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# DEVELOPMENT OF ASPHALT BINDER PERFORMANCE GRADES

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Asphalt plays a significant role in a pavement's ability to withstand thermal and fatigue cracking that contributes to permanent deformation behavior. Temperature is a significant factor that affects asphalt binder and thus the performance and life span of the whole pavement. This paper presents research developing asphalt binder performance grade requirements, according to Superpave, suitable for different climatic conditions all over Egypt. Twenty one weather stations covering Egypt were selected, then after analysis their air temperature data was converted to pavement temperatures using LTPP and performance models. Finally, the converted pavement data were used to propose asphalt binder performance grades (PG) for the various regions of Egypt. The proposed grades range from PG52-10 to PG76-10 depending on the location, the applied model, and the degree of project reliability.

*Keywords:* Superpave, LTPP model, Performance model, Air temperature, Pavement temperature, Traffic adjustment.

## 1 INTRODUCTION

Asphalt binder is a reheologically thermoplastic and viscoelastic material. Its performance characteristics vary not only with load, but also with time rate of load application and temperature. Temperature is a significant factor affecting asphalt binder, thus the performance and life span of the whole pavement.

Recognizing the significant effect of temperature on asphalt binder performance, the principal goal of The Strategic Highway Research Program (SHRP) bitumen research program is to develop performance-based specifications for bitumen for a wide range of temperatures. From here the necessity of knowing the required performance grades (PG) for Egypt, according to its climatic conditions, is evident. The following procedure was used to determine the required PG for all over Egypt. (The comprehensive literature review we conducted has been omitted due to this conference publications' constraints.)

## 2 PG SELECTION PROCEDURE

In order to achieve the objective of the study the procedure summarized in Figure 1 was applied. This procedure consisted of three main steps. The first step involved collecting the different required climatic data. The second step was conducting the statistical analysis of these data. Finally, the third step was applying the appropriate models to get the final performance grades. Three models were used in this research to predict pavement temperatures from air temperatures. LTPP model was selected to predict low pavement temperature and consequently low PG grade. As for the high pavement temperature prediction, both LTPP and the performance model were used to select the high PG grade. The later was an improved performance model applied to identify the high temperature PG grade for asphalt binders based on the rutting damage concept.

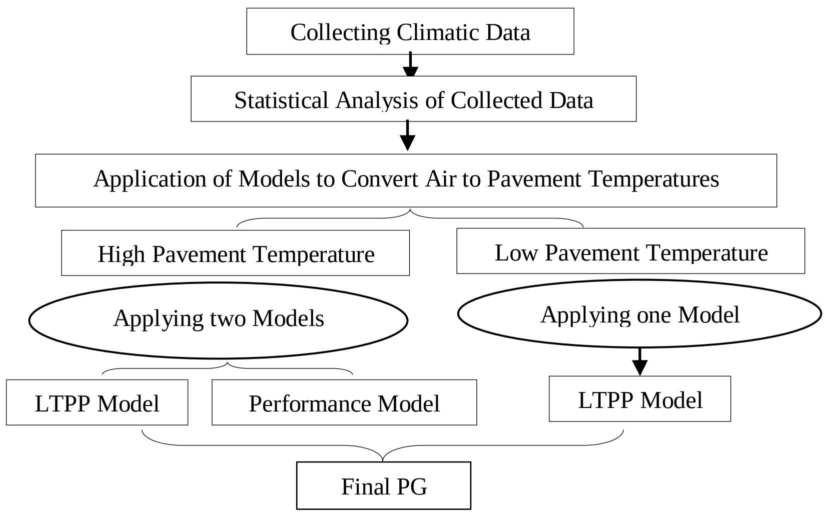


Figure 1. Performance grade (PG) selection procedure.

## 3 CLIMATIC DATA COLLECTION

Twenty one stations were selected to cover different climatic conditions all over Egypt. These stations are listed in Table 1. For each of the selected stations, the following elements were extracted from the source database to be used as the raw data: daily maximum temperature determined as the maximum temperature reading for 24 hours, daily minimum temperature determined as the minimum temperature reading for 24 hours, and the latitude for each station of the twenty one selected stations.

### 3.1 Low Air Temperature

The lowest air temperature over the year was selected for each year of the past 40 years (from 1968 to 2008) for each selected station.

### 3.2 High Air Temperature

Two different parameters were extracted from the raw data: the highest 7-day moving average of high air temperatures, and degree days over 10$^{o}$C for the past 40 years, in order to calculate the high pavement temperature using the two different models.

Degree days over 10$^{o}$C were calculated by adding the high temperatures in excess of 10$^{o}$C for the entire Egyptian summer (April through September), which was a combined measure of heat intensity and duration (Mohseni et al, 2004).

