Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Grant Ref. No.:	GBPNI/NMHS-2018-19/MG 05

Date of Submission:	0	6	0	2	2	0	2	3
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE

APPLICATION OF COLD BITUMINOUS BASED ECO-FRIENDLY ROAD BUILDING TECHNOLOGY FOR THE SPECIAL FEATURED HIMALAYAN REGIONS

Project Duration: *from* (**13.02.2019**) *to* (09**.10.2022**).

***Submitted to*:**
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the start date of the Project (as mentioned in the Sanction Order issued by NMHS-PMU) till completion of the project duration. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset printing. Colored Photographs (high resolution photographs), tables and graphs should be accommodated within the report or annexed with captions. Sketches and diagrammatic illustrations may also be given detailing about the step-by-step methodology adopted for technology development/ transfer and/ or dissemination. Any correction or rewriting should be avoided. Please provide all information under each head in serial order.
3. Any supporting materials like Training/ Capacity Building Manuals (with detailed contents about training programme, technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and submitted to the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time-to-time, so each section of the NMHS-FTR needs to be duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) hard-bound copies of the Project Final Technical Report (FTR) and a soft copy of the same should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two (02) parts:

Part A – Project Summary Report

Part B –Detailed Project Report

In addition, the Financial and other necessary documents/certificates need to be submitted along with the Final Technical Report (FTR) as follows:

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including the interest earned for the last Fiscal year and the duly filled GFR-19A (with year-wise break-up).
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign/ Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use, including location of deployment.
Annexure V	**Transfer of Equipment** through Letter of Head of Institution/Department confirming the final status of equipment purchased under the Project.
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS)/ PFMS in favor of NMHS GIA General**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

2	1	1	2	**2**	**0**	**1**	**8**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

3	1	1	0	**2**	**0**	**2**	**2**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Grant Ref. No.:	GBPNI/NMHS-2018-19/MG 05					
ii.	Project Category:	Small Grant		Medium Grant	✓	Large Grant	
iii.	Project Title:	Application of Cold Bituminous Based Eco-friendly Road Building Technology for the Special Featured Himalayan Regions					
iv.	Project Sites (IHR States/ UTs covered) (*Location Maps attached*):	Village- Jhimar, District- Almora, Uttarakhand, Pin code: 263676 29°45'07.5"N 79°08'06.3"E (the developed machine can be used for PAN Himalayan scale.					
v.	Scale of Project Operation:	Local		Regional		Pan-Himalayan	✓
vi.	Total Budget:	0.977 (in Cr)					
vii.	Lead Agency:	CSIR-Central Road Research Institute					
	Lead PI/ Proponent:	Dr. Siksha Swaroopa Kar					
	Co-PI/ Proponent:	Prof (Dr) Satish Chandra					
viii.	Implementing Partners:	Uttarakhand Rural Roads Development Agency (URRDA)					
	Key Persons (Contact Details, Ph. No., E-mail):	Chief Engineer, Uttarakhand Rural Roads Development Agency, Uttarakhand					

2. Project Outcomes

2.1. Abstract/ Summary (not more than 250-300 words)

India's mountainous and hilly regions have limited road connectivity, which severely impedes economic growth. For Himalayan border nations to meet their strategic goals, a robust and durable road network is crucial. However, environmentally fragile hilly regions might not be suitable for typical road construction techniques like hot mix asphalt. The narrow and tough site location creates difficulties in the transportation of materials and construction equipment. Also, space is not available for hot mix plants set up in hilly regions. Construction of hilly roads is generally conducted using a manual method, which leads to poor construction quality. To alleviate the issue, a machine is fabricated which can be used for cold mix production and laying. Site was finalised for the field trial at Jhimar, Uttarakhand in collaboration with Uttarakhand Rural Road Development Authority (URRDA) and Nation Rural Infrastructure Development Authority (NRIDA). In the present project, the effectiveness of the machine is evaluated through actual field trial conditions. Results show that the variability of the bituminous mix is reduced by using the mechanized method compared to manual methods. The developed machine was transferred to the industry for large scale production. Also, guidelines for laying of mechanized cold bituminous layer was recommended to NRIDA and BRO.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (***in bullets points***)
1.	To develop emulsion based cold bituminous mix design for bituminous surfacing for road construction in adverse Himalayan climatic condition	• The laboratory mix design and performance evaluation of cold mix samples using different type of filler has been completed • Recommendation for the same has been finalised and laid the section using the developed specification.
2.	To design and develop an economical mobile version of cold bituminous mixer cum paver equipment	• The machine is developed and transferred to industry for large scale production. • The trademark is filed • The patent application has been processed.
3.	To familiarize concept of mechanized construction technique using cold bituminous mix technology by laying of trial sections and its performance monitoring also through evaluation of life cycle cost analysis	• A trial section of 1000m has been laid using developed machine and cold mix specification at Jhimar, Uttarkhand. • The field performance has been evaluated.
4.	To frame specifications and guidelines for design, construction and quality control for bituminous surfacing	• Know how document has been prepared and submitted to Boarder Roads Organisations (BRO) and National Rural Infrasture Development Authority for its implementation.

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

2.3. Outputs in terms of Quantifiable Deliverables*

S.No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations, if any, & Remarks thereof:
1.	Development of low cost compact portable cold bituminous mix plant with paver for construction in hilly area	Develop emulsion based cold bituminous mix design model	Machine is developed and technology is transferred to industry.	NA
2.	Guidelines for construction of road surfacing with cold bituminous mixes in High Altitude Areas using Cold Bituminous Mix Technology	Guidelines/ best practices for sustainable road construction in high altitude areas of the Himalaya (Nos.)	Section has been laid using developed specification	NA
3.	New specifications for design, construction and quality control for bituminous surfacing	No. of Demonstrative model(s) with analytical findings and measures	1000m road was constructed using the machine.	NA
		Strategic Framework/Policy draft(s) for assisting use of technology (No)	Know how document was developed and shared with BRO and NRIDA for further implantation	NA
		Other Publications and knowledge products (Nos.)	Trademark has been filed. International Journal and conference proceedings have been published.	NA

*As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S#	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology/ Technology developed, *if any*:	1	The technology details and know how is attached as Appendix 1
2.	New Ground Models/ Process/ Strategy developed, *if any*:	1	Trademark is filed. The document is attached in Appendix 2.
3.	New Species identified, *if any*:	NA	
4.	New Database established, *if any:*	NA	
5.	New Patent, *if any*:		
	I. Filed (Indian/ International)	Yes, processed to NRDC	
	II. Technology Transfer, *if any*:	Yes, to one industry	
6.	Others, *if any*	Trademark has been filed	

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

3. New Data Generated over the Baseline Data

S#	New Data Details	Status of Existing Baseline	Addition and Utilisation New data
1	Mechanised construction process in Hilly Region using environmentally friendly cold mix technology	Manual construction is going on using hot mix technology	1000m of road was constructed using new methodology at Jhimar, Uttarakhand.

Note: Further details may be summarized in DPR Part-B. Database files in the requisite formats (Excel) may be enclosed as annexure/ appendix separately to the soft copy of FTR.

4. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S#	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Women**	**Total**
1.	Workshops	**At CSIR-CRRI,**	**To inaugurate the developed "Mobile Cold Mixer cum Paver" and dedicate the machine to nation**	**NA**	**NA**	**NA**	**250**
2.	On-Field Trainings	**Jhimar, Uttarakhand**	**To familiarize the concept, during actual laying, the site engineers have been trained.**	**NA**	**NA**	**NA**	**100**
3.	Skill Development						
4.	Academic Supports						
	Others (if any)						

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

5. Linkages with Regional & National Priorities (SDGs, INDC, etc.)/ Collaborations

S#	Linkages /collaborations	Detail of activities (No. of Events Held)*	No. of Beneficiaries
1.	Sustainable Development Goals (SDGs)/ Climate Change/INDC targets addressed	On site training to site engineers and local labours were given for effective use of mechanised construction process.	The whole Jhimar village got benefited and also connecting villages.
2.	Any other:		

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

6. Project Stakeholders/ Beneficiaries and Impacts

S#	Stakeholders	Support Activities	Impacts in terms of income generated/green skills built
1.	Line Agencies/ Gram Panchayats:	Jhimar is a Village in Sult Block in Almora District of Uttarakhand State, India. It is located 47 KM towards west from District head quarter Almora.	Road connecting to Barikot to Jhimar was constructed. The improved transport system

		Barkinda (1 KM) , Inda (1 KM) , Barikot (1 KM) , Kangari (2 KM) , Titoli (2 KM) are the nearby Villages to Jhimar.	
2.	Govt Departments (Agriculture/ Forest/ Water):	Uttarakhand Rural Roads Development Agency (URRDA)	The site engineers have been trained.
3.	Villagers/ Farmers:	Barkinda (1 KM) , Inda (1 KM) , Barikot (1 KM) , Kangari (2 KM) , Titoli (2 KM) are the nearby Villages to Jhimar. Along with villagers of Jhimar, these villagers were also benefited due to the connectivity.	
4.	SC Community:	-	-
5.	ST Community:	-	-
6.	Women Group:	-	-
	Others, *if any*:	-	-

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

7. Financial Summary (Cumulative)

Attached

8. Major Equipment/ Peripherals Procured under the Project** (*if any*)

S#	Name of Equipment	Quantity	Cost (INR)	Utilisation of the Equipment after project
1.	Mobile Cold Mixer cum Paver	1	Approx 29 lakh	In talk with BRO, for utilisation of machine for road construction
2.				

Details should be provided in details **(*ref.*** **Annexure III &IV).**

9. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States/ UTs covered:	*1*	*Uttarakhand*
2.	Project Sites/ Field Stations Developed:	*1*	*Jhimar, Uttarakhand*
3.	Scientific Manpower Developed (PhD/M.Sc./JRF/SRF/ RA):	*2 JRF for two years SRF for one year, 3MTech Student*	
4.	Livelihood Options promoted	-	

5.	Technical/ Training Manuals prepared	*Know How document of Machine is prepared*	Attached in Appendix 1
6.	Processing Units established, if any	*Mobile Cold Mixer cum Paver is developed*	*Attached photo in Appendix 3*
7.	No. of Species Collected, if any	*NA*	
8.	No. of New Species identified, if any	*NA*	
9.	New Database generated (Types):	*1000m road using the technology has been laid.*	
	Others (if any)		

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

11. Knowledge Products and Publications:

S#	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal – Research Articles/ Special Issue:		1 (published) 2(under review)	1.26 3.64	Enclosed the paper details
2.	Book – Chapter(s)/ Monograph/ Contributed:		-	-	
3.	Technical Reports:		3 (Yearly report submitted to NMHS		
4.	Training Manual (Skill Development/ Capacity Building):		Know How Document		Enclosed in Appendix 1
5.	Papers presented in Conferences/Seminars:		2		Enclosed the conference details
6.	Policy Drafts/Papers:		Trade Mark filed Agreement signed between NMHS, NRDC and CRRI		Enclosed in Appendix 2 Enclosed in Appendix 4
7.	Others, if any:		Patent document submitted		

Note: Please append the list of KPs/ publications (with impact factor, DOI, and further details) with due Acknowledgement to NMHS. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

e12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings:	An overview of current practices used for cold mix construction and its implication for project execution and quality of work was presented in the current work. Conventional road construction time and cost data were acquired from site engineers, construction contractors, site labors from multiple construction projects through questionnaires. Data during actual paving of roads using both mechanical and conventional methods was collected and evaluated. Results show that with the mechanized process of laying the rate of construction is six times faster compared to the manual construction method. The mechanized construction method results in saving fuel consumption. The bituminous mixes (both manual mixing and mechanized mixer) were collected from the site. manpower requirement is also minimized by using mechanized process of construction. A significant amount of variation in terms of aggregate gradation was found in the manual mixing method compared to the laboratory mix design.
Replicability of Project/ Way Forward:	The mechanized process can be used effectively for hilly region road construction with better quality and time-saving. The developed machine can be utilised in ongoing projects of NRIDA, BRO and NHIDCL for construction of bituminous wearing layer.
Exit Strategy:	This technology has been have been dedicated to the Nation by Sh.Nitin Gadkari, Hon'ble Union Minister for Road Transport & Highways in the presence of Dr.Jitendra Singh, Honourable Minister for Science & Technology and Earth Sciences and General (Dr.) Vijay Kumar Singh, Honourable Minister of State for Road Transport, Highways and Civil Aviation on this day. Also, know how document is presented to NHIDCL, BRO and NRIDA. BRO has already implemented the technology at Shillong and recommended for large scale implementation.

(**Dr Siksha Swaroopa Kar**)

Siksha Swaroopa

Manoranjan Parida, Director

Place: Delhi
Date: 7th Feb 2022

PART B: DETAILED PROJECT REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) **Introduction**, (ii) **Methodologies/Strategy/Approach**, (iii) **Key Findings and Results**, (iv) **Overall Achievements**, (v) **Project's Impacts in IHR** (vi) **Exit Strategy** and Sustainability, (vii) **References**, and (viii) **Acknowledgements** (acknowledging the financial grant from the NMHS, MoEF&CC, GoI).

Other necessary details/ Supporting Documents/ Dissemination Materials (*New Products/ Manuals/ Standard Operating Procedures (SOPs)/ Technology developed/Transferred, etc, if any*) may be attached as Appendix(ces).

1 EXECUTIVE SUMMARY

Design and construction of roads in high altitude Himalayan region poses more difficulties than in plain terrain. Some of these problems are listed below:

- Need to balance between developmental needs and sustenance of fragile ecosystem; Complex geology of mountainous terrains coupled with instability of slopes, rock-falls and avalanches; Large variations in sub-soil and geological conditions from location to location; Inhospitable environmental conditions such as extremely low temperatures during major part of the year especially for North facing slopes, and lack of oxygen at higher altitudes, which affects performance of men and machinery; using hot mix technology leads to heavy pollution which directly affects to health of worker; Low friction coefficients due to damp (or snow covered) pavement surface and vehicles have to negotiate steep slopes.
- The working period is less about only three months out of a year in Himalayan regions due to high rainfall and extreme cold climatic condition. Work progress is very slow with manual construction technique. During bituminous pavement layer construction, temperature of hot-mix drops drastically before compacting the material which leads to premature distress and also drying of aggregate during construction using hot mix technology is very energy consuming process. All these also restrict the required curing phase of cement concrete pavement.
- Construction of cement concrete pavement or adopting cement stabilization becomes difficult due to very low temperatures prevailing during major part of the year; Seepage of ground water and springs at several locations resulting in subgrade soil saturation/dampness; High-speed runoff after precipitation on account of steep gradients, accentuated by absence of vegetation at high altitudes, which otherwise provides soil cover and prevents erosion of soil; Strong ultraviolet radiation which affects bituminous pavements, thermal cracking has deteriorating effect.
- Transportation of construction equipment and set up of construction plant due to non availability of space in hilly roads, which results in slow progress of construction work.

To overcome the above problems, CSIR-CRRI developed Mobile Cold Mixer cum Paver for preparation and laying of black top layers using bitumen emulsion based technology. This technology has been developed by CSIR-CRRI under a project funded by Ministry of Environment, Forest and Climate Change under National Mission on Himalayan Studies (NMHS) scheme. By using the developed machine construction speed is increased by 10 times and manpower requirement is reduced by 20 times as compared to conventional manual process. For construction of 1 Km. road approximately 200 tCO_2 will be saved using this machine compared to conventional method. The construction of road using this machine results in faster progress, better quality and reduced cost as well as emissions.

2 INTRODUCTION

2.1 Background (max. 500 words)

Indian Himalayan Region (IHR) plays vital role in sustaining diversity of life and livelihoods of more than 48 million people living in mountainous areas and nearly 1.2 billion people dependent on its downstream river basins for food and energy production. This region not only holds a key strategic position but also regulates climate of the south-Asian region. The IHR, stretching from Jammu and Kashmir to the Arunachal Pradesh, has been facing various problems on account of very difficult terrain, weather conditions and extreme events, dispersed habitations, under-developed infrastructure, etc. Further, within IHR, the north-eastern states suffer from poor connectivity both with the rest of India and within the respective states of the region. Therefore, the cost of delivery of public services in the Himalaya is much higher compared to other parts of the country, largely due to topographical inaccessibility, distances and the remoteness involved. Hence, an adequate and long lasting road network is very much necessary in Himalayan areas for overall development of the region as well as fulfilling defence needs. Bituminous road construction with conventional paving grade bitumen is not desirable in high rain fall areas as intermittent rain throughout the year affect production and laying of mixes. At high attitude or snow bound areas as temperature remains very low during most part of year limiting the laying of hot mix. On the contrary, use of bitumen emulsions eliminates heating of binder and aggregate and also prevents degradation of environment and conserves energy**.** This technology will ease the construction and maintenance of existing road network. **Under this project, specific grade of binder and gradation of aggregate will be developed to overcome the shortcomings and construct the wearing course of pavement using cold bituminous mix technology**. In addition, transportation of material and construction equipment in hilly areas is a huge challenge, considering the narrow and rough roads leading up to the site. Remotely located hill sites provide only minimal space for plant set-up. The other big worry normally with remote and high altitude sites is the non availability of heavy conventional construction and operational equipments. Hence, manual process and techniques to construct road in hilly area are followed which leads to poor construction quality and is time consuming construction exercise. **To alleviate this problem, it is required to develop a cold bituminous mixer cum paver for construction of pavement using developed cold bituminous mix, which is also envisaged in the scope of this project.**

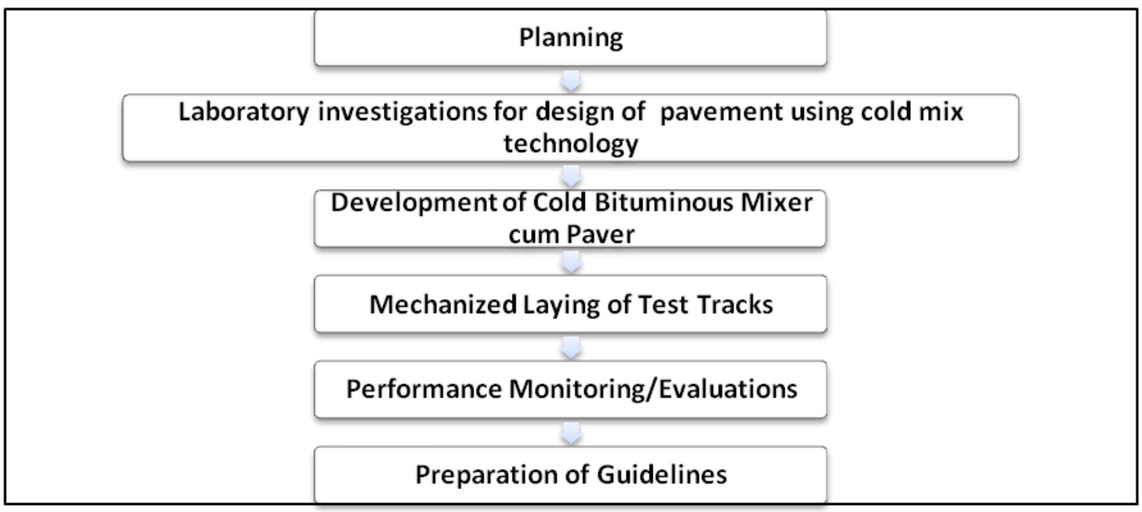
This project has been addressed the problem of surfacing of roads due to climatic and geographic periphery and enhancing their performance by means of upgraded binder and mix properties and also by enhancing the efficacy of the construction process.

