Souvenir

215th Mid-Term Council Meeting

Indian Roads Congress, Aizawl

Souvenir

215th Mid- Term Council Meeting
Aizawl
4th to 5th May, 2018

Public Works Department
Government of Mizoram

PUBLIC WORKS DEPARTMENT
GOVT. OF MIZORAM

Welcomes the Delegates to

215th

Mid-term Council Meeting of

INDIAN ROADS CONGRESS

at

AIZAWL, MIZORAM

CONTENT

Message

Shri Venkaiah Naidu
Hon'ble Vice President of India

एन. युवराज, भा. प्र. से.
N. YUVARAJ, IAS

भारत के उप-राष्ट्रपति के निजी सचिव
PRIVATE SECRETARY
TO THE VICE-PRESIDENT OF INDIA
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The Hon'ble Vice President of India is happy to know that Indian Roads Congress is organizing its 215th Mid Term Council Meeting on May 4 – 5, 2018 at Aizawl, Mizoram.

The Vice President extends his greetings and congratulation to the organizers and the participants and wishes the event all success.

26/3/2018

(N. YUVARAJ)

New Delhi
26th March, 2018.

सत्यमेव जयते

प्रधान मंत्री

Prime Minister

MESSAGE

It is a pleasure to know that the 215th Mid-Term Council Meeting of the Indian Roads Congress (IRC) is being organized at Aizawl during 4-5 May, 2018.

As we witness unparalleled expansion in roads and infrastructure across the country, IRC is expected to contribute their constructive support and ensure collaboration among the related professionals in realizing the dream of a New India.

I hope that the Mid Term Council will offer an effective platform for all the stakeholders to synergize their strategies in achieving the aims of our infrastructure goals. Best wishes for the successful conclusion of the Meeting.

New Delhi
02 May, 2018

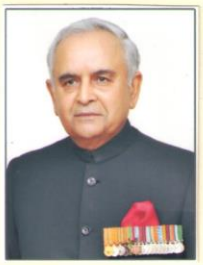
(Narendra Modi)

Shri S.K. Nirmal
Secretary General
Indian Roads Congress (IRC)
Kama Koti Marg
Sector-6, R.K. Puram
New Delhi- 110022

Lt Gen Nirbhay Sharma
PVSM, UYSM, AVSM, VSM (Retd)
Governor
Mizoram

सत्यमेव जयते

Raj Bhavan
Aizawl - 796 001
India



MESSAGE

I am delighted to learn that "Indian Roads Congress" will be holding its 215th Mid Term Council Meeting on 4th & 5th May, 2018 at Aizawl, Mizoram and will be bringing out a Souvenir to commemorate the occasion.

Indian Roads Congress plays (IRC) a very important role in the development of transportation system in India. It can be claimed that the development of roads in the country has been significantly influenced by the wise counsels given by the IRC and has progressed according to the policies enunciated by it.

I take this opportunity to congratulate all the participants and organizers on this occasion. I hope that the deliberations during the Congress will prove to be of value not only to the participating members but for the whole country.

I convey best wishes for the successful completion of the event and for the successful publication of the Souvenir.

Nirbhay Sharma

Lt. Gen. Nirbhay Sharma
PVSM, UYSM, AVSM, VSM (Retd)

Date : 2nd April, 2018

Tel : +91- 0389 - 2322262/2323200
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sharma.nirbhay@gmail.com

नितिन गडकरी
NITIN GADKARI

सत्यमेव जयते

मंत्री
सड़क परिवहन राजमार्ग
एवं पोत परिवहन
भारत सरकार
MINISTER OF ROAD TRANSPORT
HIGHWAYS & SHIPPING
GOVERNMENT OF INDIA

Message

It gives me immense pleasure to know that 215th Mid Term Council Meeting of Indian Roads Congress is being hosted by the Government of Mizoram at Aizwal from 4th to 5th May, 2018. On this occasion, I extend my greetings and felicitations to all the Highway & Bridge Engineers in their continuing role and their relentless effort in economic and social development of our country. Road is one of the most effective tool for development of backward area as well as poverty alleviation.

A good road network is one of the key component of the infrastructure that our country must create to move to a higher growth trajectory.

The Indian Roads Congress has contributed significantly to the Highway Sector in the country by developing Standards for roads and bridges, catering to the changing requirements of the infrastructure and agricultural sectors and the people at large. It is imperative that the engineering community connected with such works deliberate periodically upon the state of knowledge and participate in discussions on technical advances in construction and maintenance of roads, bridges and highways of world class.

I wish the organizers of 215th Mid Term Council Meeting of Indian Roads Congress all success.

(Nitin Gadkari)

Date : 15.03.2018
Place : New Delhi

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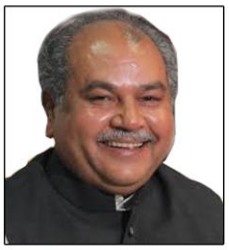
नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

सत्यमेव जयते

ग्रामीण विकास,
पंचायती राज और खान मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
MINISTER OF RURAL DEVELOPMENT,
PANCHAYATI RAJ AND MINES
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI



MESSAGE

I am glad to know that the 215th Mid-Term Council Meeting of Indian Roads Congress is scheduled to be held at Mizoram (Aizawl) during 4th – 5th May, 2018.

I have been told that Indian Roads Congress is the coordinating agency for setting standards and directing R&D efforts for road development. It has to seriously take up the subject of Asset Management by bringing out suitable technologies and processes for sustainable Maintenance Management of different types of roads, including Rural Roads. I am confident that eminent engineers will deliberate this important issue in the meeting and come out with realistic and workable solutions in tune with the expectations of the road users.

I am happy to note that Indian Roads Congress has been helpful in the development of rural roads by publishing design manuals, specifications for rural road construction, Data Book as well as manual for quality management etc. I hope, it will continue to extend support in the years to come.

I convey my warm greetings to the organisers and best wishes for the success of the Mid-Term Council Meeting of the Indian Roads Congress.

23/3/18

(Narendra Singh Tomar)

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MIZORAM, AIZAWL-796 001

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MESSAGE

I am very pleased to learn that the 215th Mid-term Council Meeting of Indian Roads Congress is being held at Aizawl, Mizoram from 4th to 5th May, 2018. It is a great honour and a matter of great pride for our State.

I trust that this Meeting will provide a common platform for highway engineers to discuss the major issues concerning development of highway engineering and provide a forum for exchange of knowledge, ideas and learning as well as field experiences amongst engineers. As Indian Road Congress was constituted to provide a forum for regular pooling of experience and ideas on all matters affecting the planning, construction and maintenance of roads in India, it is a platform for expression of professional opinion on matters relating to highway engineering, organization and administration. I am confident that the Mid-term Council Meeting will help in opening new vistas of knowledge for improvement of highway development in the country.

I extend my warm welcome to all the delegates on behalf of the Government of Mizoram to enjoy the hospitality and clean air of Mizoram during their stay here in Aizawl and wish this national event grand success.

(LAL THANHAWLA)

Dated Aizawl,
the 4th April, 2018

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उपाध्यक्ष
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VICE CHAIRMAN
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सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग
नई दिल्ली–110 001
Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog, Parliament Street
New Delhi-110 001

Message

I am happy to learn that the Indian Roads Congress (IRC), the premiere technical body of Highway Engineers in the country, is holding its 215th Mid Term Council Meeting at Aizawl (Mizoram) from 4th to 5th May, 2018.

The Indian Roads Congress has contributed significantly to the Higher Sector in the country by developing standards for roads and bridges, catering to the changing requirements of the infrastructure sector and the people at large. It is imperative that the engineering community connected with such works deliberate periodically upon the state of knowledge and participate in discussions on technical advances in construction and maintenance of roads, bridges and highways of world class.

I am sure the Council Members would deliberate on such important issues and suggest viable solutions to various problems confronting the road infrastructure sector in the country.

I wish Indian Roads Congress all success.

(Rajiv Kumar)

Dated: 5th April 2018
Place: New Delhi

स्वच्छ भारत
एक कदम स्वच्छता की ओर

राज्य मंत्री
सड़क परिवहन एवं राजमार्ग,
जहाजरानी, रसायन एवं उर्वरक
भारत सरकार

सत्यमेव जयते

मनसुख मांडविया
MANSUKH MANDAVIYA

Minister of State
Road Transport & Highways,
Shipping, Chemicals & Fertilizers,
Government of India

23rd March, 2018

Message

I am happy to know that Indian Roads Congress is holding its 215th Mid Term Council Meeting from 4th to 5th May, 2018 at Mizoram.

The Indian Roads Congress, being the Apex body of Highway Engineers in the country has been deeply involved in the advancement of highway and bridge engineering. This apex gathering of eminent Highway Engineers from across the country will be an appropriate platform for the delegates to deliberate upon important issues and bringing out realistic solutions towards achieving maximum road user's satisfaction.

It is imperative that IRC keeps itself abreast of the latest know-how and to be in line with international and national good practices.

I do hope that the 215th Mid Term Council Meeting will help in exchanging and updating the knowledge of the highway fraternity. I convey my best wishes to the organizers for success of the meeting.

(Mansukh Mandaviya)

Room No. 201, Transport Bhavan, New Delhi - 110001 Tel : 011-23717422, 23717423, 23717424, Fax : 011-23381713

किरेन रीजीजू
KIREN RIJIJU

सत्यमेव जयते

गृह राज्य मंत्री
भारत सरकार
MINISTER OF STATE FOR
HOME AFFAIRS
GOVERNMENT OF INDIA

MESSAGE

It gives me great pleasure to know that the Indian Roads Congress (IRC) is holding its 215th Mid Term Council Meeting from 4th to 5th May, 2018 at Aizawl, Mizoram.

The Indian Roads Congress, being the technical body of highway engineers, Scientist and other technical personnel, has been involved in the advancement of highways and bridge engineering for a long time. I hope the council meeting will offer a forum for the delegates to deliberate on important issues and bringing out realistic solutions towards achieving maximum road user's satisfaction to various problems confronting the country.

I extend my best wishes for the 215th Council of the Indian Roads Congress.

(KIREN RIJIJU)

20th March, 2018
New Delhi

Office : Room No. 127, North Block, New Delhi-110 001 Tel. : 23094054 Fax : 23093549

हरदीप एस पुरी
HARDEEP S PURI

आवासन और शहरी कार्य
राज्य मंत्री (स्वतंत्र प्रभार)
भारत सरकार
MINISTER OF STATE(I/C)
HOUSING AND URBAN AFFAIRS
GOVERNMENT OF INDIA

MESSAGE

The Indian Roads Congress has a long history and traces its origin to a period long before Independence.

Over the years, the organization has played a pivotal role in contributing to the knowledge base covering construction and maintenance of roads and allied fields.

Roads are the lifeline of a nation. The Indian Roads Congress, I am sure, will play an important role towards creating both awareness of related issues and a pool of competent professionals to carry this crucial work forward.

I wish them all success.

(Hardeep S Puri)

New Delhi
26 March 2018

Office:- Room No. 104-C, Nirman Bhawan, New Delhi-110011; Phone: 011-23061166, 23061162, 23062089 (Fax)

LAL THANZARA
MINISTER
H&FW/I&PR/PWD
MIZORAM, AIZAWL-796001

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MESSAGE

I am happy to learn that the Mizoram Public Works Department is host to the 125th Mid-Term Council Meeting of the Indian Roads Congress, the apex body for the development of roads and highways in the country. A fitting Souvenir is being brought out to commemorate the occasion.

The role and importance of the Indian Roads Congress is becoming more and more relevant as India is witnessing an unprecedented economic growth during recent years. The challenges is bringing in new and innovative technologies also cannot be over emphasized.

I am positive that the Indian Roads Congress will rise up to this challenge to bring even the most remote regions under its vast network of roads and highways which will in turn bring about an all round economic transformation of this great country.

I convey my best wishes for the success of the Mid-Term Council Meeting.

Thank You.

(LAL THANZARA)

Dated Aizawl,
the 3rd April, 2018

CHIEF SECRETARY
GOVERNMENT OF MIZORAM

सत्यमेव जयते

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MESSAGE

I am glad to learn that the Indian Roads Congress is organizing its 215th Mid Term Council Meeting on 4th & 5th May, 2018 at Aizawl, Mizoram to discuss various issues relating to development of roads in the Country.

Road communication facility is essential for development of any region. It has special significance for the North Eastern Region including Mizoram, which faces difficulties on account of geographical isolation and inadequate infrastructure. The Indian Roads Congress has made an immense contribution towards the growth of national highway engineering and I have no doubt that the proposed session would address itself to the current engineering and technological issues towards upgradation of the highways and border roads in the country.

I extend my warm greetings and felicitations to all associated with the Indian Roads Congress and best wishes for the grand success of the 215th Mid Term Council Meeting as well as the publication of the Souvenir.

Arvind Ray

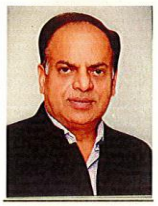
(ARVIND RAY)
Chief Secretary

Residence : 0389-2322412 Telefax : 0389-2323467

युद्धवीर सिंह मलिक, आई.ए.एस.
सचिव
Y. S. Malik, I.A.S.
Secretary

सत्यमेव जयते

सड़क परिवहन और राजमार्ग मंत्रालय
Ministry of Road Transport & Highways
भारत सरकार / Government of India



Message

I am glad that 215th Mid Term Council Meeting of Indian Roads Congress is being hosted by the Govt. of Mizoram from 4th to 5th May, 2018.

The Indian Roads Congress (IRC) is a prestigious and the oldest national forum of highway engineers & professionals. The main objective of IRC is to set up/ formulate Indian Standards; Codes, Specifications Manuals etc., in Roads, Bridges & Road Transport for adoption by Central / Govt. Road Agencies to construct and maintain sustainable road infrastructure for overall development of country.

The road sector has seen a quantum jump in investment in the current century (Rs.25,000 crore per year in 2000-01 to Rs.1,80,000 crore in the year 2016-17). Challenges in programme delivery have also increased manifold. Modes of delivery through contractors/concessioners are witnessing changes and modifications rather fast.

I do hope that the 215th Mid Term Council Meeting will help in facing challenges in highway sector as well as in exchanging and updating the knowledge of the highway fraternity. I convey my best wishes to the organizers of the 215th Mid Term Council Meeting of Indian Roads Congress.

(Yudhvir Singh Malik)

Date : March 21, 2018
Place : New Delhi

Room No. 509, Transport Bhawan, 1 Parliament Street, New Delhi-110 001, India Tel. : 91-11-23714104, Fax : 91-11-23356669
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दीपक कुमार, आई.ए.एस.
अध्यक्ष
Deepak Kumar, I.A.S.
Chairman

भारतीय राष्ट्रीय राजमार्ग प्राधिकरण
National Highways Authority of India
Ministry of Road Transport & Highways
NHAI, G-5&6, Sector-10, Dwarka, New Delhi-110075
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MESSAGE

I am glad to know that the Government of Mizoram is hosting the 215th Mid Term Council Meeting of Indian Roads Congress, Aizawl from 4th to 5th May, 2018.

Development of road infrastructure has always played a crucial role in overall development of the country. Roads provide link to the remotest part of our country which ensures faster economic development of these areas. I was informed that experts of Highway sector from all over the country will be participating in the Council. I am sanguine that their deliberations will help in disseminating knowledge about upgrading the design, construction and maintenance methodologies in the field of highways which will pave the way for faster road construction with improved quality standards.

I extend my greetings and felicitations to the participants and the organizers and send my best wishes for the success of the council.

