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IMPACT OF USING SUB-BASE COURSE ON FLEXIBLE PAVEMENT RUNWAY

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الملخص العربي

يتم انشاء الطرق الداخلية للمطار اما برصف مرن أو صلب وغالباً ما يكون رصف المدرج من النوع المرن لفاعليته في توفير تكلفة الانشاء. وهناك أكثر من بديل في تنفيذ الرصف المرن فيمكن أن ينفذ علي ثلاث طبقات أو طبقتان. وتهدف هذه الورقة البحثية الي دراسة تأثير استخدام طبقة الأساس المساعد في الرصف المرن علي تكلفة انشاء وصيانة المدرج للوصول للبديل الأمثل في أحوال مختلفة من قوة تحمل تربة التأسيس وكذا قيمة العمر التصميمي للمدرج. ومنهاجية الدراسة تشمل تأثير خمس قيم لكلاً من نسبة تحمل كاليفورنيا لتربة التأسيس والعمر التصميمي. وتم حساب سمك الرصف في كل حالة باستخدام برنامج الفارفيلد في حال استخدام طبقة الأساس المساعد وفي حالة عدم استخدامها. أظهرت النتائج أن سمك رصف المدرج المرن يزيد باستخدام طبقة الأساس المساعد لكل قيم العمر التصميمي ونسبة تحمل كاليفورنيا. وأظهرت أيضاً أن معدل الزيادة في السمك يقل بزيادة نسبة تحمل كاليفورنيا. كما أظهرت النتائج أن استخدام طبقة الأساس المساعد يقلل من تكلفة انشاء وصيانة المدرج مما يوفر في التكلفة بحوالي 10 % في جميع حالات التصميم المستخدمة في الدراسة.

ABSTRACT

Airfield pavements may be flexible or rigid type. The runway is often paved using flexible pavement. This is because its efficiency in providing construction cost. There is more than one alternative in the implementation of flexible pavement can be implemented on three layers or two layers. This paper aims to study the effect of using the sub-base layer on the cost of constructing and maintaining the runway to reach the optimal alternative in several conditions of the strength of bearing foundation soil as well as the design life of the runway. The methodology of the study includes the effect of five values for both the CBR to the foundation soil and the design life. The thickness of the pavement was calculated in each case using the FAARFIELD software in two cases (with sub-base and without sub-base layer). The results showed that the thickness of the flexible runway pavement increased with the sub-base layer for all design life values and the subgrade CBR. It also showed that the rate of increase in thickness decreased by increasing the subgrade CBR. The results also showed that the use of the sub-base layer reduces the cost of construction and maintenance of the runway and also provides a cost of about 10% in all design cases used in the study.

Keywords

FAARFIELD - Flexible pavements - Stabilized base course - Sub-base course

INTRODUCTION

Pavement of the airfield can be flexible or rigid and often the runway is flexible for its efficiency in providing construction cost. There is more than one alternative in the implementation of flexible pavement can be implemented on three layers or two layers. Flexible runway pavements consist of a hot mix asphalt wearing surface placed on a base course and, when required by subgrade conditions, a sub-base course may be added. The entire flexible pavement structure is ultimately supported by the subgrade. FAARFIELD software is considered one of the most effective software which used to design the flexible runway pavement.

Godiwalla, A. et al. [1] presented a brief comparison among the results obtained from LEDFAA, COMFAA, FEDFAA and FAARFIELD software. They found that the FAARFIELD, which based on the three-dimensional finite element, is considered one of the most effective software. Drenth et al. [2] studied the effect of the soil strength in the Amsterdam Airport Schiphol (AAS). The average subgrade CBR value of 3% has been adopted. By using APSDS software, they showed that the use of Cement Treated Base (CTB) limited the need for unrealistic in the pavement thickness and the increasing in the pavement deformation due to New Large Aircraft (NLA) types such as A-380. FAARFIELD developed by the Federal Aviation Administration (FAA) for flexible pavement. It was based on the layered elastic theory and three-dimensional finite element [3]. The thickness design in the FAARFIELD software are based on Advisory Circular 150/5320-6E [4]. The Aircraft Classification Number and the Pavement Classification Number (ACN-PCN) method adopts four standard categories of subgrade CBR for flexible pavements: ultra-low, low, medium, and high with subgrade CBR 3, 6, 10, 15% respectively [5].