2.2 Overview of the major issues addressed (max. 500 words)

There is urgent need to develop road infrastructure in hilly regions which are close to our border areas also. It will serve the twin purpose of strategic infrastructure development and economic development of the region. Himalayan roads provide connectivity to habitants. These are generally low-traffic volume roads but face many other challenges, such as heavy rains, floods, and landslides. Thus, designing pavements properly to mitigate the effects of these challenges on roads is of paramount importance. The practice of heating of aggregate and bitumen is very energy consuming and costly. Also construction time is short for making roads using hot mixes due to climatic conditions at Himalayan Region. Hence, it very much essential to construct the road using cold bituminous mix technology giving an increased span of time for construction work. In Himalayan region, the desired speed of construction of road is not achieved and conventional mechanized method is inappropriate and capital intensive. Plant setup for construction of road is difficult due to non availability of adequate place hilly region. Hence, it is very much essential to develop cold bituminous mix technique and also a low cost compact mixer and paver for construction.

2.3 Baseline Data and Project Scope (max. 500 words)

The project scope is given in Fig 1.



Himalayan mountain range separates North Indian plains from Tibetian plateau. These mountains form the border between India and many of our neighbouring countries.. In the Uttarakhand state, India's international border skirts both China and Nepal. This high altitude region has extremes of climatic conditions, complex and unsafe terrains and topography. Additionally, this area has lower population density and lacks basic infrastructural facilities vailable in plain terrain. In the current project, Jhimar, Uttarakhand was selected for the project implementation.

2.4 Project Objectives and Target Deliverables (as per the NMHS-Sanction Order)

The objective of the project is

i. to develop emulsion based cold bituminous mix design for bituminous surfacing for road construction in adverse Himalayan climatic condition;
ii. to design and develop an economical mobile version of cold bituminous mixer cum paver;

iii. to familiarize concept of mechanized construction technique using cold bituminous mix technology by laying of trial sections and its performance monitoring also through evaluation of life cycle cost analysis
iv. to frame specifications and guidelines for design, construction and quality control for bituminous surfacing

3 METHODOLOGIES/STARTEGY/ APPROACH – *supporting documents to be attached.*

3.1 Literature Review

More than 48 million people reside in hilly areas and depend on the Indian Himalayan Region (IHR) for their food and energy [1, 2]. Along with this, nearly 1.2 billion people depend on its downstream river basins for the production of food and energy [1,2] Due to extremely challenging terrain, extreme weather conditions and events, dispersed habitations, underdeveloped infrastructure, etc., the IHR has been dealing with a number of issues for its development [2]. In addition, the north-eastern states of IHR have inadequate connectivity, both with the rest of India and among their individual states. As a result, the cost of delivering public services in the Himalaya is significantly higher than in other regions of the nation. This is mostly because of the terrain's difficulty to access, the distances involved, and the remoteness of the area. Hence, an adequate and long lasting road network is very much necessary in Himalayan areas for the overall development of the region as well as fulfilling defense needs.

In places with considerable rainfall, building asphalt roads with ordinary paving grade bitumen is undesirable because seasonal rain affects mix production and laying. [3]. At high altitudes or snow-bound areas as the temperature remains very low during most part of the year limiting the laying of hot mix. On the contrary, there is no need to heat the aggregate and bitumen by using bitumen emulsion as a binder for the paving of the bituminous top layer. Use of bitumen emulsion results in a reduction in emissions and also energy consumption. This technology will ease the construction and maintenance of existing road networks. In addition, transportation of material and construction equipment in hilly areas is a major issue, considering the site terrain at IHR. Hill sites in remote areas only offer a little amount of space for plant installation. The absence of large, traditional construction and operating equipment is typically a major concern with high altitude sites. Hence, manual processes and techniques to construct roads in hilly areas are followed which leads to the poor construction quality and is time consuming construction exercise [4-5].

The performance of pavement depends majorly on construction methodology along with construction materials [4-7]. In general practice, a hot mix plant is used to produce bituminous cold mix using bitumen emulsion and then transported and paved using a construction paver [8-9]. Bowers and Powell (2021) suggest the quality of emulsified mix produced from a hot mix plant shows better performance compared to the manual production of mix [10]. The literature says the emulsified mix has a complex behavior, the quantity of material dosages (emulsion, water and cement) has a major impact on the performance of cold mix [8, 11].

In the Himalayan region, the desired speed of construction of the road is not achieved and the conventional mechanized method is inappropriate and capital-intensive [1-2]. Plant setup for the construction of roads is difficult due to nonavailability of adequate places in hilly regions [3]. Hence, it is very much essential to develop cold bituminous mix technique and also a low cost compact mixer and paver for construction. For mechanised laying of cold bituminous layer, the mixer and paver have been fabricated and the effectiveness of the fabricated machine has been analyzed in the present study.

3.2 Location and Pre-construction Condition Assessment

A stretch of 1 km road from Jhimar to Bhitakot Motor Marg, Almora Uttarakhand in the Himalayan Region has been selected for the study (Fig. 1). The yearly maximum and minimum temperature are measured 57 to -2°C, respectively. The maximum rainfall and snowfall is 252 and 187mm, respectively. During the laying of the section, the average ambient air temperature was 12°C. The minimum air temperature during laying is measured to be 7°C. Around 300 commercial vehicles will be plying on the current road as reported by the Uttarakhand Rural Development Authority in 2020. Traffic intensity for 10 years of design life is estimated to be 1.1msa. The soil material and aggregate have been collected from the site and tested in the laboratory. The laboratory analysis of soil is presented in Table 1. The crust composition as per IRC SP 72 is estimated to be 300mm (Granular Subbase of 150mm, Wet Bound Maccadam (WBM) Grade II and Grade III of 75m each). Over the WBM layer, a bituminous premix carpet layer of thickness of 20mm is to be laid to get the riding quality of the pavement.

(a) View of Site before laying of premix carpet (b) collection soil and gravel from the existing pavement

Table 1. Laboratory test results of Sub grade soil samples collected from site

Parameter	Values
Gravel %	1.43

Sand %	29.1
Silt & Clay %	67.9
FMC,%	10.4
LL %	27.4
PL %	15.1
PI	13
MDD gm/cc	1.812
OMC	10.1
Soaked CBR %	5.5
Soil type	CL

Note- LL: Liquid limit, PL: Plastic limit, PI: Plasticity index, MDD: Maximum dry density, OMC: Optimum moisture content, FMC: Field Moisture Content

3.3 Characterization of Material and Mixture Design at Laboratory

The aggregate and bitumen emulsion from the site was collected to the laboratory to evaluate the material properties as per IS standards. Optimized emulsion quantity is determined through the mixture design for SDBC (semi-dense bituminous concrete) layer construction. RS1 emulsion is used for the tack coating and MS grade emulsion is used for the SDBC mix preparation. The emulsion and aggregate properties are presented in Table 2 and Table 3, respectively. The adopted gradation of aggregates is given in Table 4 for the field laying.

Table 2: Test Results of Emulsion Sample

Properties of Bitumen	RS1	MS

Emulsion	Test results	Requirement as per IS:8887- 2004	Test results	Requirement as per IS:8887-2004
Residue on 600 micron IS sieve (% mass), max.	0.00	0.05	0.00	0.05
Viscosity by Saybolt Furol Viscometer, seconds, at 25^{0}C	34.24	-	96.5	-
Viscosity by Saybolt Furol Viscometer, seconds, at 50^{0}C	23.29	20-100	74.44	50-130
Storage stability after 24 h., %, max.	1.75	2	1.67	2
Particle charge	Positive	Positive	Positive	Positive
Tests on residue :				
(a)Residue by evaporation, % Min	61.20	60	65.13	65
(b)Penetration, 25^{0}C/100gm per 5 sec.	87	80-150	92.50	60-150
(c)Ductility, 27^{0}C/cm., Min	80	50	82	50

Table 3: Test Results of Aggregate

Test	Result	Specification Limit	Method Of Test

Grain size analysis	4%	Max 5% passing 0.075mm sieve	IS:2386 Part I
Combined Flakiness and Elongation Index	33.40 %	Max 35%	IS:2386 Part I
Los Angeles Abrasion Value	21.01 %	Max 35%	IS:2386 Part IV
Aggregate Impact Value	17.77 %	Max 27%	IS:2386 Part IV
Specific Gravity 10mm aggregates	2.65	-	IS:2386 Part III
Specific Gravity of 6mm aggregates	2.675	-	IS:2386 Part III
Specific Gravity of fine aggregates	2.87	-	IS:2386 Part III
Water Absorption of 10mm aggregates	0.37%	Max 2%	IS:2386 Part III
Water Absorption of 6mm aggregates	0.38%	Max 2%	IS:2386 Part III
Water Absorption of fine aggregates	1.15%	Max 2%	IS:2386 Part III

Table 4. Adopted Aggregate Gradation

Sieve Size,	% Passing	
	Obtained gradation	Required gradation as per

mm		IRC SP 100	
		Lower Limit	Upper limit
19	100	100	100
13.2	95	100	90
9.5	80	90	70
4.75	43	51	35
2.36	31.5	39	24
1.18	22.5	30	15
0.3	14	19	9
0.075	5	8	3

The estimated amount of binder was determined using Eq. (1), based on the gradation of the aggregate. Samples were prepared using gyratory compactor at 100 gyrations to control voids.

$$P = [(0.05 \times A) + (0.1 \times B) + (0.5 \times C)] \quad (1)$$

Where:

P = Required Emulsion quantity in percentage

A = Aggregate percentage retained on 2.36 mm sieve

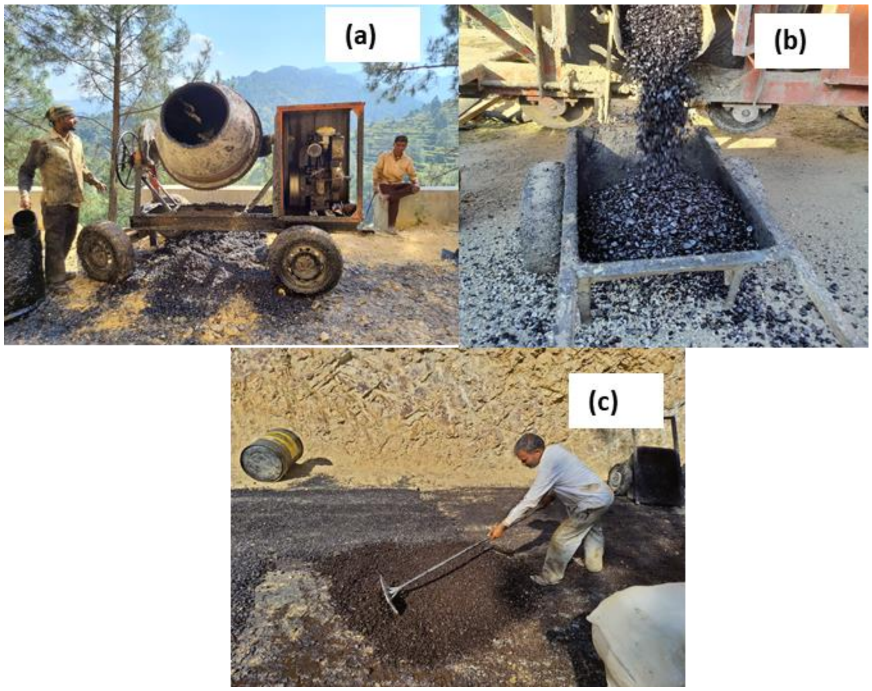
B = Aggregate percentage passing the 2.36 mm sieve and retained on the 75µ sieve

C = Aggregate percentage passing on 75µ sieve

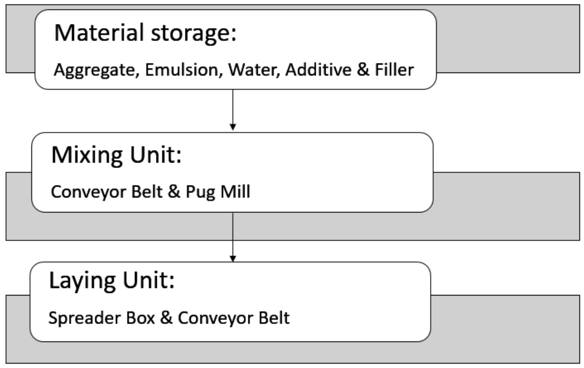
Using trial emulsion content, coating test was carried out for the aggregate used in this study, which was pre-wetted with water. Coating test was also carried over a range of water content (1 to 4% by weight of aggregate). The bitumen emulsion is then added and mixed for 1 minute until the uniform coating is obtained. New batches were prepared with an addition of an increment of 1 percent water by weight of dry aggregate. Emulsion coating over the aggregate depends on the aggregate moisture content. The optimized moisture quantity is determined to maximize the coating of emulsion over aggregate. Trial test samples were prepared at laboratory with increasing emulsion contents at a optimised moisture/water content. The maximum stability and bulk density of mix is found out to be at 9% and 2% emulsion and water content, respectively.

3.4 Test Section Construction

500m stretch is constructed using conventional manual process. Conventional manual process involves production of cold mix using concrete mixer, transportation material through trolley and laying by the labors (Fig. 2 (a), (b) and (c)). The fabricated machine is used for production of cold mix using inbuilt pug mill and paving through the inbuilt paver (Fig 3). 500 m stretch adjacent to the manual laying section is laid using the fabricated machine.



View of Conventional Manual Laying Process (a) Production of Mix (b) Transportation (c) Laying



View of Mechanized Laying System

4. KEY FINDINGS AND RESULTS

The bitumen emulsion mixed material was collected from both the concrete mix and mechanized machine at different batches of mixing and checked the gradation at the laboratory through extraction. The gradation of mix from concrete mixer and mechanized mixer is presented in Fig. 4. Results show the large variability in gradation using the concrete mixer, whereas the variability is less in case of mechanized mixer.

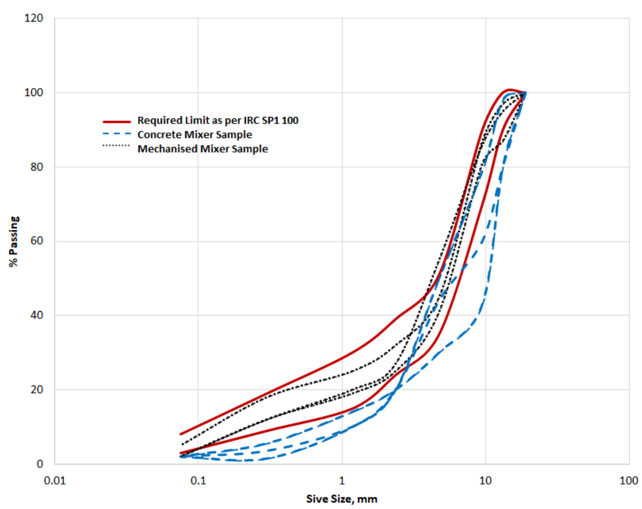


Fig. 4 Gradation of Extracted Material of Site Mix

The variability is also observed visually. The thickness of laid surface using mechanized mixer is 20mm±1mm whereas, with manual laying thickness varies by 17 to 22mm.

The total stretch that can be constructed with the conventional process comes out to be 100-150m per day which includes both the layers of Premix carpet and Seal Coat with all the necessary coatings of tack coat, wherever required. While on the other hand this stretch can be constructed up to a total length of 1-1.5km per day. This can help in fast pace construction and will be more economical to use, especially where the work is needed to be completed urgently without compromising the quality of the construction.

Fuel consumption by only the rotating conventional mixer is 8L per day. It excludes the fuel utilized by the 8tonne compacting roller and dumper truck that is used for transportation of aggregates to the site. The mechanized mixer fuel consumption is 6L per 5 hours of working. The detail comparison of other benefit using mechanized process is presented in Table 5.

Table 5. Comparison of Mechanized and Conventional Process

Parameters	Conventional Process	Mechanized Process
Total No. of Labors involved	15	7
Total stretch made in a day	200 m	1200m
Fuel consumption per day	8 Liters	6 Liters

4 PROJECT'S IMPACTS IN IHR

The Mobile Cold Mixer cum Paver (MCMP) has been designed and developed to facilitate the onsite mixing and laying of bituminous material on a prepared granular/old surface. This equipment contains storage units (aggregate, emulsion, water, filler and additive), mixing unit, spreader box and paving unit with PLC controller to proportionate the materials as per mix design and operation of mixing and paving system. This is designed to lay a the pavement cold bituminous layer ranging a thickness of 20mm to 70mm and a width ranging from 1.5m to 3m.