(Deepak Kumar)

New Delhi
24th April, 2018

Lalram thanga, IFS
PRINCIPAL SECRETARY
Public Works Department
Govt. of Mizoram

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It is a matter of great pride and privilege for Mizoram to host the **215th Mid-Term Council Meeting** of the **Indian Roads Congress** (IRC) here in Aizawl between 4 – 5 May, 2018.

Mizoram as we are aware is one of the youngest States of India having become a full fledged State only in 1987. We therefore, have a long way to catch up with the rest of India in terms of infrastructure development and other logistics. Our road network is also of recent development and we still have many miles to go. The State Public Works Department is committed to bring about this very important transformation by linking all rural habitations under the road network for bringing about an all round development. This is more so for a hilly terrain where transportation is essentially road-based.

IRC as the apex body of highway engineers in India has developed many technological innovations in the road sector and today, the country has one of the largest networks of roads across the globe.

As I look ahead, I can visualize that the IRC will grow in pursuit of higher standards of research, and continue to provide a national forum for sharing of knowledge and pooling of experience on the entire range of subjects dealing with the construction and maintenance of roads and bridges, including technology, equipment, planning and finance.

I extend my best wishes to all members of the Indian Roads Congress. I am sure that it will continue to maintain its excellence and character with great distinction.

(Lalram Thanga)

Aizawl, the 21st March, 2018

Local Organising Secretary Writes

It is with great happiness that I, on behalf of Local Organising Committee and the State Public Works Department, heartily welcome all delegates to the 215th Mid-Term Council Meeting of Indian Roads Congress at Aizawl. It is an honour and privilege for a tiny State of Mizoram that the Indian Roads Congress accepted the invitation of Mizoram Government for hosting the 215th Mid-Term Council Meeting along with meeting of Secretaries/Engineer-in-Chief /Chief Engineers and meeting of Highway Research Board of the Congress at Aizawl on 4th & 5th May, 2018. This is the second time Mizoram hosts mid-term council meeting of IRC. We would like to host bigger event like Annual IRC Meeting but ill luck would have it, we do not afford to organise such meeting for want of accommodation and other infrastructures.

Formerly known as Lushai Hills District of Assam, Mizoram attained Union Territory Status in 1972 and became the 23rd State of Indian Union in 1987 following historic and successful Peace Accord signed between Govt.of India and Mizo National Front led by its charismatic and legendary leader Laldenga on June 30, 1986. Before the advent of British, each village was independently ruled by the Chief. The State now has 8 Districts with 3 Autonomous District Councils in the south and the density of population is 52/sq.km.

Being a fully hilly terrain, the only communication link within the State is road transport. When India attained Independence in 1947, the then Lushai Hills had only 168 Kms of one ton truckable road and 1047 Kms bridle paths with just 6 local overseers. After independence, Assam PWD constructed some roads and with the induction of Project Pushpak of BRO in 1962, there were meaningful improvement in road construction. During 24 years of Assam period upto December 1971, the erswhile Mizo District had 760 Kms of surfaced roads and 786 Kms of unsurfaced roads with a road density of 7.33 Kms/100 sq.km. At the end of Union Territory period in December 1986, Mizoram had 1490 kms of surfaced roads and 2415 kms of unsurfaced roads with road density of 18.53 Kms/100 sq.kms. With a mere just one Circle in 1972, Mizoram PWD had grown to 6 working circles headed by a Chief Engineer by the time it became a full fledged state in 1987.

Today, Mizoram has a total road network of 7517.484 Kms with road density of 36.190 Kms/100 Sq.Kms against national average of 166 Kms/100 Sq.Kms and these roads are maintained by various agencies like State PWD, BRO, CPWD, Rural Development Department etc. The State PWD headed by Engineer-in-Chief assisted by C.E(Planning), C.E (Highways), C.E(Roads) and C.E(Buildings) has 9 working circles and 1 Project Implementation Unit for External Aided Projects headed by a Project Director (S.E).

There are 11 National Highways in the State with a total length of 1,410.500 Kms, of which 1,174.300 Kms are surfaced and the remaining 236.200 Kms are yet to be surfaced.. About 350 Kms stretch Aizawl-Lunglei- Tuipang section of NH-54 is to be handed over to

NHIDCL for which tender for 8 contract packages have been floated by the agency. Baring 4 NHs with a total length of 325 Kms, all NHs in the State are included in the list of Bharatmala Periyajona which are learnt to have been decided by the Govt.of India for handing over to NHIDCL. If this decision is implemented, 5 of the 7 working Divisions under Highway wing of State PWD will be redundant. Even if 3 Highways (NH-6, NH-302 and NH-102B) and about 350 Kms of NH-54 are handed over to NHIDCL in the near future as contemplated now, 2 working divisions will automatically be idle without any job as their whole jurisdictions will be transfered to other agency. It is desirable if a portion of NH 54 from Aizawl to Tuipang (about 350 Kms) is handed over to NHIDCL in the first phase and other sections may be given in a phase manner depending on their performance.

Apart from its geographical and geological disadvantage, the very challenging tasks of road construction faced by highway engineers in Mizoram are poor quality of locally available stones, poor contacting capacity and long monsoon period which always triggered heavy landslides causing road blocks and collapse of road formations. The quality of available stones in a quarry are not uniform and the contractors always faced problem of locating quarry with good quality and enough deposit. Bitumen, steel, cement and spare parts of construction machineries are imported from outside the State which are added problems.

Mizoram does not have anything to offer to the delegates except unpolluted fresh air, hospitality and a very peaceful atmosphere. I hope the delegates would understand and accept the shortcomings because of our limitations and inadequate facilities. On behalf of local organising committee, I convey my sincere wish to every delegate to have a comfortable stay at Aizawl and I hope, engineers of Mizoram in general and the State PWD in particular will tremendously benefit in one way or another from the discussion during the meeting and the experiences of top highway engineers of the country.

I would also like to take this opportunity to thank all members of the organising committee and various sub-committees for their dedication and also to all well-wishers whose supports contribute so much towards successful hosting of the prestigious mid-term council meeting of Indian Roads Congress.

I wish the IRC Programme at Aizawl a grand success

Er.K.Lalsawmvela, MES
Local Organising Secretary
&
Chief Engineer, Highways,
Mizoram PWD

INDIAN ROADS CONGRESS

OFFICE-BEARERS

Shri K.S. Krishan Reddy
(President, IRC)
Managing Director
Karnataka Road Development
Corporation Ltd.

Shri N. K Pradhan
(Imm- Past President, IRC)
Engineer-in-Chief-cum-
Secretary Govt. of Odisha

ShriManoj Kumar
(Honorary Treasurer)
Director General Road
Development &Spl. Secretary
Ministry of Road Transport
and Highways, NEW DELHI

Shri S.K. Nirmal
Secretary General, IRC

SHRI C.P. JOSHI
(VICE PRESIDENT, IRC)
SECRETARY (ROADS)
PUBLIC WORKS DEPARTMENT
MANTRALAYA
MUMBAI

SHRI. U.P. PARESEKAR,
(VICE PRESIDENT, IRC)
CHIEF ENGINEER (NH, R&B)
PUBLIC WORKS DEPARTMENT,
GOA

SHRI NEERAJ CHADHA
(VICE PRESIDENT, IRC)
COMPLETE INSTRUMENTATION
SOLUTION PRIVATE
LTD.,HARYANA

IRC Secretariat

Shri S.K. Nirmal
Secretary General

Shri D. Sam Singh
Deputy Secretary (I/c)

Shri Rahul Patil
Deputy Director (Technical)

Shri S.K. Chadha
Under Secretary-I

Shri S.K. Gosain
Under Secretary-II

COUNCIL MEMBERS OF THE INDIAN ROADS CONGRESS - 2018			
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Immediate PAST President, IRC			
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Honorary Treasurer, IRC			
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	Director General Road Development & Spl. Secretary		
	Ministry of Road Transport and Highways	**Fax**	
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Secretary General, IRC			
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COUNCIL MEMBERS OF THE INDIAN ROADS CONGRESS – 2018

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COUNCIL MEMBERS OF THE INDIAN ROADS CONGRESS – 2018

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COUNCIL MEMBERS OF THE INDIAN ROADS CONGRESS – 2018

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INDIAN ROADS CONGRESS
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Chairman, Local Organising Committee &
Principal Secretary, PWD

Er. R. Vanlaltluanga
Working Chairman, Local Organising Committee &
Engineer-in-Chief, PWD

Er. K. Lalsawmvela
Secretary, Local Organising Committee &
Chief Engineer (Highways), PWD

Er. Robin Lalrinawma
Asst Secretary, Local Organising Committee &
Sr. EE, PWD

SUB-COMMITTEES OF HOST STATE

1. VENUE SUB-COMMITTEE

Chairman : Er. Lalruatkima, SE, Project Circle
Secretary : Er. Lalthanzuala Ralte, Sr. EE, Project Divn-II

Sl/No	Name of Officer	Designation
1	Er. Hrangthanga Zote	Sr. EE, Project Div -I
2	Er. Lalngaisanga	Sr.SDO, Project Div-II
3	Er. Amelin Lallawmpuii	SDO, Project Div-II
4	Pu Lalrozama	JE, Project Div-II
5	Pu Lalhmingmawia	JE, Project Div-II PD-II

2. PROG. & SITE VISIT

Chairman : Er. Lalmuankima Henry, CE Buildings
Secretary : Er. Lalsangliana Chhakchhuak, Sr. EE, Project Divn-III

Sl/No	Name of Officer	Designation
1	Er. R. Lalpeka	Sr. SDO, NHD-I
2	Er. Lalbiaksangi	Sr. SDO, Project Div-II
3	Er. H. Lalthanpuia	SDO, Project Div-I
4	Er. Lalhmingsangi	SDO, Project Div-III
5	Er. Rebecca Zodinpuii	SDO, Building Div.
6	Er. Zothansangi	AE, Eastern Circle
7	Er. Jonathan K.	SDO, Project Div-I
8	Pi. Lalbiakengi	SDO, NHD-III

3. ACCOMODATION

Chairman : Er. J. Zothanpuia, SE, Western Circle
Secretary : Er. David Sapzova, Sr. EE, ARSD

Sl/No	Name of Officer	Designation
1	Er. R. Zirsangliana	EE, Hmuifang
2	Er. Zirthanmawia Hmar	Sr. SDO, ARSSD
3	Er. Zohmingliana	Sr. SDO, ARNSD

4. TRANSPORTATION

Chairman : Er. Bowman, SE, NH Circle-I
Secretary : Er. H. Zoramliana, Sr.EE, NH Division-I

Sl/No	Name of Officer	Designation
1	Er. R. Lalpeka	Sr. SDO, NH Div-I
2	Er. Jimmy Vanlalsiama	Sr. SDO, NH Div-II
3	Er. Thangchhuana	AE, NH Circle-I
4	Er. Dengchungnunga	Sr. SDO, NH Div
5	Er. Kaphmingthanga	Sr. SDO, NH Div-I

5. SOUVENIR SUB-COMMITTEE

Chairman : Er. Lalrinkima Hnamte, Project Director, PIU
Secretary : Er. C. Lalthlamuani, EE(Proc.), PIU

Sl/No	Name of Officer	Designation
1	Er. SR. Lalramthanga	Sr. AE, PIU
2	Er. Vansangpuii Khiangte	Sr. AE, PIU
3	Er. H. Lalthanpuia	SDO, Project Divn-I
4	Er. Lalnunnema Tochhawng	HRDM

6. FUND RAISING

Chairman : Er. R. Lalrintluanga, CE Roads
Secretary : Er. K. Lalbiakthanga, EE, PIU

Sl/No	Name of Officer	Designation
1	Er. C. Liantluanga	SE (P&W), CER
2	Er. Lalsangliana Chhakchhuak	Sr. EE, Project-III
3	Er. Gladys Hlychho	Sr. EE, CE Roads
4	Er. PC David Lalrinliana	Sr. AE, CE Roads
5	Pi Lalengthangi	AE, CE HW
6	Pi Lalthanpuii	AE, CE Bldg

7. RECEPTION & HOSPITALITY

Chairman : Er. Vanlalchhuana, SE, Eastern Circle
Secretary : Pu Lallianhmuaka, Dy. Director (Admn.), E-in-C's office

Sl/No	Name of Officer	Designation
1	Er. Lalzawmthanga	EE, Saitual
2	Er. Lalawmpuii	Sr. Architect
3	Er. PC Zokhuma	Sr. SDO, ARSSD
4	Er. Jenny Lalramchhuani	Sr. SDO, ARNSD
5	Er. Vansangpuii	Sr. AE, PIU
6	Er. Zothansangi	AE, Eastern Circle
7	Er. Jacob Lalremliana	AE, PIU
8	Er. Laltlankima	AE, PIU
9	Er. C. Lalchhuanmawii	AE, PIU

8. VENUE DECORATION

Chairman : Ar. George Lalzuia, Chief Architect
Secretary : Ar. Lalengzuali, Architect (Sr. Grade)

Sl/No	Name of Officer	Designation
1	Ar. Lalchhandami	Sr. Architect
2	Ar. Lalawmpuii	Architect (Sr. Grade)
3	Ar. Lalnunfela	Architect (Sr. Grade)
5	Ar. Hmingthanzami	Architect
6	Ar. Zoramnghaka	AA
7	Ar. Zonunpari Chhangte	AA

9. REFRESHMENT

Chairman : Er. Malsawmdawngliana, SE (P&W), CE Bldg
Secretary : Er. Lalhmingmawia, EE, NH Division-II

Sl/No	Name of Officer	Designation
1	Er. PC Lallianzuala	EE(Dsgn), CE Bldg
2	Er. Lalthansiami Ralte	EO to CE Bldg
3	Er. Lalremruata	Sr. AE(D), CE Bldg
4	Er. Zothansanga Ralte	AE(W), CE Bldg
5	Pu Hmingthanghuama	AE(W), CE Bldg
6	Pi Lalthanpuii	AE(W), CE Bldg

10. ENTERTAINMENT, CULTURAL

Chairman : Er. Lalruata Sailo, SE, NH Circle-II
Secretary : Er. Eddie Zothansanga, EE, NH Division-III

Sl/No	Name of Officer	Designation
1	Er. Samuel Ramdinthara	Sr. EE(W), CEH
2	Er. Lalenkawla	Sr. SDO, NH Divn-
3	Pi. Lalbiakengi	Sr. SDO, NH Divn-
4	Pu Lalremsanga	EE(P), NH Circle-II

11. INFORMATION & PUBLICITY

Chairman : Er. Vanlalmuana, SE(P), E-in-C office
Secretary : Er. Lalhmasaa, Sr. EE(M), E-in-C office

Sl/No	Name of Officer	Designation
1	Er. Lalrinngheta	EE(P), E-in-C office
2	Er. Thanzawna Tlau	EE(IT), E-in-C office
3	Er. C. Lalthangvela	Sr. AE (W-I), E-in-C office
4	Er. H. Lalnunpuia	Sr. AE (M), E-in-C office
5	Er. H. Lalfakzuala	Sr. AE (P-II), E-in-C office
6	Er. Lalbiaknunga	Sr. AE (P-I), E-in-C office
7	Er. Lalhmangaihzuala	AE (W-II), E-in-C office
8	Pu Danny Lalrintluanga	Supdt, E-in-C office

12. LIGHT & SOUND

Chairman : Er. N. Chhylai, SE, Mech. Circle
Secretary : Er. Francis Lalngaizuala, Sr. EE, Electrical Division

Sl/No	Name of Officer	Designation
1	Er. Lalthangkhuma Ralte	Sr. EE, Azl Mech. Divn
2	Er. Lalnunpara	Sr. SDO, Elect. Sub-Divn
3	Pu Vanlalrema	SDO, Elect Rural East Sub-Divn
4	Pu Lalnunmawia	JE, Rural East
5	Pu Lalfamkima	JE, Elect. Sub-Divn


Laying of BC at Ch:51/694 kmp


Ongoing Construction of KMMTTP Road


Ongoing construction of KMMTTP Road

S.K. Nirmal

Secretary General,

Indian Roads Congress, New Delhi

THE INDIAN ROADS CONGRESS - AN ORGANISATION DEVOTED TO THE CAUSE OF BETTER ROADS

1. INTRODUCTION

BIRTH OF INDIAN ROADS CONGRESS

Before the first World War 1914-1918, the transport system in India was based upon the all-important railways. Motor transport was no where in the picture and was hardly reckoned as a means of communication. Roads had a limited coverage, were in a rudimentary state and were expected to serve the pack animals and animal-driven vehicles. Road building was largely in the hands of Provincial Governments, lacking central authority or any policy direction and was mostly in a state of neglect. But the rapid technical developments after the war brought about a cataclysmic change in many spheres, including motor transport. An urgent need for not only more roads but also well surfaced, fully bridged and all-weather roads came to be felt. It was then that the development of roads engaged the serious attention of the Govt. The first important step in this direction was taken by way of appointment in 1927 of Indian Road Development Committee, popularly known as Jayakar Committee. This Committee recommended that since the task of road construction and maintenance was beyond the financial capacity of Provincial Local Bodies, the responsibility for road development should be assumed by the Central Government. For the purpose of raising funds, it suggested three additional taxes, namely;

(i) Excise duty on motor-spirit
(ii) Vehicle taxation
(iii) Licence fee for vehicles plied for hire.

