IMPROVING RUTTING RESISTANCE OF HOT MIX ASPHALT BY DATES KERNEL POWDER

Sahar S. Neham
Naham_1969@yahoo.com
Al-Furat Al-Awsat Technical University, Kerbalaa Technical Institute, Kerbalaa, Iraq

ABSTRACT

In Iraq, the significant increase in the number of passenger cars and trucks (increased in axle loads) in addition to the unprecedented rise of temperature in the summer has increased the risk of permanent deformation of flexible pavement (Rutting) in recent times. Lower costs maintenance and extending serves life of flexible pavements are the main objectives of this study by improving rut resisting of it using the waste locally available materials (Dates Kernel Powder).

The Superpave design criteria is used to determine optimum asphalt content at 4% air voids for hot mix with Lime Stone Dust and Dates Kernel Powder as a filler materials to three types of aggregate blend. Preparing 54 samples with dimension (400*300*50) mm at 110˚C compacted temperature to test it by Wheel-Tracking device at 40˚C, 50˚C and 60˚C. **Based** on wheel-tracking device results, it can be show that there was a significant decrease in the value of the Rut Depth when using the Dates Kernel Powder as an alternative to Lime Stone Dust as a filler materials in Hot Mix Asphalt and it can be used to improve the rut resisting; the maximum percent of reduction is 67.71 after 3000 cycle of passing at 60ºC and 49.35 as a minimum percent of reduction after 5000 cycle at 40ºC tested temperature, then it can be seen that the impact of Hot Mix Asphalt with Dates Kernel Powder is less at high temperatures than mixes with Lime Stone Dust on Rut Depth value.

KEYWORDS : Dates Kernel Powder, Superpave, Rutting, Wheel track test, Tested temperature

تحسين مقاومة التخدد للخلطة الأسفلتية الحارة بواسطة مسحوق نواة التمر

د. سحر صفاء هادي
جامعة الفرات الأوسط التقنية / المعهد التقني كربلاء

الخلاصة

في العراق، وفي الآونة الأخيرة أدت الزيادة المفرطة في عدد المركبات الشخصية ومركبات الحمل (مع زيادة في الأحمال المحورية) بالإضافة إلى الارتفاع غير المسبوق لدرجات الحرارة في فصل الصيف أدت إلى زيادة خطر التشوهات الدائمة للتبليط الأسفلتي (التخدد). الهدف الرئيسي للبحث هو أستخدام مواد متاحة محلياً كنفايات (مسحوق نواة التمر) لتقليل كلفة صيانة التبليط المرن وزيادة العمر الخدمي له.اعتمدت طريقة التبليط فائقة الأداء في تصميم الخلطة الأسفلتية الحارة لتحديد المستوى الأمثل للأسفلت بنسبة فراغات 4% باستخدام مسحوق نواة التمر وغبار الحجر الجيري كمادة مالئة لثلاث تدرجات من الركام. تم أعداد 54 بلاطة خرسانية أسفلتية بأبعاد (50*300*400) ملم عند 110 مº كدرجة حرارة حدل ليتم فحصها بجهاز العجلة المسارية للأحمال المتكررة عند 40 مº, 50مº و 60 مº كدرجة حرارة فحص. استنادا إلى النتائج يمكن ملاحظة الانخفاض الكبير في قيمة عمق التخدد عند استخدام مسحوق نواة التمر كبديل عن غبار الحجر الجيري كمادة مالئة ومن الممكن استخدامه لتحسين مقاومة التخدد للخلطة الأسفلتية الحارة. أن أعلى نسبة انخفاض كانت 67.71 بعد 3000 دورة من الأحمال عند 60 مº كدرجة حرارة فحص وأوطئ نسبة أنخفاض 49.35 بعد 5000 دورة من الأحمال عند 40 مº، كما لوحظ أن تأثر الخلطة الأسفلتية الحارة باستخدام مسحوق نواة التمر أقل عند درجات الحرارة العالية مما عليه عند استخدام غبار الحجر الجيري .

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SYMBOL DEFINTION

Dates Kernel Powder	**DKP**
Lim Stone Dust	**LSD**
Hot Mix Asphalt	**HMA**
Rut Depth	**RD**
Penetration Grade	**PG**
Tested Temperature	**TT**
Passing cycle	**PC**

INTRODUCTION

The comfort of the ride and the road safety is affected by rutting: one of the very important flexible pavement distress types.
Zahw, 1990 indicated that rutting depth increase by a factor of 2.7 when the testing temperature of the mixes increases from 25^{o}C to 60^{o}C.
Stakston, and Bahia, 2003 indicated that aggregate grading was the major factor of effect on rut resistance, also without a proper gradation that mixes prepared with the best evaluable materials would fail.
Zaniewski, and Srinivasan, 2004.State that external factors (tire pressure, temperature, load and volume of truck traffic, and construction practices) and internal factors (pavement thickness, asphalt grade, aggregate and mixture properties) have an effect on the rate and the depth of the rutting.
With increasing number of axles per axle group rutting damage is caused by multiple axles increases, Chatti *et al*, 2005.
Wang and Lu, 2017 Investigated that Rutting is caused by single and dual wheel set have the same value while increased by 33% when applied double – axle wheel load, also the maximum pavement depression increased by 7% when the tire pressure increased from 0.7MPa to 0.9MPa. Table 1 explains the summery of studies attempted to improve rutting resisting.

STUDY OBJECTIVES

According to the design guides limitations dependent on Superpave of flexible pavement, the main objectives of this study was to investigated the effects of using Dates Kernel Powder (DKP) as a filler marital and compered with mixture prepared with Lim Stone Dust (LSD) on rutting resisting through deferent factors as; aggregate gradation, testing temperature and loading.

