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LABORATORY EVALUATION OF HOT ASPHALT MIXES FOR AIRFIELD PAVEMENTS IN EGYPT

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ABSTRACT

The main purpose of road or runway pavement is to carry traffic loads conveniently, economically, and safely during its design life. Pavement safety is usually evaluated through several components; among them the skid resistance is one of the most important indicators. It may cause a serious safety hazard in specific situations especially when water exists in any form. If rutting exists, the risk may increase significantly. As many agencies, owners and operators have recently reported problems related to the poor frictional properties of newly constructed hot-mix asphalt concrete (HMAC) mixes, extensive research work has been carried out to enhance friction of asphalt pavement surfaces. For airfield pavements, friction characteristics are extremely important. It provides the spin-up of the wheels, which is required to operate the electronically controlled antiskid braking systems installed in most modern aircraft. In other words, adequate runway surface friction is essential to braking and deceleration operations. Previous studies emphasized the role of skid resistance to reduce the accident rates. The main objective of this paper was to increase safety on Egyptian airfield pavements through the enhancement of friction characteristics without compromising the other properties of asphalt surface mixes. To achieve that, several asphalt mixes utilized in Egypt were prepared and tested for their friction and basic properties. The work conducted in this paper provide important guidelines for selection of the proper hot asphalt mixes when water is expected to exist in any form on runway/road surface.

Keywords: Airfield Pavement, Surface friction, Marshall Stability and Aggregate Gradation.

INTRODUCTION AND BACKGROUND

The main purpose of road and/or airfield pavements is to carry traffic loads conveniently, economically, and safely during its design life [1]. Pavement safety is usually evaluated through several components including; skid resistance, rutting susceptibility, pavement surface light reflectivity, area demarcation, and Debris of foreign objects.

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Among these components, pavement slipperiness in terms of skid resistance is the most important component to measure the pavement safety. The lack of skid resistance can provide a serious safety hazard in specific situations, where water exists in any form [2]. On the other hand, surface deformations of asphalt surfaces such as rutting have been observed and reported since the late 1950's. It was found that rutting of flexible pavements is a common distress type [3]. Flintsch et al. (2003) suggested that water ponds on the road surface due to rutting could cause deficiency in frictional characteristics of pavement surfaces [1]. Federal aviation Administration, FAA concluded similar finding [4]. It was found that pavement structural failure, such as rutting or raveling, is a contributing factor to airfield friction losses. Existence of rutting can restrict the use of pavement and cause serious safety problems when exceeds a certain limit [5]. If the amount of water on the pavement surface exceeds the combined drainage capacity of the tire tread and pavement macrotexture, dynamic hydroplaning occurs. In such case, the channelization or depression caused by the effect of the wheels can represent a serious problem. Sufficient inertial forces exist and separate the tires from the pavement surface [6]. Rutting and exceeded deformations allow puddles to form and consequently increase the hazar d of skidding.

Several airport agencies, owners and operators have recently reported problems related to the poor frictional properties of newly constructed hot -mix asphalt concrete (HMAC) mixes. The key for improving the air traffic operations and optimi zing the use of runways is to improve skid resistance of asphalt surfaces without compromising the main mix properties. Since the lack of adequate friction is a safety concern, there is a need to review the current Egyptian HMAC specifications for Airport pavements and update them, if necessary. The main objective of this paper was to evaluate airfield hot asphalt mixes in Egypt based on their frictional, physical and mechanical properties and to provide guidelines for the design of improved airfield mixes with higher quality both in terms of safety and performance.

ROLE OF SKID RESISTANCE TO CONTROL TRAFFIC ACCIDENTS

For highway pavements, previous study concluded that there is a good correlation between skid resistance and accident rates [7]. Skid resistance provides the needed friction between tires and pavement surface to control vehicle direction and speed. It was found that on wet pavements, skidding problems were the reasons or at least factors of more than a quarter of roads accidents in the United Kingdom [8]. Andrey et al. (2003) has studied the effect of winter precipitation events on accident rate in Ottawa, Ontario, Canada. He concluded that the collision risk have increased significantly during winter season [9]. Panagouli and Kokkalis (1998) found that, for constant traffic volume, the accident rate decreases significantly as the skid number increases [10]. Hosking (1987) found that an enhancement of 10 % in the level of skid resistance resulted in 13 % reduction in the wet accident rate [11]. Other studies indicated that the microtexture and macrotexture have a substantial influence on accident rate especially at high speeds on wet pavements. As a general conclusion they found that “wet weather accident rates are a little bit more than twice those of dry pavement accidents” [12]. Chelliah et al. (2003) have developed a relationship between the number of wet accidents and the friction of pavement surface. The model was developed using all wet accident data for U .S. highways occurring in 2001 [13].

