International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 07 | July 2018 www.irjet.net p-ISSN: 2395-0072

Cost Deviation Approach to Obtain Direct Construction Cost Escalation or Savings for Different Flexible Pavements at Traffic Volume 50-150msa and Various CBR Conditions

Harshavardhan N. Shinde[1]

[1]M Tech, Department of Civil , IIT Guwahati

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Abstract - Effect on direct construction cost of a road due to change in flexible road crust type as a result of change in construction methodology or change in scope, can be obtained by comparing the cost deviation percentages. Cost deviation percentages are calculated in comparison with the minimal costing flexible pavement crust type for various combination of traffic volumes and subgrade CBRs. Cost savings or escalation can be easily calculated for any combination of flexible pavement crust type, subgrade CBR and Traffic volumes ranging from 50msa to 150 msa. By referring the cost deviation percentages presented in this paper, The construction cost baseline, construction planning and cost optimization for flexible pavements can be done easily.

***Key Words*: Material cost, Direct Construction cost, Cost deviation, percentage Cost escalation, Traffic, CBRs & Material, Crust Types.**

1. INTRODUCTION

Road infrastructure and economic development is a continuous process and progress in development has to be preceded, accompanied, and followed by progress in infrastructure. Considering the fact the Government of India has given a massive push to the infrastructure sector by allocating Rs 5.97 lakh crore (US$ 92.22 billion) in the Union Budget 2018-19. The majority of allocation is for power, roads and renewable sectors. Road construction in India contributes 3.64% of total GDP. Road project goes through various challenges throughout their project life cycle. However, one crucial challenge is to understand of cost deviation over-time at planning and actual construction phases. It is observed that the cost deviation mainly appear in the pre-construction phase [1]. Though the planning phase is the most critical phase, escalation could happen at any stage of the project [2]. Cost escalation is the aggregate effect of a number of different factors throughout the whole phases of the projects [3]. In developing countries cost overrun is a common problem worldwide, but it is a significant challenge and completing the projects on time and within budget has become the major concerns of the clients [4]. It is observed that the average of cost deviation in road construction is 16.73% [5]. A number studies observed that 9 out of 10 construction projects experienced cost overrun with an average budget overrun of 28% [6]. It is also observed that smaller road projects with less construction period have higher cost deviation as compared with road construction with higher construction time and budget [7]. To minimize the direct construction cost, minimal direct construction cost approach can be used for various combinations of flexible pavement crusts at varying CBRs and varying traffic volumes [8][9]. With change in the road crust types during the ongoing construction has huge impact on the construction cost budgeting , so it is very important to obtain the data about the cost overrun at the primary stage before selecting the road crust type or construction methodology. IRC 37-2012 has included five types of flexible pavement road crusts [10]. This paper deals with the effect on direct construction cost due to change in flexible road crust type as a result of construction methodology or change in scope for any combination of subgrade CBRs ranging from 3-15% and traffic from 50-150 msa. Cost baseline can be formed or updated based on the cost deviation percentages included in this paper.

2. COST DEVIATION ANALYSIS

Structural cost, cross drains, office establishment, cutting, filling, embankment cost, manpower employed in office, road signs, road marking and other miscellaneous indirect costs are same in any combination of pavement crust, traffic and subgrade CBR. So the cost escalation due to change in crust type is mainly based on the direct construction cost of the road. This analysis considers the direct construction cost for different combinations of road crusts as cited in IRC 37-2012 and traffic varying from 50-150 msa for different subgrade CBRs.

Direct construction cost is obtained by using "DSR rates of government of Maharashtra PWD for year 2017-18" [11], along with "Basic approach and general conditions and assumption for the preparation of standard data book published by NHAI, confirming to the MORTH specifications and standards" [12]. Direct construction and material costs calculated for every combination of CBR, flexible pavement crust type and traffic volume ranging between 50 to 150 msa.

A sample road of 1km length, 3.75m width and depths confirming to the road crusts as per IRC 37-2012 is considered for calculation of material and construction cost deviation. Along with this the overhead charges and contractors profit is considered as 7.5%. Minimal construction costing combination is obtained. By using the reference of the minimal construction costing pavement crust, costs deviations for the different flexible pavement crusts are calculated. Comparing the cost deviation percentages presented in this paper, The cost escalations or savings at any point of construction can be obtained if in any case of crust type is to be changed. Cost deviation percentages can also be used for the tendering purposes and baseline cost formation.