MATERIALS SELECTION

In Baghdad; from, Al-Daurah refinery Asphalt binders PG 64-16 was adopted, from Al-Nibaie quarry three aggregate blending were recombined in the proper proportions after sieved to meet the wearing course gradation limitation requirements by Superpave and SCRB, 2003; **Table 2** and **Fig.1** represented the selected gradation as well as **Table 3** and **Table 4** explain the physical properties of selected materials for aggregate and asphalt cement sequential.
Iraq is a country of palm trees and therefore there are very large amounts of Dates Kernel, which are considered as a wasted material, through the mentioned, and because the Dates Kernel contains a reasonable proportion of the fiber the idea of using the powder of it as a filler material in the hot asphalt mixture and compared it is effect on rut resisting with the normally mixes prepared by LSD from the factory in Karbala city, physical properties were stated in **Table 5**.

PREPARING DATES KERNEL POWDER (DKP)

After collecting a quantity of Dates Kernel, clean it, drying at oven in 110±10°C up to 24 hour, grinding and sieving by sieve #200 to prepare DKPas shown in **Fig. 2**.

METHODOLOGY

Superpave system has been adopted as a structural approach to material selection, aggregate structure design and optimum asphalt cement content to improve pavement performance, Khan, and Kamran and Mumtaz, 2012.

Brown, and Cross, 1992 and many researchers indicated that the rutting occurred on the top of the flexible pavement layers, according to these studies: the current research deles with wearing course layer, to achieve the requirement of this study, traffic level of 10-30 million ESAL, well be adopted to designed the mixture, (Nini=9, Ndes=135, and Nmax=220) D'Angelo, et al., 2001.

Superpave Gyratory Compactor was used to prepare cylindrical specimens to determine the optimum asphalt content to each type of filler with the three aggregate blending according to AASHTO Designation: T 312-2010, Fig. 3 shows the value of optimum asphalt content at 4% air voids.

Table 6 explains and compeer the properties of prepared hot mix asphalt at optimum asphalt content for each mix with the specification limits.

Roller Compactor Devices are used to prepare 54 slab (400*300*50) mm in dimensions at the optimum asphalt content with 4% air voids at 110˚C compaction temperature.

According to the AASHTO Designation: T 340, 2010, wear ability of prepared slabs of asphalt mixes by simulating roadway conditions were test by Wheel Tracker Device, 780 N loading from a wheel rubber tire after the slabs using the three aggregate blending with DKP and LSD are heated to three tested temperature (TT) 40˚C, 50˚C and 60˚C to simulate the rapid rise in temperature in Iraq recently after 3000, 4000, 5000 passing cycle (PC).

RESULTS AND DISCUSSION OF LABORATORY TEST

Effect of DKP on Optimum Asphalt Content

Table 7 summarized the percent of reduction in value of optimum asphalt content of prepared mixes with the two types of used filler for the three aggregate gradation selected.

Effect of DKP at Different Tested Temperatures on Rut Depth

Table 8 to **Table 10** explain the value of Rut Depth (RD) according to the Wheel Tracker Device result as well as **Fig.4** to **Fig.6** shows the effect of DKP as a filler materials at deferent tested temperature on RD compering with mix prepared using LSD after 3000, 4000, 5000 cycle of passing sequences. **Table 11** listed the factor value of mixes with DKP and LSD as a filler materials when tested temperature change from 40˚C to 50˚C and 50˚C to 60˚C, on the other hand this table explain the factor value after cycle No. 3000 , 4000 and 5000.

Table 12 listed the mean value of RD of three selected gradation after each cycle of passing adopted at three tested temperatures, on the other hand **Fig.7** to **Fig.9** explain the percent of change in RD when test the prepared mixes with DKP and LSD at 40˚C, 50˚C and 60˚C after 3000, 4000 and 5000 cycle of passing sequins.

Finally **Fig.10** shows the percent reduction in the RD value when using mixes with DKP comparing with mixes using LSD as filler materials at each tested temperature and after 3000, 4000 and 5000 cycle of passing.

CONCLUSIONS

Within the limitations of materials selection, aggregate structure, mix design and testing program dependent in this study, the following conclusions are based on the findings of the investigations:

1. From **Table 7,** using DKP as a filler material in HMA reducing the optimum asphalt content by 3.51% this may be due to the low value of the specific gravity compared with LSD, then the interlock between aggregate particles (fraction) was decrease; therefore, the value of the rutting of asphalt concrete mixture is expected to decrease.
2. **Table 8** to **Table 10** investigated that: the value of RD of HMA with DKP is lower than the HMA with LSD at each tested temperature and for all aggregate gradation selection after three cycles of passing loading and **Fig. 4** to **Fig. 6** explain: the RD value of mixes with LSD highly effected at 60 ºC rather than mixes with DKP.
3. **Table 11** investigated that: maximum factor of increase in RD value is 1.51 and 1.68 of mixes prepared with DKP and LSD when temperature was increased from 50ºC to 60ºC after 5000 cycle of passing with the finer aggregate gradation, on the other hand the minimum factor of increase is 1.1 and 1.2 when temperature was increased from 40ºC to 50 ºC after 3000 cycle of passing with the coarser aggregate gradation.
4. **Fig. 7** to **Fig. 9** the maximum Percent increase in RD value of mixes with DKP and LSD is 51.44 and 68.11 in a sequence due to the rising tested temperature from 50ºC – 60ºC after 5000 cycle of loading and the minimum Percent increase in RD value is 10.05 and 20.14 when tested temperature increases from 40ºC – 50ºC after 3000 cycle of loading**.**
5. **Fig. 10** shows the percent reduction of HMA RD when using DKP as an alternative of LSD at 40ºC, 50ºC and 60ºC by 62.60, 66.20 and 67.71 after 3000cycle, 53.07, 58.66 and 64.12 after 4000cycle and 49.35, 57.19 and 62.02 after 5000cycle, These results are likely to be due to the percentage of fiber contained in the DKP giving them some flexibility.

