Performance Evaluation of Modified Asphalt Concrete Mixes Containing Natural Sand

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Abstract

The performance of Hot Mix Asphalt (HMA) mixtures is greatly affected by the properties of the aggregate characteristics. Although, the natural sand is readily available and less expensive as compared with crushed sand. The Standard Iraqi Specification for Roads and Bridge (***SCRB, R/9***) allowed using it with a ratio not exceed 25%.

In this study, the performance of modified asphalt concrete mixes containing natural sand (desert sand and river sand) and five replacement ratios for each one (0, 25, 50, 75 and 100% by weight of the sand passing sieve no. 8 and retained on sieve no 200) were evaluated. The performance of modified asphalt concrete mixes tensile strength, rutting is evaluated using indirect tensile test and wheel track test.

The experimental work showed that the rutting depth for the modified specimens with polymers is lower than unmodified specimens at any percent of natural sand content and all test condition due to use of polymer modifier increased the stiffness of the binder at high pavement service temperature. The possibility of using natural sand specially desert sand with ratio exceed 25% by weight of the sand passing sieve no. 8 and retained on sieve no 200 for modified asphalt concrete mixes by polymers.

Keywords: modified asphalt mixture performance, natural sand content, wheel track test

الخلاصة

اداء الخلطات الاسفلتية يتأثر بشكل كبير بخصائص مزيج الركام. بالرغم من ان الرمل الطبيعي متوفر بكميات كبيرة ورخيص بالمقارنة بالرمل المكسر لكن المواصفة العراقية للطرق والجسور تسمح باستخدام الرمل الطبيعي بنسبة لا تتجاوز 25%. لقد تم في هذه الدراسة تقييم اداء الخلطات الاسفلتية المعدلة بالبوليمرات والتي تحتوي على نسب مختلفة من الرمل الطبيعي بنوعية (الصحراوي والنهري) وهذه النسب هي (0، 25، 50، 75 و 100 % من وزن الركام الناعم العابر من منخل رقم 8 والمتبقي على منخل رقم 200) وتمت الاضافة عن طريق الاستبدال الجزئي للرمل المكسر. حيث تم اجراء فحصين الفحص الاول مقاومة الشد غير المباشر وفحص الثاني مقاومة التخدد والحساسية للرطوبة بواسطة جهاز العجلة المتحركة.

اظهرت النتائج المختبرية ان عمق التخدد للعينات المعدلة بالبوليمرات هي اقل من العينات غير المعدلة بالبوليمرات عند اي محتوى للرمل الطبيعي وعند كل حالة اختبار وذلك بسبب استخدام البوليمرات يزيد صلابة الاسفلت عند ارتفاع درجة حرارة التبليط و امكانية استخدام الرمل الطبيعي وخاصا الرمل الصحراوي بنسبة تزيد عن 25% من وزن الركام الناعم العابر من منخل رقم 8 والمتبقي على منخل رقم 200 للخلطات الاسفلتية المعدلة بالبوليمرات.

الكلمات المفتاحية: اداء الخلطات الاسفلتية المعدلة، محتوى الرمل الطبيعي، فحص جهاز العجلة المتحركة

Introduction

Aggregate shape properties are known to influence asphalt pavement performance. Angularity and texture govern the frictional properties and dilation of the aggregate structure. Aggregate texture plays a major role in influencing the adhesive bond between the aggregate and the binder, while aggregate form influences the anisotropic response of asphalt mixes (Dallas and Barry, 2003).

Since approximately 94 to 95 percent of the weight of Hot Mix Asphalt (HMA) mixtures consists of aggregates, the performance of HMA mixtures is greatly affected and influenced by the properties of the aggregate blend. The aggregate properties that significantly influence the performance of HMA mixtures are gradation shape, angularity and texture (roughness). The quality of a HMA mixture is influenced by the shape of the aggregate gradation because gradation controls the matrix void structure. A very dense gradation (maximum density line) theoretically produces the strongest HMA mixtures, but because of low aggregate voids, this mixture is very sensitive and changes significantly with small variations in asphalt content. The shape and texture of coarse (plus No.4 sieve) and fine (minus No.4 sieve) aggregates control the mixture's strength and rut resistance thus affecting performance and serviceability. Rough angular aggregates produce higher quality pavements than smooth uncrushed aggregates.Shape and texture of the fine aggregate (smaller than 4.75 mm in diameter) are of particular importance in dense graded mixes, because the coarse aggregate (greater than 4.75 mm in diameter)are usually not in contact with each other; rather, they are suspended in the fine aggregate, which is forced to carry the load (Roberts *et al.*,1991 &1996).

