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DEVELOPMENT OF EDC SOFTWARE FOR ECONOMIC ANALYSIS OF PAVEMENTS

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Abstract - *Economic aspects play an important role in deciding the appropriate pavement options. In this ceaseless flux, towns have grown into cities, cities have transformed into metros and metros into megalopolises. In India most of the roads are black topped. The reason behind this is low initial cost of flexible pavement. It is difficult to generalize which option will give largest economic returns as it varies from case to case. So it becomes a necessity to analyze flexible pavements and rigid pavements options to check the economic viability and best pavement choice. For this various pavement options are designed with different database and their costs are computed. Many important design parameters that govern the pavement design are Traffic, Design CBR, vehicle damage factor, Lane configuration, growth rate, design life, modulus of elasticity, grade of concrete and temperature differential. Using the common input parameters, proper designs would be chosen for the given traffic and soil strength. All the pavements are designed and their costs are computed with the help of Economic design and costing (EDC) software developed on Microsoft.net framework. To compare the cost of two types of pavements, it is necessary to make sure that they are designed for the same traffic loading. The costs include the initial construction cost, fixed maintenance cost and a life cycle cost. For a particular set of data a mathematical equations are also developed to relate the cost of pavements with soil CBR and traffic in msa. Line separating pavement option is identified*

***Key Words*: Soil CBR, Traffic loading, initial cost, Construction cost, Life cycle cost, Pavements etc.**

1. INTRODUCTION

Nowadays, the most dynamic and expensive component of a highway is the pavement structure. Since the concept are continually changing as new data become available. The common perception among Engineers and Decision makers is that Concrete Pavements are costly to build. While this might have been true in the past, when bitumen was available at cheap rates, the cost equation has drastically changed in recent times with the steep rise in bitumen price. In this paper to compare the cost of concrete and flexible pavement an user friendly EDC software is developed in Microsoft .net framework to analyze the different database according to our choice. It is possible to generate the design based on the requirement. This also helps to compute the fatigue life consumed with the axle load of different categories and optimize the thickness. It includes common input parameters such as average traffic, modulus of subgrade reaction, growth rate, design life, lane configuration, modulus of elasticity, grade of concrete and temperature differential for rigid pavement whereas the type of terrain, design CBR, vehicle damage factor, lane distribution factor etc for flexible pavement. The two pavements also differ in their ages. The life of flexible pavements is 15 to 20 years, while concrete pavements have an analysis period of 30 years. The software implements design and computation of costs with the mentioned database and automatically generates the outputs report. These designs are mainly based on IRC: 58:2002 for concrete pavement and IRC: 37:2001 for flexible pavement. The two most important design parameters in pavement design are subgrade soil strength and traffic loading. This brings them into the same platform making it possible to compare their costs. So the flexible and rigid pavements are designed for similar soil CBR and traffic conditions and their costs are compared. The present paper examines how various pavement option offer an alternative and to choose the best with the lowest life cycle cost. In other words, the study is made to find out the critical combinations of soil and traffic conditions to shift the choice of pavements from one to the other.

2. LITERATURE REVIEW

Veeraragavan & Devasena (2001) investigated about the performance and life cycle costs of pavements overlaid with and without Geosynthetics. Mechanistic-empirical models are used to relate traffic loading and environment and concluded that overlays with Geosynthetics have longer life and retard the reflection cracking. Patankar and Kumar (2004) discussed life cycle cost analysis model and highlighted economic benefits of pavements. Sreenivasulu and Singh (2004) concluded that economics of flexible and rigid pavements options for a national highway section using HDM-4 model to take decision on whether a project should be taken up and how to invest. Sabnis (2004) discussed the long-term economic viability of pavement types using the service life of concretized roads is 5 to 6 times longer. Ramanajee (2004) describes that concrete pavements are most appropriate and discussed the suitability of concrete as a material for airfield pavements especially on touchdown portions. Naidu et al. (2004) presented some experiences to combine the life cycle cost aspects of different pavements as outlined in HDM-4 and concluded that they had lower maintenance cost and a low roughness progression coefficient when compared with flexible pavements. Pandey et al. (2004) dealt with innovative designs for determination of thickness of concrete pavement so that lower thickness are required for the same axle loads. Prasad (2007) dealt with the long term viability of pavement types using present worth method of analysis. It considered the life cycle cost which includes the discounted maintenance and overlay costs that are incurred during the design life of the pavement. Besides the maintenance costs of pavement, Vehicle operating costs (VOC) and Fuel saving on rigid pavement compared to Flexible pavement should also be considered which may not effect to the construction agency but certainly effect to the user and the nation. Bezabih & Chandra (2010) considered two parameters that govern pavement design are soil sub-grade and traffic loading. The cost comparison of two types of pavement was observed and a study was also done to convert the traffic load given in msa into ALD and vice versa from individual vehicle count. Chand et al. (2011) presented a scientific approach for the design of Plain jointed rigid pavements and used a finite element method based on computer program for the computations of stresses in concrete pavements due to edge loading for single as well as tandem axles.