STUDY OBJECTIVE

The main objective of this paper is to improve understanding of the relative impact of using sub-base course in the flexible runway pavement.

METHODOLOGY

The study methodology is shown in Figure (1).

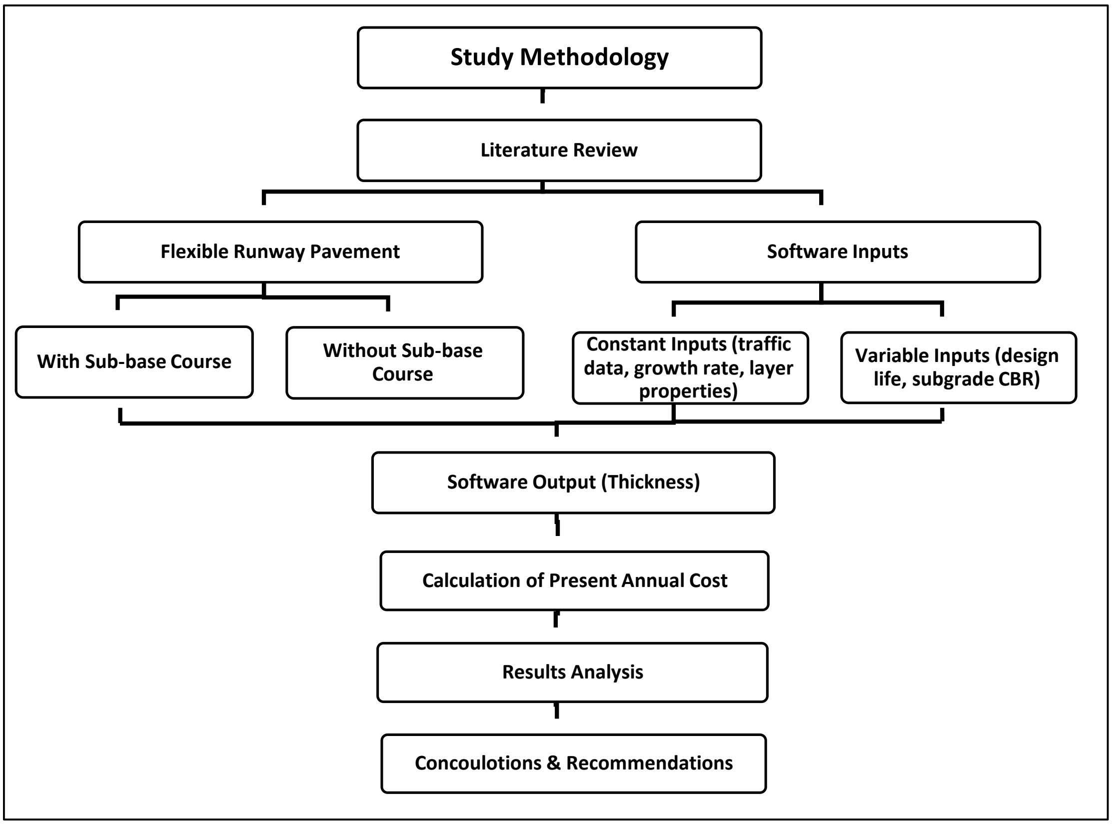

Figure (1): Study Methdology

The flexible runway pavement is designed two times with the sub-base course and without sub-base course. The first pavement structure (with sub-base course) is consist of four layers: Asphalt Concrete (AC) (P-401), stabilized flexible base (P-403), uncrushed aggregate sub-base (P-154), and natural subgrade. The second pavement structure is consist of three layers: Asphalt Concrete (AC) (P-401), stabilized flexible base (P-403), and natural subgrade. The thickness and modulus of the layers are shown in Table 3. FAARFIELD software is calculated these modules automatically and cannot be modified. The subgrade soil modulus of Elasticity (E) for flexible pavement design was calculated by multiplied the subgrade CBR by 1500 [4].

