Asphalt production, paving and compaction techniques

Process of Mix Design Based Cold Mix Laying and Paving Road

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Abstract

In current practice, conventional bitumen emulsion is used which pose different limitations like low binding properties, availability of varied aggregate quality, need of pre-wetting of aggregates, presence of moistures in aggregates, inability to utilise existing hot mix equipment etc. Therefore, a process of mix design based cold mix laying and paving road which overcomes all the barriers of the current “State- of -the - Art” technology is needed. Key Elements are Aggregate, Tailor Made Cold Mix Binder, RCMD (Recommended Cold Mix Design) Process – Simulation of Site Condition, Equipment and Application type. In accordance with the technology, the designed bitumen emulsion (Tailor made) is a key element. The process includes diagnosing characteristic of aggregates, it includes physical properties of aggregates, defining a type of road to be laid and paved, preparing a designed bitumen emulsion, the composition of the designed bitumen emulsion is selected on the basis of the physical properties of the aggregates, available existing modified hot mix equipment, climatic condition, type of road to be laid; and mixing the aggregate with designed bitumen emulsion to pave the resultant bitumen emulsion-aggregate mix for road construction to ensure required lead time of the mix to meet desired workability on transportation to site during laying of the mix. Cold mix as per design is produced in modified hot mix plant to eliminate the need of heating of aggregate in controlled condition, transported to the site, laid by self-propelled mechanical paver. After breaking of the laid mix, it is compacted by the pneumatic roller, a vibrating roller (vibrating option switch off) of 15-30 ton having tyre pressure of 7 kg/sqm followed by a static roller 8-10 ton with speed of maximum 5 km/hr to achieve finish road and to allow the traffic within half an hour time.

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1. INTRODUCTION

Tailor Made Cold Mix technique is the field application of mix design based tailor-made CRRI-BitChem bitumen emulsion binders with the available or recommended aggregates through modified HMP plant or site mixing and to eliminate the need of any pre-wetting of aggregates or heating of aggregate-binder mix. The said technique helps in production of dense/ semi-dense mixes like seal coat & SDBC as well.

In current practice, Bitumen Emulsion based cold mixes are being used in the application of Open Graded Premix Carpeting (OGPC) and Seal Coat, 20 mm thick in rural road sector which is difficult to continue the construction and has the challenges to work with varied quality of aggregates available at different sites, different climatic condition, lack of proper chemical combination in bitumen emulsion, need of pre-wetting of aggregate before mix production, not to able to utilize existing hot mix equipment in the operation, high cost in construction for very low progress of work etc. To overcome all these challenges, Close Graded Premix Carpeting (CGPC) may stand complete replacement of conventional Bitumen Emulsion based Cold Mixes (OGPC-SC) for its different types of advantages and benefit as mentioned below.

2. KEY CHALLENGES OF CONVENTIONAL BITUMEN EMULSION BASED MIXES

1. Pre-wetting of Aggregates Prior to mixing - As per IRC specifications, it needs pre-wetting of aggregate before cold mix production resulting in non-performance of mix quality as there is no limitation of adding of water with the aggregates by the site people and needs increased vigilance on quality control.
2. Presence of existing moisture in aggregates- Post-rains the dampness and presence of moisture in aggregates becomes an additional factor of poor quality due to run-off of bitumen emulsion from the mix when pre-wetting of aggregates is done prior to mixing operations.
3. Need of IRC specification of aggregates at sites - Conventional Bitumen Emulsion based mixes needs standardized recommended aggregates as per IRC specifications, which is practically not found throughout the country. It needs clean aggregate to perform the mixing operations and achieve the necessary coating and anti-stripping properties, which is not possible as per site condition. Only Open Graded Pre-mix carpeting is possible with such clean aggregates. Other applications like Seal Coat, MSS, BM, and SDBC are not possible for the chemical combination is standardized in conventional Bitumen Emulsion and varied quality of site aggregates.
4. Need of mechanization for all types of Cold Mix operations - Cannot utilize existing hot mix equipment to prepare dense/ semi-dense mixes for inadequate design properties of conventional bitumen Emulsion.
5. Adequate binding and performance of the mix - Performance of Emulsion based cold mixes in road construction does not provide the enhanced anti-stripping properties due to very low use of the necessary chemicals and hence gets easily worn out during rains etc., especially when mix design-based approach with varied aggregates is not undertaken.

