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Recycling of asphalt from roads with metropolitan lahore environment and their compatibility assessment

Muhammad Habib-ul-Haq[1], Mohammad Nawaz Choudhry[2], Sajid Rashid Ahmad[1], Zafar Iqbal[*3]

[1]*College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan*

[2]*Lahore School of Economics, Lahore, Pakistan*

[3]*Applied Chemistry Research Centre, PCSIR laboratories Complex Lahore, Pakistan*

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Abstract

Asphalt roads are very popular in urban areas and a major share of its budgetary provisions has spent over rehabilitation of road network in Metropolitan Lahore-Pakistan. Furthermore, release of GHG emissions in rehabilitation activities impacts negatively over the environment. Ultimately the government decided to opt hot in-place recycling of such old roads. This strategy is not only economical but saves heavy GHG emissions and landfill allocations. During the year 2011 a group of urban asphalt roads were selected for hot in-place recycling. It consists of heating, mixing, placing and compacting the upper asphalt layer at site, in one go. Innovative job mix formula (JMF) using maximum quantity of reclaimed materials and addition of minimum quantity of virgin asphalt binders were adopted. Amongst this group of roads, one segment of road, from Punjab Civil Secretariat to historical monument of Chouburji was selected to observe the operational asphalt behavior throughout its life period till June 2018. This trial segment was closely watched and there was no sign of shearing, scuffing and rutting etc. associated with aging of asphalt surfaces. The test chunks and cores from asphalt layer were subjected to lab testing. Quantity of bitumen binder and compaction of asphalt core values have been found with in permissible limits of original job mix formulae. The results indicate that environmental factors like ultraviolet sun rays, rain precipitation and variable traffic volume of Lahore could not damage the asphalt behavior during its anticipated life time till latest inspection in June 2018.

* **Corresponding Author:** Zafar Iqbal ✉ zafarmayo2000@yahoo.com

Introduction

Roads are vital part of our energetic life, while most people take the roads for granted. In an Asian country like Pakistan road and highway construction has turned into major developmental activity involving major share of budgetary provisions and Green House Gases emissions.

The Punjab Roads network has been developed over many decades. It has now become the society's most valuable asset and its asphalt pavements are "Treasure Trove" in the form of reclaimed (Mallic, 2015). This research is focused on the recycling suitability of asphalt roads with urban Lahore environment. The road infrastructures can, through recycling, become sustainable for generations to come (Bentenson, 1979). Bituminous pavement recycling technology is not popular in South Asian Countries as yet. However in advance countries, bituminous material is the most recycled material in the construction industry.

Time and again recycling of construction material can give well appreciated benefits of asphalt and asphalt roads. If the developing and innovative techniques are adopted, the scope of recycling potentials shall be increased. If we optimize the recycling hierarchy of asphalt road, it clearly makes sustainable sense in the roads of next century (Greeman, 2007).

The surface of recycled roads has less chances of reflective cracking (Mallic, 2005). It uses less time to overlay, conserves the energy, reduces cost of constructions and preserves environment and ecosystem. Recycled mix when laid, decreases the shearing, scuffing and rutting and there are less chances of reflective cracking. It discourages unwanted and frequent changes of road and adjoining building plinth levels and reduces carbon foot print, which is mainly responsible for climate change.

In-place pavement includes various paving technologies that can restore the structural capacity of distressed pavements while using little virgin materials. Various in-place recycling techniques have been successfully demonstrated by many highway agencies (Mohammad *et al.*, 2003; Levis, 2008; Hill, 2012).

Durability of asphalt roads diminishes due to ageing. Ageing is defined as change in rheological properties of asphalt properties of mixtures due to change in chemical and physical properties during construction and operational phases of asphalt roads. In our case since the recycling is done at site where all process of mixing, laying and compaction are done within shortest possible time at the site, therefore the chances of aging in construction phase are minimum. This is the main advantage of recycling of hot mix asphalt at site.