Table (1): Layer Thicknesses and Modules for the Pavement Structures

Layer	Modulus (psi)	Pavement Structure	
		First Structure (With Sub-base) (in)	Second Structure (Without Sub-base) (in)
Asphalt Concrete (P-401)	200,000	5	5
Stabilized Base (P-403)	400,000	5	Calculated with the software
Uncrushed Aggregate (P-154)	32,785	Calculated with the software	----------
Natural Subgrade	Variable	----------	----------

The software inputs divided to two categories: constant and variable inputs. The constant software inputs includes the traffic data, growth rate, and the layer properties. The thickness and the layer properties were showed in Table 1. Cairo International Airport is one of the most congested airport in Africa. It serves about 100,000 flights per year per runway [6]. The growth rate and the traffic data of the aircrafts are collected from Cairo International Airport as shown in Table 2. The runway dimensions were 4 km length and 65 m width as a common dimension used in Egyptian international airports. The variable software inputs includes the design life and the subgrade soil CBR. Five design life values are selected: 10, 20, 30, 40, and 50 years. There are five values of the subgrade soil CBR standard support conditions are used to represent a range of subgrade conditions as: 5, 10, 15, 20 and 25%.

Table (2): Traffic Data

Aircraft	Growth Rate %	Gross Weight (lbs)	Aircraft Percent/Annual Departure (%)	Annual Departure
A320-200 Twin opt	5	172842	40.7	40,110
A321-200 opt	5	207014	9.7	9,560
DC8-63/73	5	358000	19.1	18,823
A330-200 opt	5	515661	6.7	6,603
A319-100 opt	5	150796	3.7	3,647
A300-B4 std	5	365747	3	2,957
A340-500 opt	5	840402	2.2	2,168
A340-500 opt Belly	5	840402	2.2	2,168
B737-900 ER	5	188200	3.5	3,450
B737-800	5	174700	1.5	1,484
B777-300 ER	5	777000	7.5	7,392
B747-8 Intercontinental (Preliminary)	5	978000	2.4	2,365
Total			100	98,559

There are 50 cases to design by the FAARFIELD software. These cases of software design includes two pavement structures, five values of the traffic, and four values of the subgrade soil CBR. **Error! Reference source not found.**

The flexible runway pavement thicknesses for each single case is designed by FAARFIELD software. To compare between these cases, the present annual cost; which based on standard practice and published data; was calculated.

RESULTS AND DISCUSSIONS

Based on the information in the previous section, the thicknesses of the flexible runway pavement was designed for each single case by FAARFIELD software. The results of thicknesses and cost will present in the following sections.

Effect of Using Sub-base Course on Pavement Thickness

The effect of using the sub-base course on the total flexible pavement thicknesses and the design life for different values of subgrade CBR as shown in Figure 2.

