Material & Construction Cost Deviation In Road Construction for Different Flexible Pavement Crust Types at Various Traffic & Subgrade CBR Conditions

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Abstract : This study is done to find out the maximum possible direct cost deviations in materials and construction of flexible road crust type among the five flexible road types cited in IRC 37-2012, So as to frame maximum baseline cost variation for optimization of cost and proper planning of construction at various CBRs from 2% to 15 % and different traffic volume conditions from 2msa to 30 msa. This analysis can be utilized for obtaining probable direct construction and material cost escalation or savings in project if in case the road crust type is required to be changed. The material, equipment and direct construction cost and their proportions for various types of flexible pavement are calculated based on the district schedule rates and the specification and standards of the Roads (MORTH Specifications). Minimal costing road pavement crust type is selected among all crust types and the cost deviation in direct cost of material and construction for remaining pavement crust types is found out, which could serve the purpose of selecting lowest construction costing road crust.

IndexTerms **- Material cost, Direct construction cost, Cost deviation, Cost escalation, Traffic, CBRs & Material, Pavement Crust Types.**

I. INTRODUCTION

Road construction in India contributes 3.64% of total GDP. With 33 lakh Km. Indian road network is second largest in the world. Road transportation is vital among all the transportation modes available and it is major contributor in the development of nation. As its GDP contribution is more, huge amount of money is involved in the road construction industry. Cost overrun is a common problem worldwide, but it is a significant challenge in developing countries. The inability of the construction industry to complete the projects on time and within budget has become the major concerns of the clients [1]. The results reveal that the average of cost deviation in road construction is 16.73% and it is ranging from -20.33% to 56.01% [2].

A number studies have been conducted to study cost variance and it is revealed that 9 out of 10 construction projects experienced cost overrun with an average budget overrun of 28% [3]. It is also observed that smaller road projects have higher cost deviation, unlike the building construction, road construction showed negative correlation between cost and construction time [4]. The variations between feasibility and contract cost, ranging between 28.5% and +36%, construction industry accounts 6–9% of GDP in many countries [5]. Minimal Cost Approach is introduced for Selecting the Flexible pavement crust types to minimize the direct road construction cost [6] [7].

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 or savings at the primary stage before selecting the road crust type or construction methodology. IRC 37-2012 has included five types of flexible pavement road crust [8]

This paper would be helpful to obtain the percentage escalation or savings of direct construction cost and material cost of flexible road crusts due to change in road crust as a result of change in construction methodology or unavailability of material or equipment's for any combination of CBRS ranging from 3-15% and traffic from 2-30 msa. Best suited low costing road can also be obtained.

II. COST DEVIATION ANALYSIS

Direct construction cost is calculated for the different road types at various CBRs and traffic conditions as per IRC 37-2012 [8]. For the same "Basic approach and general conditions and assumption for the preparation of standard data book published by NHAI and confirming to the MORTH specifications and standards" is used [9]. Different road crust types cited in IRC 37-2012 are as follows,

1. Granular Base and Granular Subbase.(GB and GSB)
2. Cementitious Base and Cementitious Subbase of aggregate interlayer forcrack relief. (CB and CSB)
3. Cementitious base and subbase with SAMI at the interface of base and the bituminous layer. (CB and CSB with SAMI)
4. Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase.(RAP)
5. Cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base. (CB and GSB with crack relief layer).

Whole analysis is done based on a requirement of material and equipment's for sample road of 1km length, 3.75m width and depths confirming to the road crusts as per IRC 37-2012. Along with this the overhead charges and contractors profit is considered as 7.5%. For Direct material and construction rate analysis DSR rates of government of Maharashtra PWD for year 2017-18 are used [10]. All indirect costs, cost of structures and cross drainage works, cutting, filling, Embankment preparation, road singes and road markings, manpower employed, miscellaneous works are not considered in the analysis as these will be constant throughout the various road types cited in IRC 37. So analysis of direct construction cost escalation or saving would be effective in case of obtaining optimal direct construction costing road crust type.

