IJBPAS, May, 2015, 4(5): 2417-2432

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

INVESTIGATING OPTIMUM THICKNESS IN ASPHALT RECYCLING

SEID HAMED MOUSAVI[1] AND MASOUD NASR AZADANI[2]

Correspondence: E Mail: H_mousavi@iau_ahar.ac.ir; nasrazadani@iust.ac

1: M Sc. at Islamic Azad University of Ahar

2: Assistant professor Iran University of Science & Technology

***This article is extracted from Master's Thesis**

ABSTRACT

Today, energy resources have economic and environmental role in asphalt recycling. In general, asphalt material recycling refers to a process that old materials become usable through another process. In addition, determining thickness of asphalt and lower layers has specific importance in road construction, which can have considerable effect on electromagnetic pulses. One of the main advantages of reuse of materials in recycling project in addition to protection of natural resources can be reduction of thickness of layers. Recycled Asphalt Pavement (RAP) may result in undesirable effects. In this study, efficiency of optimum thickness in recycled asphalt using recycled materials would be studied. In fact, the study has compared recycled materials (recycling asphalt hot mix and asphalt rubber). In this regard, one zone of Tehran has been studies, assuming that hot mix asphalt is equal to 3.45 (KPT), thickness of asphalt is 5cm and its lifetime if 6 years. Using hot mix asphalt in same situation can reduce 23% of relevant problems with it. According to lifetime difference among different materials, the present study would apply each material in a 40-year period for purpose of evaluation of the environment. Obtained results indicate that high percent of the problems are related to two sources: asphalt binder (39-48%) and required thermal resources (42-50%) that can be applied in materials of sidewalk. The results indicate that the most effective way for reduction of environmental problems may be decreasing required heat in production process. Hence, the present study has investigated thickness recycles asphalt and its effect on road construction.

Keywords: Optimum Thickness, Recycled Materials, Hot Mix, Road Construction, Asphalt

INTRODUCTION

Asphalt is being used for many years as a construction material; although it has been produced for the first time in 1983 and has been supplied to the market by 1901. In Iran, because of existence of abundant oil and asphalt resources, most roads have asphalt pavement, which is so complicated in terms of structure and is a system that its efficiency is under effect of various factors such as traffic, environmental conditions, and type of soil and materials of the area. The main objective by designing flexible pavements is providing asphalt that can be resistant against traffic and can also supply some elements that are able to provide desirable efficiency for the road. Hence, some actions should be taken to prevent early destructions of superstructures. This is because; presence an efficient road network needs planning for maintaining it. Over the years protection of roads has been significantly considered. According to limitation of capital and budget in Iran and also for purpose of protecting existing capitals, maintenance of asphalt pavements is an essential action. Today, determining asphalt thickness and lower layers is so important in road construction, so that lack of observance of asphalt thickness and its lower layers can cause fines for the contractor. For purpose of determining the thickness, currently ground penetrating radar (GPR) is being applied. In this method, short electromagnetic pulses would be applied (Daryaei, 2012).

Recycling asphalt mixes has been studied in Iran and some other countries and has been designed and implemented in from of various methods such as cold, hot, in place and factory recycling (Park, 2005). In the recycling process, badly produced or badly implemented materials would be reused. Old asphalt can be applied for purpose of building superstructures or repairing existing superstructures (Mazinani & Kamkar, 2010).

The first step in regard with reuse of existing superstructure is changing asphalt and aggregated materials into standard and usable materials in construction of new superstructures. Asphalt particle chips can be applied in all asphalt operations such as renewal, implementation of coating and repairing road pavement. In general, asphalt recycling refers to a process, in which pitch and old aggregates would become usable through another process (Ministry of Transportation, 2004).

Reclaimed asphalt pavement, which can be produced as waste material as a result of renewal and exfoliation of asphalt pavements, can form large part of waste materials (Okafor, 2010).

Asphalt recycling methods include two cold and hot types. Cold method as one of the main methods for maintenance and renewal of roads includes some operations as follow:

- Removing asphalt layer
- Plowing asphalt layer
- Exfoliation of asphalt layer
- Grinding asphalt layer

Cold recycling refers to two in place and factory recycling (Iran's Management and Planning Organization, 2006). In many countries and especially Iran, main part of good and passenger transportation would be conducted through roads, so that other transportation methods are placed in other positions. Road transportation is one of the key elements of social-economic development and attracts mostly main part of national budgets. Road transportation helps process of development through facilitating domestic and international commerce and helps also improvement of access to jobs, education, healthcare services, relief in critical situations and so on (Okafor F, 2010). In Iran, in addition to the mentioned characteristics, geographical conditions and also insufficiency of railway network can cause more importance for the road transportation network. Road transportation of goods in Iran has possessed about 89% and its portion in transferring passengers is about 93%.

Hence, it could be found that road network is one of the vital sectors of transportation in Iran. Due to amount of investment in construction of roads, it is necessary to maintain the large national resource seriously. Destruction of roads can result in wastage of the above mentioned capital in addition to other indirect costs such as more depreciation of vehicles, increase in traveling time and destruction of the environment. Hence, it seems essential to study efficiency of asphalt thickness in recycling scope. According to the mentioned, it seems that the resent study has considered investigation of efficiency of optimum thickness in recycled asphalt.

RESEARCH LITERATURE

Fakhri and Ghani Zadeh (2004) have conducted a study under the title of "optimization project of Ashto using linear planning method". Proposed model in this study has been able to determine optimum structure and thickness of pavement layers in form of a linear planning model. The mentioned model has the ability to determine optimum structure of pavement composed of asphalt layers, aggregate structure and aggregate infrastructure. The model has not the ability to determine thickness of asphalt materials including Topeka Cortex, binder and pitch foundation based on maximum size of aggregate. Obtained results from the study indicated that optimum thickness and optimum configuration of pavement had direct relationship with ratio of implementation cost to cortex coefficient of each layer. The lower the implementation cot to cortex coefficient ratio is, the more the probability of thickness in this layer should be, so that the pavement can be cost effective (Fakhri, 2004).