3. THE KEY ELEMENTS OF TAILOR MADE COLD MIX TECHNOLOGY

1. Aggregate
2. CRRI- BitChem Cold Mix Binder (Tailor made)
3. RCMD (Recommended Cold Mix Design) Process – Simulation of Site Condition
4. Equipment
5. Application type

3.1 Aggregate

The coarse aggregate or fines shall consist of crushed rock, crushed gravel or other hard material as per specification. They shall be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious matter. The aggregate gradation differs largely in all sites either being under-graded or over-graded and mostly not adhered to IRC specifications especially in rural areas in difficult geographies. Soil coted aggregates which are generally unacceptable for such paving operations are also found to be used in practice in States like Himachal Pradesh, Uttarakhand, and various States of NE region as marginal materials.

The testing of aggregates is done as per the desired physical properties or determining the actual properties of aggregates to be used.

3.2 CRRI-BitChem Cold mix binder (Tailor- made)

It is a mix design-based tailor-made bitumen emulsion with enhanced binder characteristics using certain performance additives and anti-stripping agent along with the regular emulsifiers to provide medium or medium

and slow characteristics within the single grade of binder in cold mix technology in various applications of road construction. The main feature of this cold mix binder is that this binder has been customized to use with the aggregates available from any source in India i.e. dusty Aggregates, soil coated Aggregates, clean Aggregates, damp Aggregates, pea gravel Aggregates or the Cal carious (lime mix) Aggregates. As well as the varied gradation of aggregates, in case it cannot be supplied as per the IRC recommended specifications.

The tailor-made cold mix binder exceeds the specifications of IS 8887:2004 and is a step ahead of IRC SP: 100:2014.

3.2.1 Typical properties, specification and test result of tailor-made cold mix binder:

Followed IS 8887 and IRC standard to meet the desired workability, adhesion, breaking & curing time, lead time, coating, stripping and compatibility of the cold mixes when mixed with aggregates.

Table 1. Properties, specification & test result of Cold Mix Binder

Properties	Specification	Test Result
Viscosity at 25ºC (Saybolt Furol Viscometer), Sec	30 – 100	33 – 40
Residue on 600 Micron IS Sieve, % max	0.05	0.002 – 0.02
Storage Stability after 24 hrs, % max	2	0.3 – 0.5
Binder Residue by Evaporation, % min	60	65 – 66
Average Setting time, hrs. (As per site condition)		~1.5

3.3 RCMD (Recommended Cold Mix Design) Process – Simulation of Site Condition

RCMD process is conducted looking at the following site conditions -

a) Aggregate gradation
b) Aggregate fines content
c) Mixing equipment
d) Lead time from plant to site
e) Weather condition
f) Moisture in aggregates at site level
g) Different types of aggregates like granite, Cal Carious type etc.

3.3.1 Cold mix design activities and Recommended Cold Mix Design Report (RCMD)

Table 2. Cold mix design activities & recommendation

Step	Activity
Step 1	Aggregate sample collection from sites
Step 2	Gradation of aggregate using standard IS Sieve to meet the specification
	Physical Property Test of the aggregate
Step 3	Mix Design with Graded Aggregate and Cold Mix Binder
	Test to know the breaking, setting & lead time; coating & adhesion
	Test to know the coating of the mix design in wet and dry condition
	Stripping & compatibility Test
	Marshall test for flow, stability, air voids, density, ITS etc.
Step 4	Recommendation of the mixing proportion of course and fine aggregate
	Recommendation of consumption of cold mix binder of the mix to be produced