For airfield pavements, friction characteristics are extremely important. It provides the spin-up of the wheels, which is required to operate the electronically controlled antiskid braking systems installed in most modern aircraft. In other words, adequ ate runway surface friction is essential to braking and deceleration operations. The national transportation safety board reported that "runway conditions were a cause or factor in 115 aircraft accidents between 1983 and 1987" [14]. Contaminated runway surface, by snow and/or ice, was also a factor in approximately 30 aircraft accidents between 1983 and 1995. Additionally, inaccurate data on runway friction conditions was a reason for many dangerous aircraft operations [15]. At Los Angles International Airport, a jumbo jet DC-10 was completely loss due to lack of skid resistance of runway surface in 1970s. The touch down zone was very slippery at the time of accident [16]. Because of inaccurate runway friction information, a fatal aircraft accident occurred in Dryden, Ontario, Canada, in 1989 [17]. Another aircraft accident occurred at a Mexican airport due to insufficient data on runway friction. The DC-9 aircraft was thoroughly damaged during a thunderstorm and 4 passengers were killed [18]. In 1991, "Although the weather conditions were good, a brand new British aircraft skidded more than 1,000 m into the Beagle channel, Chili, during landing. Among 60 tourists on board, 20 people died". An investigation was conducted to figure out why the aircraft skidded. It was found that the skid resistance of runway surface was low and the accident took place due to viscous hydroplaning [14]. In 2007, Airbus A320-233 operated by TAM Airlines continued off the end of the runway due to skidding as shown in Figure (1). The aircraft exploded on impact with a four-story TAM Express facility, resulting in a large fire and killing everybody on board instantly. 199 people were killed including 12 on ground. The accident report points several factors that may have contributed to the accident, as a high volume of rain on the day, with the formation of puddles on the runway, as well as the absence of grooving [19].

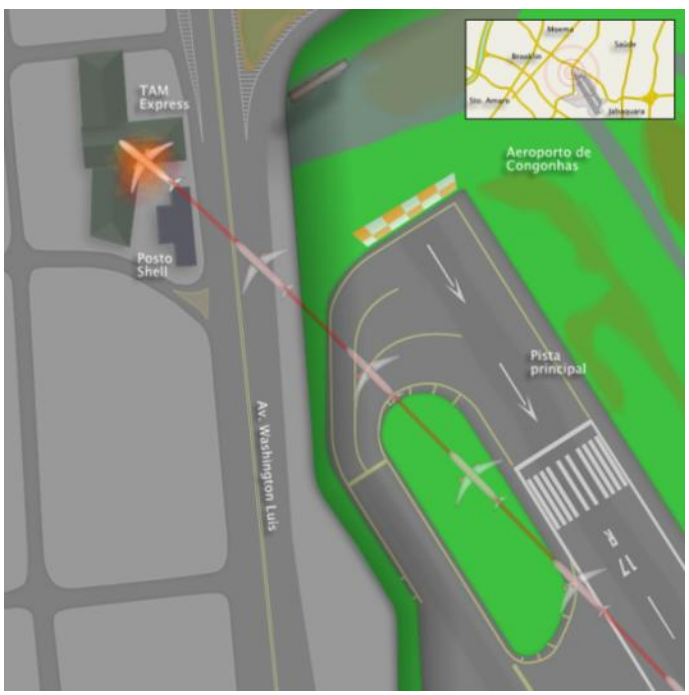

Figure (1): Path of the aircraft after skidding, São Paulo, Brazil [19].

TESTING PROGRAM

Mix Design and Preparation

Five different job mix design formulas were obtained from the General Authority of Roads & Bridges and Land Transport, Egypt. The aggregate samples were prepared and graded by sieve analysis according to ASTM (1996) [20]. Aggregates for mix1 to mix4 (surface courses) and for mix5 (base course) were blended according to pre-specified aggregate percentages. For mix6 to Mix11, prepared at laboratory, many trials were performed to blend the aggregates in one gradation that fit in the Egyptian Standards [21]. Based on these trials, four aggregate gradations were chosen for the mix design stage. These four aggregate gradations were referred to Grad1 to Grad4, respectively. Aggregate gradations were used to prepare six different asphalt mixes as follows;

