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Examining roads' pavement management and flexibility of elasticity theory

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ABSTRACT

Roads are economic arteries of any country, without which there is no possibility of any social and economic activities. The more expansion and quality of roads networks increase, the more transportation of travellers through ground channels will be and as a result, far and near points will enjoy more facilities and in the end, the country will move towards development. Roads are comprised of various sections and are divided into various formats. However, the most definite and tangible section of any road is its pavement. Pavements are thought of national investment of any country where, annually a large part of construction budget coming from relevant organizations is spent on repair, maintenance, and perseverance of them. Securing sufficient budget for this issue is among subjects that have always obsessed the minds of high ranking officials. In the past, focus was always directed at preserving the pavements and pavement management was an unknown task. The determining factor in choosing the most appropriate way of repair and maintenance was the engineers' analysis and little attention was focused on life cycle incurred costs or prioritization based on the necessity at the network level. In modern economy, as with the life of pavements, there is a need for a systematic method for determining necessities with regards to repairing and marinating. Today, pavement networks need management and maintenance cannot suffice alone. Attempts have been made in this research to examine the asphalt pavement management as affected by vertical loading at the top of the paved surface under investigation where through the elasticity theory and simplifying theory by way of Burmister for layered model, the relevant mathematical theory was expanded and foundations of a computer program was accordingly formed. Progress recently made in the area of microcomputers and technology of pavement management have brought about the tools needed for managing the pavements economically, thereby creating a systematic and coherent pavement

management system for choosing necessities related with delineation, maintenance, specification of priorities and optimal time for repair through creating pavement situation in the future.

***Keywords*:** Pavement management; Roads; Ways; Elasticity; Pavement network

1. INTRODUCTION

The goal of pavement of a road or a runway is construction of a smooth and even surface with sufficient safety for those using the roads or runways. Pavement should be built such that it can sustain the weight of vehicles and be usable in any climate situation. The ground, under normal conditions has not the enough resistance for withstanding loads coming from wheels of heavy machineries and vehicles like trucks and airplanes and loading such soil will engender in the failure of the soil's shear and creation of excessive deformations. To avoid soil's shear failure creation of excessive deformations, the severity resulting from the vertical pressured tensions on soil need to be reduced. This task is done with placing a layer of high quality material with high resistance on soil. Genus and thickness of this layer which is known as pavement should be capable of withstanding loads while reducing severity of the vertical pressured tensions for degree to which the pavement bed soil can withstand. Analysis of pavement is a major issue which assumes special importance in accordance with expansion of building industry and road construction industry. Various ways have been offered or analysis of pavement and each of which, in its turn involves weak and strong points. Two major methods in analyzing these issues are the logic of layered theory and theory of limited components. It is clear that using each of the methods requires observance of primary assumptions as well as special conditions governing on that method. That which is discussed in t6hios project is introduction of two major ways of flexible pavement analysis where one of which is using the elasticity theory and layered system and the other is limited components. Efforts are made to examine the layered system and accordingly, the Burmister's method layer resolution and hence more mathematical details are to be discussed.

2. STATEMENT OF THE PROBLEM

Pavements are usually affected by many factors and from this viewpoint, their designing in comparison to designing bridges and building s and other technical buildings are more complicated. One of the problems that exist in designing pavements is variability of factors which affect designing pavement. Regarding flexible pavements, bed soil plays a major role in designing pavement and hence, cares needs to be taken while investigating and studying pavement bed soil. Rigid pavement which includes concrete pavements is pavements in which one or several layers with high rigidity are used. These kinds of pavements transfer external loads to the bed soil without high deformation of the concrete surface at a relatively wide surface. Flexible pavements could be analyzed by using Burmister's multi layered theory. The most important limitation of the above theory is the assumption of infinity of each of the layers at a horizontal surface which makes the above theory unusable for use in rigid pavement with cracks. In addition, the above theory regarding rigid pavement where the load is exercised over their angles cannot be applied because this incoherence will result in large tensions at the edges. Using flexible pavements engenders in the fact that the load distribution to be done in concentrated form and almost approaching the points where the points leave effects. In case, the distance of the wheel from the edge is more than two feet, incoherence of the edge will leave a meager effect on tensions and critical strains (Yoder & Witczak, 1975). Conventional flexible pavements consist of a multiple layered system, above their sections where the amount of tension is high, high quality material is used and in their lower sections, where the amount of tension is low, material with low quality is used. Above events allow for this fact that one can apply local; material where this issue will result in making the plot more economical. The recent case hold true especially in regions where material with high quality is expensive and material with low quality is cheap. Figure (1) indicates cross-section of a conventional flexible pavement. The material applied in this kind of pavement from above is: plastering; sub-basis layer and compacted bed. Application of each of the layers or clusters mentioned depends on requirements of the plot and economic observations.

