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TECHNICAL NOTE

ECONOMIC AND FINANCIAL ANALYSIS FOR POLYMER MODIFIED BITUMEN

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Abstract: Presently conventional bitumen and polymer modified bitumen are widely available in the market for road and highway construction. Reliable and robust bituminous concrete can be produced using both conventional bitumen and polymer modified bitumen. Thickness requirement of polymer modified bitumen is lesser than that of conventional bitumen but initial cost of construction of the former is comparatively higher. Moreover, maintenance and repair cost of polymer modified bitumen is also relatively lower than that of conventional mix during service period of road and highway infrastructure. The paper presents the advantage of polymer modified bitumen over conventional materials based on results of economic and financial analysis from a real case study with the provision of glare screen for road median barrier. Net present value and internal rate of return are determined using HDM 4 software. Road with polymer modified bitumen is found economically and financially most viable option.

Keywords: *polymer modified bitumen, economic and financial analysis, road, highway.*

1.0 Introduction

Polymer modified bitumen is capable of improving the fatigue life, softening point, flash breaking point, aging resistance of the binder and increases time period for structural overlay, hence decreases maintenance cost. For these advantages, polymer modified bitumen has found potential application in road and highway projects. Initial construction cost using polymer modified bitumen is more than that of conventional mix, but polymer modified bitumen requires lesser thickness. Therefore, an economic analysis is required to determine the life cycle cost/Net Present Value (NPV) and Internal Rate of Return (IRR) of conventional and polymer modified bitumen so as to identify the best material for road and highway construction. Financial analysis is also required for financial viability and most financial viable option for a road and highway construction under Build Operate Transfer (BOT) Project.

2.0 Literature Review

King *et al.* (1986) reported that the polymer increases the softening point, lowers the flash breaking point and improves the aging resistance of the binder in addition to imparting high elasticity. The change in the physical properties, in turn, alter the properties of the mix in which the modified binder is used. They carried out rutting resistance test and found that polymer modified bitumen mix was able to withstand four to ten times more loading cycles than conventional mix before ruts of various specified depths occurred.

Kumar *et al.* (2004) proved that elastomers have better elastic recovery than that of plastomers and loss in weight of Styrene Butadiene Styrene(SBS) modified blend is lower than that in case of neat bitumen indicating lower oxidative hardening. It has also better crack relief property. While Valkering *et al.* (1990) brought out that dynamic creep test predicts better the strain rate in polymer modified bitumen mixes. It has more viscosity value and softening point so that road lasts longer period. It was found economically viable based on life cycle cost analysis.

Collins *et al.* (1991) showed that the compatibility decreases with increase AC grade of the base bitumen and increase in temperature susceptibility. They found from laboratory study that modified bitumen increases softening point, decreases penetration, increases elastic modulus and economically viable. Oliver and Tredrea (1997) conducted tests on dynamic shear and found that long-term aging of polymer modified bitumen reduces the advantages that fresh polymer modified bitumen has over unmodified binders.

Airey and Brown(1998) carried out the conventional tests of penetration, viscosity, softening point on SBS and polymer modified bitumen and found that penetration decreased and viscosity increased with aging similar to the trend shown by pure bitumen. Yet, the softening point of the polymer modified bitumen decreased after aging contrary to what happens in case of pure bitumen. This may be because of breaking polymer affected by heat and oxidization. Pandey (1990) investigated the performance of bituminous mixes and developed fatigue prediction equations correlating the number of cycles to failure and initial tensile strain.

Collins (1991) found that tensile strain and mix stiffness are the two main factors which influence fatigue life. Fatigue life has increased to more than two times compared to that of conventional mix. Palit *et al.* (2001) carried out a laboratory study on the effect of adopting modified Marshall Compaction on the engineering properties of neat and crumb rubber modified bituminous mixtures. They reported that the densities attained using modified Marshall compaction were similar to those obtained by gyratory compaction. Indirect tensile strength elastic modulus, fatigue life as well as resistance against rutting were found to improve with modified compaction. It was also observed that the performance of mixes prepared with bitumen modified using crumb rubber is much superior when compared to that of normal mixes prepared with net bitumen for both standard and modified Marshall compaction.