Marshall mix design procedures were used in this phase of study. Aggregates were combined and placed in the oven for four hours to attain the mixing temperature. Binder was placed in the oven and heated to a temperature that would reach the proper viscosity (165°C). The mixing bowl was also heated to the same temperature to prevent temperature loss during the blending process. Then the binder was added to the hot aggregates according to the selected AC, in percent of total mass, of the mix. The Asphalt cement used was 60/70 asphalt of specific gravity 1.02. The mixing temperature was 165°C. After that the mixture was mixed until the binder completely and uniformly coated all aggregate particles. About three kilograms from each mix was kept in its loose condition to be tested for its Maximum density (MD). Preheated moulds of 4 inches in diameter were used to make the core samples. Two filter paper were used during compaction to avoid sample sticking to the mould and compactor hammer and to get smooth sample surface. The specimens were compacted with 50 blows on each side. The compaction temperature was 140°C. Once the compaction was completed, the filter papers were removed and the specimens were cooled in room temperature for 24 hours. Specimens were then extracted from moulds and dimensions were measured. The specimens were tested for their (bulk density) BD, and MD, Marshall stability and flow. Air voids (Av) and voids in mineral aggregates (VMA) were calculated and the optimum AC was determined for each aggregate gradation. The optimum asphalt contents (AC) of Grad1 and Grad2 were determined to prepare Mix6 and Mix7, respectively. Figure (2) illustrates the aggregate size distribution for all aggregate gradations used in this study. The figure shows that Mix5 had the coarsest aggregate gradation and Mix6 had the finest aggregate gradation as indicated by the percentage passing a given sieve. The optimum AC values were determined to be 4.5% and 5% for Mix6 and Mix7, respectively. To study the effect of AC on the performance of HAM, tow different AC were used with Grad2 to prepare Mix8 (4.5%) and Mix9 (6%), respectively. Mix10 and Mix11 were prepared using Grad3 and Grad4 with the same optimum AC of Grad2 (5%) to study the effect of aggregate gradation on the properties of HMA. Table (1) presents the basic properties for the seven mixes prepared in this study.

Preparation of Friction Test Specimens

For each mix under study, a slab of dimensions 70 × 25 × 7.5 cm was prepared and compacted using the plate compactor as shown in Figure (3). A ramp was prepared at the end of the wooden form to allow the compactor to move back and forth on top of asphalt slabs without damaging the wooden edges of the forms. For each wooden form an asphalt layer of approximately 85 mm was laid on top of the wooden base and leveled off manually. The compaction was completed after 10 passes per slab. The slabs were labeled from S1 to S11 and were tested for their frictional properties using the British Pendulum Tester (BPT), [22]. After testing for their frictional properties, three cores were extracted from each slab to check that the slab had a homogenous density.

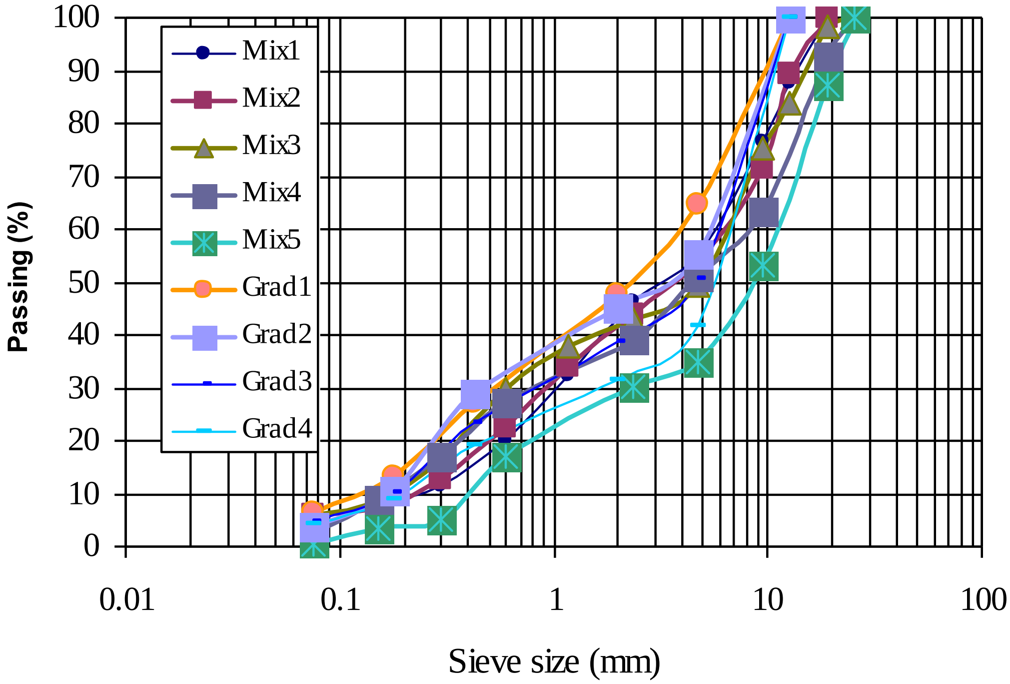

Figure (2): Gradations of different used aggregates.

