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Field Investigation of Modified Asphalt Mix in Pakistan

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Abstract

Pavement distresses such as Rutting, fatigue, Potholes and moisture induced damage are common Pavement distress that causes the pavement failure at early design life of pavement which causes huge financial constrain to national exchequer. Since developed countries are adopting pavement preventive technique as compared to pavement reconstruction. This strategy of pavement prevention can be beneficial for developing countries to enhance serviceable life of Pavement, which can save huge amount of Cost. In this research four different Pavement section were selected based on the type of treatment applied on that specific section along Islamabad-Lahore motorway (M-2), Pakistan. The first pavement section was a blend of 15 percent Rap and 7 percent crumb rubber (Rap 15%, CR 7%), the second pavement section was a blend of asphalt with crumb rubber modified bitumen as binder (Rap 0%, CR 7%), the third Pavement section was a blend of 15 percent Rap with grade 60-70 bitumen as binder (Rap 15%, CR 0%), the fourth section was asphalt concrete wearing course with grade 60-70 bitumen as binder(Rap 0%, CR 0%). Cores were extracted from the selected four section which were further evaluated at laboratory for pavement distresses such as fatigue and damage induced to pavement due to moisture at lab. It was concluded that section one performance against fatigue was substantially better than other pavement sections while section one performance against moisture induced damages was lesser as compare to other section. Moreover, it was observed that resistance against moisture damage was considerable in section 3.

Keywords: Crum Rubber, Reclaimed Asphalt Pavement (RAP), Indirect Tensile Fatigue Test (ITFT), Tensile Strength Ratio Test (TSR), Asphalt Concrete Wearing Course (ACWC)

I. Introduction

The Highways play a vital role in Country progress. The construction and rehabilitation of road infrastructure requires substantial demand of non-renewable resources such as Asphalt binder. Pakistan also constitutes huge network of roads and is constantly increasing. According to the economic survey of Pakistan in 2016-2017 the road network constitute of 265,000km, out of which most of the pavement comprised of hot mix asphalt (HMA) and its asset value worth over 2500 billion. About 20% of GDP is invested in highway infrastructure and road network is also one of the cheapest modes of transport in Pakistan (NHA statistics). But in spite of this huge investment, it has been observed that most of the highway pavements do not serve their design life and premature failure occur in the form of fatigue, cracking, rutting, moisture damage, potholes and many other pavement distresses. The main cause of afore mentioned distresses is inadequate initial pavement structure design, rapid increase in number of commercial vehicles and use of conventional mix design procedures, which further leads to pavement reconstruction and huge financial loss to national exchequer. To cope with the situation different pavement preventive and rehabilitation techniques rather than pavement reconstruction, at regular interval, has been adopted. These pavement preventive and rehabilitation techniques can be beneficial for developing countries i.e. Pakistan to enhance the serviceable life of pavement, which can save huge amount of money.

The pavement preventive and rehabilitation techniques include the overlay of flexible pavement and modification of virgin asphalt with Reclaimed asphalt pavement (RAP) and Crum rubber. These techniques are not only economical but also environment friendly and can effectively resist different pavement distress. According to National Asphalt Pavement Association (NAPA), U.S. produces almost 60 million tons of RAP that is recycled and utilized in new asphalt pavements. According to an estimate majority of the states in U.S utilize on average 10% to 20% of RAP in mix design of Hot Mix Asphalt (HMA), while according to the UK Specification for Highway Works, maximum RAP material to be used in the production of asphaltic wearing course is 10 % and 50% in all other layers.

Nowadays, modified and innovated rehabilitation technique has been used which is economical, effective and resist all pavement distresses for maximum years. In Pakistan most of these innovated and modified rehabilitation techniques were practiced during the overlay of Islamabad to Lahore Motorway (M-2).Asphalt mixture was modified with RAP, Crum Rubber and the combination of both in different percentages to increase the resistance against rutting, fatigue, moisture damage and to increase the resilient modulus of ACWC.