The Jayakar Committee also recommended that the road conferences should be held periodically to discuss, inter-alia, questions relating to road construction and maintenance. In pursuance of this recommendation, the Central Govt., after consulting the State Govts. convened an inaugural meeting of Highway Engineers in New Delhi on 10th day of December in 1934 under the chairmanship of Mr D G Mitchell, Secretary to the then Govt. of India in the department of Industries and Labour, Public Works Branch. This meeting was attended by 73 Engineers from all

parts of India, which marked the birth of Indian Roads Congress. It was the humble beginning of an institution, rising of a new star on the firmament. As the activities of Indian Roads Congress expanded, it was formally registered as a Society on 24th day of September in 1937 under the Societies Registration Act of 1860. Over the years the Indian Roads Congress has burgeoned and grown into a multi-dimensional, many-faceted, unique organization, devoted to the cause of better roads in the country. Starting with a modest membership of 73 in 1934, the Congress now has more than 15,987 members, of which, 15,581 are life members comprising engineers of all ranks from Central and State Governments, Engineering Services of Army, Border Roads Organization, Road Research Institutes, Engineering Colleges, Local Bodies and commercial organisations.

2. OBJECTIVES OF IRC

The Congress provides a NATIONAL FORUM for sharing of knowledge and pooling of experience on the entire range of subjects dealing with the construction and maintenance of roads; bridges; tunnels and road transportation including technology, equipment, research, planning, finance, taxation, organization and all connected policy issues. In more specific terms, the objectives of the Congress are:

(a) to advise the legislation and provide a channel to pool collective wisdom in order to promote and encourage the excellence for building the road infrastructure conforming to the cutting edge environmental friendly clean techniques; use of indigenously available new/innovative materials; to formulate and promote the use of standard specifications/guidelines uniformly through-out the country for planning, design, construction, operation & maintenance of roads, bridges, tunnels and road transportation.

(b) To promote efficient and well-integrated transport system and creation of mass awareness to follow traffic regulations aiming of zero road crash fatalities and contribute to the economic growth and quality of life and hence serves the public interest by enhancing mobility and delivery safe, secure and environmentally responsible in collaboration of corporate houses under Public Private Partnership (PPP) in confirmation to the Companies Act, 2013 and financial regulations (100% tax exemption on contribution towards road safety and related activities)

(c) To align itself to global initiatives of environmental strategy for promotion of cleaner, less energy intensive and less polluting construction techniques, use of recycled wastes; minimize drawing of natural resources and encourage the profession to aim at earning carbon credit in life cycle analysis for construction/transportation projects under Environment Management Plan (EMP) and earn Green Credit.

(d) To pool knowledge (Library and Museum) with exchange facility through web to the reputed national and international organizations engaged in the profession and shared publications and literature conforming to cutting edge technologies.

(e) To promote on R&D activities of applied nature aiming at (i) "Appropriate Carbon calculators and processes for getting carbon credits in life cycle analysis for road/transportation projects under Environment Management Plan (EMP)" (ii) road accidents through inclusive approach (human factor, road geometry and vehicle condition) and (iii) flesh assessment of the stock of stone aggregates/bitumen/cement/steel etc for the set goals versus merchandise for development of road infrastructure.

(f) To endeavor for imparting Skill development of construction work force; training of technicians; engineers and machine operators.

(g) To publish the proceedings of annual/mid-term council meets; seminars; workshops; conferences etc; periodicals (monthly Indian Highways, quarterly journals); State of the Art Reports (SOAR) and other literature for the promotion of the objectives of the Indian Roads Congress.

The Congress has relentlessly strived to achieve these objectives and fulfil its charter.

To achieve its objectives, IRC has been relentlessly making efforts towards modernizing its day-to-day working and fulfil its charter. Apart from extensive use of computers, Internet and e-mail, it has developed its own Website, which has the domain name www.irc.nic.in.

3. ANNUAL ACTION PLAN

To achieve the above objectives, following activities are undertaken annually by IRC with approval of Ministry through Director General (Road Development) & Special Secretary to the Govt. of India

a. Annual Session of four days, wherein General Body meeting is held. All 15,987 members are invited during Annual Session.
b. Two meetings of Engineer-in-Chief/Chief Engineers of All State PWDs/UTs in India during Mid Term and Annual Session.
c. Three Meetings of Council (Governing Body) – details of Council given in Para VI hereinafter
d. 7-8 meetings of Executive Committee (Management Committee)
e. At least four meetings of each Technical Committees
f. About 10 new Codes/Standards/Guidelines are brought our annually and 10 old Codes/Standards/Guidelines are revised every year.
g. Two Meetings of Highway Research Board
h. Publication of different periodicals – 12 MONTHLY "Indian Highways", 4 quarterly Journal, 2 Highway Research Journal and 1 Highway Research Record are published every year.
i. Medals and commendation certificates provided to Authors during Annual Session.
j. 15 to 25 technical papers pertaining to road design, construction and maintenance are discussed every year during Annual Session.
k. At least 3-4 meetings of Committee for Accreditation of New Materials.

4. ADMINISTRATIVE SET-UP

The affairs of IRC are controlled by a Council, which is the Governing Body. The Council, headed by the President, comprises Heads of Departments/Secretaries/Engineers-in-Chief/Chief Engineers from Central and State Government Departments as its members. Some seats in the

Council are earmarked for business interests connected with roads & road transport industry besides representatives of Municipalities, Local Bodies and Members elected by the General Body.

The Council is supported by a Executive Committee in discharge of routine activities of IRC, under delegated powers, on behalf of the Council. The Executive Committee of IRC comprises the President, Immediate Past-President, four Vice-Presidents, Honorary Treasurer (DG(RD)&SS, MORT&H) and Secretary General.

The IRC works in close collaboration with the Ministry of Road Transport and Highways. The Director General (Road Development), Department of Road Transport & Highways, Govt. of India is the Honorary Treasurer and Administrative Head.

The IRC has a Secretariat, which manages day-to-day functioning including publication of magazines viz. 'Indian Highways (monthly)', 'IRC Journals (Quarterly)', 'Highway Research Journals (Half-yearly) and Highway Research Records (General Report on Road Research Work done in India)', State-of-the-Art Reports, besides, publications of Manuals, Codes, Specifications, etc. There are at present 24 Technical Committees examining various technical issues and making recommendations on issues relating to Roads, Bridges, Traffic, Transport Planning, Road Safety, Materials, etc. besides the three Apex Committees, namely; Highways Specifications & Standards Committees, Bridges Specifications & Standards Committee and General Specifications & Standards Committee. In addition, there are three Committees i.e "Identification, Monitoring and Research Applications (IMRA)" , "Committee for Accreditation of New Materials and Techniques" and "Pilot Project Committee" under the Highway Research Board. Experts from all over the country drawn from various bodies are member of these Committees.

The IRC Secretariat is headed by the Secretary General. The Secretary General is assisted by the Deputy Secretary (Admn.) in administrative matters and by the Deputy Director (Tech.) and Asstt. Director (Tech.) in technical matters. There are Under Secretaries, and Section Officers to manage the various routine activities of IRC. In a way, functioning of IRC is broadly similar to the American Association of State Highways and Transportation Officials (AASHTO), which lays down standards pertaining to roads and bridges in the USA.

5. ROLE OF THE IRC

The problems of road planning, design, construction and maintenance are becoming more and more complex in the wake of the phenomenal growth of traffic, heavy axle loads plying on the roads in recent times and sharp increase in the cost of material and labour. The IRC has contributed significantly to the improvement of various facets, such as, planning, design, construction and maintenance of roads. The IRC has been closely associated with road planning in the country beginning with formulation of the famous Nagpur Plan in the year 1943, which heralded the advent of systematic planning and development of roads on an all-India basis. This was followed by the Bombay Plan (1961-81). Road Development Plan (1981-2001), published in 1984, provided the general emphasis on measures to conserve energy, to preserve environment and to improve safety on our highways. Current 20-Year Road Development Plan (2001-2021) "Road Development Plan Vision: 2021" has been published in 2001 covering major thrust areas relating to mobility in respect of main roads and accessibility in respect of rural roads to connect all villages in a time bound programme, strategies for capacity augmentation and preservation of assets have been brought out together with measures to mobilise additional resources and capacity building of Government organisations, consultancy and contracting industry to meet the challenges facing the Highway Sector.

Ministry of Rural Development has also taken up a massive rural roads programme. In this context, the IRC had been entrusted to prepare Rural Roads Development Plan on long-term basis. The Rural Road Development Plan: Vision 2025 was finalized by IRC, which provides general framework for rural road development in India in next two decades and were published by IRC on behalf of Ministry of Rural Development.

For better and planned development of various categories of roads in the country, the IRC was engaged in preparation of Manual for Two Laning of State Highways on BOT Basis. This document has been finalized & printed as a special publication. Four Laning of Highways on BOT Basis, (framing of both these documents were entrusted to IRC by the Planning Commission), Manual on Design, Construction and Maintenance of Gravel Roads and Quality Assurance Handbook for Rural Roads for PMGSY since finalized and printed. Both these works were entrusted by National Rural Roads Development Agency (NRRDA).

6. TECHNICAL COMMITTEES

The measure of success of a professional body of this kind is largely dependent on the work of its Technical Committees and Expert Groups. There are 10 Highways Committees under the Highways Specifications and Standards Committee, 9 Bridges Committees under the Bridges Specifications and Standards Committee and 5 Technical Committees under the General Specifications and Standards Committee. The three Apex Committees are responsible for the formulation of Codes of Practice, Standards and Guidelines for Highways and Bridges. The Committees have experts in the relevant areas as members and are reconstituted every three years. Present term of the Committees is upto the 31st December, 2020.

7. RESEARCH AND DEVELOPMENT

The IRC plays an active role in the promotion of road research. In the first instance, the IRC took active interest in setting-up of the road research laboratories in the country. As far back in 1944, a detailed scheme was worked out for setting-up Central Road Research Institute at New Delhi and a chain of research laboratories in the States in addition to the work of gathering information concerning road research within the country.

8. HIGHWAY RESEARCH BOARD

In October, 1973, the Highway Research Board (HRB) was set up under the auspices of the IRC for giving undivided attention to research and development activities. Identification, Monitoring and Research Application (IMRA) Committee looks after the Research work and compiles data of road research work done in the country on yearly basis. Under the aegis of HRB, an Expert Committee for "Accreditation of New Materials and Techniques" was constituted for the purpose of recommending usage of New Materials/Products/Technologies on trial basis for road and bridge works in India. For wider dissemination, the HRB publishes State-of-the-Art Reports, Highway Research Record and Highway Research Journal. The HRB identifies the R&D requirements of the country and acts as the forward-looking group of Science & Technology Advisory Committee (STAC) of the Ministry of Shipping, Road Transport and Highways.

9. ACHIEVEMENTS

9.1 Periodicals

The IRC is popularizing modern ideas on road development and road engineering by publishing Papers and articles on all aspects of Highway Engineering. The IRC brings out the following periodicals:

(i) Indian Highways (Monthly)
(ii) Journal of the Indian Roads Congress (Quarterly)
(iii) Highway Research Journal (erstwhile Highway Research Bulletin) (Half Yearly)
(iv) Highway Research Record (Yearly)

9.2 IRC Standards, Special Publications & Research Publications

The IRC has so far published 126 Standards and Codes of Practice, 112 Special Publications, 24 State-of-the-Art Reports, 78 Highway Research Journal and 40 Highway Research Records. It has also brought out 31 important publications on behalf of the Ministry of Road Transport and Highways (now named as Ministry of Shipping, Road Transport & Highways), two publications on behalf of the Ministry of Rural Development and four publications on behalf of Planning Commission. Various Standards, Codes of Practice and Guidelines published by the Indian Roads Congress have helped in achieving uniformity in design and construction practices of roads and bridges in the country.

9.3 Publications in the Pipeline

A large number of new documents and revision of existing documents are under active consideration of the various IRC Technical Committees.

9.4 Seminars & Workshops

In order to pool the latest knowledge from experts on various topics of importance connected with roads and bridges and to disseminate the knowledge to practicing highway engineers, the IRC regularly organizes Seminars and Workshops both at International and National level. The Seminars have provided an excellent opportunity and effective forum for exchange of information and ideas among highway engineers on new developments in the road sector.

9.5 IRC Annual Sessions

The Indian Roads Congress holds Annual Sessions regularly during which a number of Technical Papers on important issues concerning roads, bridges and transportations are discussed. Other major activities of the IRC Sessions include Council meetings, presentations on technical and research topics, expert talk, panel discussions, HRB meeting, Technical Committee meetings, Secretaries/ Engineers-in-Chief/Chief Engineers' meeting and Business Meeting. The discussions and feedbacks received from the professionals at these meetings provide valuable inputs for planning of IRC activities and dissemination of knowledge. The 79th Annual Session of IRC is being hosted by the Govt. of Maharashtra at Orange City Nagpur in the month of November, 2018.

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Cost Effective Durable Pavements for Low Volume Roads

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Conventional rural roads made up of Water Bound Macadam and premix carpet need continuous maintenance for their up keep to maintain a minimum level of riding quality. Construction cost of pavements of rural roads is very high in many places due to large lead of aggregates since good quality aggregates are not available locally. It is, therefore, necessary to use innovative technology to address the above issues so that maximum benefit is realized with lower investment. The paper presents a few innovative ideas which can be used to construct long lasting rural roads.

