Software Development (PAKPAVE) for Flexible Pavement Design

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Abstract— In today's world, the road and surface failure of the flexible pavement has become the most important and attention diverting problem, which may be due to the low quality of materials used, less and inadequate experience of the technical staff, and errors that may occur during the designing of the pavement. The design of thickness of the flexible pavement has taken the backbone place in determining the overall performance and providing high level of serviceability of the pavement structure for the heavy traffic loads under the adverse climatic conditions, during the expected design period. The aim of this research is to develop software for the flexible pavement design based on the AASHTO, Group Index, and CBR. This software can be used to determine the thickness of each layer, design life evaluation, knowing the relative damage factor, finding the various design variables like calculating the structural number and equivalent single axle load etc and climatic effects. The results obtained from this software were analyzed and compared with the theoretical (manual) design and with the DARWin, a design software of AASHTO, and were found absolutely feasible and accurate. This flexible Pavement software can save the precious time and avoid the errors and difficulties occurring during the conventional methods of design.

Keywords— PAKPAVE, AASHTO, CBR, Group Index, Flexible Pavement Design Software, PAKPAVE for Flexible Pavement Design

I. INTRODUCTION

Nowadays, due to the high volume of trade, ease of access and travel, and many other activities the traffic volume is increasing day by day. In order to accommodate this traffic, roads have to be constructed. Due to a good level of serviceability provided, comparatively economical then the rigid pavements, and their feasibility, the flexible pavements are the most common structures constructed. The design of the flexible pavement requires the field tests and survey, and besides these requires lots of tedious calculations with the use of various graphs and tables, which makes it a difficult job to

do and there occurs lots of errors and mistakes during the design stage, which results into the failure of the road. So there was need to develop software for design of the flexible pavement, as the software's developed by AASHTO and the Asphalt Institute are very expensive and not of common use.

Therefore, we carried out the research on developing software to counter this problem, using the Visual Basic.net language of the Microsoft, which enables you to program for the designing, calculation, saving, making the installable format of your program, and provides various other features.

II. LITERATURE REVIEW

Pavement is the structure which consists of the superimposed layers of the processed materials that keep apart the tyres of vehicles from the materials used as foundation and the soil sub grade which distributes the load coming from vehicles, and protects it from failure.

A. AASHTO Design Method

The design method developed by American Association of State Highway and Transportation officials (AASHTO) is an empirical method based on the tests results conducted in Ottawa and Illinois.

The pavement has to be designed for the traffic loading and the stresses caused by the temperature and moisture variations, incorporating various design variables and time constraints.

The basic equation of AASHTO flexible pavement design given in 1986 design guide for the structural number is as:

$$\log_{10}(W_{18}) = ZR \times So + 9.36 \times \log_{10}(SN + 1) - 0.2 +$$

$$\frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40+\frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(MR) - 8.07 \qquad (1)$$

Where,
W18= 18 kips Equivalent single axle load
Zr= Normal deviation showing Reliability
So= Over all standard deviation
SN= Structural number
ΔPSI= Design present serviceability loss, which is a function of initial, terminal serviceability and the ΔPSI due to environmental effect
MR= Resilient modulus of the soil sub grade
The structural number and Equivalent single axle load can also be determined from a graph presented by AASHTO called the Nomo graph.

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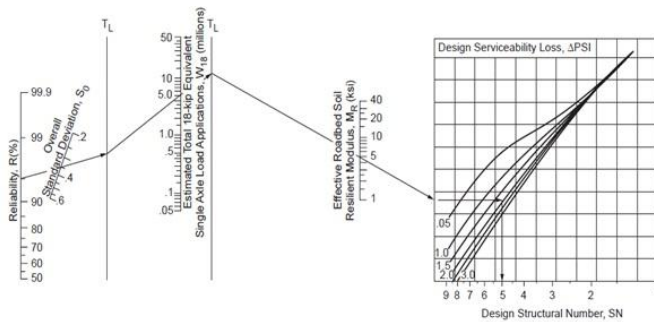
Fig. 1: AASHTO Nomo graph for Flexible Pavement Design