II. Related Work

RAP and Crum Rubber has been used since the mid-1970s and their usage in overlay of flexible pavement has proved to be economical, effective in increasing the rutting resistance, resilient modulus and other pavement distresses i.e. fatigue, cracking, moisture damage and potholes etc. Most of the research has been carried out by adding different percentages of RAP and Crum Rubber in virgin asphalt binder to make HMA mixture in the laboratory. Rare research has been carried out on field extracted pavement cores. Past research has proved that HMA mixture with RAP and Crum Rubber as binder has performed same or better than the HMA mixture using virgin asphalt as a binder. After finding the potential benefits and effects of RAP and Crum Rubber, researcher started examined on various performance measures which include rutting, Resilient Modulus, fatigue, cracking and moisture damage of Modified asphalt mixture.

Moghaddam and Baaj studied that recycling of HMA is an old idea which was recognized as far back as 1915, although its demand s become greater due to oil embargo of the mid-1970. Due to insufficiency of excellence aggregates match with the point of application and higher costs for asphalt, increased the demand for RAP which also have a lot of incentives in terms of environmental and economic benefits. Approximately 10 million tons of RAP has been utilized since the mid-1930 with equal performance characteristics along with considerable saving in cost as compared to virgin HMA mixes [V].

Ghabchi, Singh, Zaman and Hossain Studied the effect of RAP and reclaimed asphalt shingles in new hot-mix asphalt. From the results he concluded that the fatigue life increases with increasing RAP content up to 25% and decreases when the RAP or RAS content exceeded 25%. HWT test results showed increased resistance to rutting with increase in the amount of RAP and /or RAS [III]

Wand et al conducted a study on fatigue cracking property of asphalt mixture. The results proved that the gap graded CRM asphalt mixture had a longer fatigue life and a lower crack growth rate than the continuous graded mixture. The optimum content of 20% Crum rubber results in longer fatigue life and crack growth rate was much lower at smaller loading time with higher loading frequency [IX]

Ibrahim et al has proven that Crum rubber addition enhance the properties of pure bitumen. The wet process of Crum rubber modification has the ability to enhance the rutting resistance, resilient modulus and fatigue cracking of asphaltic mixes [IV].

Solanki et al studied the effect of high RAP content with hot mix asphalt (HMA) in base and surface courses. Four super pave mixes having different percentages of RAP namely, 25% RAP and 40% RAP for base course and 0%RAP and 10% RAP for surface course were designed, constructed and tested. The result showed that the increase in RAP content reduced rutting susceptibility but increase moisture damage of both base course and surface course [VIII].

Al-Qadi et al carried out research that addition of RAP in HMA changes the physical behavior of the mix. RAP binder increased the Modulus of HMA and low temperature cracking. The tensile strength and tensile strength ratio of the HMA increased as RAP content increased. Fatigue life of HMA is also slightly improved with the addition of RAP [I].

Xiao et al carried out research that the addition of Crum rubber improves rutting resistance of mixture regardless of rubber size and type. Crum rubber also extended the fatigue life of the modified mixtures [X].

Al-Qadi et al studied that the RAP materials might provide stronger moisture resistance than virgin HMA because the aggregate are already covered and protected with binder. He also said that the rutting performance of asphalt mixes has been improved by the use of RAP but the fatigue and thermal performance has been inconsistent. He reported that fatigue resistance is increased due to the stiffer nature of the recycled material [II].

Palit et al concluded that the Crum rubber modified mix improved the fatigue resistance as compared to normal mix. He also concluded that field fatigue life of Crum rubber modified mix is at least two times longer than that of normal asphalt mix [VII].