Kohli *et al.* (2003) had studied on the use of Hugo hammer method in design of dense bituminous macadam. They reported that by using Hugo hammer method, there is clear-cut saving in bitumen in the range between 6 to 18 percent for the three gradations namely gradations suggested by Kandhal and Cooley (2001), The Federal Highway Administration (FHWA) (0.45 power gradation or maximum density gradation) and Ministry of Road Transport and Highways India (MoRT&H) for DBM using large size aggregate. Stability values are little higher than the recommended value given by MoRT&H for the three grading using Hugo hammer method. The stability and bulk density values for maximum density gradation using Hugo hammer was as high as 2500 kg and 2.4 gm/cm^3 respectively indicating that the comparative effort plays a major role in achieving the strength of mix.

Pandey (2008) carried out investigation to improve the pavement design standard used in India with polymer modified bitumen. Improved design methodology has considered the fatigue life of polymer modified bitumen as two times greater than that of conventional bituminous mix design. As a result, thickness requirement for polymer modified bitumen is lesser than that of conventional mix. The suggested thicknesses are shown in Table1 (Pandey 2008).

Overall, polymer modified bitumen can improve the properties of conventional bitumen by increasing softening point, viscosity, modulus of elasticity of mix, service life of pavement as well as reducing penetration, maintenance cost and pavement thickness. It has some potential to decrease life cycle cost of the road since modified bitumen makes road more durable and lasting longer over service period. Since the performance of polymer modified bitumen has been scientifically proven according to earlier research works, it is necessary to investigate the overall performance of this alternative material upon financial aspects. Hence this technical report is presenting a simple analysis on the use of conventional and polymer modified bitumen from an economic and financial point of view based on real case study.

Table 1: Thickness with Conventional Mix and Polymer Modified Bitumen Mix

Sl. No.	CBR %	Traffic MSA	Thickness as		Thickness	
			H_1	H_2	H_1	H_2
1	3	50	200	630	145	630
2		100	230	630	165	630
3		150	260	630	180	630
4	5	50	180	550	125	550
5		100	200	550	145	550
6		150	220	550	160	550

Note: MSA: Million Standard Axle, IRC: Indian Roads Congress

3.0 Methodology

A case study has been considered to justify the use of polymer modified bitumen as an alternative material for main road and highway construction. A section of National Highway 4 of India or known as NH 4 (Km 600 to Km 725) has been considered in this study. NH 4 links four of the 10 most populous Indian cities - Mumbai, Pune, Bangalore and Chennai. NH 4 is 1,235 km (767 mi) in length and passes through the states of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

The above mentioned section is considered for upgrade from two lanes to four lanes of divided carriageway. Traffic, road inventory, and condition survey data of existing two lanes road were taken from the Detailed Project Report (DPR). Pavement compositions, project cost and other related data required for HDM 4 analysis are based on reports from the authority. The project cost considered are rehabilitation cost of existing two lanes, cost of new carriageway, glare screen on road median barrier, periodic and structural overlay costs and annual maintenance cost. Pavement thickness was referred to Table 1 for both cases i.e., use of conventional bitumen and polymer modified bitumen. Brief description of the case study is mentioned in the next subsection.

4.0 Economic Analysis

The data of speed limit, pavement condition, road link and traffic have been collected from field work according to the requirement of input data for carrying out economic analysis using Highway Design Maintenance (HDM 4). Secondary data sourced from an ongoing project in consultation with Central Road Research Institute (CRRI) are Vehicle Fleet Input Files and Configuration Files as required by HDM 4.

4.1.1 Speed Limit

Design speed limit of 100 kilometer per hour has been recommended for new upgrade of four lanes road for economic analysis. The previous speed limit was set at 25 kilometer per hour for the existing two lanes road.

4.1.2 Pavement Condition

Pavement condition data has been collected from field study and summary of the data is presented in Table 2.

Table 2 Pavement Distress Data

Average Distress Data	Value
Rut Depth(mm)	30
Pothole (Per km)	10 Nos
Edge Break(Sqm/ km)	11
Roughness(m/km)	3.2
Crack (%)	3.9

4.1.3 Road Link

The existing road is measured at 25 km long, 7.2 m wide of carriageway and 1.3 m wide of earthen shoulder on both sides.

