to cause such distresses.

3 Discussion

This study has been conducted through site visits during which number of a particular distress along with its severity is being observed and noted. There is an immense increase observed in the distresses as per pavement age. 1.1% distresses were found in newly constructed concrete pavements, 9.3 % in 6 months old, 36.3 % in five years old and 74.2 % in ten years old respectively. The design life of concrete pavements is mostly taken as 20 years by highway body in its development schemes. But statistics of evaluated data depicts that upon passage of half of pavement life, it is indicating 74.2 % failures with respect to all failures found.

On a whole, it is observed distresses that shrinkage cracking is the root cause of these distresses which further with time results in various other pavements. Usage of crack sealant, asphaltic overlays is the most economical, adopted maintenance techniques by the local body and can be used to mitigate the current identified failures. But again these solutions are not reliable. Therefore, more sustainable construction techniques and materials need to be introduced. Just like the usage of shrinkage reducing admixture has been proposed by many researchers, because of its ability to reduce micro shrinkage cracking.

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