3. OBJECTIVES

The objectives of this study are:

3.1 To prepare input database for selection of type of pavement.

3.2 To develop a software in c# language with the help of Microsoft visual studio 2008.

3.3 To generate various designs based on prepared database in the Microsoft.net environment.

3.4 To compare costs of various options.

3.5 To identify the most cost effective and economic pavement option.

3.6 To trace the array of soil and traffic conditions for use in flexible and rigid pavement database.

4. DEVELOPMENT OF DATABASE

In order to prepare an array of costs it is necessary to build a strong database, preferably in computer environment. The database considered in this study are traffic, Traffic growth rate per annum , design life, modulus of subgrade reaction, grade of concrete, elastic modulus of concrete, Thermal coefficient of expansion, Load safety factor, Temperature differential Zone, Type of terrain, Design CBR, Vehicle damage Factor Lane Configuration and Distribution Factor, Inflation rate during Analysis Period and discount rate. The most important aspect of the database is variation in the cost of pavements designed with varying soil and traffic conditions results in an array. Nine subgrade soil conditions (CBR 2% to 10 %) and ten designed lane traffic conditions (1 msa to 150 msa) including traffic growth rate of 7.5%, 5% inflation and 12% of discounted rate has been considered in this study. The thickness of layers would vary with CBR of soil and it would affect the cost of the pavement. These ranges of soil and traffic values are assumed to cover almost all possible combinations of soil CBR and traffic loading.

5. DEVELOPMENT OF EDC SOFTWARE

This is a software which gives initial & life cycle costs of flexible & rigid pavement. For preparation of EDC software following steps are involved:

STEP 1: Various input data and formulas are included in SQL server database window of Microsoft visual studio 2008 using c # language as a platform. Various forms were prepared and databases are entered manually in MS Access 2007, this helps to obtain the EDC software for the pavements.

STEP 2: To start with using the software, "login box" is appeared in which username and password is entered.

STEP 3: The input data mentioned in section 4 is included in SQL server database window then an input database sheet is prepared. It is used for entering the data required for designing the pavement as shown in Fig 1.

Input database sheet consists of 5 windows:

5.1 Design of concrete pavement.

5.2 Axle load spectrum.

5.3 Estimation of thickness.

5.4 Design of bituminous pavement.

5.5 Estimation of costs.

5.1 DESIGN OF CONCRETE PAVEMENT: It is prepared for input data required for designing of concrete pavement as shown in Fig. 3.In this window, while entering data, the dropdown box appears to choose the lane Configuration option shown in Fig. 2. This window also facilitate for designing dowel bar and tie bar as shown by screen shots in Fig. 4.

5.2 AXLE LOAD SPECTRUM: The axle load spectrum data are entered in prescribed format and is given in Fig.5.

5.3 ESTIMATION OF THICKNESS: Window given in Fig. 6 shows the computation of stresses, stress ratio, fatigue life and fatigue life consumed. Finally it will give thickness of concrete pavement.

5.4 DESIGN OF BITUMINOUS PAVEMENT: In this window, various layer thicknesses will be generated. The same is shown in Fig. 7.The input data for this are average traffic, type of terrain, design life and lane configuration.

5.4 ESTIMATION OF COSTS: In this cost of concrete and flexible pavement were calculated separately using 2011 PWD schedule of rates (SoR) for road and bridge works for Indore city.

The costs include the initial construction cost, fixed maintenance cost and a life cycle cost. The life cycle cost of concrete and bituminous pavement is calculated separately in the Microsoft excel 2007 by the net present value method. The same is shown in Fig. 8.

STEP 4: Output sheets for flexible and rigid pavement are obtained. The screen shot of output and their after report is shown in Fig. 9.

STEP 5: Conclusion window will give best option depending upon initial and life cycle cost amongst two pavements. Fig.10 shows the same.

6. ANALYSIS OF COSTS & DEVELOPMENT OF EQUATIONS

A typical pavement composition and its cost for a two lane NH road have been adopted for the assessment. Life cycle cost of flexible pavement for different msa and soil CBR are obtained. The same is tabulated in Table 1. Equation 1 shows the relation between the cost of flexible pavement and soil CBR conditions and traffic loading. The equation has an R value of 0.93.

$$Flexible\ pavement\ Cost = 140.47 \times (CBR)^{-0.203} \times (msa)^{0.161} \quad ...1$$

Life cycle cost of rigid pavement for different msa and soil CBR are also obtained. The same is tabulated in Table 2. Equation 2 shows the relation between the cost of rigid pavement and soil CBR conditions and traffic loading in msa for a particular set of data. The equation has an R value of 0.99.

$$Rigid\ pavement\ Cost = 118.86 \times (CBR)^{0.253} \times (msa)^{-0.003} \quad ...2$$

The initial aim of this study is to determine the critical values of CBR and msa beyond which one of the pavements becomes economical in its life cycle cost. The points of equal cost on the Cost versus Soil CBR graph were determined using equation 1 and 2 and these points are plotted in Fig 11. Rigid pavements are found to be economical in the lower portion of the graph and flexible pavements are economical in the upper portion of the graph. Straight line separating pavement option of equal costs is obtained.

7. CONCLUSIONS

From this study the following conclusions have been drawn:

- Computer software namely "Economic design and costing" (EDC) is developed in Microsoft .net environment for different input parameter for various pavement options.
- The EDC software will give best pavement option depending upon initial and life cycle cost.
- Flexible pavements show wider range of variation in cost with respect to design parameters of traffic and soil CBR, while the overall variation in cost of rigid pavements is comparatively small.
- It is observed that flexible pavements are more economical for lesser volume of traffic.
- For a particular set of condition mathematical equations are developed for rigid and flexible pavement showing the relation between the cost of pavements with different Soil CBR conditions and traffic loading in msa.
- The line separating pavement option of equal costs (fig 11.) signifies the region for choosing the type of pavement option. The points of equal costs on the Costs Versus Soil CBR graph were determined. For a particular set of condition mathematical equation shows:

Life cycle cost = 7.473*CBR+125.6, on this line both pavements will have the same cost

It is found that flexible pavements are economical in the upper region of the graph, whereas rigid pavements are economical on the lower portion of graph.