4.1.4 Traffic

Information on classified traffic volume, speeds and growth factors data have been collected from the field study. The Traffic data is listed in Table 3 as below.

Table 3 Annual Average Daily Traffic (Year 2000)

Tollable Traffic		Non Tollable Traffic	
Vehicle Type	**Number**	**Vehicle Type**	**Number**
Car/Van/jeep	3211	Scooter	444
Mini Bus	211	Motor Cycle	510
Bus	864	Animal drawn vehicle	34
LCV	983		
2 Axle	2179		
3 Axle	1168		
M. Axle	179		

4.1.5 Project Cost

Preliminary project cost has been determined based on pavement design and widening of the road from two-lanes to four-lanes. Economic cost was estimated at Rs 54 million per kilometer (currency in Rupee). Economic cost is equivalent to 90 % of financial cost as recommended by World Bank.

4.1.6 Maintenance and Repair Policy

The various routines and schedule maintenances as practiced by Ministry of Surface Transport of India are presented in Table 4 (MOST, 2001).

Table 4 Maintenance Policy

Maintenance and Repair Alternative	Maintenance and Repair Work	Intervention Criteria
i) Functional	40 mm bituminous concrete	Schedule every fifth year
ii) Structural	40 mm bituminous concrete + 100 mm dense graded bituminous concrete	Schedule every tenth year.
iii) Routine maintenance	Patching, pot hole repair, crack sealing, repair of drain cleaning, culvert bridge etc.	Schedule annually

4.1.7 Economic Analysis

Economic analysis has been carried out for design period of 25 years. An economic analysis is also conducted with a discount rate of 12 percent.

4.1.8 Pavement Management at Project Level

Project level of pavement management analysis has been carried out using the "project analysis" application of the HDM-4. Project analysis is concerned with the evaluation of one or more road projects or investment options. In the present study, the following options have been under taken for the project level pavement management.

Case – 1 Base Option – do minimum
This consists of routine maintenance-annually, functional overlay – every fifth year, structural overlay - every tenth year.

Case – 2 Improvements Option
Widening of existing two lanes road to four lanes along with routine maintenance-annually, functional overlay – every fifth year, structural overlay- every tenth year.

4.1.9 Results

Economic analysis has been carried out using HDM-4. The unit rate of polymer modified bitumen is more than that of rate of conventional mix, but polymer modified bitumen requires lesser thickness as mentioned in Table 1. Then economic analysis has been carried out to determine the Net Present Value (NPV), Road Agency Cost (RAC), Road User Cost (RUC), Total Transportation Cost (TTC) and Internal Rate of Return (IRR) to justify the selection of material for road and highway construction. The optimum solution may be found out by considering the following results of economic analysis of conventional and polymer modified bitumen mix which is the highest IRR and NPV and the lowest TTC.

Economic analysis was conducted by considering both conventional bitumen grade 60/70 and polymer modified bitumen for the existing two lanes as a base case and four lanes with conventional /polymer modified bitumen as an improvement cases. Economic analysis results are mentioned in Table 5.

Table 5: Results of Economic Analysis

Case	**IRR %**	**NPV Rs Million**	**TTC Rs Million**
Conventional Mix	21.3	1121.5	22170.3
Polymer Modified Bitumen Mix	23.0	1161.2	22124.9

According to the calculation as above, the project is regarded economically viable using conventional and modified bitumen, since internal rate of return (IRR) is greater than 12 % as mentioned in Table 5. This project is also viable since the net present value (NPV) is greater than zero. When more than one option is considered to identify the best option, the following points should be considered:

- Maximum IRR value;
- Maximum NPV; and
- Minimum Total transportation cost.

It is clearly found that polymer modified bitumen for construction of road is the best option. From Table 5, it is found that the construction which using polymer modified bitumen is more beneficial for use in road construction based on the aforementioned three criteria.