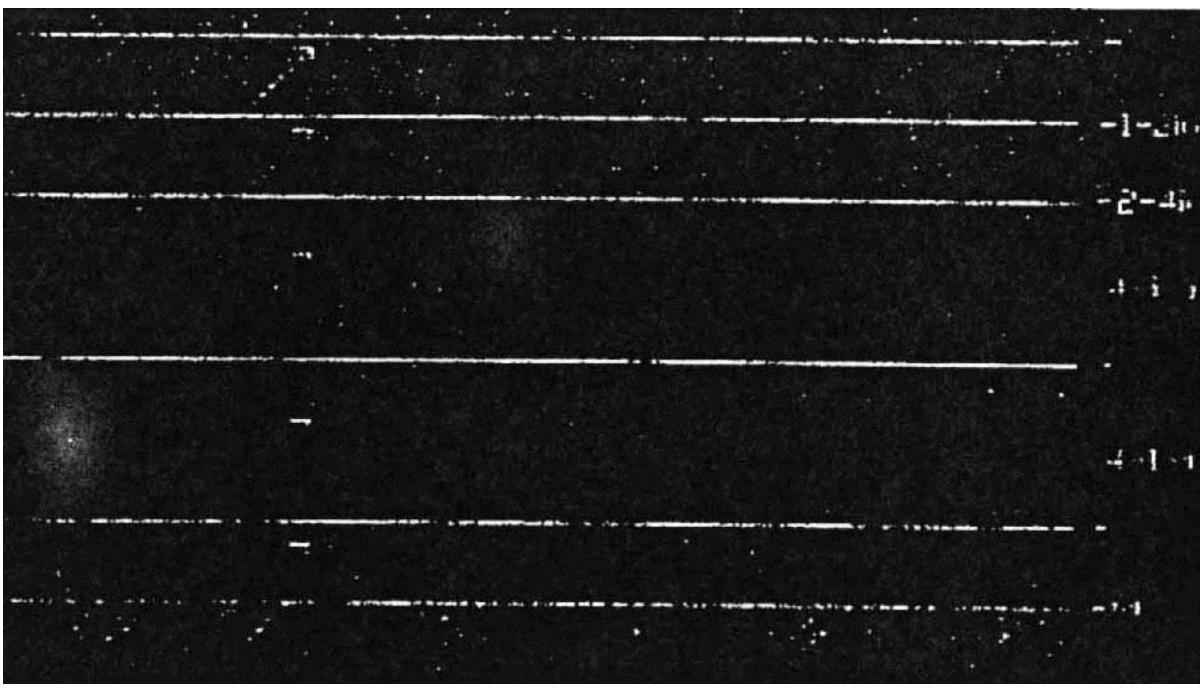

Figure 1. Cross-section of a conventional flexible pavement.

3. EFFECTS OF LOADING AND CLIMATIC FACTORS ON PAVEMENT SYSTEM

Severity of vertical pressured tensions which are created as a result of sol mass is different in various points. The severity of these tensions in points located under the surface loaded is at a maximum and with an increase of distance of these points from the surface loaded, the severity of these vertical pressured tensions will also decline. In Figure (2), the curve of vertical pressured tension changes in a mass of soil as a result of a homogenous load with a circular surface level is seen. In accordance with the principle, in cases where the thickness of pavement is great, one can administer and implement it with several layers with different requires in order making the pavement's building more economical.