Fig – 1: Input Database sheet Windows

Fig – 2: Drop down Box for Lane Configuration

Fig – 3: Design of Concrete Pavement Window

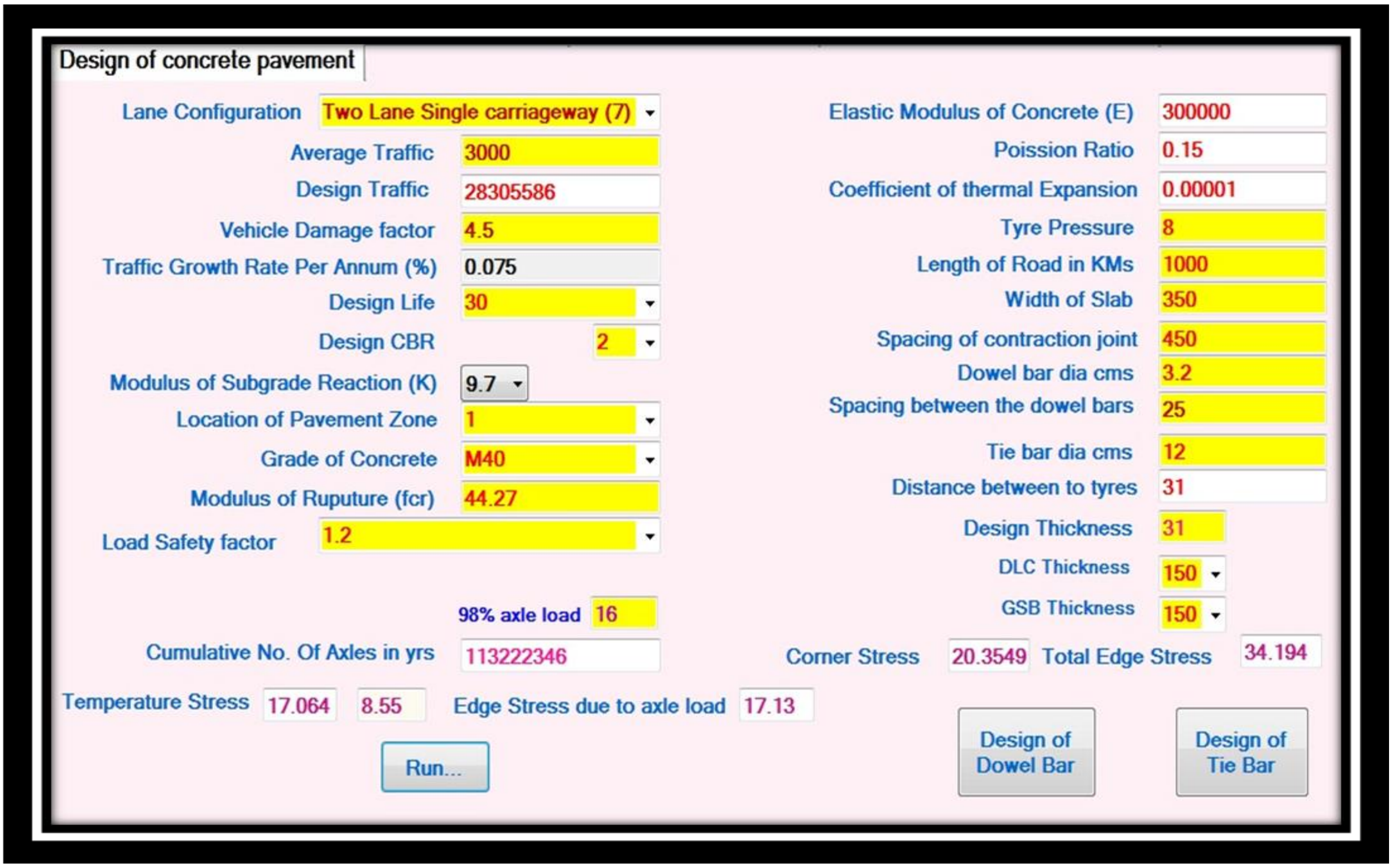
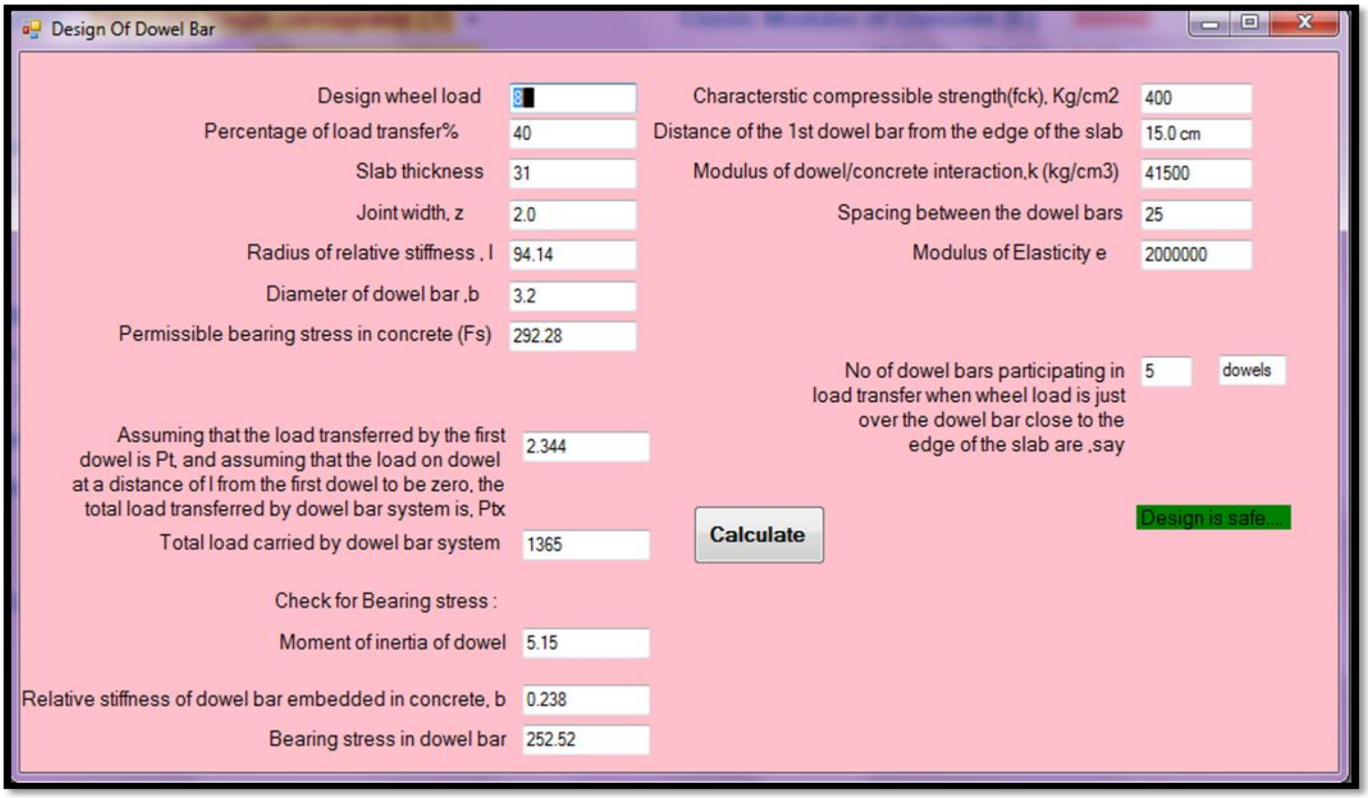