Afra and Kamkar Ruhani (2010) have also presented a study under the title of identification and determination of asphalt layer thickness using GPR method. In this study, it was mentioned that GPR method (Ground Penetrating Radar) has acted so successful in regard with facilitation and acceleration of data perception, which electromagnetic specifications change in the boundary between two areas incidentally. One of the main successful fields in regard with GPR is separation of different layers of asphalt in roads from lower layers to the pavement. In this study, the subject has been conducted on obtained data using GPR method with fork antenna (1GHz) in communicative axis of Shiraz-Jahrom (Fars Prvince). Determining depth was also conducted using velocity analysis method, which is specified to gained data from roads. Studied axis was 36km in length. Spatial distance considered for the study was in range of 8840-9080m from beginning point of vector data. Obtained results from the study indicated that asphalt had 4 layers in the studied area. The first layer (pavement) was about 5cm; second layer (sub asphalt) was about 12cm; third layer (base) was about 10cm and the fourth layer (sub base) was about 30cm in thickness. The thicknesses were confirmed by relevant data of excavated samples (Afra, 2010).

Ali Akbari Bidokhti (2012) has conducted a study under the title of using reclaimed asphalt pavement (RAP) in the base pavement layer. The study has mentioned that in the current age of shortage of energy resources, economic and environmental role of reuse of recycled asphalt materials is a clear issue. One of the main layers in pavement is base layer, in which recycled asphalt materials can be applied. Advantages of reusing the materials in base layer is that in addition to preserve natural resources, it can enhance loading ability of the pavement and as a result, it can reduce thickness of pavement layers. The advantages, along with low costs of road construction compared to the new materials, have provided the conditions or further study of allowed values of using it in base layer. The study ahs estimated allowed value for using RAP in base layer to 50% (Ali Akbari Bidokhti, 2013).

Apeagyei et al (2011) has investigated rutting resistance of asphalt-concrete mixtures that contain recycled asphalt pavement. The study has evaluated rutting resistance of AC produced in the laboratory. 9 asphalt-concrete (AC) samples were applied in the study. The mixture contained RAP varying from in 0-25% range. Statistical analyses in this study indicated that RAP value is the most effective factor in rutting resistance in hybrid studies. There was also a reverse linear relationship between RAP and FN, which was able to describe data properly (Apeagyei, Diefenderfer, B. K., & Diefenderfer, S. D 2011).

Wen (2011) conducted a study in order to investigate high percent of recycled asphalt pavement as the core material. The study has indicated that increase in RAP percent, the value would be increased and also increase in humidity and heat degree can result in reduction of RAP materials. The study found that freezing and melting have no effect on this process. More amounts are more applicable for the pavement operation, since RAP resistance in base layer can protect the surface layer. As a result, tensile stress would be reduced in lower part of asphalt. The study also indicated that rutting potential in base layer was high under high temperature and humidity, which its penetration could be decreased with the increase of RAP percent (Wen, 2011).

METHODOLOGY

Methodology is a series of rules, instruments, and valid and systematic methods for purpose of investigating realities, exploring ambiguities and achieving solution of problems. It should be noted that reliability of research achievements are significantly under effect of reliability of applied methodology. The present study has been an applied research in terms of objective and is a descriptive-analytical study in terms of method of data collection. In this study, 3 kinds of sample have been examined. One RAP sample has been selected and other two samples have been selected from materials in the base layer. Then, thickness of pavement in each sample has been calculated using formulation.

Data analysis method

For purpose of careful assessment of available evidences in this study and using hybrid database of study of Park et al (2005), obtained results have been analyzed using MATLAB software.

Sensitivity analysis of asphalt responses

Common structure of asphalt with long lifetime has been depicted in **Figure 1**. Asphalt pavement has been composed of three different layers including pavement, mid layer and base layer.

Through sensitivity analysis of asphalt responses, input variables were determined that can be mainly effective in fatigue cracks and wheel effects. In sensitivity analyses of each layer thickness and modulation in the mid and base layer, they would be changed from assumed base value one by one; although other parameters have been remained fixed to the base value. Change in predicted critical response of asphalt as a result of change in the given parameter has been estimated using finite element program ILLIPAVE. This is because; treading and paving processes have been applied on pavement layer in intervals of 5-10 years. The layer has been excluded form this study and the thickness value have been obtained equal to 50mm with modulation of 3Gpa.

Base thickness in mid and base layers has been respectively equal to 150 and 100mm. Each layer thickness has been changed ±30% of its base value. **Figure 2** illustrates percent of change in predicted strain resulted from changes associated with thickness.

Percent change in ε_t and ε_c in mid layer was 2.3 times higher than base layer. According to **Figure 2**, change in thickness in mid layer is significantly sensitive to ε_t and ε_c.

Base modulation in mid and base layer has been assumed to 8GPa and 3.5GPa. Similar to sensitivity analysis for layer thickness, percent change in ε_t and ε_c would be changed with layer modulation of ±30%. Analytical results have been presented in **Figure 3**.

It could be observed that percent change of ε_t in change of mid layer modulation is approximately 1.4 times larger than it in base layer. However, there is no difference in ε_c variation, when the modulation in mid and base layer is changed. As a result, sensitivity analysis of thickness in mid layer is the most effective factor for controlling critical responses of asphalt and should be considered in regard with designing thickness of asphalt layer.

Structure of asphalt that is conventionally being used is composed of 4 layers including pavement, mid, base and sub base layers. Layer thickness and modulation would be selected using production of random number and have been placed in ILLIpave program, so that sensitive asphalt responses could be obtained. Contact pressure for loading is equal to 689KPa and contact diameter is equal to 152.4mm in forward calculation. Critical asphalt responses considered here are tensile strains under the AC layer. **Figure 4** has illustrated structure of standard asphalt and table 1 has indicated limit of input parameters for analysis.

Pavement layer thickness has been considered to 5cm, since treading and paving would be only performed once every 5-10 years in asphalt with long lifetime. As asphalt with high resistance has been applied for purpose of resistance modification, modulation of mid layer is 4 times higher than modulation of conventional asphalt materials. In order to decrease tensile strain beneath the AC layer, asphalt materials in base layer have at least modulation equal to 2GPa.

