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THE CITY OF EILAT IS GOING FOR CONCRETE BLOCK PAVING

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Note: The following is the notation used in this paper: (.) for decimals and ( ) for thousands.

Summary

The city of Eilat is located in the southern point of Israel. It is the most popular domestic seaside desert resort and attracts many tourists. On top of its 60 000 inhabitants, Eilat hosts more than 2.5 million domestic and foreign visitors annually. Consequently, with its 13 000 hotel rooms, the city provides continuous municipal services for the equivalent of 140 000 inhabitants. The transportation infrastructure within the city limits includes about 2 millions square meters of streets and highways (including the arterial state highways No.12 and No.90), a major seaport, a busy airport, and an oil depot.

Despite the fact that there is not a single asphalt plant in Eilat (due to cost-benefit considerations), most streets, and highways within the city, were constructed in the past using flexible asphaltic pavements. The very hot climate, the vast increase of traffic loads, together with the very high asphaltic maintenance costs, has resulted with a rapid deterioration of pavement condition all over town. Several modern maintenance solutions (i.e. hot in-place asphalt recycling, milling and overlay, and deep pavement recycling) were experimented, but they were found to be unsuitable for the unique local logistics and environmental conditions.

Early in the nineties, the Concrete Block Paving (PAC) alternative was first introduced and tried in several streets, roundabouts, and parking lots. A few years thereafter, it was found that the pavement condition and serviceability of these sections remains at very high levels, while the adjacent new and old asphaltic streets were deteriorated rapidly. A brave decision was then made to re-pave the major roundabout intersection of inter-state 90 with PAC. Despite its heavy loaded traffic, it is exhibiting an excellent performance during the last fifteen years.

Consequently, a strategic decision was made by the city administrative and engineering officials to gradually change city streets in neighborhoods from asphaltic to PAC. This was done after analyzing an economical-engineering model, developed at the Technion, and adopting a proper PAC pavement design and evaluation method. Today this trend is on the rise, and the city of Eilat

is really going for Concrete Block Paving. Recently, 63 street intersections were converted to PAC roundabouts, and most of the intersections in Highway 90 were repaved with PAC.

The paper outlines in details the revolutionary evolution occurred in Eilat of vast shifting from asphaltic to concrete block paving. It presents the unique engineering-economical model & analysis and the pavement design method & solutions adopted. The by-product benefits, such as: traffic restrain, underground utility management, aesthetic aspects, etc., are also introduced. Examples of selected paving projects, both in urban streets and heavy loaded highways, are also presented, and illustrated.

1. THE CITY OF EILAT

Eilat is Israel's southernmost city, a busy port as well as a popular resort, located at the northern tip of the Red Sea. Home to 60,000 people, the city is part of the Southern Negev Desert, at the southern end of the Arava. The city is adjacent to the Egyptian village of Taba, to the south, and the Jordanian port city of Aqaba, to the east (see Figure 1). The city's beaches, nightlife and desert landscapes make it a popular destination for domestic and international tourism (see Figure 2). Eilat hosts more than 2.5 million domestic and foreign visitors annually. Consequently, with its 13 000 hotel rooms, the city provides continuous municipal services for the equivalent of 140 000 inhabitants. Eilat's arid desert climate is moderated by the proximity to a warm sea. Temperatures often exceed 40°C (104°F) in summer, and 18°C (64°F) in winter, while water temperatures range between 20°C and 26°C (68°F and 79°F).