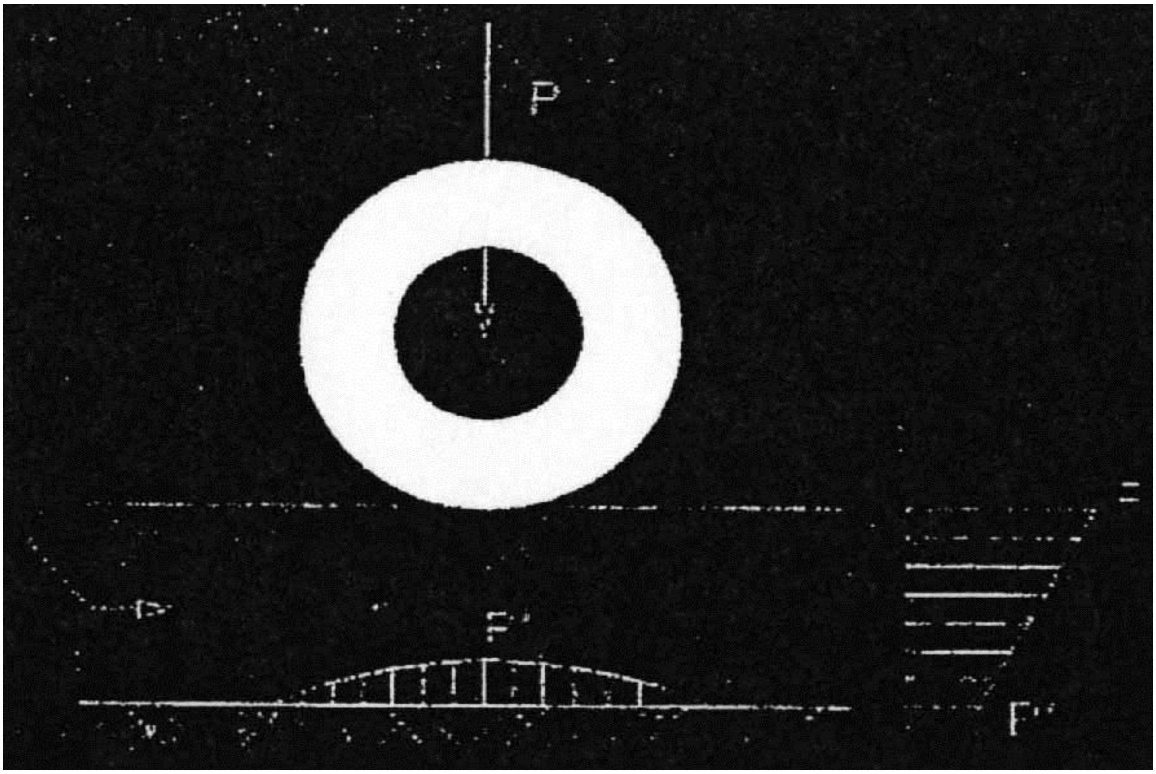

Figure 2. Distribution of vertical tensions in a mass of soil.