Table (1): Results of Marshall mix design process.

Mix	Stability (lb)	Density (kg/cm^2)	Air voids (%)	Flow (1/100")	VMA (%)	AC (%)
Mix1	3020	2.393	3.6	10.8	15.7	5.5
Mix2	2370	2.394	3.5	11.4	15.85	5.45
Mix3	2510	2.331	3.6	11.8	15.3	5.5
Mix4	1990	2.301	4.8	11.9	15.2	4.8
Mix5	1830	2.285	4.7	11.3	15.1	4.0
Mix6	2795	2.285	3.99	11.5	20.42	4.5
Mix7	2810	2.303	3.21	8.0	19.93	5.0

Figure (3): Compaction process of slab specimens.

RESULTS AND ANALYSIS OF THE TESTING PROGRAM

Friction test results

Frictional properties of asphalt mixes were measured using the BPT [22] as shown in Figure (4). Instrument was leveled using the leveling screws until the bubble was centered in the sprit level. After leveling, the pendulum was adjusted such that its free swing carried pointer to zero. Zero-adjustment was performed by raising the pendulum mechanism to allow slider to swing free of test surface. Locking knob was then tightened and the pendulum was placed in release position. Pendulum was released and pointer reading was noted. Adjustment procedures were repeated until the pendulum free swing carried pointer to zero. With pendulum hanging free, pendulum was lowered such that the edge of slider just touched the pavement surface. Contact path length was adjusted using a marked ruler provided with the pendulum. Enough water was applied to cover the test area completely. One swing was executed but the reading was not recorded. After that four more swings were carried out with the surface rewetted each time and results were recorded. For each slab, five different locations were marked to be tested. These locations were labeled form L1 to L5. The friction test was performed in the direction of compaction at all locations. The friction was measured four times at each location and the results were recorded as R1 to R4. The average British pendulum number (BPN) was calculated at each location and the mean BPN for each mix was determined.

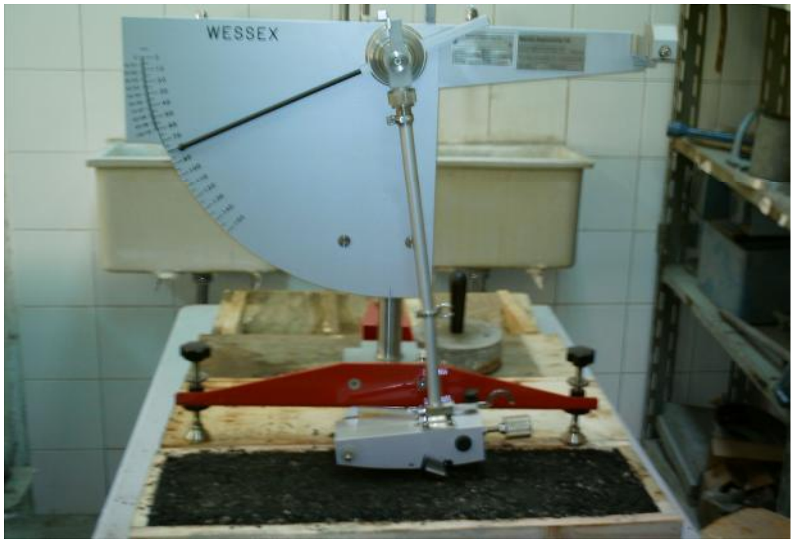

Figure (4): Friction test using BPT.

The mean BPN values vary from a minimum of 55 (Mix6 of finest aggregate gradation) to a maximum of 80 (Mix5 of coarser aggregate gradation). Table (2) summarizes the results of friction test as well as Marshall stability for all mixes. In general, the friction val ues increased as the aggregate gradation got coarser. To investigate that clearly, friction test results of Mix7, Mix10 and Mix 11 were plotted on Figure (5) as indicated by the solid bars. These mixes had the same AC of 5% and different aggregate gradatio ns; Grad2, Grad3 and Grad4, respectively. The figure shows that the friction values of asphalt surfaces increased for coarser aggregate gradations. In addition, the figure demonstrates the benefit of using the optimum AC to obtain higher values of surface friction where friction test results of Mix7, Mix8 and Mix9 were plotted as the hatched bars. These mixes had the same aggregate gradations (Grad2) and different AC values of 5%, 4.5% and 6%, respectively. The figure shows that the Optimum AC value of 5% yielded the higher BPN of 66. Lower or higher values of the optimum AC resulted in smaller BPN of 62.