By using the developed machine construction speed is increased by 10 times and manpower requirement is reduced by 20 times as compared to conventional manual process. For construction of 1 Km. road approximately 200 tCO_2 will be saved using this machine compared to conventional method. The construction of road using this machine results in faster progress, better quality and reduced cost as well as emissions.

Considering the above, the technological know-how for its manufacturing has been transferred to an entrepreneur leading to a 'Made in India' equipment. MCMP also represents a step towards 'Clean India' by introducing green technology for construction and maintenance of roads in the country.


ASHOK LEYLAND


MOBIL COLD MIXER


MCMP LAY
NMHS CRRI
27-12-21

Laying of Bituminous Layer at Jhimar, Uttarakhand

5 EXIT STRATEGY AND SUSTAINABILITY – *supporting documents to be attached.*

An overview of current practices used for cold mix construction and its implication for project execution and quality of work was presented in the current work. Conventional road construction time and cost data were acquired from site engineers, construction contractors, site labors from multiple construction projects through questionnaires. Data during actual paving of roads using both mechanical and conventional methods was collected and evaluated. Results show that with the mechanized process of laying the rate of construction is six times faster compared to the manual construction method. The mechanized construction method results in saving fuel consumption. The bituminous mixes (both manual mixing and mechanized mixer) were collected from the site. manpower requirement is also minimized by using mechanized process of construction. A significant amount of variation in terms of aggregate gradation was found in the manual mixing method compared to the laboratory mix design.

The mechanized process can be used effectively for hilly region road construction with better quality and time-saving. The developed machine can be utilised in ongoing projects of NRIDA, BRO and NHIDCL for construction of bituminous wearing layer.

This technology has been have been dedicated to the Nation by Sh.Nitin Gadkari, Hon’ble Union Minister for Road Transport & Highways in the presence of Dr.Jitendra Singh, Honourable Minister for Science & Technology and Earth Sciences and General (Dr.) Vijay Kumar Singh, Honourable Minister of State for Road Transport, Highways and Civil Aviation on 9^{th} May 2022 day. Also, know how document is presented to NHIDCL, BRO and NRIDA. BRO has already implemented the technology at Shillong and recommended for large scale implementation.

6 REFERENCES/BIBLIOGRAPHY

1. Singh, J. S. "Sustainable development of the Indian Himalayan region: Linking ecological and economic concerns." *Current science* (2006): 784-788.
2. Nandy, S. N., P. P. Dhyani, and Prasana K. Samal. *Resource information database of the Indian Himalaya*. Almora: Environmental Information System on Himalayan Ecology, GP Institute of Himalayan Environment and Development, 2006.
3. Pundhir, N. K. S., and P. K. Nunda. "Development of bitumen emulsion based cold mix technology for construction of roads under different climatic conditions of India." (2006).
4. Plantulli, A. "Progress in The Laying of Flexible Paving Maintenance Equipment." *Publication of: Svenska Vaegfoereningen Foerlags AB* (1981).
5. Chen, Yanlong. "Quality problems and preventive measures for municipal road and bridge construction." *Journal of Architectural Research and Development* 3, no. 2 (2019).

6. Yap, Jeffrey Boon Hui, Ian Ni Chow, and Kamran Shavarebi. "Criticality of construction industry problems in developing countries: Analyzing Malaysian projects." *Journal of Management in Engineering* 35, no. 5 (2019): 04019020.
7. Hasan, Abid, Bassam Baroudi, Abbas Elmualim, and Raufdeen Rameezdeen. "Factors affecting construction productivity: a 30 year systematic review." *Engineering, Construction and Architectural Management* (2018).
8. Bražiūnas, Justas, and Henrikas Sivilevičius. "The bitumen batching system's modernization and its effective analysis at the asphalt mixing plant." *Transport* 25, no. 3 (2010): 325-335.
9. Sivilevičius, Henrikas, and Šarūnas Šukevičius. "Manufacturing technologies and dynamics of hot-mix asphalt mixture production." *Journal of Civil Engineering and Management* 15, no. 2 (2009): 169-179.
10. Bowers, Benjamin F., and R. Buzz Powell. "Use of a Hot-Mix Asphalt Plant to Produce a Cold Central Plant Recycled Mix: Production Method and Performance." *Transportation Research Record* 2675, no. 11 (2021): 451-459.
11. Day, Dennis, Ian Michael Lancaster, and Dougie McKay. "Emulsion cold mix asphalt in the UK: A decade of site and laboratory experience." *Journal of Traffic and Transportation Engineering (English Edition)* 6, no. 4 (2019): 359-365.

7 ACKNOWLEDGEMENTS

APPENDICES

Appendix 1 – Know How Document

Appendix 2 – Trade Mark Application

Appendix 3 – Inaguration of developed machine by Ministers (Photographs) and proceedings

Appendix 4 – Accepted Paper details

Appendix 5 – Technology transfer agreement and certificate

Appendix 6 – Media Coverage

Appendix 7- Brochure of developed machine

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CSIR-CRRI Mobile Cold Mixer Cum Paver

KNOW HOW DOCUMENT

Technology developed by:

1. Applications

CSIR-CRRI MCMP Mobile Cold Mixer cum Paver is mainly used to construct the new roads and to maintain the existing once. It can also be used to correct road damages such as rutting, ravelling, descending friction resistance of road surface, cracks and so on. It can be used to place road construction layers using cold mix technology like Pre-mix Carpet, seal coat and slurry seal to seal the surface, to enhance the skid resistance and other benefits to the road surface. This equipment can be widely used in the construction processes of general cold mix asphalt layers, slurry seal course, modified slurry seal surface sealing etc.

2. Technical Specification of Machine

Mobile Cold Mixer cum Paver (MCMP) provides facility for onsite mixing and laying of cold mix bituminous material on a prepared granular/old surface. It is a single integrated unit which can be mounted on chassis of truck. It is having separate arrangement for storage and proportionating (by weight) of following materials

- Two grades of aggregates (two separate aggregates bins)
- Mineral Filler material bin
- Bitumen emulsion tank
- Water tank
- Chemical additive tank

Along with this, the integrated unit has the power supply arrangement and all the accessories required for proportionating and mixing etc.

- The MCMP is having:
  - Capability of laying; (a) a thin bituminous surfacing (20-30mm), (b) liquid seal coat and (c) structural cold bituminous layer (minimum 40mm) in mechanized manner.
  - Provisions/arrangement to weigh each individual material as per design mix proportions. The tolerance limit of weighing shall not be more than ±2% of each ingredient.
  - A capacity to produce a minimum 3 cubic metre of cold mix per a charge/batch
- The mix is being laid by a hydraulic driven detachable spreader box. The width of spreader box shall vary from 1.75m to 2.25m. It shall have capability to evenly spread the mix to the specified thickness.
- Maximum height and width of the fabricated unit (over and above the standard chassis) are not to be exceed 2.0 m and 2.5m, respectively.

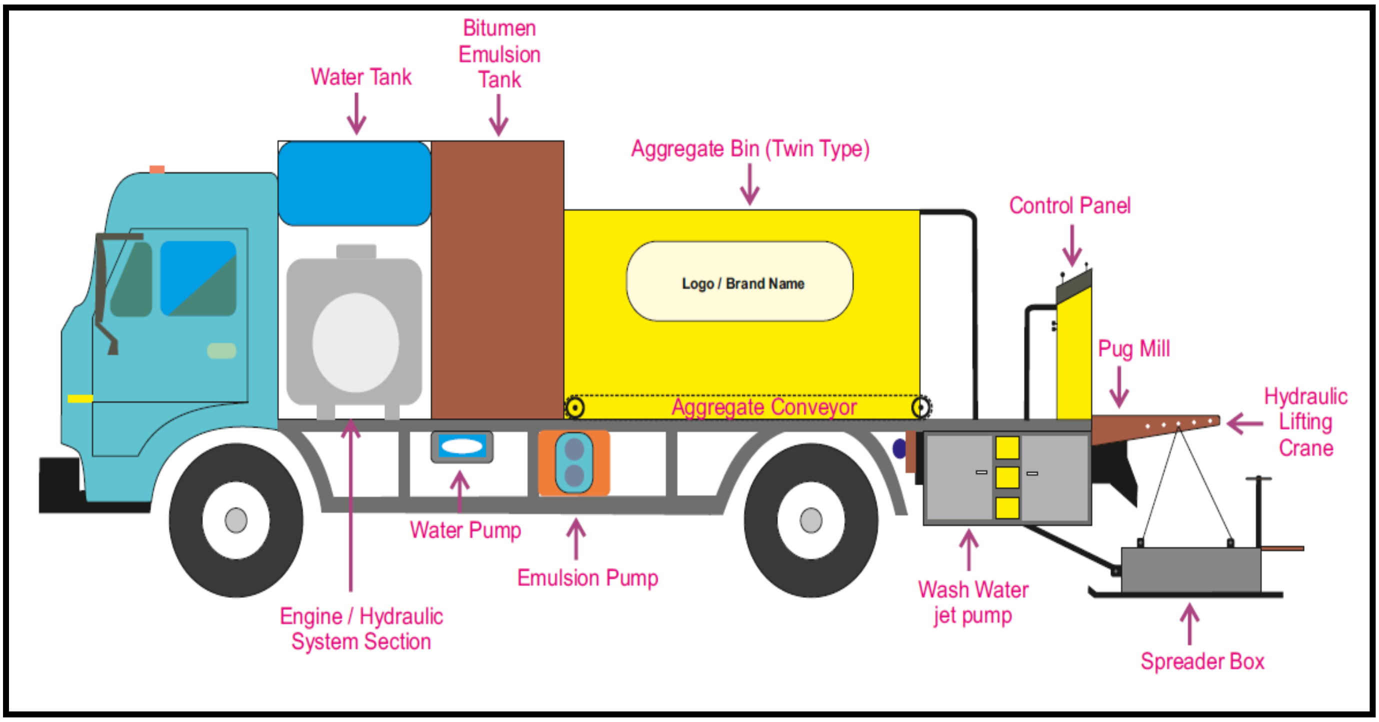
- Maximum length of fabricated unit with and without spreader box is not to be exceed exceed 9m and 7.2m, respectively.
- The hydraulic/pneumatic control /electronic control panel units is having the real time display.
- The material of construction and fabrication of facility capacity of each parts are as below:
  - Aggregate Bin 1:
    - Minimum 2 Cubic Meters (minimum 3 tonne) capacity
    - Made of Mild Steel (MS) sheet of sufficient thickness to bear the aggregate load without bending/failure
  - Aggregate Bin 2:
    - Minimum 1 Cubic Meters (minimum 1.5 tonne) capacity
    - Made of MS sheet of sufficient thickness to bear the aggregate load without bending/failure
  - Filler Bin:
    - Minimum 200kg Capacity.
    - Made of MS sheet of sufficient thickness to bear the material load without bending/failure
  - Bitumen Emulsion Tank:
    - Minimum 1000litre Capacity
    - Made of corrosion resistant MS sheet of sufficient thickness to bear the material load without bending/failure
  - Water Tank:
    - Minimum 1000litre Capacity
    - Made of profile and corrosion resistant MS sheet/Plastic of sufficient thickness to bear the material load without bending/failure
  - Chemical Additive Tank:
    - Minimum 100litre Capacity
    - Made of non reactive to alkaline/acid material and corrosion resistant Stainless-steel sheet of sufficient thickness to bear the material load without bending/failure
  - Twin shaft pug-mill:
    - Minimum output 400kg per minute.

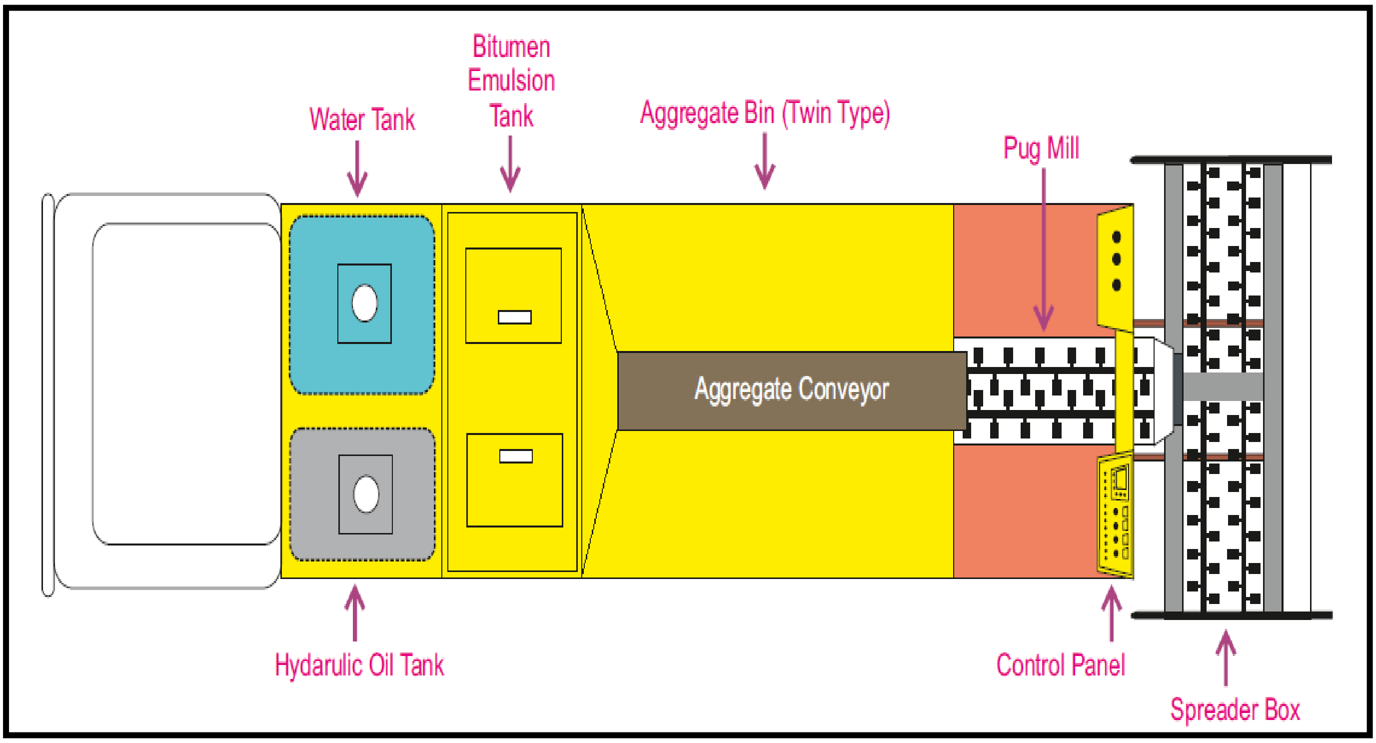
    - Made of MS sheet with ceramic coating of sufficient thickness to bear the material load without bending/failure

- Required hydraulic and pneumatic tubing should be attached for proper working of machine
- Storage bins, storage tanks, pipelines/tubes used in fabrication shall be corrosion resistant.

➢ In addition to material storage tank and bins, the machine is having following parts and arrangement:

- Sufficient capacity Diesel/petrol engine for driving hydraulic pumps.
- Sufficient capacity Hydraulic pumps and motors
- Electronic integrated pneumatic system including solenoid control and valves
- PLC (programmable logic controller) based control panel with HMI display.
- Illuminated selector switches-based control panel with emergency stop.
- Hydraulic system driven Conveyor Belts/ Screw conveyors for proportionating of Aggregates and Filler.
- Hydraulic system driven heat jacketed Lobe/gear Pump for dosage of Bitumen Emulsion.
- Hydraulic system driven gear pump made of stainless steel for dosage of chemical additive.
- Hydraulic system driven Centrifugal and Pressure jet pump for dosage of water and cleaning, respectively
- Hydraulic system driven twin shaft pug- mill with strong augurs for mixing components.
- Hydraulic system driven Spreader Box with adjustable opening and fixing of layer thickness.





3, Working Principle of Machine

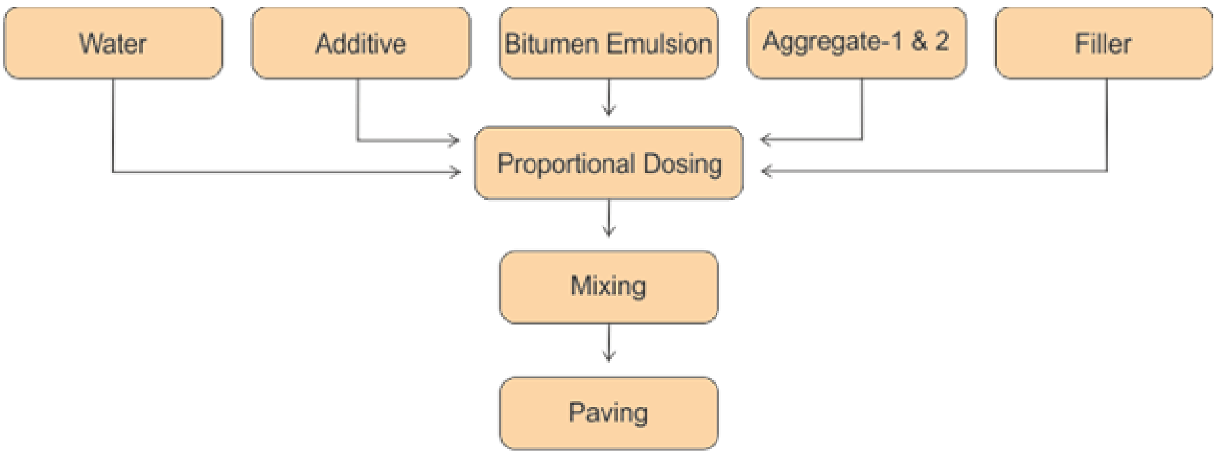
The cold-mix asphalt technologies environment friendly road construction and maintenance techniques where no heating of bituminous or other components is done during mixing or laying phase of road construction or maintenance. Applications of cold-mix asphalt technologies include CM-BM (Bituminous Macadam), CM-SDBC (Semi

Dense Bituminous Concrete), CM-PMC (Pre-mix Carpet), CM-Seal Coat, Slurry Seal, Micro-surfacing, CM-Pothole Filling, CM-Surface Dressing etc as per IRC SP 100 (Indian Road Congress).