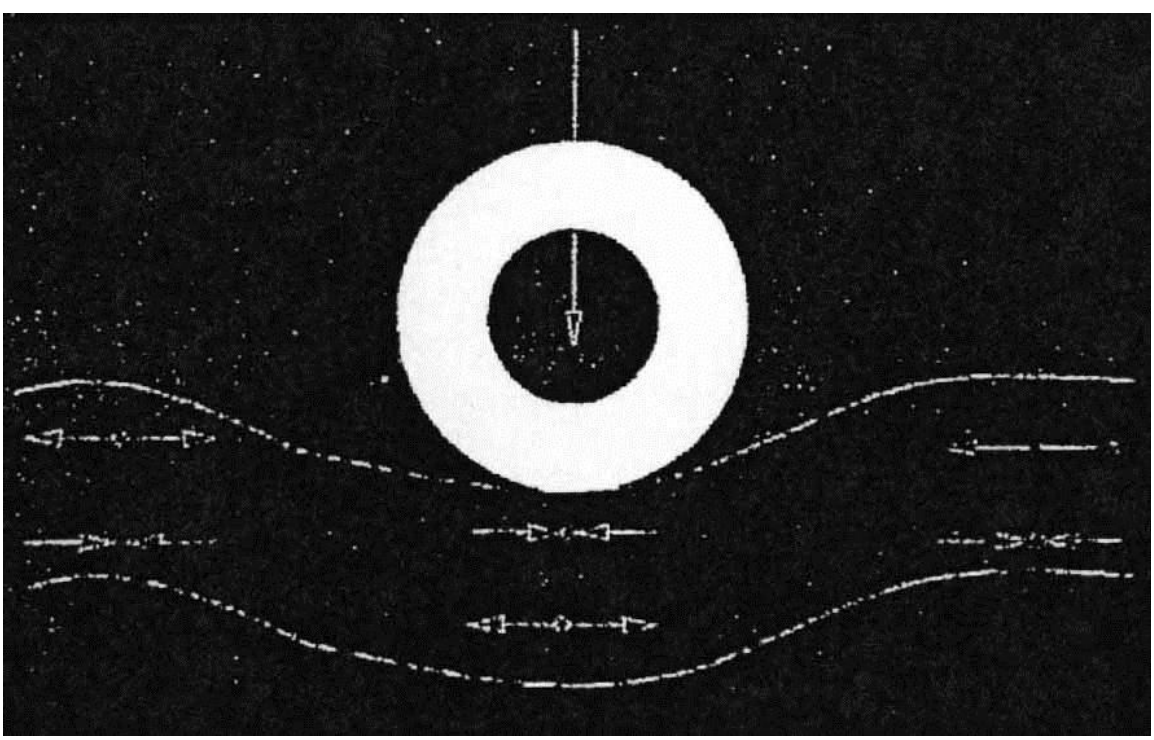

Figure 3. Creation of tensile and pressures tensions on pavements.

The way in which pavement layers are commonly arranged need to be in such respects where layers with more resisting and high quality material is placed layers above the pavement, because in these points, severity of pressures tensions will be great on the pavement and material with low quality and resistance in lower layers where tension level is lower therein is used (Austroads, 1992).

Genus and material of pavement layers need to be chosen such that they can resist against tensions incoming on it and reduce the severity of the tensions to the level the lower layers can withstand. Roads and ways with high frequency and airports, higher layers of pavement and especially paved layer are made of cement and bitumen material. As a result of pavement loading, these paved surfaces will get deformed and horizontal tensile and behavioral tensions will be created (Figure 3).

When the severity of horizontal tensile tensions on the pavement layer get greater than the tensile strength of the material of that, cracks will appear. Therefore, genus and thickness of pavement layers built with cement and bitumen material must be chosen such that it will resist against horizontal tensions and do not crack.

4. FACTORS AFFECTING DESIGNING OF PAVEMENTS

Pavements are affected by numerous factors and from this viewpoint, their designing compared to designing bridges and buildings and other technical constructions are more complicated. One of the problems that exist in designing pavements is variability of factors which affect designing pavement. Regarding flexible pavements, bed soil plays a major role in designing pavement and hence, cares needs to be taken while investigating and studying pavement bed soil. Rigid pavement which includes concrete pavements is pavements in which one or several layers with high rigidity are used. These kinds of pavements transfer external loads to the bed soil without high deformation of the concrete surface at a relatively wide surface (Romanoschi Sefan & Mtacalf, 2001).