Due to aging the compaction status of asphalt roads declines. Ageing converts the soft asphalt materials into stiffen and brittle which ultimately lowers the durability of roads and causes cracks and break down of surfaces. % age of asphalt binder / bitumen is reduced in such cases. Aging is due to inner causes which include type of asphalt mixture, type of aggregates, intensity of voids and thickness of asphalt coating and external factors during operational phases which include traffic load and other meteorological and environmental conditions.

Pavement design and then its performance are mainly due to many boundary conditions such as the interaction of climate factors such as temperature, moisture. The mechanical performance of loose and bound materials and traffic load spectrum of the area are also there as on. Therefore theory alone cannot define the pavement design to overcome the difficulty of indefinite empirical pavement design. The pavement designers have started to understand the linkage between pavement structure and its envisaged environment as a system. The pavement mechanical response is analyzed, taking into account the external traffic loading and environmental conditions simultaneously (Fahad, 2015). In order to establish a more robust and motional pavement design and analysis, a thorough understanding of the factors involved, such as material behavior and response to traffic load induced stresses and environmental factors, is essential (Robert *et al.*, 1996).

For dense graded mixture it is generally agreed that the air void content of the pavement should be no higher than 08 % and should never fall below 03 %

during the service life of the pavement (Alderson, 2011). One rule of thumb based upon field performance data that is often cited for dense graded mixtures is that pavement life is reduced about 10 % of each / pavement increase in in-place air voids above 07%. Many researchers have studied the effects of compaction on the properties of asphalt concrete mixtures. The general consensus of these studies is increased compaction or decreased air voids have the effects like reduced oxidative aging of the binder, decreased permeability, increase strength, Increase mixture stiffeners, increased resistance to moisture damage, increased resistance to rutting and increased resistance to fatigue cracking (Lesueun, 2009).

Even though the instant hot in-place, recycling has been applied over trial stretch with novel Job mix formulae (JMF) of reclaimed and virgin materials blends but its sustainable operation is also necessary for logical success. Laboratory test results derived from asphalt chunks and cores from existing asphalt layers have proved that recycling of asphalt technique and formulae both are valid and friendly for Lahore Metropolitan environment. This study will not only save the huge capital spent, but also it will pave the way for the recycling of materials for the road construction and maintenance.

Materials and methods

Determination of bitumen contents

Four Samples (Asphalt Chunks) were taken from each kilometer of existing trial road during June, 2018. Quantitative extraction of these asphalt samples collected from M.A.O College to Chouburji length of Lahore was carried out by following the reported procedure. Generally, the test portion of asphalt chunks were placed into a bowl, and extraction was carried out with trichloroethylene and 1,1,1 trichloroethane methylene chloride. The material was dried at 110 ± 5° C, followed by centrifugation and extraction with trichloroethylene three times. Combined extract was collected and mineral matter was determined. Then the aggregate was transferred in the centrifuge bowl into a metal pan, dried in air until the fumes dissipated. The mass of this extracted aggregate is equal to the mass of the contents in the pan minus the initial dry mass of the filter ring (ASTM, ND T-166) Calculations were carried out by following formula:

Bitumen Content, % = $(W_1 - W_2) - (W_3 - W_4) / W_1 - W_2 \times 100$

Whereas, W_1 = mass of test portion

W_2 = mass of extracted mineral

W_3 = aggregate

W_4 = mass of mineral matter in the extract

Table 1. Quantitative comparison of (Asphalt) content %age found in four samples during June 2018 with contents of Job Mix Formula (JMF) adopted in 2011.

Description	Sample 1	Sample 2	Sample 3	Sample 4	Job Mix Formula (JMF 2011)
Weight of premix material before test	1179	1150	1146.5	1096	
Weight filter paper before	10	10	10	10	
Weight filter paper after test	12	14	12	13	
increase in weight	2	4	2	3	
Weight of material after test	1110	1072	1079	1027	
Weight of filter	18	24	16	20.0	
Total Recovered aggregate	1130	1100	1097	1050	
Loss in weight	49.0	50.0	49.5	46.0	
Asphalt (Bitumen) Content %age	4.2	4.3	4.3	4.2	4.5 ± 0.3

JMF: Job Mix Formula for Asphalt Mixture adopted during 2011 for recycling of Asphalt Pavement.