1. Cell filled concrete pavements (CFCP): This consists of pavement made of formwork of cells of recycled plastic filled with concrete after stretching the formwork. It is cast-in –situ concrete block pavements. It has proved to be durable wherever it was constructed. A CFCP constructed in a village near IIT Kharagpur in April 2005 at fifty percent of the cost of conventional pavement is still in a reasonably good condition with zero maintenance. Figure 1 shows formwork of cells stretched over a compacted subbase. Figure 2 shows cells being stitched by unemployed ladies. Figure 3 shows a CFCP being constructed in Mizoram

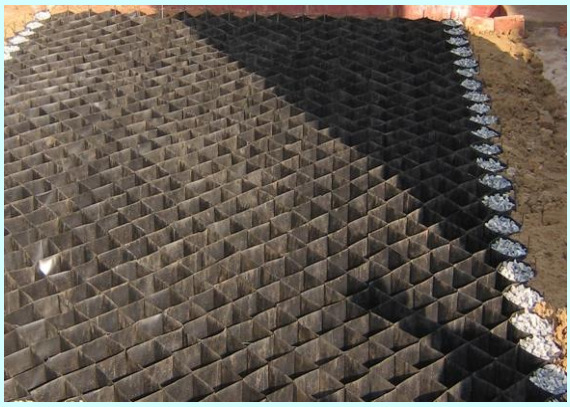

Figure 1 Formwork of cells of recycled plastic.

Figure 2 Formwork of cells being stitched by unemployed women

Cells are filled up with concrete and compacted with a plate vibrator.After the cell filled concrete pavement is damaged after a long use, an overlay of 50mm thick CFCP will prolong the pavement life by another ten years. Concrete can be recycled after crushing and grading to make another CFCP to conserve the material.

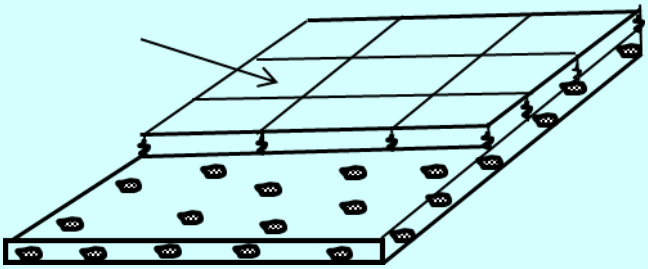

Figure 4 Typical Panel concrete pavement

Figure 3 CFCP constructions in Mizoram

Figure 5 Panel concrete pavement in a village in West Bengal

It consists of placing of thin concrete slab with thickness from 75mm to 125mm. Panels are formed by sawing cutting joints to depths of one third of the thickness with panel size being 0.50mmx 0.50m to 0.75m X 0.75m

3 **Ultrathin reinforced concrete pavement:**

Ultrathin reinforced concrete pavement can be another very attractive solution for durable roads for villages. It is jointless but such pavements crack into panels which are held together by reinforcements ensuring a good riding quality

4 Fibre concrete pavement:

This consists of concrete pavement of thickness 75mm to 199mm with a central longitudinal and transverse single cut thin joints sawed to a depth of one third the thickness of the pavement @2 m c/c. The individual panels may further crack into smaller size panels held together by fibres added to concrete.

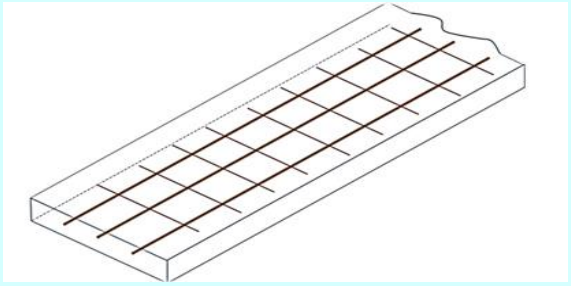

Fig.6 Ultrathin reinforced concrete pavement with nominal reinforcement

Fig.6 Thin fibre concrete pavement

5 **Pavement with soft aggregates**:
Many areas of the country including Mizoram have soft aggregates which crush during rolling and apparently not suitable for road construction. Research at IIT Kharagpur has shown that soft aggregates can be stabilized with cement if sand content is in between 40 to 50 percent. The sand acts as cushion between aggregates and breakage of aggregates can be avoided during the rolling of cement stabilized material. Only those aggregates which are touching each other may undergo degradation.

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Engineering Upliftment of Locally available Aggregates of Mizoram

By

Er. Lalrinkima Hnamte*[1]

Er. Vansangpuii**

Er. Bidur Kant Jha***

Er. J.K.Das****

Abstract

Over the last four years, the CentralGovernment has been giving maximum attention to improve road conditions in North Eastern India. The government is planning to invest about Rs. 1.45 lakh crore in the North-East for development of Highway. The highway construction cost in this region is about two to three times more than that of construction cost in plains of India. The prime cost driver is too much lead of aggregates outsourcing from nearby States due to unsuitability of the locally available aggregate for pavement layers construction. Also sometimes, the nearby States do not allow the aggregate to be imported to the other States and the progress of the works also getsaffected. Excessive lead also damages the existing roads due to movement of overloaded construction vehicles.

While preparing detailed engineering design of about 400km of State Highway under World Bank funded projects, the Design Consultant has encountered the same problem and PWD;Mizoram instigatedthe Consultant to find out the possible engineering solution so that the local available aggregates can be made suitable for the pavement layer construction. An investigation **Team** instituted with Engineers from PWD, Mizoram & Consultant to work out the engineering treatment of marginal aggregate to make it suitable for pavement construction. The Consultant's R&D laboratory at New Delhi has been utilized for testing purposes and team has devised the engineering solution in form of in-place treatment of locally available aggregate withabout 3.0% cement to make it suitable for granular pavement layer construction i.e. base and sub-base as well as pre-coating of coarse aggregate with cement to make it suitable for bituminous layers construction.

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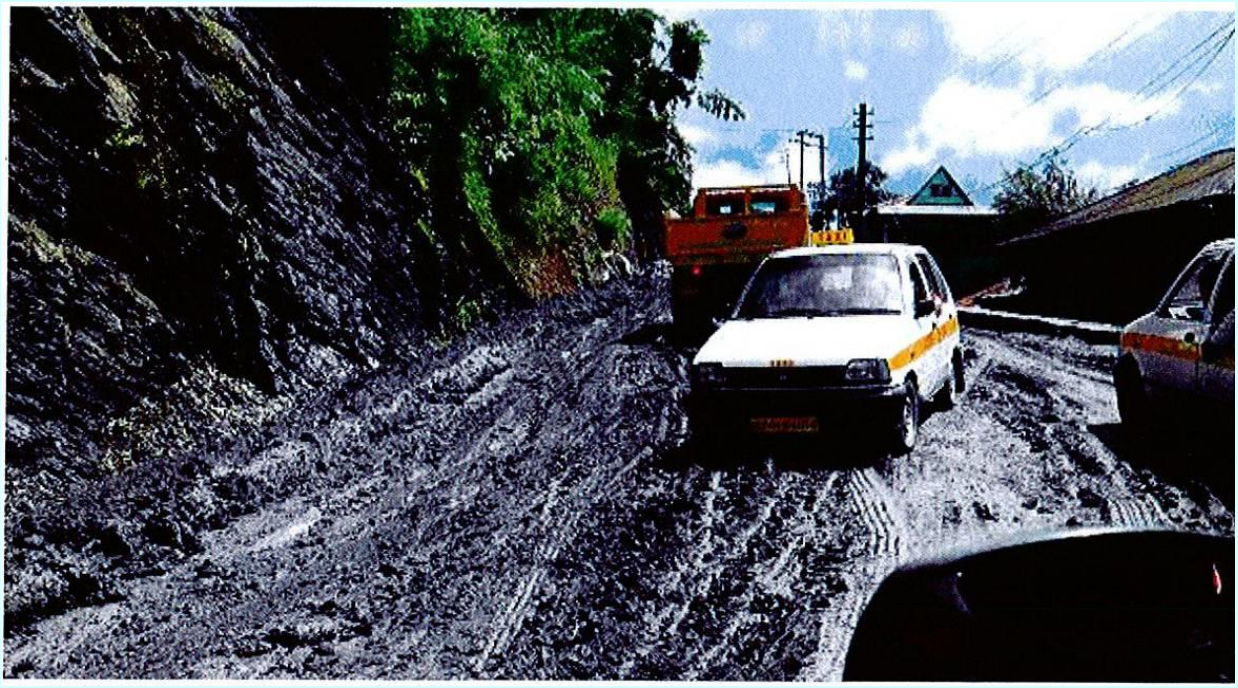
Introduction

The Central Government plans to invest about Rs. 48,000 crore in Assam, Rs. 22,000 crore in Manipur, Rs, 20,000 crore in Nagaland, Rs. 17,000 crore in Sikkim, Rs. 12,000 crore in Mizoram, Rs. 10,000 crore in Arunachal Pradesh and Rs. 8,000 crore each in Meghalaya and Tripura for building roads. The State Government also through own resources or funds from Word Bank/ Asian Development Banks willing to construct as much as possible the roads in the State. The highway construction cost in this region is about two to three times more than that of construction cost in plains of India. The prime cost driver is too much lead of aggregates outsourcing from nearby States due to unsuitability of the locally available aggregate for pavement layers construction. Also sometimes, the nearby States do not allow the aggregate to be imported to the other States and the progress of the works also gets affected. Further, wherever the locally available aggregates have been used for pavement layers construction, it dis-integrated and became muddy /slushy after exposure to extremely heavy rainfall. The resulting performance of the major sections constructed is shown in the photo below.



The photo shows the "Completed" pavement during the first monsoon in 2007.
This paper deals with the study of the geological nature and engineering evaluation of locally available aggregates and brings out possible engineering solution to make it suitable for pavement layers construction.

GEOLOGYAND ENGINEERING PROPERTIES OF LOCALLY AVAILABLE AGGREGATES

Altogether ten aggregate sources spreaded across the Mizoram have been identified by the team as a part of study. Some of the typical photographs are presented next:

MZ-AQ-2 between Lawngtalai & Diltlang

MZ-AQ-3 near Diltlang

Geology of Locally Available Aggregates

The rock samples were tested for their petrography at Sriram Institute, New Delhi. Petrographic examination reveals that

The rock is metamorphosed micaceous quartz or calcareous quartz consisting predominantly of quartz.

20-25% of the total quartz show strain effects with undulatory extinction angle ranging from 18-24 degrees known to cause deleterious chemical reaction in concrete, and

Local experience gained over the years confirms that in dry state rock is compact and hard; however with exposure to water in tandem with traffic load it becomes mud/slush.

Engineering Properties of Locally Available Aggregates

All the ten aggregate samples were tested for physical properties to find out their suitability for pavement layers construction i.e. non-bituminous layers granular sub-base, base & bituminous layers DBM and BC as per MORT&H specifications. Typical photographs of laboratory testing are presented below for ready appreciation.

The summary of laboratory test results is presented in table below:

Table 1: Laboratory Test Results of Aggregate Samples

Sl. No.	Name of Quarry	Description of Sample	Water Absorption (%)	Specific Gravity	AIV_ Dry (%)	AIV_ Wet (%)	Coating and Stripping of Bitumen-Aggregate mixtures	Soundness (%) Loss with Sodium Sulphate)	Suitability
1	Aizawl	Aizawl	1.7	2.643	24.9	28.8	>95%	3%	Suitable for non-bituminous works
2	West Lungdar	West Lungdar	1.1	2.682	27.6	28.1	>95%	3%	Suitable for non-bituminous works
3	Champhai	Tuipui River (Champhai)	2.4	2.546	24.5	21.5	>95%	-	Unsuitable due to high water absorption
4	Kawnpui (PWD)	MZ-AQ-4	3.1	2.507	22.1	-	>95%	94%	Unsuitable due to abnormally high % loss in soundness and high water absorption
5	Lawngtlai-Ditlang Road (BRO)	MZ-AQ-2	4.8	2.316	59.5	-	<95%	99%	Unsuitable due to abnormally high % loss in soundness, high water absorption , abnormally high AIV and poor affinity to bitumen.
6	Chawngtelui	Chawngtelui	4.9	2.419	50.2	41.9	>95	15%	Unsuitable due to high water absorption, abnormally high AIV and %loss more than specified in soundness test.

Sl. No.	Name of Quarry	Description of Sample	Water Absorption (%)	Specific Gravity	AIV_ Dry (%)	AIV_ Wet (%)	Coating and Stripping of Bitumen-Aggregate mixtures	Soundness (%) Loss with Sodium Sulphate)	Suitability
7	Lawngtlai-Ditlang Road (BRO)	BRO	2.3	2.384	25.6	32.3	>95	13%	Unsuitable due to high water absorption, high AIV and %loss more than specified in soundness test.
8	Lawngtlai-Ditlang Road (BRO)	BRO A	5.8	2.297	51.3	38.8	>95	26%	Unsuitable due to high % loss in soundness, high water absorption and abnormally high AIV.
9	Ditlang	MZ-AQ-3	2	2.598	15.8	-	>95%	86%	Unsuitable due to abnormally high % loss in soundness
10	Aizawl	Liapaha-Kolodyne River	2.3	2.575	23.8	24.8	>95%	-	Unsuitable due to high water absorption
Specified Limits of Parameters as per MORT&H (fifth edition),2013		for sub-base	Max. 2.0		Max. 40	Max. 40		Max. 12	
		for base	Max. 2.0		Max. 30			Max. 12	
		for DBM	Max. 2.0		Max. 27		Min. 95	Max. 12	
		for BC	Max. 2.0		Max. 24		Min. 95	Max. 12	

From above table, it can be inferred that

Out of ten samples tested, eight samples have water absorption more than the specified maximum of 2.0%.Water absorption of these samples varies in the range of 2.0-5.8%.Thus, only two sources are suitable for pavement layers construction on the basis of water absorption.

Out of ten samples tested, five samples have aggregate impact value more than the specified maximum of 30.0%/40.0% for base and sub-base respectively. Thus, only five sources are suitable for granular base and sub-base layer construction.

Out of ten samples tested, seven samples have aggregate impact value more than the specified maximum of 24.0%/27.0% for BC and DBM respectively. Thus, only three sources are suitable for bituminous layer construction i.e. BC and DBM.

Out of ten samples tested, ten samples have retained coating more than specified minimum of 95.0%. Thus, nine sources are suitable for bituminous layer construction i.e. BC and DBM in view of bitumen affinity.

Altogether eight samples have been tested for soundness to determine % loss using Sodium Sulphate solution. Out of eight samples tested for soundness, six samples have measured % loss more than the specified maximum of 12.0%. Soundness of these samples varies in the range of 13.0%-99.0%.Thus, only two sources have been found suitable for pavement layers construction in view of soundness which indicates durability. The high losses of aggregate with Sodium Sulphate solution, indication of low weather resistance, are the main reason of early pavement failure.
From aforementioned inferences, it can be concluded that the locally available aggregates in Mizoram is marginal i.e. neither premium quality nor poor quality. These are satisfying one or two physical properties simultaneously out of specified four or five properties required for suitability.

DEVISED ENGINEERING SOLUTION

Team has done a thorough literature review to find out the available engineering solution to improve water absorption and soundness properties. There is only one solution recorded in the available literature i.e .pre-coating with bitumen.

