Title of the paper – High Life Pollution Free Cold Mix Technology Using Converted Hot Mix Plant (HMP) in Rural Road Construction and Maintenance in India

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Abstract: National Rural Infrastructure Development Agency (NRIDA), India is taking lead to construct and repair Rural Roads under PMGSY schemes which is 73 % of total road network. Both hot mix and cold mix technologies are being used in the construction and maintenance of Rural Roads for black-topping (wearing course) applications.

Cold mix technology using Patented Tailor-made Cold Binder is being implemented in Rural Road construction and maintenance in India. The tailor-made cold binder exceeds the specifications of IS 8887:2017 and is a step ahead of IRC: SP: 100:2014.

In tailor-made cold mix technique, compulsorily needed Recommended Cold Mix Design (RCMD) as per site condition to select best aggregate-binder compatibility for achieving better mix quality looking into all site condition factors and thereafter produce the cold mix in converted HMP where dense graded mix like SDBC (Semi Dense Bituminous Concrete), BC (Bituminous Concrete) and Seal Coat are possible.

As per statistic, till March'22, 9000 + km of rural roads are constructed using Patented Tailor-Made Cold Binder in India and performance of these roads are better than hot mix and traditional bitumen emulsion based cold mix roads as per reports of various reputed technical institutes.

Biggest challenges in rural road constructions and maintenances are – progresses are very slow against set target; specification in quality is not followed which causing damaging of roads year after year; lack of sufficient facilities of many road contractors are delayed the construction to long time; hot mix technology being seasonal gets very less time a year to construct roads which is also the barrier to reduce the progress.

Best solution for Rural Roads is – to use high life pollution free cold mix technology using patented tailor-made cold binder through converted HMP to accelerate the progress in construction as this can be executed throughout the year; to make Technology Management Agreement (TMA) between department, contractor and the technology provider to define scope of works for each party with a view to speedy construction, to make quality roads in a systematic manner by supervision of all execution activities by technology provider.

Conclusion: By Cold Mix Technology using Tailor Made cold binder in Rural Road construction, Nation can contribute to Hon'ble PM of India's Vision by reducing 1-billion-ton Carbon Emission by 2030. We can save 5000-liter fuels in per km road construction and nation can save USD 2656500 in PMGSY schemes in India and saves 6.5 lakh ton Carbon Emission per annum in PMGSY projects in India.

1. INTRODUCTION:

Tailor Made Cold Mix technique is the field application of mix design based tailor-made bitumen emulsion binders with the available or recommended aggregates processed through modified HMP plant or site mixing through Concrete Mixer and Spot Mix Plant 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 (Semi Dense Bituminous) Concrete, BC (Bituminous Concrete) and CGPC (Close Graded Pemix Carpeting) as well in the construction of Flexible Pavements in Rural Roads or other District and State Roads for single layer road construction over structural layer using single graded binder.

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 in two different layers using two grades of Bitumen Emulsion 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), SDBC (Semi Dense Bituminous Concrete), BC (Bituminous Concrete) may stand complete replacement of conventional Bitumen Emulsion based Cold Mixes (OGPC-SC) for getting its different types of advantages and benefit.

2. Research and Development:

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 to eliminate the need of heating and burning, 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.

The technology provider supervises the entire activities in road construction like cold mix production, laying and compaction to achieve quality and durable road construction as per standard.

3. Key Elements of Tailor-made Cold mix technology

1. Aggregate – As per IRC standard or Available Source
2. Tailor-Made Cold Binder (Patented)
3. RCMD (Recommended Cold Mix Design) Process – Simulation of Site Condition
4. Equipment – Converted HMP by conversion tools, Paver and Roller
5. Application type – OGPC-SC, MSS/CGPC, BM-SDBC, DBM-BC

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 coated 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.

Gradation and physical properties of aggregates are conducted as per specification of IRC: SP:100-2014, MoRTH & MORD.

3.2 Tailor-made Cold binder (Patented)

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 binder within the single grade of binder in cold mix technology in various applications of road construction. The main feature of this cold 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 binder exceeds the specifications of IS 8887:2018 and is a step ahead of IRC SP: 100:2014.

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 Silicon Oxide type, Carbonate type or others.

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

Table 1 - Mix design activity & 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. Cold SDBC samples are prepared by adding various contents of tailor-made emulsions ranging from 7 to 9 % 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 75 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, flow, air voids, density and ITS test. The results are graphically shown in Figure. Optimum Emulsion content and design requirements for SDBC with different tailor-made binders are given.