While finalizing the Job Mix Formula (during 2011) for the recycling of Asphalt Road, the bitumen contents at rate of 4.5 percent of total Asphalt weight was fixed. However, ± 0.3 flexibility was allowed. The quantity of bitumen extracted from all the four samples taken from existing asphalt layer in 2018 is within allowable limits of JMF.

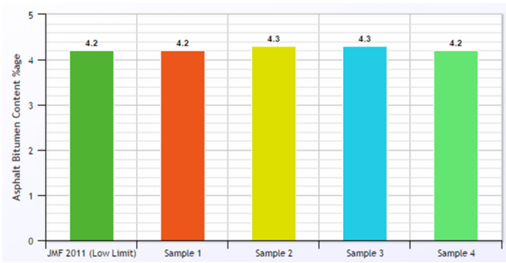

Fig. 1. Bitumen %age in all 4 Samples is within permissible limits of JMF 2011.

Sieve Analysis

The aggregates portion of all the four Asphalt samples have been subjected to Sieve Analysis. The sizes of each aggregate group and percentage pass and retained through each kind of Sieve size have been found within the JMF specified limits. The above table A2 gives complete description of Sieve Analysis of aggregate portions obtained from all the four Asphalt chunks samples.

Table 2. % age Coarse Aggregate Sizes (After titration) Compared with Original JMF Limits.

Sieve Size	Sample 1 %age Pass	Sample 2 %age Pass	Sample 3 %age Pass	Sample 4 %age Pass	JMF specified %age limits
3/4"	-	100	100	100	100
½"	98.1	92.5	97.2	95.4	90-100
3/8"	72.3	69.8	70.5	66.9	65-79
No. 4	58.4	51.5	51.6	55.8	47-61
No. 8	39.2	34.6	34.6	37.5	29-41
No. 50	14.2	11.5	12.2	10.4	8-18
No. 200	6.1	5.5	5.3	6.2	3-9

Determination of Asphalt Core Compactions

Four Asphalt core samples were drilled from the laid Asphalt Layer for determination of compaction status of existing layer during June, 2018. The specimen from these cores was immersed in the water bath at 25°C (77 F). The mass under water was recorded, and the specimen was taken out of the water, blotted quickly with a damp cloth towel, and weighed in air. The difference between the two masses was used to measure the mass of an equal volume of water at 25°C. The test method provides guidance for determination of the oven dry or thoroughly dried mass of the specimen. The bulk specific gravity was calculated from these masses. Then the density was obtained by multiplying the specific gravity of the specimen with density of the water. Bulk specific density of non-absorptive compacted bituminous mixtures was determined by following the ASTM method D-2171-88.

The values obtained from this test method were used to determine the unit weight of compacted dense bituminous mixtures and in conjunction with Test Method D3203, to obtain percent air voids. These values in turn were used in determining the relative degree of compaction. Since specific gravity has no units, it was converted to density in order to do calculations which require units. This conversion was made by multiplying the specific gravity at a given temperature by the density of water at the same temperature.

Table 3. Compaction of Asphalt Core Samples Derived From Densities 2018.

Description	Sample 1	Sample 2	Sample 3	Sample 4	As per JMF 2011
A, Dry weight in air (g)	989	996	982.7	985.9	
B, SSD weight (g)	995	1005.2	991.5	994.4	
C, Weight in water (g)	570	579	569	571.5	
Volume (cc) D = B – C	425	426.2	422.5	422.9	
E, Bulk SP gravity	2.327	2.337	2.326	2.331	
F, Marshal Reference Density gm/c	2.407	2.407	2.407	2.407	
Compaction = E/F) x 100	96.7	97.0	96.6	96.9	97.5 ± 1

SSD: Saturated Surface Density, MRD: Marshall Reference Density.