Pre-coating with Bitumen

One aggregate sample MZ-AQ-2 has been pre-coated with 0.8% (by weight of aggregate) neat bitumen as well as 0.8% neat bitumen along with 0.4% (by weight of bitumen) anti-stripping agent. Some of the typical photographs are presented next for ready appreciation.
Soundness test results are given in the table below:

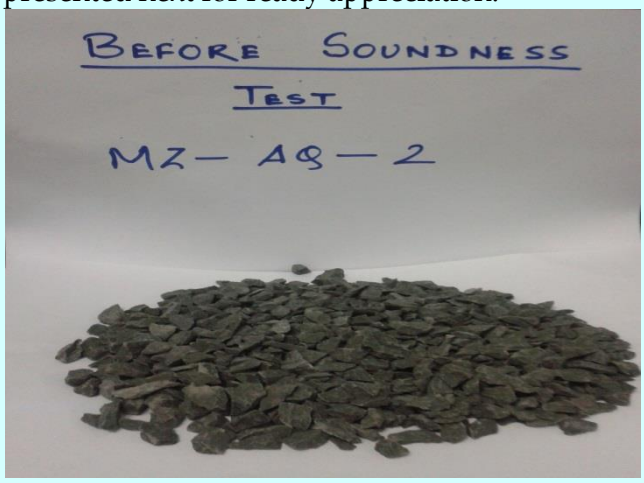
Table 2: Soundness Results of Aggregate pre-coated with Bitumen

Sl. No.	Sample	Description	% Loss with Sodium Sulphate in Soundness Test
1	MZ-AQ-2	Neat Sample	99.0%
2	MZ-AQ-2	Pre-coated with 0.8% Bitumen	79.5%
3	MZ-AQ-2	Pre-coated with 0.8% Bitumen and 0.4% anti-stripping agent	62.9%

From above table, it can be inferred that though % loss has reduced for aggregates pre-coated with bitumen but not substantially and the aggregate is still unsuitable for its use in pavement layers construction.

Pre-coating with Cement

After not getting encouraging results of pre-coated aggregates with bitumen as found in the available literature, Team has thought to pre-coat with cement. One aggregate sample MZ-AQ-2 has been pre-coated with varying % of cement i.e. 1.0%-5.0%. Some of the typical photographs are presented next for ready appreciation.



20mm size aggregate before the soundness test, without any treatment.

20mm size aggregate after soundness test, without any treatment.

20mm size aggregate before the soundness test, pre-coated with 3% cement.

20mm size aggregate after soundness test, pre-coated with 3% cement.

20mm size aggregate before the soundness test, pre-coated with 5% cement.

20mm size aggregate after soundness test, pre-coated with 5% cement.

Soundness test results are given in the table below:

Table 3: Soundness Results of Aggregate pre-coated with Cement

Sl. No.	Sample	Description	% Loss with Sodium Sulphate in Soundness Test
1	MZ-AQ-2	Virgin Sample	99.0%
2	MZ-AQ-2-Cem-1%	Pre-coated with 1.0% Cement	47.0%
3	MZ-AQ-2-Cem-2%	Pre-coated with 2.0% Cement	20.2%
4	MZ-AQ-2-Cem-3%	Pre-coated with 3.0% Cement	7.2%
5	MZ-AQ-2-Cem-4%	Pre-coated with 4.0% Cement	6.1%
6	MZ-AQ-2-Cem-5%	Pre-coated with 5.0% Cement	3.6%

From above table, it can be inferred that Cement is more effective than bitumen to reduce % loss in soundness test.

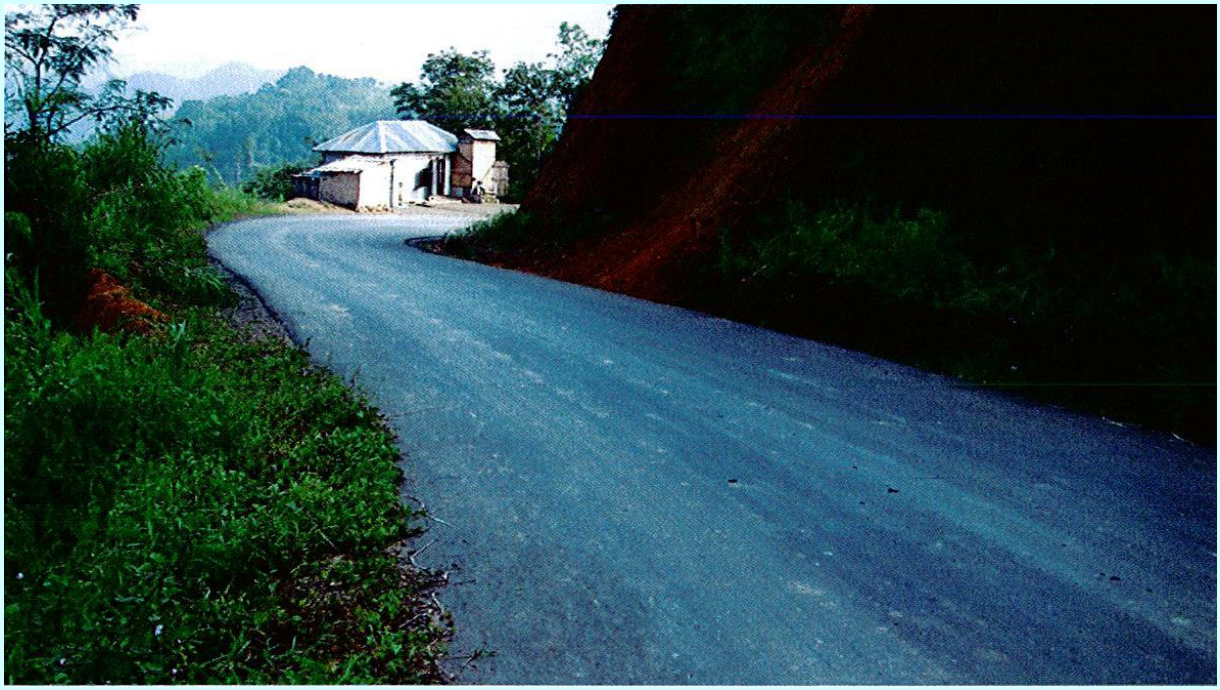
The aggregate sample satisfies the % loss in soundness test when pre-coated with 3.0% and more cement.

The local available marginal aggregates can be used for granular sub-base and base layer construction by doing in-situ treatment with 3.0% Cement.

To enhance the durability of the bituminous layers, it is recommended to pre-coat the coarse aggregate with 5.0% cement prior to its use in bituminous mix.

The same findings of the Team is also gets validated with the locally performance of the pavement constructed with WMM of local aggregates treated with 1.25% cement. After getting the premature failure of the local pavement as shown in the introductory photograph of the paper, the photo

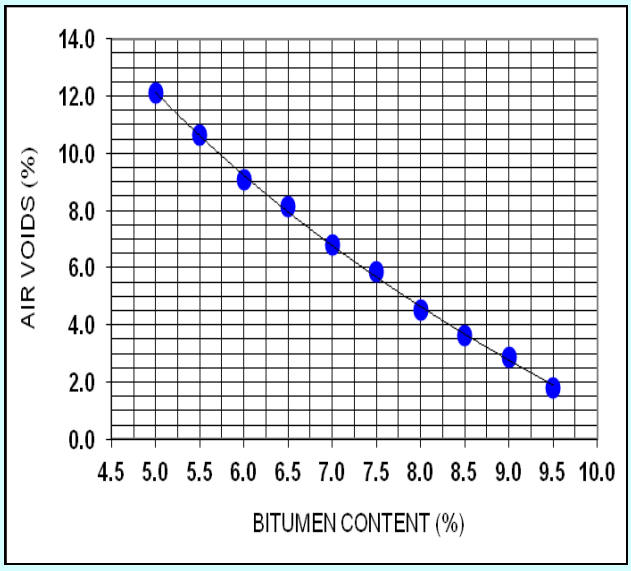
given below shows the better performing pavement constructed with WMM treated with 1.25% Cement.

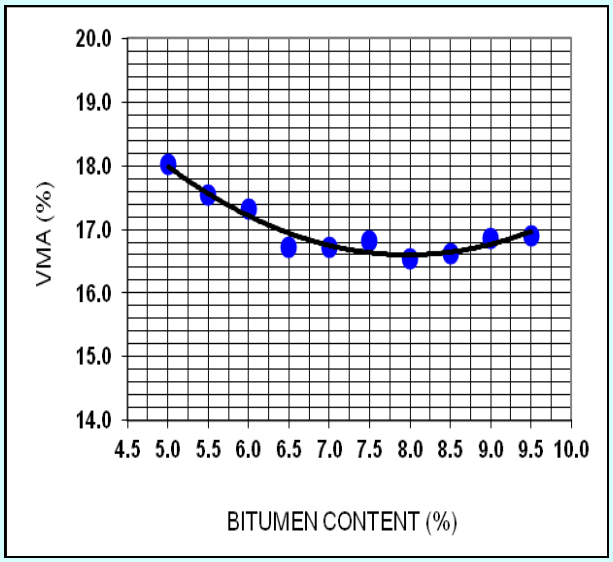


The performance of the pavement over the past three years has been good.

BITUMINOUS MIX DESIGN OF AGGREGATES PRE-COATED WITH 5.0% CEMENT

A mix design of DBM Grade-II has been carried out for this pre-coated coarse aggregate with 5.0% cement. Marshall Test Property Curves are presented in **Figure 1** below for ready reference.





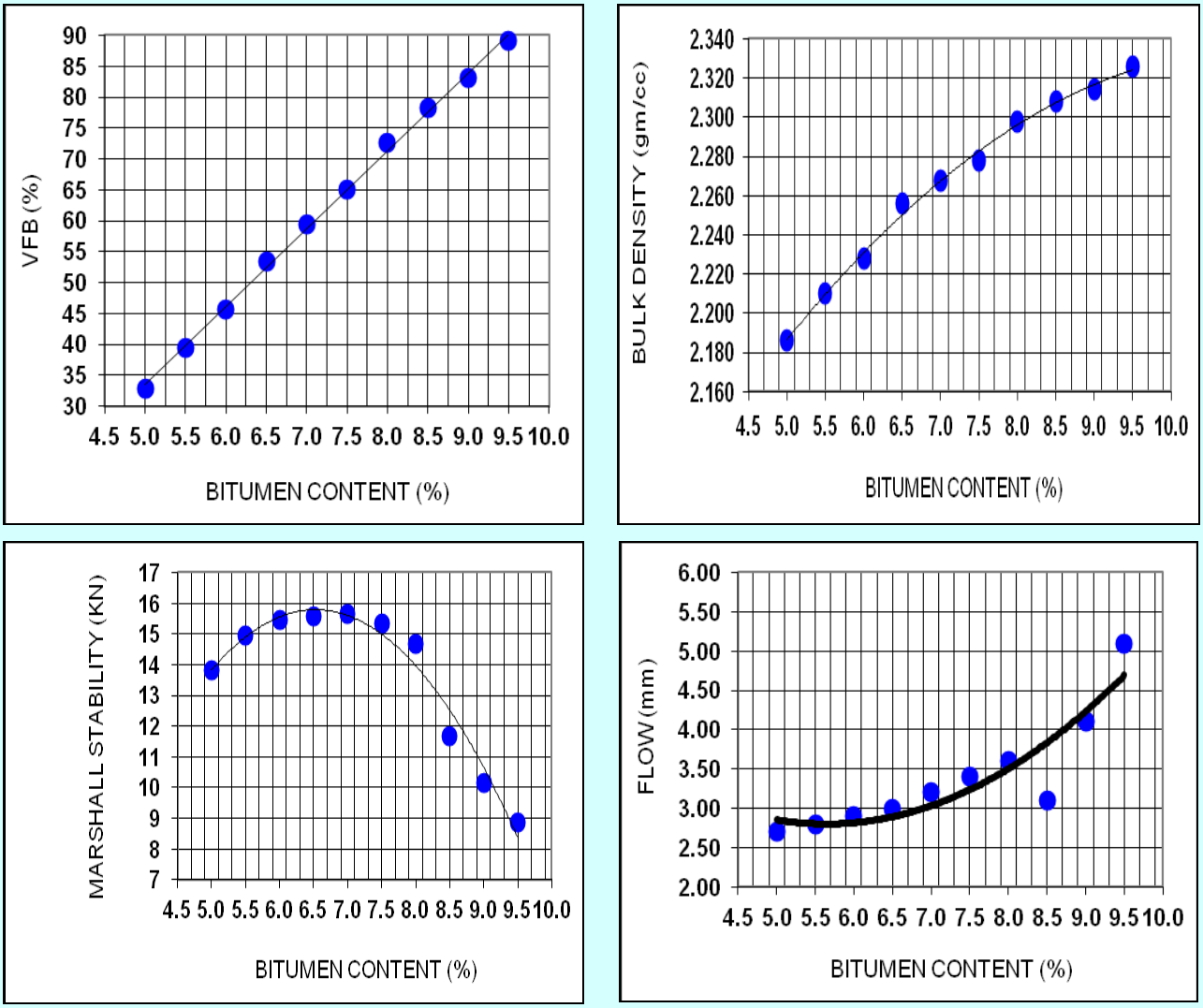


Figure 1: Marshall Test Property Curves of DBM Grade-II

From above figure it can be inferred that

The design binder content is 8.0% by weight of mix.

The demand design binder content is more than that of the generally required percentage of bitumen due to pre-coating with cement. However, the total mass of bitumenrequired in one cubic meter of mix will slightly increase as the bulk density of the mix is 2.3, whereas the bulk density of generally DBM mix varies in the range of 2.4-2.5.

The design mix has satisfied all the specified mix design parameters i.e. Marshall Stability-Flow and Mix Volumetrics.

Conclusions

5.1 There are plenty of rock quarries available in the State of Mizoram. The quality of locally available aggregates is marginal i.e. neither premium quality nor poor quality. These are satisfying one or two physical properties simultaneously out of specified four or five properties required for suitability.

5.2 Team has devised the engineering solution to improve the engineering properties of these marginal aggregates by pre-coating these aggregates with bitumen or cement.

5.3 Pre-coating of aggregates with bitumen is not worthy.

5.4 Pre-coating of aggregates with 3.0% cement made it suitable for granular base and sub-base layer construction as the soundness i.e. % loss reduced substantially. Therefore, in-place treatment of locally available marginal aggregates with 3.0% cement, the durable sub-base/base layer may be constructed

5.5 Pre-coating of coarse aggregates with 5.0% cement made it suitable for bituminous layers i.e. DBM/BC construction as the soundness i.e. % loss reduced substantially. Therefore, pre-coating of coarse aggregates of locally available marginal aggregates with 5.0% cement, the durable bituminous layers DBM/BC may be constructed.

5.6 To give impetus to the highway development plan of the Government, to give pace to the slow progress due to scarce of locally available aggregates,to eliminate dependency on nearby State, to reduce highway construction cost and construct more lane km of highways with the allotted budget, it is high time that the ***Ministry of Road Transport & Highways(MORT&H)/State Government shall initiate a comprehensive research project toevaluate and devised the possible engineering solution to uplift the locally available marginal aggregates of North-Eastern States to premium quality aggregates suitable for pavement layers construction***.