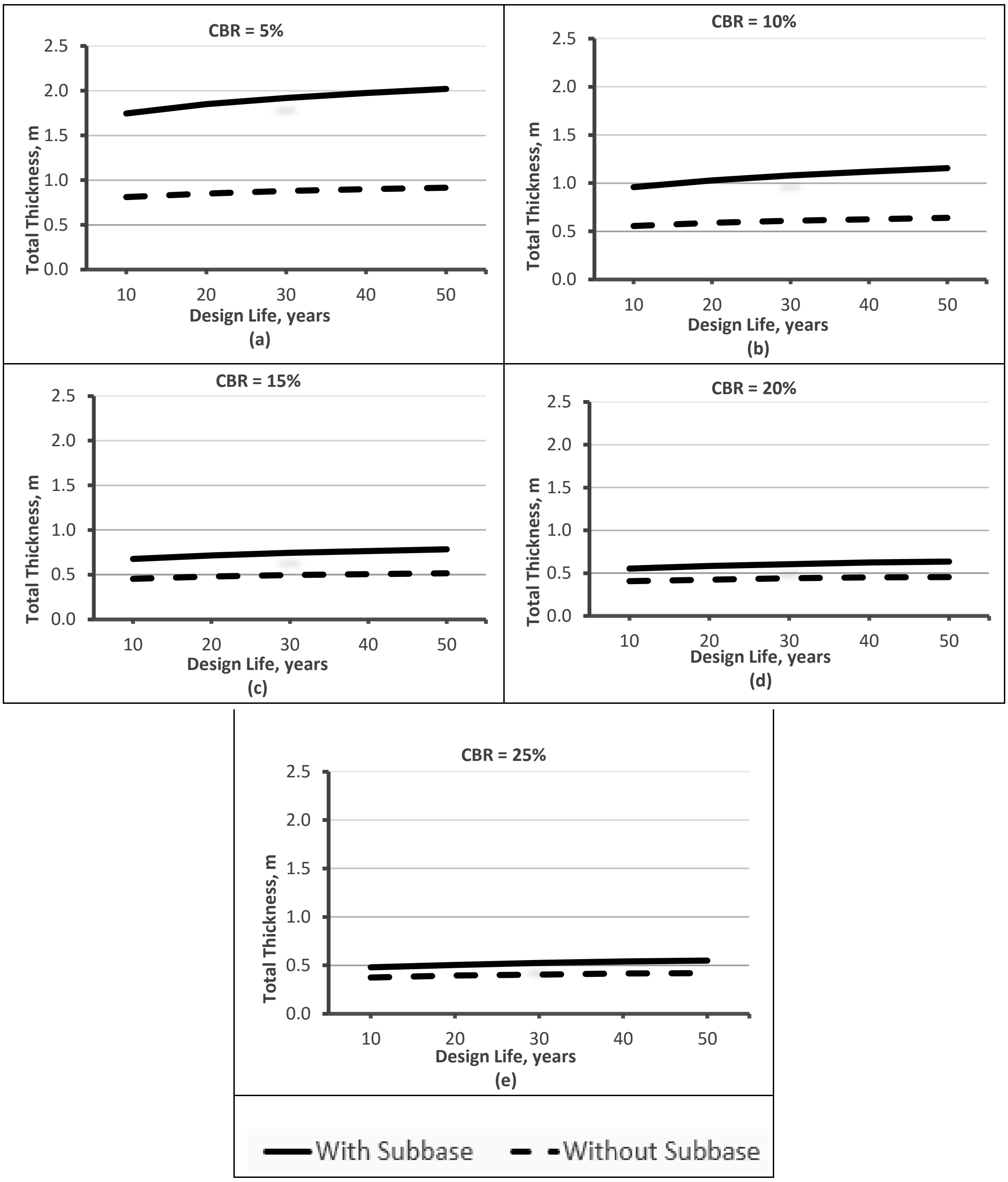

Figure (2): Effect of Using Sub-base Course on Thickness for Different Runway Design Life

Figure 2-a shows that the flexible pavement runway thickness increase by using sub-base course for all values of the design life for subgrade CBR = 5%. For design life = 10 years, the total thickness increase from 0.81 m to 1.75 m after using the sub-base course. For design life = 50 years, the total thickness increase from 0.90 m to 2.02 m after using the sub-base course. Figure 2-e shows that the flexible pavement runway thickness increase by using sub-base course for all values of the design life for subgrade CBR = 25%. For design life = 10 years, the total thickness increase from 0.38 m to 0.48 m after using the sub-base course. For design life = 50 years, the total thickness increase from 0.42 m to 0.55 m after using the sub-base course. Similar effect was found for other subgrade CBR as shown in Figure 2-b and Figure 2-d. This is because the modules of the sub-base course is lower than the modules of the base course.