As there is a wide range of vehicles over the highway having different axle types and axle loads, which has to be converted to the standard 18 kips (8.2 tons) Equivalent single axle load (ESAL) to avoid facing problems in design, so by the convention this ESAL causes a unit damage per pass and axle load higher or lower then ESAL causes damage greater and lower than one respectively. The load equivalency factor (Relative damage factor) can be calculated as

Relative Damage Factor (Load Equilancy Factor) =

$$\left[\frac{\text{Axle Load}}{\text{ESAL}}\right]^4 \qquad (2)$$

Structural number, which is a function of layer thickness, layer coefficient, and drainage coefficients, is given by

$$SN = a_1 \times D_1 + a_2 \times D_2 \times m_2 + a_3 \times D_3 \times m_3 \qquad (3)$$

Various layer thicknesses can be determined as follows;

$$D_1 \geq \frac{SN_1}{a_1} \qquad (4)$$

$$D_2 \geq \frac{SN_2 - a_1 \times D_1}{a_2 \times m_2} \qquad (5)$$

$$D_3 \geq \frac{SN_3 - a_1 \times D_1 - a_2 \times D_2 \times m_2}{a_3 \times m_3} \qquad (6)$$

Where,
a1, a2, a3= Layer coefficients of the wearing course, base and sub-base course respectively
D1, D2, D3= Thickness of wearing, base, and sub-base course.
m2, m3= Drainage coefficients for base and sub-base course.

The design period analysis is used to determine the design life of the pavement. At first a design life for the pavement is assumed using which on the graph to determine the ΔPSI due to environmental effect according to the conditions of the area, which is then used to find the present serviceability loss as the difference in initial and terminal serviceability.

B. Group Index Method of Flexible Pavement design

According to this method the thickness of the pavement is determined in reference to the design traffic load in terms of commercial vehicles and the value of group index, which is formulated on various soil properties as percent fineness,

liquid limit, plastic limit, and plasticity index. For a soil, the group index can be found by using the equation:

$$G.I = 0.2 \times a + 0.001 \times a \times c + 0.01 \times b \times d \qquad (7)$$

Where,
a = Portion of percentage passing # 200 sieve between 35 and 75%, represented by a whole number from 0 to 40.
b = Portion of percentage passing # 200 sieve between 15 and 55%, represented by a whole number from 0 to 40.
c = Portion of liquid limit between 40 and 60%, represented by a whole number from 0 to 20.
d = Portion of plasticity index between 10 and 30%, represented by a whole number from 0 to 20.

The data collected from the tests conducted in the field is put in the concerned equation to find out group index value of the soil.

A field survey is carried out to find the design traffic load for the design life using the equation

$$A = P \times (1 + r)^n \qquad (8)$$

Where,
A = Design traffic load for design life (vehicles/day)
P = Present daily commercial vehicles (vehicles/day)
r = Annual growth rate (%)
n = Design life (Years)

The sub grade soil is characterized on the basis of group index number, then on the basis of G.I number and the design traffic load for design life, the thickness of the pavement is determined using the following graphs:
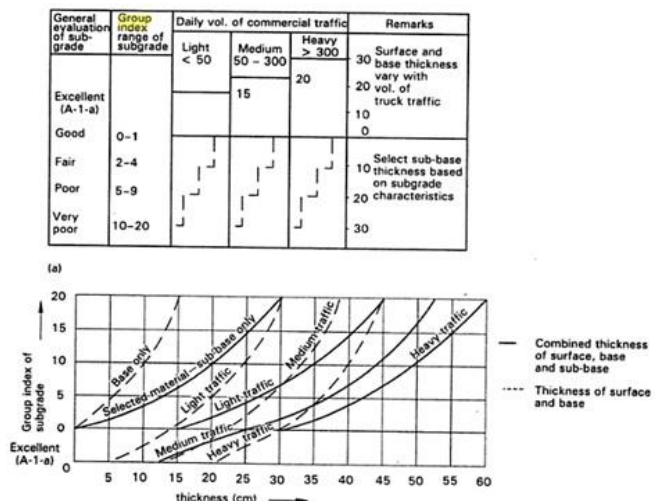

Fig. 2: Group Index Graphs

C. CBR Method of Flexible Pavement Design

California bearing ratio method was developed by the California division of highway. In this method the strength of the soil is represented by the CBR value and the traffic load as heavy commercial vehicles (load ≥ 1.5 tons) per day of the design period. On the basis of this method, the US corps of