The operational principle of the Mobile cold mixer cum paver is the automated process of convey the aggregate, filler (mostly cement), water, bituminous emulsion and a break control additive (any or all of components) in a certain ratio, into the mixer, which quickly mix the components properly in a homogenous, workable mass and discharge it into the paving box (also called spreader box), which with the movement of carrier truck, pave it evenly on the desired surface.

Mobile cold mixer cum paver is the special machine for producing and laying of various cold-mix asphalt layers, with advantage of automated dosing of components, very short mixing time, quick and homogenous mix mass and spreading in desired thickness. It provides advantages like exceptional quality control, fast construction, low wastage, less cost and low energy consumption etc.

Flow Chart of Construction Process



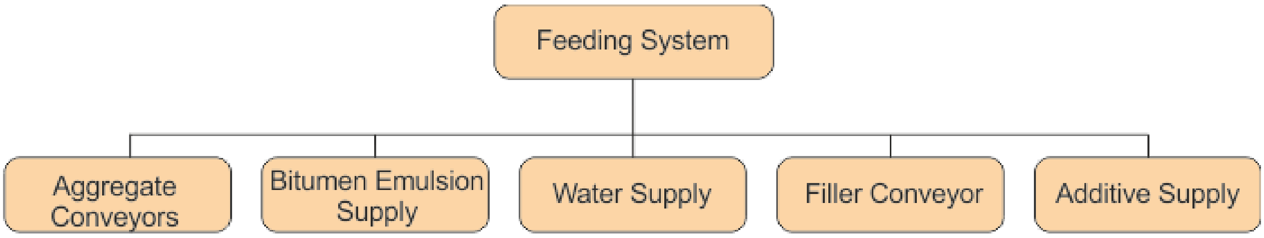
4. The structural components of fabricated machine is given as below:

Chassis

Special auxiliary chassis fixed below the machine is heavy duty and durable.

Feeding System

Feeding system is one of the most important part of the Mobile cold mixer cum paver, as the continuous feed of right proportion of each component is utmost important to ensure quality and mix consistency. This machine has been provisioned to feed any or all of five components as below depending on type of surfacing, mix design and application requirements.



Aggregate Conveyors

This system provides required quantity of two type of aggregates to the cold-mix asphalt mixtures, and including the following units:

Aggregate Bin-1: Storage volume of aggregate is 2 m^3.

Aggregate Bin-2: Storage volume of aggregate is 1 m^3. This bin is removable with little efforts to make more room for aggregate bin-1 in case need arises.

Independent Aggregate Conveyor-1: Independent aggregate conveyor for aggregate bin-1 is easy to fix and remove for maintenance. It is fully adjustable for belt tightening and rectification of faults.

Adjustable Feed Gate-1: A sliding gate type adjustable door on feed mouth of aggregate bin-1 is easy and fast way of controlling the quantity of aggregate discharge from this bin. In synchronization with conveyor belt speed hydraulic control, it gives infinite flexibility in maintaining aggregate gradation requirements of cold mix asphalt mixes.

Independent Aggregate Conveyor-2: Independent aggregate conveyor for smaller aggregate bin-2 is also easy to fix and remove as need arise. It is also fully adjustable for belt tightening and rectification of faults. Both conveyor-1 and 2 have interlocking proportionating through chain linkage.

Adjustable Feed Gate-2: A sliding gate similar to feed gate-1 on feed mouth of aggregate bin-2 is also the easy and fast way of controlling the quantity of aggregate discharge from this bin. In synchronization with conveyor belt speed hydraulic control, it gives infinite flexibility in maintaining aggregate gradation requirements of cold mix asphalt mixes.

Strong Power: Strong hydraulic motor drives both the conveyors at stable speed, which provides accurate and convenient control of aggregate dosing and the system is equipped with highly sensitive and advanced speed sensing device with real time feedback of motor speed.

Bitumen Emulsion Supply System

This system supplies bitumen emulsion to the cold-mix asphalt mixtures. This includes the following units:

Emulsion Tank: 1000 Litres

Emulsion Pump at Stable Flow Rate: This pump is state of the art positive displacement pump made of Stainless Steel; corrosion resistant grade specially designed for MCMP. It has high volume efficiency and stable flow rate; It is jacketed pump with warming function from engine radiator water to help pump retain effortless working even in harsh working environments. With strong pumping action, this pump ensures complete drainage of emulsion from the tank and double up as emulsion loading pump by providing sucking action when three-way valve is kept in proper position.

Solenoid Direction Control Valve: Advanced solenoid direction control valve provides the running of emulsion pump in clockwise and counter clockwise direction for dosing or emulsion loading functions as well as flushing of pipelines. In combination with hydraulic flow control valve at operator panel it ensures accurate and convenient dosing of bitumen asphalt into the asphaltic mix. The calibrated flow can be scaled up and down by the operator in case of changing material and weather conditions.

Pneumatic Control Valves: The pneumatic control vales can run on automatic or manual mode by the operator. They control the flow of bitumen emulsion to mixer or re-circulate it to the tank by pneumatic interlocking for better reliability.

Strong Power: Powerful hydraulic motor drives emulsion supply system at stable speed. Efficient speed sensing through special sensors ensures real time reporting of dosing parameters.

Water Supply System

This system supplies water for aggregate moistening, formation of slurry / micro-surfacing mix consistency, high pressure wash flushing and water spraying. This system includes the following units:

Water Tank: 1000 Litres

Stable Water Pump: The high output in-line centrifugal pump provides uniform pressure and quantity of water which can be controlled through pneumatic and check valves available in loop system.

High strength Acrylic Rotameter: This rotameter is used to assess the rate of flow of water and is placed at a convenient spot for easy observation by the machine operator. This instrument is rugged built and better suited for mobile machinery with high levels of vibration. It also ensures 360-degree observation as the readings are visible from around the rotameter.

Hydraulic Solenoid Valve: As the pump is driven by specialized hydraulic motor, the operation of same is achieved by the electro-hydraulic solenoid valve, which is controlled from the main control panel. The speed of water output can be regulated through control of hydraulic oil flow by special valves installed in hydraulic system.

Pneumatic Control Valve: The pneumatic control vales can run on automatic or manual mode by the operator. They ensure start / stop of water dosing as well as bypass to the tank for no overload system.

High Pressure Washing / Flushing Device: Equipped with variable jet type adjustment on spray gun, this system provides the convenience of the daily washing, cleaning and maintenance of paving parts and other equipment. This system can also double up to pre-wet the application surface in case of hot weather or the mix requirements.

Filler Supply System

This system supplies the mineral filler (mostly cement or hydrated lime) to the mixer as per requirement of mix design. This is in feed chute style with twin shaft drive for loosening of fine powders and the spiral feeder which ensure stable discharge volume and accurate proportioning. Driven by strong hydraulic motor, this gives trouble free service for years.

Additive Supply System

This system supplies break control additive to certain mixes where controlled breaking of emulsion is important like slurry seal, micro-surfacing etc. Since this system uses chemicals, all its components are made from chemical resistant stainless steel. The flow of additive is controlled by the pneumatic vales which can be run on automatic or manual mode by the operator.

Mixing System

The mixing system is designed to produce homogenous mixes (complete coating with bituminous emulsion) at shortest possible time. It consists of mixer barrel, gear box, mixer shaft, blades and distribution bin. The above-mentioned materials are continuously fed to the mixer to produce accurate mixture as per mix design. This system is made of properly arranged paddle blades fixed on fast rotating double shafts in overlapping circular and angular motion, which ensures complete and quick mixing. The mixer is run by a very strong, high torque hydraulic motor which is controlled by the operator from control panel. The RPM of the mixer can be changed by controlling the flow of hydraulic oil to the motor, if a need for changed mix properties are required. The components of the mixer are made from better abrasion-resistant mild steel for long service life. The mixer is also tilt-able downwards for ease of discharge of some mixes with higher percentage of heavy aggregates and while working on hilly slopes and overbridges. The tilting mechanism is also hydraulically controlled by the operator. The discharge volume (Max. 700 Kgs/min) is applicable to all mix types.

Spreader Box / Paving System

The Paving system consists of the specially built spreader box and is independent of materials or mixing part of the main paver. This part is detachable from the main paver by simple removal of few lock-bolts and hydraulic hoses. This system spreads the cold-mix asphalt materials (discharged from the mixer) on the required surface in even layers in required width and thickness. This box is specially built to handle bigger aggregate size and comparatively drier mixes. For more liquid or slurried materials, a strip of rubber is placed on discharge slit of the box to prevent splaying.

Power System

This system holds strong and enough power for smooth working and control operations. It consists of auxiliary engine and the hydraulic units.

Auxiliary Engine

The auxiliary engine is Kirloskar make water-cooled internal combustion engine with rated power of 70kw/2000rpm. This engine is equipped with turbocharger for better power, performance, and reliability.

Hydraulic Systems

All the parts of this unit such as hydraulic pump, hydraulic motors and hydraulic control valve are all from prestigious international companies for stable and reliable running of entire machinery. The hydraulic system is separately controlled by a complex mix of five independent systems with integration of electronics and sub-systems, and it gives the actual and independent power to each individual dosing part to ensure standard working.

Control System

This system is Programmable Logic Controller based centralized system which is guided through a touch screen HMI with real time reporting of dosing parameters. In automatic mode, this system ensures sequential control and dosing of all components. The machine operator can view the engine and other physical characteristics at one place through divided panels (for Engine running and paver controls) arranged nearby and can effectively control entire machine through easy electronic interface and physical controllers. All controllers used in this system are built for off-road machinery and ensure accurate control over all parameters. The software-based calibration is one of its class in this segment to help operator assess dosing parameters in a glance over a custom graph available for main 3 components. The system when running in automatic mode, has logics and intelligence for best performance. This system is integrated with pneumatics and hydraulics for seamless performance.

5. Application Process Requirements

Cleaning the work-site area

The application surface must be cleared of all contaminants such as dust, dirt, debris, loose aggregates, stagnant water etc. Any deformity on this surface like pot-hole, cracks, rutting etc must be corrected and the surface made level to ensure better mix application. The cleaning can be carried using compressed air through a high-pressure road air-compressor. In case of wet dirt, dust, debris etc sticking to road surface, pressure cleaning with water van be employed to ensure better surface cleaning.

Marking the area of application

Since the paving is usually done in multiple width to ensure traffic management and to ensure better coverage and less overlapping of joints, the area of application should be clearly marked using any standard method of marking. The driver of the truck carrying the machine must be made aware of the length and width of each application. He should be able to drive the truck in manner of marking and at a certain speed required to ensure fine paving.

Paving Process and Requirements

The communication between the machine operator and the truck driver is very important as this will ensure the right movement of the truck at time when the operator is ready with the proper level of mix in the spreader box. Usually there is a sign language between these two persons owing to noise produced by the auxiliary engine and long distance between both of them. Optionally head mounted wireless communication can be utilised.

Ensure the truck is parked on the application area with the spreader box in position of start point. Lower the spreader box to the ground while gentle forward movement of truck to ensure right direction of guide rubbers of the spreader box. Check and adjust the layer thickness by manually checking the skid opening on back of spreader box. For thin surfacing where a finishing rubber is used as secondary strike-off, ensure it is straight and not having any bends on lower surface. Check if the data being shown on HMI is OK.

Speed up the auxiliary engine to paving RPM, turn the maual / auto switch to Auto mode. Start the mixer and the components motor start switches on first line of the control panel. From HMI start dosing of components in automatic mode. Operator will visually check the consistency of the mix being discharged in the spreader box and will make adjustments in water or additive dosing if any required due to changed weather conditions.

When the mix reaches a certain height in spreader box, deemed fit for paving by the operator, the operator would signal the truck driver to start moving the truck on certain speed in the line of marking. The manual water spray system can be utilized in case of surface pre-wetting is required under certain weather conditions.

In the mix spreading process, it is important for the operator to be attentive to the mix consistency and the level of the mix in the spreader box for quality and better finish of the application layer.

Precautions to be taken:

The dosing of each component and the output discharge volume is dependent on RPM of the auxiliary engine, which will change proportionately with the change in engine speed. However, the ratio of the components can become different as the calibration is done on a fixed speed of engine. So, keeping the engine speed constant is important.

To ensure even spread of the mix on road surface, the speed and direction of the augurs of the spreader box must be watched and adjusted by the operator.

Paving Completion Processes

On completion of paving cycle, wash the mixer and the spreader box with pressure water jet, if next paving is required at the same site, disconnect the spreader box hydraulic and mechanical parts from the machine and leave it on site. Turn-off all the functions and stop the auxiliary engine after reducing the RPM and cool down.

If the spreader box is not required or no additional paving is planned for the day, The spreader box can be hung in the back of machine using hydraulic lifts, with hydraulic and mechanical parts attached to paver for transporting back to the camp site.

Complete the balance cleaning operations of the machine at camp site like removal of deposited asphalt material, aggregate, mix lumps etc from the spreader box, mixer and the discharge box of the mixer. Emulsion pump must be washed with some diesel to maintain effortless start for next paving.

Transportation

Since the machine is in special shape and with protruding mixer / hydraulic lift / jack in the rear, please pay attention to the followings precautions when transporting the truck before or after use:
Drive the truck slowly in traveling, especially when turning.
For long distance travel, pay attention to check the truck for essential spares.
The spreader box should not be kept hanging on the hydraulic Lift / jack for long transportation. It is strictly prohibited to hang it for more than 15 minutes or travel of max 10 kilometres. If the longer transportation is required, it should be transported with a separate vehicle.
For long distance shifting, the spreader box should be loaded in a utility truck. Care should be taken to avoid any damage to spreader box as it would give imperfections in next paving or the entire working can get interrupted.

Storage

When the machine is expected to keep idle for a long time, it should be thoroughly cleaned and prepared as given below:

- Empty the aggregate bins / Filler bin, drain water, additive and emulsion completely.
- Remove deposits of bitumen from the emulsion tank and clean with any flush oil.
- Check water tank for any rusting and apply automobile grade white primer inside the tank.
- Wash additive tank thoroughly with water and dry.
- Check aggregate bins and filler bin for any rusting or scratches. Clean and apply silicon polish to prevent further rusting.
- Release the pneumatic pressure completely, close all feed valves, shut-off power supply and detach the battery terminals from power supply.
- Clean the control panel, check sealing ring for any damage, lock properly.
- If possible, cover the machine with a terpulin cover and store inside a shed.
- Restart the machine for some time every 15 days to lubricate the parts.

1. softcopy of image/ words/letters/ proposed mark*

Mobile Cold
Mixer cum Paver

2.Describe the service & classification for proposed Mark.

The proposed mark represents the pavement construction and maintenance machine indigenously developed by CSIR-CRRI for mixing and laying of bituminous layer over the granular layer.

3. A para or page note about the newness/novelty of the proposed mark.

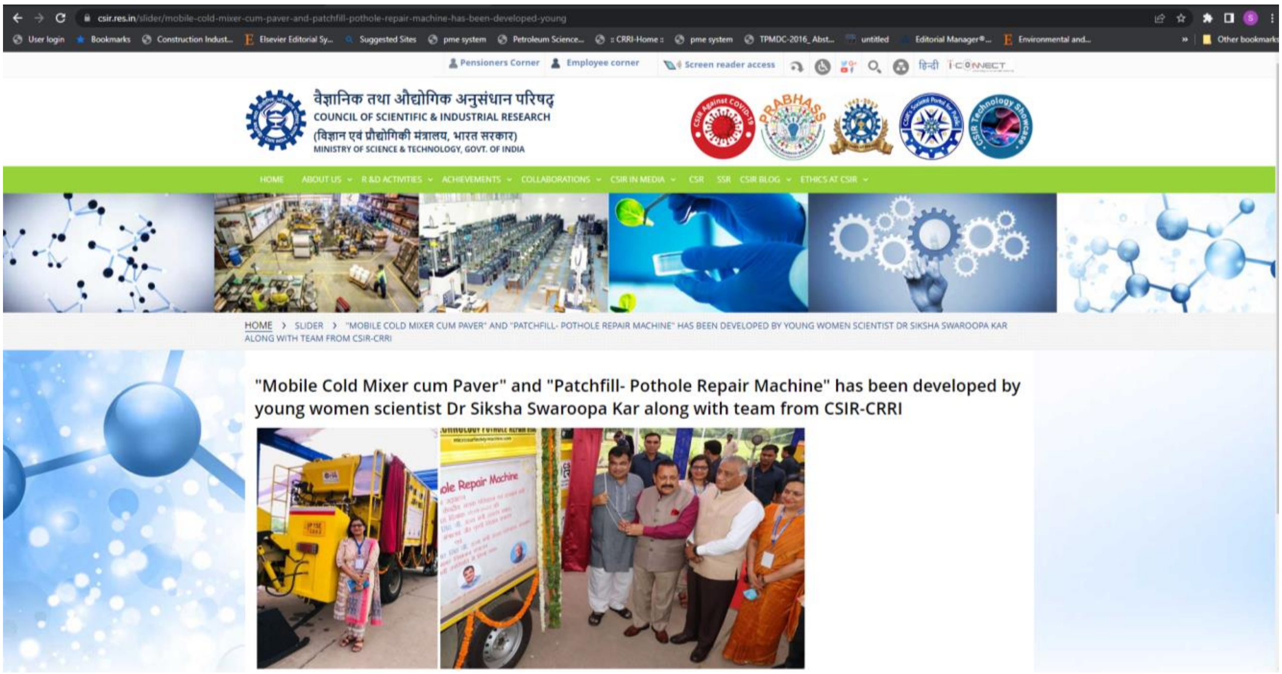
The nomenclature of the product is given by CSIR-CRRI. There is no item found while searching "Mobile Cold Mixer cum Paver" on ipindiaonline.gov.in website. The proposed mark bears the novelty of being unique and associated with machine used for mixing and laying of bituminous layer over the granular surface.

4 . Please inform the class(es) *on the basis of use/application of product , under which the protection is required.*

Class	Basis
7	This is a machine consisting of motors, compressors, mixers, spreader box etc for construction and maintenance of pavement.
37	This is used for road repair and construction service.