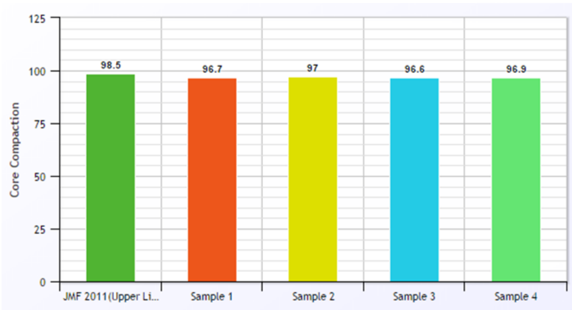

Fig. 2. Compaction status of recycled asphalt layer.

Results and discussions

Before the recycling of old and deteriorated Asphalt layers during 2011, its capacity to be recycled was anticipated through evaluation of coarse aggregates and quality and quantity of bitumen binder. Thus Job Mix Formula which governed the recycling of layer was fixed. This became the standard for subsequent performance and quality parameters of recycled trial road. In order to ascertain the capability and success of Recycling attempt the test samples have been subjected to verification of aggregate and bitumen quantities as specified in Job Mix Formula, 2011.

The initial Job Mix Formulae (JMF) which specified the materials to be cited in recycling of asphalt roads during 2011 was proposed to make up the deficiencies found in reclaimed asphalt materials. However in order to compensate the aged binder bitumen and loss of its volatility during re-burning, quantity of 1% virgin bitumen binder was supposed to be added by the Road Research Institute Lahore. While arriving at Job Mix Formulae (JMF) during the year 2011 (Laher, 2011, Mohammad *et al.*, 2013) strong principles were applied for salvaged asphalt materials proposed in J.M.F. These principles include:

The identical grading requirements and design pavement were used while specifying T.M.F. for recycled pavement as compared with virgin mix old surface. Design Strength Equivalences in recycled J.M.F were comparable with conventional pavement. Asphalt consistence and gradation properties for recycled asphalt concrete mixtures were monitored according to normal asphalt component in old surface (Pourtamash and Karim, 2010). Placement, leveling and compaction techniques during recycled asphalt lay did not deviate from standard construction yard stick (Hill T, 2012, Kuang *et al.*, 2014, Zapata, 2009). These were pursuant to any normal paving operations. In this way 100% of reclaimed material and only 1% of virgin bitumen binder had been opted for Job Mix Formulae (JMF) of Recycled Asphalt Mix which is innovative.

Keeping in view the application constraints, a tolerance limit $\pm$ 3 to $\pm$ 8% for aggregate portion while $\pm$ 3% for bitumen binder was allowed in this Job Mix Formula (JMF).

The compaction of sample cores and quality of binding bitumen oscillates between permissible limits of their design. The aggregate portion of original adopted J.M.F remained intact with the road surface. The environment of Lahore remained passive against the chemical properties of asphalt layer and without remarkable signs and adverse effect (increasing or decreasing) the compaction status of asphalt surface.

The test sample extracted during operational period (June 2018) when subjected to compaction and extraction of bitumen testing have been found satisfactory and within the above tolerance limits. From the Table 1, 2 and 3, it is clear that even after the lapse of design period of rehabilitated roads, the aging of bitumen and environment of Urban Lahore could not damage the roads. There is no surface distress and traffic is still plying smoothly. The instant recycling process is novel as it remained successful after the operational trial from 2012 to 2018.

Conclusion

The asphalt surface of trial road was decided to be recycled during the year 2011. Execution through recycling was completed in pursuance of job mix design during Feb 2012. This recycled asphalt layer is still intact without any structural damage or surface deterioration, inspected and tested in June 2018. The compaction status of asphalt layer and percentage of aggregate / bitumen binder is still within tolerance limits; meaning there by that recycling of asphalt roads technique is consistent and compatible with environmental and traffic conditions of Metropolitan Lahore, Punjab.

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Conflict of interest

The authors declare no conflict of interest.

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