Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi

Afyon Kocatepe University Journal of Science and Engineering

AKÜ FEMÜBİD **20** (2020) 055601 (873-882) AKU J. Sci. Eng. **20** (2020) 055601 (873-882)

DOI: 10.35414/akufemubid.713979

Araştırma Makalesi / Research Article

Comparative Design and Economic Analysis of Asphalt and Concrete Overlays for Airfield Pavements

Orhan KAYA[1*]

[1] *Adana Alparslan Turkes Science and Technology University, Department of Civil Engineering, Adana.*

** Corresponding author email: okaya@atu.edu.tr ORCID ID: http://orcid.org/0000-0001-6072-3882*

Geliş Tarihi: 09.05.2020 Kabul Tarihi: 28.10.2020

Keywords
Airfield pavements; Concrete overlays; Asphalt overlays; Pavement design

Abstract

Overlays for airfield pavements are one of the cost effective and efficient pavement rehabilitation options. In this study, the Federal Aviation Administration's state-of-the-art mechanistic-empirical overlay design methodology (FAARFIELD) was explained, design examples using FAARFIELD version 1.42. for both concrete and asphalt overlays were presented, and the results of these examples were compared. For the overlay design scenarios on existing asphalt surface layers, it was found that, overlay thickness decreases, as existing asphalt surface layer thickness increases, and calculated concrete overlay thicknesses were higher than calculated asphalt overlay thicknesses for the same existing asphalt surface layer thicknesses. On the other hand, for the overlay design scenarios on existing concrete surface layers, both asphalt and concrete overlay thicknesses were found to be very similar to each other. Based on FAARFIELD-calculated overlay thicknesses, an economic analysis was carried out to find out the most economic overlay design options for a variety of design scenarios. Although for some overlay cases concrete overlay design thicknesses were found to be higher than asphalt overlay design thickness, cost of concrete overlays was found to be less than that of asphalt overlays. This is because unit cost for concrete materials is less than that for asphalt materials. Incorporating a state-of-the-art mechanistic-empirical overlay design for airfield overlay pavements as well as considering local cost in the economic analysis to determine which type of overlay would be a more suitable option for a variety of pavement design cases would be very beneficial to Turkish airfield pavement design practices.

Havaalanı Kaplamalarını Asfalt ve Beton ile Yeniden Kaplamanın Karşılaştırmalı Dizayn ve Ekonomik Analizi

Anahtar kelimeler
Havaalanı kaplamaları; Beton yeniden kaplamalar; Asfalt yeniden kaplamalar; Havaalanı kaplama dizaynı

Öz

Havaalanı kaplamaları için yeniden kaplama uygun maliyetli ve verimli kaplama rehabilitasyon seçeneklerinden biridir. Bu çalışmada, Amerikan Federal Havacılık İdaresi'nin (FAA) son teknoloji mekanik-ampirik kaplama tasarım metodolojisi (FAARFIELD) açıklanmış, hem beton hem de asfalt yeniden kaplamalar için FAARFIELD versiyon 1.42 kullanılarak tasarım örnekleri sunulmuştur ve bu örneklerin sonuçları karşılaştırılmıştır. Mevcut asfalt yüzey katmanları üzerindeki yeniden kaplama tasarım senaryoları için, mevcut asfalt yüzey katmanı kalınlığı arttıkça yeniden kaplama kalınlığının azaldığı ve hesaplanan beton yeniden kaplama kalınlıklarının, aynı mevcut asfalt yüzey katman kalınlıkları için hesaplanan asfalt yeniden kaplama kalınlıklarından daha yüksek olduğu bulunmuştur. Öte yandan, mevcut beton yüzey tabakaları üzerindeki yeniden kaplama tasarım senaryoları için, hem asfalt hem de beton yeniden kaplama kalınlıkları birbirine çok benzer bulunmuştur. FAARFIELD tarafından hesaplanmış yeniden kaplama kalınlıklarına dayanarak, çeşitli tasarım senaryoları için en ekonomik yeniden kaplama tasarım seçeneklerini bulmak için bir ekonomik analiz gerçekleştirilmiştir. Bazı yeniden kaplama durumları için beton yeniden kaplama tasarım kalınlıkları asfalt yeniden kaplama tasarım kalınlığından daha yüksek bulunmasına rağmen, beton yeniden kaplamaların maliyeti asfalt yeniden kaplamalardan daha düşük bulunmuştur. Bunun nedeni, beton malzemeler için birim maliyetin asfalt malzemeler için olan maliyetten daha az olduğudur. Havaalanı yeniden kaplamaları için son teknoloji ürünü mekanik-ampirik yeniden kaplama tasarımının yanı sıra, çeşitli yeniden kaplama tasarım durumları için hangi yeniden kaplama tipinin daha uygun bir seçenek olacağını belirlemek için ekonomik analizde yerel maliyeti göz önünde bulundurmanın, Türk havaalanı kaplama tasarım uygulamalarına faydalı olacağı belirtilmiştir.