Fig -4: Screen shots of Designing dowel bar and tie bar



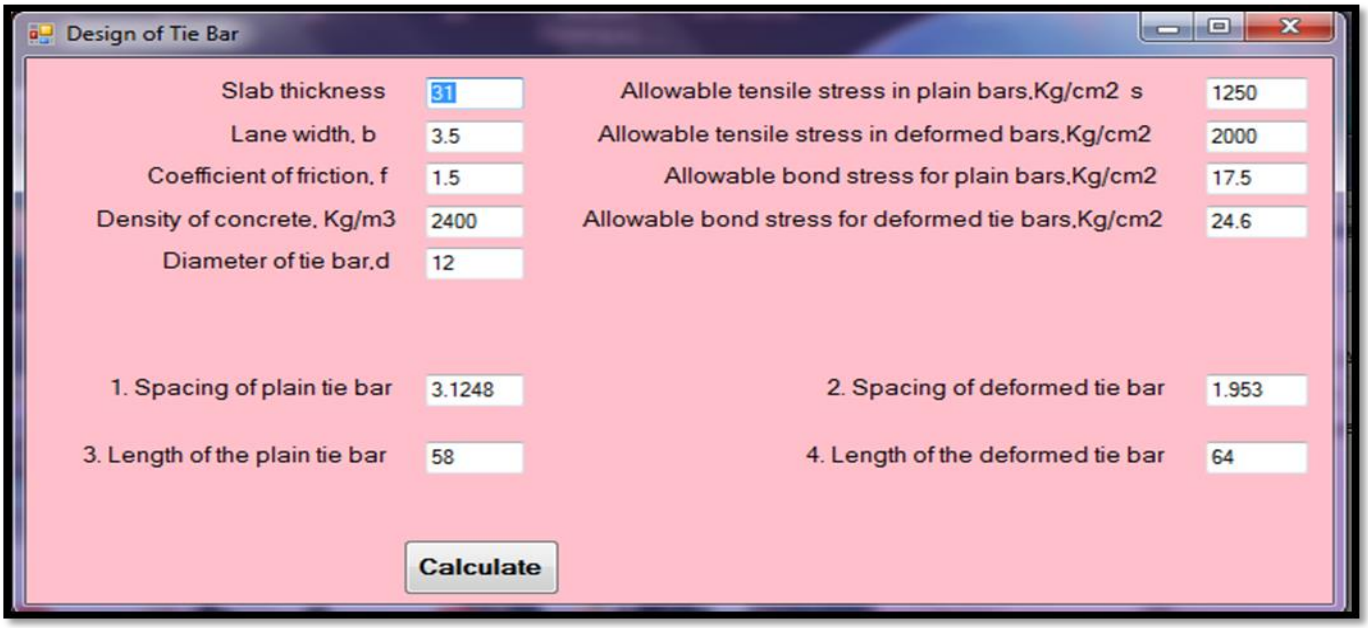
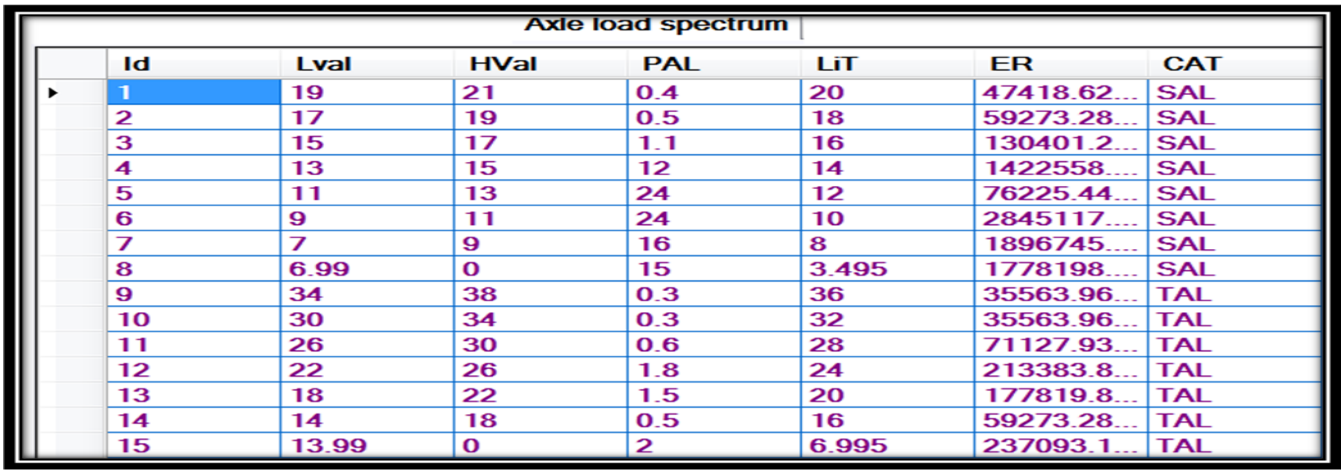