Step 5	Issue of RCMD report

3.3.2: Mix Design of Cold Mix Semi Dense Bituminous Concrete (SDBC)

Semi dense bituminous concrete (SDBC) is a continuously graded mix, which can be used as binder course or wearing course in a flexible pavement. Cold SDBC technology is a highly engineered solution for construction of layer of 25-40 mm thickness. Gradation of aggregate for SDBC is given in the Table 3. Cold SDBC samples are prepared by adding various contents of tailor-made emulsions ranging from 7 to 9.5 % by weight of aggregate. The emulsion is added with the aggregate and mixed thoroughly for about 2 minutes and then loose mix is kept in oven at 60°C for 1 to 2 hrs. After completion of curing this loose mix was transferred to Marshall Moulds and compacted by applying 50 blows on both sides. The Marshall samples are de moulded after 24 hrs and these samples are kept in oven at 40°C for 72 hrs. After curing is done the samples are kept in environmental chamber at 25°C for 72 hrs and tested for stability, density and ITS test. The results are graphically shown in Figure 3. Optimum Emulsion content and design requirements for SDBC with different tailor made binders are given.

3.3.3: Gradation of aggregates (IRC: SP-100: 2014 & MORTH specification)

Table 3. Gradation of SDBC aggregate

IS Sieve (mm)	Cumulative % by wt. of total aggregate passing (35 -40 mm, Grade 1)	Cumulative % by wt. of total aggregate passing (25-30 mm, Grade 2)	Actual Conforming to Grade 2
19	100		
13.2	90-100	100	
9.5	70-90	90-100	
4.75	35-51	35-51	
2.36	24-39	24-39	
1.18	15-30	15-30	
0.6	-	-	
0.3	9-19	9 -19	
0.15	-	-	
0.075	3.8	3.8	

3.3.4: Properties & test result of cold mix semi dense bituminous concrete (SDBC) with cold mix binder

Table 4. Properties & test result of cold mix semi dense bituminous concrete

SL No	Properties	Cold mix binder content		
		7 %	8 %	9 %
1	Binder residue %	4.2	4.8	5.4
2	Bulk density, gm/cc	2.33	2.37	2.34
3	Voids %	9	8	11
4	Stability, kg at 25°C	470	600	535
5	Flow, mm	8.2	7.2	9