5. FLEXIBLE PAVEMENTS' LIFE SPAN DECLINE

Flexible pavement layers are usually made of different genus in various thickness for some economic observations. The way in which two different layers contract on multiple layer pavements will determine their "inter-layer conditions". Inter-layer conditions are effective in the degree of reflections under loading. Premature failures seen on pavements occur mostly because of designing a construct without considering that which occurs in implementation. Currently, in the ,method of "mechanistic thickness design" which is done based on level of reflections of the object's construct, knowing inter-layer conditions has found a major role. Using "single coating" and "Prim coating" between two asphalt layers or an asphalt layer and a stone material layer, will bring about inter-layer adhesion. The level of inter-layer friction, in addition to existence of above plastering depends on density, genus and quality of layers' material; the more density of higher layers is, the more compactness (depression) of inter-layer components will be and the internal friction level will decline. The level of stone material resistance between layers will cause the resistance of friction to rise (Young & Huang, 1993).

6. IMPACTS OF HORIZONTAL LOADS AND INTER-LAYER FRICTION ON THE LIFE OF PAVEMENTS

Lack of existence of infinite inter-layer conditions in horizontal loads will engender occurrence of wave like deformations in slopes, walkways and points at which heavy vehicle start to move. Examining inter-layer conditions and horizontal loads has been performed with the help of Finite Elements Software (ABAQUS) where in these studies, the pavement geometric model has been created with different elements and inter-layer conditions have been made via definition of kinds of knots. In other researches, measurement of inter-layer friction has been accompanied wit mechanical-laboratory experiences including Shear Test Guillotine Type and Direct Test. All studies have demonstrated that horizontal loads will increase higher and lower tensile tensions of the above paved surface and high end of the lining layer, thus rendering in the premature decline of then paved surface. Accumulating effects of inappropriate inter0layer conditions and horizontal forces on the pavement surface are great which will reduce the pavement life for as many as 300 times the half rigid pavement and 15 times the flexible pavements.

7. THEORETICAL ANALYSIS OF INTER-LAYER CONDITIONS EFFECTS

Two various layers which are placed on each other is a simple model of layered pavement; when these two layers are placed under the effects of vertical loading, some deformations will be created in them which bring about some tensions and strains therein. Relations 1, 2, and 3 are related to tensions and strains (Stephen, 1965).

$$\varepsilon_x = \frac{1}{E}(\sigma_x - \vartheta(\sigma_r - \sigma_t)) \qquad (1)$$

$$\varepsilon_r = \frac{1}{E}(\sigma_r - \vartheta(\sigma_1 + \sigma_2)) \qquad (2)$$

$$\varepsilon_t = \frac{1}{E}(\sigma_t - \vartheta(\sigma_1 + \sigma_2)) \qquad (3)$$

where:

ε_z, σ_z = vertical pressure tension and strain

ε_r , σ_r = radial pressures tension and strain

ε_t, σ_t = tangential pressure tension ad strain

The directions of these strains are observed in Figure, 1. When the two layers are made to move on each other, in the distance between the two layers, tangential and radial strains will equal 0 and according to above relations, the vertical strain will be acquired from relation 4.

$$\varepsilon_{z1} = \frac{1}{E}\sigma_{z1} \quad (4)$$

when the two layers are not made to move on each other, racial tensions σ_r and tangential tensions σ_t contradict 0 and the value of ε_{z2} will decline.

$$\varepsilon_{z2} = \frac{1}{E}(\sigma_{z1} - \vartheta)(\sigma_{t1} + \sigma_{rh})) \quad (5)$$

In accordance with the two above relations ε_{z2} the vertical strain in the second state is less than ε_{z1} of the vertical strain in the first state; i.e.7

$$(6) \quad \varepsilon_{z1} > \varepsilon_{z2} (6)$$

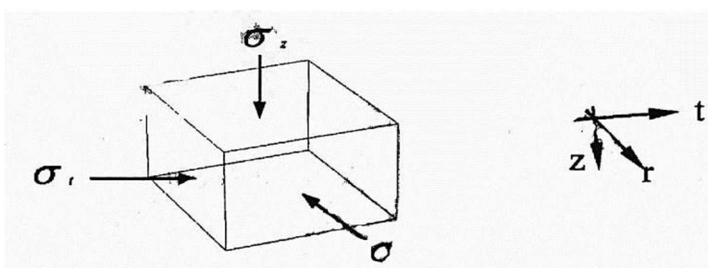

Figure 4. Simple model of layered pavement with systems' specifications determined.