After all analysis of direct material and construction cost, the road with minimal direct cost is selected and with reference to same, the cost deviation of other types of roads is obtained. So if prevailing conditions of material and construction equipment's are not favorable , next less costing flexible road type can be selected based on the cost deviation percentages w.r.t to minimal cost. If in case of change in any road crust type due to certain construction requirements, the percentage cost savings or escalations can be obtained. Same analysis can be used at preconstruction tendering analysis.

III. EQUIPMENT'S USED

Apart form Labors, Mate, Skilled mazdoors, the equipment's considered for the equipment cost analysis for preparation of the pavement crust layers are as follows,

Pavement layer	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	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

Pavement layer	Equipment's Required
Bituminous Macadam (DBM)	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.

IV. MATERIAL COST DEVIATION

On the basis of above analysis material cost deviation in road construction among different flexible pavements crust types at various traffic & subgrade CBRs conditions are obtained and these are as per follows,

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

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
2	48%	6%	15%	26%	0%
5	56%	15%	18%	35%	0%
10	70%	8%	14%	24%	0%
20	73%	5%	11%	18%	0%
30	74%	2%	8%	13%	0%

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
2	46%	12%	20%	32%	0%
5	58%	18%	24%	38%	0%
10	66%	13%	20%	29%	0%
20	70%	10%	16%	22%	0%
30	69%	8%	11%	18%	0%

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
2	48%	20%	27%	40%	0%
5	59%	21%	31%	41%	0%
10	69%	19%	27%	34%	0%
20	64%	16%	22%	28%	0%
30	73%	15%	16%	24%	0%

Here in these tables 0% cost deviation indicates that particular road crust type of having least direct material cost among all five crust types at given traffic and CBR conditions. Material cost deviation for 3% CBR "Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase (CB + COLD MIX RAP)" is least among all other crust types. Cost deviation varies from minimum 2% to maximum 74% for Traffic ranging from 2-30 msa at 3% CBR.

Material Cost deviation at 5% CBR varies from minimum 15% to maximum 73% for Traffic ranging from 2-30 msa. It can be observed that "Cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base (CB and GSB with crack relief layer)", Is having least deviation in most of the cases, so if "Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase (CB + COLD MIX RAP)" can't be used then second choice of pavement crust would be "CB and GSB with crack relief layer".

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
2	37%	18%	25%	38%	0%
5	44%	19%	28%	39%	0%
10	54%	15%	24%	31%	0%
20	48%	14%	20%	25%	0%
30	53%	12%	9%	21%	0%

Table. 5. Direct Material Cost deviation 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
2	30%	17%	24%	36%	0%
5	36%	17%	26%	37%	0%
10	41%	12%	21%	28%	0%
20	39%	11%	18%	22%	0%
30	47%	10%	2%	18%	0%

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
2	27%	16%	22%	35%	0%
5	28%	16%	24%	36%	0%
10	32%	10%	19%	25%	0%
20	29%	9%	16%	20%	0%
30	34%	12%	0%	20%	4%

Here in case of CBR 8% and Traffic 30 msa, least material cost requirement crust type is “Cementitious base and subbase with SAMI at the interface of base and the bituminous layer. (CB and CSB with SAMI)” as the deviation w.r.t minimal cost is 0%.

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
2	49%	26%	34%	48%	0%
5	49%	30%	41%	49%	0%
10	59%	34%	41%	49%	0%
20	55%	27%	31%	40%	0%
30	61%	26%	48%	38%	0%

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

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
2	49%	26%	34%	48%	0%
5	49%	30%	41%	49%	0%
10	59%	34%	41%	49%	0%
20	55%	27%	31%	40%	0%
30	61%	26%	48%	38%	0%

It can be observed that as CBR increasing the material cost deviation is reducing. In most of the cased “Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase (CB + COLD MIX RAP)” is least costing road as deviation from the minimal cost is 0%.

Above tables and percentages can be utilized for getting probable material cost deviation in project if road crust type is to be changed. Suppose if here in case of CBR 8% and Traffic 30 msa, at first “CB and GSB with crack relief layer” with material cost deviation 20% was selected and now if its proposed to change the road crust type to “Granular Base and Granular Subbase” with direct material cost deviation 34%, The total percentage cost escalation in material cost would be

$$\% \text{ Escalation in material cost} = \frac{(34-20)}{20} * 100 = 70\%$$

V. 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,

Table no 9 Indicates, For subgrade CBR 3%, minimal direct construction costing road is "Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase.(RAP)" upto 2-10 msa. And for 20-30 msa the least costing road is cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base".