Table 1: Literature Review to studies Permanente Deformation of HMA

Author and Year	Stydy Idea	Test	Summary of Finding
Sylvester 2002	HMA Properties	Asphalt Pavement Analyzer (APA) Rut Depth	Changes in the aggregate gradation or structure do not significantly affect the rutting performance for mixtures that contain excessive asphalt. Apparent relationships between rutting resistance of mixtures and: rate of change of gyratory shear per cycle and the gyratory stability index measured from the Gyratory Testing Machine.
Asmaiel 2010	Pavement: Structure;Performans and Marshall Properties	Field Mesuearment	Ln RD = 1.659 + 0.131 (Ln KESAL) - 0.084 (SN) + 0.061 (VTM) + 0.055 (VMA) - 0.004 (MS) … R^2 =0.6
Amir et al., 2012	aggregate gradation upper, middle and lower limit with 19 mm nominal maximum aggregate size	Dynamic Creep	Permanent deformation is reduced and rutting resistance will be increased when aggregate gradation near to upper limitation
Khan, *et al.*, 2013	Applied load; temperature and material properties	Accelerated Pavement Testing	RD= $0.005_{NO\cdot PA}.^2 + 0.2368_{NO\cdot PA}. + 1.1988$. R^2=0.865 After 4 mm of rut depth which is quite minimal, the effect of further number of load repetitions is not visible.
Mohammed, *et al.*, 2016	Asphalt Cement Grade and Aggregate Structure	Finite Element Simulation	Rutting of asphalt pavements can be analyses from creep model based on finite element method.
Mohamed & Abdolsamed 2016	Aggregate types (dolomite and limestone) Aggregate gradations (coarse; open and dense gradations)	Wheel track	Mixes with coarser gradation produced more resistance to rutting than dense gradation mixtures or open gradation mixtures. Weak to good correlation between stability, flow and stiffness index and rut depth.
Ahmad & Jung 2016	Hotmixasphaltmaterial properties Asphalt Content & binder grades	Dynamic Modulus ($\|E*\|$) Binder Dynamic Shear Modulus($\|G*\|$)	Increase of the upper binder grade number, rutting decreased, and with the increase of the lower binder grade number, rutting increased. Mechanistic approach is a better tool to determine the performance of asphalt pavement than commonly used methods.
Hasan & Hasan 2017	Filler Type cement & limestone dust	Wheel track	LnRD= -6.592+0.84LogN+0.066T+0.462AC-0.281FT …. R^2 =0.96 The analyzing of results shows that the rut depth (RD) decrease about 16 percent when using cement instead of limestone dust.

Table 2: Percent Selected Aggregate Gradation Pass by Weight for Wearing Course with 12.5 mm Nominal Maximum Size

Sieve Size		**% Selected Passing Gradation**			**Iraqi Specification***		**Superpave Specification**			
Standard Sieve(mm)	**English Sieve**	**Blend (1)**	**Blend (2)**	**Blend (3)**	**Min.**	**Max.**	**Control Point**		**Restricted Zone**	
19	¾"	100	100	100	100	100	100	100	----	----
12.5	½"	98	97	94	90	100	90	100	----	----
9.5	3/8"	85	80	82	76	90	----	----	----	----
4.75	#4	65	60	53	44	74	----	----	----	----
2.36	#8	34	33	28	28	58	28	58	39.1	39.1
1.18	#16	30	21	19	----	----	----	----	25.6	31.6
0.6	#30	18	15	11	----	----	----	----	19.1	23.1
0.3	#50	14	10	5	5	21	----	----	15.5	15.5
0.075	#200	8	6	4	4	10	2	10	----	----

*: State Corporation of Roads and Bridges (SCRB, 2003/ R9)

Table 3: Summery of Physical Properties of Aggregate

Property	**ASTEM Test No.**	**Coarse Aggregate**	**Fine Aggregate**	**Superpave Specification**
Bulk Specific Gravity	C - 127 & C – 128	2.687	2.698	-----
Apparent Specific Gravity	C - 127 & C – 128	2.645	2.734	-----
Percent of Water Absorption	C - 127 & C – 128	0.75	1.32	-----
% of Wear Abrasion (Loss Angeles)	C – 131	18.46%	-----	35 – 45
Soundness Loss by Sodium Sulfate Solution %	C – 88	3.12%	----	10 – 20
Fractured Pieces	----	96	----	95 Min.
Deleterious Materials,%	C -142	0.38	3.1	0.2 – 10
Sand Equivalnt,%	D – 2419	-----	57	45 Min.
Fractured pieces,%		96	---	95 Min.

