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Evaluation of Application of Roller Compacted Concrete versus Asphalt Concrete as Pavement Surface Layer for High Traffic Volume Routes

Mehdi Koohmishi

Ph.D. Student, School of Civil Engineering, Faculty of Engineering, University of Tehran, Tehran, Iran

ABSTRACT

One of recently developed materials in pavement construction is roller compacted concrete. RCC pavements can be used in low volume streets or heavily trafficked places. In this research, RCC pavements were evaluated by considering advantages and disadvantages of them, and then, performance of this kind of pavement for high traffic volume routes was evaluated by MEPDG software. In other words, distresses in RCC pavements are compared with flexible pavements to evaluate their performance. According to this study, by considering economical aspects, roller compacted concrete pavements can be used instead of flexible pavements especially for warm weather conditions.

KEYWORDS: Roller Compacted Concrete, Flexible Pavement, Pavement Performance, MEPDG.

1. INTRODUCTION

Roller-compacted concrete (RCC) for paving is a construction technique that uses zero-slump concrete. This type of concrete is transported, placed, distributed, and finally compacted using heavy road-construction equipments [1]. Usually, RCC is constructed without joint and it needs neither forms nor finishing after construction[2]. One of the main advantages of this concrete is reduction of construction costs between 15 to 40% versus conventional concrete [3, 4].In various projects, it has been shown that pavements surfaced by RCC will have the following advantages when compared with traditional Portland cement concrete (PCC) [5]:

1. It has a flexural strength equivalent to that of PCC.
2. Reduced time of construction.
3. Easy construction.
4. Reduce construction and maintenance costs.

Also, when RCC is compared with asphalt concrete for using in pavement, it has following advantages[5]:

1. About 25% higher flexural strength than central-mixed cement-treated bases (CTB).
2. High resistance for abrasion.
3. It does not need a protective layer; however, a protective layer can be used in future after possible deterioration of the wearing surface.
4. Higher resistance to fuel and hydraulic spills.
5. Better resistance for high temperatures.

Asphalt pavements in some highways in the Middle East region have suffered extensive pavement problems characterized by severe wheel path rutting and cracking. In addition, by increasing the cost of bitumen production, applying flexible pavements may be non-economical. Therefore, in this study, application of roller compacted concrete pavement(RCCP)instead of flexible pavement is evaluated. Because of rough surface of this kind of pavement, it is applied usually in low volume roads. But, here application of RCCP for high traffic volume routes is considered. So, first properties of RCC is mentioned then a comparison between performance of RCC pavement with asphalt concrete pavement is done for high volume routes and warm weather condition. MEPDG, the software used to evaluate flexible and RCC pavement performance, employs a layered elastic model developed under the National Cooperative Highway Research Projects 1-37A and 1-40D. This software will be integrated with the coming AASHTO pavement design guide [6]. In this study, version 1.1 of the software is used (Release date: August 2009). The main criteria for comparing RCC pavement with flexible one is IRI, because in MEPDG software, this parameter contains all other types of distresses.

2. RCC Properties and its Application as Pavement Surface Layer

According to laboratory tests done in previous studies, properties of RCC have been investigated. Following gives a brief description of RCC characteristics were found in these researches.

Corrsponding Author: Mehdi Koohmishi, Ph.D Student, School of Civil Engineering, Faculty of Engineering, University of Tehran, Tehran, Iran, E-mail: m_koohmishi@ut.ac.ir

Hassaniet al. [7] worked on the RCCP performance and they saw against conventional concrete decreasing the water cement ratio below optimum value did not increase the strength of RCCP and the very fine aggregate plays the major rule in controlling the strength properties of RCCP and not the cement content[7].

One of concerning about RCC is that producing air-entrained RCCP is a very difficult task. For this reason, various efforts have been done to use new additives for increasing its strength against freezing and also maintaining concrete mixture flowing. One of these works had been substitution of cement with silica fume or fly ash. In this research, it was found that using silica fume as additive cementations materials in RCCP was a practical solution and more appropriate than air blowing[8]. Replacing the percentage of portl and cement with natural pozzolan in Portland cement concrete has been done in a previous research. According to this work, using pozzolan can mitigate alkali-silica reaction in the concrete mixture[9].

A conventional problem in RCCP is that it is prone to cracking due to thermal stress or drying shrinkage, and this prevents the placing of pavement slabs with long joint spacing. For this reason, steel fiber roller compacted concrete has been developed. In this mixture, steel fibers were used to increase flexural strength and therefore to resistance cracking [10].