3.3.5: Mix design for cold mix SDBC using Marshall Equipment

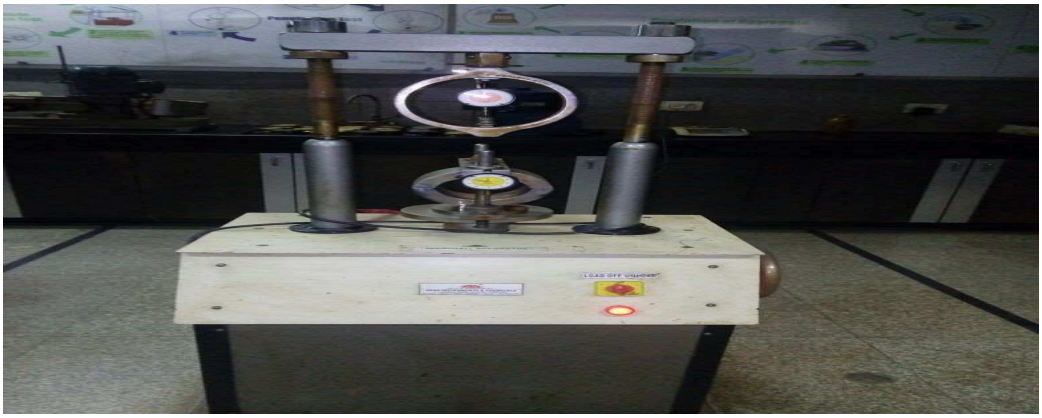

Figure 1: Marshall Equipment

Figure 2: Cold Mix SDBC Marshall Mould

3.3.6 Properties of Marshall Test for Cold Mix SDBC and Test Result for final sample

Table 5: Properties of Marshall test of Cold Mix SDBC & test result

SL NO	Properties	Requirement	Test result
1	No of compaction blows on each side of Marshall Specimen.	50	50
2	Marshall Stability at 25ºC in Kg after curing the specimen in air for 72 hours ,min.	500	600
3	Marshall Flow (mm) at 25ºC, max.	8	7
4	Per cent voids in mixture	6-10	8

5	Binder content (residual bitumen),by weight of total mix(%),min.	4.5	4.8
6	Retained indirect tensile strength at 25ºC after conditioning for 72 h in air and 24 h at 40ºC in water, %	75	>75

3.3.7 Marshall Properties of Cold Mix SDBC with different cold mix binder for ITS, Stability, Density & Voids

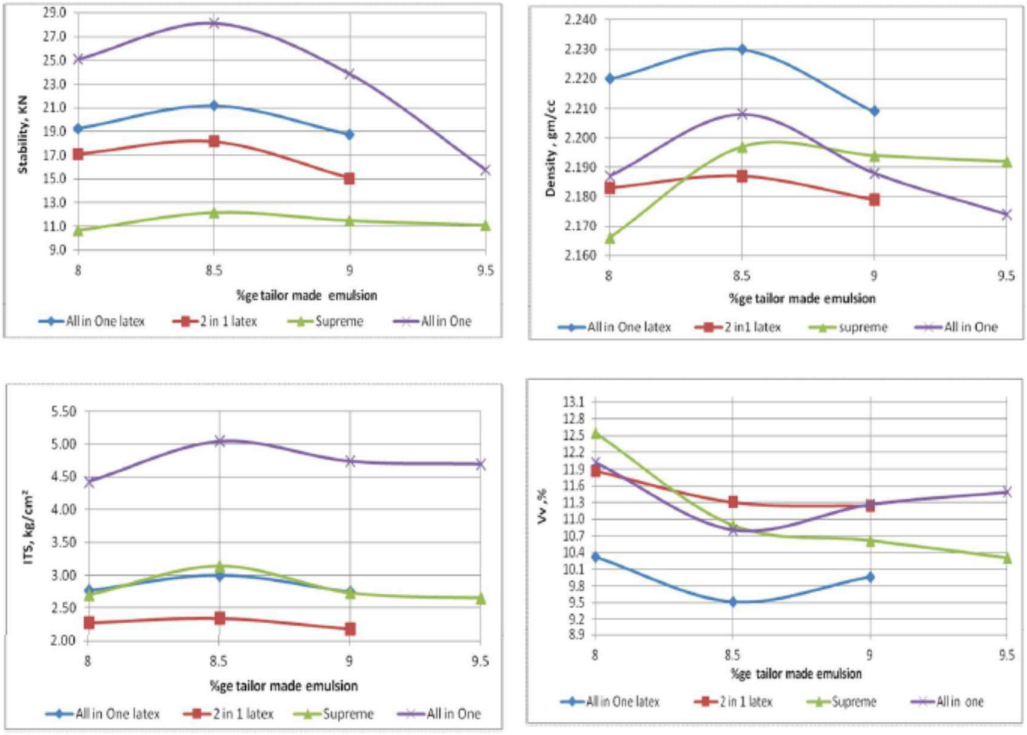

Figure 3: Marshall properties of ITS, stability, density & voids

3.3.8 Other cold mix test

Table 6: Other cold mix test

SL NO	Design Mix Test	IRC SP:100-2014 specification	CRRI-BitChem Cold mix value
1	Coating	The binder should coat the aggregate effectively without balling of fines.	100 % coating
2	Curing time	Depends on whether condition, ambient temperature, aggregate quality and type of application and type of binder used	1-2 hrs
3	Breaking time	Depends on whether condition, ambient temperature, aggregate quality and type of application and type of binder used	5-15 min
4	Run-off	Binder should not drain down through the voids in aggregate	No run-off