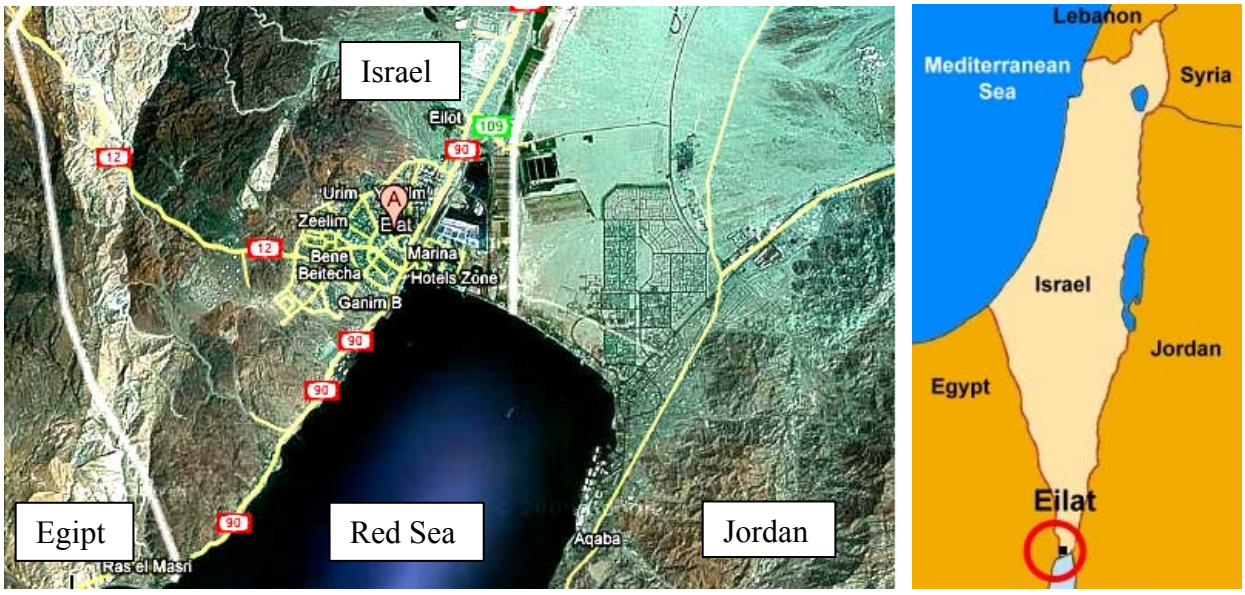

Figure 1. Geographic positioning of Eilat - Israel's southernmost city on the Red Sea.

Eilat is connected to the rest of Israel, and internationally by air, road, sea, and bus. Eilat Airport is located in the city centre, and used largely for domestic flights. Eilat has two main roads connecting it with the center of Israel (state highways No.12 and No.90). There are also two open border crossings: the Taba Border Crossing to Taba, Egypt and Wadi Araba Crossing to Aqaba, Jordan. Although there is currently no rail network to the city, the Port and the Eilat Marina allow travel by sea. Near-term plans call for a rail link to substantially decrease travel times from Eilat to Tel Aviv and Jerusalem, via the existing line at Beer Sheba. Planning work for this line is already underway.

The transportation infrastructures within the city limits includes about 2.7 millions square meters of streets and highways, sidewalks, and traffic isles (including the arterial state highways No.12 and No.90 that cross the town, the industrial park, and the hotels district), a major sea port, a busy airport and a national oil depot.



Figure 2. The city of Eilat on the shores and beaches of the Red Sea.

2. THE ASPHALT PROBLEM

From the city early days in 1949 until the nineties, the roads and street within Eilat were constructed using flexible asphaltic pavements. This was the major paving technology in the country. However, differently from other part of Israel, and despite the structural sturdiness of the pavements, the asphalt layers were deteriorated very rapidly. Many cumulative factors contributed to this deterioration:

- Rapid oxidation and aging of the bitumen (asphalt cement) due to the high temperatures and the strong UV radiation.
- Large temperature gradient (of about 20°C and more) between day and night, which make it impossible to chose the proper bitumen grade (fatigue-rutting optimization).
- Due to cost-benefit considerations, and the lack of proper aggregate sources, there is neither a single asphalt plant nor asphalt paving equipment in the southernmost Israeli Negev. The closest asphalt plant is 240 km north of Eilat. This create a large increase of asphalt paving costs, and thus, a sever inability to provide the proper maintenance reaction in time.
- Vast increase of traffic growth, mainly heavy loading, due to the rapid development of the city, the erection of new neighborhoods, and the creation of new industrial and recreational facilities.
- Budget difficulties to provide the costly asphaltic maintenance, and a tendency to delay maintenance works due to the functional character of the asphaltic pavement distresses,

The early pavement damages and distress modes in Eilat roads and streets are mainly of functional character. They are mainly consisted of surface oxidation and weathering and block cracking. In time and traffic, they deteriorate to alligator cracking and disintegration. Typical pavement distress modes are illustrated in Figures 3 and 4.