Rehabilitation of Vaitarna River Bridge on Zai-Bordi- Revas –Reddi-Satarde Road MSH-4 (Km. 90/050) Dist. Palghar. (Maharashtra)

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(3). Co-Author: Er. Rahul U. Vasaikar, Executive Engineer, P.W. Division, Palghar

1. Introduction :-

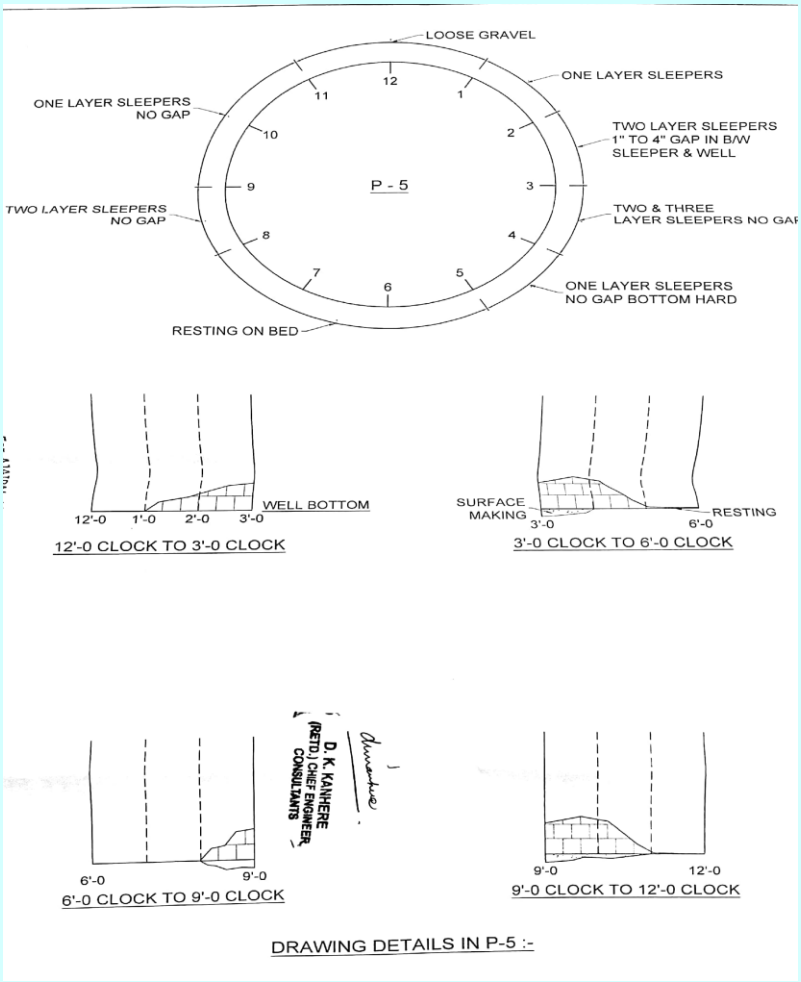
The construction ofVaitarna Bridge was completed and opened to traffic in the year 198 Total length of the bridge is 325.00 Meters, end spans are land spans with 25.00m. each& 30. m. each. Middle 6 spans are of 2 sets of 3continuous spans 45m in length each, supported wi neoprene pad bearings at continuous support & with concrete roller bearings at discontinuo support. Foundation of bridge is RCC well foundation, rested on rock beneath @ approx metrs from high tide water level with RCC pier substructure, superstructure is of double c prestressed concrete box girder. The left & right abutments are rested on under reamed ty pile foundations.

2. Background :-

During periodical inspection of bridge in December 2014, it was observed that the level of sanchi type parapet of 3 span continuous set consisting units P-4,P-5,P-6 of this bridge was lowered down by 15cm at P-5. In view of this, the bridge was inspected from the under neath& it was observed that the well foundation of pier P-5 has shown the considerable tilting (with tilt of about 1 in 133) and the neoprene bearings at pier P-5 was dislocated by 15cm from pedestals. Due to this, the continuous span of P-4, P-5, P-6, P-7 became unsupported with settlement of pedestals at pier P-5. The minor diagonal & horizontal hair cracks were also observed in the webs of the continuousspans. Underwater survey was carried out for all piers, the standing water level is about 12.00 meters at low tide and about 15.00 meters at high tide level. It was observed that pier well

No.5 wascritical with wide crack varying from 6 to 12 inches at curb level of well, causing apparent split in the well staining the crack extended upto the bottomof well cap. Also, it was observed that peripheral strata (sand) was completely washed away over the period time and the well was standing alone on its own self weight and super structure dead load over the cutting edge with approximate 30% of founding area.

Dislocated Neoprene pad Bearing Crack observed in well



30% founding Area of well standing on Self weight

3. Immediate Action :-

1. Heavy traffic on bridge was immediately stopped from 29.12.2014 and tilted side of bridge (2/3 of total width) was restricted for light traffic too.
2. Considering the serious nature of the problem a study committee was immediately formed by Govt. of Maharashtra to inspect the cause& suggest a possible remedial solution. After detailed deliberations, discussions and observations it was concluded that the problem had been created mainly due to illegal sand dredging carried out over a period of many years. (Approximate wash out of 15 to 16 meters of bed over the rock) Also, this had eroded substantial part at the base of the well foundation of P-5. Only 30% of the area of the well bottom was found resting on rock and was in a destabilized condition. Hence it was necessary to urgently stablise the well without further deterioration.
3. Glass strips were fixed over the crack at an interval of 1Meter each from the cutting edge of the well till soffit to observe any minute further damage (cracking) to the well, if any
4. Underwater investigation by means of scuba divers was summoned for, immediately.

4.Permanent Action

4.1:- Alternatives for Rehabilitation

After due deliberations, analysis and scrutiny, rehabilitation of bridge committee suggested followingfouralternatives .-

1) Construction of piles all around the P-5 well & transferring the super structuralload on pile cap. Later the unstabilised well to be abandoned/ dismantled.
2) Construction of new well foundation surrounding the existing well by means of sheet piling and transferring pier-on new well cap.
3) Establishing new well on U/S side of existing well and providing common well cap for counter balance of super structure load.
4) Construction of group of piles on U/S and D/S side with pile cap and transferring the super structure load on it.

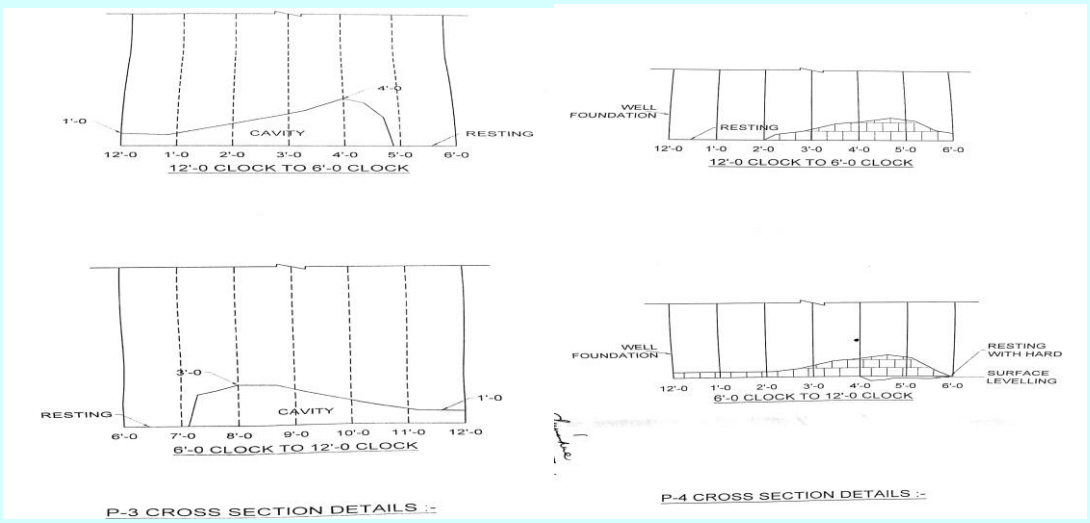
As first three option were found to be difficult for emergency execution and uneconomical, Option 4 was selected for execution and estimation was done for that scheme for inviting "C" (Lump sum) tender. Finally the scheme submitted for independent portal system consisting of pile foundation was selected for award of contract.

In this scheme, it was proposed to raising up of independent scheme of pile system on U/S & D/S side of existing distressed well foundation and complete load is to be transferred on new safer system of structures.The department appointed Mr.D.K. Kanhere,Jt. Managing Director, MSRDC *(Retd.),* as departmental special consultant to scrutinize and approve the scheme and methodology submitted by contractor for execution. The detailsare discussed further.

4.2 Methodology :-

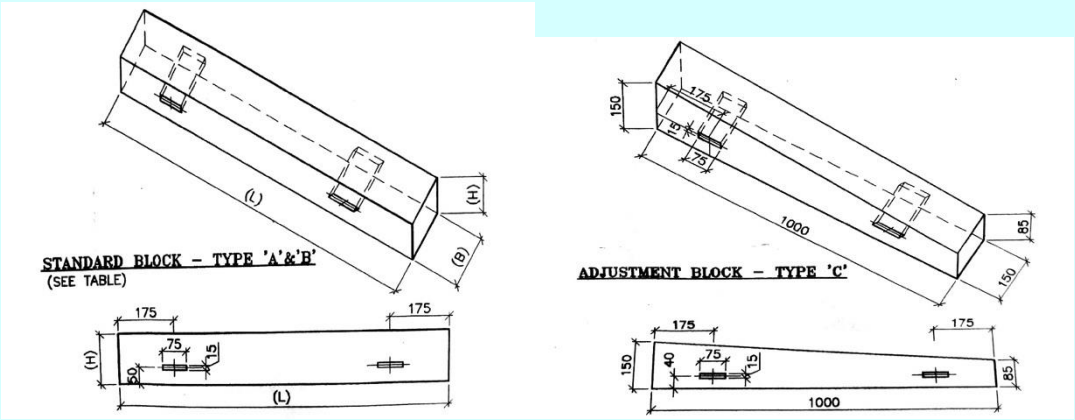
4.2.1 **<u>Geotechnical Investigation</u>**- Initially the detailed geotechnical investigation was done by taking two bore holes on U/S and D/S of existing well. The depth of bore holes was about 7.00 Meters from the bed to acertain existing condition in the river bed/ under neath strata.It was observed that hard rock found and hence it was decided to anchor the piles at this level.

4.2.2 **Under Water Suvery** - Under water survey was carried out for all well foundations, with expert divers and equipments. It was observed that all well foundations were in stable condition except P-3, P-4 and P-5. It is observed that the bottom of P-3, P-4 was exposed and there was gap between bottom and rock surface, though there was no tilting or any unusal distress found in these two structures. Separate scheme for stabilization of well no.3 was prepared; accordingly the work was carried on.



Position of P3 with 70 % founding Area **Position of P3 with 60 % founding Area**

4.2.3 **Stabilisation of distressed Well –** Initially the gap between the well bottom and ground was filled up by inserting wedge schemed precast M-40 RCC sleepers of required sizes in layers. The remaining gap was filled with 3 to 5mm thick M.S. Plates. The loose material on the sides was cleared with air compressed pressure. Then RCC ring beam of size 0.50mt x 1.00 Meter. was casted under water with quick setting adhesives. Finally cement grouting was carried out at the bottom of the well with required pressure using mechanical equipment and ramping. Similar treatment was given to P-3 and P-4 and the wells were made stable for any further distresses. All the works were carefully done by experienced scuba divers. The work was very critical and execution of work could be only done during the low tide (i.e. 4 hours in a day), which affected the work speed and time progress chart than proposed schedule.

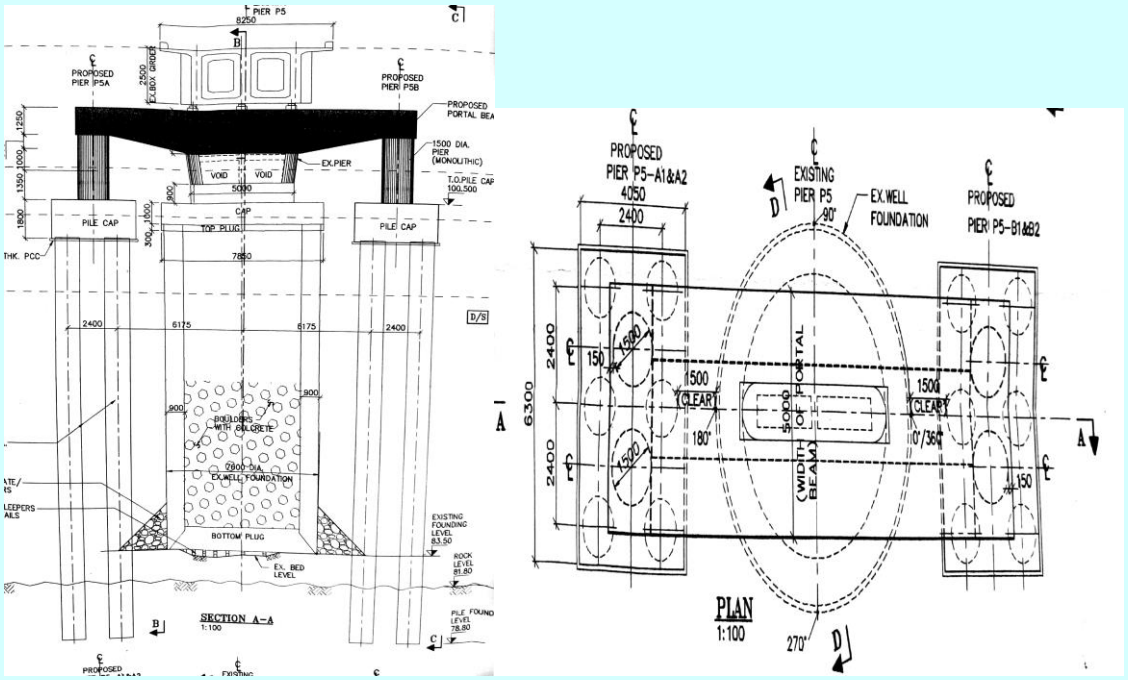


ELEVATION – TYPE 'A' & 'B'

DIMENSION TABLE – BLOCK TYPE 'A'&'B'

TYPE	(L)	(B)	(H)
'A'	1000	150	150
'B'	1000	150	100
'C'	1000	150	175
'D'	1000	150	200

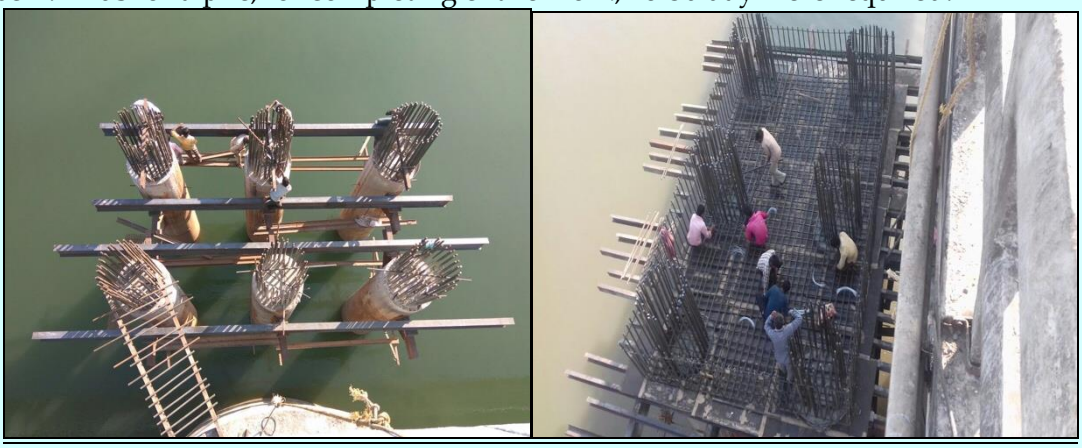
4.2.4 **Foundation** - On the basis of geotechnical investigation and survey, the load assessment of existing super structure was done and foundation was designed which consists total 12 number piles of 1200mm. diameter (Six on U/S and six on D/S). Accordingly for the construction of proposed piles temporary Jacks Platform on pontoon were constructed. As per IRC-78 the socketing depth of piles in rock required was 1.0 x D = 1.0 x 1.20 = 1.200 but where as minimum socketing depth in rock 3 x D = (3 x 1.20) = 3.60 meters was adopted for design. But for execution, socketting depth of 5 meters was recommended.