1. Introduction

Overlays are one of the cost effective and efficient pavement rehabilitation options because reconstruction of airfield pavements requires greater construction times (and so a greater closure time of an airport) and more money compared to overlays. Increasing closure time of a runway in a busy airport negatively affects both user and agency costs. Therefore, overlays, adding another layer(s) of pavement on available surface layer would be a good alternative to reconstruction. Some of the reasons why airfield pavements may need rehabilitation are as follows (FAA 2016):

- To improve functional and structural conditions of airfield pavements
- To eliminate material-related distresses and distresses related to overloading
- To increase overall structural capacity of pavement to enable heavier aircraft land on them or extend number of operations on them

Rehabilitation strategies are an important part of pavement management systems (Dong and Huang 2012, Huang 2003). An effective and efficient pavement management system should consider all reconstruction, maintenance and rehabilitation options together and manage them well in order to keep all pavement sections in a road network in an acceptable condition (Yu and Lu 2012, Morova vd. 2016). Especially for the developed countries where road network is quite well-distributed nationwide, keeping whole road network in both structurally and functionally good condition requires spending a significant portion of total budget for roads on pavement rehabilitation and maintenance compared to building new pavements. Turkey is one of the developing countries where many new road sections are built. However, if the newly built road sections are not well maintained and rehabilitated, these road sections might deteriorate fast, so bringing deteriorated road sections in good condition might require greater amount of money compared to the one needed to timely maintain and rehabilitate them (Şengün vd. 2020).

Design and construction of overlays require many considerations such as: Transition and drainage between existing layer and overlays should be considered and condition of the existing pavement should be assessed and improved, if needed. Namely, distressed asphalt layers could be milled to some extent to remove severely deteriorated portion of the asphalt layers or severely cracked slabs could be partially or fully repaired to ensure that existing layers have enough structural capacity. If an existing pavement section has poor subsurface drainage; then its drainage condition should be improved before overlay is applied.

Overlays are broadly categorized into two groups: asphalt and concrete overlays. Both asphalt and concrete overlays have been widely used for highway pavements for quite long time but not much in airfield pavements (Harrington and Fick 2014).

Concrete overlays are also broadly separated as bonded and unbonded concrete overlays. Bonded concrete overlays are used as preventative maintenance or minor rehabilitation options and mostly used on highway pavements. They are required to be overlaid on an existing pavement layer with good to fair structural condition. They are designed to add some structural capacity to the existing surface. Bonded concrete overlays are relatively thin (2–6 in. [50–150 mm]) compared to unbonded concrete overlays. Design philosophy in bonded concrete overlays is that they should be bonded to the existing surface well that both overlays and existing surface layers behave as a one monolithic structure. On the other hand, unbonded concrete overlays are applied on an existing surface with moderate or severe distresses, where existing surface layer is treated as a stable base, so existing surface layer is not counted as a structural surface element in the overlay design. Unbonded concrete overlays are used as minor or major rehabilitation options (Harrington and Fick 2014, Bhattacharya *et al.* 2017, Vandenbossche and Fagerness 2002). Both bonded and unbonded concrete overlays have subcategories depending on the type of existing surface layer (Figure 1).

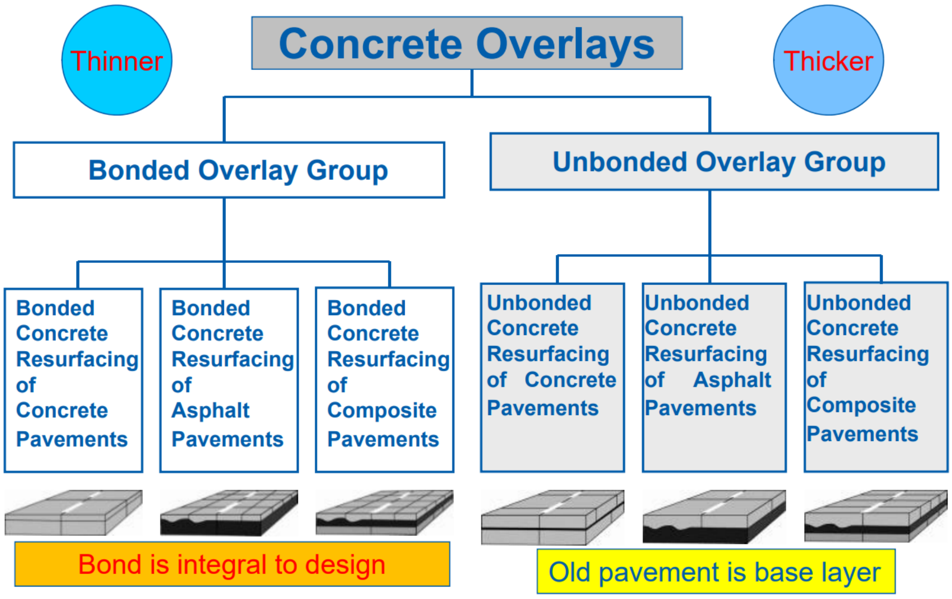


Figure 1. Types of concrete overlays (Harrington and Fick 2014)