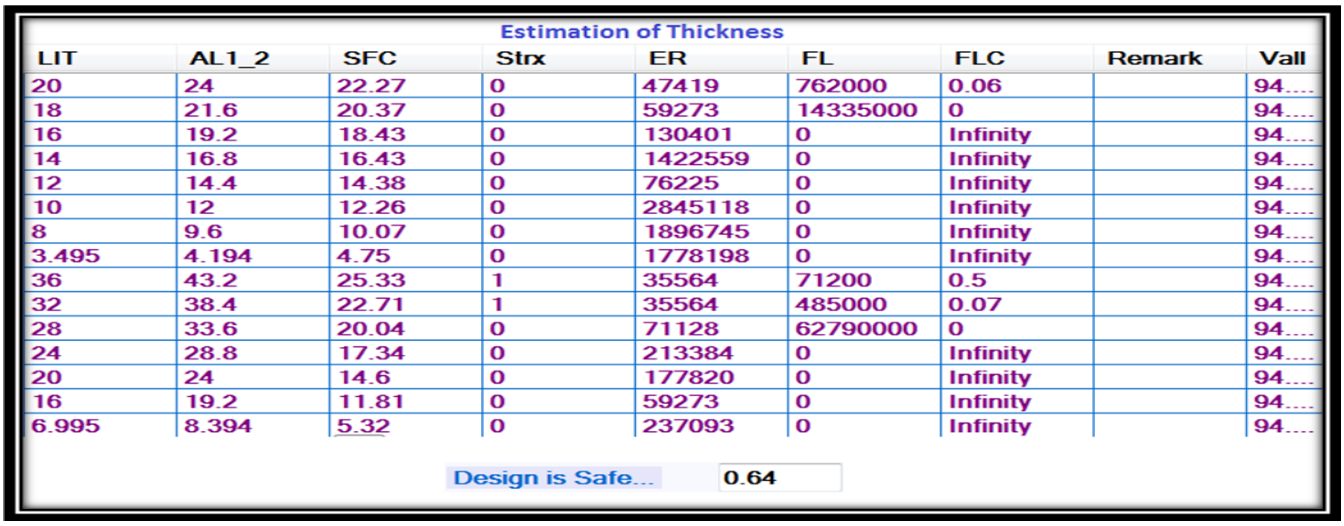
Fig -5: Window showing axle load spectrum



Axle load spectrum

Id	Lval	HVal	PAL	LiT	ER	CAT
1	19	21	0.4	20	47418.62...	SAL
2	17	19	0.5	18	59273.28...	SAL
3	15	17	1.1	16	130401.2...	SAL
4	13	15	12	14	1422558....	SAL
5	11	13	24	12	76225.44...	SAL
6	9	11	24	10	2845117....	SAL
7	7	9	16	8	1896745....	SAL
8	6.99	0	15	3.495	1778198....	SAL
9	34	38	0.3	36	35563.96...	TAL
10	30	34	0.3	32	35563.96...	TAL
11	26	30	0.6	28	71127.93...	TAL
12	22	26	1.8	24	213383.8...	TAL
13	18	22	1.5	20	177819.8...	TAL
14	14	18	0.5	16	59273.28...	TAL
15	13.99	0	2	6.995	237093.1...	TAL

Fig -6 : Window showing Estimation of thickness



Estimation of Thickness

LIT	AL1_2	SFC	Strx	ER	FL	FLC	Remark	Vall
20	24	22.27	0	47419	762000	0.06		94....
18	21.6	20.37	0	59273	14335000	0		94....
16	19.2	18.43	0	130401	0	Infinity		94....
14	16.8	16.43	0	1422559	0	Infinity		94....
12	14.4	14.38	0	76225	0	Infinity		94....
10	12	12.26	0	2845118	0	Infinity		94....
8	9.6	10.07	0	1896745	0	Infinity		94....
3.495	4.194	4.75	0	1778198	0	Infinity		94....
36	43.2	25.33	1	35564	71200	0.5		94....
32	38.4	22.71	1	35564	485000	0.07		94....
28	33.6	20.04	0	71128	62790000	0		94....
24	28.8	17.34	0	213384	0	Infinity		94....
20	24	14.6	0	177820	0	Infinity		94....
16	19.2	11.81	0	59273	0	Infinity		94....
6.995	8.394	5.32	0	237093	0	Infinity		94....