2.1. EQUIPMENT'S CONSIDERED

Apart form Labours, Mate, Skilled mazdoors the equipments considered for the equipment cost analysis are as follows,

Types	Equipment's Required
GSB	Wet mix plant @ 75 tonne capacity per hour Electric generator 125 KVA Water tanker 6 KL capacity 5 km lead Front end loader 1 cum bucket capacity Tipper 10 tonne Motor Grader 110 HP Vibratory roller 8-10 t
Cement treated Soil Sub base	Excavator 0.90 cum bucket capacity Tipper for carriage of soil Motor Grader 110 HP @ 50 cum per hour Vibratory roller 8 - 10 tonne Tractor with Rotavator and blade @ 25 cum per hour Water tanker 6 KL capacity
Cement treated crushed Rock or combination sub base	Motor Grader 110 HP @ 50 cum per hr Vibratory roller 8 - 10 tonne Tractor with Rotavator and blade @ 25 cum per hour Water tanker 6 KL capacity Tipper
Wet Mix Macadam (WMM)- Premixed	Wet mix plant of 75 tonne hourly capacity Electric generator 125 KVA Front end loader 1 cum capacity Paver finisher or motor grader Vibratory roller / Smooth 3 wheeled steel roller (8 - 10 tonne) Water tanker 6 KL capacity Tipper
Aggregate interlayer or Crack relief layer.	Wet mix plant of 75 tonne hourly capacity Electric generator 125 KVA Front end loader 1 cum capacity Paver finisher Vibratory roller 8 - 10 tonne Water tanker 6 KL capacity
Stress absorbing membrane interlayer (SAMI)	Mechanical broom @ 1250 sqm per hour Air compressor 250 cfm capacity Bitumen pressure distributor @ 1750 sqm per hour Hydraulic Chip spreader Smooth wheeled road roller 8-10 tonne
Prime coat & Tack coat	Mechanical broom @ 1250 sqm per hour Air compressor 250 cfm Bitumen pressure distributor @ 1750 sqm per hour Water tanker 6 KL capacity @ 1 trip per hour
Bituminous Concrete and Dense Graded Bituminous Macadam (DBM)	Batch mix HMP @ 75 tonne per hour Paver finisher hydrostatic with sensor control @ 75 cum per hour Generator 250 KVA Front end loader 1 cum bucket capacity Tipper 10 tonne capacity Smooth wheeled roller 8-10 tonnes for initial break down rolling. Vibratory roller 8 tonnes for intermediate rolling. Finish rolling with 6-8 tonnes smooth wheeled tandem roller.
Surface dressing	Mechanical broom @ 1250 sqm per hr Air compressor 250 cfm Hydraulic self-propelled chip spreader @ 1500 sqm per hour Tipper 10 tonne capacity for carriage of stone chips from stockpile on road side to chip spreader Front end loader 1 cum bucket capacity Bitumen pressure distributor Smooth wheeled roller 8-10 tonne wt.

Based on working capacity and efficiently, The direct equipment cost analysis is calculated as per the equipment requirement of the pavement layers preparation.

2. 2. MATERIAL COST DEVIATION

Cost deviation percentages in road construction for various combinations of flexible pavements crust types, traffic from 50 to 150 Msa. along with various subgrade CBRs conditions are as below,

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	56%	11%	0%	20%	18%
100	64%	13%	0%	19%	24%
150	69%	14%	0%	19%	28%

Table. 1. Direct Material Cost deviation w.r.t the minimal cost at 3% CBR.

For 3% CBR minimum material cost is in case of "cementitious base and subbase with SAMI at the interface of base and the bituminous layer (CB and CSB with SAMI)" as its material cost deviation with minimal costing combination is 0%. Cost deviation for the 3% CBR is highest in case of "Granular Base and Granular Subbase (GB and GSB)" crust type. Cost deviation is varying from 0 to 69%.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	45%	12%	0%	19%	16%
100	53%	13%	0%	19%	20%
150	57%	15%	0%	19%	24%

Table. 2. Direct Material Cost deviation w.r.t the minimal cost at 4% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	41%	12%	0%	18%	13%
100	46%	14%	0%	18%	16%
150	50%	15%	0%	18%	20%

Table. 3. Direct Material Cost deviation w.r.t the minimal cost at 5% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	31%	12%	0%	19%	15%
100	39%	14%	0%	18%	18%
150	41%	15%	0%	18%	22%

For 4% and 5% CBR, minimum material cost is in case of "cementitious base and subbase with SAMI at the interface of base and the bituminous layer (CB and CSB with SAMI)".

Material cost deviation is highest in case of "Granular Base and Granular Subbase (GB and GSB)" crust type.

Table. 4. Direct Material Cost deviation w.r.t the minimal cost at 6% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	22%	12%	0%	19%	18%
100	35%	14%	0%	19%	19%
150	37%	16%	0%	19%	23%

Table. 5. Direct Material Cost deviation w.r.t the minimal cost at 7% BR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	14%	12%	0%	19%	21%
100	29%	14%	0%	19%	21%
150	29%	16%	0%	19%	24%

Table. 6. Direct Material Cost deviation w.r.t the minimal cost at 8% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	15%	13%	0%	17%	1%
100	30%	14%	0%	17%	11%
150	25%	14%	0%	16%	15%

Table. 7. Direct Material Cost deviation w.r.t the minimal cost at 9% & 10% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	6%	13%	0%	16%	4%
100	14%	14%	0%	15%	9%
150	21%	14%	0%	15%	13%

Table. 8. Direct Material Cost deviation w.r.t the minimal cost at 15% CBR.