Asphalt overlays could also be applied on both existing concrete and asphalt surface layers. They can be used for preservation or structural purposes. Preservation overlays are used to preserve existing surface in good condition whereas structural overlays are used to add some structural capacity to the existing surface layer. Therefore, structural asphalt overlays are mostly thicker than preservation asphalt overlays. In the design and construction of asphalt overlays, several parameters should be considered such as: whether a pre-overlay repair is needed; how reflection cracking coming from existing surface layer should be controlled; how future traffic will change; and whether an improvement in sub-drainage is needed etc. (SCAPA 2016).

Some mechanistic and mechanistic-empirical pavement design methodologies have been developed for both concrete and asphalt overlays, mostly for highway pavement applications. Some of these design methodologies developed for highway overlay pavement applications are summarized in Table 1. Detailed information on each design methodology can be found in Harrington and Fick (2014). As can be seen in Table 1, some of these design methodologies are specifically developed for either asphalt or concrete overlays whereas some of them are developed for both overlay types.

Historically, Asphalt Institute's design method (Asphalt Institute 1983) and The American Association of State Highway and Transportation Officials (AASHTO)'s 1993 guide for design of pavement structures (AASHTO 1993) have been widely used in the design of asphalt overlays whereas AASHTO 1993 guide for design of pavement structures (AASHTO 1993) has been widely used in the design of concrete overlays. However, all these three methodologies were based on empirical relations and equations. To advance the design methodologies and carry out the overlay design based on mechanistic relations, based on mechanics of materials principals, some mechanistic-empirical pavement design methodologies have been developed (Table 1).

Although some design methodologies and associated design software have been developed for highway overlay pavements, there has been not much study regarding the overlay design for airfield pavements. Some empirical equations and graphs have been developed by International Civil Aviation Organization (ICAO) for overlay designs (ICAO 1983). These empirical equations have also been used in Turkey for overlay designs (DLH 2007).

Table 1. Design methodologies developed for highway overlay pavements

Overlay Type	Name	Empirical or Mechanistic-Empirical	Reference
Concrete Overlay	ACPA bonded concrete overlay on asphalt (BCOA) thickness designer	Mechanistic-Empirical	(Int Kyn. 1)
	BCOA ME	Mechanistic-Empirical	(Vandenbossche *et al.* 2017)
	Optipave V2.0	Mechanistic-Empirical	(Covarrubias and Covarrubias 2008)
	StreetPave	Empirical	(Int Kyn. 2)
Asphalt Overlay	Asphalt Institute design method	Empirical	(Asphalt Institute 1983)
	CALTRANS's flexible overlay design method	Empirical	(CALTRANS 1972)
Both Concrete and Asphalt Overlays	AASHTO 1993 guide for design of pavement structures	Empirical	(AASHTO 1993)
	AASHTO Pavement ME design guide	Mechanistic-Empirical	(Int Kyn. 3)

However, more advanced methodologies considering mechanistic relations as well as accommodating newly emerging wide-body aircraft in the design methodology were needed as an alternative to ICAO's old empirical equations. The Federal Aviation Administration (FAA) has developed a mechanistic-empirical based overlay pavement design methodology where it considers all mechanical loads coming from a set of aircraft projected to land on overlaid pavements and calculating all fatigue damage coming from these mechanical loads in order to do overlay thickness design. Its design methodology has been incorporated into its design software, FAA Rigid and Flexible Iterative Elastic Layered Design (FAARFIELD). Latest version of FAARFIELD is version 1.42, where its aircraft library includes a wide-range of aircraft including newly emerging wide-body aircraft (Int Kyn. 4).

In this study, FAARFIELD design methodology for overlays will be explained in great detail. Design examples using FAARFIELD version 1.42 for both concrete and asphalt overlays will be presented, and the results of these examples will be compared. Based on FAARFIELD-calculated overlay thicknesses, an economic analysis will be carried out based on unit costs for both concrete and asphalt overlays obtained from 2019 Construction and Installation Unit Prices Book of Republic of Turkey, the Ministry of Environment and Urbanism (CSB 2019), to find out the most economic overlay design options for a variety of design scenarios. Incorporating a state-of-the-art mechanistic-empirical overlay design methodology for airfield overlay pavements as well as considering local cost in the economic analysis to determine which type of overlay would be a more suitable option for a variety of pavement design scenarios would be very beneficial to Turkish airfield pavement design practices. This study also highlights that rehabilitation options should also be fully considered as an alternative to reconstruction as they are mostly cheaper and faster alternatives compared to reconstruction.