Scope of the Study

Three types of testing techniques were used, to find the optimum asphalt concrete for the mixtures, Marshall Methods was used, indirect Tensile Stress for fatigue properties, Wheel Track Test was measured moisture susceptibility and permanent deformation.

This research aims at :

- Performance evaluation of modified asphalt concrete mixes containing natural sand in both types (desert and river) with five replacement ratio for each one (0,25, 50, 75 and 100% by weight of the sand passing sieve no. 8 and retained on sieve no 200) for wearing course.
- Evaluate the effects of the polymers as high density polyethylene (HDPE) and styrene butadiene styrene (SBS) on the performance of asphalt concrete mixes with high natural sand content.

Backgroung

Hot Mix Asphalt Concrete (HMAC) consists primarily of mineral aggregates, asphalt cement (or binder), and air. It is important to have suitable proportions of asphalt cement and aggregates in HMAC so as to develop mixtures that have desirable properties associated with good performance. These performance measures include the resistance to the three primary HMAC distresses: permanent deformation, fatigue cracking, low temperature cracking (Taylor & Francis Group ,2006) and moisture damage.

Effect of Materials Properties on Asphalt Concrete Mix

All materials of asphalt mixtures and their characteristics will affect in one way or other, the outcome when predicting permanent deformation, fatigue cracking and moisture damage. Characteristics of asphalt mixtures and test or field conditions which affect rutting and fatigue cracking. The weather and the loading distribution, mentioned as test and field conditions, in every different location will play an important role in the outcomes of a rutting test or prediction (Eduardo and Liu,2009).

Aggregate

Aggregate comprise 94 to 95 percent of an asphalt concrete mix by weight, and they are the main load carrying component. It, therefor, follows that selecting aggregates with desirable chemical and physical properties is an important step in achieving pavement quality and durability(Asphalt Institute, 1998).

The largest portion of the resistance to permanent deformation of the mixture is provided by the aggregate structure. Aggregate is expected to provide a strong, stone skeleton to resist repeated load applications. Gradation, shape, and surface texture have a great influence on HMA properties. Angular, rough-textured aggregate provide more shear strength than rounded, smooth-textured aggregate. When a load is applied to the aggregate in an asphalt mixture, the angular, cubical, rough-textured aggregate particles lock tightly together and function as a large, single elastic mass, thus increasing the shear strength of the asphalt mixture. Conversely, instead of locking together, smooth, rounded aggregate particles tend to slide past each other (Button, 1991; Chowdhury *et al*.,2001 ; Park and Lee,2002).

Effect of Fine Aggregate on Asphalt Concrete Mix

Shape and texture of the fine aggregate (smaller than 4.75 mm in diameter) are of particular importance in dense graded mixes, because the coarse aggregate(greater than 4.75 mm in diameter) are usually not in contact with each other; rather, they are suspended in the fine aggregate, which is forced to carry the load. Aggregate particles suitable for use in HMA should be cubical rather than flat, thin, or elongated. In compacted mixtures, angular-shaped particles exhibit greater interlock and internal friction, and, hence, result in greater mechanical stability than do rounded particles. On the other hand, mixtures containing rounded particles, such as most natural gravels and sands, have better workability and require less compactive effort to obtain the required density. This ease of compaction is not necessarily an advantage, however, since mixtures that are easy to compact during construction may continue to density under traffic, ultimately leading to rutting due to low voids and plastic flow. Surface texture also influences the workability and strength of HMA. A rough, sandpaper-like surface texture, such as found on most crushed stones, tends to increase strength and requires additional asphalt cement to overcome the loss of workability, as compared to a smooth surface found in many river gravels and sands. Voids in a compacted mass of rough-textured aggregate usually are higher also, providing additional space for asphalt cement. Smooth textured aggregates may be easier to coat with an asphalt film, but the asphalt cement usually forms stronger mechanical bonds with the rough-textured aggregates (Roberts *et al*., 1996).