5. Please send copies of supported publication material *(if any) regarding commercial use/production of the proposed mark ,like news paper clippings , leaf lets, cash memos regarding sale of product, exhibition/display record, cartons, packaging etc,*

Copies of news articles & screenshot of online published documents are attached.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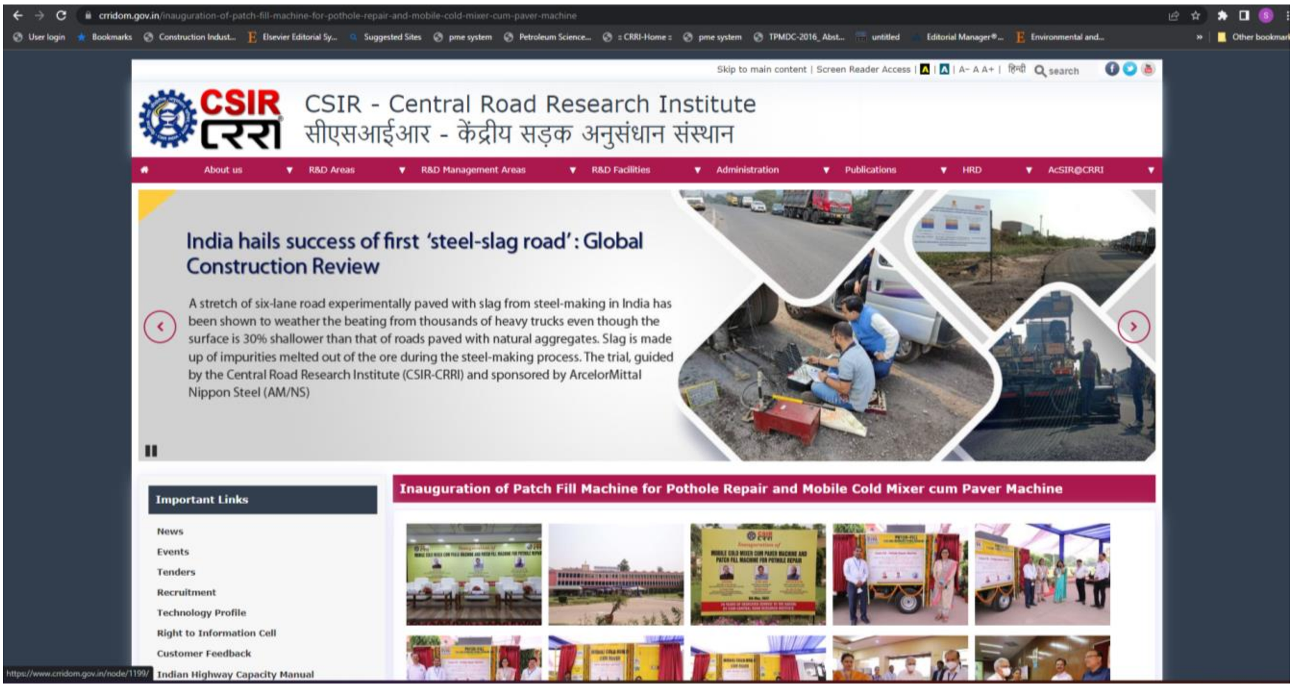
"Mobile Cold Mixer cum Paver" and "Patchfill- Pothole Repair Machine" has been developed by young women scientist Dr Siksha Swaroopa Kar along with team from CSIR-CRRI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India hails success of first 'steel-slag road': Global Construction Review
A stretch of six-lane road experimentally paved with slag from steel-making in India has been shown to weather the beating from thousands of heavy trucks even though the surface is 30% shallower than that of roads paved with natural aggregates. Slag is made up of impurities melted out of the ore during the steel-making process. The trial, guided by the Central Road Research Institute (CSIR-CRRI) and sponsored by ArcelorMittal Nippon Steel (AM/NS)
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Indian Highway Capacity Manual
Inauguration of Patch Fill Machine for Pothole Repair and Mobile Cold Mixer cum Paver Machine

Appendix 3

Inauguration of Mobile Cold Mixer cum Paver by Sh.Nitin Gadkari, Hon’ble Union Minister for Road Transport & Highways in the presence of Dr.Jitendra Singh, Honourable Minister for Science & Technology and Earth Sciences and General (Dr.) Vijay Kumar Singh, Honourable Minister of State for Road Transport, Highways and Civil Aviation


xer cum Paver
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Mobile Cold Mixer cum Paver
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Proceeding of the event

Press Note - CSIR-CENTRAL ROAD RESEARCH INSTITUTE

9th May 2022, New Delhi: CSIR-Central Road Research Institute (CRRI), a premier national laboratory established in 1952, a constituent of Council of Scientific and Industrial Research (CSIR) is engaged in carrying out research and development projects on roads, runways, utilisation of sustainable materials, bridges & structures, traffic and transportation planning.

CRRI has indigenously developed road construction/maintenance equipment **(Patchfill- Pothole Repair Machine and Mobile Cold Mixer cum Paver)**. These technologies have been dedicated to the Nation by **Sh.Nitin Gadkari**, Hon'ble Union Minister for Road Transport & Highways in the presence of **Dr.Jitendra Singh**, Honourable Minister for Science & Technology and Earth Sciences and **General (Dr.) Vijay Kumar Singh**, Honourable Minister of State for Road Transport, Highways and Civil Aviation on this day.

Dr. Ranjana Aggarwal, Director, CSIR-CRRI welcomed the dignitaries and made a presentation on R&D activities carried out by the institute.

Dr. Rajesh S Gokhale, DG, CSIR in his opening remarks appreciated the work carried out by CRRI

Dr. Jitendra Singh ji ---Appreciated the Scientists for the development of new equipments which are aligned to Atma Nirbhar Bharat. Further he suggested to focus on collaboration with intra / inter departmental institutes as well as private sector in scientific R&D. Also suggested to increase capability and capacity in R&D to meet the country's needs in next 25 years.

Gen.(Dr.)V.K.Singh ji – He appreciated the work carried out by CRRI. He emphasized on the need for lab R&D to field implementation in shortest possible time.

Institute should focus on challenging projects for development of sustainable, low cost and long lasting, environment friendly roads without compromising the quality.

Sh. Nitin Gadkari ji -

Country needs not only high quality but also low cost construction technologies. He emphasized for taking up need based R&D. Further said that filing patents is not the end of the R&D, it should be commercialized.

He suggested that the developed Patchfill - Pothole Repair Machine should be commercialized for use by Urban development authorities and State road owning agencies. In this process MSME/ industries should be involved. Also he emphasized on the following points:

- Developing cost effective technologies by using locally available materials as well as alternative materials for road construction especially to reduce usage of cement and steel.
- Implementing new technologies for cost effective and high quality construction(such as use of Plastic Waste, Tire Rubber, Municipal Solid Waste, Beema Bamboo, Agricultural and industrial waste)
- Need to solve the problems faced by the Country with regard to Bridge Expansion Joints. Also should focus on developing technologies for long span bridges.

The Hon'ble Ministers also visited various R&D Facilities of the Institute and addressed to the gathering on this occasion. This event has been attended by DG, CSIR and officials from MORTH, NHAI, Ministry of Science & Technology, NRIDA, NRDC, IIT Roorkee, Petrochem Pvt. Ltd. etc.

During this event the Honorable Ministers Released the Special edition of "Science Reporter" on "India's S&T Missions Making India Future Ready - National Technology Day Special 2022".

Dr. Shekhar C Mande, Former DG, CSIR was felicitated by the honorable ministers for his exemplary contribution to CSIR. The meeting ended with Vote of thanks to the Ministers and diginitaries.

<u>Mobile Cold Mixer cum Paver</u>

Design and construction of roads in high altitude Himalayan region poses more difficulties than plain terrain, due to :

- Issues related to non-availability of skilled labour in areas like the North eastern states and Himalayan Region.
- Non-availability / limited availability of space for set up of plant for road construction
- Non availability of heavy conventional construction and operational equipments.

To overcome the above problems, CSIR-CRRI developed Mobile Cold Mixer cum Paver for preparation and laying of black top layers using bitumen emulsion based technology. This technology has been developed by CSIR-CRRI under a project funded by Ministry of Environment, Forest and Climate Change under National Mission on Himalayan Studies (NMHS) scheme. By using the developed machine construction speed is increased by 10 times and manpower requirement is reduced by 20 times as compared to conventional manual process. For construction of 1 Km. road approximately 200 tCO_2 will be saved using this machine compared to conventional method. The construction of road using this machine results in faster progress, better quality and reduced cost as well as emissions.

Journal of Testing and Evaluation

Siksha Swaroopa Kar,[1] Nipun Beniwal,[2] and G. Bharath[2]

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Microstructure Analysis of Cold Bituminous Emulsion Mixture Using Different Filler Type

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Reference

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ABSTRACT

In today's scenario, the environmental impact of the transport sector plays a major role in net carbon emission generation and global warming. Seeing the emerging environmental issue, it has been mandatory to adopt sustainable technologies in every sector. The use of bitumen emulsion in the construction of pavement has been rapidly enhanced in the last decade. This technology eliminates the heating of aggregate and binder, resulting in a reduction of greenhouse gas emissions and energy consumption, which is also termed as cold mix technology. Filler has a major role in the formation of bonds between bitumen emulsion and aggregate. In the present study, cement, lime, and fly ash have been considered as filler materials along with stone dust and the required optimum emulsion content and water content were determined. The impact of filler on the breaking of bitumen emulsion is studied through scanning electron microscope image analysis. The impact of filler on pH of bitumen emulsion mastic is also evaluated. The optimum emulsion content in cold bituminous emulsion mixtures (CBEMs) depends on the particle size of the filler. The required water content for lime is less compared to other filler materials. The results show that cement and fly ash are pozzolanic in nature, form hydration products in the presence of water in CBEM, and result in higher density and stability. The study depicts the role of filler material in CBEM at the microlevel.

Keywords

bitumen emulsion, mineral filler, volumetric properties, performance, hot mix asphalt

Introduction

In recent days, cold bituminous emulsion mixture (CBEM) is considered to be a better option for road construction rather than conventional hot mix asphalt (HMA). It is used as

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a surface course and as a stabilized base layer in the flexible pavement structure.[1,2] CBEM is composed of bituminous emulsion, aggregates, and filler material, and the mixture is prepared at ambient temperature. CBEM releases less emissions relative to HMA and ingests a lower amount of energy.[3,4] The energy and emission that is reduced by using emulsion is caused by eliminating the heating and drying of aggregates. The use of bituminous emulsion mixtures proves to be environmentally friendly and economical compared to conventional bituminous mixes.[1,2]

The process of coating of binder over aggregate and developing the strength in CBEM is considered in two phases. In the first phase, chemical interaction takes place between the emulsion and aggregates. The chemical interaction results in the breaking of emulsion on the surface of aggregates. In the second phase, bitumen emulsion forms a coating around the particles of aggregates. The geometry of emulsion particles after coating on the aggregates is maintained because of the breaking characteristics of emulsion in CBEM. The evaporation of water from the emulsion composition that is caused by breaking results in the development of the strength of stabilized aggregate, which henceforth is capable of traffic load resistance.[5,6] When coating forms, filler particles passing the 0.075-mm-size sieve act together with emulsion; it improves the stiffness and cohesion in the binder in a significant manner. The higher surface area of the finer particles initiates faster interaction with the emulsion in the mix. Performance properties of the bituminous mixtures for both cold and hot mix asphalt get significantly affected with filler material type and its content.[7,8] Several studies indicate the improvement of the mechanical properties with the replacement of filler in CBEM for a specified proportion with ordinary portland cement (OPC), fly ash, or lime.[9–11]

The filler present in the mix interacts with both the water and bitumen present in the emulsion. Firstly, during the curing period, it influences the development of strength, and secondly, after the complete curing is achieved, it influences the rheological properties of the bitumen.[12–14] Research showed that the replacement of conventional mineral filler with fly ash, especially with higher percentages of fly ash (4.5 and 6 %) in cold mix, significantly improves the resilient modulus value of mixture.[13,15] Du (2014) showed that optimum water content (OWC), optimum emulsion content (OEC), and indirect tensile strength (ITS) are influenced by filler type during the CBEM mix design.[7] Use of OPC and a combination of slag and hydrated lime works as an additional binder in CBEM and results in reduction of optimum fluid contents and increase in tensile strength.[15,16] Hdabi and Nageim (2017) used fly ash and ground-granulated blast-furnace slag as an additive to strengthen CBEM mixtures and substantial development in the permanent deformation resistance had been reported with two days curing period.[17] Moisture resistance of CBEM with addition of OPC was found to be improved, resulting in higher retained marshal stability and tensile strength ratio (TSR) values.[18–20] Many studies reported that the addition of 2 % of cement found to be optimum in cold bituminous mixtures.[20–23]

Some studies showed that the performance of bituminous mix such as stiffness, elasticity modulus, moisture resistance, rutting resistance, adhesion, and healing depend on the microstructure of the bitumen and aggregate.[24–27] Gao and Wu[28] conducted scanning electron microscopy (SEM) studies of cement asphalt mortar and showed that cement hydration products and asphalt formed a porous gel structure. The curing effects on the performance of emulsified mixes are being evaluated using microstructural analysis.[28–31] Qiang et al.[32] concluded that asphalt presence in emulsified mixes hinders the hydration reaction of cement, lowering the strength of mix. Du (2014) conducted SEM analysis of emulsion mastic sample with and without cement.[33] SEM images of cement emulsion mastic showed the well-distributed micro air voids in a mix that are caused by the presence of hydration compound. The microstructure of cement emulsion mastic was denser than only emulsion mastic without cement. Du (2016) also studied the microstructure analysis of cement emulsion mastic with and without reclaimed asphalt material, and SEM images showed that hydration products improved the adhesion and interface bonding between aggregates and mastic.[34]

Past studies show that filler influences the workability of mixture, affecting the reorientation of aggregates in the mix structure.[10,35] The presence of filler contributes to changes in the breaking mechanism of bitumen emulsion in the mix.[36] Limited studies have been reported, showing the impact of filler on both the breaking mechanism of emulsion and performance on mix. The performance of mix in terms of different climatic and loading conditions depends on the chemical interaction of emulsion and filler. It is essential to study the chemical and mechanical impact of different filler on mix behavior. The aim of this research study is to understand the chemical interaction between the emulsion and different fillers; to investigate the bituminous emulsified mixture structure at micro and nano scale; and to evaluate the impact of different fillers on performance of mix.

Materials and Methods

CHARACTERIZATION OF MATERIALS

A bitumen emulsion of slow setting (SS-2) cationic type was selected for this study conforming to IS 8887 (2018), *Bitumen Emulsion for Roads (Cationic Type)-Specification*,[37] and physical properties have been tabulated in Table 1. The results of aggregates testing are within the range as per IRC SP 100 (2014), *Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsion*,[38] and presented in Table 2. Research indicates that the replacement of stone dust with different fillers such as portland cement and fly ash significantly improves the mechanical properties of the mix.[39,40] Fillers generally in cold mixes impact bitumen emulsion in two ways, i.e., by influencing the development of strength during curing and by influencing the rheological properties of the emulsion residue after curing. In the present study, natural mineral stone dust is replaced by 2 % (by weight of total aggregate) with fly ash, OPC, and hydrated lime.

TABLE 1
Properties of SS-2 emulsion

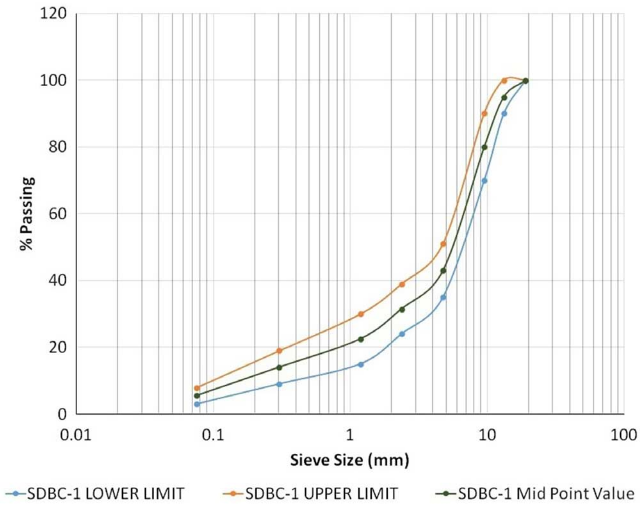
Properties of Bitumen Emulsion SS-2	Obtained Result
Residue on 600 micron IS sieve (% mass), max.	0
Viscosity by Saybolt-Furol viscometer, s, at 25°C	39.83
Viscosity by Saybolt-Furol viscometer, s, at 50°C	28.6
Storage stability after 24 h, %, max.	1.94
Particle charge	Positive
Test on residue:	
a) Residue by evaporation, % min	66.3
b) Penetration, 25°C/100 gm/5 s	112.35
c) Ductility, 27°C/cm, min	88

TABLE 2
Properties of aggregates

Test		Result
Combined flakiness and elongation index		38.40 %
Los Angeles abrasion value		21.01 %
Aggregate impact value		17.77 %
Specific gravity	20-mm aggregates	2.648
	10-mm aggregates	2.650
	6-mm aggregates	2.675
	Stone dust	2.870
	Hydrated lime	2.321
	Cement	3.106
	Fly ash	2.981
Water absorption	20-mm aggregates	0.36 %
	10-mm aggregates	0.37 %
	6-mm aggregates	0.38 %
	Stone dust	1.15 %

FIG. 1

Particle size distribution of CBEM.



SAMPLE PREPARATION

In the present study, the aggregate grading for the semi-dense bituminous concrete with nominal size aggregate 19 mm, in accordance with the IRC SP 100 (2014),[38] is used and shown in **figure 1**. For the preparation of CBEM, an optimized quantity of water was added to the blended aggregate and cement followed by mixing. The bitumen emulsion was then added and mixed for approximately 1 min to get proper coating of aggregate. Then the mix was placed in an oven for breaking of emulsion followed by compaction using Marshall compactor. The compacted sample was cured for 72 h at 40°C in an oven and then used for further testing on samples.