Figure 3. All surface Block Cracking on structurally stable pavement in arterial Highway 90 within town, about 3 years after overlay.



Figure 4. All surface Weathering and Block Cracking on structurally stable pavements in residential street, about 5 years after construction.

3. THE PAC INSIGHT

Early in the nineties few street intersections in Eilat were redesigned and turned over into traffic roundabouts with flexible asphaltic pavements. As early as the next summer after construction, in the heavily trafficked streets, shoving failures and corrugations with vertical amplitudes up to 200 mm, were occurred in the asphaltic layers. Soon after, the asphaltic layers were milled and replaced by concrete pavers on top of a bedding sand layer. This rehabilitation act consists of 30 mm of sand and 10/20 rectangular blocks, 80 mm thick, lay by a "stretcher" pattern. This solution lasted year after year without any sign of damage. Two typical early PAC roundabouts, after more than 15 years of service, are shown in Figure 5. Today there are 63 roundabouts around town, and 29 are planned for the near future. All of them, except 2, are and will be constructed using PAC.

The major revolutionary success of the PAC roundabouts changed the engineering-economical considerations with regard to the selection of the paving technology in the town. Consequently, the second stage in this direction was the implementation of PAC in street sections adjacent to stop lines in intersections (see Figure 6). This stage was also found to be very successful, mainly by the elimination of the asphalt shoving failure that usually occurred at these locations due to the horizontal shearing forces developed by vehicle stopping.



Junction of arterial Highways 90 & 12.



Junction of collector residential streets.

Figure 5. Today condition of PAC roundabout constructed about 15 years ago.





Figure 6. Street sections at intersection stop-lines converted from asphalt to PAC.

The third and the main stage was a strategic one. The city engineering and administrative officials have outlined a long term program; by which existing damaged asphaltic street will be gradually replaced by concrete block pavements. This program was supported by an economic model and cost-benefit analysis, and by a proper pavement design methodology. Since the beginning of this decade, at a pre-determined management system, old residential streets in Eilat were rehabilitated by replacing the top asphaltic layers with concrete pavers. The sound structural stability that characterized the majority of pavement in the town, enabled to replace only the top asphaltic layers without rehabilitating the entire pavement structure. In new residential neighborhoods, the majority of the streets were designed and constructed as PAC. The main goal in City Hall was to reach, to a total of 70% block paved streets, rehabilitated or newly constructed, within a period of ten years. Figure 7 presents the current status of asphaltic street areas that were and will be replaced by concrete block paving (excluding the arterial highways within the city limits).