Ahlrich (1991& 1996) conducted a laboratory study to determine the influence of various amounts of natural sands on the engineering properties of asphalt concrete mixtures and to set quantitative limits of natural sand to prevent the use of unstable mixtures and reduce rutting potential. The study indicated that the use of natural sand materials decreased the stability and strength characteristics of asphalt concrete mixtures and that replacing natural sand materials with crushed sand materials increased the resistance to permanent deformation. The author found that the amount of natural sand did affect the results of the indirect tensile, resilient modulus and unconfined creep-rebound tests. The indirect tensile results indicated a reduction in mixture strength as the percentage of natural sand increased. The axial and permanent deformation values increased significantly as the natural sand content increased. He also stated that if natural sands were to be used, a maximum limit of 15 percent by weight should be specified. The (FAA)% test was originally developed by the National Aggregate Association (NAA) and was later adopted by the American Society for Testing and Material (ASTM) as method C1252 and by AASHTO as method T304. It measures the loose uncompacted void content of a sample of fine aggregate that fall from a fixed distance through a given sized orifice. It was found that Method A of ASTM C 1252 produced a stronger relationship with percent crushed fine particles and the natural sand content than Method C. It was also proposed that ASTM C 1252 be used to characterize aggregate particle and texture in specifications instead of percent crushed particles.

Effect of Fine Aggregate on Rutting

Brown *et al*.,(1992&2001) evaluated available information on permanent deformation, fatigue cracking, low-temperature cracking, moisture susceptibility, and friction properties, and recommended performance tests that could be immediately adopted to ensure improved performance. The authors focused more on the permanent-deformation testing procedures. On the basis of equipment availability, cost, testing time, quality control-quality assurance (QC-QA) aspects, and easiness to use, the researchers ranked the following permanent-deformation tests in the order of priority for recommended use: Hamburg wheel-tracking device (HWTD) and French rutting tester (FRT). Rutting on high volume roadways can be prevented if angular coarse and fine aggregates are used and if the air voids in the mixture do not fall below approximately 3.0 percent.

Al-Beiruty (2012) studied the effect of natural sand on the performance of asphalt concrete mixes. Two types of natural sand (desert and river) and five replacement rates for each one (0,25,50,75, and 100% by weight of the sand passing sieve no. 8 and retained on sieve no. 200) were evaluated. The conclusions were replaced of all crushed sand in a mix with a natural sand results in an increment in the accumulation rate(slope) vale of permanent deformation, reduction in fatigue life and decreased in the tensile strength ratio(T.S.R.), the mixes containing desert sand showed better performance as compared to that prepared using river sand, the optimum asphalt cement demand is increased 0.3 percent if the natural sand content exceeds 50 percent in the asphalt concrete mixes and it is recommended in future researches that variables in testing conditions for fatigue and permanent deformation (temperature and pressure) .

Effect of Fine Aggregate on Fatigue Cracking.

The geometric irregularity of both coarse and fine aggregate has a major effect on mechanical behavior and physical properties of HMA mixtures. This geometric irregularity can be attributed to the aggregate particle shape, angularity, and surface texture**(Butcher, 1997)**.

Effect of Fine Aggregate on Moisture Susceptibility

The contradiction between practice and ideal mixture properties for moisture resistance necessitates consideration of the natural sand contribution to the fine aggregates in the blends used in this study. To address this issue the proportion of natural sand in the fine aggregate (passing the number 4 sieve) in the job mix formula will be examined. Further examination of the individual contributions of the mix constituents to the fine aggregate proportion could reveal that the fine aggregates in a mix thought to be composed of mainly manufactured materials could actually be primarily natural sand. This would result in more rounded fine aggregate particles in the mix, potentially reducing moisture susceptibility. The shape of the natural sand particles is determined by measuring fine aggregate angularity (FAA)% **(Bahia *et al.*, 2003)**.

Asphalt Modification

Roberts *et al.* (1991) , described that the technical reasons for using modifiers in asphalt concrete mixtures are to produce stiffer mixes at high service temperature to resist rutting as well as to obtain softer mixtures at low temperature to minimize thermal cracking and improve fatigue resistance of asphalt pavement.