Engineers showed that the pavement thickness also depends upon the wheel load, tyre pressure, and CBR value. To find out the pavement thickness the following formulas are used

$$T = \sqrt{P} \times \left[\frac{1.75}{CBR} - \frac{1}{p \times \pi} \right]^{\frac{1}{2}} \tag{9}$$

$$T = \left[\frac{1.75 \times P}{CBR} - \frac{A}{\pi} \right]^{\frac{1}{2}} \tag{10}$$

Where,
T=Pavement thickness, (cm)
P=Wheel Load, (kg)
CBR=California bearing ratio, (%)
p=Tire pressure, (kg/sqr cm)
A=Area of contact, (sqr cm)

III. OBJECTIVES OF THIS STUDY

The specific objectives are to develop software that could be utilized to;

1) Design the various pavement layers thickness according to the soil conditions of the project site, using the desired design method.
2) Estimate the design life of the road according to the conditions of the area.
3) Estimate the future design traffic using the current traffic survey conducted.
4) Find the various unknown design variables and time constraints used in the road design.
5) Find the effect of various environmental conditions like swelling, frosting or both, on the road serviceability.

IV. SCOPE AND BACKGROUND OF THE STUDY

The previous research and work done in this regard are of DARWin and SW-1. DARWin is the designation for and represents the series of AASHTO's computer software programs for pavement design. DARWin is a metric-compliant AASHTOW are computer software product that conforms to and is compliant with the pavement design models presented in the respective design guide documents, While SW-1 is the product of Asphalt Institute.

Owing to the bottlenecks concluded in the cited software are that these are very expensive and of limited usage especially in Pakistan. Single copy of the software which is made to be installed only on a single system costs up to 40,000 USD, and one has to renew its license every year, Numerous departments in brown sectors i.e. NHA, NESPAK etc use the trial and error method using the conventional spread sheets for the design process in order to avoid buying such an pricey software. The underline research aims at facilitating access to the works and services line departments by providing locally available pavement design software.

The construction industries and various government departments concerned would not have to acquire the highly expensive software of AASHTO, revealing a huge cut down to their economy, and at the same time encouraging them to use the latest software and technologies, leaving behind the use of old, local and manual design procedures. It would also encourage the market competitors to develop the software industry by launching such innovation in IT sector.

V. METHODOLOGY FOR DEVELOPING SOFTWARE

The methodology plays a key role in carrying out a research and making it successful. The overview of the methodology adapted in carrying out this research is as that, first the algorithm was prepared that was necessary for developing the software. All the graphs that are used in the manual design process of all of the three methods (AASHTO, CBR, and G.I) were digitized and made the required corrections. Then using these digitized graphs and rest of the data software was developed for the design process encompassing all the three mentioned methods, using the visual basic.net computer programming language.

Once the software was developed, then input data was collected to test the software for its accuracy and authenticity. The data collected was put in the software and results were obtained. The same data was used in the design through manual and conventional methods and the results were compared with those obtained from the software, in case of any error or mistakes necessary measures were taken and changes made to remove the errors. Again both of the results were taken and compared, giving the satisfactory and accurate results finally.

After comparison with the manual design procedures, for further authenticity checks the results based on the same data from the developed software were compared with DARWin; the AASHTOWare computer software for the pavement design, if there were any errors found, research was made to improve the results. Finally the software developed through the research carried out was found absolutely accurate and authentic, hence can be used for education, research, and design in field giving fully accurate and trustworthy results.

VI. RESULTS AND DISCUSSIONS

The software is developed on the basis of AASHTO, G.I, and CBR methods of the flexible pavement design using the Visual basic.Net language. All the tables and graphs are incorporated to codes so that to design the pavement with ease. After running the software, we get the front interface which provides us with the choice to select the design method and function we want.
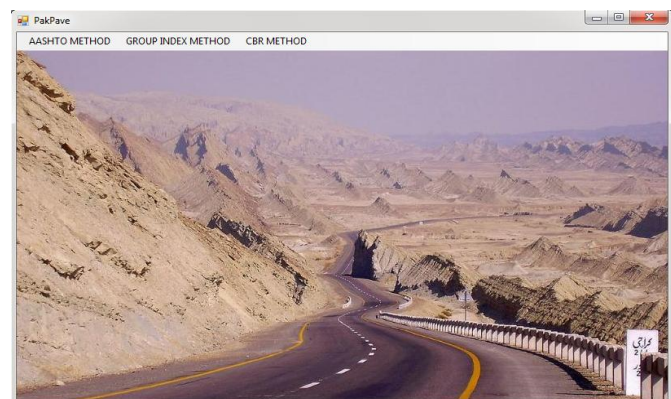