2. FAARFIELD Overlay Design

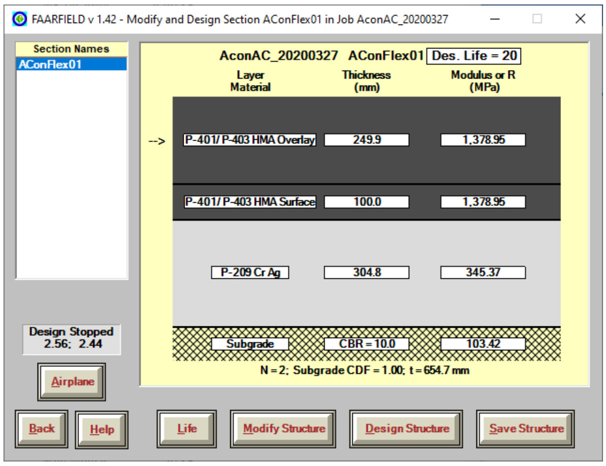
FAARFIELD allows users to design four types of overlays: asphalt overlays on existing asphalt or concrete surfaces and concrete overlays on existing asphalt or concrete surfaces. In terms of mechanistic models, FAARFIELD uses a layered elastic analysis for asphalt overlays and three-dimensional finite element analysis (3D-FE) for concrete overlays. Design life for overlays could be selected by the users with a range between 1 year and 50 years, 20 years being the default value (FAA 2016).

2.1 Design comparisons of asphalt and concrete overlays on existing asphalt surfaces

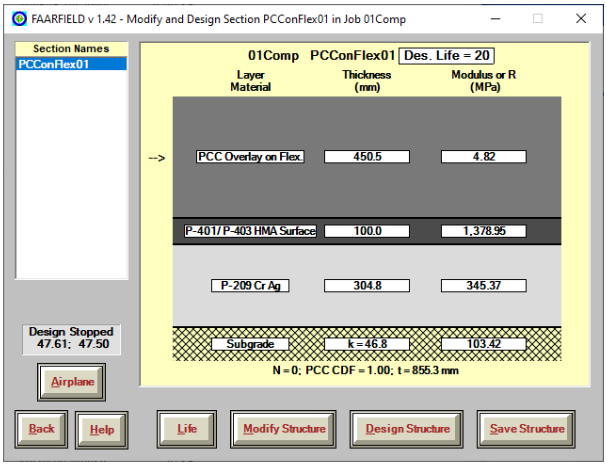
FAARFIELD requires a minimum asphalt overlay thickness of 2 inches (50 mm) for nonstructural asphalt overlays and 3 inches (75 mm) for structural asphalt overlays on existing asphalt surface layers. Thickness design for asphalt overlays on existing asphalt surfaces is carried out by FAARFIELD as follows: FAARFIELD first assigns a trial asphalt overlay thickness on an existing pavement structure and revises this assigned thickness as a result of an iteration process until a cumulative damage factor, ratio between number of applied load repetitions coming from design airplane mix and number of allowable load repetitions to failure, reaches the value of “1”. Calculated asphalt overlay thickness as a result of this iteration process is determined as design asphalt overlay thickness, given that calculated thickness values are higher than minimum thicknesses mentioned above (FAA 2016). As part of this iteration process, mechanical loads coming from an aircraft mix are applied on overlays with the trial asphalt overlay thickness and pavement responses are calculated in critical pavement response locations using the mechanistic models. Then, the calculated pavement responses are input into the fatigue damage model to determine cumulative damage caused by the aircraft mix. If the ratio between the calculated cumulative damage and the allowable damage is not equal to “1”, the trial asphalt overlay thickness is changed and the whole iterative process is repeated until the ratio reaches “1”.

FAARFIELD also designs an unbonded concrete overlay on an existing asphalt surface by treating the existing asphalt surface layer as a stabilized base layer and optimizing unbonded concrete overlay thickness. Similar to asphalt overlays, FAARFIELD first assigns a trial unbonded concrete overlay thickness and revises this thickness based on an iteration process until a CDF value of “1” is reached. Minimum allowable unbonded concrete overlay on an existing asphalt surface layer in FAARFIELD is 6 inches (150 mm).

Screenshot examples of FAARFIELD runs can be seen in Figure 2 for (a) an asphalt and (b) an unbonded concrete overlay on existing asphalt surfaces. As can be seen in Figure 2, all pavement structure could be customized and corresponding input parameters for each pavement layer could be entered and revised. Design life could also be input by the user. Aircraft mix that will be used in the analysis, annual departures and percent annual growth for each aircraft in the mix could be customized as well, which will be discussed later in this paper. Once all inputs are entered, “Design Structure” button is clicked to initiate the iteration process. FAARFIELD revises the overlay thickness until a CDF value of “1” is reached (Figure 2).