5	Stripping test	Max 5 %	< 5 %
	Compatibility test	Min. 75% retained coating	>75 %

4. EQUIPMENT

Hot Mix Equipment are required for the technology for production, laying & spreading and compaction of cold mixes, these are as under –

1. Hot Mix Plant (HMP) for cold mix production
2. Shelf-propelled Mechanical Paver for laying & spreading of the cold mix
3. Roller for compaction of the cold mix on the surface, Rollers are –
   a. 8-12 tones three-wheel steel roller for initial break down rolling
   b. 15-30 tones smooth wheel pneumatic roller for intermediate rolling
   c. 8-10 tones tandem roller for final rolling

4.1 Hot Mix Plant: Drum Mix Plant being used for hot mix technology can be used for cold mix technology by little more modification in the plant setup. It is a modified HMP by installing suitable conversion kits with adequate heat tracing tap to eliminate the need of heating and burning with heat tracing assembly. All components of the Hot Mix Plant will be used in the cold mix operation, but burner section will be switch off. For storage of cold mix binder, either clean bitumen storage tank or other clean tank (MS tank or HDPE tank) may be used capacity of which will be minimum five tons. As per recommended cold mix design for the required application, aggregate and binder are selected, put the recipe in PLC (Programmable logic control) and produced the cold mix in minimum 40-50 ton/hr. to construct road.

Figure 4: Existing Hot Mix Plant (HMP)