Limit of resistance of critical responses of asphalt that can be satisfied by asphalt with long lifetime can be reported based on TRL. For resistance level of fatigue crack, tensile strain in sub layer should be equal to or below 65 strain µ. Suppressive strain above the sub grade is equal to 200 strain µ in limit of resistance for constant deformation. As value of actual strain is lower than the resistance level, asphalt has more than 40 years lifetime and can be considered as asphalt with long lifetime.

Figures 5 and 6 illustrate relationship between total thickness of AC, ε_t and ε_c by integrated database. As it is illustrated in the mentioned figures, if ε_t asphalt is lower than 65 strain µ, usually ε_c below 200 strain µ indicates that ε_t can be controlling factor for the relationship. Hence, relationship between ε_t and thickness of AC layer has been analyzed in this study. When thickness of AC total is lower than 250mm (zone A), regardless of modulation and thickness of other layers, calculated strain in most cases is more than resistance level. The asphalts can't be considered as asphalts with long lifetime. Asphalts with thickness of AC layer above 410mm (zone C) can be considered as asphalts with long lifetime. In regard with zone B, long lifetime asphalt would be determined based on modulation of materials and thickness of other layers.

Figures 7 and 8 have illustrated effects of thickness and modulation of mid layer on tensile strain in AC sub layer. It could be observed that tensile strain tends for reduction, while the thickness and modulation is increased. Thickness of mid layer in 95% asphalt is more than 150mm and modulation is 5GPa and ε_t lower than 65 strain µ. For purpose of increasing lifetime of asphalt, thickness of mid layer should be larger than 150mm and asphalt materials with modulation more than 5GPa should be also applied. It was cleared that there is no clear relationship between ε_t and thickness and modulation of layer in base, sub base and sub grid layers.

At the present study, it has been attempted to use regression model to generalize response of asphalt, which has been reported by Park et al. it has been also attempted to calculate 3 kinds of RAP materials and base layer.

It should be mentioned that as thickness and modulation of sub grid can't affect tensile strain of AC sub layer, they would be excluded from regression equation.

Layer thickness and modulation in mid and base layers are given to the regression equation as inputs and then ε_t has been calculated.

$$\log(\varepsilon_t) = 5.545 - 1.91\log(H_2) - 0.2731\log(H_3) - 0.397\log(E_2) - 0.288\log(E_3)$$

$$[R^2 = 0.9579, SEE = 0.0375] \quad (4\text{-}4)$$

ε_t = tensile strain in AC sub layer (strain µ)

H2: mid layer thickness (mm)

H3: base layer thickness (mm)

E2: mid layer modulation (GPa)

E3: base layer modulation (GPa)

As a result of analysis, flowchart for procedure of determining layer thickness in asphalt has been presented in **Figure 9**. Optimum thickness of layer has been determined through changing thickness and modulation, so that the requirements of asphalt can be satisfied.

A simplified procedure for determining layer thickness has been proposed in this study. **Figures 10-12** have illustrated relationship between layer thickness and mid layer modulation in different thickness and modulation for base layer. Gray-colored zone in this figure refers to probable candidates of layer thickness and modulation. When resistance of applied materials is determined, desirable layer thickness can be also determined in both mid and base layers according to diagrams in **Figures 10-12**.

1. Relationship between E2 and E3 (H_3=25.4 mm)
2. Relationship between E2 and H2 (H_3=25.4 mm)
3. Relationship between E2 and H2 (H_3=76.2 mm)
4. Relationship between E2 and (H_3=152.4 mm)

Table 1: limit of input parameters

input parameter	MIN(mm, GPa)	MAX(mm, GPa)
H_1	50.8	50.8
H_2	101.6	304.8
H_3	0	152.4
E_1	3.00	3.00
E_2	4.00	12.06
E_3	2.07	5.00
E_4	0.03	0.10