It can be observed that as CBR increasing the material cost deviation is reducing. In all cases "Cementitious base and subbase with SAMI at the interface of base and the bituminous layer (CB and CSB with SAMI)" is least costing road as deviation from the minimal cost is 0%.

The probable direct material cost escalations can be calculated by using cost deviation percentages presented in above tables. Suppose for 5% CBR and traffic 150msa, at first "Foamed bitumen/bitumen emulsion treated RAP" with cost deviation of 20% w.r.t. minimal cost is selected and now if there is requirement of change in road crust type as "Cementitious Base and Cementitious Subbase of aggregate interlayer for crack relief (CB and CSB)" having 18% material cost deviation for same CBR and Traffic volume, Then the cost escalation or savings is obtained as,

$$\% \text{ Escalation in material cost} = \frac{(18-20)}{20} * 100 = -10\%$$

Here "-10%" indicates there will be 10% cost savings in material cost if pavement crust type is changed.

2.3. DIRECT CONSTRUCTION COST DEVIATION

The direct construction cost deviation percentages are obtained by using same analysis as used in case of material cost deviation estimation and these are as follows,

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	60%	3%	4%	0%	12%
100	73%	5%	4%	0%	19%
150	78%	6%	4%	0%	23%

Table. 9. Direct construction Cost deviation w.r.t the minimal cost at 3% CBR.

Highest construction cost deviation is in case of 3% CBR. Cost deviation w.r.t. the minimal construction cost is ranging from 0% to 78%. The direct construction cost is minimum in case of the cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base as the cost deviation is 0% w.r.t. the minimal construction cost.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	54%	4%	5%	0%	10%
100	62%	6%	5%	0%	16%
150	67%	7%	5%	0%	20%

Table. 10. Direct construction Cost deviation w.r.t the minimal cost at 4% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	46%	6%	6%	0%	8%
100	56%	7%	6%	0%	12%
150	61%	8%	6%	0%	17%

Table. 11. Direct construction Cost deviation w.r.t the minimal cost at 5% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	38%	5%	6%	0%	10%
100	48%	7%	6%	0%	14%
150	53%	8%	6%	0%	18%

Table. 12. Direct construction Cost deviation w.r.t the minimal cost at 6% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	28%	5%	5%	0%	13%
100	41%	6%	5%	0%	15%
150	49%	8%	5%	0%	19%

Table. 13. Direct construction Cost w.r.t the minimal cost at 7% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	24%	5%	5%	0%	16%
100	34%	6%	5%	0%	16%
150	42%	8%	5%	0%	20%

Table. 14. Direct construction Cost w.r.t the minimal cost at 8% CBR.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	31%	10%	11%	3%	0%
100	38%	9%	8%	0%	7%
150	44%	8%	8%	0%	12%

Table. 15. Direct construction Cost w.r.t the minimal cost at 9% & 10% CBR.

For the 90-10% CBR and traffic volume of 50 msa, the minimal construction costing is “Foamed bitumen/bitumen emulsion treated RAP”.

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
50	16%	9%	9%	0%	1%
100	27%	10%	9%	0%	6%
150	35%	10%	9%	0%	11%

Table. 16. Direct construction Cost w.r.t the minimal cost at 15% CBR.

It can easily observed that the direct construction cost deviation is reducing as the CBR% is increasing. It is also observed that direct construction cost deviation percentages are increasing with increasing the traffic volume.

By using same analysis as used for the percentage material cost escalation, the direct construction cost escalation or saving due to change in road crust type can be calculated for any combination of Traffic volume with subgrade CBR. Suppose if here in case of 9-10% CBR and Traffic 150 msa, at first “Cementitious base and subbase with SAMI” with direct construction cost deviation 8% was selected and now if it’s proposed to change the road crust type to “Foamed bitumen/bitumen emulsion treated RAP” with construction cost deviation 12%. The total percentage cost escalation in direct construction cost would be

% Escalation in direct construction cost = $\frac{(12-8)}{8} * 100$ = 50%

So here in this case the direct construction cost escalation due to change in the flexible pavement crust type is 50%.

By using the same analysis, effect of change in flexible pavement crust type as a result of change in construction methodology can be obtained easily.

3. CONCLUSION

This analysis can be used to obtain the effect on direct construction cost due to change in flexible road crust type as a result of construction methodology at any point of construction. Cost savings or escalation percentages can be easily obtained for any combination of flexible pavement crust type, subgrade CBR with Traffic volume ranging from 50msa to 150 msa. The construction cost baseline, construction planning and cost optimization for flexible pavements can be done effectively by using the cost deviation percentages presented in this paper.

4. FUTURE SCOPE

Material cost: Construction cost ratios for various combinations of flexible pavement road crust at various subgrade CBRs for traffic volume between 2-150MSA, can be obtained. Same analysis can also be applied for the rigid pavements and feasibility is checked.

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