Another important problem in relating to RCCP is its surface roughness that causes to use only for low volume roads and streets. To solve this problem, applying a bonded concrete overlay has been proposed that the best time for applying this overlay is a short time after construction of RCC [11]. The other method is to apply a thin asphalt concrete overlay in 50 millimeters thickness on the RCC. Also, using an appropriate paving machine can be a good idea. If asphalt paving machines are used for RCC, 85% of its density will gain, however, high density pavers give 95 to 98% density[12].In a project done in Kansas [12], RCC used as base layer for overlaying asphaltic shoulder on the March 2011. Until this time, there has been no problem in this project. Only, the steel rollers stick has been found on the surface of RCC pavement during construction. The main reason for this phenomena was adding water to keep the pavement from drying out before it was sufficiently rolled [12].

The Virginia Port Authority recently completed construction of a roller-compacted concrete pavement for a large container storage and handling area at the Norfolk International Terminals (NIT) in Norfolk, Virginia. This project included 420 millimeters thickness of RCC pavement, topped with 75 millimeters of asphalt concrete to allow for adjustments to future differential settlement. Pavements for port facilities must be strong and durable because of the heavy loading of the container handling equipments that can cause significant pavement distresses, therefore, several possible pavement strategies were evaluated, including asphalt concrete, conventional concrete, concrete paver blocks, and RCC. An overall evaluation of strength, cost, time of construction, and expected performance resulted in RCC being selected. The final cost and especially the time required for construction resulted in a lower cost and faster construction than other comparable paving projects at the NIT. This is not surprising since RCC has been successfully used at the Port of Boston (Conley Terminal) or Port of Los Angeles (Pier 300) [13].

3. Pavement Layers Characteristics

Considered sections for asphalt concrete pavement and RCC pavement are shown in Table 1 that consist of hot mix asphalt layer or RCC layer and base layer. Type of subgrade soil is A-2-4, also. In addition, characteristics of asphalt concrete mixture and RCC are described in Tables 2 and 3 according to [14] and [15].

Table 1. Sections considered for flexible and RCC pavements

No	Thickness of each layer (mm)		Abbreviated name for each section	Initial Two-Way AADTT
	Asphalt concrete or RCC layer	Base layer		
1	150 (AC)	250	AC15-25	4000
2	200 (AC)	250	AC20-25	4000
3	150 (AC)	400	AC15-40	4000
4	150 (RCC)	250	RCC15-25	4000

Table 2. Mix design properties of dense graded asphalt rubber mixture[14]

Characteristic	Unit	Value
Type of asphalt binder	-	PG 58-22
Specific gravity of asphalt binder	-	1.04
Penetration degree of asphalt at 25 0C	0.1mm	34
Absolute viscosity	P	8000
Softening point	^{0}C	65
Optimum asphalt binder content	%	5.4
Asphalt mixture air voids content	%	7

Table 3. Mix design properties of RCC [15]

Characteristic	Unit	Value
28-day compressive strength	Mpa	21
Ware/cement ratio	%	0.3
Cementitious material content	Kg/m^3	270

Gradation of base layers materials is illustrated in Table 4 according to the ministry of road and urban development code No. 234 that type III is selected for base layer. Also, amount of CBR considered for base is equal 80 that is minimum criteria [16].

As mentioned previously, principal arterial routes are considered here. Therefore, because of heavy traffic in these areas, AADT is considered equal 20000 and traffic level is equal 2000 AADTT for design lane by assumption of 20% of traffic is truck. Also, climatic conditions according to Ahvaz and Tehran (cities in Iran with different amount of mean annual air temperature) are considered as climatic inputs to software. Table 5 shows the climatic characteristics of these regions [17].

Table 4- Gradation used for granular base layer [16]

Specifications	Unit	Base (Type III)						
Sieve size	mm	50	25	9.5	4.75	2	0.425	0.075
Percentage passing	%	100	85	57.5	45	32.5	22.5	5

Table 5- Characteristics of climatic conditions in selected regions [17]

Climatic properties	Unit	Tehran	Ahvaz
Scanned period	Year	1982-2002	1982-2002
Mean annual air temperature	^0C	17.9	25.75
Mean annual rainfall	mm	234.7	241.3
Freezing index	^0C- day	12	0
Average annual number of freeze-thaw cycles	-	2	0

4. RESULTS

According to considered properties for pavement layers, comparison between roller compacted concrete and asphalt concrete can be done. But, initially, effects of RCC properties on the pavement performance are investigated. Figure 1 illustrates variations of IRI on the RCC pavement surface by considering different values for 28-day compressive strength of RCC. It is obvious that IRI decreases as long as compressive strength increases. As mentioned in Table 2, amount of compressive strength of RCC is equal 21 Mpa and this value has been changed to investigate effects of RCC strength on the pavement performance. In addition, Figure 2 shows variations of IRI on the pavement surface after 20 years by increasing or decreasing amount of water cement ratio. As expected, IRI increases as water cement ratio increases because of reduction in strength of RCC.