Fig. 3: Main window of software

AASHTO Design Method

Fig. 4: Dropdown list showing different parameters of AASHTO Design

Now let's say we have to determine the structural number and ESAL, so we go to the required interface by clicking its name, put the inputs required, click on the calculate button and get the required result.
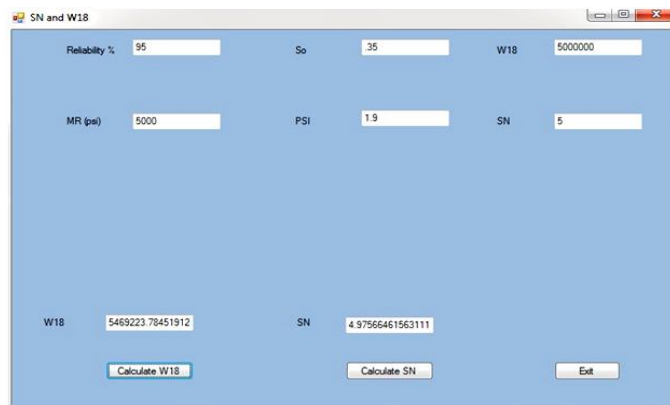

Fig. 4: W18 and SN

The ESAL can also be calculated from the traffic data based on the number of vehicles, truck factor, and growth factor.
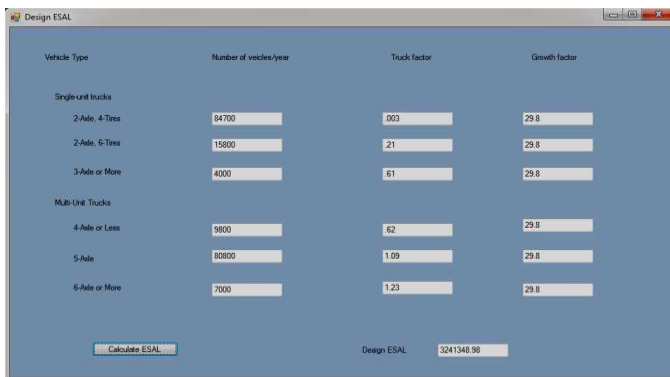

Fig. 5: Calculating design ESAL from traffic data

The thickness of the pavement can be designed by putting in the data from the field survey and the soil tests conducted.

Fig. 6: Thickenss determination of various layers

Similarly for given loading, environmental and soil conditions, the pavement design life can also be estimated as shown below.
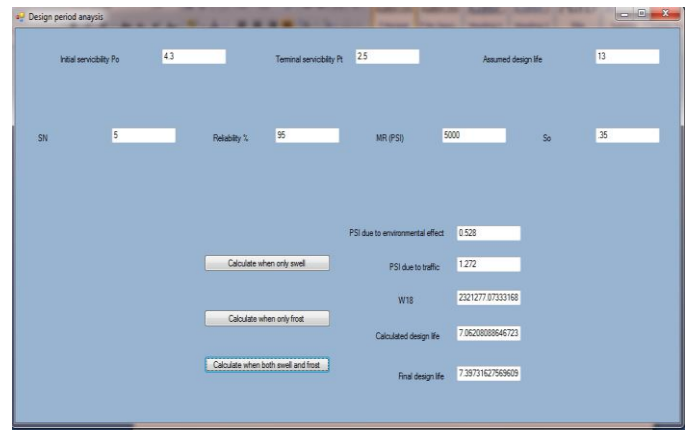