TESTING METHODOLOGY

Bulk specific gravity and Marshall stability tests are two significant parameters in Marshall mix design of cold mix emulsion specimens. Bulk specific gravity test was done by automatic vacuum sealing method. A CoreLok vacuum sealing apparatus was used throughout the testing procedure. The test was conducted as per ASTM D6752 (2018), *Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method*.[41] Marshall stability test was performed in accordance with to ASTM D6927 (2015), *Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures*.[42] For both tests, prior conditioning of samples at 25°C for 3–4 h is done.

The indirect tensile test (ITS) was conducted according to ASTM D6931-12, *Standard Test Method for Indirect Tensile (IDT) Strength Of Bituminous Mixtures*.[43] The test is used to evaluate the cohesive strength of emulsion mixes. Dry ITS was calculated after the specimen was kept for conditioning for 4–5 h at 25°C. Using failure load and specimen dimensions, ITS was calculated using equation (1).

$$\sigma_t = \frac{2P}{\pi D t} \tag{1}$$

where:

P = maximum load;

D = diameter of the specimen; and

t = thickness of specimen.

For the conditioned sample, the specimens were placed in a water bath at 25°C for 24 h and then placed in an environmental chamber maintained at 25°C for 2 h. After 2 h of conditioning at 25°C, ITS was determined to check the resistance toward moisture damage of samples. The TSR of specimen is computed by equation (2).

$$\mathrm{TSR} = \frac{\sigma_{t,\mathrm{conditioned}}}{\sigma_{t,\mathrm{unconditioned}}} \tag{2}$$

where:

$\sigma_{t,\mathrm{conditioned}}$ = average ITS of conditioned specimens; and

$\sigma_{t,\mathrm{unconditioned}}$ = average ITS of unconditioned specimens.

Field emission scanning electron microscope (JEOL JSM Model, gold coated, EHT: 10 kV, Japan) was used to observe the microstructures images of CBEM samples prepared with different filler type. The fine materials extracted from samples were coated with gold before the examination.

Dynamic creep test was carried out at a temperature of 35°C as per BS EN 12697, *Bituminous Mixtures. Test Methods*,[44] for determination of rutting resistance of mix. The compacted specimens were subjected to a series of rectangular axial compressive load pulses at a frequency of 0.5 Hz, with a loading time of 1.0 s and a rest time of 1.0 s.

Mix Design

As per the Indian Road Congress specification, minimum emulsion content for CBEM is determined as per following equations and found to be 6.3 %, by weight of aggregate.[38]

$$P = [0.05A + 0.1B + 0.5C] \times 0.7 \tag{3}$$

where P is minimum total bitumen emulsion demand (%), A is percent aggregate retained on 2.36-mm sieve, B is percent aggregate passing 2.36-mm sieve and retained on 0.075-mm sieve, and C is percent aggregate passing on 0.075-mm sieve.

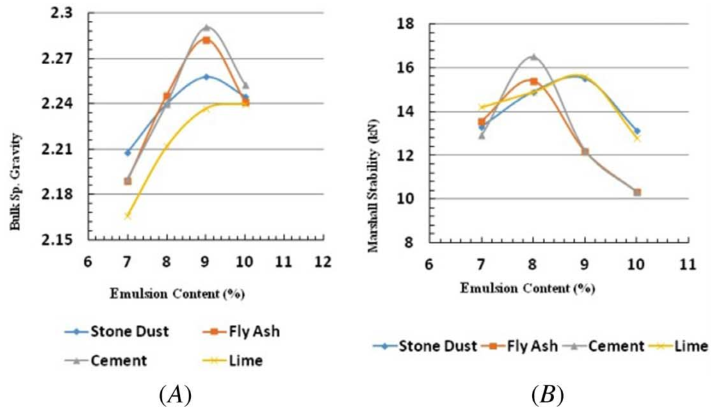
The first stage of mix design is to determine the prewetting water content. In the present study, it is termed the OWC. Mix samples were prepared by varying water concentrations between 2 and 5 % at 1 % interval keeping constant emulsion content equivalent to the P value derived from the above equation (3). All percentage concentrations were taken by weight percentage of total dry aggregates. For this CBEM design, OWC for all the samples containing different fillers was obtained through coating test. The OWC values for different filler specimens are given in **Table 3**. For the second stage, determination of the OEC was carried out after taking the water content as constant equivalent to OWC obtained in first stage and samples were prepared by varying emulsion concentration between 6 and 9 % at 1 % interval. Similar conditions and tests were performed after curing of the prepared samples for every filler material type, and OEC was obtained by maximum value pertaining to Marshall stability test and bulk specific gravity test. The variation of bulk density, stability, and ITS with respect to emulsion content are presented in **figure 2*A*–*C***, respectively.

TABLE 3

Optimum water and emulsion content for different filler type

Parameter	Stone Dust	Fly Ash	Cement	Lime
Optimum water content, %	2.5	4	4	2
Optimum emulsion content, %	9	8	8	9.5
Total fluid content, %	11.5	12	12	11.5
Air voids at OEC, %	11.8	12.3	12.5	11.2

FIG. 2 (*A*) Bulk density versus emulsion content; (*B*) stability versus emulsion content; (*C*) dry ITS versus emulsion content.



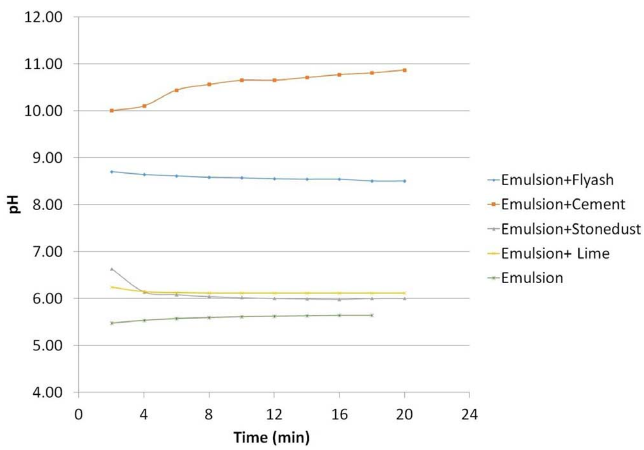
Test Results and Discussion

EFFECT OF FILLER TYPE ON PH OF EMULSION

The pH of the emulsion with and without filler in the ratio of 4:1 (emulsion to filler) was measured using a pH-meter (Wenser 5-point calibration pH meter, India) with a combination pH electrode calibrated against buffer solutions (pH 4.0 and 7.0 at 25°C) with an accuracy of ±0.1 pH unit at room temperature. All the results of pH are given with an accuracy of ±0.1 and are means of at least two values. pH values of the emulsion and emulsified mortar are measured for 20 min in an interval of 2 min and presented in figure 3. Results show the sudden rise of pH values with the addition of cement and fly ash in emulsion from 5.5 to 10 and 8.5, respectively. When the cement and fly ash contacted with bitumen emulsion, the hydration reaction produces a large number of Ca^{2}+, K+, Na+, OH^{-}, SO_4^{2-}, and HSO_3^{-}, attracting the surrounding free emulsifier molecules having positive charge over it showing a drastic increase of pH value.

FIG. 3

Effect of filler on pH values.



EFFECT OF FILLER TYPE ON OFC, OEC, AND OWC

The total fluid content (TFC), OWC, and OEC is presented in Table 1. Results show that TFC was observed to be 12 % for cement and fly ash specimens and 11.5 % for lime and stone dust samples. Studies reported that the coatability of emulsion over aggregate depends on the TFC.[11,25] Inadequate fluid content results in balling of emulsion with finer material. It reduces the coating of residual binder over aggregate. From the SEM image analysis, it is observed that the particle size of hydrated lime and stone dust is higher compared to cement and fly ash material (fig. 4). When the cement and fly ash are used as the filler material, the aggregate surface area is greater compared to the sample prepared with stone dust and lime.

The required water content for lime is less compared to other filler material. This is because of the fact that the absorbed water in lime is released during curing of CBEM.[45] For the cement and fly ash having pozzolonic behavior, higher water is required to stabilize the CBEM. Also, the mix with cement requires more water because the cement itself consumes it during the hydration reaction. The lower specific gravity of lime compared to other filler material results in higher requirement of bitumen emulsion to attain maximum bulk density and strength.

EFFECT OF FILLER ON MARSHAL STABILITY, ITS, AND VOIDS OF CBEM

Maximum bulk density of CBEM was observed with samples prepared with cement and fly ash (fig. 2). Figure 5 presents the SEM images of CBEM samples with different filler material at higher magnification (more than 20K×). A large amount of needle-shaped crystals are visible in the CBEM sample prepared with cement representing ettringite in the sample. Also, the fly ash sample shows a flower-shaped structure showing the presence of C-S-H gels in the mix. Similar observations were presented by other studies.[45–47] The flower-shaped C-H-S gel structure is circled in the figure 5. Both fly ash and cement mixes produce the hydration products, which are

FIG. 4 SEM images of filler material at 100x magnification.

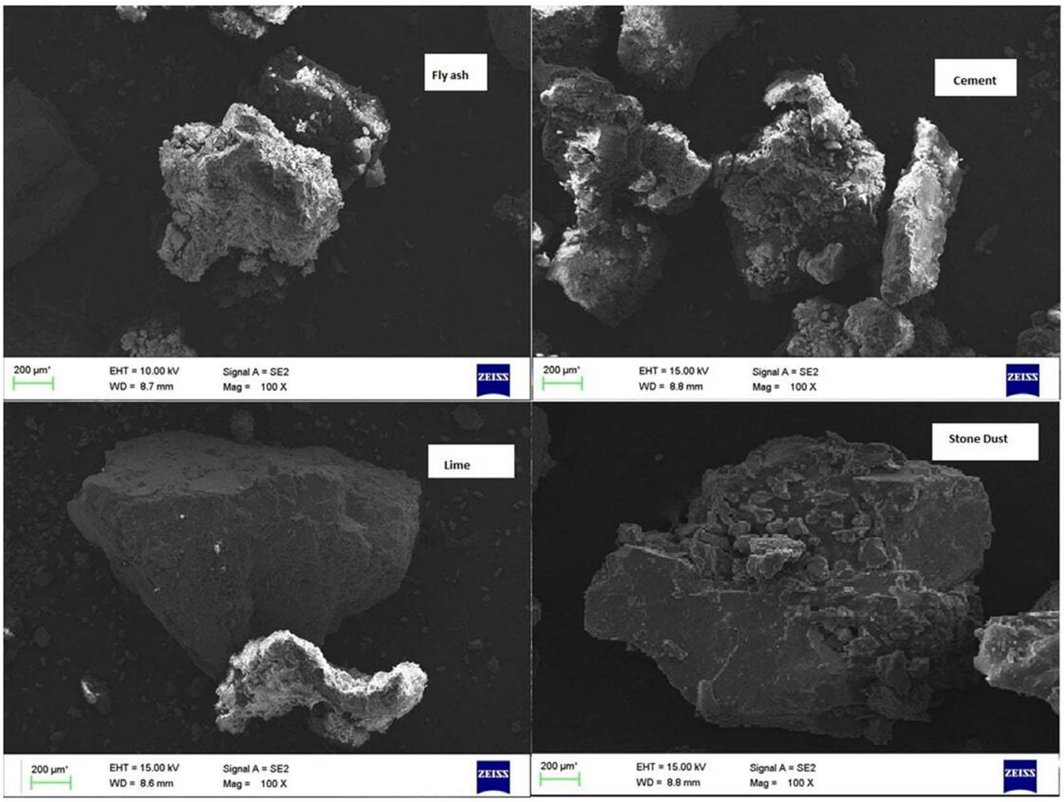
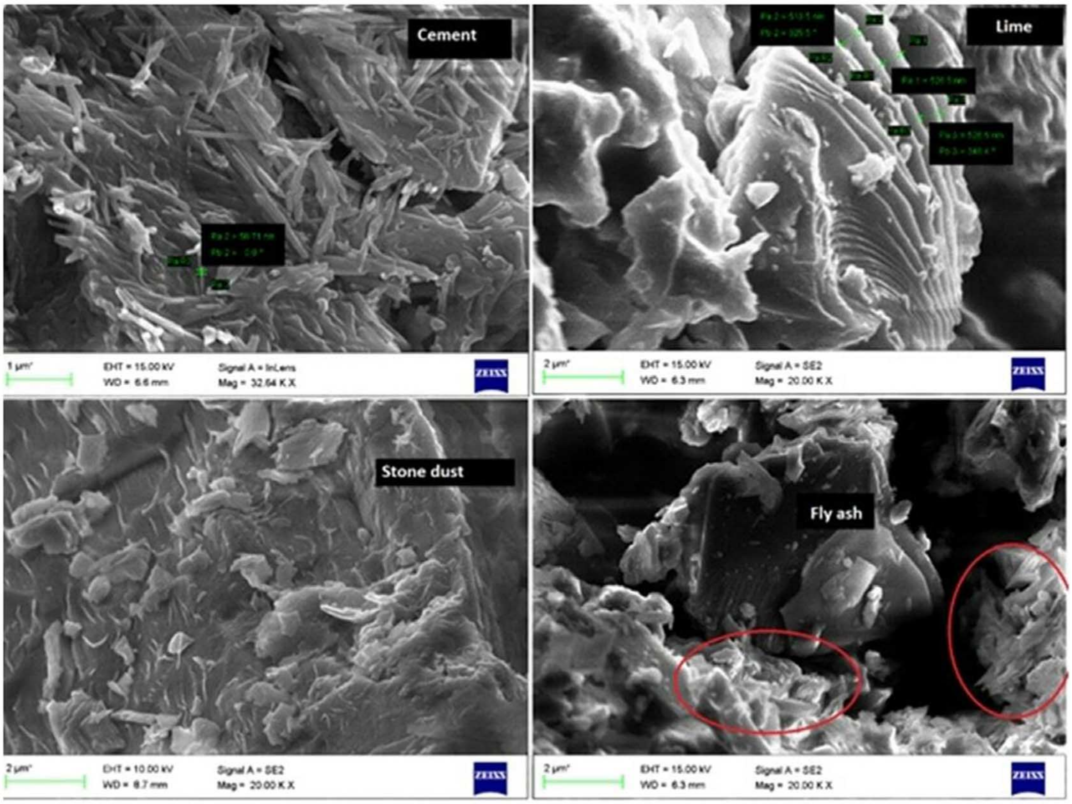


FIG. 5 SEM images of CBEM mix samples with different filler material.



missing from the other two samples. The hydrated products fill the voids and give higher density compared to stone dust and lime samples. Research studies stated that C-S-H gel acts as the main binding agent in the CBEM mix, giving higher stiffness.[47] In lime mix, rough surface has been seen from figure 5. This may be because of the precipitation of calcium carbonate in the presence of emulsion and water, which forms a rough surface. Results corroborate with the previous study done with HMA.[48,49] The cement samples present higher stability compared to the other filler material (fig. 2). A similar trend is seen in the case of ITS results also. The cement gives the maximum strength compared to other filler material.

EFFECT OF FILLER ON MOISTURE RESISTANCE

In order to evaluate moisture resistance, TSR was measured and the variation of TSR with filler type is presented in figure 6. Mixes prepared with alternative filler (convention mix with stone dust) have TSR values above 80 %. Cement and fly ash samples show higher TSR values because of the formation of hydration products. It may be because of hydration products filling the voids in the sample reducing the water ingress and hence, resulting in better resistance toward moisture damage. Lime mix shows higher TSR value compared to other mix. The presence of calcium carbonate in lime mix gives better resistance toward moisture damage of mix. These results were corroborated with previous studies.[50] Also, the presence of lime improves the aggregate texture through the mechanism of cation exchange, lowering the stripping of aggregate.

EFFECT OF FILLER ON RUTTING RESISTANCE

The deformation resistance characteristics of mix were evaluated through a dynamic creep test at 35°C. The total permanent strains in the different mixes at OEC are given in figure 7. The total permanent strain in a mix is an

FIG. 6

Effect of filler on tensile strength ratio.

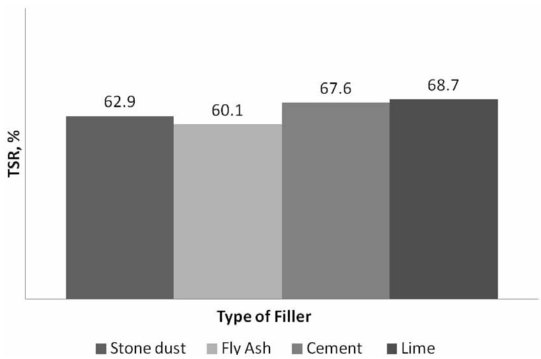
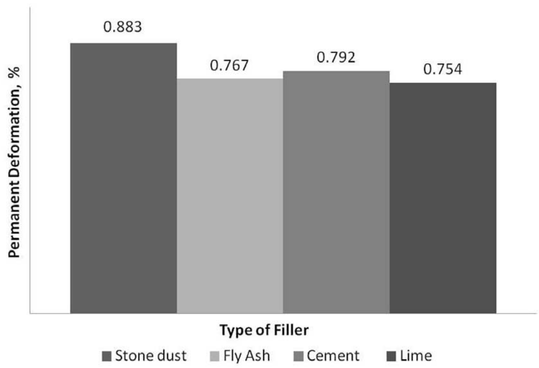


FIG. 7

Effect of filler on total permanent deformation.



indicator of rutting resistance and the results show low permanent deformation with alternative filler material (lime, cement, and fly ash) when compared with conventional mix. The minimum strain is observed with cement mix followed by fly ash. It is attributed to the pozzolanic behavior of cement and fly ash. The past study shows that lime filler actually stiffens the asphalt film and leads to better stiffness at high temperatures.

Conclusion

In the present article, microstructure analysis of CBEM prepared with cement, lime, fly ash, and stone dust has been carried out using SEM. Also, the pH of the emulsion with and without filler in the ratio of 4:1 (emulsion to filler) was measured to evaluate the impact of filler on the breaking of bitumen emulsion. The effect of filler on the optimum emulsion and water content was determined by adopting the mix design procedure. The main conclusions from this study are as follows.