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

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
2	69%	7%	8%	5%	0%
5	77%	15%	11%	14%	0%
10	93%	7%	6%	4%	0%
20	92%	4%	4%	0%	1%
30	101%	5%	27%	0%	7%

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
2	69%	14%	14%	11%	0%
5	81%	19%	17%	16%	0%
10	91%	12%	13%	8%	0%
20	88%	8%	8%	3%	0%
30	91%	7%	26%	0%	2%

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
2	73%	23%	22%	18%	0%
5	85%	23%	25%	18%	0%
10	92%	19%	20%	12%	0%
20	88%	15%	14%	7%	0%
30	91%	13%	30%	4%	0%

Construction cost deviation in 4% and 5% CBR ranges from 2-91% with reference to minimal cost. It also can be observed that cost deviation in Traffic 30 msa is highest.

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
2	60%	21%	20%	16%	0%
5	68%	21%	22%	17%	0%
10	74%	15%	17%	9%	0%
20	69%	12%	12%	5%	0%
30	69%	10%	27%	1%	0%

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
2	51%	19%	18%	14%	0%
5	58%	18%	20%	15%	0%
10	60%	12%	14%	7%	0%
20	59%	10%	10%	3%	0%
30	65%	9%	27%	0%	2%

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
2	47%	17%	16%	13%	0%
5	49%	16%	18%	13%	0%
10	49%	8%	11%	4%	0%
20	47%	7%	8%	0%	0%
30	53%	10%	28%	0%	4%

Table. 15. Direct construction Cost 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
2	77%	31%	30%	26%	0%
5	78%	34%	36%	26%	0%
10	86%	37%	36%	27%	0%
20	82%	28%	25%	19%	0%
30	88%	26%	42%	18%	0%

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

TRAFFIC (msa)	GB & GSB Pavement	CTB + CTSB + Crack Relief Layer	CB + CTSB + SAMI	CB + GSB + Crack Relief Layer	CB + COLD MIX RAP
2	72%	39%	35%	28%	0%
5	81%	42%	41%	28%	0%
10	94%	42%	41%	31%	0%
20	78%	34%	27%	23%	0%
30	71%	28%	44%	17%	0%

It can easily observed that the direct construction cost deviation is reducing as the CBR %. For the CBR below 5 % construction cost is deviating from 0% to above 90%, but CBR above 5% construction cost is deviating from 0% to below 90%.

By using same analysis as used for the percentage material cost escalation, the direct construction cost escalation or saving in case of the changed crust type can be obtained. Suppose if here in case of CBR 15% and Traffic 20 msa, at first "Granular Base and Granular Subbase" with direct construction cost deviation 71% was selected and now if its proposed to change the road crust type to "CB and GSB with crack relief layer" with construction cost deviation 17% The total percentage cost escalation in direct construction cost would be

$$\textbf{\% Escalation in construction cost} = \frac{(17-71)}{71} * 100 = \textbf{-76\%}$$

Here "-76%" indicates the "cost saving" in direct construction cost due to change in crust type. This method can be applied to any combination of the Traffic and CBRs.

VI. CONCLUSIONS

Based on the Direct construction and material cost deviation analysis produced in this paper it is possible to obtain the % cost savings or % cost escalation in case of the change in the road crust type for any traffic volumes varying from 2 to 30msa and CBRs varying from 3-15%.

Minimal direct construction costing road crust type among the five road types cited in IRC 37-2012, can be selected by using the above analysis. All tables included in this paper can be utilized at any stage of construction also at preconstruction tendering purpose for checking various cost deviation for different combinations of CBR, Traffic Volume and Different flexible road crusts.

VII. FUTURE SCOPE

Material and construction cost deviation, % escalation and % savings approach can be applied for various Flexible road crusts cited in IRC 37-2012 at traffic volumes between 50-150msa. Also cost proportions as Material cost: Equipment cost: Construction cost can be obtained for the same flexible pavement crusts.

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