8. CHOOSING MODEL AND ANALYTICAL METHODS

In investigating the impacts of inter-layer conditions of the pavement performance, models are used which involve various pavements so that the impacts of proper non-implementation of interlayer conditions are comparatively estimated on the pavement performance. Also, loading condition is selected such that it considers the maximum heavy weights which render the highest destruction in the paths. Also, the life of pavement is estimated on the basis of passing standard axes through theoretical relations (Stephan, 1965).

9. PAVEMENT GEOMETRIC MODEL

Pavement is modeled in three various states. Pavement models along with material used are provided n the following tables.

a) Weak bed (CBR = 3/5); weak pavement (SN = 4)

Table 1. Geometric model of pavement along with information related with material.

Paved	5cm	↕	$V = 0/35$	$E = 20000 kg\ cm^2$
Lining	5cm	↕	$V = 0/35$	$E = 15000 kg\ cm^2$
Base	20cm	↕	$V = 0/3$	$E = 3500 kg\ cm^2$
Base	20 cm	↕	$V = 0/4$	$E = 2000 kg\ cm^2$
	V = 0/4	↕	$E = 350 kg\ cm^2$	

b) Strong bed (CBR = 35); weak pavement (SN = 4)

Table 2. Geometric model o pavement along with information related with material.

Paved	5cm	↕	$V = 0/35$	$E = 20000\ kg\ cm^2$
Lining	10 cm	↕	$V = 0/35$	$E = 15000\ kg\ cm^2$
Base	20 cm	↕	$V = 0/3$	$E = 3500\ kg\ cm^2$
Paved	20 cm	↕	$V = 0/4$	$E = 2000\ kg\ cm^2$
	V = 0/4	↕	$E = 3500 kg\ cm^2$	

c) Strong bed (CBR=35); string pavement (SN=6)

Table 3. Geometric model of pavement along with information related with material.

Paved	5cm	↕	$V = 0/35$	$E = 30000\ kg\ cm^2$
lining	10 cm	↕	$V = 0/35$	$E = 25000\ kg\ cm^2$
Base	20 cm	↕	$V = 0/3$	$E = 5000\ kg\ cm^2$
sub-base	20 cm	↕	V = 0/4	E = 3500 cm^2
	V = 0/4		E = 3500 cm^2	

10. RESOLUTION OF LAYERED SYSTEMS BY USING MULTI-LAYERED THEORY

The simplest way for examining flexible pavement behavior under the influence of circular effects is to consider the fact that these pavements are homogenous in form of a half space. The Baussinesq's principle theory (1885), has been stated on the basis of effective concentrated load on a half elasticity. Via combination of tensions, strains and displacements arising from the concentrated loads, these parameters can be obtained under the influence of a circular load. Prior to presentation of layered theory by Burmister (1983), much attention was paid to Baussinesq's equations, because the above method was the only method available. In case the ratio of layers' elasticity modules approaches one, one can obtain tensions, strains and displacements via Baussinesq's theory. In case, the ratio of layers' elasticity modules does not approach one, equations need to be reformed where this case has been under concentration in the Kansas's designing. Figure, 5 indicates a half space on which a circular load with radius and homogenous pressure q inflicts.