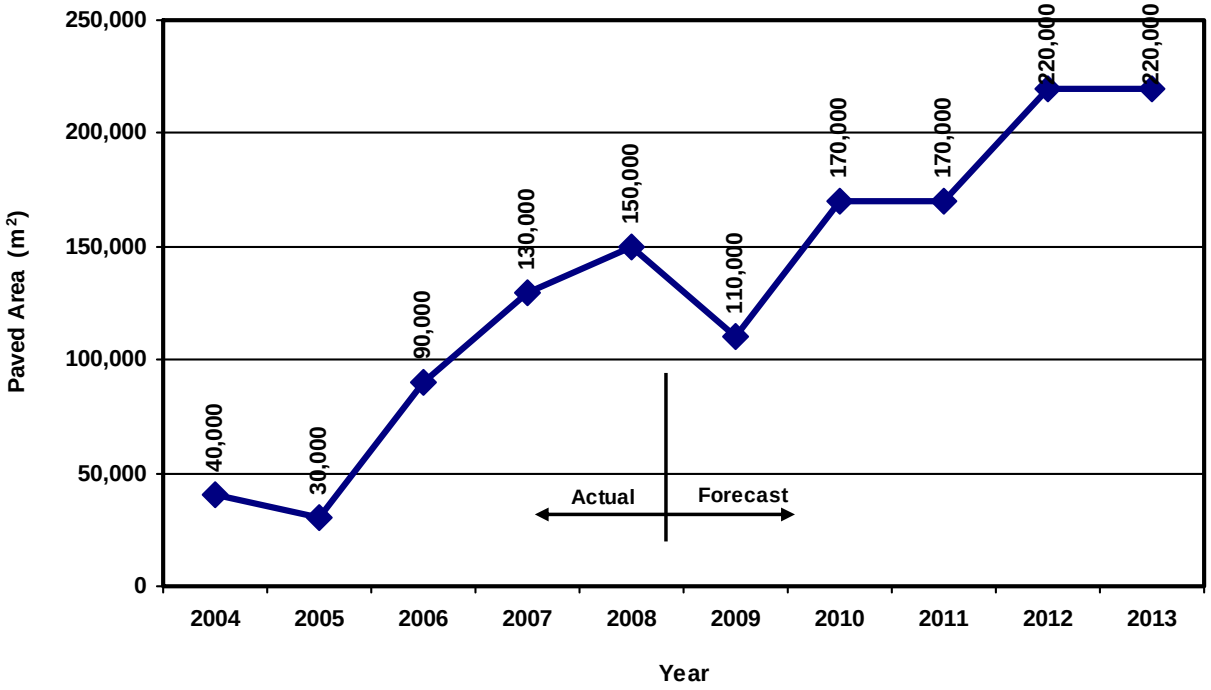

Figure 7. Status of annual asphaltic street area (actual and forecast) that will replaced by PAC.

Within the decision making process of forming this revolutionary strategic program, it was necessary to consider and confront the different types of public involved:

- The professional and engineering public that is concerned with the structural and functional long lasting sustainability of the alternative PAC solution.
- The city finance staff that is concerned with the life cycle and cost-benefit value of the alternative solution, despite its somewhat higher initial rehabilitation prices.
- The neighborhood inhabitants that are concerned with the aesthetic benefits of the block paved streets, and the increasing value of their property.
- The transportation and police officials that are concerned with the traffic safety impacts of the new streets surfaces.
- The politicians that are concerned with the opinions of the inhabitants (their potential future voters).

Fortunately, the reactions of these different types of public were generally very positive. This feedback made it quite easier to reach the necessary decisions towards the fast and smooth implementation the PAC conversion program in the rehabilitation of existing streets as well as in the erection of new residential neighborhood in the city of Eilat.

The typical results of the PAC street rehabilitation program that took place since the mid nineties are illustrated in Figure 8:



Figure 8. Typical examples of different residential streets in Eilat that were converted from asphaltic to PAC surfaces during the last 10 years.

4. THE ECONOMIC MODEL AND ANALYSIS

The basic economic model, that initially adopted in the decision making process, was developed at the Technion for engineering-economy comparison between the three basic types of pavements – Flexible-asphaltic, Rigid-concrete, and PAC (Ishai, 1996, 2003). Recently, a modified updated economic model was developed, taking into account the current parameters and prices of the various alternatives (Ben Moshe, 2009). For a simple illustrative demonstration, the following are the key parameters and data involved in these models:

- The calculated economic comparison between the asphaltic pavement and PAC is valid for a service life period of 50 years.
- The comparison will be conservative - neglecting the continuous depreciated value of the asphaltic pavement.
- Under this condition, the estimated time length of the maintenance cycles is 12 years for asphalic pavement and 15 years for PAC.
- The agreed upon advantage of the PAC compared to the asphaltic one, mainly due to aesthetic and traffic safety considerations, was quantified to be 19% of the basic initial asphalt rehabilitation cost.
- The initial rehabilitation costs of the two alternatives, and the cycle maintenance costs of the asphaltic pavement (based on current local bid prices), are as follows:

Table 1. Rehabilitation and maintenance costs.