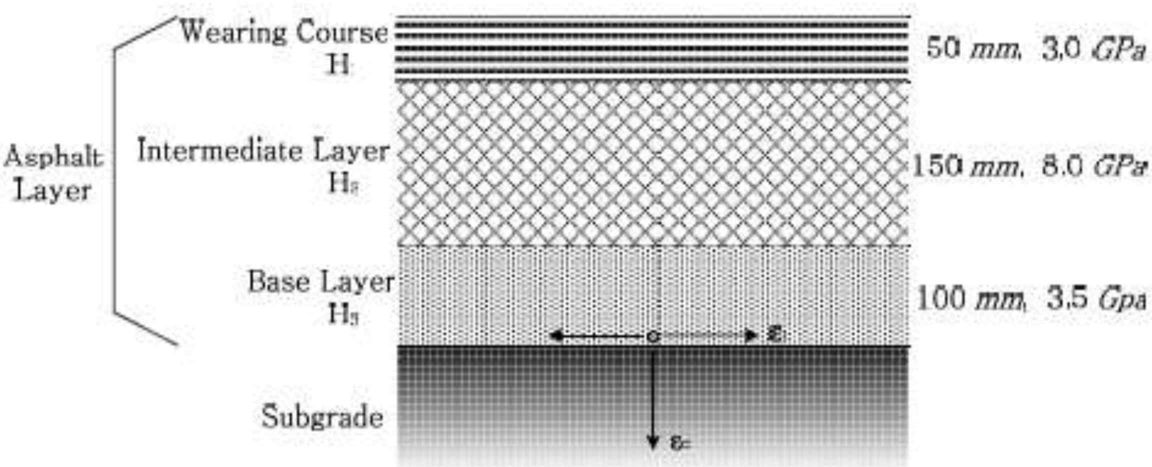

Figure 1: Common structure of asphalt with long lifetime

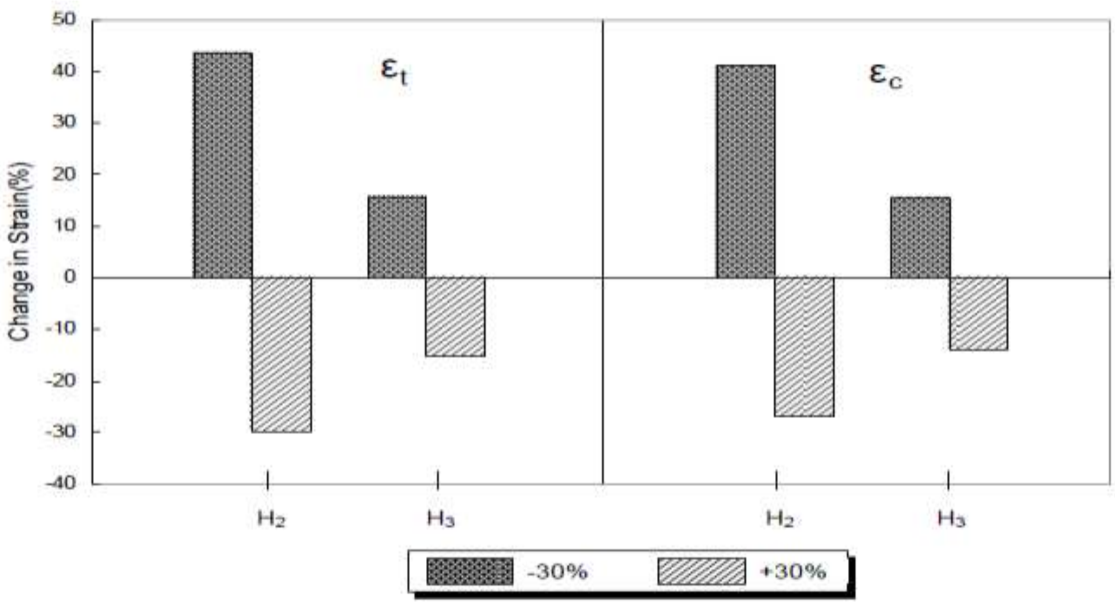

Figure 2: Sensitivity of strain against change in mid and base layers

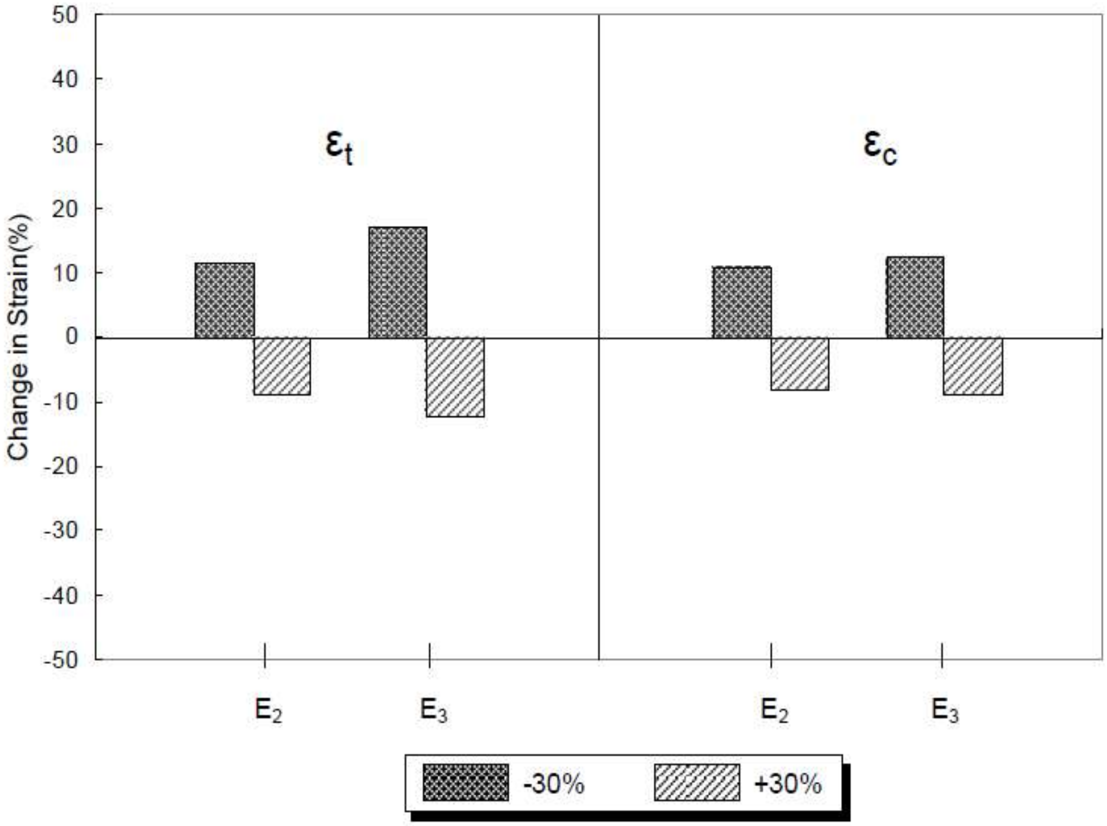

Figure 3: sensitivity of strain in modulation changes in mid and base layer

Wearing Course, H_1 (fixed 50.8 mm)	**E_1 (fixed, 3.00 GPa)**
Intermediate layer, H_2	**E_2**
Base Layer, H_3	**E_3**
Sub grade, H_4	**E_4**