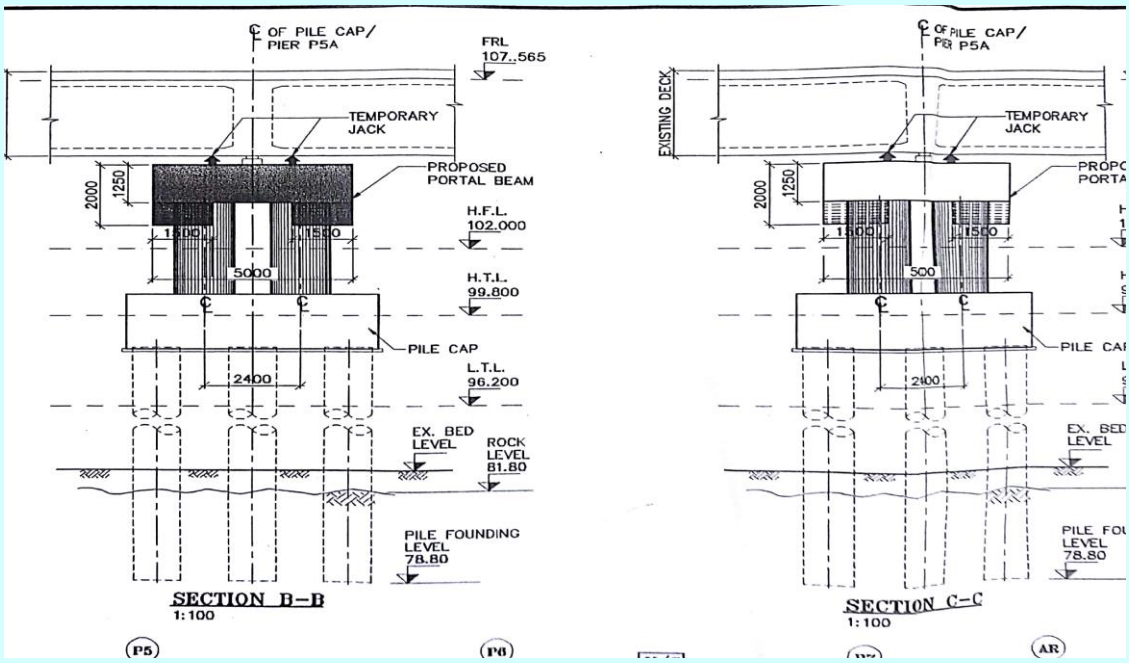
4.2.5 **Construction of bored Cast-in-situ piles**- Total 12 numbers of piles of 1.20meter diameter six on U/S and six on six on D/S were constructed by using 8mm thick M.S. liner used upto the refusal/rock level. The reinforcement cage as per the design consisting of 32 mm dia. – 52 no of bars was used and the concerting with M-50 Grade was done with the help of tremmie method with minimum slump of 150mm. After completion of all 12 numbers piles height upto existing well cap, R.C.C. pile cap was casted with 1800mm depth concrete. Above pile cap, 2 numbers on each side R.C.C.

Circular pier having 1500mm was Casted with M-50 Grade Concrete.

The piling work could be only executed during low-tide (i.e. 4 hours/day) in non-rainy season. Also, due to the strata, the pile during could be only achieved upto 40cm. Thus for a pile, for completing entire work, 28-30 day were required.



4.2.6 **Quality Control &Assesment** : - For all concrete work, mix design was prepared by Government of Maharashtra'sregional laboratory of V.Q.C.C. (Vigilance& Quality Control Circle) and all materials were tested before construction. As per mix design the concrete work was carried out. Necessary care was taken to keep the quality of work and material as per specifications. For steel reinforcement, CPCC coating was used for anti-corrosive treatment.



4.2.7 **Portal Beam-** Theportal beam spanning between already constructed circular piers consists of 2 beams with varying depth of 1250mm at support to 2000mm. at mid span. These 2 beams are connected by 1250mm dia. Meter thick slab. In first stage these two portal beams along with diaphragrh/ slab of 1250mm.depth completed except the middle portion of existing R.C.C. Pier.

Form work for Portal Beam

After the curing period of portal beam, the load of superstructure was transferred on portal beams with the help of specially designed hydraulic Jacks of 400 M.T. Capacity each. Total six numbers of Jacks are used (3 on each sides) and temporary supports of chairs (fabricated by 12mm thick M.S. plate)parallelyprovided.

During the load transfer activity the light vehicle traffic was totally stopped for one day. The activity started at 9.00 am. Morning and finished at 3.00 pm. At noon. Evening the light vehicle traffic allowed to ply on bridge.

4.2.8 **Dismantling of existing R.C.C. Pier**– Removing of existing R.C.C. pier was a challenging job.Also, the well & pier bothwere tilted and unstable uptocertain stage,The superstructure load was then transferred on portal beams by the support of hydraulic Jacks. With vigilant observation and precautions the existing R.C.C. pier was dismantled with the help of hydraulic breakers. There were no distress changes observed in tilted well and it was found to be stable in its position.

Casting of portal beam **Dismantling existing pier**

4.3 The work to be executed and in progress.

4.3.1 **Casting of Stitch Concrete –** The middle portion (9.00Meter x 1.90 Meter x 1.25 Meter) of **portal** beam which is not casted due to existing pier is to be casted. As per design, steel rods are extended for lapping purpose in second stage concrete. The lapping is proposed be done by using couplers and conventional lapping method. In coupler system 25mm.dia. Rodsthreaded for 65mm length & joined with the help of S. S. couplers. The strength of coupler is to be tested duly before casting the concrete.

4.3.2 **Pedestal & Bearing** - After the curing period of stitch concrete, R.C.C. pedestals is proposed tocasted with M-50 concrete as per design. Subsequently, neoprene pad bearingswill be kept on pedestals and finally the super structure load will be transferred on regular and permanent pedestals.

4.3.3 **Repairs to Super Structure**– Complete exhaustive mapping of super structure (Box Girder) is carried out including locations & thickness depth etc. to ascertain measures for repair. The detailed scheme is taken by contractor for filling the cracks by grouting or any other suitable means depending on the type, depth and location of cracks. As per scheme the repair work will be completed. Also, the structural stability report of box girder is submitted by contractor. There is no major distress in super structure. The loss of prestressing is checked and necessary action of restoration of concrete is being done

5. Conclusions –

5.1 Tilting/Failure of well foundations in similar circumstances may occur at variable locations with different geological and bedding conditions. The deliberations discussed and mentioned in this paper, suggestone solution to such problems.IRC may bring out a set of journal with case studies andsuggest suitable standards and methodology by publication of special issue.For such critical conditions, also, standardization of specifications and procedures to be adopted for under water exploration may be brought out in special publication. The safety norms mandatorily need to be standardised for theses explorations.

5.2 Destabilizationof R.C.C. well foundation by uncontrolled sand dredging, causing

major structural distress for bridges is observed in many cases. As per study committee opinion the reason for tilting of well is, unlimited and uncontrolled sand dredging at bridge locations and also on upstream & downstream sides of bridges. So, for such type of all creek and river bridges, periodical under water survey and investigation is necessary and sand dredging at bridge area and at least 500 meters on upstream and down stream side of bridges shall be strictly prohibited and shall be totally banned by District Magistrate to avoid such incidents and consequent traffic disruption issues.

5.3 It is very important to carry out annual under water survey beneath the water level for health assessment of foundation of bridges. For such activities, limited supply of services and knowledgeable staff is available. Hence, advance courses in under water explorations in civil engineering along with professional courses for structural engineers may please be conducted to increase awareness amongst the field engineers.

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Environment Friendly Cost Effective Sustainable Technologies in perspective of Rural Roads

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Introduction

Rural Road Connectivity being a key component of rural development by promoting access to economic and social services and thereby generating increased agricultural incomes and productive employment opportunities. It is also, a key ingredient in ensuring sustainable poverty reduction. In the past, many programmes have been initiated by Government of India as well as different State Governments with a focus on rural infrastructure. In the recent budget also Government of India has focused on much needed boost to rural infrastructure. However, the requirements are huge and the pace of delivery needs to be improved, with available resources. The main thrust is to build good quality, sustainable and environment friendly road infrastructure in rural India. Construction of road infrastructure in rural roads is mostly traditional and availability of natural construction materials, limited working time, skilled manpower, limited resources for maintenance are some constraints in creating environment friendly and cost effective sustainable Rural Roads. Pradhan Mantri Gram Sadak Yojana is a flagship programme of Government of India in which some of these technologies have been adopted and evaluated. The present paper is an effort to discuss some of the environment friendly, cost effective and sustainable technologies which can be adopted in construction of rural roads for faster delivery and proper upkeep of rural roads.

Stabilized Base and Sub Base courses.

In construction of rural roads traditionally granular sub-base course and water bound macadam base courses have been practised. However, the scarcity of these materials has led to very high unit costs. As an alternate, locally available materials can be stabilized using stabilizers like cement or lime for construction of stabilized base and sub-base courses. Many commercial materials, accredited by Indian Roads Congress (IRC) are also available in the market which can be used for stabilization. The stiffness and tensile strength of the materials are sufficiently enhanced by the addition of cement or any other commercial stabilizer to have a practical application in stiffening of the pavement. Cement-Treated Base (CTB)/ stabilized base (using commercial stabilizer) is an intimate mixture of soil and/or aggregates or granular soils combined with measured amounts of Portland cement and water that hardens after compaction and curing to form a durable paving material. A bituminous or Portland cement concrete wearing course is placed on the CTB to complete the pavement structure. CTB is widely used as a pavement base for highways, rural roads, parking areas, airports, and materials handling and storage areas. In CTB construction the objective is to obtain a thorough mixture of granular material with the optimum quantity of cement and adequate water to permit maximum compaction. The completed CTB must be adequately cured to both let the cement hydrate and to harden the cement-aggregate mixture. Major steps involved in the process of construction of cement treated base/ sub bases are:

- Fixing the type and dosage of Stabilizing agent/cement considering the properties of soil
- Preparation of ground to be stabilized
- Mixing of cement with soil/aggregate
- Compaction and Finishing
- Joint Construction
- Curing of the compacted soil

Fig.1. In-situ mixing by using rotavator

Fig.2.In-situ mixing by Agricultural Disc Harrow

Fig.3. Compacted layer after curing

Fig.4.Completed road

Stabilization of local materials using cement and other commercial stabilizers such as RBI-81, Terrazyme, Soilteck MK-III, Zycosoil etc has been adopted under PMGSY and a total length of 663 km has been constructed till March, 2018. Most of the roads are performing well with usual routine maintenance. Adoption of such stabilization practices, has resulted in cost of construction varying from 5-15% as well as protection of environment because of utilization of local materials for stabilization and reduction in requirement of costly aggregates for base and sub base courses.

Cell Filled Concrete Technology

This technology has been developed by IIT Kharagpur and is well known as Cell filled Concrete Pavement technology. It has proved to be very promising solution for long lasting (permanent asset), low initial cost and maintenance free roads together with employment generation opportunity in rural areas. The technology consists of covering the compacted sub grade / sub base with a formwork of plastic cells as shown in **Figure 5**. The form work of plastic cells is stretched and iron spikes are driven at the corners of the cells so that the form work remains taut. Nylon ropes through the cell walls prevent collapse of the cells during the placing concrete or stones into the cells. The plan of the formwork will appear as shown in **Figure 6** on stretching.

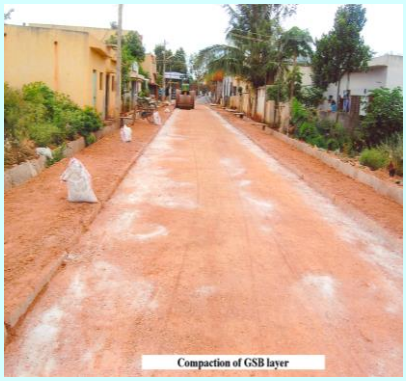

Fig. 5 Welding and stitching of plastic sheet strips at 300 mm interval

Fig. 6 A view of stretched cell placed over compacted GSB layer

Different types of concrete such as conventional concrete/ zero slump concrete with a 28 day characteristic strength of 30 MPa is placed into the cells. Since the subgrade/subbase have the proper camber, the top of the cells also will have the same camber. After leveling the concrete, a vibratory/static road roller of 6 to 8 ton capacity may be used for compaction.

Fig. 7.Curing of concrete

Fig.8. Completed Road

Cell Filled Concrete Pavements have been adopted in different states under PMGSY. The construction cost of such pavement is almost equal to a bituminous pavement. Under PMGSY a total length of 237 km has been constructed till March, 2018 in West Bengal, Karnataka, Mizoram, Rajasthan, Madhya Pradesh. Most of the roads are performing well with usual routine maintenance. Adoption of cell filled concrete technology has resulted in cost of construction varying from 30-40% (with respect to cost of construction of concrete pasvements) as well as protection of environment because of utilization of local materials for sub base stabilization and reduction in requirement of costly aggregates for base course because of substantial reduction in thickness of pavement. Such roads can be constructed almost at the cost of bituminous pavement.

Panelled Concrete Pavement

This consists of 100 mm thick concrete slab laid over granular subbase (GSB). If heavy traffic is anticipated, the GSB may be treated with 2 to 3% cement to get a strength of about 3 MPa at 7 days. The cement concrete slab is weakened by cutting 25mm to 30mm deep grooves by a stone cutter so that the slab forms interlocking panels. The grooves may be filled with bitumen. The panelled concrete pavement can be laid over damaged premix carpet for rehabilitation.

For 1 km length, 3.75m wide and 100 mm thick panelled concrete pavement, the concrete needed is 375 m3 whereas for the same length and width the thickness required for plain concrete pavement as per IRC SP : 62- 2014 is about 200 mm and concrete required is 750 m3. The panel size is 0.5m x 0.5m for thickness of 100mm and for a maximum wheel load of 8 tons. The cost is almost 60% of

the cost of 200mm thick M 30 grade standard cement concrete pavement considering the cost of cutting of joints in panelled cement concrete pavement. This gives a saving of almost 30 to 40% in the cost of cement concrete pavement.

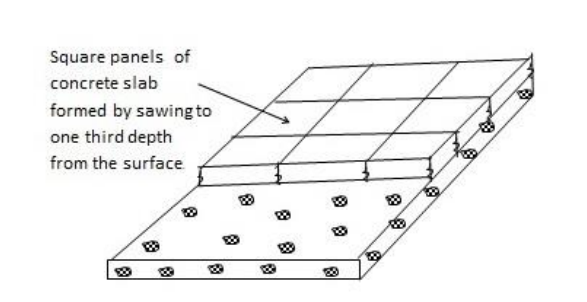

Fig. 9 Typical Panel Concrete Pavement

Fig.10. Completed Road

Paneled Concrete Pavements have been adopted in different states under PMGSY. The construction cost of such pavements is almost equal to a bituminous pavements. Under PMGSY a total length of 93 km has been constructed till March, 2018. Most of the roads are performing well with usual routine maintenance.

Cold Mix Technology

In the hot mix technology generally used for paving, the aggregates and binder are heated to specified temperature, mixed in desired proportion, transported to the work site, placed, and compacted while the mix is still hot. The laying and compaction is to be carried out at temperatures above 110 degree Celsius. Bituminous road construction using conventional paving grade bitumen (i.e hot mix technology) is sometimes not technically feasible and logistically in high rainfall areas, as intermittent rains throughout the year affects the production and laying of hot mixes. Similarly, at high altitude and/ or in snow-bound areas, very low pavement temperatures make laying of hot mixes rather impossible. Bituminous hot mix technologies create environmental pollution by way of high emission, consume high amounts of energy and the mix gets cooled during transportation from long distances leading to compaction problems. It also has limitation for use in wet and low temperature conditions. Because of air quality restrictions, the hot mix plants are also prohibited in certain metropolitan areas. In the cold mix technology, the aggregates and binder are mixed, transported, placed, and compacted in cold state. The cold mix technologies, on the other hand, use environmental friendly materials and techniques involving use of bitumen emulsion, which can provide effective, energy efficient and long lasting solutions

Cold Mix technology can be used as an alternative method of laying hot mix asphaltic roads. The simple process of mixing unheated mineral aggregates with suitable grade of Bitumen Emulsion having suitable workability during mixing at plant or site, and maintain specified residue Binder content.