Experimental Work

Selection of Materials and Variable

The materials used in this study depend mainly on the availability of these materials in the local market. The selected materials are used widely in roads paving in Iraq. The asphalt cement binder from Al-Daurah refinery was used with two types of locally available polymers as asphalt modification with one aggregate gradation for wearing course layer type IIIA. In order to evaluate the effect of natural sand content, five replacement ratios were used (25, 50, 75,and 100% by weight of the sand passing sieve no. 8 and retained on sieve no. 200) and the standard mix (control) which contains natural sand at 0% . Two types of natural sand are used in this study, desert sand and river sand. This chapter provides detailed information on the materials used and their properties.

Materials

The materials used in this study are asphalt cement, aggregate, mineral filler and two types of polymers. The properties of aggregates and asphalt cement are evaluated using routine type of tests and the obtained results are compared with the Standard Iraqi Specification for Roads and Bridge (**SCRB R/9, 2003**) requirements.

Asphalt Cement

One type of asphalt cement is used with (40-50) penetration grade which is obtained from AL- Daurah refinery in this study.

Course Aggregate

Coarse aggregate is that portion of the combined aggregate retained on the 4.75 mm (No.4) sieve used for asphalt concrete. The source of crushed aggregate is Al- Najaf quarry. This aggregate is widely used in the middle and south areas of Iraq for asphalt pavement construction.

Fine Aggregate

The fine aggregate is that portion of the combined aggregate passing the 4.75 mm (No.4) sieve shall consist of stone screenings and natural sand. The source of crushed sand from Al- Najaf quarry (Laboratory crushers Sami Al-Chammkhi) and natural sand (desert sand from Karbala quarry and river sand from Euphrates river).

The coarse and fine aggregates used in this work are sieved and recombined in the proper proportions to meet the wearing coarse gradation as required by SCRB specification **(SCRB, R/9. 2003)**.Routine tests are performed on the aggregate to evaluate their physical properties. The results together with the specification limits as set by the ***SCRB*** are summarized in table (1).Fine aggregate gradation for crusher, desert and river sand is presented in table (2).The selected gradation with specification limits are presented in table (3).

Filler In this study , one type of mineral fillers is used ; ordinary Portland cement (Tasluja).

Polymers

In order to evaluate the performance of modified asphalt concrete mixes using natural sand, two types of polymers are used, High-Density Polyethylene (HDPE) is used with 2% by weight of asphalt cement and styrene butadiene styrene (SBS) are used with 3% by weight of asphalt cement with a suitable blending time and temperature of mixing that concluded by **AL-Harbi,(2012**).

Binder Mixing

The process of mixing polymer with asphalt binder used in this study is the wet process, in which the polymer is added to the asphalt binder before introducing it in the asphalt concrete mixture. All types of used polymers will be directly blended with asphalt binder in blending machine at suitable blending times for each type of polymer at specified range of temperature. The polymer is added to the asphalt binder at a blending speed of 2620 rpm.A brief description along with the blending machine and its accessories can be found in (**AL-Bana'a, 2009**).

Test Methods

In this research a total of 417 hot mix asphalt specimens are prepared and tested (108 specimens with Marshall test, 81 specimens with indirect tensile strength test, 228 specimens with Wheel Track test).

Marshall Test

This test is carried out according to the **(ASTM D-6927)** to find the optimum asphalt content for compacted asphalt concrete specimens at ***(4%)*** air voids.

Indirect Tensile Strength Test

The tensile strength of compacted asphalt specimens is typically determined by the indirect tensile strength test, which is determined according to the method described in ***ASTM D4123***.

Wheel Track Apparatus Testing(WTA)

The Wheel Track Apparatus (WTA) device had been manufactured locally and developed in road laboratory of civil engineering department , university of Babylon accord specification of Hamburg Wheel-Track testing (HWTT). The device is developed to measure moisture susceptibility in addition to measure permanent deformation**,**the specification of the manufactured equipment according to **(AASHTO T324-04).**

Samples

The load applied on the specimen with dimensions 320 mm (12.60 inch) long and 260 mm (10.24 inch) wide , using steel mold with two holders have 151mm (6 inch) diameter and 6cm (2.36 inch) thick to put cylindrical specimens with diameter 150 mm (5.91 inch). The hot mixtures asphalt HMA specimens are prepared in steel compaction mold and compacted by using standard Marshall compacter with many trials numbers of blows (75,100,125,150,175,200) for each percent of natural sand content for the mixture to obtained 4 % air voids for dry case and 7 % air voids for moisture case according to Standard Iraqi Specification for Roads and Bridge **(SCRB, R/9. 2003)**.