Figure 4: structure of standard asphalt

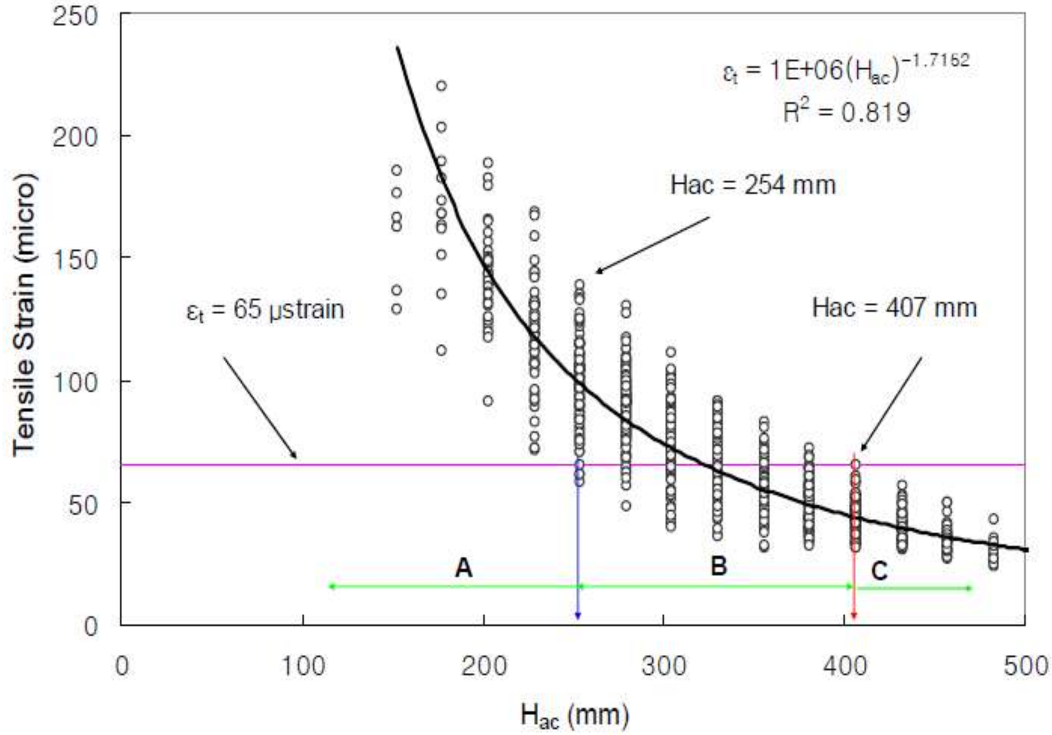

Figure 5: relationships between total thickness of AC and ε_t

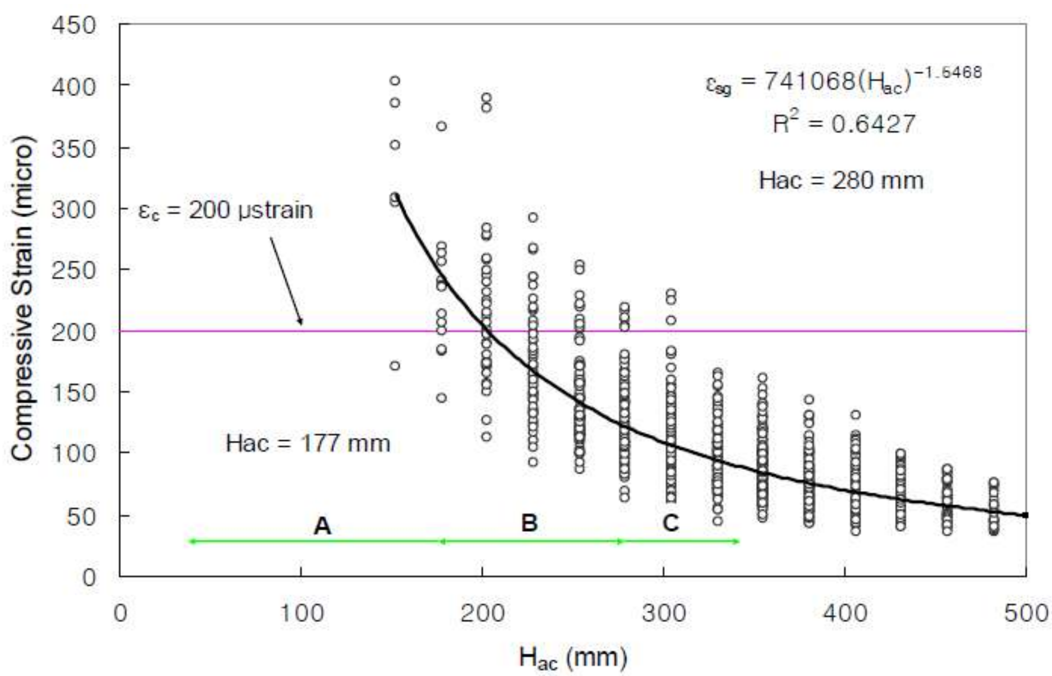

Figure 6: relationship between AC layer thickness and ε_c