Figure 3 illustrate the effect of using the sub-base course for the different values of the design life and the subgrade CBR on the flexible runway pavement thickness.

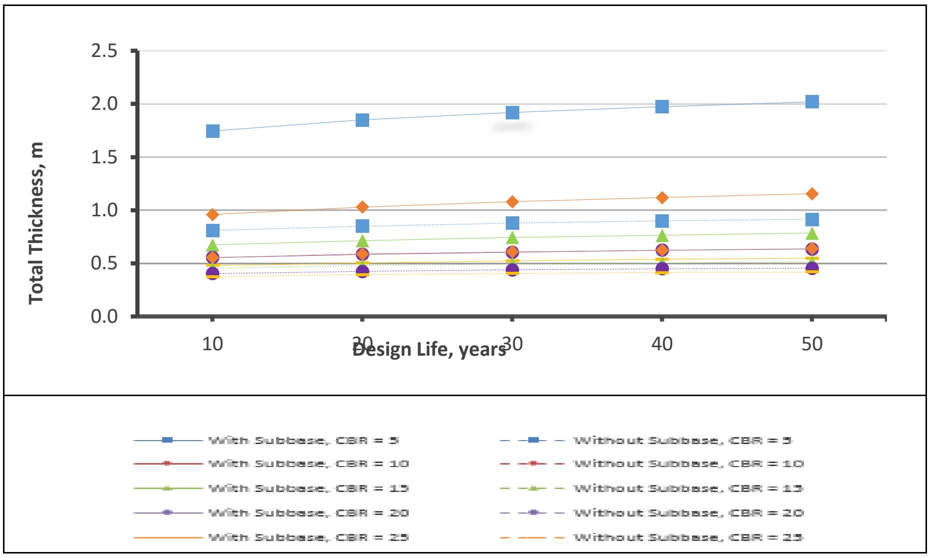

Figure (3): Effect of Using Sub-base Course on Thickness for Different Runway Design Factors

As Figure 3 illustrate, the total flexible runway thickness for subgrade CBR = 5% and design life = 10 years is increase by using sub-base course. This is because the weakness of sub-base material compared with the base course. Similar effect was found for other subgrade CBR and design life.

Figure 3 also showed that the increasing in the total pavement thickness in the case of using sub-base layer for the lower value of the subgrade CBR is more than the increase of it for the higher value of the subgrade CBR. This is due to the fact that the increase in the subgrade CBR makes the soil resist the applied loads so that it's so that its thickness is less than required.

The increase in the thickness by using sub-base course does not mean that will be increase in the annual cost. This is because there are different layer in the structure and these layers are different in the material, quality, and the cost. So, the present annual cost was calculated to be easy to show the effect of using the sub- base course for flexible pavement.

Impact of Pavement Design Factors on Annual Cost

The effect of the using of the sub-base course on the annual cost and the design life for the different values of the subgrade CBR as shown in Figure 4.

Figure 4-a shows that the annual cost decrease by using sub-base course for all values of the design life for subgrade CBR = 5%. For design life = 10 years, the annual cost decrease from 2.1 million dollar to 1.9 million dollar after using the sub-base course. For design life = 50 years, the annual cost decrease from 0.66 million dollar to 0.60 million dollar after using the sub-base course. Figure 4-e shows that the annual cost decrease by using sub-base course for all values of the design life for subgrade CBR = 25%. For design life = 10 years, the annual cost decrease from 1.10 million dollar to 0.96 million dollar after using the sub-base course. For design life = 50 years, the annual cost decrease from 0.42 million dollar to 0.39 million dollar after using the sub-base course. Similar effect was found for other subgrade CBR as shown in Figure 4-b

and Figure 4-d. This is because the material, quality, and cost of the sub-base course is lower than the stabilized base course by about 70%.