3.3.3: Properties and test results of cold mix SDBC design in Marshall Test Equipment

Table 2 – Marshall Test Results

SL No	Properties	Cold mix binder content		
		7 %	8 %	9 %
1	Bitumen 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℃	470	600	535
5	Flow, mm	8.2	7.2	9

Note - Design is recommended with 8 % binder

3.3.4: Mix design for cold mix SDBC using Marshall Equipment

Image 1 – Marshall Equipment

Image 2 - Mould of cold mix SDBC prepared for Marshall test

3.3.5 Properties of Marshall Test for Cold Mix SDBC and Test Result

Table 3 - Properties of Marshall Test for Cold Mix SDBC (IRC:SP:100-2014)

SL NO	Properties	Requirement	Test result

1	No of compaction blows on each side of Marshall Specimen.	75	75
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

3.3.6 Other cold mix test

Table 4 - Other cold mix test

SL NO	Design Mix Test	IRC SP:100-2014 specification	Value of Tailor-made cold mix
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 %
6	Compatibility test	Min. 75% retained coating	➢ 95 %

3.4 Equipment

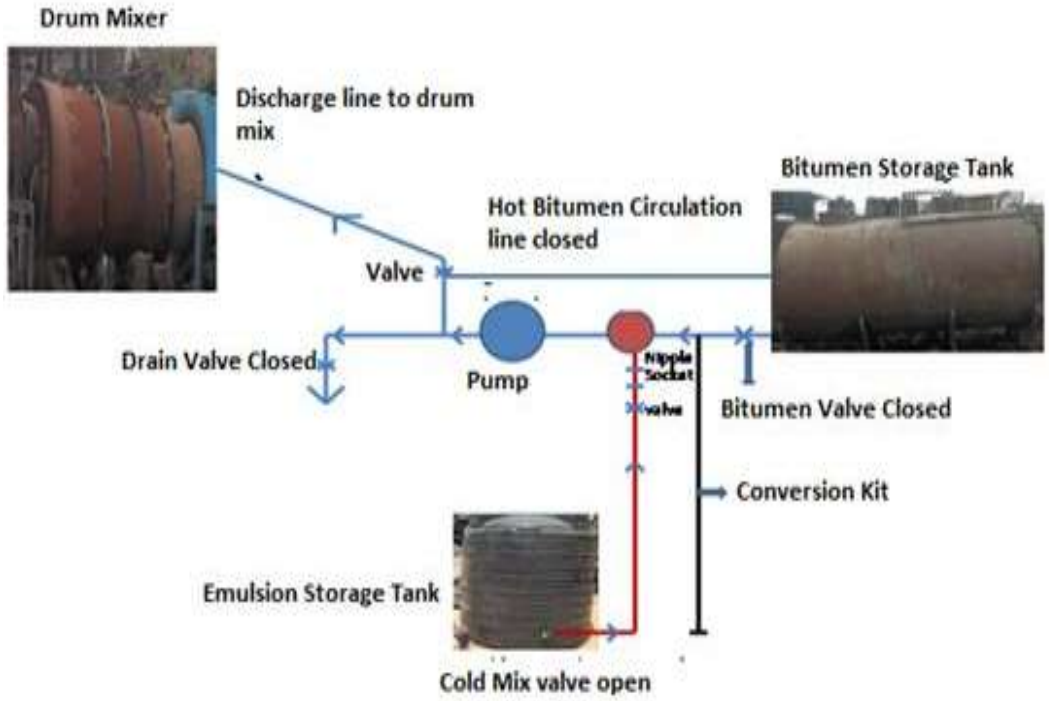
Hot Mix Equipment are required for the technology for production, laying & spreading and compaction of cold mixes, these are as under –

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

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.

Image 3 - Modification of Hot Mix Plant by installing conversion kits



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

Table 5 – 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

3.4.2 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.

3.4.3 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.

4. 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. Dense Graded Bituminous Concrete (DBM) for Sate roads, town roads and District roads etc.
6. Bituminous Concrete (BC) for State Road, town road and District Road.

5. 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.

6 Cold mix process in modified HMP on sequence

Image 4 – Cold Mix Process

Plant Cold Mix Process

Aggregate charging in the feeder bin

Aggregate feeding to the Drum Mixer through Conveyor Belt

Unloading Binder into HDPE Tank

Produced Cold Mix® is being carried through conveyor belt

Produced Cold Mix® is getting collected at the Tipper

Tipper Unloading Mix into Paver

Paving

Rolling at Progress

Image 5 – Success Sories

Success Stories of Patented Cold Mix® Technology Road at Kendukana, Rangia - ASSAM, India in 2013

Image 6 – Success Stories

Success Stories of Patented Cold Mix® Technology Road at CSIR-NEIST Jorhat - ASSAM in 2016

Image 7 – Success Stories

Proven 8 Years Surface Life of Tailormade Coldmix Road executed in 2014 at Pandhripada, Nashik -Maharashtra, India as on May, 2022

7. **ENVIRONMENTAL CONSIDERATION - Savings of fuel in cold mix**

Table 8 – Environmental consideration

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 Tailor-made Cold Mix	NIL	NIL	NIL

8. BENEFITS and USP 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.

9. **Key Highlight of Tailor-made Cold Mix Technology in India**

As per Vision Document of NRIDA, India, till 31st March'22, 16955 km roads are constructed using Cold Mix technology in PMGSY scheme in Rural Roads, out of which 9000 + kms are constructed using Tailor-made cold mix technology, 53 % + with Tailor-made cold mix technology.

10. **CONCLUSION**

Development of 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 coordination for road construction agency in India. 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.

10. REFERENCE

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