Table 4: Physical Properties of Asphalt Cement (Binder) specifications

Test	Test Condition	ASTM, Designation	Units	Binder 40-50	SCRB Criteria *
Penetration	100 gm, 25 °C, 5 Sec., 0.1 mm	D5	1/10 mm	48.06	40-50
Rotational Viscosity	135°C	D4402	Pa.S.	0.465	----
	165 °C			0.138	----
Specific Gravity	25 °C	D70	----	1.033	----
Ductility	25 °C, 5 cm/min	D113	Cm	>150	>100
Flash Point	----	D92	°C	294	>232
Softening Point	----	D36	°C	44	----
Solubility in trichloroethylene	----	D2042	% wt.	99.3	> 99
% Loss After Thin Film Oven Test	5 h at 163 °C, 50 gm	D1754	% wt.	0.12	< 0.75
% From Origin Penetration After Thin Film oven Test	100 gm, 25 °C, 5 Sec., 0.1 mm	D5	%	59.3	>55%
Ductility After Thin Film Oven Test	25 °C, 5 cm/min	D113	Cm	>150	> 25

SCRB Criteria **: State Corporation for Roads and Bridges (2003/R9)

Table 5: Physical Properties of Mineral Filler

Property	Test Result	
	Lime Stone Dust	Dates Kernel Powder
Specific Gravity	2.84	2.71
Passing Sieve No.200 (0.075 mm)	95	93

Table 6: Hot Mix Asphalt Properties at Optimum Asphalt Content

HMA Properties (%)	Blend 1		Blend 2		Blend 3		Superpave Specification
	DKP	LSD	DKP	LSD	DKP	LSD	
VTM	4%	4%	4%	4%	4%	4%	4%
VMA	14.54	15.41	15.84	14.85	14.57	15.32	14% (min)
VFA	72.49	74.04	74.75	73.06	72.55	73.89	65-75
DP	0.82	0.87	0.80	0.84	0.67	0.78	0.6-1.2
Gmm@Nini =9	84.86	86.93	84.01	85.84	81.83	82.72	<89%
Gmm@Ndesign =135	96%	96%	96%	96%	96%	96%	96%
Gmm@Nmax =220	95.87	97.94	93.76	96.50	92.72	93.07	<98%

Table 7: Effect of DKP on Optimum Asphalt Content

HMA Prepared	Blend 1		Blend 2		Blend 3	
	Filler Type					
O.A.C	DKP	LSD	DKP	LSD	DKP	LSD
	4.7	4.9	4.6	4.8	4.3	4.4
% Reduction	4.08		4.17		2.27	
Mean % Reduction	3.51					

HMA: Hot Mix Asphalt

Table 8: Wheel Track Test Results after 3000 Cycle

Tested Temperature ˚C	Rut Depth mm					
	Blend 1		Blend 2		Blend3	
	DKP	LSD	DKP	LSD	DKP	LSD
40	2.29	6.63	1.95	5.49	1.29	2.64
50	2.73	8.61	2.20	7.01	1.42	3.17
60	3.73	12.21	2.78	9.21	1.71	4.02

DKP: Dates kernel powder; **LSD:** Lime Stone Dust

Table 9: Wheel Track Test Results after 4000 Cycle

Tested Temperature ˚C	Rut Depth mm					
	Blend 1		Blend 2		Blend3	
	DKP	LSD	DKP	LSD	DKP	LSD
40	3.72	9.03	3.21	7.03	2.49	4.01
50	4.69	13.24	3.82	9.39	2.91	4.97
60	6.53	21.10	5.13	14.52	3.71	7.20

DKP: Dates kernel powder; **LSD:** Lime Stone Dust

Table 10: Wheel Track Test Results after 5000 Cycle

Tested Temperature ˚C	Rut Depth mm					
	Blend 1		Blend 2		Blend3	
	DKP	LSD	DKP	LSD	DKP	LSD
40	4.46	9.29	4.00	8.57	3.16	5.08
50	5.79	14.68	5.11	12.41	3.53	6.60
60	8.76	24.68	7.52	20.55	5.01	10.85

DKP: Dates kernel powder; **LSD:** Lime Stone Dust

Table 11: Factor Value

Tested Temperature ˚C	Factor Value					
	Blend (1)		Blend (2)		Blend (3)	
	DKP	LSD	DKP	LSD	DKP	LSD
	After 3000 cycle					
40 – 50	1.19	1.30	1.13	1.28	1.10	1.20
50 – 60	1.36	1.42	1.26	1.31	1.21	1.27
	After 4000 cycle					
40 – 50	1.26	1.47	1.19	1.34	1.17	1.24
50 – 60	1.39	1.59	1.34	1.55	1.28	1.45
	After 5000 cycle					
40 – 50	1.30	1.58	1.28	1.45	1.12	1.30
50 – 60	1.51	1.68	1.47	1.66	1.42	1.64

Table 12: Rut Depth Mean Value

Tested Temperature ˚C	Mean Value of Rut Depth					
	After					
	3000 cycle		4000 cycle		5000 cycle	
	DKP	LSD	DKP	LSD	DKP	LSD
40	1.84	4.92	3.14	6.69	3.87	7.65
50	2.12	6.26	3.80	9.20	4.81	11.23
60	2.74	8.48	5.12	14.27	7.10	18.69