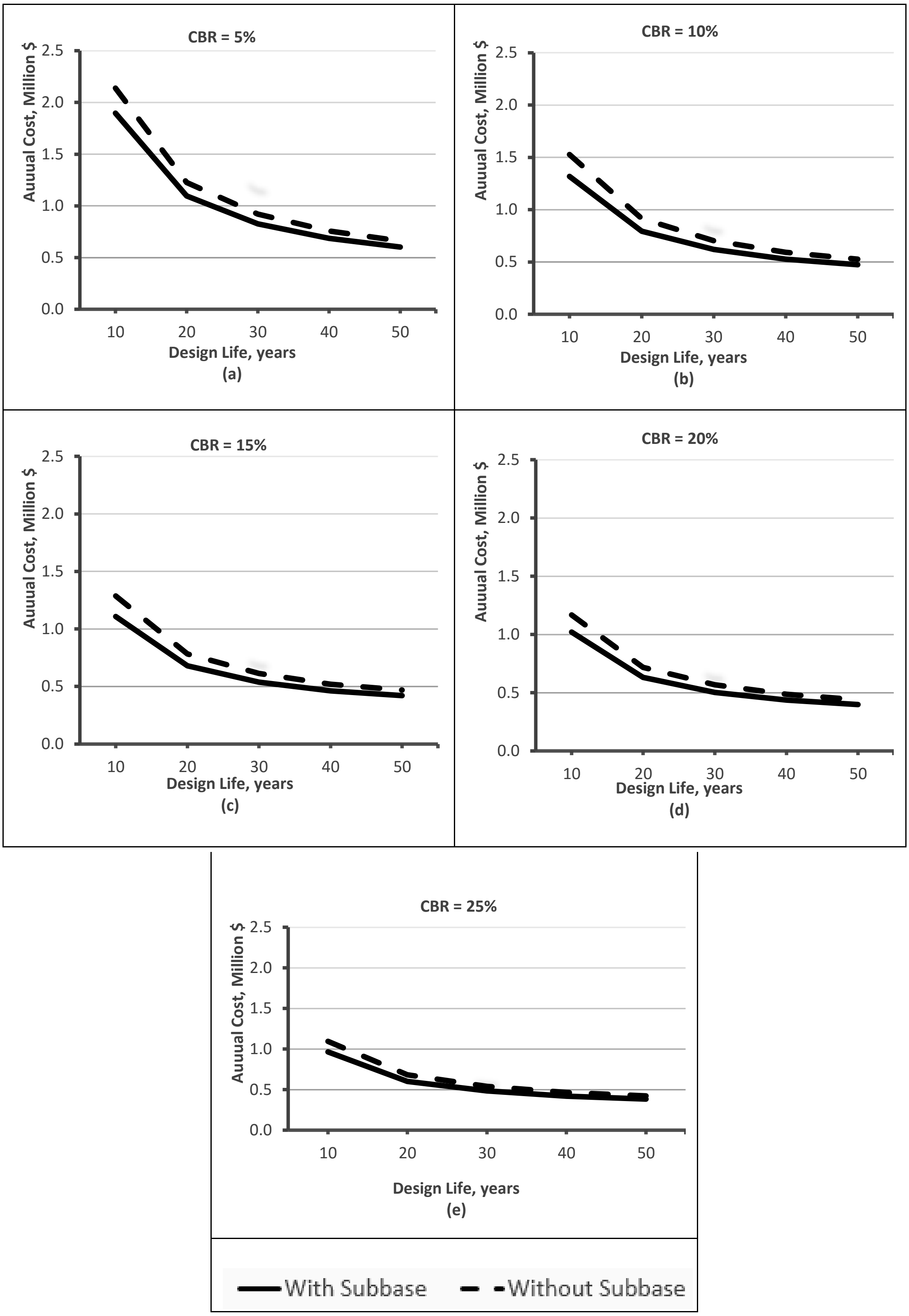

Figure (4): Effect of Using Sub-base Course on Annual Cost for Different Runway Design Life

Figure 5 illustrate the effect of using the sub-base course for the different values of the design life and the subgrade CBR on the present annual cost.