Results and Discussion

Mix Design Using Marshall Method

Standard method of Marshall as in (***ASTM D-6927***) specifications is used to find the optimum asphalt content for compacted asphalt concrete specimens. Four different percentages of asphalt contents (4.2 , 4.8 , 5.4 and 6) % by weight of mixture for each percentage of desert and river sand content are used. Properties of the asphalt concrete mix at optimum asphalt content are shown in tables (4 and 5). According to stability, the mixtures that contain natural sand show that the stability decreases with increases in natural sand content. The decrement was 0.25, 1.85, 2.35 and 2.55 (kN) with desert sand content at 25%, 50%, 75% and 100% respectively, while was 0.4, 2.05, 2.55 and 2.85(kN) with river sand content at 25%, 50%, 75% and 100% respectively.

Effect of Natural sand on Indirect tensile strength test

Figure (1) shows the effect of natural sand (desert and river) on indirect tensile strength. It is noticed that the indirect tensile strength decreases with increase in natural sand content. The decrement rate on indirect tensile strength(ITS) is using natural sand and compared with standard mix shown in table (6). The decrement rate was 7% every 25% increment in desert sand content while was 9% and 10% every 25% increment in river sand content. This decrement in indirect tensile strength because of the effect rounded particles in properties of mixture which reduce interlock and internal fiction, this agreement with **Ahlrich,(1996)** and (**Dallas et al.,2003).**

Effects of polymers with natural sand content on indirect tensile strength(I.T.S.)

Effects of SBS on indirect tensile strength

The indirect tensile strength increases with the increase in percentage of natural sand content for SBS modified mixes. The maximum percentage of increase on indirect tensile strength was 33% for desert sand content 100% and 38% for river sand content 100 %. The percentage of increase on indirect tensile strength was 18%, 22%,26% and 29% for desert sand content 0%, 25%, 50% and 75% respectively, where was 18%, 19%, 24% and 28% for river sand content 0%, 25%, 50% and 75% respectively. Therefore, it can be concluded that using modified(SBS) mix which contains natural sand in the construction of surface course will increase the resistance of this course to tensile stresses. The reason behind that is the use of SBS polymer which improve the flexibility of the binder at low temperature which lead to an increase resistance to the asphalt cracking at low temperature **(Lu and Isacsson 1997).**

Effect of HDPE on indirect tensile strength

The effect of modified mixtures with HDPE on indirect tensile strength is at different percentage of natural sand content. It is noticed that the percentage of increase on indirect tensile strength increases with the increase in natural sand content for SBS modified mixes. The maximum percentage of increase on indirect tensile strength was 54% for desert sand content 100% and 62% for river sand content 100 %. The percentage of increase on indirect tensile strength was 38%, 41%,45% and 51% for desert sand content 0%, 25%, 50% and 75% respectively, where was 38%, 38%, 45% and 56% for river sand content 0%, 25%, 50% and 75% respectively. The highest values of strength (ITS) occur in the modified mixtures by polyethylene (PE) in comparison with SBS agreement with (**AL-Harbi, 2012**).

Wheel Track Test Results

Effects of Natural Sand Content on Rutting

The rutting increase with increases in natural sand content for two types of natural sand were used at all conditions of testing. The mixture with desert sand (100%) having maximum rutting were (6.55, 6.63, 6.4 and 7.0) mm at ($40C^0$ dry, $40C^0$moisture, $50C^0$ dry and $50C^0$moisture) cases respectively, where were (7.35, 7.56, 7.26 and 7.9) mm at ($40C^0$ dry , $40C^0$moisture, $50C^0$ dry and $50C^0$moisture) cases respectively for mixes containing river sand (100%). All above values for maximum rutting are obtained for maximum number of passes to failure. The increments rate on rutting depth for mixtures with natural sand are shown in tables (7) and (8). The main notes from this tables are:

1- The rutting depth increases with increasing the content of natural sand.
2- The increments rate on rutting depth for mix content natural sand at 25% was not significant when compared with mix content natural sand at 50%.
3- The effect of increasing temperature is greater than the moisture for rutting depth.
4- The increments rate on rutting depth for mix content river sand is greater than mix content desert sand