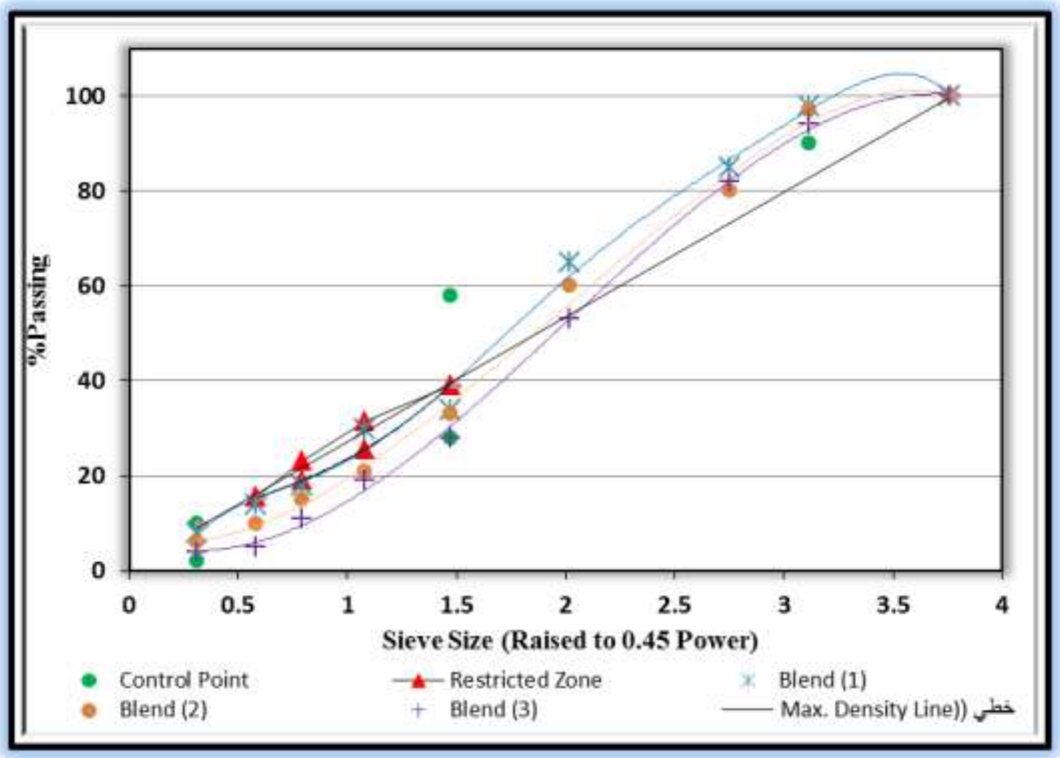

Fig. 1: Aggregate Gradation for Three Blend Selection

Fig. 2: Steps of Preparing DKP

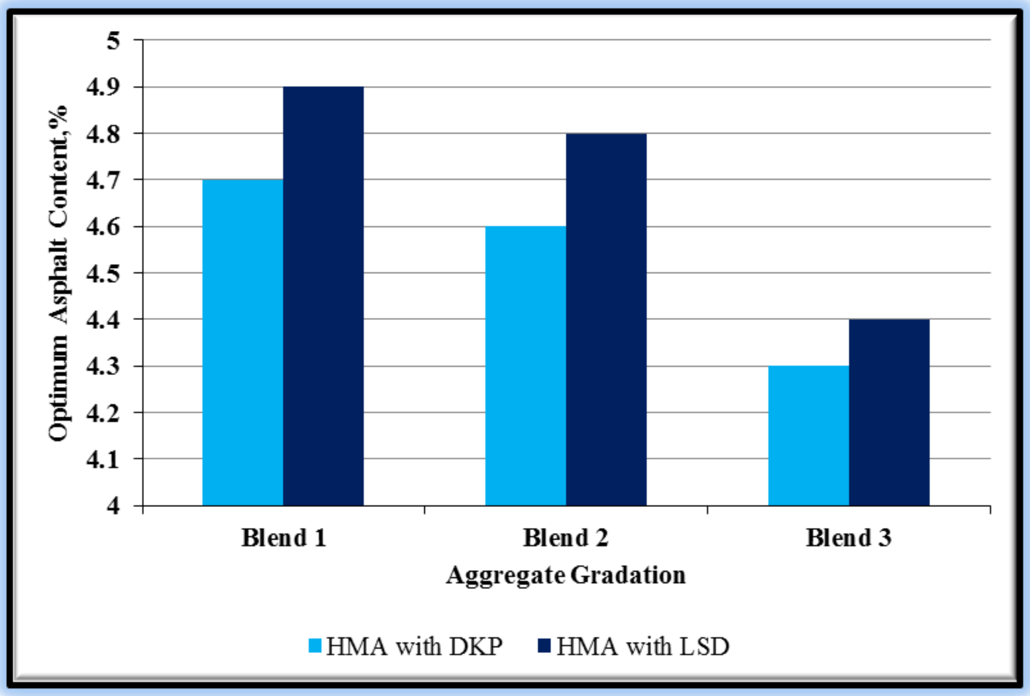

Fig. 3: Optimum Asphalt Content

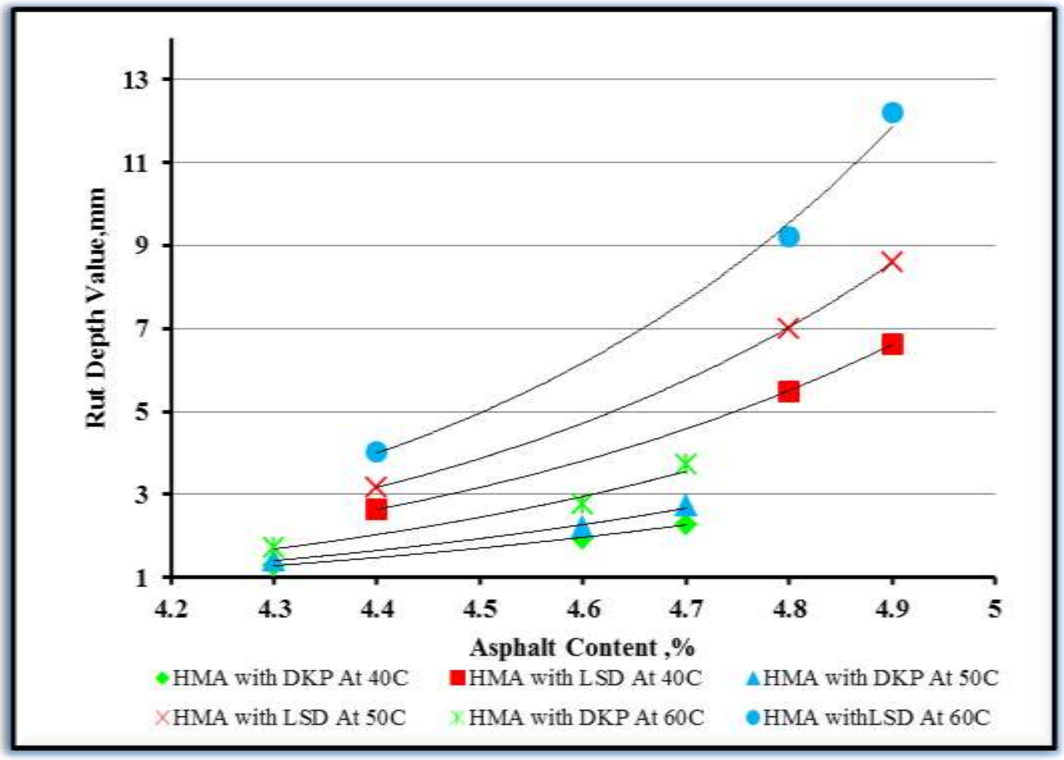

Fig. 4: Effect of DKP at deferent Tested Temperatures after 3000 cycle on Rut Depth