(a)



(b)

Figure 2. Screenshot examples of FAARFIELD runs for (a) an asphalt and (b) an unbonded concrete overlays on existing asphalt surfaces

In this study, FAARFIELD runs will be carried out based on mechanical loads coming from a mix of aircraft shown in Table 2. These aircraft mix was selected in the runs because they are the four most common aircraft in Turkish Airline’s fleet as of 2019 (Int Kyn. 5). Corresponding gross weights, assumed annual departures and percent annual growth of traffic are also presented in Table 2. B777-300 ER is the heaviest aircraft, a wide-body aircraft, in its fleet. Another wide body aircraft in its fleet is A330-200 aircraft, while other two aircraft, B737-800 and A321-200, are categorized as narrow-body aircraft.

Annual departures of each aircraft were selected proportionally to their numbers in Turkish Airline's fleet (Int Kyn. 5).

Table 2. List of aircraft, their gross weight, annual departures and percent annual growth in FAARFIELD runs

Name of Aircraft	Gross Weight (tons)	Annual Departures	% Annual Growth
B777-300 ER	352.441	1,200	2.00
B737-800	79.243	3,600	2.00
A321-200 std	89.400	3,600	2.00
A330-200 std	230.900	2,400	2.00

In this study, these aircraft loads will be applied on a pavement structure with the following configuration: a subgrade with a California Bearing Ratio (CBR) value of 10%, a P-209 type crushed aggregate granular base, a type of granular base with specific gradation defined by FAA (FAA 2018), with a thickness of 304.8 mm and a modulus value of 345.37 MPa laying on the subgrade (Figure 2). On top of this granular base, an existing asphalt surface layer is laid. Overlays are applied on top of the existing asphalt surface layer. Existing asphalt surface layer thickness was varied and both asphalt and concrete overlay thicknesses are calculated for each existing asphalt surface layer thickness (Table 3). In terms of design life, 20 years was assumed (Figure 2). As can be seen in Table 3, in both asphalt and concrete overlay designs, overlay thickness decreases, as existing asphalt surface layer thickness increases. Also, calculated concrete overlay thicknesses were found to be higher than calculated asphalt overlay thicknesses for the same existing asphalt surface layer thicknesses (Table 3).

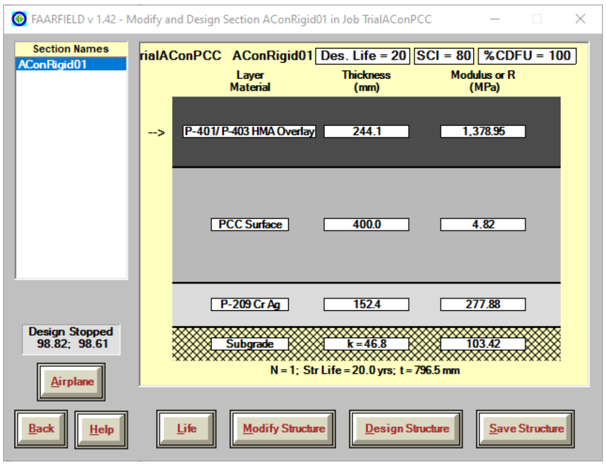
Table 3. Comparison of calculated asphalt and concrete overlay thicknesses by FAARFIELD based on various existing asphalt surface layer thicknesses

Existing Asphalt Layer Thickness (mm)	Calculated Asphalt Overlay Thickness by FAARFIELD (mm)	Calculated Concrete Overlay Thickness by FAARFIELD (mm)
40	309.9	454.6
60	289.9	453.2
80	269.9	451.9
100	249.9	450.5
120	229.9	449.2

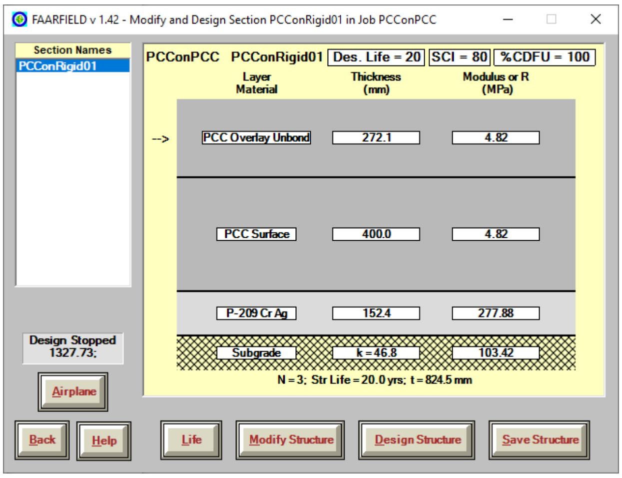
2.2 Design comparisons of asphalt and concrete overlays on existing concrete surfaces