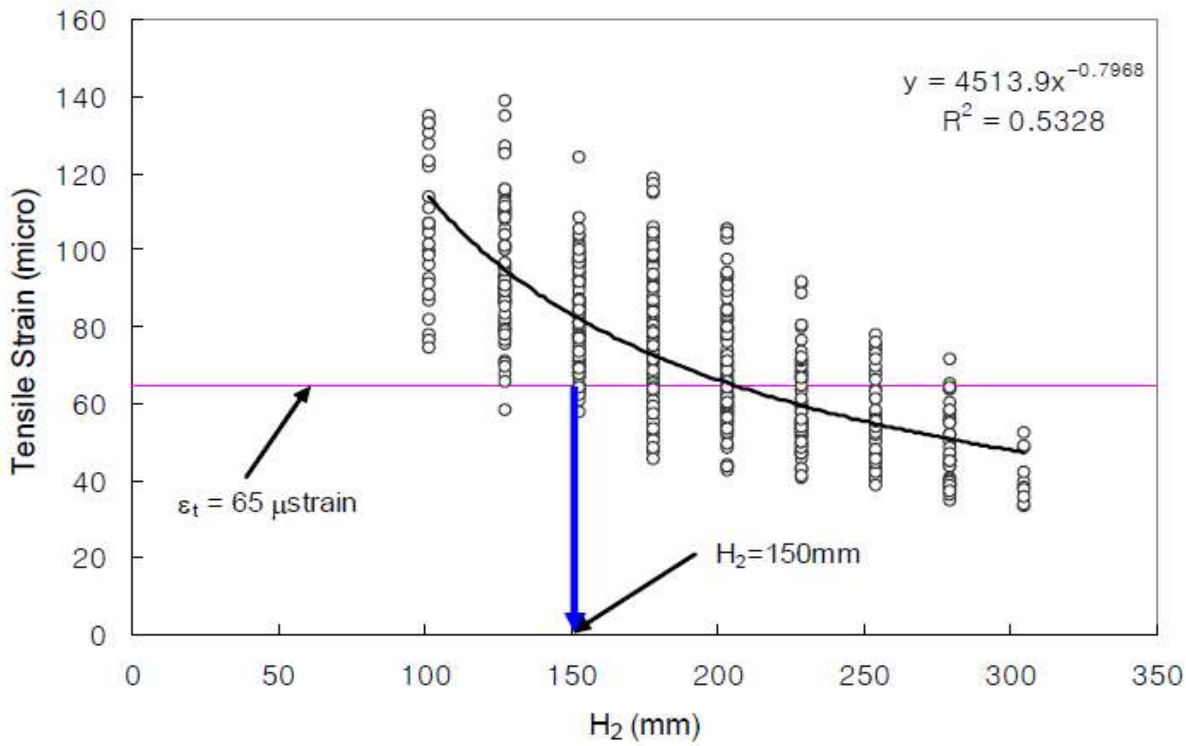

Figure 7: effect of mid layer thickness on tensile strain of AC sub layer

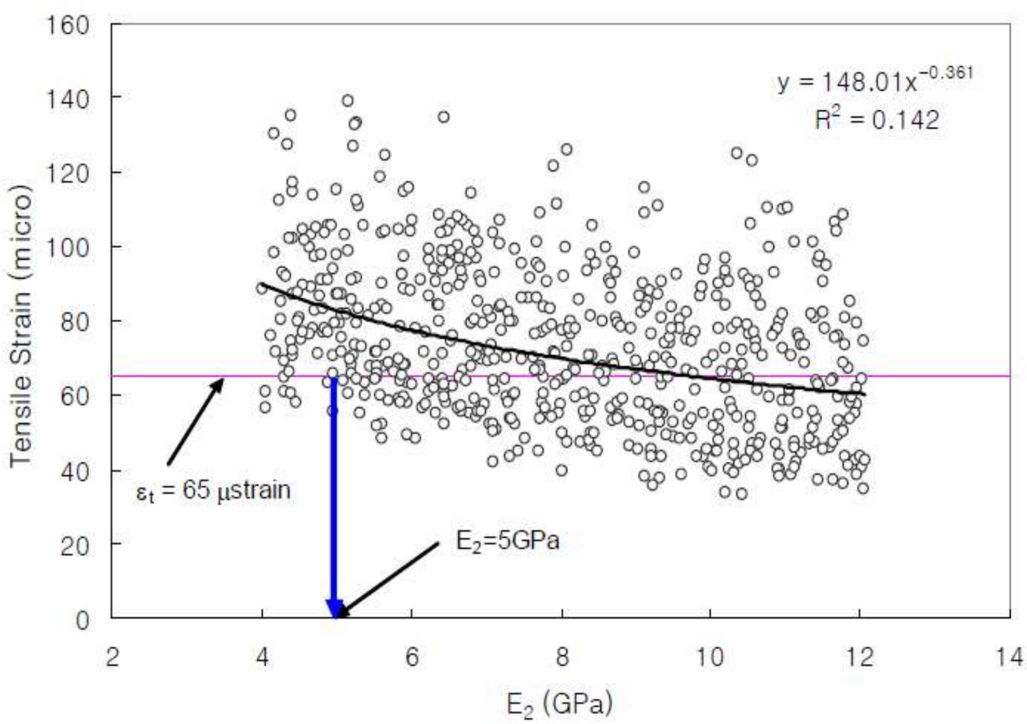

Figure 8: effect of mid layer modulation on tensile strain of AC sub layer

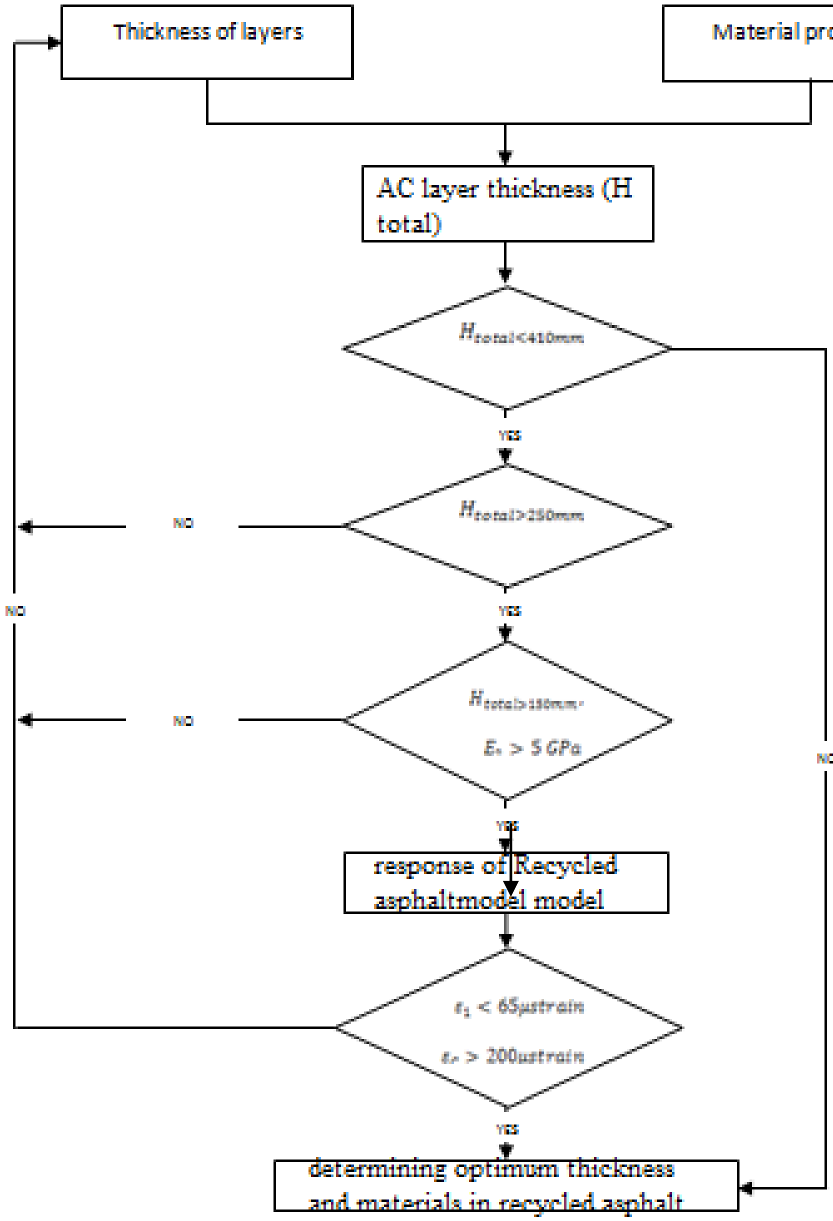