5.0 Financial Analysis

After the improvement of existing facility, road users are benefited from better road geometric, riding quality, lesser travel time, shorter distance etc. Existing traffic may be capable to generate more trips due to lesser travel time/increasing travel speed for the up gradation of the road. Some traffic from other zone will be diverted to the improved road due to better facility. This diverted traffic is assumed as 10 % of traffic at the time of opening in year 2004. Traffic at this year is obtained by multiplying projected 2004 year traffic by 1.1 as shown in Table 3. Tollable traffic is determined based on growth rate factor of 0.05 for all vehicles as mentioned in Model Concession Agreement (MCA) Guide line (refer Table 3). Only tollable traffic is considered in financial analysis. The Annual Average Daily Traffic (AADT) values are used for future projections of 25 years analysis period.

5.1 Toll Rate

Toll rate has been selected using guideline prepared by the Government of India. Average inflation rate has been determined based on the Whole Price Index (WPI) according to the Reserve Bank of India Bulletin from 1977 to 2000. This value was set at 8.3%. Based on this value, future toll rate has been projected and toll rate for the opening year in 2004 is listed in Table 6. Toll rate increasing factor for the year 2004 is 1.083^7=1.74.

Table 6: Toll Rate Per / km Vehicle Wise

Year	Car	Full Bus	Multi Axle	LCV	2A,3A Truck
Toll Rate Rs (1997)	0.40	1.40	3.00	0.70	1.40
Toll Rate Rs (2004)	0.69	2.40	5.20	1.20	2.40

5.2 Discount Rate

Discount rate has been calculated using following formula:

$$\textit{Discount rate} = (\textit{\% of equity} \times \textit{Return on equity}) \pm (\textit{\% interest of debt} \times \textit{\% of debt}) \qquad (1)$$

Assuming interest of debt and return on equity of 15% and 20 % respectively. Proportion of debt and equity is in the ratio of 4:1(80 %:20%).

$$\textit{Discount rate} = (15 \times 0.8) + (20 \times 0.2) = 16\ \%.$$

5.3 Project Cost

The project road is 25 km long and the total cost is estimated at Rs 60 million per km (Financial cost). The cost of anti-glare screen barrier was also considered in the analysis. Financial analysis has been carried out by taking the following major cost components:

- Project Cost of Rs 60 million per km;
- Annual Routine Maintenance (repair of pot hole, crack sealing, clearing CD structure etc.) 0f Rs 0.2 million per km;

- Periodic Maintenance Cost (Thin overlay is to be provided in 5th, 15th and 25th year) of Rs 2.8 million per km;
- Structural overlay is assumed to be provided in 10th and 20th year with cost of Rs 5.0 million per km and
- Toll Operation (Toll administrative cost) of Rs 6 million for toll plaza.

5.4 Concession Period

Concession period has been determined based on MCA guideline and the estimated concession period is 25 years (Construction period of 3 years + operation period of 22 years).

5.5 Results

A BOT transport infrastructure project shall be considered as financially viable, when the following conditions are simultaneously satisfied (Esther, 1998):

a) The Net Present Value (NPV) for the project should be positive.
b) The Financial Internal Rate of Return (FIRR) should have a value greater than the discount rate.
c) The cash flow (liquidity) situation in each year of the concession period should be satisfactory. In other words, the cash balance at the end of every year should be positive (It may be negative in the first three to five years of operation).
d) Payback period/Break down year should be lesser than concession period.

Financial analysis has also been carried out by considering traffic data, project cost and toll rates. The test results for concession period of 25 years are presented in Table 7.

Table 7 Results of Financial Analysis

Case	**Financial Internal Rate of Return %**	**NPV Rs Million**
Conventional Mix	24.1	1308.5
Polymer Modified Bitumen Mix	24.8	1398.3

Discount rate of the case study is set at 16 % (refer to equation 1). Financial internal rate of return is found at 24.1 % and 24 .8 % using conventional and polymer bitumen. So both cases are considered viable financially. Net present values are greater than zero for both cases. From Tables 5 and 7, it is found that the construction of road using polymer modified bitumen is more beneficial economically and financially.

6.0 Conclusions

The use of modified bitumen is economically and financially viable. Modified bitumen requires less thickness, longer life and less maintenance cost. It also increases the application of rehabilitation period i.e., overlay application period (functional and structural). It is highly recommended to use modified bitumen in lieu of conventional/traditional bitumen in road construction especially under Built Operate Transfer, Design Built Operate Transfer and Item Rate Project due to its superior properties and its positive impact on overall cost of service life.

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