In the design of overlays on existing concrete layers, FAARFIELD requires structural condition of existing concrete surface layer to be evaluated and input into the software. Structural condition of the existing concrete surface layer is estimated in terms of structural condition index (SCI), a similar parameter to pavement condition index but only considering structural failures, 100 being no visible structural cracks and 0 being total failure (FAA 2016). An SCI value of 80 means that 20% of the structural capacity of the existing concrete pavement is lost during its previous use. In this study, a SCI value of 80 will be used to characterize structural condition of the existing concrete surface layer and both asphalt and unbonded concrete overlays will be placed on it. Similar to overlays on existing asphalt surface layer cases, a subgrade with a k value, modulus of subgrade reaction, of 46.8 Mega-newton (MN) per cubic meter, an equivalent number to a CBR value of 10%, on top of which, a P-209 granular crushed aggregate base with 152.4 mm thickness will be used (Figure 3). Figure 3 shows examples of FAARFIELD runs for asphalt and concrete overlays on existing concrete surface layers. In terms of mechanical load, the same aircraft mix used in overlay cases on existing asphalt surface layers (Table 2) are used. Minimum allowable unbonded concrete overlay on existing concrete layer thickness in FAARFIELD is 6 inches (150 mm). In FAARFIELD runs, a design life of 20 years was used, the same as overlay cases on existing asphalt surface layers.

Table 4 shows comparisons of FAARFIELD-calculated asphalt and concrete overlays on a existing concrete surface layers with a variety of thicknesses. As can be seen in Table 4, as existing concrete surface layer thickness increases, both asphalt and concrete overlay thicknesses decrease. Different than overlays on existing asphalt surface layer cases, both asphalt and concrete overlay thicknesses on existing concrete surface layers were found to be very similar to each other, especially for 350 and 400 mm existing concrete surface layer thickness cases. Moreover, as can be seen in Table 4, the rate of decrease in overlay thickness was found to be higher for asphalt overlays than for concrete overlays as existing concrete surface layer thickness increases.



(a)



(b)

Figure 3. Screenshot examples of FAARFIELD runs for (a) an asphalt and (b) an unbonded concrete overlays on existing concrete surfaces

Table 4. Comparison of calculated asphalt and concrete overlay thicknesses by FAARFIELD based on various existing concrete surface layer thicknesses

Existing Concrete Layer Thickness (mm)	Calculated Asphalt Overlay Thickness by FAARFIELD (mm)	Calculated Concrete Overlay Thickness by FAARFIELD (mm)
350	337.7	320.3
400	244.1	272.1
450	117.1	209.1

Why selected existing asphalt surface layer thicknesses in the previous chapter of this paper were significantly less than the existing concrete surface layer thicknesses is that, before overlays are applied on the existing asphalt surface layer, mostly, asphalt layer is milled to some extent to remove highly distressed top portion of the existing asphalt surfce layer, reducing its thickness. However, existing concrete surface layer could not be milled but rather cracked and fault on its surface could be treated.

3. Economic Analysis of Overlay Designs

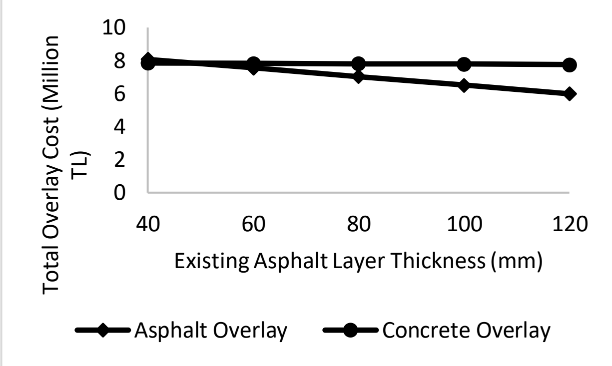
An economic analysis of various overlay design options based on FAARFIELD design calculations presented in the previous chapters of this paper will be carried out. In the economic analysis, only initial cost of overlays, or construction cost, is considered; while maintenance cost of ovarlays is not considered. In terms of construction cost, a unit price considering material, equipment, labor and transportation costs for both concrete and asphalt overlays, obtained from 2019 Construction and Installation Unit Prices Book of Republic of Turkey, the Ministry of Environment and Urbanism (CSB 2019), is used. As stated in the previous chapters of this papers, in the comparison of overlay design thicknesses, the same existing pavement configuration (the same subgrade material, the same granular base and existing surface layer materials and thicknesses) was used for the same overlay cases, only overlay thicknesses were optimized. Therefore, cost of existing surface layers was the same for both concrete and asphalt overlay cases. That is why, only both asphalt and concrete overlay costs for the same existing pavement type and configuration were compared in the economic analysis.