Figure 9: flowchart of determining layer thickness in asphalt

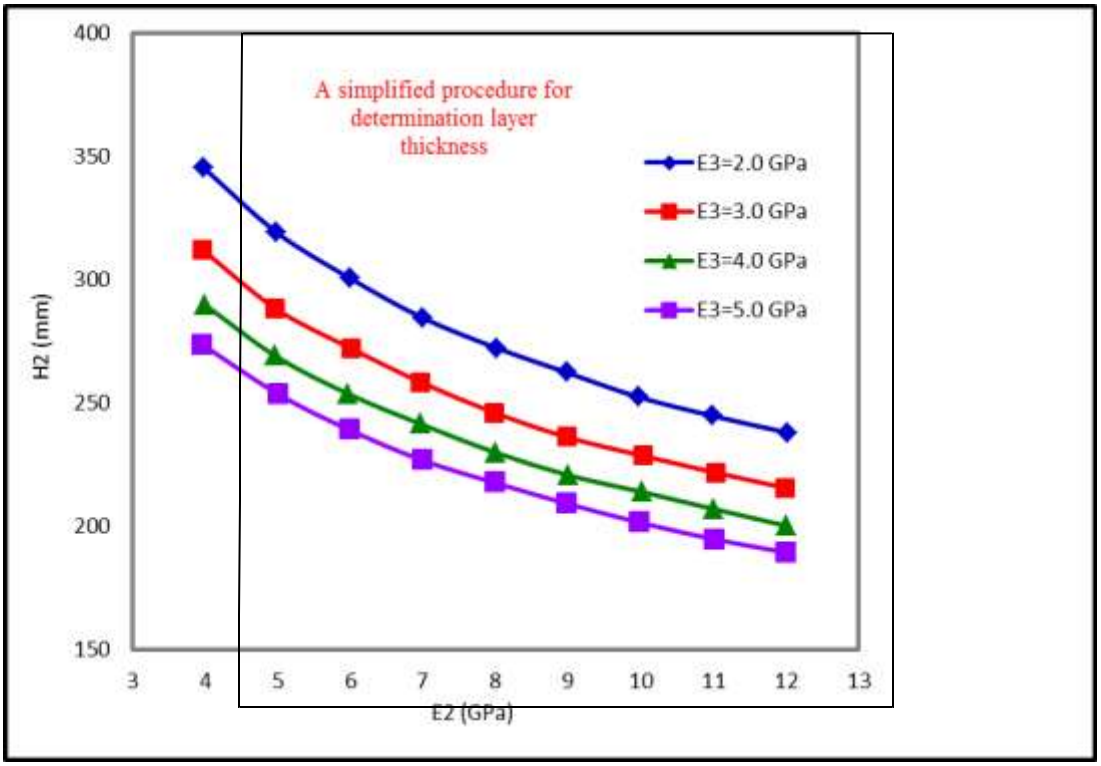

Figure 10: relationship between E2 and H2 (H_3=25.4 mm)

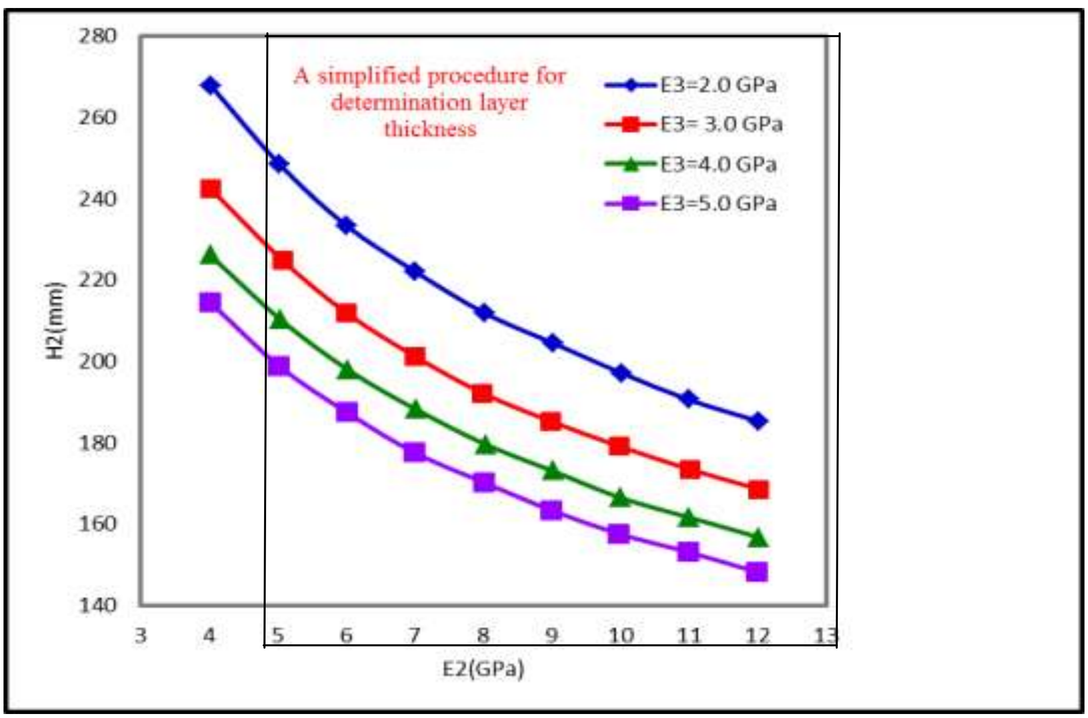

Figure 11: relationship between E2 and H2 (H_3=76.2 mm)