Marshall Stability test results

The main purpose for this phase of results analysis is to select a surface layer that may improve the frictional properties without compromising the other mix properties. Marshall stability test results for all mixes are presented in Table (1), the Table shows that Mix 6 of the finest aggregate gradation yielded a stability value of 2795 lb, while Mix5 of the coarsest aggregate gradation yielded a lower value of 1830 lb only. Although Mix5 (base layer) yielded the highest friction value of 80 in terms of BPN, it can not be used as a surface layer based on its stability value. Similarly, Mix6 (of finest aggregate gradation) had the lowest friction value of 55 and the highest stability value (after Mix1) of 2795 lb. Ignoring Mix5, Tables (1, 2) shows that Mix1 had medium aggregate gradation (compared to the base coarse, Mix5) and it resulted in the highest stability and friction values followed by Mix3 (of medium gradation as a surface course) that gave a high friction value of 75 and a very good stability value of 2510 lb. The obtained stability results suggest that using coarser aggregates might improve both the surface friction and stability.

However, caution should be observed when choosing coarse aggregates (as that used for base courses) that may cause lack of particle to particle contact and consequently reduce the stability.

Table (2): Summary of friction test results (BPN).

Mix No.	1	2	3	4	5	6	7	8	9	10	11
Friction	77	65	75	74	80	55	66	62	62	68	70

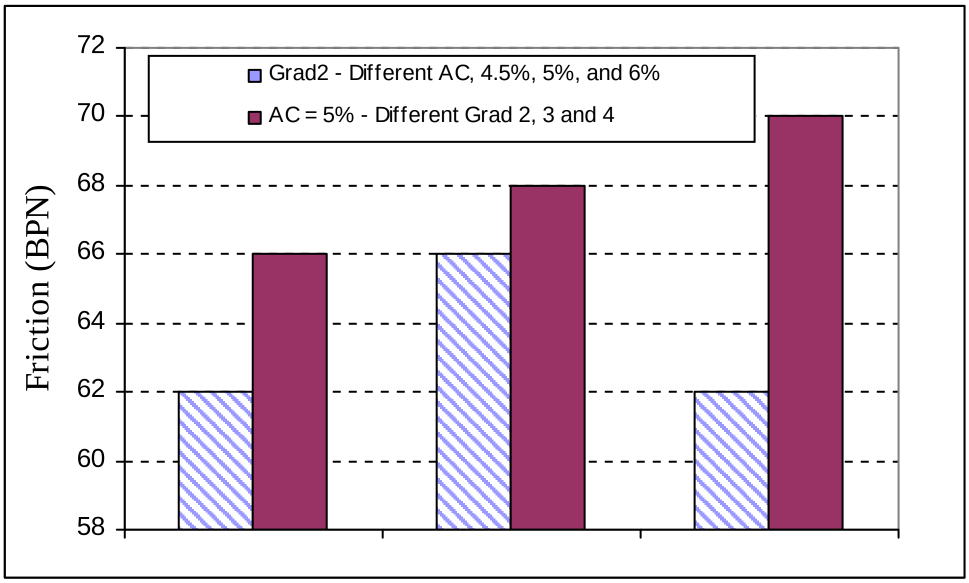

Figure (5): Effect of AC and aggregate gradations on the measured friction values.

CONCLUSIONS

Based on the results of this study, the following can be concluded:

1. It has been shown that surface friction of airport/road mixes could be quantified in the laboratory utilizing simple measuring device.
2. Using coarser aggregates could improve frictional properties of asphalt pavement surfaces. In most cases, this improvement was accompanied with better stability. However in few cases using coarse aggregate did not enhance the stability.
3. Use of relatively excessive coarse aggregate could enhance frictional properties of asphalt pavements. The analysis indicated the presence of an optimum value after which increasing the proportion of coarse aggregates may actually reduce the desired properties.
4. Using the optimum asphalt content has been shown to be a key factor in obtaining asphalt

mixes with high surface friction.

5. It is recommended to use the coarsest aggregate gradation of the aggregate band in Egyptian Code of Practice for surface courses when it is expected that surface water may exist on the airfield/road surface in any form.

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