Tailor-made Cold Mix Technology for construction and maintenance of roads

Acknowledgement

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Abstract

In current practice, conventional bitumen emulsion based technology is used for construction and maintenance of roads 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 "tailor-made cold mix technology for construction and maintenance of roads" overcomes all the barriers of the current "State- of -the -Art" technology is needed.

Key Elements of the technology are Aggregate, Tailor Made Cold Mix Binder, Recommended Cold Mix Design Process (RCMD) for 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 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.

Cold mix as per design is produced in modified hot mix plant to eliminate the need of heating of aggregate and binder in controlled condition, transported to the site, laid by self-propelled mechanical paver followed by compaction by the roller to achieve finished road as per standard quality norms.

The technology is environment friendly, energy efficient, controls pollution to large extent, all weather execution, user friendly, ready to use – simple to use, fast progress in construction and achieve durable roads. Using the technology, solution is provided to construct 7000 + kms roads in India.

The technology is developed by CSIR-CRRI, New Delhi in India and transferred the technology to BitChem Asphalt Technologies Ltd, Guwahati in 2011. The technology has tremendous potentials in the construction of Rural Roads and Forest Roads across India.

Keywords: Tailor-made; Cold Mix Technology; Conventional; Hot Mix Technology; Aggregate

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.

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 nonperformance 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. 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 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 CRRI-BitChem Tailor-made Cold mix binder

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 Test parameter & specification of tailor made cold mix binder

Followed IS 8887-2204 and IRC: SP:100-2014 standard to meet the desired workability, adhesion, breaking time, curing time, lead time, coating, stripping and compatibility of the cold mixes when mixed with aggregates.

Table 1: Test parameter and specification of Tailor-made cold mix binder

SL NO	Properties of Cold Mix Binder	Specification	Actual
1	Residue on 600 micron IS sieve (% mass)	0.05 max	0.031
2	Viscosity by Say bolt Furol Viscometer (second)	30 – 100	37
3	Coagulation of emulsion at low temperature	NIL	NIL
4	Storage stability after 24 hrs (% mass)	1	0.58

5	Particle charge	+ ve	+ve
6	Stability to mixing with cement (% coagulation), max	2	0.5
7	Miscibility with water (coagulation)	NIL	NIL
8	Test on residue (a) Residue by evaporation, % (b) Penetration at 25º C/100 GM/5 Sec (c) Ductility at 27º C, cm (d) Solubility in Trichloroethylene, %	60 min 60 – 120 75 min 97.5 min	65.21 97 100 + 99.2

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)

Activities in sequence are –

1. Aggregate sample collection from sites
2. Gradation of aggregate using standard IS Sieve to meet the specification
3. Physical Property Test of the aggregate
4. Mix Design with Graded Aggregate and Cold Mix Binder
5. Test to know the breaking, setting & lead time; coating & adhesion
6. Test to know the coating of the mix design in wet and dry condition
7. Stripping & compatibility Test
8. Marshall test for flow, stability, air voids, density, ITS etc
9. Recommendation of the mixing proportion of course and fine aggregate
10. Recommendation of consumption of cold mix binder of the mix to be produced
11. 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 8 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 ITS result is shown in Figure 1. Optimum Emulsion content and design requirements for SDBC with different tailor made binders are given in Table 3.

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

For gradation 1, thickness to be maintained in construction is 35 - 40 mm
For gradation 2, thickness to be maintained in construction is 25 - 30 mm
Cumulative % by wt. of total aggregate passing will be as per standard IS sieve.
The design taken is confirmed to aggregate Grade 2.

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

Table 2: Properties of cold mix SDBC with cold mix binder and test result

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°C	470	600	535
5	Flow, mm	8.2	7.2	9