Table 1. Stations selected to determine the required asphalt PG all over Egypt.

| Station | Code | Latitude (in deg.) | Station | Code | Latitude (in deg.) |
|---|---|---|---|---|---|
| Matrouh | 1 | 31.33 | Hurghada | 12 | 27.18 |
| Alex | 2 | 31.18 | Port Said | 13 | 31.17 |
| Arish | 3 | 31.09 | K. Sheikh | 14 | 30.58 |
| Tanta | 4 | 30.82 | El Natroon | 15 | 30.24 |
| Cairo | 5 | 30.13 | Assiut | 16 | 27.03 |
| El Minia | 6 | 28.08 | Qena | 17 | 26.11 |
| Aswan | 7 | 23.97 | Siwa | 18 | 29.12.2 |
| Abu Simbel | 8 | 22.37 | Ismailia | 19 | 30.36 |
| El Kharjah | 9 | 25.45 | El Suez | 20 | 29.52 |
| St. Katherine | 10 | 28.68 | Benase | 21 | 23.58 |
| Sh El Sheikh | 11 | 27.97 | | | |

## 4 CONVERTING AIR TO PAVEMENT TEMPERATURES AND SELECTING PG

### 4.1 Low Temperature PG Selection

Low temperature PG was selected using the model developed from Long Term Pavement Performance (LTPP) climatic data. The empirical model was developed from LTPP's Seasonal Monitoring Program (SMP) data. This model related low pavement temperature to air temperature, latitude, and depth as follows, Eq. (1):

$$T_{pav} = -1.56 + 0.72\, T_{air} - 0.004\, Lat^2 + 6.26 \log10 (H+25) - z\, (4.4 + 0.52\, S_{air}^2)^{0.5} \quad (1)$$

where: $T_{pav}$ low AC pavement temperature below surface, °C
$T_{air}$ low air temperature, $^{o}C$
Lat latitude of the station, degrees
H depth to surface, mm
$S_{air}$ standard deviation of the low air temperature, $^{o}C$
z standard normal distribution table, z = 2.055 for 98% reliability

This model was applied and the low pavement temperatures were predicted at all stations over a period of 40 years. The final low PGs of different Egyptian stations for two different reliabilities (more than 50% and more than 98%) were found to be PG-10.

### 4.2 High Temperature PG Selection

High temperature PG was selected using two different models: the LTPP model and the performance model (rutting damage model).

#### *4.2.1 High temperature PG selection using LTPP model*

The LTPP model for high temperature is an empirical model developed from LTPP seasonal monitoring data. This model relates high pavement temperature to air temperature, latitude, and depth as follows in Eq. (2):

$$T_{pav} = 54.32 + 0.78\ T_{air} - 0.0025\ Lat^2 - 15.14\ \log10\ (H+25) + z\ (9 + 0.61\ S_{air}^2)^{0.5} \quad (2)$$

where: $T_{pav}$ high AC pavement temperature below surface, $^oC$
$T_{air}$ high air temperature, $^oC$
$S_{air}$ standard deviation of the high 7day mean air temperature, $^oC$

When this model was applied to predict high pavement temperature, the different high PGs for different Egyptian stations were determined at H = 20 mm below the pavement surface.

#### *4.2.2 High temperature PG selection using the performance model*

This model was developed for high temperature PG based on a rutting damage model. The rutting damage model was developed using hourly pavement temperatures for a 20-year period generated for 187 sites throughout the U.S., and PG was calculated based on a rutting damage model.

This model consisted of an equation that estimated base PG binder using degree-days concept and target rut depth for 50% reliability, Eq. (3). Another equation estimated the PG variability with latitude, Eq. (4). The base PG was then adjusted for reliability higher than 50% using a third equation, Eq. (5) as follows:

$$PGd = 48.2 + 14\ DD - 0.96\ DD^2 - 2\ RD \quad (3)$$

$$CVPG = 0.000034\ (Lat-20)^2\ RD^2 \quad (4)$$

$$PGrel = PGd + Z * PGd * CVPG/100 \quad (5)$$

where: PGd = PG damage at a rut depth
DD = 40-year degree-days >10°C (x1000°C)
RD = rut depth (5-13 mm), target rut depth was taken to be 12.5 mm.
CVPG = yearly PG coefficient of variation, %
Lat = latitude of site, degrees

The previous model was applied and then different high-end performance grades (PGs) were determined.

## 5 THE FINAL PG

Finally, the performance grades of binders required to be used all over Egyptian stations can be summarized in Table 2.

### 5.1 Regional Performance Grade (PG) Requirements in Egypt

Selecting the suitable PG for a flexible pavement project will depend on:

- Category (class) of road that controls the required level of reliability. Higher reliability corresponds to a high scale projects.
- Model for predicting pavement temperature (a performance model is more conservative than the LTPP model).
- Location (i.e., geographic location in Egypt).

- Traffic (magnitude and repetitions). Heavier traffic warrants the use of a higher PG. Table 3 shows the required PGs after traffic adjustments for the base PG, developed according to the performance model for more than 98% reliability. It is clear from Table 3 that higher traffic level gives higher PGs with one step for most Egyptian regions.