III Methodology

To achieve the objectives, four different sections were selected on Islamabad to Lahore Motorway M-2, Pakistan, having virgin asphalt and modified with RAP, Crum rubber and the combination of both at different percentages i.e. The first pavement section was a blend of 15 percent Rap and 7 percent crumb rubber (Rap 15%, CR 7%), the second pavement section was asphalt concrete with crumb rubber modified bitumen as a binder (Rap 15%, CR 7%), the third Pavement section was blend of 15 percent Rap with grade 60-70 bitumen as binder (Rap 15%, CR 7%), the fourth section was asphalt concrete wearing course with grade 60-70 bitumen as binder(Rap 15%, CR 7%). Distress survey was done using distress survey [VI] and Pavement cores were extracted from the selected pavement sections of M-2 with the collaboration of Frontier Works Organization (FWO), Thallian camp. Pavement cores were extracted according to the standards defines by AASHTO, ASTM, ALDOT and EN standards, for the performance testing and were brought to the Laboratory of National Institute of Transportation (NIT), NUST, Islamabad, Pakistan. Pavement performance testing i.e. Tensile Strength Ratio (TSR) Test, Indirect Tensile Fatigue Test (ITFT) were executed on extracted pavement cores. Afterwards, analysis of result was done and the four different pavement sections were compared with respect to fatigue and moisture resistance. The section with better performance in terms of fatigue and moisture resistance was considered to be the best pavement section.
The detail about specification of section, location and direction from where cores were extracted is given below in the table.

Section	Specification	Direction	Location(km)
I	ACWC Class-B with 60/70 Bitumen (RAP 0%, CR 0%)	North Bound Slow Lane (Lahore to ISL)	35+000-73+725
2	ACWC Class-B with PG Bitumen (RAP 0%, CR 7%)	North Bound Slow Lane (Lahore to ISL)	106+640-118+950
3	ACWC Class - B with 15% RAP (RAP 15%, CR 0%)	North Bound Slow Lane (Lahore to ISL)	81+725-106+640
4	ACWC Class-B 15% Rap with PG Bitumen (15%RAP, 7%CR)	North Bound Slow Lane (Lahore toISL)	242+000-270+700

Table 1: Detail Specification, direction, location and pavement cores required

Pavement visual distress survey was done in order to identify and quantify the amount and severity of the surface distress in a given segment of pavement. Oregon manual was used in conducting the distress survey [VI]. Distress survey map sheet was used while conducting distress survey in the field. As the "overlay and modernization of Lahore to Islamabad Motorway (M-2)" project was started in Oct 2014 and was completed in Aug 2016 and was conducted under the supervision of Frontier Works Organization (FWO), a well-established and organized construction company in Pakistan, so there were no such noticeable distress.

Figure 1: Measurement of rutting on field

After that cores were extracted using electrically driven core cutting machine with 6 inch diameter coring bit, from the selected pavement sections of Lahore to Islamabad Motorway (M-2), mentioned above in the table. Cores were extracted from the slow lane outer wheel path and from each section because heavy traffic mostly passes through slow lane and this lane is mostly affected by the heavy vehicle wheel load. After the extraction, the core specimens were marked according to the section and the R.D's was recorded from where the core was extracted.

Figure 2: Core cutting process on field

The core specimen has a diameter of 6 inch, as 6 inch diameter coring bit was used for the extraction of core but we know that the performance testing to be conducted on Universal Testing Machine (UTM) require a standard diameter of 4 inch core specimen. Electrically driven coring machine was used to take out 4 inch core from a 6 inch field core specimen. Four inch coring bit was fixed in the coring machine and the core specimen was properly fixed in assembly. Core cutting of the specimen is shown in the figure below.

Figure 3: Core cutting of field cores in laboratory

According to the standard the core specimen should have standard thickness and it's both surfaces should be level and smooth. So after core cutting, a saw cutter was used to cut the core specimen to the standard thickness and its surface was also smoothening with the help of saw cutter. For ITFT and TSR test 4 inch and 1.5 inch thick core specimen was prepared having both the surface leveled.

Performance Testing on Field Cores

After core cutting and saw cutting the core specimen were evaluated were subjected to the following performance testing.

- Tensile Strength Ratio Test
- Indirect Tensile Fatigue Test

IV. Results/Discussion

The results obtained from Tensile Strength Ratio Test, Indirect Tensile Fatigue Test were compiled to investigate the effect of Reclaimed Asphalt Concrete (RAP), Crum Rubber and the combination of both at different percentages on different pavement distresses i.e. Fatigue and moisture resistance. The screened data was further analyzed to find out the effectiveness of RAP, Crum Rubber and both, as fatigue resistant agent to reduce alligator cracking and to reduce the moisture damage of Hot Mix Asphalt (HMA) pavement.