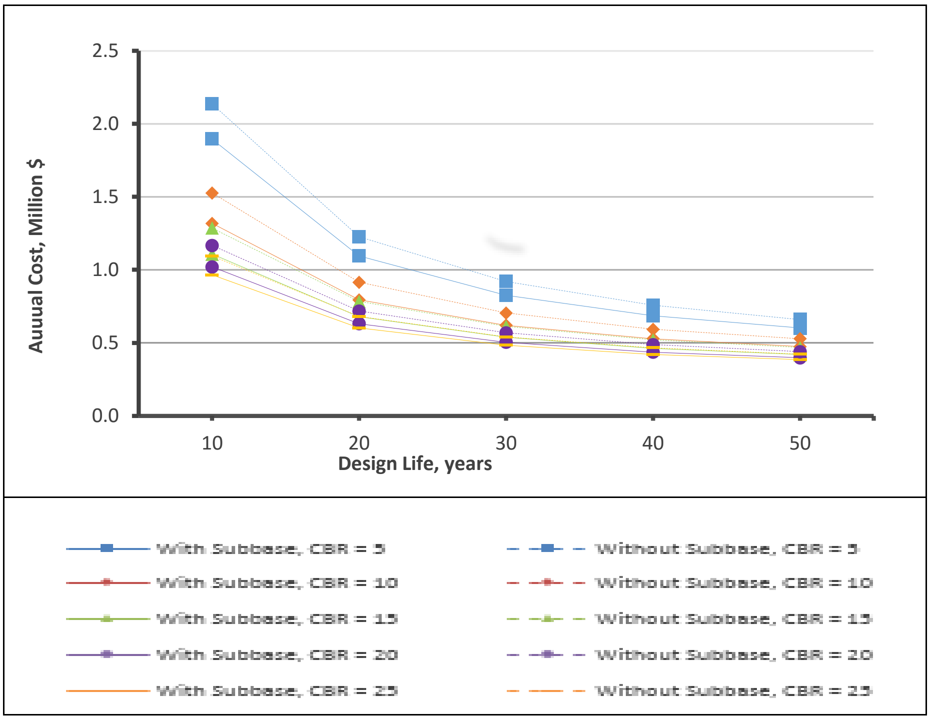

Figure (5): Effect of Using Sub-base Course on Annual Cost for Different Runway Design Factors

As Figure 5 illustrate, the annual cost for subgrade CBR = 5% and design life = 10 years is decrease by using sub-base course. Similar effect was found for other subgrade CBR and design life. The rate of decreasing in the annual cost is almost constant for all values of the design life and the subgrade CBR by about 10%.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This paper presented a methodology for studying the effect of using sub-base course in the flexible runway pavement. The effects of using the sub-base course for different values of the design life and the subgrade CBR were recognized. The following conclusions can be drawn:

For all values of the design life and the subgrade CBR of runway flexible pavement:

- The total pavement thickness increases in the case of using sub-base course. The increasing in the total pavement thickness in the case of using sub-base layer for the lower value of the subgrade CBR is more than the increase of it for the higher value of the subgrade CBR.
- The pavement annual cost decreases by using sub-base course. The using sub-base course decrease the annual cost by about 10% for all values of the design life and the subgrade CBR.

It is recommended to use sub-base course in construction of the flexible runway pavement especially in cases of lower values of the subgrade CBR and the design life.

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