- SEM images show that large amounts of needle-shaped crystals are visible in the CBEM sample prepared with cement representing ettringite in the sample. Also, the fly ash sample shows a flower-shaped structure, showing the presence of C-S-H gels in the mix.
- Cement and fly ash being pozzolanic in nature, form hydration products in the presence of water in CBEM and result in higher density and stability.
- Also, the pH of emulsion with the addition of cement and fly ash increases rapidly, accelerating the breaking of bitumen emulsion and hence giving early strength in CBEM.

- The particle size of filler material plays a major role in obtaining the optimum fluid and emulsion content.
- The required water content in CBEM for lime is less compared to other filler materials.

These conclusions may constitute a starting point for the further study of CBEM: at various filler contents and filler types and by changing the type of bituminous emulsion in order to verify the impact of filler in breaking of emulsion at the microlevel.

References

1. H. K. Shanbara, A. Dulaimi, T. Al-Mansoori, S. Al-Busaltan, M. Herez, M. Sadique, and T. Abdel-Wahed, "The Future of Eco-Friendly Cold Mix Asphalt," *Renewable and Sustainable Energy Reviews* 149 (October 2021): 111318, https://doi.org/10.1016/j.rser.2021.111318
2. S. S. Dash, A. K. Chandrappa, and U. C. Sahoo, "Design and Performance of Cold Mix Asphalt—A Review," *Future of Eco-Friendly Cold Construction and Building Materials* 315 (January 2022): 125687, https://doi.org/10.1016/j.conbuildmat.2021.125687
3. S. Jain and B. Singh, "Cold Mix Asphalt: An Overview," *Journal of Cleaner Production* 280, Part 2 (January 2021): 124378, https://doi.org/10.1016/j.jclepro.2020.124378
4. A. K. Arshad, E. Shaffie, F. Ismail, W. Hashim, and Z. Abd Rahman, "Performance Evaluation of Dense Graded Cold Mix Asphalt," *International Journal of Civil Engineering and Technology* 9, no. 10 (October 2018): 549–557.
5. A. James, "Overview of Asphalt Emulsions," *Transportation Research Circular E-C102: Asphalt Emulsion Technology* (August 2006): 1–15.
6. H. A. Khalid and O. K. Monney, "Moisture Damage Potential of Cold Asphalt," *International Journal of Pavement Engineering* 10, no. 5 (September 2009): 311–318, https://doi.org/10.1080/10298430802169838
7. S. Du, "Interaction Mechanism of Cement and Asphalt Emulsion in Asphalt Emulsion Mixtures," *Materials and Structures* 47, no. 7 (July 2014): 1149–1159, https://doi.org/10.1617/s11527-013-0118-1
8. P. S. Kandhal and F. Parker, *Aggregate Tests Related to Asphalt Concrete Performance in Pavements, NCHRP Report 405* (Washington, DC: Transportation Research Board, 1998).
9. G. O. Bamigboye, D. E. Bassey, D. O. Olukanni, B. U. Ngene, D. Adegoke, A. O. Odetoyan, and A. T. Nworgu, "Waste Materials in Highway Applications: An Overview on Generation and Utilization Implications on Sustainability," *Journal of Cleaner Production* 283 (February 2021): 124581, https://doi.org/10.1016/j.jclepro.2020.124581
10. A. Zulkati, W. Y. Diew, and D. S. Delai, "Effects of Fillers on Properties of Asphalt-Concrete Mixture," *Journal of Transportation Engineering* 138, no. 7 (July 2012): 902–910, https://doi.org/10.1061/(ASCE)TE.1943-5436.0000395
11. S. Al-Busaltan, H. Al Nageim, W. Atherton, and G. Sharples, "Mechanical Properties of an Upgrading Cold-Mix Asphalt Using Waste Materials," *Journal of Materials in Civil Engineering* 24, no. 12 (December 2012): 1484–1491, https://doi.org/10.1061/(ASCE)MT.1943-5533.0000540
12. S. S. Kar, S. Chandra, and M. N. Nagabhushana, "Mix Design Approach of Cold Mix Asphalt Using Response Surface Method," in *Advances in Materials and Pavement Performance Prediction II*, ed. A. T. Anupam, A. Bhasin, and D. Little (San Antonio, TX: CRC Press, 2000), 282–287, https://doi.org/10.1201/9781003027362
13. A. Dulaimi, H. Al Nageim, F. Ruddock, and L. Seton, "High Performance Cold Asphalt Concrete Mixture for Binder Course Using Alkali-Activated Binary Blended Cementitious Filler," *Construction and Building Materials* 141 (June 2017): 160–170, https://doi.org/10.1016/j.conbuildmat.2017.02.155
14. X. Fang, *A Fundamental Research on Cold Mix Asphalt Modified with Cementitious Materials* (PhD diss., ETH Zurich, 2016).
15. A. Al-Hdabi, H. A. Nageim, F. Ruddock, and L. Seton, "Laboratory Studies to Investigate the Properties of Novel Cold-Rolled Asphalt Containing Cement and Waste Bottom Ash," *Road Materials and Pavement Design* 15, no. 1 (2014): 78–89, https://doi.org/10.1080/14680629.2013.852612
16. H. Al Nageim, S. F. Al-Busaltan, W. Atherton, and G. Sharples, "A Comparative Study for Improving the Mechanical Properties of Cold Bituminous Emulsion Mixtures with Cement and Waste Materials," *Construction and Building Materials* 36 (November 2012): 743–748, https://doi.org/10.1016/j.conbuildmat.2012.06.032
17. A. Al-Hdabi and H. Al Nageim, "Improving Asphalt Emulsion Mixtures Properties Containing Cementitious Filler by Adding GGBS," *Journal of Materials in Civil Engineering* 29, no. 5 (May 2017): 04016297, https://doi.org/10.1061/(ASCE)MT.1943-5533.0001859
18. A. K. Arshad, E. Shaffie, F. Ismail, W. Hashim, and Z. Abd Rahman, "Performance Evaluation of Dense Graded Cold Mix Asphalt," *International Journal of Civil Engineering and Technology* 9, no. 10 (October 2018): 549–557.
19. I. N. A. Thanaya, "Evaluating and Improving the Performance of Cold Asphalt Emulsion Mixes," *Civil Engineering Dimension* 9, no. 2 (January 2007): 64–69.
20. S. Swaroopa, A. Sravani, and P. K. Jain, "Comparison of Mechanistic Characteristics of Cold, Mild Warm and Half Warm Mixes for Bituminous Road Construction," *Indian Journal of Engineering and Materials Sciences* 22, no. 1 (February 2015): 85–92.

21. S. S. Dash, A. K. Chandrappa, and U. C. Sahoo, “Design and Performance of Cold Mix Asphalt—A Review,” *Construction and Building Materials* 315 (January 2022): 125687, https://doi.org/10.1016/j.conbuildmat.2021.125687
22. A. Dulaimi, H. Al Nageim, F. Ruddock, and L. Seton, “A Novel Cold Asphalt Concrete Mixture for Heavily Trafficked Binder Course,” *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering* 9, no. 15 (August 2015): 734–738.
23. Y. Niazi and M. Jalili, “Effect of Portland Cement and Lime Additives on Properties of Cold In-Place Recycled Mixtures with Asphalt Emulsion,” *Construction and Building Materials* 23, no. 3 (March 2009): 1338–1343, https://doi.org/10.1016/j.conbuildmat.2008.07.020
24. S. K. Badroodi, M. R. Keymanesh, and G. Shafabakhsh, “Experimental Investigation of the Fatigue Phenomenon in Nano Silica-Modified Warm Mix Asphalt Containing Recycled Asphalt Considering Self-Healing Behaviour,” *Construction and Building Materials* 246 (June 2020): 117558, https://doi.org/10.1016/j.conbuildmat.2019.117558
25. A. Behnood and M. M. Gharehveran, “Morphology, Rheology, and Physical Properties of Polymer-Modified Asphalt Binders,” *European Polymer Journal* 112 (March 2019): 766–791, https://doi.org/10.1016/j.eurpolymj.2018.10.049
26. P. Deb and K. L. Singh, “Mix Design, Durability and Strength Enhancement of Cold Mix Asphalt: A State-of-the-Art Review,” *Innovative Infrastructure Solutions* 7, no. 1 (October 2021): 61, https://doi.org/10.1007/s41062-021-00600-2
27. X. Zhao, Y. Sheng, H. Lv, H. Jia, Q. Liu, X. Ji, and J. Meng, “Laboratory Investigation on Road Performances of Asphalt Mixtures Using Steel Slag and Granite as Aggregate,” *Construction and Building Materials* 315 (January 2022): 125655, https://doi.org/10.1016/j.conbuildmat.2021.125655
28. C. Gao and W. Wu, “Using ESEM to Analyze the Microscopic Property of Basalt Fiber Reinforced Asphalt Concrete,” *International Journal of Pavement Research Technology* 11, no. 4 (July 2018): 374–380, https://doi.org/10.1016/j.ijprt.2017.09.010
29. O. Xu, Z. Wang, and R. Wang, “Effects of Aggregate Gradations and Binder Contents on Engineering Properties of Cement Emulsified Asphalt Mixtures,” *Construction and Building Materials* 135 (March 2017): 632–640, https://doi.org/10.1016/j.conbuildmat.2016.12.095
30. S. Du, “Effect of Curing Conditions on Properties of Cement Asphalt Emulsion Mixture,” *Construction and Building Materials* 164 (March 2018): 84–93, https://doi.org/10.1016/j.conbuildmat.2017.12.179
31. M. Mazumder, R. Ahmed, A. W. Ali, and S. J. Lee, “SEM and ESEM Techniques Used for Analysis of Asphalt Binder and Mixture: A State of the Art Review,” *Construction and Building Materials* 186 (October 2018): 313–329, https://doi.org/10.1016/j.conbuildmat.2018.07.126
32. W. Qiang, Y. Peiyu, A. Ruhan, Y. Jinbo, and K. Xiangming, “Strength Mechanism of Cement-Asphalt Mortar,” *Journal of Material Civil Engineering* 23, no. 9 (September 2011): 1353–1359, https://doi.org/10.1061/(ASCE)MT.1943-5533.0000301
33. S. Du, “Interaction Mechanism of Cement and Asphalt Emulsion in Asphalt Emulsion Mixtures,” *Material Structure* 47, no. 7 (June 2013): 1149–1159, https://doi.org/10.1617/s11527-013-0118-1
34. S. Du, “Influence of Chemical Additives on Mixing Procedures and Performance Properties of Asphalt Emulsion Recycled Mixture with Reclaimed Cement Stabilized Macadam,” *Construction Building Materials* 118 (August 2016): 146–154, https://doi.org/10.1016/j.conbuildmat.2016.05.050
35. J. Choudhary, B. Kumar, and A. Gupta, “Utilization of Solid Waste Materials as Alternative Fillers in Asphalt Mixes: A Review,” *Construction and Building Materials* 234 (February 2020): 117271, https://doi.org/10.1016/j.conbuildmat.2019.117271
36. A. I. Nassar, M. K. Mohammed, N. Thom, and T. Parry, “Mechanical, Durability and Microstructure Properties of Cold Asphalt Emulsion Mixtures with Different Types of Filler,” *Construction and Building Materials* 114 (July 2016): 352–363, https://doi.org/10.1016/j.conbuildmat.2016.03.112
37. *Bitumen Emulsion for Roads (Cationic Type)-Specification (Second Revision)*, IS 8887(2004) (New Delhi, India: Bureau of Indian Standards, 2004).
38. *Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsion*, IRC: SP 100 (2014) (New Delhi, India: Indian Road Congress, 2014).
39. D. Lu, Y. Wang, Z. Leng, and J. Zhong, “Influence of Ternary Blended Cementitious Fillers in a Cold Mix Asphalt Mixture,” *Journal of Cleaner Production* 318 (October 2021): 128421, https://doi.org/10.1016/j.jclepro.2021.128421
40. A. Behnood, M. M. Gharehveran, F. G. Asl, and M. Ameri, “Effects of Copper Slag and Recycled Concrete Aggregate on the Properties of CIR Mixes with Bitumen Emulsion, Rice Husk Ash, Portland Cement and Fly Ash,” *Construction and Building Materials* 96 (October 2015): 172–180, https://doi.org/10.1016/j.conbuildmat.2015.08.021
41. *Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method*, ASTM D6752 (West Conshohocken, PA: ASTM International, approved August 15, 2018).
42. *Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures*, ASTM D6927 (West Conshohocken, PA: ASTM International, approved February 1, 2015).
43. T. Bualuang, P. Jitsangiam, T. Suwan, U. Rattanasak, W. Tangchirapat, and S. Thongmunee, “Influence of Asphalt Emulsion Inclusion on Fly Ash/Hydrated Lime Alkali-Activated Material,” *Materials* 14, no. 22 (November 2021): 7017, https://doi.org/10.3390/ma14227017
44. W. Tian, M. Wang, Y. Liu, and W. Wang, “Ohmic Heating Curing of High Content Fly Ash Blended Cement-Based Composites Towards Sustainable Green Construction Materials Used in Severe Cold Region,” *Journal of Cleaner Production* 276 (December 2020): 123300, https://doi.org/10.1016/j.jclepro.2020.123300

45. P. Azarsa, R. Gupta, and A. Biparva, "Inventive Microstructural and Durability Investigation of Cementitious Composites Involving Crystalline Waterproofing Admixtures and Portland Limestone Cement," *Materials* 13, no. 6 (March 2020): 1425, https://doi.org/10.3390/ma13061425
46. D. Lesueur, J. Petit, and H. J. Ritter, "The Mechanisms of Hydrated Lime Modification of Asphalt Mixtures: A State-of-the-Art Review," *Road Materials and Pavement Design* 14, no. 1 (2013): 1–16, https://doi.org/10.1080/14680629.2012.743669
47. K. P. Murugan, M. Balaji, S. S. Kar, S. Swarnalatha, and G. Sekaran, "Nano Fibrous Carbon Produced from Chromium Bearing Tannery Solid Waste as the Bitumen Modifier," *Journal of Environmental Management* 270 (September 2020): 110882, https://doi.org/10.1016/j.jenvman.2020.110882
48. M. Ameri, M. Vamegh, S. F. C. Naeni, and M. Molayem, "Moisture Susceptibility Evaluation of Asphalt Mixtures Containing Evonik, Zycotherm and Hydrated Lime," *Construction and Building Materials* 165 (March 2018): 958–965, https://doi.org/10.1016/j.conbuildmat.2017.12.113
49. P. E. Sebaaly, D. N. Little, and J. A. Epps, *The Benefits of Hydrated Lime in Hot Mix Asphalt* (Arlington, VA: National Lime Association, 2006).
50. B. Singh and S. Jain, "Effect of Lime and Cement Fillers on Moisture Susceptibility of Cold Mix Asphalt," *Road Materials and Pavement Design* 23, no. 10 (September 2021): 1–17, https://doi.org/10.1080/14680629.2021.1976254

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(b) the Author is the sole legal owner of (and/or has been fully authorised by any additional rights owner to grant) the rights licensed in the Clause "**Rights Granted**" and use of the Contribution shall in no way whatever infringe or violate any intellectual property or related rights (including any copyright, database right, moral right or trademark right) or any other right or interest of any third party subject only to the provisions in the Clause "**The Author's Responsibilities**" regarding Third Party Material (as defined above); and
(c) the Contribution shall not contain anything that may cause religious or racial hatred or encourage terrorism or unlawful acts or be defamatory (or contain malicious falsehoods), or be otherwise actionable, including, but not limited to, any action related to any injury resulting from the use of any practice or formula disclosed in the Contribution and all of the purported facts contained in the Contribution are according to the current body of research and understanding true and accurate; and
(d) there is no obligation of confidentiality owed in respect of any contents of the Contribution to any third party and the Contribution shall not contain anything which infringes or violates any trade secret, right of privacy or publicity or any other personal or human right or the processing or publication of which could breach applicable data protection law and that informed consent to publish has been obtained for all research or other featured participants; and
(e) the Contribution has not been previously licensed, published or exploited and use of the Contribution shall not infringe or violate any contract, express or implied, to which the Author, or any co-author, who had entered into this Agreement,is a party and any academic institution, employer or other body in which work recorded in the Contribution was created or carried out has authorised and approved such work and its publication.

7.2 The Author warrants and represents that the Author, and each co-author who has entered into this Agreement, shall at all times comply in full with:
(a) all applicable anti-bribery and corruption laws; and
(b) all applicable data protection and electronic privacy and marketing laws and regulations; and
(c) the Publisher's ethic rules (available at https://www.springernature.com/gp/authors/book-authors-code-of-conduct), as may be updated by the Publisher at any time in its sole discretion. The

Publisher shall notify the Author in the event of material changes by email or other written means (the "**Applicable Laws**").
If the Author is in material breach of any of the Applicable Laws or otherwise in material breach of accepted ethical standards in research and scholarship, or becomes the subject of any comprehensive or selective sanctions issued in any applicable jurisdiction (e.g. being subject to the OFAC sanctions list) or if, in the opinion of the Publisher, at any time any act, allegation or conduct of or about the Author prejudices the production or successful exploitation of the Contribution and the Work or brings the name and/or reputation of the Publisher or the Work into disrepute, or is likely to do so, then the Publisher may terminate this Agreement in accordance with the Clause "**Termination**".

7.3 The Publisher reserves the right to amend and/or require the Author to amend the Contribution at any time to remove any actual or potential breach of the above warranties and representations or otherwise unlawful part(s) which the Publisher or its internal or external legal advisers identify at any time. Any such amendment or removal shall not affect the warranties and representations given by the Author in this Agreement.

8. Author’s Discount and Electronic Access

8.1 The Author, or each co-author, is entitled to purchase for their personal use the Work and other books published by the Publisher at a discount of 40% off the list price, for as long as there is a contractual arrangement between the Author and the Publisher and subject to any applicable book price law or regulation. The copies must be ordered from the affiliated entity of the Publisher (Springer Nature Customer Service Center GmbH or Springer Nature Customer Service Center LLC, respectively). Resale of such copies is not permitted.