Tensile Strength Ratio Test Results

The tensile strength ratio test was carried out to find the moisture susceptibility of hot mix asphalt pavement. The test was performed according to ASTM 6931-07 and the conditioning of the sample was done according to the ALDOT 361. A total of 24 samples were used to perform this test for the four different section. For a single test, three specimens were tested unconditioned and three specimens were tested conditioned. Unconditioned sample were placed at 25°C in water bath for 2 hours while conditioned sample were placed at 60°C in water bath for 24 hours fallowed by 2-hour conditioning at 25°C before being test for ITS. The average ITS value for conditioned and unconditioned sample and their respective TSR values is shown in the table below.

Table 2: Tensile Strength Ration Test Results

Samples	Tensile Strength Ratio (TSR) Test Results			
	SECTIONS			
	R0+CR0	**R0+CR7**	**R15+CR7**	**R15+CR7**
Average Unconditioned Strength S1 (KN)	8.08	8.201	8.124	8.251
Average Conditioned Strength S2 (KN)	8.183	8.5	8.487	8.665
TSR (%) = S2/S1	98.74	96.48	95.72	95

Figure 4: Tensile Strength Ration Test Results

The above table summarize the TSR values of unmodified and all modified asphalt concrete pavement section and the figure shows the trend fallowed by the TSR values with the addition of RAP, Crum Rubber and combination of both. The trend shows that modified asphalt pavement section has TSR value less than the un-modified asphalt pavement section, which shows that modified asphalt mixture is more susceptible to moisture damage as compared to unmodified asphalt mixture. The section having combination of both RAP and CRMB are more susceptible to moisture damage as compared to pavement section modified with RAP and Crum Rubber separately. Furthermore, the pavement section having CRMB are more susceptible to moisture damage than the pavement section having RAP as a modifier.

Indirect Tensile Fatigue Test Results:

ITFT is used to characterize the behaviors of bituminous mixture under repeated load applied with constant load mode on the cylindrical shaped sample according to European Standard EN 12697-24: 2004 (E). Cored samples were used in the test to give an insight of the condition on site. The cylindrical shaped specimen is exposed to repeated compressive haversine load in the vertical along the diameter of the specimen. The test was conducted at a stress level of 350kpa and at a test temperature of 25°C.The test results are shown in the table below.

Table 3: Indirect Tensile Fatigue Test Results

No of Cycles to Failure				
Samples	**SECTIONS**			
	R0+CR0	**R0+CR7**	**R15+CR7**	**R15+CR7**
1	3121	3321	3634	4541
2	2706	3451	3557	4331
3	2923	3382	3590	4336
Average Value (mm)	2916	3386	3593	4402
Improvement (%)	0%	13.88	18.84	33.75

Figure 5: Indirect Tensile Fatigue Test Results

The result shows the effect of RAP, Crum Rubber and the combination of both in different percentages on the fatigue resistance of asphalt pavement section. The above table summarize the cycles to failure of unmodified and all modified asphalt pavement section and the figure shows the trend fallowed by the different pavement sections against fatigue. The results show that the modified asphalt pavement section has higher fatigue resistance as compared to unmodified pavement section. The pavement section having CRMB and RAP shows greater resistance against fatigue as compared to unmodified and section modified with RAP and Crum rubber separately.

Furthermore, the pavement section having CRMB have lower fatigue resistance than the pavement section having RAP as a modifier.

V Conclusion

The results show that the modified asphalt pavement section has higher fatigue resistance as compared to unmodified pavement section. The pavement section having CRMB and RAP shows greater resistance against fatigue as compared to unmodified and section modified with RAP and Crum rubber separately. Furthermore, the pavement section having CRMB have lower fatigue resistance than the pavement section having RAP as a modifier.

The trend shows that modified asphalt pavement section has TSR value less than the un-modified asphalt pavement section, which shows that modified asphalt mixture is more susceptible to moisture damage as compared to unmodified asphalt mixture. The section having combination of both RAP and CRMB are more susceptible to moisture damage as compared to pavement section modified with RAP and Crum Rubber separately. Furthermore, the pavement section having CRMB are more susceptible to moisture damage than the pavement section having RAP as a modifier.

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