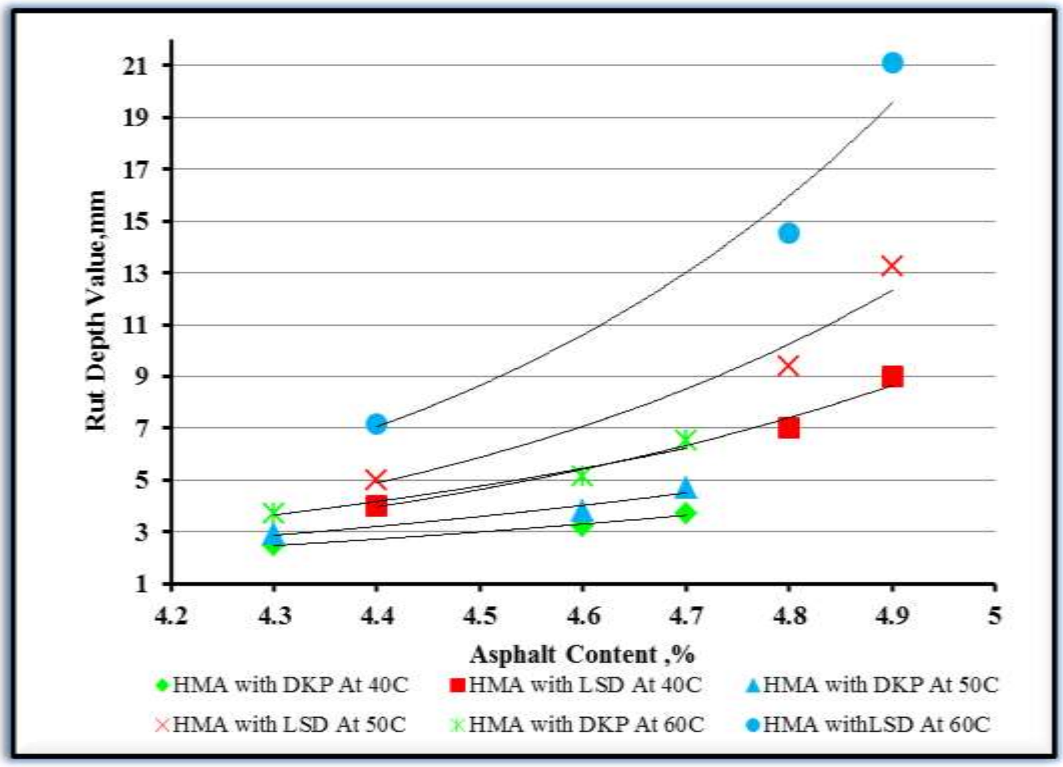

Fig. 5: Effect of DKP at deferent Tested Temperature after 4000 cycle on Rut Depth

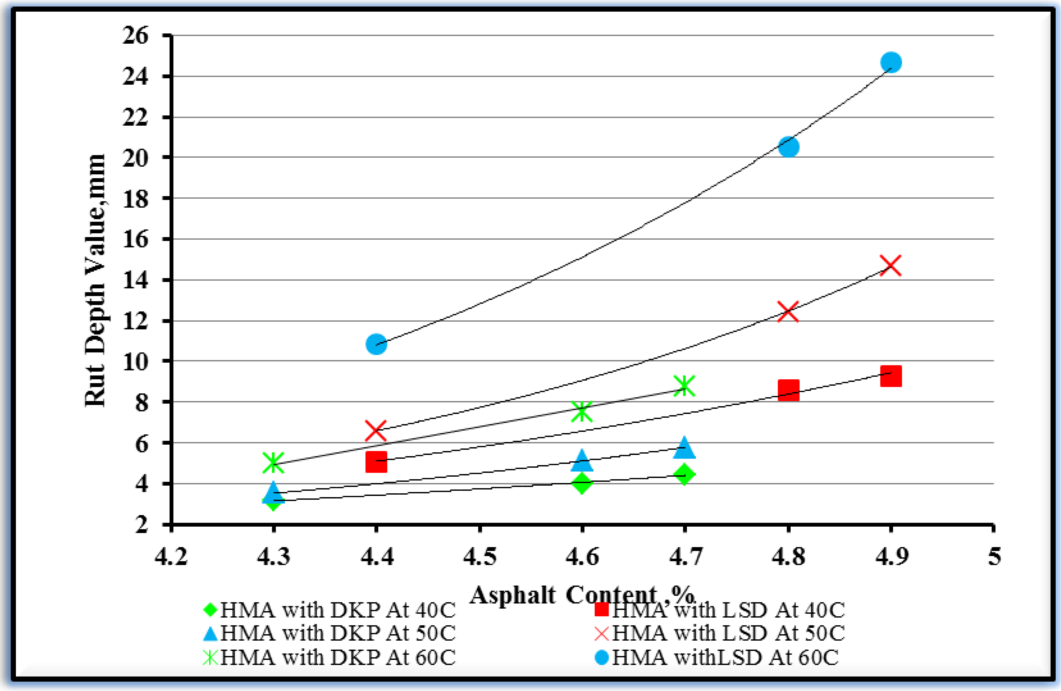

Fig. 6: Effect of DKP at deferent Tested Temperature after 5000 cycle on Rut Depth