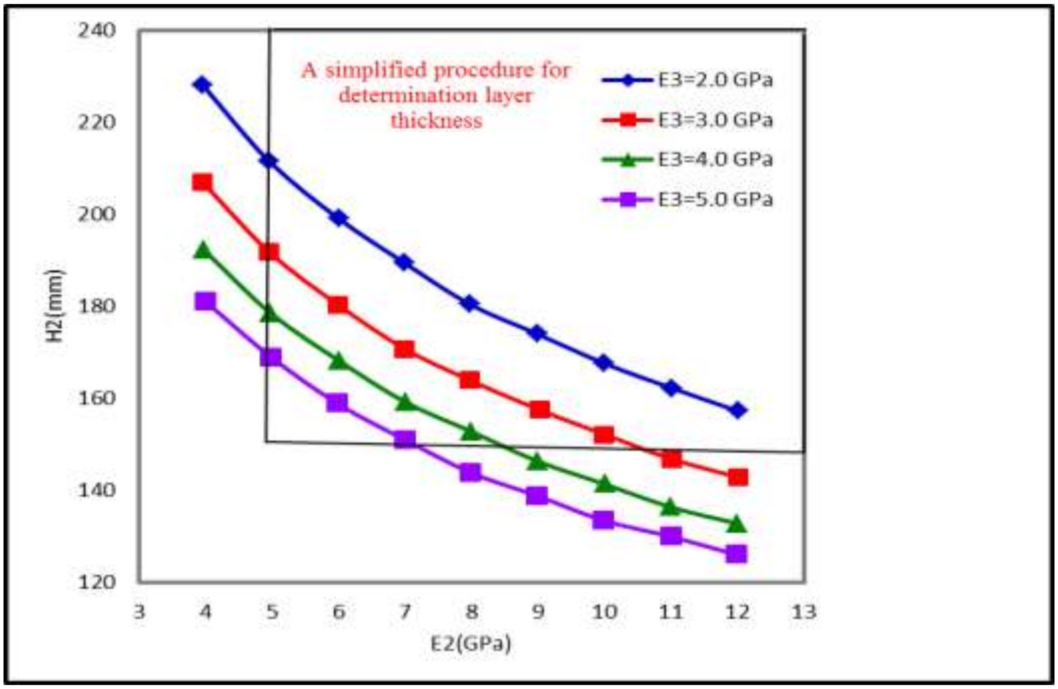

Figure 12: relationship between E2 and H2 (H_3=152.4 mm)

CONCLUSION

Today in the age of technology, due to shortage of energy resources, economic and environmental role of reuse of recycled asphalt materials is a clear issue. Recycled asphalt pavement is a kind of waste material that may have negative effects on surrounding area. Due to properties of the mentioned material, many different solutions have been reported so far for purpose of reusing the materials. One of the pavement layers, in which recycled materials can be applied, is base layer. Main advantages of using the materials in base layer is that it can cause enhance loading capacity of the pavement and decrease in thickness of pavement layers in addition to preservation of natural resources.

The present study has attempted to be focused on providing a procedure for purpose of determining layer thickness in asphalt with long lifetime. Obtained results from the study are as follows: asphalt with total thickness of AC layer of 410mm has been considered as asphalt with long lifetime, regardless of properties of materials and thickness of each layer. Process of designing has been presented in this study for purpose of determining thickness and modulation of every layer in asphalt with thickness of AC layer from 250 to 410mm. Asphalt response model has been developed for type of asphalt with long lifetime and designation process for determining thickness of layer has been also suggested in this study.

Suggestions

In this section, some suggestions would be presented for purpose of considering formation of suitable ideas for further studies:

- Identifying and determining thickness of recycled asphalt layers using GPR method
- Evaluation and experimental comparison of cold and hot method of asphalt recycling
- Using recycled asphalt pavement as aggregate in pavement.

REFERENCES

[1] Afra, M. K. (2010). identifying and determining asphalt layer thickness using GPR method.

[2] Ali Akbari Bidokhti, M. R. (2013). using recycled asphalt pavement in base layer of pavement. *First National Conference of Transportation Infrastructures*.

[3] Apeagyei, A. D. (2011). rutting resistance of asphalt concrete mixtures that contain recycled asphalt pavement. *Transportation Research Record: Journal of The Transportation Research Board*(2208(1)), 9-16.

[4] Daryaei, D. H. (2012). using asphalt recycling as a solution for suerstructure management.

[5] Fakhri, M. G. (2004). project of pavement optimization in Ashto method using a linear planning model. *Academic Journal of Transportation Research*, *1*(1).

[6] Mazinani, A., & Kamkar, A. (2010). determination of thicknesss and qualitative propertied of asphalt using GPR method in inside area of Shahrood's Industrial University.

[7] Okafor, F. O. (2010). perfromance of recycled asphalt pavement as coarse aggregate in concrete. *Leonardo Electronic Journal of Practices and Technologies*(9 (17)), 47-58.

[8] Organization, I. M. (2006). technical-executive features of asphalt cold recycling.

[9] Park, H. K. (2005). determination of the layer thickness for long-life asphalt pavements. *W: EASTS*, 791-802.

[10] Transportation, M. O. (2004). methods of hot and cold asphalt recycling and its economic feasibility in Iran.

[11] Wen, H. W. (2011). Evaluation of high percentage recycled asphalt pavements as base materials.