- Unit asphalt overlay cost including materials, transportation (up to 10 km distance), construction and labor is calculated as approximately 180.79 Turkish Lira (TL)/ton (CSB 2019). Considering the density asphalt as 2.4 ton/m^3, 180.79 Turkish Lira (TL)/ton can be converted into 433.90 TL/m^3.
- Unit concrete overlay cost including materials, transportation (up to 10 km distance),

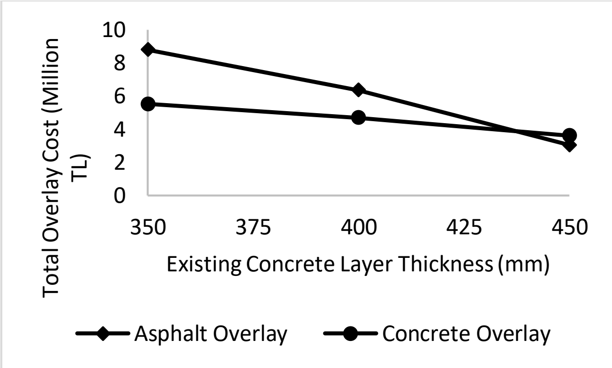
construction, labor, concrete curing and jointing is calculated as approximately 287.81 TL/m^3 (CSB 2019).

Total overlay cost comparisons will be based on a runway with a width of 60 m. and a length of 1,000 m. Figure 4 shows comparisons of estimated construction costs for both asphalt and concrete overlays on existing asphalt (Figure 4a) and concrete (Figure 4b) surface layers with various thicknesses. As can be seen in Figure 4a, construction cost of asphalt overlay was slightly higher than the one of concrete overlay on an existing asphalt surface layer with a 40 mm thickness, although FAARFIELD-calculated concrete overlay thickness was higher than asphalt overlay thickness. This is because, unit cost of concrete overlay for the same thickness is lower than the unit cost of asphalt overlay. However, after the existing asphalt surface layer thickness of 50 mm, construction cost of concrete overlay exceeds the construction cost of asphalt overlay. This is because, the rate of decrease in overlay thickness was found to be higher for asphalt overlays than for concrete overlays as existing concrete surface layer thickness increases (Table 3).

Cost of asphalt overlays on existing concrete surface layers were calculated to be significantly higher than the cost of concrete overlays on existing concrete surface layers for the existing concrete surface layer thickness of 350 mm. The cost difference between asphalt and concrete overlays on existing concrete surface layer decreases as existing concrete surface layer thickness increases. This is because FAARFIELD-calculated asphalt and concrete overlay thicknesses were similar for the existing concrete surface layer thickness of 350- and 400-mm cases (Table 4) and unit cost of concrete overlay was less than the unit cost of asphalt overlay.



(a)



(b)

Figure 4. Overlay Cost Comparisons for (a) Overlays on Existing Asphalt Surface Surface Layers and (b) Overlays on Existing Concrete Layers

4. Conclusions and Discussion

In this study, FAA's state-of-the-art mechanistic-empirical based FAARFIELD design methodology for overlays was explained in great detail. Then, design examples using FAARFIELD version 1.42. for both concrete and asphalt overlays were presented, and the results of these examples were compared. In these design examples, the four most common aircraft in Turkish Airline's fleet as of 2019 were used as mechanical loads. For the overlay design scenarios on existing asphalt surface layers, it was found that, overlay thickness decreases, as existing asphalt surface layer thickness increases. It was also found for the overlay design scenarios on existing asphalt surface layer that, calculated concrete overlay thicknesses were higher than calculated asphalt overlay thicknesses for the same existing asphalt thicknesses. On the other hand, for the overlay design scenarios on existing concrete surface layers, both asphalt and concrete overlay thicknesses were found to be very similar to each other especially for 350 and 400 mm existing concrete surface layer thickness cases.

Based on FAARFIELD-calculated overlay thicknesses, an economic analysis was carried out based on unit costs for both concrete and asphalt overlays obtained from 2019 Construction and Installation Unit Prices Book of Republic of Turkey, the Ministry of Environment and Urbanism, to find out the most economic overlay design options for a variety of design scenarios. It was found that construction cost of asphalt overlay was slightly higher than the one of concrete overlay on an existing asphalt surface layer with 40 mm thickness, although FAARFIELD-calculated concrete overlay thickness was higher than asphalt overlay thickness. On the other hand, cost of asphalt overlays on existing concrete surface layers were calculated to be significantly higher than the cost of concrete overlays on existing concrete surface layers for the existing concrete surface layer thickness of 350 mm. This result can be explained by the fact that unit cost of concrete overlay for the same thickness is lower than the unit cost of asphalt overlay.