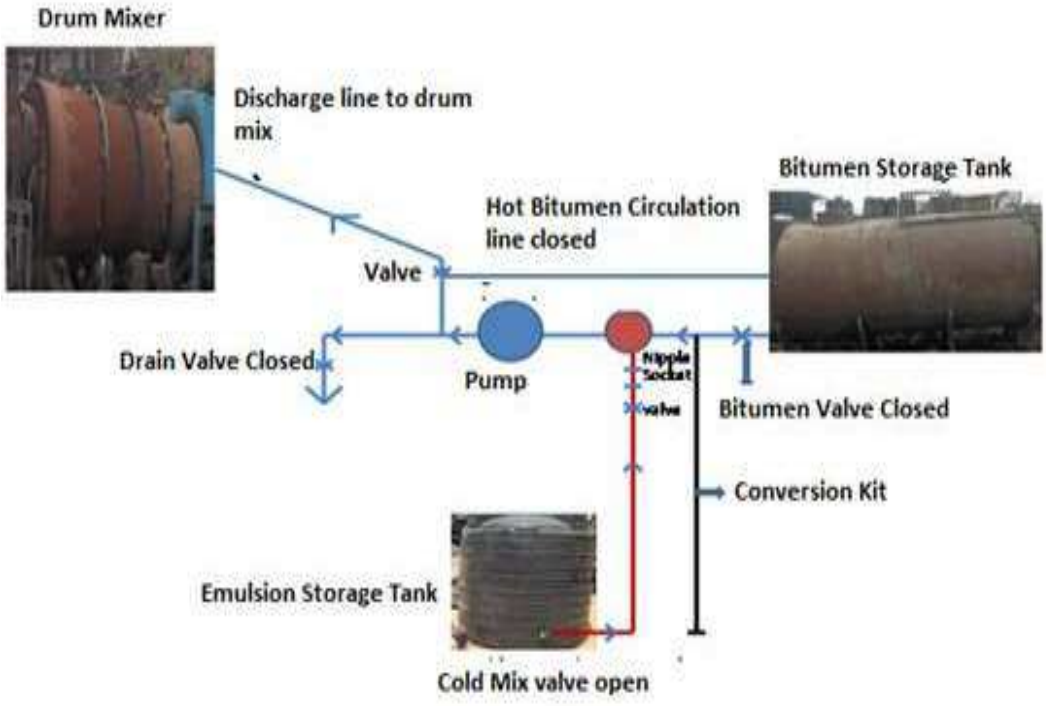

Figure 5: Modification of Hot Mix Plant by installing conversion kits

4.2 Operational procedure for cold mix production through converted Hot Mix Plant

Table 7: Operational procedure for cold mix production

Step	Procedure
1	Check all the sections of the plant by running
2	Fill the aggregates in the feeder bins
3	Cold mix binder filling in the tank
4	Setting of recipe in the control room panel (PLC) as per design of the application
5	Placement of clean tipper at the ramp
6	Start power supply
7	Switch on the main power supply of the control room &supply of PLC system
8	Start the exhauster
9	Start loader conveyor belt
10	Start drum mix
11	Start aggregate vibrating screen
12	Open aggregate feeder bin valve
13	Start aggregate feeding
14	Start the binder pump to dose binder
15	Check outlet of produced mix, it should be clean and clear
16	Produced cold mix is carrying through conveyor belt
17	Check the mix to know the coating and workability
18	Start loading the cold mix at the tipper and transport to the concern site

4.3 Shelf-propelled Mechanical Paver: Self-propelled mechanical paver is used with an appropriate speed capable of spreading, tamping and finishing the mix true to proper grade, line and cross-section. The mix shall be spread in such a manner that after compaction, the required thickness of layer is laid uniformly for desired thickness. It is advisable to maintain minimum loose thickness to get desired compacted surface as per design. Compacted thickness of the road surface is varied application to application.

4.4 Roller: After change of colour from brown to black of the mix already laid, shall be thoroughly and uniformly compacted through a set of rollers at a speed not more than 5 km per hour. The initial or break down rolling shall be done with 8-12 tons three-wheel steel roller followed by final rolling with 8-10 tons' tandem rollers. Before finishing with tandem roller, break down rolling shall preferably be followed by smooth wheel pneumatic roller15-30 tons having a tyre pressure of 7 kg/sq.cm. All the compactions i.e. breakdown rolling, intermediate rolling and final rolling shall be accomplice by using a vibrating roller (Vibratory system shall be switch off) of 8-10 tons' weight. Rolling activity shall exercise by cleaning the wheels of the roller and by moistening it to prevent the mix from sticking to the wheel. Rolling shall continue until all voids are filled up and to get desired compaction and to achieve the required density of not less than 97 % of the laboratory design density. Compaction shall enable the specified thickness, surface level & regulatory requirements. Traffic may be allowed from 1-2 hour after completion of the construction depending on the site condition.

Adequate quality control at every stage of work is essential as per norms and standard.

5. APPLICATION TYPE

1. Open Graded Premix Carpeting and Seal Coat (OGPC-SC) for rural roads and PMGSY schemes
2. Close Graded Premix Carpeting (CGPC) for rural roads and PMGSY schemes
3. Bituminous macadam (BM) for state road, town road, district roads
4. Semi dense bituminous concrete (SDBC) for state road, town road, district roads
5. Micro-surfacing for maintenance in highways, express highways etc.
6. Patching and pot hole repairing for all roads.