This increment on rutting is due to the effect of rounded particles in fine aggregate which reduce interlock and internal fiction to cause reduce in permanent deformation resistance for mixtures that contain natural sand. The rutting for mix content river sand is greater than that contain desert sand to be due to the angular and rough-textured of desert sand higher than river sand as representing on FAA test to be equal 35 for river sand and 40 for desert sand, this agreement with **(Chowdhury *et al.*, 2001; Park *et al.*, 2002)**

Effects of Temperature on Rutting and Number of Passes Wheel Loading

The effect of temperatures on the rutting depth and on the number of passes wheel loading is clearly apparent , primary for the limitation of the number of loading passes to failure of wheel track sample in which the test must end to compare between factors relating to measure rutting depth according to ***(AASHTO, T324-04)*** for typical curve of Hamburg wheel track test results. The number of wheel loading passes at failure of the sample is 12000 passes (6000cycles) at temperature 40 C^o test , and 6000 passes (3000cycles) at temperature 50 C^o test. The decrement rate of wheel loading passes is 50% due to increase of temperature from 40 C^o to 50 C^o for dry case.

Effects of Moisture on Rutting and Number of Passes Wheel Loading

The effect of moisture on the rutting depth and on the number of passes wheel loading is clearly apparent by the number of wheel loading passes at failure of the sample are 12000 passes (6000cycles) for dry case at temperature 40 C^o while are 10000 passes (5000cycles) for moisture case at same temperature test while for dry case at temperature 50 C^o are 6000 passes (3000cycles) and 4000 passes (2000cycles) for moisture case. The decrement rate of wheel loading passes due to change from dry to moisture case at temperature 40 C^o is 17% while is 33% at temperature 50 C^o.

Conclusions and Recommendations

Conclusions

1- Marshall stability decreased by increasing the natural sand content. The maximum decrement is 2.55 and 2.85 kN at 100% desert sand and river sand content, respectively. as well as at 25% natural sand content the decrement in Marshall stability was not significantly influence as compared with mixtures content natural sand at 50%, this conclusion is agreement with **(SCRB, R/9, 2003).**

2- The results from wheel track test showed that the rutting depth for the modified specimens with polymers is lower than unmodified specimens at any percent of natural sand content and all test condition.

3- The possibility of using natural sand specially desert sand with ratio exceed 25% by weight of the sand passing sieve no. 8 and retained on sieve no 200 in modified asphalt concrete mixes by polymers.

4- The effect of temperature on the rutting depth is greater than effect of the moisture, The decrement rate of wheel loading passes is 50% due to increase of temperature from 40 C^o to 50 C^o for dry case, while the decrement rate of wheel loading passes is 16.7% due to change from dry to moisture case at temperature 40 C^o and is 33% due to change from dry to moisture at temperature 50 C^o.

5- Indirect tensile strength test shown that increase natural sand content leads to reduction in the fatigue resistance. The replacement of a crushed sand in a mix with a natural sand results in an decrement in the indirect tensile strength by 7%, 14%,21% and 27% with desert sand content 25%, 50%, 75 % and 100%, respectively, while are 9%, 18%, 29% and 39% with river sand content 25%, 50%, 75 % and 100%, respectively.

6- Modified asphalt binder with High Density Polyethylene(HDPE) at 2% gives mixture with a significant higher performance properties (fatigue resistance, permanent deformation resistance and moisture resistance) than modified asphalt binder with Styrene Butadiene Styrene(SBS) at 3% at any natural sand content due to HDPE have higher stiffness related to its molecule weight and create strong bond with asphalt binder.

7- In general using desert sand in asphalt mixture gives better results than river sand for Marshall stability, indirect tensile strength and Wheel Track tests.

8- The fine aggregate angularity (FAA) was measured using a simple laboratory test. The higher values of fine aggregate angularity, the more angular are the particles with rougher surface texture. This resulted in a better interlocking mechanism between the particles and thus offering better shear strength. Crusher sand was found to have the higher (FAA) values compared to the desert sand and river sand, it comes after the second desert sand.

Recommendations for Future Research

The main recommendations based on this work is evaluation of the fatigue resistance for mixtures that contain natural sand using four point bending beam fatigue test.