WORK DESCRIPTION	ASPHALT – COST IN US$/m^2		PAC – COST IN US$/m^2	
	BASIC INITIAL ASPHALT REHABILITATION COSTS	CYCLE ASPHALT MAINTENANCE COSTS	BASIC INITIAL CONVERSION TO PAC COSTS 60 mm BLOCKS	BASIC INITIAL CONVERSION TO PAC COSTS 80 mm BLOCKS
Asphalt milling, removal & disposal	5.25	3.25	5.25	5.50
Treatment of Granular Layers	4.50		3.25	3.25
Asphaltic Prime Coat	0.50			
50 mm Asphaltic Binder Course	10.75			
Asphaltic Tack Coat	0.50	0.50		
30 mm Asphaltic Wearing Course	8.75	10.00		
Blocks + Bedding Sand			23.75	26.25
TOTAL	30.25	13.75	32.25*	35.00*
* For 80% use of 60 mm blocks in residential streets, the equivalent average PAC cost is 33.00 US$/m^2				

- The cycle maintenance cost of the PAC is estimated as 10% of its basic initial rehabilitation costs, namely 3.30 US$/m^2 per maintenance cycle.

Based on these parameters and data, Table 2 presents the summary of the economic analysis:

Table 2. Summary of the Economic Analysis.

ITEM	UNIT	PAC	ASPHALT
Service Life Period	**Years**	50	50
Basic Initial Rehabilitation Investment	**US$/m^2**	32.80	30.25
Adjustment for Comparable Value (19%)	**US$/m^2**	5.75	0
Total Basic Investment	**US$/m^2**	27.05	30.25
Basic investment for an Average Year	**US$/m^2**	0.55	0.60
Recommended Maintenance Cycle Length	**Years**	15	12
Maintenance Cost per Cycle	**US$/m^2**	3.30	13.75
Remaining Period after Investment	**Years**	35	38
Remaining Maintenance Cycles	**Cycles**	2.33	3.17
Total Cost for Remaining Period	**US$/m^2**	7.70	43.60
Maintenance Cost for an Average Year	**US$/m^2**	0.15	0.85
Total Direct Annual Average Cost	**US$/m^2**	0.70	1.45

As can be seen, despite the comparable initial rehabilitation prices of the two technologies, and despite the conservative assumptions in favor of the asphalt technology (neglecting the other added values of the segmental paved street), for a long term cost-benefit consideration the transfer from asphalt to PAC is about two times worth.

5. PAVEMENT DESIGN METHODOLOGY

For the engineering design of the concrete block pavements in the city of Eilat (either for the rehabilitation of existing asphaltic pavements or for newly constructed streets), the Israeli national pavement design methodology for urban streets was adopted (MHC, 2000). This methodology was presented in details by Ishai et al (2003).

Figures 9 and 10 present the design curves for the total pavement thickness and for the layer component. This was set for seven traffic categories that are defined in Table 3. In the rehabilitation design process, the conversion of the flexible pavement structure into a PAC structure, and other pavement adjustments, were done using the layer equivalency factors presented in Table 4.