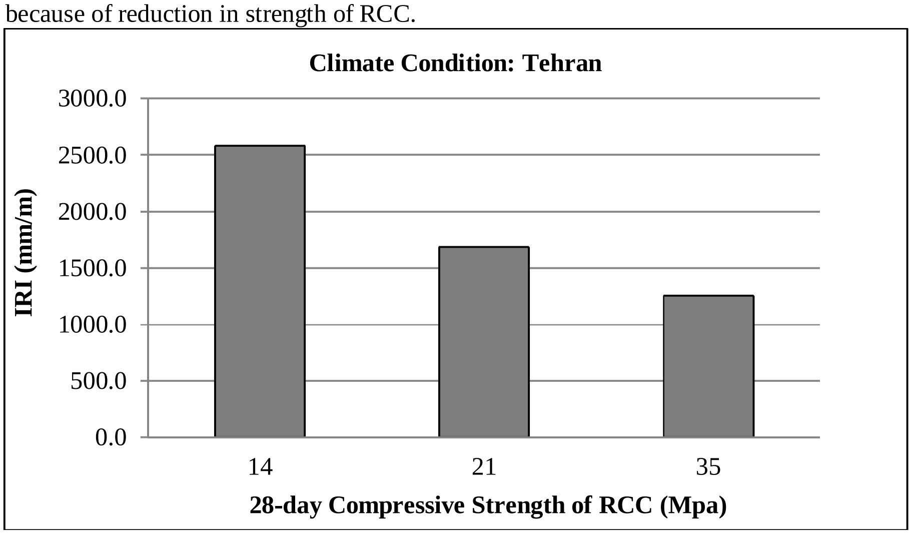

Figure1- Effect of compressive strength of RCC on the IRI in RCCP after 20 years

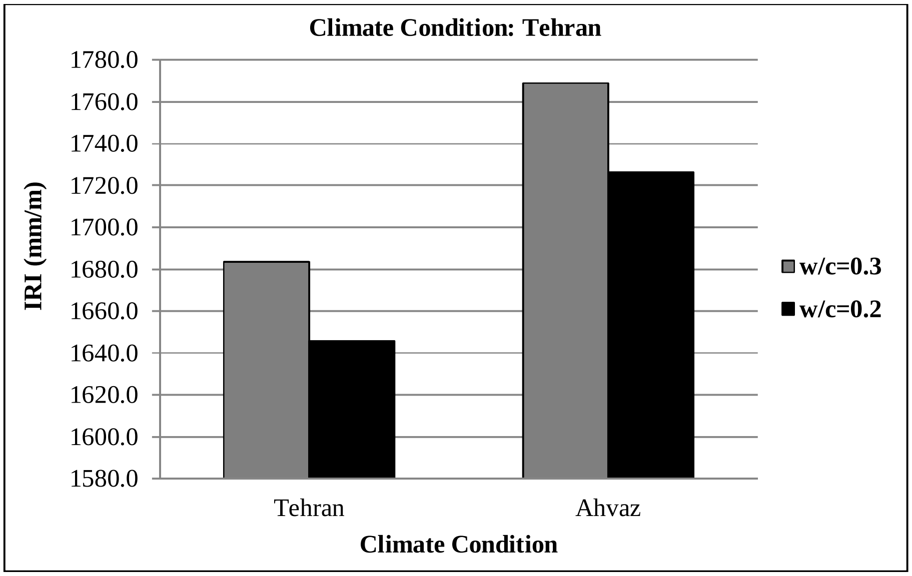

Figure2- Effect of water cement ratio on the IRI in RCCP after 20 years

To compare performance of RCC with AC for application of them as surface layers, two outputs are obtained by MEPDG software. In these two runs, all conditions are the same, and only asphalt concrete layer is used instead of RCC layer. Figure 3 compares performance of these two types of construction. This figure shows by considering the same thicknesses for pavement layers, amount of IRI after 20 years is more for pavement with asphalt concrete as surface layer than one with RCC as surface layer. Also, Figure 4 illustrates better performance of RCC than asphalt concrete against cracking and by increasing thickness of pavement layers for flexible pavement, RCC shows less distresses than asphalt concrete. In addition, RCC pavement shows insignificant rutting but, flexible pavement shows remarkable rutting. Table 6 compares amount of rutting in asphalt concrete layer for Ahavz and Tehran cities. That is obvious amount of rutting in Ahvaz is more than Tehran because of higher MAAT in this city. So, that is a good idea to use RCC as pavement surface layer at least for warm climatic condition.