Design is Safe... 0.64

Fig -7: Design of Bituminous Pavement Window

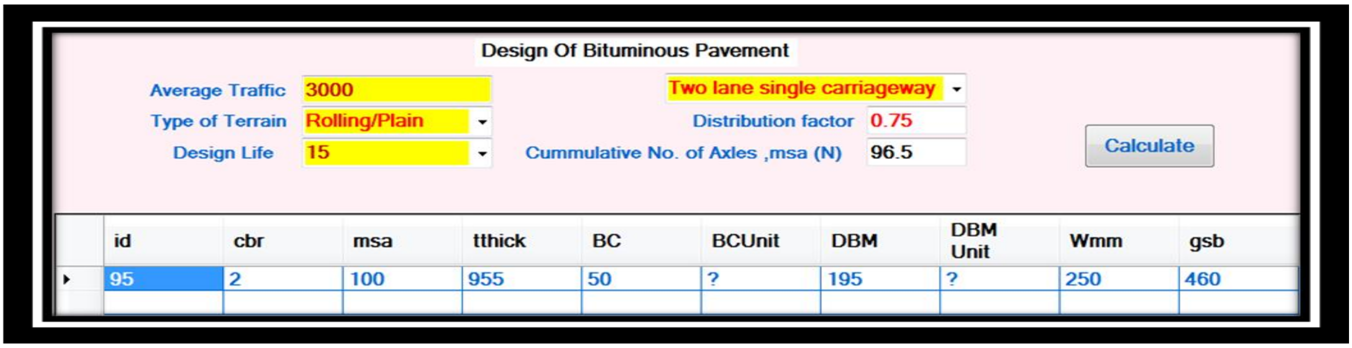


Fig - 8 : Estimation of Costs Window

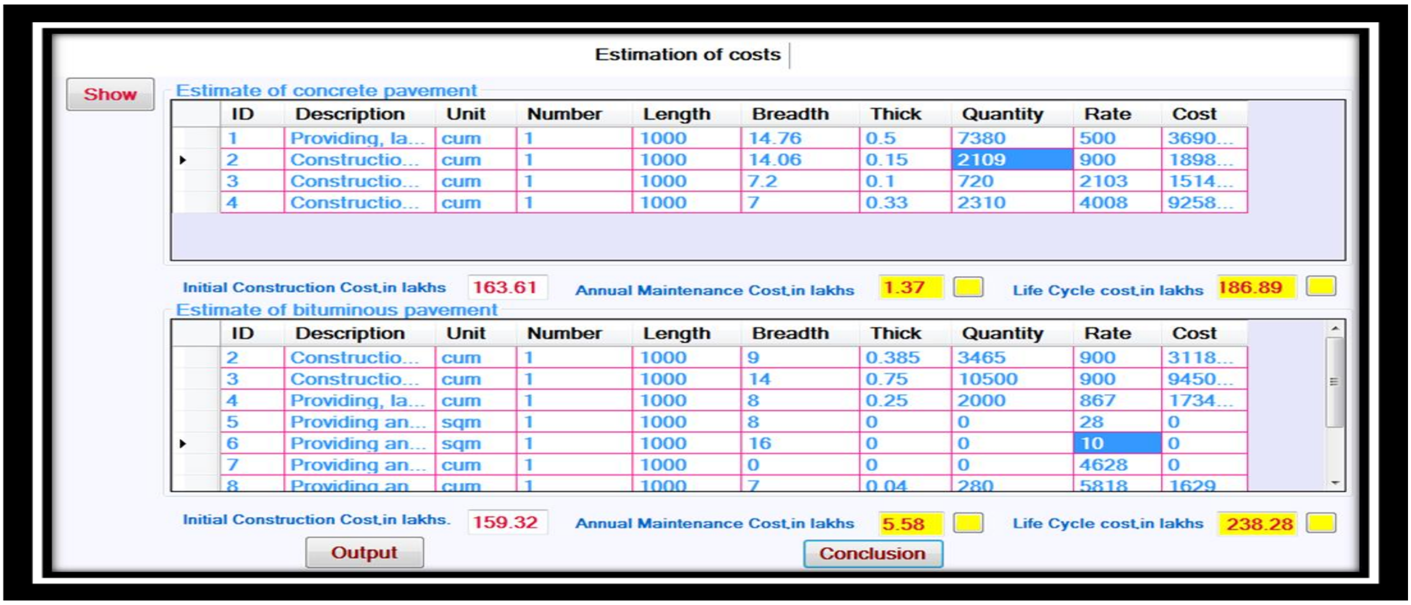
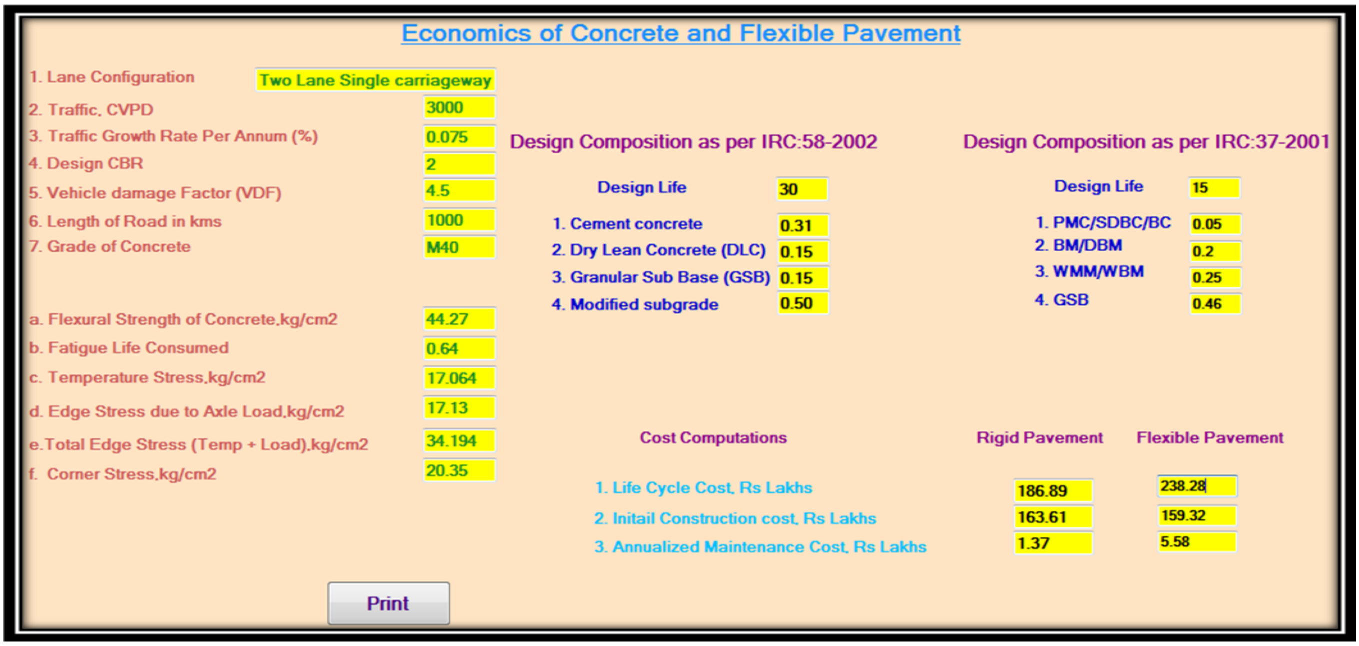