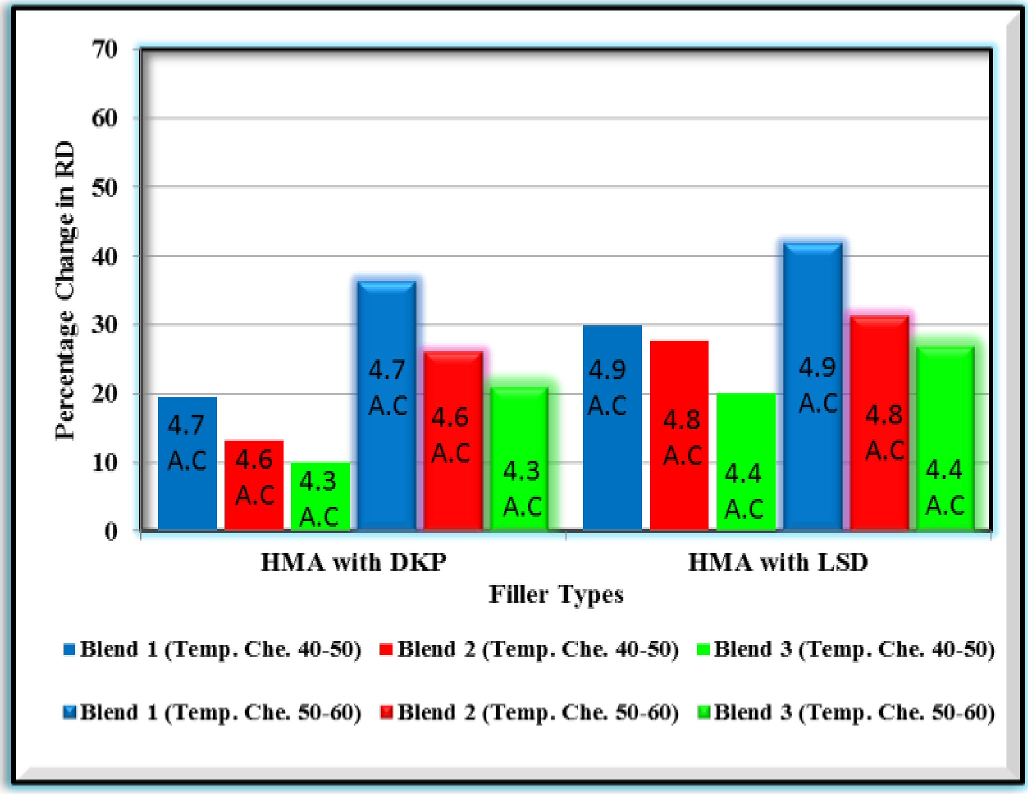

Fig. 7: Percentage of Change in Rut Depth after 3000 cycle

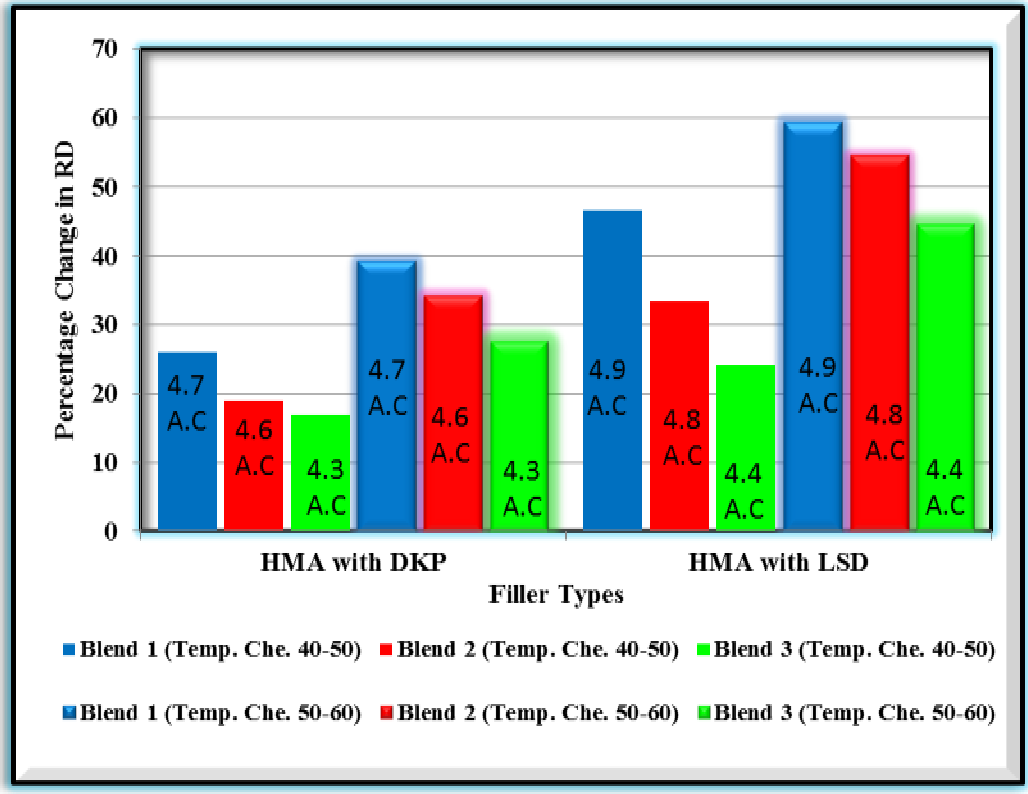

Fig. 8: Percentage of Change in Rut Depth after 4000 cycle