3.3.5: Marshall properties of ITS of Cold Mix SDBC

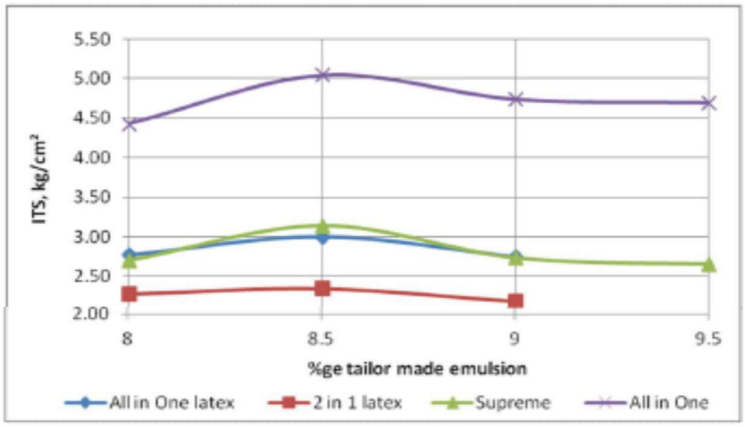

Figure 1: Marshall properties of ITS of Cold Mix SDBC

3.3.6: Mix design for cold mix SDBC using Marshall Equipment

Figure 2: Marshall Equipment

Figure 3: Mould of cold mix SDBC prepared for Marshall test

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

Table 3: Properties of Marshall Test for Cold Mix SDBC

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

3.3.8 Other cold mix test as per IRC: SP:100-2014 and CRRI-BitChem cold mix value

1. Coating - The binder should coat the aggregate effectively without balling of fines – value 100 %
2. Curing time - Depends on whether condition, ambient temperature, aggregate quality and type of application and type of binder used – value 1-2 hrs.
3. Breaking time - Depends on whether condition, ambient temperature, aggregate quality and type of application and type of binder used – value 5-15 min.
4. Run-off - Binder should not drain down through the voids in aggregate – value no run-off
5. Stripping – Max 5 % - value < 5 %
6. Compatibility test – Min 75 % retained coating – value > 75 %

4. Equipment

Equipment required for the technology is 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 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 parts 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 (Drum Mix)

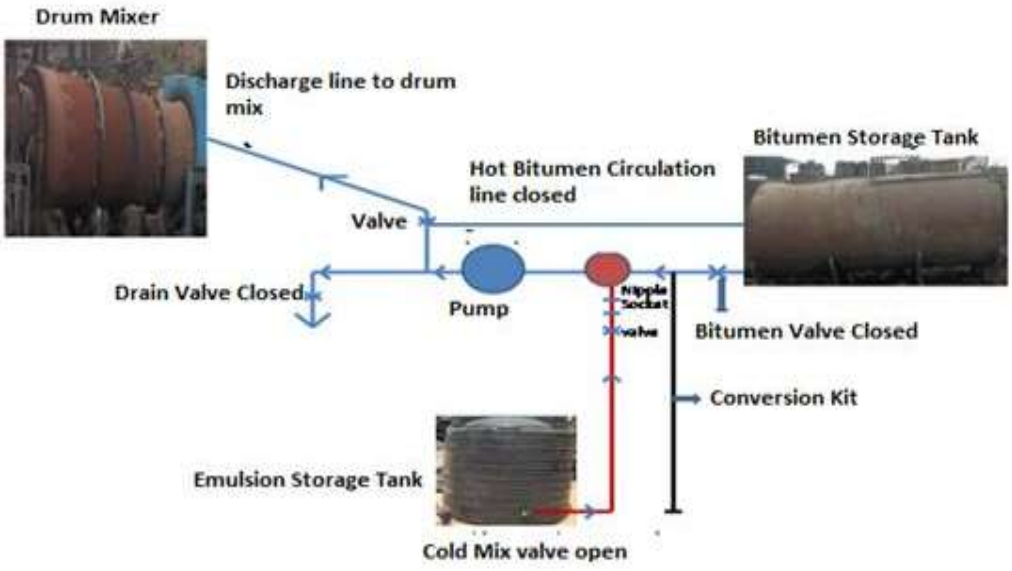

Figure 5: Modification of HMP by conversion kits (Development on Collaborative project with CRRI-BitChem)

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

Operational procedure in sequence

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

4.2 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.

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.

5. Application types

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

5.1 Cold Mix execution procedure for SDBC application

Procedure in 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 under
    - 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.

5.2: Application of Cold Mix SDBC

Figure 6: Production of cold mix SDBC through modified HMP

Figure 7: Laying of Cold Mix SDBC by Paver

Figure 8: Compaction of Cold Mix SDBC surface by Roller

6. Total km of cold mix road constructed by modified hot mix plant operation in different states.

1. Assam	30 km	in 2013-2017
2. Maharashtra	45 km	in 2013-2016
3. Karnataka	74 km	in 2016-2018
4. Andhra	44 km	in 2016-2018
5. Telangana	74 km	in 2016-2018
6. Madhya Pradesh	10 km	in 2017-2018
7. Himachal Pradesh	15 km	in 2016-2018
8. Chhattisgarh	106 km	in 2016-2019
9. Bihar	1 km	in 2014

Total 399 km

7. Benefits of 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, Assam.
- 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.

8. Environmental Consideration- Savings of fuel in per km cold mix road construction and comparison with hot mix road for fuel consumption based on site construction data

Table 4: Savings of Fuel in Cold Mix® Technology

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

9. Do's (As per CRRI-BitChem operational procedure)

a. Follow standard operational procedure (SOP) during execution.
b. It is all weather execution, but execute in dry-spell of rainy season.
c. Before execution of cold mix, road surface should be dry. Can be used in damp surface also.
d. Use dry and standard aggregate, can be used damp aggregate also.
e. If aggregates are wet, re-shuffle it manually or by JCB to remove moisture from aggregates before use.
f. Follow the five finger tips – Check aggregate, binder, equipment, mix design and application.
g. Stop execution if it rains

10. Don't (As per CRRI-BitChem operational procedure)

a. Don't execute in loose surface
b. Don't execute in rainy days
c. Don't execute in wet surface or where there is water logging
d. Don't use wet aggregates.