Fig -9: Screen shot of output and report



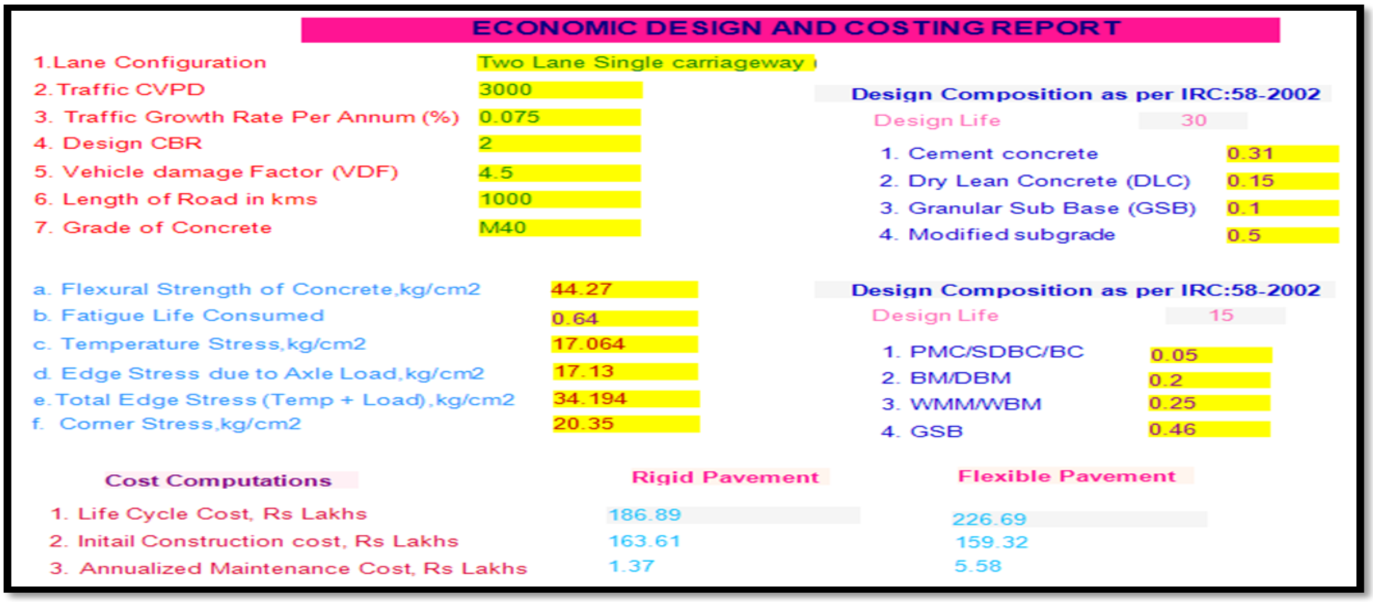


Fig -10: Screen shot of conclusion window

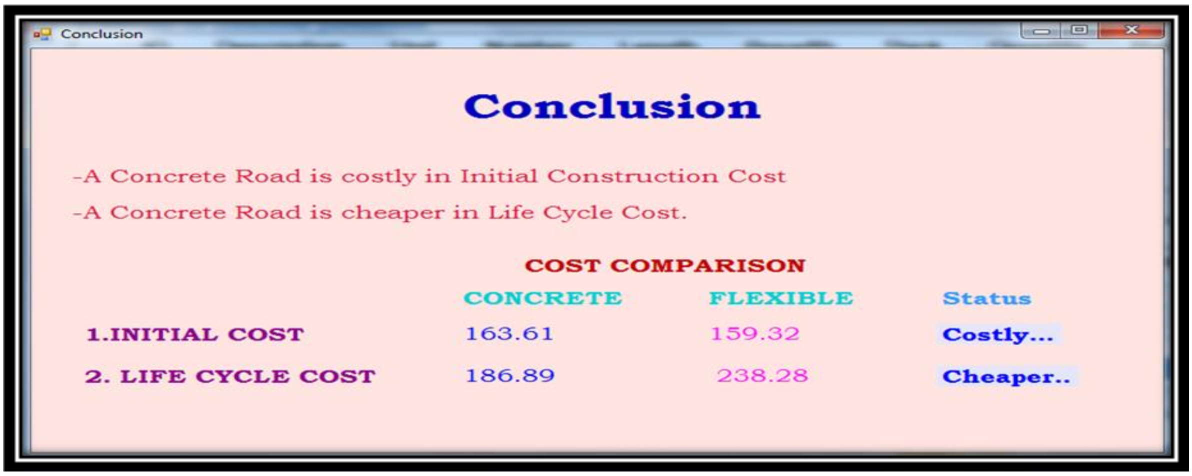


Fig -11: Line separating pavement option

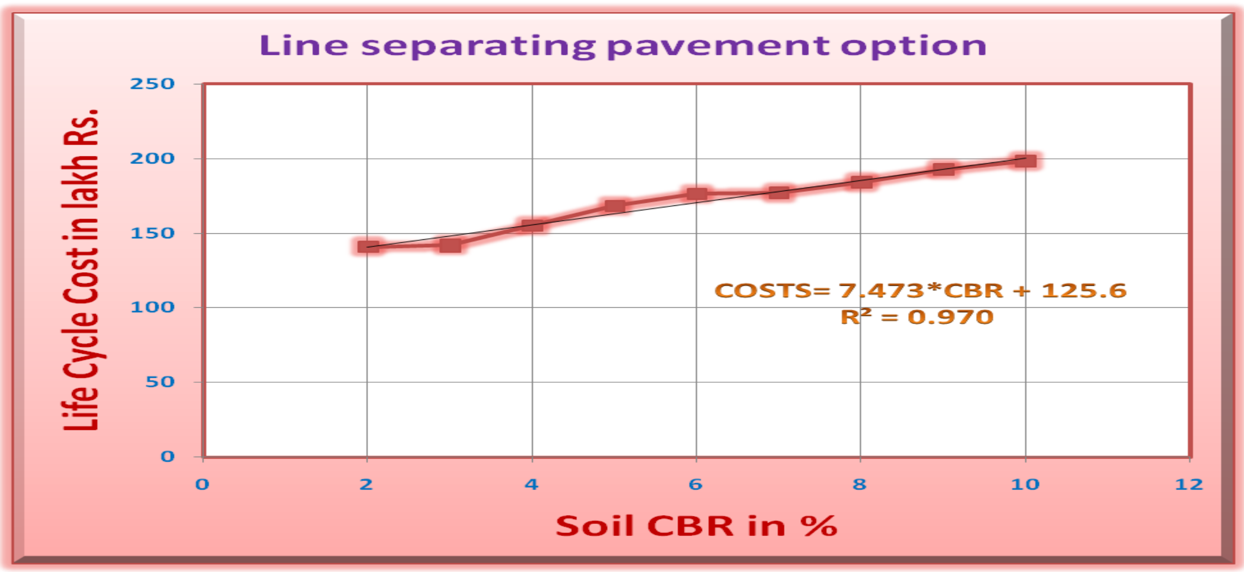


Table 1: Life cycle Cost of Flexible Pavements (in lakh) for Different Combinations of Soil and Traffic in msa

Soil CBR (%)	Traffic Load (msa)									
	1	2	3	5	10	20	30	50	100	150
2	119.72	137.31	142.53	128.23	175.61	190.28	197.04	209.57	223.03	231.96
3	119.36	133.01	138.23	122.94	168.31	181.17	189.75	198.32	211.78	226.08
4	112.60	130.38	132.68	121.06	161.69	175.01	182.45	196.44	205.62	214.19
5	110.72	128.50	130.80	119.79	156.28	169.59	177.81	186.74	197.04	204.49
6	108.86	126.65	128.94	117.62	152.63	163.45	169.88	178.80	189.77	198.34
7	108.30	125.71	127.81	116.50	149.36	162.32	170.89	179.82	190.79	199.71
8	108.30	125.71	127.44	115.37	148.23	159.05	165.48	174.40	187.52	196.09
9	108.30	125.71	127.44	115.37	143.94	156.80	163.34	171.91	185.37	194.30
10	108.30	125.71	127.44	115.37	143.94	154.66	161.19	170.12	183.58	192.15

Table 2: Life cycle Cost of Rigid Pavements (in lakh)for Different Combinations of Soil and Traffic in msa

Soil CBR (%)	Traffic Load (msa)						
	5	10	20	30	50	100	150
2	137.53	140.79	140.83	144.14	157.47	168.7	165.53
3	136.27	139.53	139.57	139.57	155.02	160.57	157.37
4	136.27	139.5	139.53	139.53	163.88	163.94	157.34
5	135.09	138.31	138.34	138.34	155.99	162.68	148.55
6	136.19	136.08	139.42	139.42	157.11	160.41	153.80
7	142.89	146.12	146.12	146.12	160.38	160.41	160.50
8	142.89	146.12	146.12	146.12	163.73	163.73	165.13
9	149.60	152.84	152.84	152.84	163.76	163.76	160.47
10	152.95	156.20	156.19	156.19	163.76	163.76	160.47

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