Incorporating a state-of-the-art mechanistic-empirical overlay design for airfield overlay pavements as well as considering local cost in the economic analysis to determine which type of overlay would be a more suitable option for a variety of overlay design cases would be very beneficial to Turkish airfield pavement design practices. This study also highlights that rehabilitation options should also be fully considered as an alternative to reconstruction as they are mostly cheaper and faster alternatives compared to reconstruction. It should be noted that Turkey is one of the leading cement producers and importers in the World. On the other hand, Turkey is an oil exporter country, where the most expensive component of asphalt, asphalt binder, is a byproduct of. That is why, unit material cost of concrete is significantly less than that of asphalt in Turkey. From the economic analysis perspective, concrete overlays made out of locally produced cement would be a cost-effective rehabilitation option along with asphalt overlays.

5. References

AASHTO, 1993. Guide for Design of Pavement Structures. 4th ed. Washington, DC: American Association of State Highway and Transportation Officials.

Asphalt Institute, 1983. Asphalt Overlays for Highway and Street Rehabilitation, Manual Series.

Bhattacharya, B., Gotlif, A. and Darter, M., 2017. Implementation of the Thin Bonded Concrete Overlay of Existing Asphalt Pavement Design Procedure in the AASHTOWare Pavement ME Design Software. *Transportation Research Record,* **2641(1)**, 12–20.

CALTRANS, 1972. Methods of Testing to Determine Overlay and Maintenance Requirements by Pavement Deflection Measurements, Test Method No. Calif. 356-C.

Covarrubias T. and Covarrubias V., 2008. TCP Design for Thin Concrete Pavements. 9th International Conference on Concrete Pavements, San Francisco, CA.

CSB, 2019. Construction and Installation Unit Prices Book of Republic of Turkey, the Ministry of Environment and Urbanism.

DLH, 2007. Havameydanları Planlama ve Tasarım Teknik Esasları. T.C. Ulaştırma Bakanlığı Demiryollar, Limanlar, Havameydanları İnşaatı Genel Müdürlüğü.

Dong, Q.and Huang, B., 2012. Evaluation of effectiveness and cost-effectiveness of asphalt pavement rehabilitations utilizing LTPP data. *Journal of Transportation Engineering*, **138(6)**.

FAA, 2016. Advisory Circular, Airport Pavement Design and Evaluation, AC 150-5320-6F.

FAA, 2018. Advisory Circular, Standard for Specifying Construction of Airports, AC 150/5370-10H.

Harrington, D. and Fick, G., 2014. Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements (3rd edition), ACPA Publication.

Huang, Y. H., 2003. Pavement analysis and design, 2nd edition. Pearson, Upper Saddle River, New Jersey, USA, 600-652.

ICAO, 1983. Aerodrome Design Manual, Second Edition. International Civil Aviation Organization (ICAO).

Morova, N., Terzi, S., Gökova, S. and Karaşahin, M., 2016. Pavement management systems application with geographic ınformation system method. *Süleyman Demirel University, Journal of Natural and Applied Sciences*, **20(1)**, 103-110.

SCAPA, 2016. Asphalt Pavement Design Guide for Low Volume Roads and Parking Lot. The South Carolina Asphalt Pavement Association (SCAPA). https://www.scasphalt.org/scapa-asphalt-pavement-design-guide.html.

Şengün, E., Öztürk, H.I. and Yaman, İ.Ö., 2020. Mekanistik-Ampirik ve Geleneksel Beton Yol Tasarım Yöntemlerinin Karşılaştırılması: Afyon-Emirdağ Deneme Kesimi. *Teknik Dergi*, 10251-10274.

Vandenbossche, J. M. and Fagerness, A. J., 2002. Performance, Analysis, and Repair of Ultrathin and Thin Whitetopping at Minnesota Road Research Facility. *Transportation Research Record,* **1809**, 191-198. https://www.engineering.pitt.edu/Vandenbossche/BCOA-ME/

Vandenbossche, J. M., Dufalla, N. and Li, Z., 2017. Bonded concrete overlay of asphalt mechanical-empirical design procedure. *International Journal of Pavement Engineering,* **18(11)**, 1004-1015.

Yu, B. and Lu, Q., 2012. Life cycle assessment of pavement: Methodology and case study. *Transportation Research Part D: Transport and Environment*, **17(5)**, 380-388.

İnternet kaynakları

1- http://apps.acpa.org/apps/bcoa.aspx, (09.03.2020)

2- http://www.acpa.org/streetpave/ (09.03.2020)

3- www.aashtoware.org (09.03.2020)

4- https://www.faa.gov/airports/engineering/design_software/ (09.03.2020)

5- http://web.shgm.gov.tr/tr/kurumsal/4547-istatistikler (09.03.2020)