Table 2. Final performance grades (PG) required for different Egyptian stations.

| PG | LTPP Model | | Performance Model | |
|---|---|---|---|---|
| | **>50% Reliability** | **>98% Reliability** | **>50% Reliability** | **>98% Reliability** |
| PG52-10 | Station 13 | Non | Non | Non |
| PG58-10 | Stations: 1,2,3,4,5,10,14,15,19,20 | Non | Non | Non |
| PG64-10 | 6,7,8,9,11,16,17,18,21 | 1,2,3,10,13,14 | Non | Non |
| PG70-10 | Non | 4,5,6,11,12,15,16,18,19,20,21 | 1,2,13,14 | Non |
| PG76-10 | Non | 7,8,9,17 | 3 through 12, 15 through 21 | All |

Table 3. Performance grades after traffic adjustments for different Egyptian stations.

| PG | Traffic Level M ESAL | | |
|---|---|---|---|
| | **3-10** | **10-30** | **Above 30** |
| 76-10 | Stations 1,13, and 14 | - | - |
| 82-10 | Stations from 2 to 12 and from 15 to 21 | Stations 1,2, 10, 13, and 14 | - |
| 88-10 | - | Stations from 3 to 9, stations from 15 to 21, and stations from 11 to 12 | - |

Figures 2 and 3 show the required base PG grade in different locations around Egypt with 98% reliability using the LTPP and the performance models, respectively, with no traffic adjustment. When traffic is considered, higher PGs are required for heavier (slower) traffic as depicted in Table 3.

It is also important to mention that the selection of the PG was based on temperature considerations at depths of 20 mm below pavement surface for high PGs, and at the surface of the wearing course for low PGs.

From Figure 2, when the LTPP model is considered, Egypt could be divided into 3 zones. These zones are Zone I (north coast and St. Katherine), Zone II (middle of Egypt), and Zone III (upper of Egypt).

The hottest zone (Zone III) requires a high PG of PG76-10, the middle zone (Zone II) requires PG70-10 which is more moderate, and finally Zone I requires PG 64-10.

It is clear that only a high PG differs from zone to zone, whereas a low PG remains constant all over Egypt. The low temperature grades experienced all over Egypt were well above the available low binder grades provided by Superpave specifications.

From Figure 3, when the performance model is considered, Egypt could be represented by only one zone with PG76-10 (with one exception: Kafr El Sheikh, with PG 70-10).

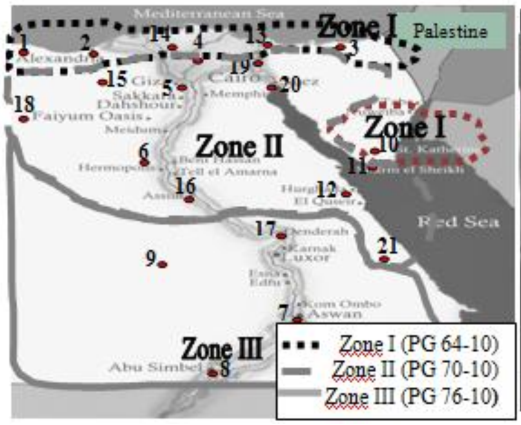


Figure 2. Final performance grades (PG) for high reliability projects all over Egypt (using the LTPP model with a 98% reliability level).

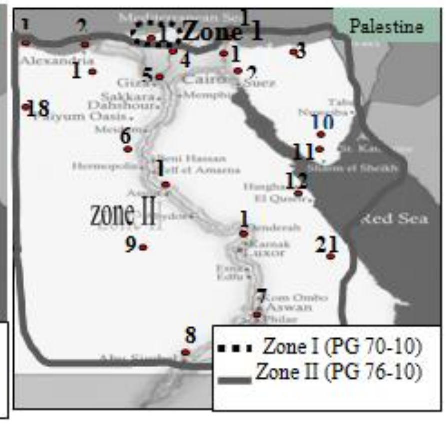


Figure 3. Final performance grades (PG) for high reliability projects all over Egypt (using a performance model with a 98% reliability level).

## 6 CONCLUSIONS

(1) According to the LTPP model, the high temperature performance grade required for Egyptian climatic conditions ranges from 64°C to 76°C for high reliability projects, and from 52°C to 64°C for lower reliability projects.

(2) According to performance model, the high temperature performance grade required for Egyptian climatic conditions is 76°C for high reliability projects (with only one exception, Kafr El Sheikh with PG70), and ranges from 70°C to 76°C for lower reliability projects.

(3) A performance model is more conservative, since it gives higher PGs than those given by the LTPP model.

(4) The low-temperature grades experienced all over Egypt are well above the available low-binder grades provided by Superpave specifications. The low temperature performance grade of all climatic regions all over Egypt satisfies -10°C.

## References

Mohseni, A., Carpenter, S., D'Angelo, J., *Performance Based Algorithm for the Selection of SUPERPAVE High-Temperature Performance Grade (PG) for Asphalt Binders*, TRB Annual Meeting, Washington D.C., 2004.