5.4 Cold Mix execution procedure for Cold Mix SDBC application

Procedure on sequence

1. **Compliance of Pre-Execution report by site engineer**
   - Inspection of the site to be executed to know about the site condition before execution is as under
   - Surface condition, availability of equipment and condition, workman force, availability of aggregates and quality, distance from the plant site to execution site, climatic condition etc
   - Mix design at site to know gradation of aggregate, consumption of binder, quality of mix design to know adhesion, breaking time-setting time-lead time and report through standard format
2. **Arranging necessary requirements**
   - Apply Tack Coat on cleaning BM or Bituminous surface as per standard
   - Let the tack coated surface break or convert into black before laying the mix
   - Be ready with necessary team with required setup at the site
3. **Laying of Cold mix SDBC**
   - Receive the Tipper loaded with Cold mix SDBC at site
   - Unload the cold mix at the paver from the tipper
   - Lay the mix by self-propelled mechanical paver with suitable speed capable of spreading, tamping and finishing the mix true to proper grade, line and cross-section. Maintain minimum loose thickness to get compacted surface as per design
   - Longitudinal joints and edges shall be constructed true to the line marking parallel to the center line of road
4. **Rolling & Compaction**
   - After breaking the cold mix surface, roll the surface first by Pneumatic Tyred Roller followed by Static Roller (8-10 ton) at a speed of not more than 5 km/hr

- Rolling activity shall exercise by cleaning of wheels/tyres of the roller and by moistening it to prevent the mix from sticking to them.
- Rolling shall continue until all voids are filled up and to get required compaction and to achieve the required density of not less than 97 % of the laboratory design density
- Compaction shall enable the specified thickness (25 mm), surface level & regulatory requirements
- Allow traffic 1 hour after completion of the construction

5. **Post-RCMD report**
   - After streamline construction of the road, need to highlight the following status
   - Per day construction, binder consumption, aggregate quality, quality of road surface, troubleshooting if any etc
6. **Submission of project report**
   - After completion of the project, project report is submitted within 7-10 days stating all details as site name, road name, package no, total km constructed, quality of construction, binder consumption, comment of department engineer- contractor, details of aggregate gradation and quality and all photos step by step. Followed by credential certificate from department engineer within one month.

5.4.1 Application of Cold Mix SDBC

Figure 6: Cold Mix production

Figure 7: Laying & spreading of cold mix

Figure 8: Compaction of cold mix surface

Figure 9: Completed cold mix road

6. BENEFITS OF THE TAILOR MADE COLD MIX TECHNOLOGY

- 2-3 times faster progress without need of capital expenditure in new equipment for execution of field works.

- Due to increased adhesion properties, 50% higher life than conventional cold-mix as found in field performance evaluation by CSIR-NEIST, Jorhat.
- Use of marginal materials as well as laboratory level diagnostic services helps improve quality of materials to be used at site by contractors.
- By removing the need of pre-wetting of aggregates by at least 2% of the total mix weight, we save around 3000 liters of water which is estimated at Rupees 1500/- per km as compared to conventional cold mix.
- Eliminating chances of increased adulteration and quality control vigilance by removal of on-site water use in pre-wetting operations
- Simple and ready to use- No open firewood, tyre heating arrangements required for heating the pipelines, tank, pumps etc.
- Production of dense/ semi-dense mixes like seal coat, MSS, SDBC allows complete elimination of hot mix process.
- Works 12 months a year in all climatic zones expect rainy or snowy days and when water or snow is accumulated on the surface.

7. ENVIRONMENTAL CONSIDERATION - Savings of fuel in cold mix

Table 8: Savings of fuel in cold mix road construction

Particulars	**Rural Roads**	**State Roads**	**State Highway/City Roads**
Specifications of Bituminous Black-topping	3.75 mtr width 2 cm thickness	5.5 mtr width 2.5 cm thickness	7 mtr- 10 mtr width 5cm - structural bituminous layer 2.5 cm- wearing coat
Fuel Needs in Blacktopping in hot mix	1500 lit/km	2500 lit/km	5500 lit/km
Fuel needs in Blacktopping in Cold Mix	NIL	NIL	NIL

8. ENERGY CONSUMPTION IN HOT MIX AND COLD MIX TECHNOLOGY

Source: http://www.i-cema/past_event/P.K.Jain.pdf

Table 9: Energy consumption in cold mix and hot mix

Specification	**Energy Kilo cal x 108**	
	Hot Mix Technology	**Cold Mix Technology**
Mix Seal Surfacing (20 mm)	1.16	0.92
Premix with seal coat	1.02	0.88

9. COMPARISON OF GHG EMISSION FOR COLD MIX AND HOT MIX TECHNOLOGY (1 Km rural road construction) (Using Changer)

Detail of changer can be found on the IRF web site: http://www.irfghg.org/index.php.