SUBGRADE CBR (%) **TRAFFIC CATEGORIES**

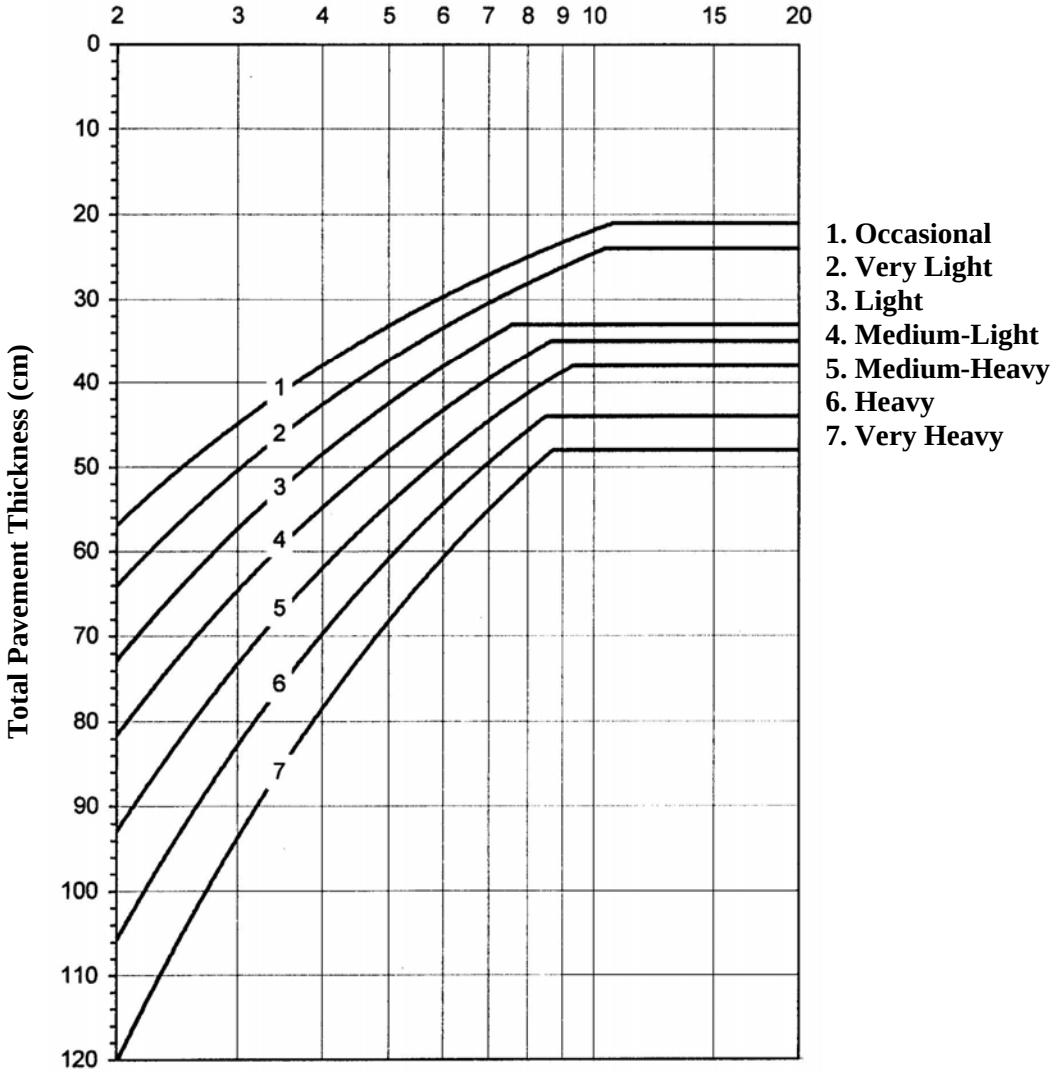

Figure 9: Design curves for Concrete Block Pavements – Total pavement thickness.

