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Numerical Study of Stress Intensity in Flexible Pavement Under Airplane Loading

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Summary

Stress in the pavement structure leads to all types of failures in road and runway surface. Pavement stress from foreign indicators of failure that the cause of loading, environmental factors, poor construction or a set of them pavement failure can be structural or functional.

Structural failure requires detailed analysis of failure mechanisms and layers are contributing in pavement failure. Repairs are generally very expensive and runway pavement may require reconstruction. One of the common methods for studying of cracks derived from fatigues is fracture mechanics method. In this study, to evaluate the development of sample crack, the airport pavement was modelling by finite element software and the amounts of stress were measured at the crack tip. The results show that, by increasing the thickness of the layer of asphalt, the stresses and displacements are reduced.

KEYWORDS: Numerical study, Runway cracking, fatigues, Crack initiation, Crack growth, Asphalt pavement.

1. INTRODUCTION

Ground facilities are an integral part of the airport which the most important ones are runway pavements. Since the airplane wheels is opened directly on the pavement system, the behaviour and status of pavement has an effective impact on the performance of pavement traffic. Therefore, having a good road system is essential affairs due to consider all design conditions [1].

One of the problems and failures of the pavement is cracking. Cracking is damages in flexible pavement, seen in most flying areas. There are several factors that cause pavement lead to cracking which traffic loads on the pavement that play most important role. On the other hand, the periodic nature of loading pavement causes appearance of a phenomenon known as fatigues in asphalt layer [2].

The phenomenon of fatigue in the pavement is the failure of pavement due to repeated load, temperature fluctuations or a combination of those two. This

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phenomenon appeared as cracks in pavement and it is the major events of asphalt pavements in Iran and other countries of the world, especially in cold and temperate regions.

Failure due to fatigue is the most important issues in the airport pavement design that has been under periodic loading. The occurrence of failure due to fatigue can be started from a small crack and crack growth continues somewhat, it will lead to failure. During the crack growth process from initial to final length can be express as fatigue crack propagation (FCP), that was numerically examined in this papers [3,4].

The fatigue cracking is one of the major problems in the long-term performance of asphalt. Nowadays, many researchers have been done to study the fatigue behaviour of asphalt pavement. There are various methods of fatigue analysis, which many of them are using now, and many do not provide accurate results in predicting the fatigue performance of pavements. As a result, the predicting of fatigue cracking continues as a main concern for engineers. The process involved parameters that a number of fracture mechanic and other related material are obtained by laboratory methods [5, 6].

In this paper, we examine the numerical growth of fatigue cracks in the runway due to airplane wheel loading, by finite element software. Finite element method is one of numerical methods for linear and nonlinear problems. This method has many advantages over other methods of numerical solution.

Analytical solution for the many problems that have complex differential equations, special boundary conditions or non-linear terms is very hard, so the use of numerical methods increase very much the quality of the results.

According to the previous content and the importance of cracks in the pavement airport from the safety perspective, this article reviews the results of previous studies and conducted with numerical analysis by the help of finite element software method has been examined from stress concentration in the cracking pavement runway.

2. REVIEW OF LITERATURE

Until now, many studies have been done to investigate the damages on the airport pavement and the effect of different types of airplane. Also in 2004, Kim and Tutumluer have carried out many experiments on the basis of passenger airplane and a few sample of military airplane in the studies lasting deformations pavement airport [7].

In 2005, Wang and Chia-Pei based on field research results in the Chiang Kai Sheck Taiwan international airport and generalize the results in three-dimensional

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environment finite element software, showed that the characteristics of the main wheels of the airplane on the amount of damage pavement has an important role and it is effective on the useful lifetime of pavement and the thickness of the concrete pavement slab is effective [8].

In 2006, a study has been done by Joel on the some software of US aviation department, including LEDFAA and FEDFAA by using the formers researches on the analysis, designing airport in the world and the required development or progress for future wide-body airplane, the following results were presented: It is required to predict the status of runway pavement in the future, by considering new generations of wide-body airplane and damage through each of them with above software in two and three-dimensional environment of finite element, as regards, the next generation of air plane are more heavy and larger. The number of wheels and their arrangements has more important with increasing total weight of the next generation airplane and the need to select the best type of geometric arrangement of the wheels by producers [9].