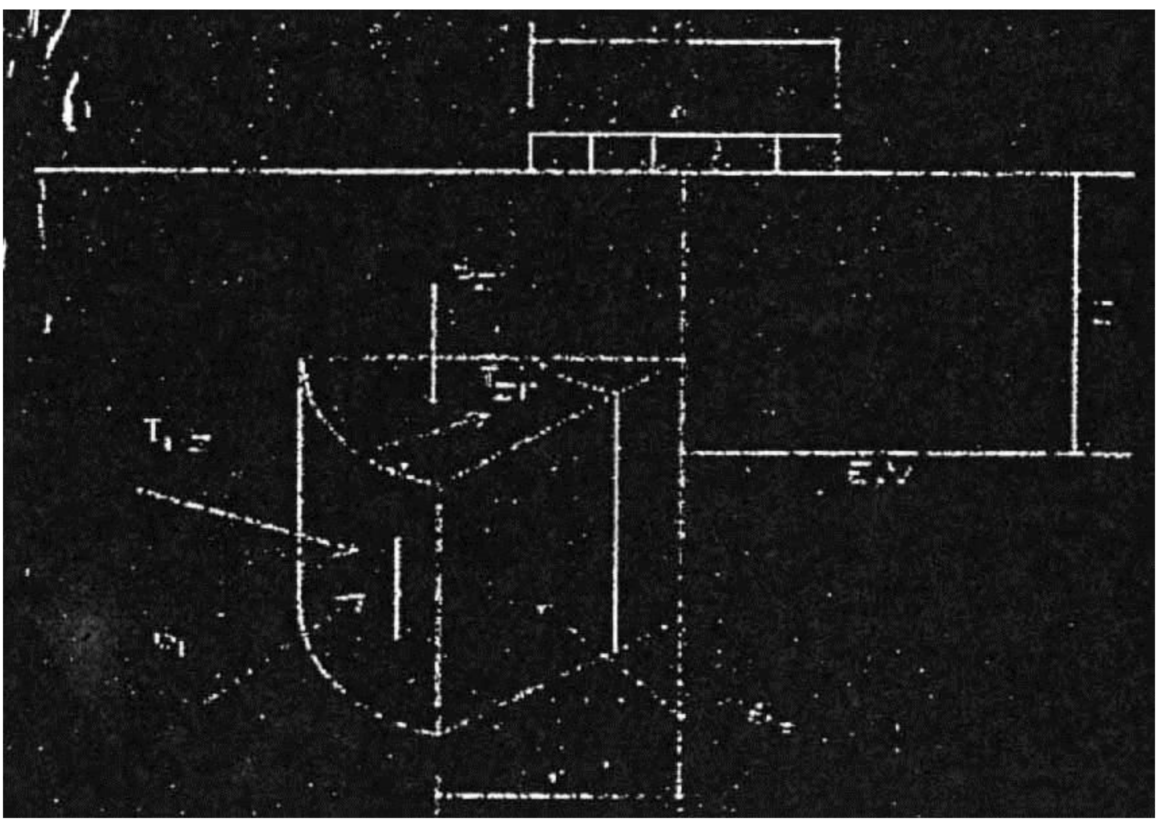

Figure 5. Limited half space from above.

Figure 6, demonstrates multi layered system in a cylindrical axis system. The n layer contains unlimited thickness. In the elasticity theory, an appropriate way for estimating the issues related with axial symmetry is a tension function which signs differential equations being compatible with as well as coherence. Having after estimating this tension function, tensions and displacements can be obtained.