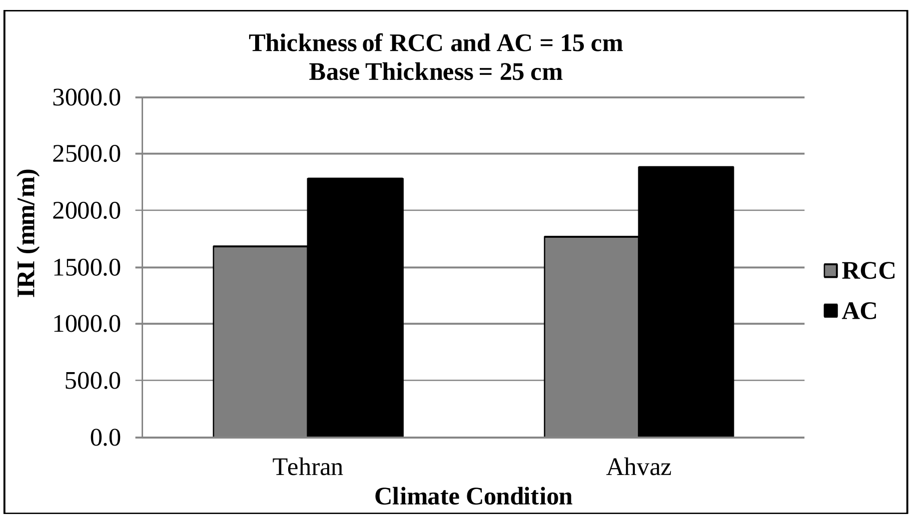

Figure3- Comparison performance of RCC and AC under similar conditions

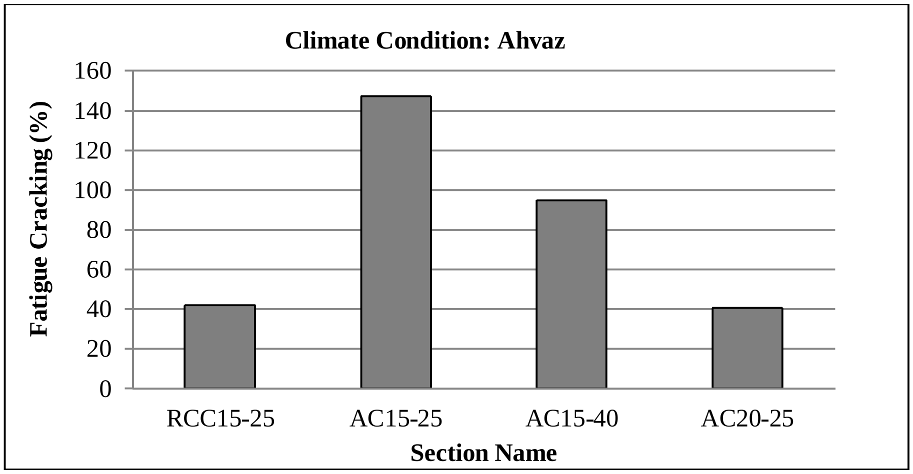

Figure4- Comparison percentage of cracking after 20 years for RCC with AC by considering various thicknesses for pavement layers

Table 6- Amount of rutting inflexible pavement after 20 years

Characteristic	Unit	Climatic condition	
		Tehran	Ahvaz
Permanent deformation (AC only)	mm	5.3	9.4
Permanent deformation (Total pavement)	mm	11.2	15.8

5. SUMMARY AND CONCLUSION

Roller compacted concrete is an appropriate material that can be used instead of asphalt concrete as surface layer. Performance of RCCP has been well in previous constructed projects and recent researches have illustrated that some concerns about performance of RCC can be solved. Also, under the same condition, RCC pavements require less thickness rather than flexible pavements. The high strength of RCC pavements eliminates common and costly problems traditionally associated with asphalt pavements, specially rutting, because RCC pavements will not soften under high temperatures. So, applying RCC pavement instead of flexible pavement can be a good idea specially for high traffic volume routes and warm weather condition. In summary and conclusion, the main benefit of pavement construction using RCC over asphalt concrete is its economical advantage resulting from its less thickness rather than flexible pavement, in addition to its ease of production, construction, and speed of operation.

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