In 1999, the America Aviation department used field test with real scale and through related facilities to real simulation of the airplane movement. Different types of airplane in terms of arrangement of wheels, their weights and simulate the effects of each other on the pavement [10].

3. RESEARCH METHODOLOGY

3.1. Introducing research place

Early studies for the establishment of Kerman airport commenced in 1925, building construction activity has started in 1956. Start transferring passengers and carrying cargo occurred from 1970 with two flights from DC6 kind during a week between Tehran and Kerman and return.

Kerman airport terminal has initial area of 600 square meters and length of the main runway 2,600 meters with a width of 45 meters and 2,000-meter secondary runway with width 45 meters. In 1981, lengthening operations and the cover of main runway has improved with a length of 3845 meters, a width of 60 meters in which it has obtained in 1366 and delivered certainly in 1990. The current situation of airport pavement can be seen in the figure 1.

3.2. Introducing modelling software

ABAQUS software is used extensively in the automobile industry, aerospace and industry of manufacturing industrial goods. Also, this software packages due to extensive capabilities in modelling for various materials, as well as the ability to

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customize it by programming, it is very popular in academic research area. Primarily, ABAQUS is designed for non-linear physical behaviour [11]. Overview of model has brought in Figure 2 after definition of crack and the manner of stress distribution.

Figure 1. Overview of cracks in the Kerman Airport runway

Mechanical and geometrical specifications for runway pavement layer were selected base on the table (1), it has been tried that they were close to realities of Kerman runway airport. Modelling has been done like three-dimensional and made model to prevent in the vertical and horizontal movement floor bed layer is completely closed. Crack like circle shape with length 40 cm were selected and with dimensions of 3 x 2.5 cm was chosen and for loading, wheeled Airbus A-320 was used which has the most number of flights in Kerman airport. Analysis was considered with assumption linear elastic behaviour, materials of pavement layers and loading in static (non-dynamic).

Table 1. Specifications of materials and geometry of pavement layer for flight runway

The type of used materials	*Sub-base*	*Base*	*Asphalt*	*Bed*
Density(kg/m^3)	*2200*	*2250*	*2300*	*1900*
E -Modulus of Elasticity (MPa)	*470*	*1250*	*12500*	*155*
Poisson's ratio(υ)	*0.35*	*0.35*	*0.3*	*0.45*
Thickness(cm)	*45*	*30*	*20-30*	*200*

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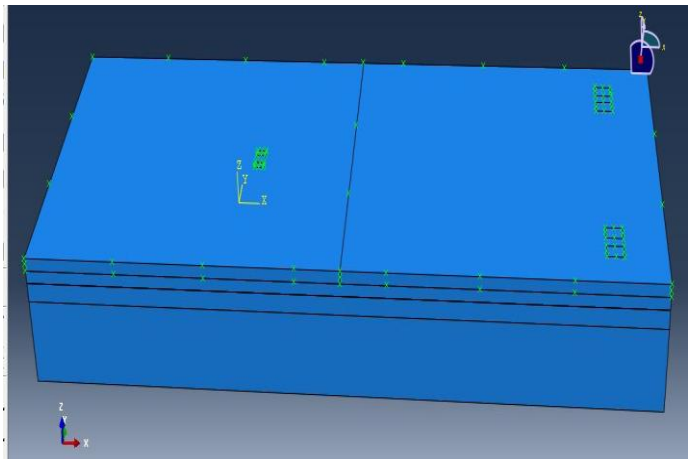
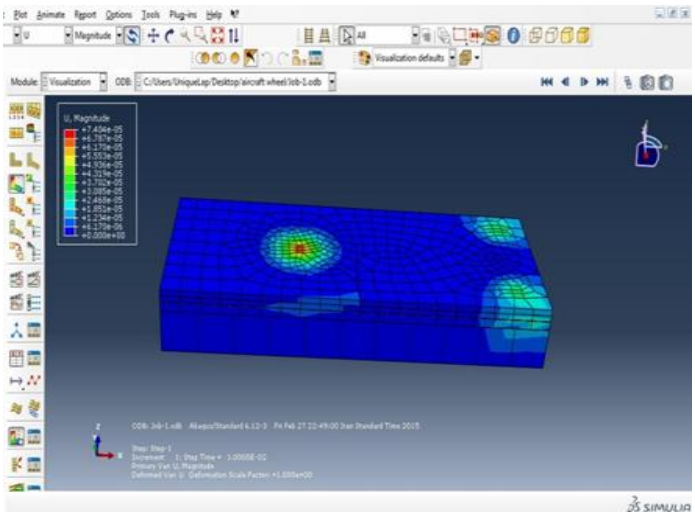


a)



b)