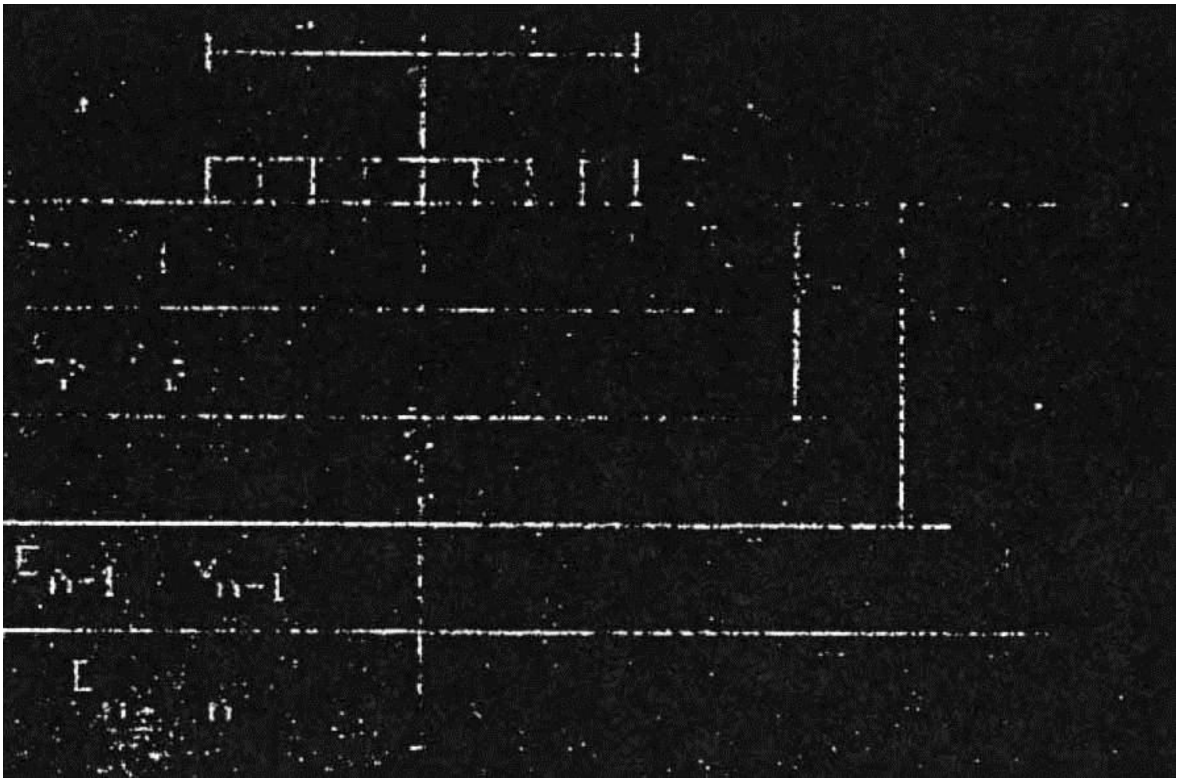

Figure 6. Multi layered system in a cylindrical axis system.

11. SUMMARY AND CONCLUSION

1. There are two common ways for analyzing flexible pavements which are multi layered method and limited components method
2. The multi-layer method, with the assumption of infinite has been [resented in the horizontal and infinite line and the depth of the lowest layer and has been accepted as a resolution for analyzing flexible pavements. Currently, most flexible pavement analysis programs utilize the above methods, because modeling pavements is simpler via the above method and the solution of the system by the computer needs les time in comparison with limited components. Of most limitations of this research, we can refer to the inability of this method in limited systems analysis and also systems which are under the influence of environmental factors (like heating tensions).
3. The most appropriate way for the non-linear resolution of pavement is the method of limited components. The mentioned method can be applied for analyzing limited systems. In choosing elements and modeling pavements via using limited components, care needs to be taken so that responses can be provided.
4. Pavement resolution by computer via using limited components requires more time compared to multilayered method. Also, by using the limited components method, one can obtain responses to pavement under heating tensions and model each of the material based on its characteristics.

References

[1] Austroads, S. (1992). Pavement Design-a Guide to the structural Design of pavemen, Sydney.

[2] Yoder, E.J., & Witczak, M.W. (1975). Principles of Pavement Design, 2nd edition, John Wiley and Sons INC/Incorporating the south Africa Mechanistic Pavement Design, "PADS 1.10 User's Guide", Computer program.

[3] Yang, H., & Huang, D. (1993). "Pavement Analysis and Design", Prentice Hall, Englewood Cliffes, New Jersey.

[4] Young, H., & Huang, D. (1993). "Pavement Analysis and Design", Prentice – Hall, 1993, pp. 590.

[5] Romanoschi Sefan, A., & Mtacalf, J. B. (2001). "Effects of Interface Condition an Horizontal Whell Loas on the Life of Flexible Pavement Structures", *Transportation Research Record*, 1778 (2001) 123-131.

[6] Romanoschi Stefan, A. & Metcalf, J. B. (2001). "Characterization of Asphalt Concerete Layer Interfaces", *Transportation Research Record*, 1778 (2001) 132-139.

[7] Timenshko Stephan, P. (1965). "Mechanics of Materials", McGraw – Hill, pp. 629.

[8] Shell International Petroleum Company Limited, "Shell Pavement Design Manual", Shell Company, 1995, pp. 250.

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