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Table (1): Physical properties of aggregate .

Property	ASTM **Designation**	Coarse aggregate	Fine aggregate			SCRB Specification
			Crushed	**Desert**	**River**	
Bulk specific gravity	C-127 C-128	2.52	2.68	2.66	2.63	————
Apparent specific gravity	C-127 C-128	2.65	2.7	2.68	2.65	————
% water absorption	C-127 C-128	0.89	0.85	0.63	0.62	————
Resistance to Degradation of Coarse Aggregate in the Los Angeles Machine(Wear%)	C-131	25 %	———	———	———	30 max
Soundness loss by sodium sulfate solution	C-88	1.42	------	--------	---	12 Max
Percent of fractured with at least one or two fractured face.	D-5821	95 %				90 Min.
Clay Lumps and Friable Particles in Aggregate %	C-142	-----	0.23	0.13	0.33	3% Max
Uncompacted Void Content of Fine Aggregate(FAA)	C-1252	------	49	40	35	------

Table (2): Fine Aggregate Gradation.

Sieve size		*% Passing*		
Standard sieves (mm)	*English sieves (in)*	*Crusher Sand*	*Desert Sand*	*River Sand*
9.5	3 /8"	100	100	100
4.75	No.4	96	98	98
2.36	No.8	60	87	90
0.3	No.50	20	24	47
0.075	No.200	7	5	3

Table (3): Asphalt mixture grading for surface wearing course (Type IIIA).

Sieve size		*(Selected% passing by weight of total aggregate + filler)*	*Specification limits for wearing coarse (SCRB) Type IIIA*
Standard sieves (mm)	*English sieves (in)*		
19	3/4"	100	100
12.5	1/2"	95	90-100
9.5	3/8"	83	76-90
4.75	No.4	59	44-74
2.36	No.8	43	25-58
0.3	No.50	13	5-21
0.075	No.200	6	4-10

Table (4): Properties of Asphalt Concrete with Desert Sand at Optimum Asphalt Content

Property	*Desert Sand Content (%)*					*Requirements (SCRB) 2007*
	0% (Standard mix)*	*25%*	*50%*	*75%*	*100%*	
Stability (KN)	10.05	9.8	8.2	7.7	7.5	8 min.
Flow (mm)	3.2	3.25	3.33	3.56	3.7	2 - 4
Air Voids (%)	4.3	4.25	4.15	4.05	4	3 - 5
VMA (%)	16.69	16.32	15.43	15.21	15.06	14 min
Optimum Asphalt content	5	5	4.8	4.8	4.8	4-6

Table (5): Properties of Asphalt Concrete Mix with River Sand at Optimum Asphalt Content .

Property	*River Sand Content(%)*					*Requirements (SCRB) 2007*
	0% (Standard mix)*	*25%*	*50%*	*75%*	*100%*	
Stability (KN)	10.05	9.65	8	7.5	7.2	8 min.
Flow (mm)	3.2	3.3	3.45	3.65	3.88	2 - 4
Air Voids (%)	4.3	4.23	4.12	4	4	3 - 5
VMA (%)	16.69	15.96	15.43	15.06	15.	14 min
Optimum Asphalt content(%)	5	5	4.8	4.8	4.8	4-6