Figure 2. Cracks width modelling on the airport's asphalt runway and the manner of stresses intensity in uploading

4. THE SIMULATION'S RESULTS

4.1. Analysis model by changing the thickness of the pavement layer

On the designed model, to determine the effect of pavement layer thickness that this thickness is changed by covers frequent asphalt layer, the thickness of the asphalt's layer once 30 and once 20 cm was considered (Figure 3) changes of

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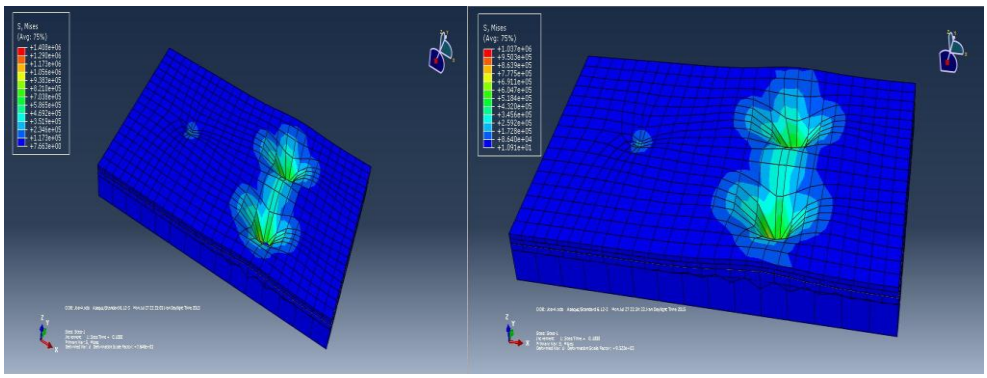
tension was shown in this layer, the stress reduced from 7.34×105 to 5.22×105(Pa).

4.2. Analysis model by changing the location of cracks in the surface layer

To determine the effect of changes for cracks occurrence on the rate of the stress concentration, was evaluated in two issues, crack in the latter manner was located between the wheels of the plane. The manner of changing the level of tension is considered which is displayed in Figure 4.



a) b)

Figure 3. Changing of stresses

a) 20 cm asphalt's thickness b) 30 cm asphalt's thickness

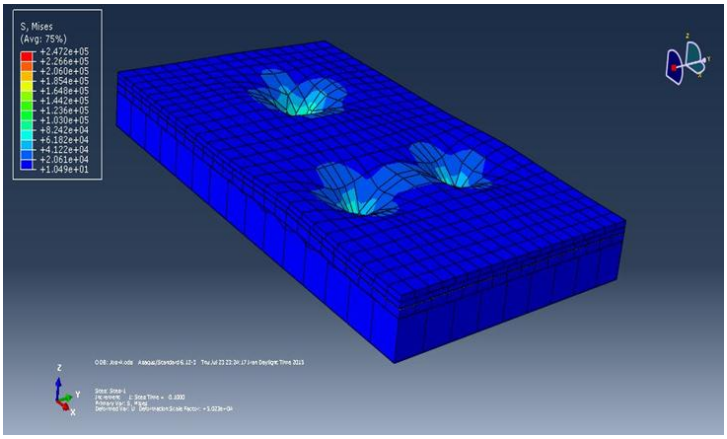


Figure 4. Changes intensity stresses with change location of cracking

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5. CONCLUSIONS

In this research was studied the aircraft wheel loading effect on stress at the fatigue crack by the finite element software. For compliance with real condition, crash data of the Kerman airport pavement actual was examined. Results show:

1. According to adapt the results of modelling runways and loading airplane was determined, the model and conditions of work has been properly treated;
2. In the first case, the thickness of the asphalt has changed, it can be seen that by increasing the asphalt's thickness, displacement and stress levels was reduced with about 30%;
3. In the second case, the crack displacement does not have effect on stress and moving.
4. Continuous assessment of airport pavement and identification the rate of damage in the airport pavement, particularly cracks predicted the possibility of damage growth and reduction the life chances.

It is necessary to mention that the results of this part of these studies include special case of a plane load and for different loading and the wheel movement is required to apply different load and the structural conditions in the software.

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