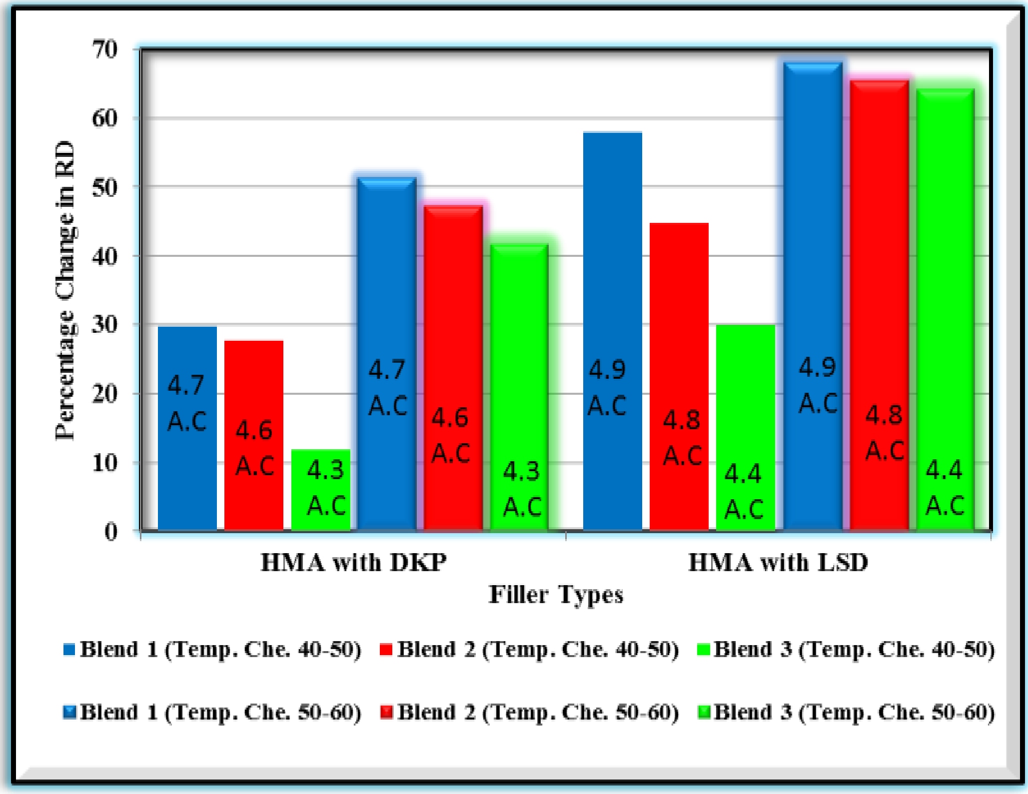

Fig. 9: Percentage of Change in Rut Depth after 5000 cycle

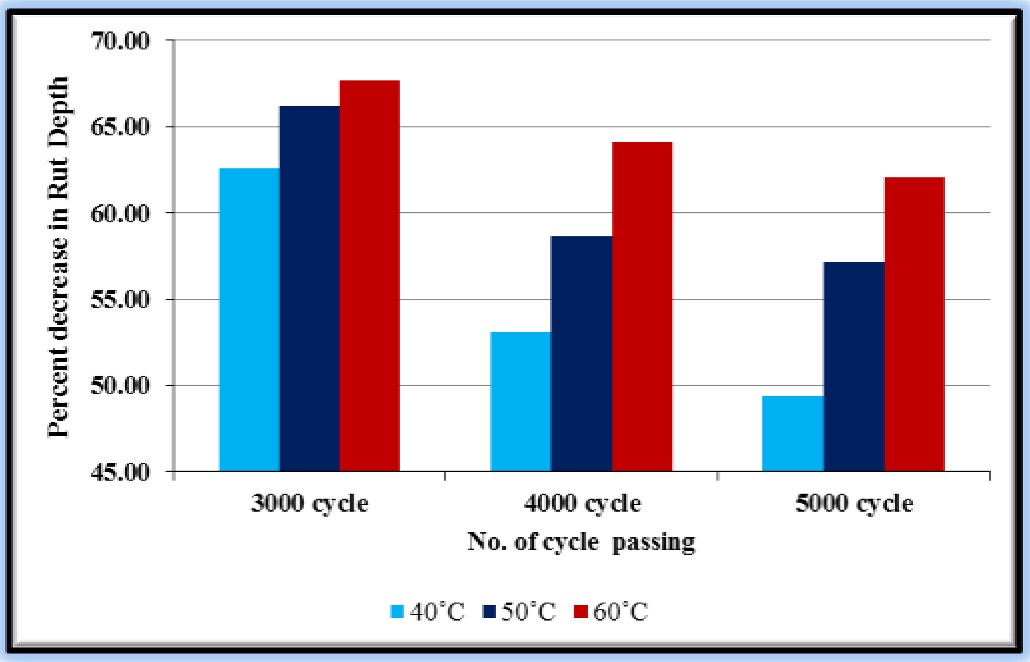

Figure 10: Rut Depth Percent of Reduction

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