Table 10: Comparison of GHG emission for cold mix and hot mix

Input Materials	**CO2 Emitted (in Tonne CO2 eq)**			
	Premix Carpeting		**Seal Coat**	
	Hot Mix	**Cold Mix**	**Hot Mix**	**Cold Mix**

Bitumen/Cold Mix Binder	40.2	21.4	43.5	18.2
Crushed Aggregates	8.2		2.7	
During construction	141.5	7.5	141.5	7.5
Total	189.9	37.1	187.7	28.4

10. GHG Emission for per km per lane Roads using (a) 20mm MSS (b) 40mm SDBC in cold mix & hot mix

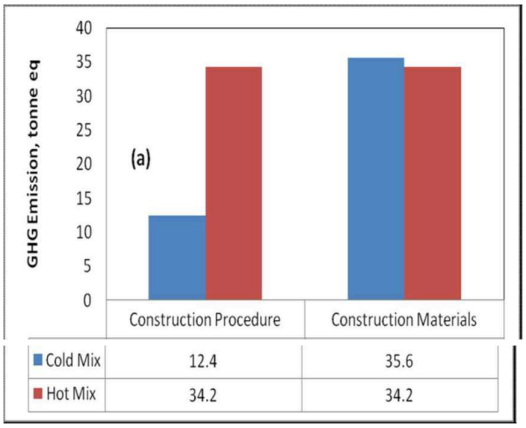

Figure 10: GHG emission in cold & hot mix

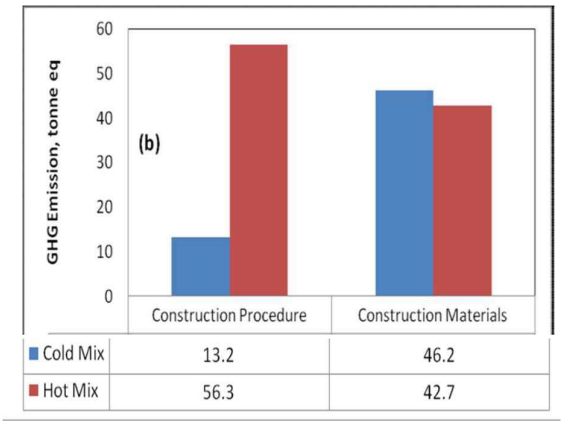

Figure 11: GHG emission in cold & hot mix

11. CONCLUSION

Development of CRRI-BitChem Tailor-made cold mix® technology and implementation across India by using existing Hot Mix Equipment for different types of cold mix applications in road construction and maintenance is now in streamline operation after successful year to year lab evaluation, filed study and outcome of site execution with the support and guidance of Central Road Research Institute (CRRI) New Delhi. This development has definitely up-charged the knowledge of road construction agencies for their future course of road construction. This will provide opportunity to the department and the contractors to construct roads having wide ramification for the benefit of the society at large. This in turn will encourage and benefit young engineers and the contractors of the region and enable them to contribute their efforts in development with green technologies.

12. ACKNOWLEDGEMENT

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2. CSIR-CRRI, New Delhi, 110025
3. State PWD of NE States of India, North India, East India, West India & South India
4. CSIR-NEIST, Jorhat, Assam, India
5. IIT, Guwahati, Assam, India
6. Assam Science Technology & Environment Council, Guwahati, Assam, India
7. University of Science & Technology, Meghalaya, India
8. NIT, Warangal, Andhra Pradesh, India

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