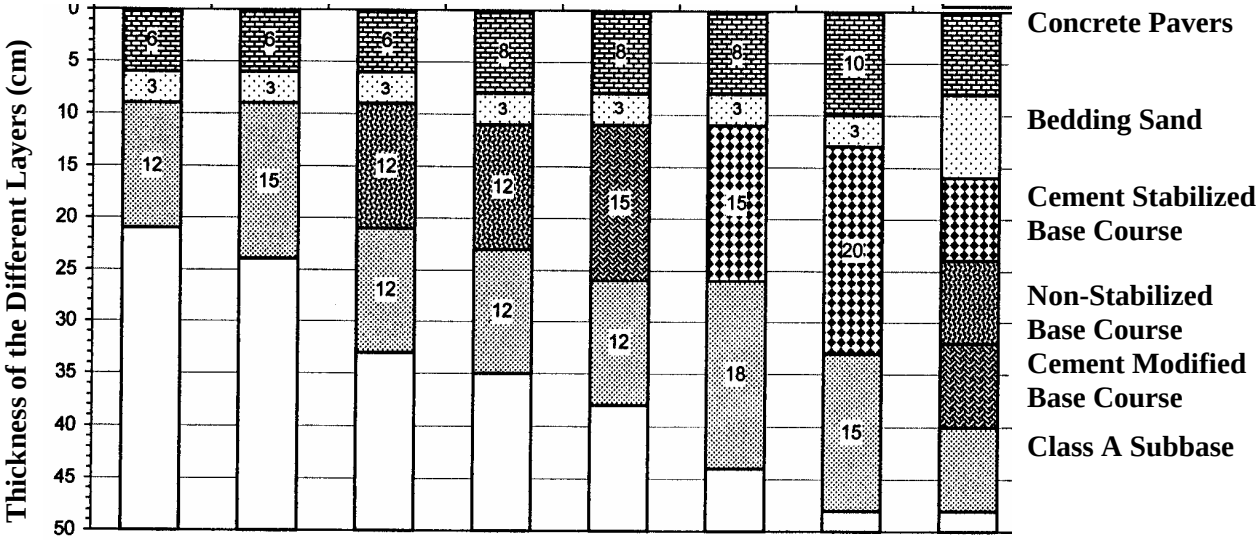

Figure 10. Design curves for Concrete Block Pavements - Thickness of the different upper layers (the

remain bottom layers are of Class B Subbases).

Table 3. Definition of Traffic Categories.

TRAFFIC CATEGORY	CATEGORY NUMBER	ACCUMULATIVE NUMBER OF 18 000 lbs ESAL'S
Occasional Traffic	1	$0.0 \times 10^4 - 3.8 \times 10^4$
Very Light Traffic	2	$3.8 \times 10^4 - 1.0 \times 10^5$
Light Traffic	3	$1.0 \times 10^5 - 3.6 \times 10^5$
Medium-Light Traffic	4	$3.6 \times 10^5 - 1.2 \times 10^6$
Medium-Heavy Traffic	5	$1.2 \times 10^6 - 5.5 \times 10^6$
Heavy Traffic	6	$5.5 \times 10^6 - 1.5 \times 10^7$
Very Heavy Traffic	7	$1.5 \times 10^7 - 8.0 \times 10^7$

Table 4. Layer Equivalency Factors Related to the Thickness of Class A Dense Graded Asphaltic Concrete.

LAYER AND MATERIAL	THICKNESS OF THE LAYER EQUIVALENT TO 1.0 cm OF ASPHALTIC CONCRETE
Concrete Pavers	0.8
Cement Stabilized Base Course	1.2
Cement Modified Base Course	1.3
Non-Stabilized Base Course	1.5
Class A Subbase Course	2.0
Class B Subbase Course	2.5
Bedding Sand	∞*
*** The bedding sand has no structural value**	

6. SPECIAL ADVANTAGES AND ADDED VALUES

With the significant economic benefit of the asphaltic conversion to PAC, this replacement of paving technology has additional advantages and added values that are general, or uniquely typical to the special conditions of Eilat:

- Contribution to the landscape, environment and general aesthetic feeling. Ideal adaptation to the unique colors of the local soils, rocks and mountains.
- Open possibilities to use permeable surfaces for the down penetration of the scarce rain water runoff for subsurface irrigation. Also decreasing the amount of soil erosion in the steep slopes of the city streets.
- Increasing traffic safety by general reducing of travel speed, especially at intersections.
- Integration with the city trend and effort to transfer all above-ground utility lines down to subsurface systems.
- Almost zero maintenance needed associated with longer time cycles, especially under the local stable subgrade and Pavement conditions. Avoiding the dependence on the unavailable asphalt plant and equipment.
- The outcome is a unanimous positive agreement that comes from diverse types of public: architects and engineers, city finance staff, neighborhood inhabitants, transportation and police officials, and politicians.

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