8.2 The Publisher shall provide the electronic final published version of the Work to the Author, provided that the Author has included their e-mail address in the manuscript of the Contribution.

9. Consideration

9.1 The Parties agree that the Publisher’s agreement to its contractual obligations in this Agreement in respect of its efforts in considering publishing and promoting the Contribution and the Work is good and valuable consideration for the rights granted and obligations undertaken by the Author under this Agreement, the receipt, validity and sufficiency of which is hereby acknowledged by the Author. The Parties expressly agree that no royalty, remuneration, licence fee, costs or other moneys whatsoever shall be payable to the Author.

9.2 The Publisher and the Author each have the right to authorise collective management organisations (“**CMOs**”) of their choice to manage some of their rights. Reprographic and other collectively managed rights in the Contribution (“**Collective Rights**”) have been or may be licensed on a non-exclusive basis by each of the Publisher and the Author to their respective CMOs to administer the Collective Rights under their reprographic and other collective licensing schemes (“**Collective Licences**”). Notwithstanding the other provisions of this Clause, the Publisher and the Author shall each receive and retain their share of revenue from use of the Contribution under Collective Licences from, and in accordance with, the distribution terms of their respective CMOs. To the fullest extent permitted by law, any such revenue is the sole property of the Publisher and the Author respectively and, if applicable, the registration and taxation of that revenue is the sole responsibility of the respective recipient party. The Publisher and the Author shall cooperate as necessary in the event of any change to the licensing arrangements set out in this Clause.

10. New Editions

10.1 The Publisher has the sole right to determine whether to publish any subsequent edition of the Work containing an updated version of the Contribution, but only after reasonable consultation with the Author. Once notified by the Publisher that an update of the Contribution is deemed necessary, the Author agrees to deliver an updated manuscript in accordance with the terms of the Clause "**The Author's Responsibilities**" and the other relevant provisions of this Agreement, together with the material for any new illustrations and any other supporting content including media enhancements, within a reasonable period of time (as determined by the Publisher) after such notification. Substantial changes in the nature or size of the Contribution require the written approval of the

Publisher at its sole discretion. The terms of this Agreement shall apply to any new edition of the Work that is published under this "**New Editions**" Clause.

10.2 If the Author, for whatever reason, is unwilling, unable or fails (including as a result of death or incapacity) to submit an updated manuscript that meets the terms of this Agreement within the above stated period, then the Publisher is entitled to revise, update and publish the content of the existing edition or to designate one or more individuals (which, where co-authors have entered into this Agreement, may be one or more of the co-authors) to prepare this and any future editions provided that the new editions shall not contain anything that is a derogatory use of the Author's work that demonstrably damages the Author's academic reputation. In such case, the Author shall not participate in preparing any subsequent editions. The Author agrees that the Publisher shall be entitled but not obliged to continue to use the name of the Author on any new editions of the Work together with the names of the person or persons who contributed to the new editions. Should the Author or the Author's successors object to such continuing use then they must notify the Publisher in writing when first contacted by the Publisher in connection with any new edition.

11. Termination

11.1 In addition to the specific rights of termination set out in the Clause "**The Publisher's Responsibilities**" and the Clause "**The Author's Responsibilities**", either Party shall be entitled to terminate this Agreement forthwith by notice in writing to the other Party if the other Party commits a material breach of the terms of the Agreement which cannot be remedied or, if such breach can be remedied, fails to remedy such breach within 45 days of being given written notice to do so.

11.2 Termination of this Agreement, howsoever caused, shall not affect:
(a) any subsisting rights of any third party under any licence or sub-licence validly granted by the Publisher prior to termination and the Publisher shall be entitled to retain its share of any sum payable by any third party under any such licence or sub-licence;
(b) except where stated otherwise in this Agreement, any claim which either Party may have against the other for damages or otherwise in respect of any rights or liabilities arising prior to the date of termination;
(c) the Publisher's right to continue to sell any copies of the Work which are in its power, possession or control as at the date of expiry or termination of this Agreement for a period of six months on a non-exclusive basis.

12. General Provisions

12.1 This Agreement, and the documents referred to within it, constitute the entire agreement between the Parties with respect to the subject matter hereof and supersede any previous agreements, warranties, representations, undertakings or understandings. Each Party acknowledges that it is not relying on, and shall have no remedies in respect of, any undertakings, representations, warranties, promises or assurances that are not set forth in this Agreement. Nothing in this Agreement shall exclude any liability for or remedy in respect of fraud, including fraudulent misrepresentation. This Agreement may be modified or amended only by agreement of the Parties in writing. For the purposes of modifying or amending this Agreement, "in writing" requires either a written document signed by both the Parties or an electronic confirmation by both the Parties with DocuSign or a similar e-signature solution. Any notice of termination and/or reversion and, where applicable, any preceding notices (including any requesting remediable action under the Clause "**Termination**") must be provided in writing and delivered by post, courier or personal delivery addressed to the physical address of the relevant Party as set out at the beginning of this Agreement or any replacement address notified to the other Party for this purpose. All such notices shall become effective upon receipt by the other Party. Receipt is deemed to have taken place five working days after the respective notice was sent by post or left at the address by courier or personal delivery. If the Publisher is the terminating Party the notice need only be provided to the address of the Corresponding Author. If the Author is the terminating Party a copy of the notice must also be sent to the Publisher's Legal Department located at Heidelberger Platz 3, 14197 Berlin, Germany.

12.2 Nothing contained in this Agreement shall constitute or shall be construed as constituting a partnership, joint venture or contract of employment between the Publisher and the Author. No

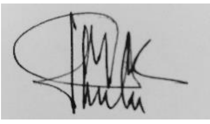
Party may assign this Agreement to third parties but the Publisher may assign this Agreement or the rights received hereunder to its affiliated companies. In this Agreement, any words following the terms "include", "including", "in particular", "for example", "e.g." or any similar expression shall be construed as illustrative and shall not limit the sense of the words preceding those terms.

12.3 If any difference shall arise between the Author and the Publisher concerning the meaning of this Agreement or the rights and liabilities of the Parties, the Parties shall engage in good faith discussions to attempt to seek a mutually satisfactory resolution of the dispute. This Agreement shall be governed by, and shall be construed in accordance with, the laws of the Republic of Singapore. The courts of Singapore, Singapore shall have the exclusive jurisdiction.

12.4 A person who is not a party to this Agreement (other than an affiliate of the Publisher) has no right to enforce any terms or conditions of this Agreement. This Agreement shall be binding upon and inure to the benefit of the successors and assigns of the Publisher. If one or more provisions of this Agreement are held to be unenforceable (in whole or in part) under applicable law, each such provision shall be deemed excluded from this Agreement and the balance of the Agreement shall remain valid and enforceable but shall be interpreted as if that provision were so excluded. If one or more provisions are so excluded under this Clause then the Parties shall negotiate in good faith to agree an enforceable replacement provision that, to the greatest extent possible under applicable law, achieves the Parties' original commercial intention.

The Corresponding Author signs this Agreement on behalf of any and all co-authors.

Signature of Corresponding Author:



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Manoj Kumar Shukla

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   (b) a legally compliant, non-commercial preprint server, such as but not limited to arXiv, bioRxiv and RePEc; provided always that once the "Version of Record" (as defined below) of the Contribution has been published by or on behalf of the Publisher, the Author shall immediately ensure that any Preprint made available above shall contain a link to the Version of Record and the following acknowledgement:
   "This is a preprint of the following chapter: [author of the chapter], [chapter title], published in [book title], edited by [editor of the book], [year of publication], [publisher (as it appears on the cover of the book)] reproduced with permission of [publisher (as it appears on the copyright page of the book)]. The final authenticated version is available online at: http://dx.doi.org/[insert DOI]".

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   (b) the Author's employer's internal website or their academic institution or funder´s repository; provided that in each case the respective part of the AAM is not made publicly available until after the Embargo Period.
   The "**Embargo Period**" is a period ending twelve (12) months from the first publication of the "Version of Record" (as defined below) of the Contribution by or on behalf of the Publisher.
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   Once the Version of Record (as defined below) of the Contribution has been published by or on behalf of the Publisher the Author shall immediately ensure that any part of the AAM made available shall contain a link to the Version of Record and the following acknowledgement:
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   (b) Reuse of the Version of Record (as defined below) of the Contribution or any part of it is permitted in a thesis written by the same Author, and the Author is entitled to make a copy of the thesis containing content of the Contribution available in a repository of the Author's awarding academic institution, or other repository required by the awarding institution; an acknowledgement should be included in the citation: "Reproduced with permission from Springer Nature"; and
   (c) any other Reuse of the Contribution in a new book, book chapter, proceedings or journal article, whether published by the Publisher or by any third party, is limited to three figures (including tables) or a single text extract of less than 400 words; and
   (d) any further Reuse of the Contribution is permitted only to the extent and in so far as is reasonably necessary: (i) to share the Contribution as a whole to no more than 10 research colleagues engaged by the same institution or employer as the Author for each colleague's personal and private use only; (ii) for classroom teaching use by the Author in their respective academic institution provided that the Contribution or any part of it is not included in course packs for sale or wider distribution to any students, institutions or other persons nor any other form of commercial or systematic exploitation; or (iii) for the Author to use all or parts of the Contribution in the further development of the Author's scientific and/or academic career, for private use and research or within a strictly limited circulation which does not allow the Contribution to become publicly accessible nor prejudice sales of, or the exploitation of the Publisher's rights in, the Contribution (e.g. attaching a copy of the Contribution to a job or grant application).

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3. In each case where the Author has Reuse rights or the Publisher grants specific use rights to the Author according to the above provisions, this shall be subject always to the Author obtaining at the Author's sole responsibility, cost and expense the prior consent of any co-author(s) and/or any relevant third party.

4. Any linking, collection or aggregation of reused Contributions from the same Work is strictly prohibited.

Licensing of the technology entitled, "Mobile Cold Mixer cum Paver" developed at CSIR-CRRI, New Delhi

2 messages

A K Srivastava <asrivastava@nrdc.in> Sat, 26 Feb 2022 at 10:00
To: petrochemspecialities@gmail.com
Cc: sikshaswaroopa@gmail.com

No. NRDCHQ/BD/PETROCHEM/2022 February 26, 2022

Shri Manish Chandra Agarwal

Proprietor

M/s. Petrochem Specialities

B-24, Industrial Estate

Near ITI, Meerut Road, Industrial Estate, Muzaffarnagar - 251003 (Uttar Pradesh)

Phone: +91-131-2620315, 3252992

Mobile: +91-9837186655

Email: info@petrochemsp.com; petrochemspecialities@gmail.com

Sub: Licensing of the technology entitled, "Mobile Cold Mixer cum Paver" developed at CSIR-CRRI, New Delhi

Dear Sir,

We acknowledge with thanks the receipt of License Agreement duly executed at your end for the process, "**Mobile Cold Mixer cum Paver",** developed at CSIR-CRRI, New Delhi.

We are requesting Dr Siksha Swaroopa Kar, Principal Scientist, CSIR-Central Road Research Institute (CSIR-CRRI), Mathura Road, New Delhi to give you know-how package, training and demonstration of process at the laboratory scale and also give you such other help, as may be possible to enable you to go into production at an early date. We request you to contact the CSIR-CRRI for the Process Know-how, demonstration and training of your personnel. You may please depute your technical representative(s) for demonstration and training at the laboratory after obtaining clearance from Dr Siksha Swaroopa Kar, Principal Scientist, CSIR-CRRI, New Delhi regarding the basic minimum qualification of the trainee(s), duration of the training period and the date on which he/they should report to the Laboratory/Institute.

Thanking you,

Yours faithfully,

(Dr. Ashish Kumar Srivastava)

Manager

Siksha Swaroopa <sikshaswaroopa@gmail.com> Wed, 2 Mar 2022 at 11:24
To: PME, CRRI <pme.crri@nic.in>

Dear Sir,

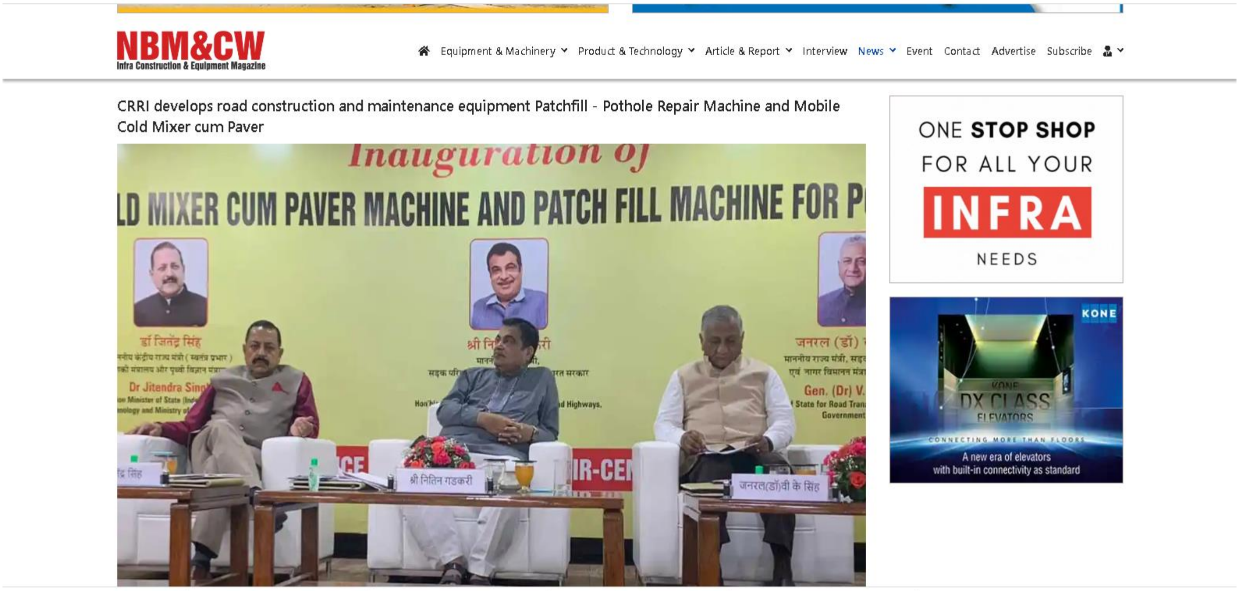
For your information.

Dr Siksha Swaroopa Kar
Principal Scientist, Room No 168 A
Flexible Pavement Division
CSIR-Central Road Research Institute
Mathura Road, New Delhi 110025
URL: http://www.crridom.gov.in/sites/default/files/CV%20Mrs%20Siksha%20Kar%20UPDATED%202018.pdf
Public URL: https://scholar.google.co.in/citations?user=Q1pJgloAAAAJ&hl=en
[Quoted text hidden]

Appendix 6

Tweet by Minister Nitin Gadkari

CSIR Website



https://www.nbmcw.com/news/roads-highways/crri-develops-road-construction-and-maintenance-equipment-patchfill-pothole-repair-machine-and-mobile-cold-mixer-cum-paver.html

https://www.constructionworld.in/heavy-construction-equipment/gadkari-inaugurates-cold-mixer-paver-and-patch-fill-machine/34144 https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1823891

Shri Nitin Gadkari emphasizes proven technology, economic viability, availability of raw material and effective marketing are necessary for successful completion of projects

Posted On: 09 MAY 2022 4:18PM by PIB Delhi

Union Minister for Road Transport and Highways Shri Nitin Gadkari has emphasized that proven technology, economic viability, availability of raw material and effective marketing all of these are necessary for successful completion of projects. Inaugurating Mobile Cold Mixer Cum Paver Machine & Patch Fill Machine for pothole repair by CSIR-CRRI he said most important thing in road sector is that cost of construction has to be reduced and quality of construction has to be improved. The minister said patent registration of any technology is not the end of the matter. He said till the patent is not commercialized and fully utilized it is the responsibility of the organization to do regular follow-ups and take it to final culmination .

Shri Gadkari said due to various reasons there is hesitancy in the system to adopt proven technology. He said total synchronization in communication, coordination and cooperation is required for implementing new systems and

Appendix 7

Mobile Cold Mixer cum Paver

Need of the Invention

Design and construction of roads in high altitude Himalayan region poses more difficulties than plain terrain, due to:

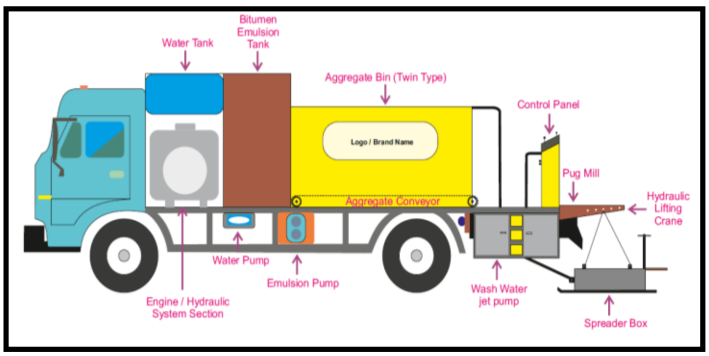
- Issues related to non-availability of skilled labour in areas like the North eastern states and Himalayan Region.
- Non-availability / limited availability of space for set up of plant for road construction
- Non availability of heavy conventional construction and operational equipments.

Solution

CSIR-CRRI developed Mobile Cold Mixer cum Paver for preparation and laying of black top layers using bitumen emulsion based technology,

Equipment Features

Engine Power:	70kW/2000rpm
Aggregates Bin-1 Capacity:	2 m^3
Aggregates Bin-2 Capacity:	1 m^3
Emulsion Tank Capacity:	1000 Litre
Water Tank Capacity:	1000 Litre
Additives Tank Capacity:	100 Litre
Fillers Tank Capacity:	200 kg
Discharge Capacity of Mixer:	≤700 kg/min
Paving Width:	1.75～2.25 m (manually adjustable)
Overall Dimensions:	5550mm×2180mm×2420mm (L×W×H)



For any queries, please contact:
Director, CSIR-CRRI, director.crri@nic.in