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.

Reference

IRC: SP:100 – 2014 on Use of Cold Mix Technology in Construction and Maintenance of Roads using Bitumen Emulsion.

Performance Evaluation Report on Rural Roads constructed using CRRI-BitChem Cold Mix Technology by CSIR-NEIST, Jorhat, Assam, India in October 2013 vide Report No: QSP/MR/19/ACED/BTCM/214/2013.

Collaborative project with CSIR-CRRI & BitChem on Up-gradation and modification of Cold Mix Technology, March 2016.

CRRI: SP:1-2011 on Design and Construction of Bituminous Surfacing Using Cationic Emulsion Based Cold Mixes.

Report on Field Performance Study of Structural Layers of Flexible Pavement with Bitumen Emulsion in Different Conditions conducted by Flexible Pavement Division of CSIR-CRRI in October 2010.

Specifications for Road and Bridge, Ministry of Road Transport & Highways.

Hand Book on Quality Control: Road Works, Pradhan Mantri Gram Sadak Yojana.

Reviewer's queries:

Query 1. I do not understand why author is calling it tailor made technology. At the most bitumen emulsion binder can be referred as tailor made. However there is nothing in paper to support it.

Reply – As mentioned in the Abstract, Introduction, Key Challenges of Conventional Bitumen Emulsion Based Mixes and CRRI-BitChem Cold Mix Binder, Tailor-made cold mix technology is not like conventional bitumen emulsion based technology. The novelty of Tailor-made cold mix technology is that -

1. "It does not require pre-wetting of aggregates before preparing cold mix", on the other hand conventional bitumen emulsion based mixes require pre-wetting of aggregates which is mentioned in the paper.

2. "Single grade tailor-made cold mix binder is used for all applications like OGPC-SC, MSS, BM, SDBC" etc. But single grade general emulsion binder cannot be used for OGPC-SC, they need two different binders for both applications. Moreover, other applications like MSS, BM, SDBC are not possible with Bitumen Emulsion for limited characteristic of the emulsion. It is well described in the paper about tailor-made cold mix technology and tailor-made cold mix binder in the Abstract, Key Challenges and Tailor-made cold mix binder. Also, it is mentioned in IRC: SP:100-2014 about tailor-made binder, Reference is given at the end. The application of cold mix SDBC as mentioned in the paper is possible in cold mix for tailor cold mix technology where tailor-made cold mix binder is used.

3. Utilized existing Hot Mix Plant to produce cold mix production by the modification of conversion kits and installation of heat tracing tap eliminating heating and burning" which is possible with only tailor-made cold mix binder to maintain desired lead time and workability of the produced cold mix on transportation to the site before paving. It is not possible with the conventional bitumen emulsion for the limited characteristic of the emulsion. It is mentioned in the Abstract and Equipment.

   So, it is Tailor-made cold mix technology and binder is the Tailor-made cold mix binder.

Query 2. The paper is informative that is what a final comment can be made. I do not see any research component or value addition except if author was involved in developing this technology.

Reply – Already mentioned in Reference about "Collaborative project with CSIR-CRRI & BitChem on Up-gradation and modification of Cold Mix Technology, March 2016". Development of the tailor-made cold mix technology, tailor-made cold mix binder, cold mix design various applications, modification of Hot Mix Plant for cold mix production are the result of collaborative research and development by CRRI-BitChem. It is possible only to construct 399 kms + roads by the application of cold mix SDBC using Tailor-made cold mix technology in India. Normal Bitumen emulsion cannot be used for SDBC application in India. Also, it is possible to construct 7000 kms + roads in India using Tailor-made cold mix technology by site mixing and plant mix operation. In this paper, road construction by Plant Mix Operation using modified HMP is mentioned.

Query 3. References must be cited in the literature and references guidelines of paper submission.

Reply – It is done accordingly.

Plagiarism Report –

Reply – Paper prepared and submitted with the outcome what was developed by the collaborative research between CRRI and BitChem. Already mentioned above that it is a tailor-made cold technology and different from conventional bitumen emulsion based cold mixes. The required texts, words, sentences needed to use in the paper preparation to align with the subject matter and the purpose. Actually, we are confused about the similarity mentioned in our paper.

In present time, in India and abroad, hundreds of research papers are available on cold mix technology/bitumen emulsion/cold re-cycling, cold surface, cold pavement etc. But these development/technology/product are not the

similar with Tailor-made cold mix technology which is already explained above. We have not seen all these papers as mentioned, objectives of our paper is different than those papers. We are not aware about the similarity of the word, sentences etc. with other papers.

We have CRRI-BitChem Knowledge Centre in Guwahati where Research and subsequent Development are being carried out since last 10 yrs.