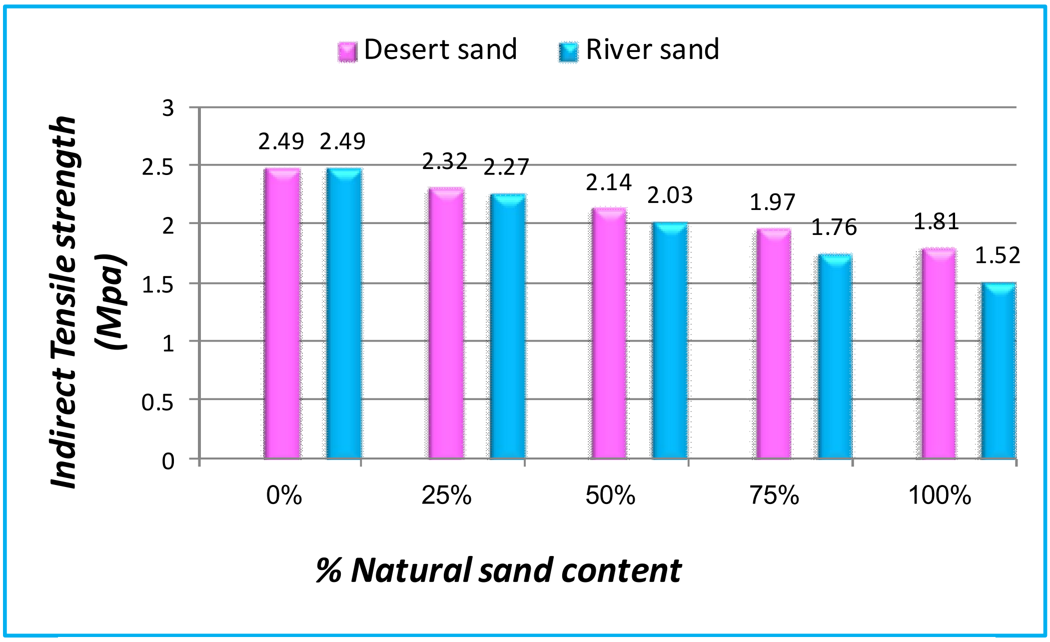

Figure (1) Effect of Natural sand content on indirect tensile strength

Table (6) :The decrement rate on Indirect tensile strength(ITS) for using natural sand

Natural Sand Content	*The decrement rate on Indirect tensile strength(ITS)* (%)*	
	Desert sand	*River sand*
25%	7	9
50%	14	18
75%	21	29
100%	27	39

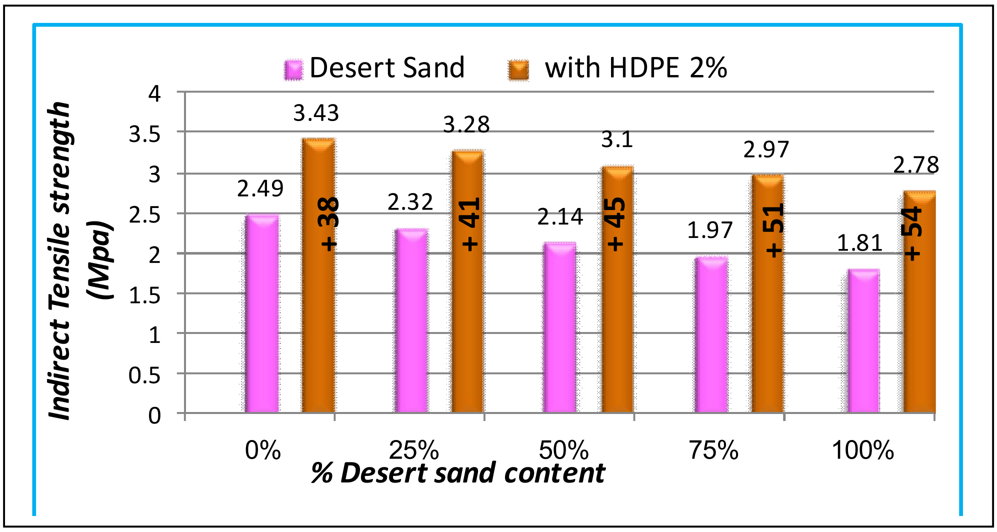

Figure (2) Effect of HDPE with desert sand content on indirect tensile strength

Table (7): The increments rate on Rutting Depth for mixture with Desert Sand*

Desert Sand Content	*The increment rate on Rutting Depth (%)*			
	Dry Case		*Moisture Case*	
	At 40 C^0	*At 50 C^0*	*At 40 C^0*	*At 50 C^0*
25%	2	7	6	11
50%	5	14	15	20
75%	8	16	21	24
100%	12	18	22	28

***All above values compared with standard mix which content (100%)crushed sand.**

Table (8) The increments rate on Rutting Depth for mixture with River Sand.*

River Sand Content	*The increment rate on Rutting Depth (%)*			
	Dry Case		*Moisture Case*	
	At 40 C^0	*At 50 C^0*	*At 40 C^0*	*At 50 C^0*
25%	5	11	9	15
50%	16	22	22	24
75%	19	26	26	32
100%	26	34	40	45

**** All above values compared with standard mix which content(100%) crushed sand.***