Fig. 7: Calculating the Design Life of pavement

Group Index Method of Design

To use the group index method of design click on its name at the main window this will take you to the concerned interface. Flexible pavement based on the traffic volume, and soil characteristics in terms of group index values can be designed here as follows:
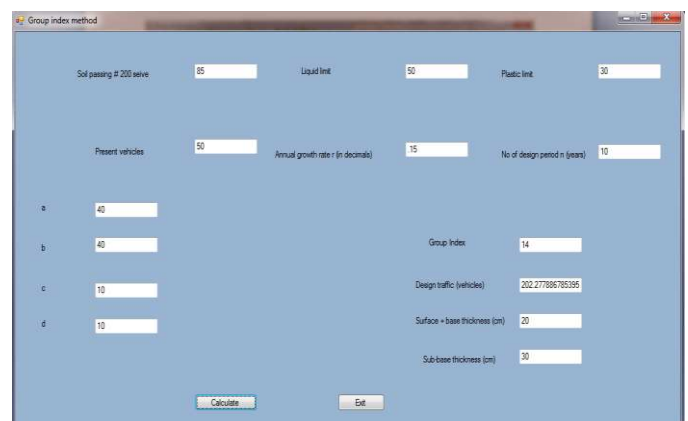

Fig. 8: Determination of Layer Thicknesses by Group Index Method

CBR Method of Design

By clicking at the CBR design method takes you to the required window where by putting in the values of CBR, tyre pressure, area of contact etc you can get the desired design of the flexible pavement.
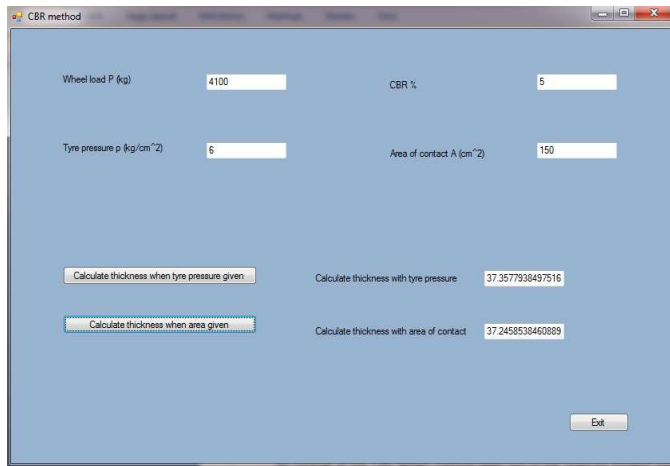

Fig. 9: Layer Thickness by CBR Method

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The research carried out to develop the software successfully accomplished and the results it gives are as accurate as expected. The developed software can be used to design the flexible pavement by AASHTO, Group Index, and CBR methods. The design results obtained from each method could be compared and hence select the best design. The results obtained by each of the method using this software were compared with results obtained from the manual design and with that of DARWin: AASHTO'S design software and were found absolutely accurate.

The development of software for the pavement design is very important as it makes the design process very easy and accurate and saves a lot of precious time. Hence the design process can be done in very short time and accurately avoiding the computational and calculation errors of the conventional manual design method.

B. Recommendations

This software is limited to the flexible pavement design based on the AASHTO, Group index, and CBR methods so it can further be extended for Asphalt institute design method and Road Note 31 as well as for the rigid pavement design.

The use of this software also needs a good understanding of the manual design methods, hence to use this software for education, research, and designing in field; one has to be fully aware of the manual design methods.

APPENDIX

Sample Code for AASHTO Design

```
Dim a1, a2, a3, m2, m3, sn1, sn2,
sn3, t1, t2, t3 As Double

  a1 = Val(TextBox7.Text)
  a2 = Val(TextBox8.Text)
  a3 = Val(TextBox9.Text)
  m2 = Val(TextBox10.Text)
  m3 = Val(TextBox11.Text)
  sn1 = Val(TextBox12.Text)

 'where  m1=1  so  no  need  of
mentioning  it,  and  t1,t2,t3 stands
for  the  layers  thicknesses  of
d1,d2,d3

  sn2 = Val(TextBox13.Text)
  sn3 = Val(TextBox14.Text)
  t1 = sn1 / a1
  TextBox15.Text = t1
  t2 = (sn2 - a1 * t1) / (a2 * m2)
  TextBox16.Text = t2
  t3 = (sn3 - a1 * t1 - a2 * t2 *
m2) / (a3 * m3)
  TextBox17.Text = t3
```

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