In rural road network, bituminous construction is carried out only of a thin layer where it works as a wearing course on a Water-Bound Macadam (WBM). A 20 mm open graded premix carpeting1 (OGPC) is applied followed by a seal Coat using 6.7 mm aggregates with 5-10% fines. In India, Indian Road Congress (IRC), the apex body for developing specifications and procedures for roads and bridge construction, has published guidelines on "Use of Cold Mix Technology in construction & maintenance of roads using bitumen emulsion", as IRC : SP: 100:2014. The basic system of cold mix methodology is to use higher quantity of bitumen emulsion as a binder to get the desired

bitumen content on the road surface as evaporation of water shall take place. Bitumen Emulsions used are as per Specifications developed by Bureau of Indian Standards code IS 8887:2004.

Aggregate quality and grading requirement for 20 mm Open graded premix carpeting (OGPC) with Bitumen Emulsion (Cold Mix) is similar to the aggregates used in Hot Mix. Medium setting grade with a medium to high viscosity range of Cationic Bitumen Emulsions is used for carpeting works in India having minimum 65 % of binder content, where open graded aggregates are used.

Successful implementation of Cold Mix technology depends upon the mix design of the mixes prior to the start of the work. The emulsion manufacturer has to play a major role in selection and indexing of appropriate quality of emulsions based on various parameters noticed in the Cold Mix Design Laboratory. A close co-operation with the emulsion manufacturer, contractor and government department is the main criteria for successful implementation of cold mixes on site using the application support service**.**

Fig. 11 Cold Mix Material

Fig12 Cold Mix Road after Five years

Considering the numerous advantages of Cold Mix Technology using Bitumen Emulsion and the weather conditions, Cold Mix Technology has been adopted on large scale in construction of Rural Roads in PMGSY. The performance of this technology has been evaluated on some selected roads in the States of Assam, Meghalaya & Uttarakhand by IIT, Guwahati and TERI, Delhi. Most of the roads are performing well with usual routine maintenance.

It has been reported that a saving of about 4002 Kg of CO_2 emissions can be made by using Open Graded Pre Mix Carpet per km of 3.75 m wide road length in place of hot mix paving method commonly used for rural roads. Cold Mix Technology has been adopted in different states under PMGSY. Under PMGSY a total length of 4812 km has been constructed till March, 2018 in the States of Assam,West Bengal, Karnataka, Meghalaya, Sikkim, Odisha, Bihar, Andhra Pradesh, Mizoram, Madhya Pradesh. Thus, reduction of Carbon footprint (CO_2 emissions) of about 19,257 tonnes has been made contributing a lot to protection of environment.

Conclusions

Some of the technologies presented above have been used and their performance is found to be satisfactory with advantage of cost economy, protection of environment and sustainable roads and can be adopted on large scale for construction and maintenance of rural roads.

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Advantages of Laser Scanning for 3D Road Profiling

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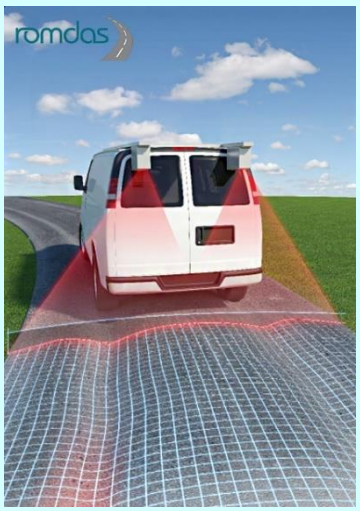
Overview:

Those in the industry of managing roads are likely aware of trends towards using high-speed scanning lasers to collect pavement condition data. The most commonly recognized, being Laser Crack Measurement System (LCMS). These scanning lasers have been incorporated into survey systems by several manufacturers and are no longer exclusively used on road networks in Europe and Northern America, instead becoming more and more sort after in developing countries like India.

While this trend might be known, the range of technological and practical benefits of using this equipment is less widely understood. Furthermore, it is also taking time for engineers and institutions to develop ways of utilizing the new dataset offered by LCMS and 3D profiling. Because LCMS outputs roughness, rut depth and other typical dataset; most engineers will simply format and apply these datasets to existing maintenance and planning templates. However, there is a wealth of additional information obtained by LCMS which could provide new benefits to engineers, both at a project and network level.

This article is aimed at providing a clear, and somewhat simplified, overview of how LCMS records and then processes pavement condition. It will also try to highlight some of the unique advantages of this technology over traditional survey equipment, ending with a specific example from New Zealand on how a new dataset is being utilized at the project level.

LCMS Operating Principles



The first myth to dispel is that it is a standalone system. LCMS needs to be integrated into a larger data collection system. The manufacturers of LCMS provide the scanning lasers and develop the processing algorithms to calculate the various datasets; however they then provide these sensors to 'system integrators' who integrateLCMS into their survey systems. This means the performance and accuracy of LCMS should be the same between system manufacturers offering LCMS.

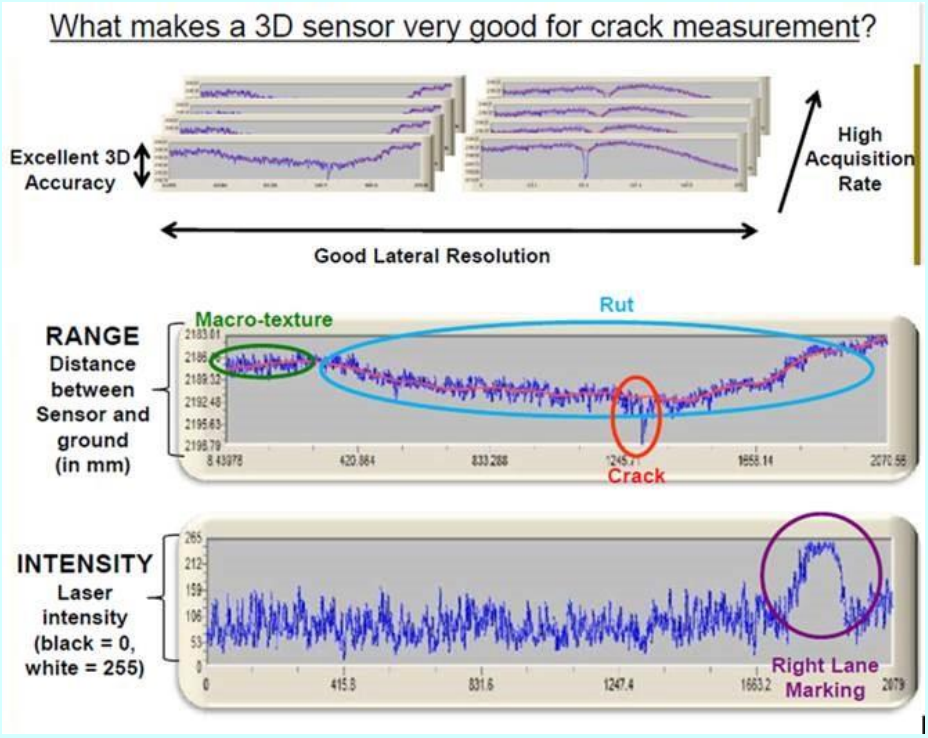
A typical Network Survey Vehicle (NSV) would often include additional components like High Resolution distance Measurement Instrument, hardware interfaces, Right of Way (ROW) cameras, GPS receiver and all controlled by central data collection software. In practice the key differences between

manufacturers tend to be the features of the peripheral components and software which makes NSV as very user friendly equipment.

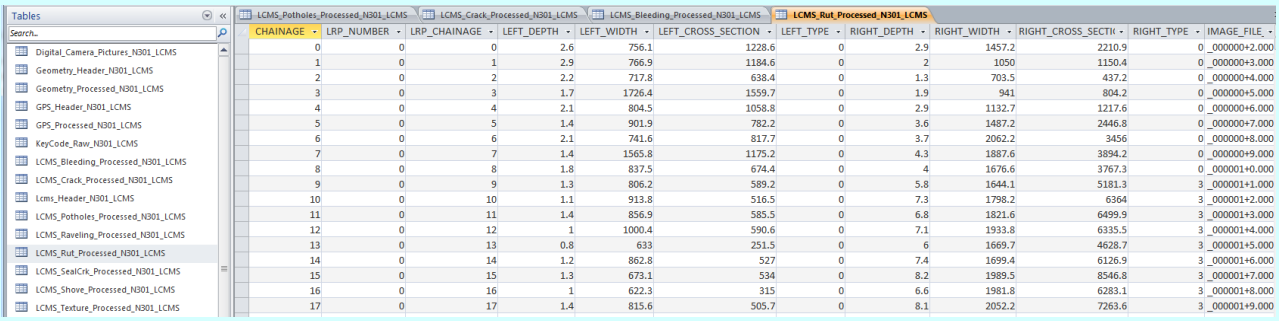
In its simplest form the methodology of LCMS itself can be summaries into 2 steps…

Step 1: Record a high-resolution 3D profile of the road surface
As the LCMS is driven down a road it scans a 4m profile across the lane. It records 5,600 of these transverse profiles per second and combines them together to create a very high resolution 3D profile of the road.

Step 2: Analyze the 3D profiles with algorithms to identify surface defects
Once the survey is complete processing algorithms are applied to analyze the 3D road profile. Typically these algorithms are looking for specific trends in the profile which are associated with certain defects.



At the end of this processing phase most manufacturers will outputs summaries of each dataset and JPEGs images of the pavement surface with defects and severities overlaid.



CHAINAGE	LRP_NUMBER	LRP_CHAINAGE	LEFT_DEPTH	LEFT_WIDTH	LEFT_CROSS_SECTION	LEFT_TYPE	RIGHT_DEPTH	RIGHT_WIDTH	RIGHT_CROSS_SECTI	RIGHT_TYPE	IMAGE_FILE_
0	0	0	2.6	756.1	1228.6	0	2.9	1457.2	2210.9	0	_000000+2.000
1	0	1	2.9	766.9	1184.6	0	2	1050	1150.4	0	_000000+3.000
2	0	2	2.2	717.8	638.4	0	1.3	703.5	437.2	0	_000000+4.000
3	0	3	1.7	1726.4	1559.7	0	1.9	941	804.2	0	_000000+5.000
4	0	4	2.1	804.5	1058.8	0	2.9	1132.7	1217.6	0	_000000+6.000
5	0	5	1.4	901.9	782.2	0	3.6	1487.2	2446.8	0	_000000+7.000
6	0	6	2.1	741.6	817.7	0	3.7	2062.2	3456	0	_000000+8.000
7	0	7	1.4	1565.8	1175.2	0	4.3	1887.6	3894.2	0	_000000+9.000
8	0	8	1.8	837.5	674.4	0	4	1676.6	3767.3	0	_000001+0.000
9	0	9	1.3	806.2	589.2	0	5.8	1644.1	5181.3	3	_000001+1.000
10	0	10	1.1	913.8	516.5	0	7.3	1798.2	6364	3	_000001+2.000
11	0	11	1.4	856.9	585.5	0	6.8	1821.6	6499.9	3	_000001+3.000
12	0	12	1	1000.4	590.6	0	7.1	1933.8	6335.5	3	_000001+4.000
13	0	13	0.8	633	251.5	0	6	1669.7	4628.7	3	_000001+5.000
14	0	14	1.2	862.8	527	0	7.4	1699.4	6126.9	3	_000001+6.000
15	0	15	1.3	673.1	534	0	8.2	1989.5	8546.8	3	_000001+7.000
16	0	16	1	622.3	315	0	6.6	1981.8	6283.1	3	_000001+8.000
17	0	17	1.4	815.6	505.7	0	8.1	2052.2	7263.6	3	_000001+9.000

Figure 2: Example of tabular data from ROMDAS (LCMS-Rutting)

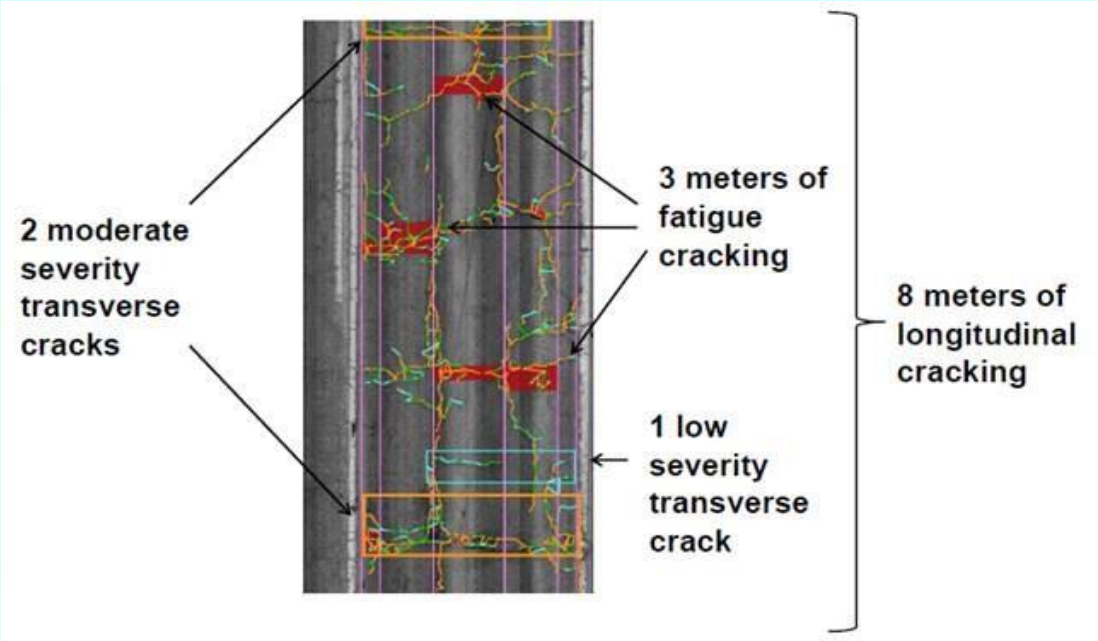


Figure 3: Example of JPEG image with defects

List of outputs

Due to the two-step process of collecting 3D profiles and then using algorithms to identify defects, this allows Pavemetrics to develop new algorithms and export new datasets without physical hardware changes. Below is a current list of the typical data outputs from LCMS; however this may grow as Pavemetrics released new processing algorithms.

- ✓ Road crack detection (length, depth, width)
- ✓ Road rut detection (width, depth, cross-sectional area and type)
- ✓ Road macro-texture evaluation (MPD)
- ✓ Road ravelling evaluation (RI – ravelling index)
- ✓ Pothole detection (area, depth, volume)
- ✓ Sealed crack detection
- ✓ Detection of man-made objects (e.g. manhole and storm drain)
- ✓ Bleeding and Pick-Outs
- ✓ Detection of lane markings, shoulders, drop-offs, curbs
- ✓ Detection of joints and faulting on concrete roads
- ✓ Longitudinal Profile and Roughness (IRI)
- ✓ Road Geometry (gradient, cross-slope and radius of curvature)

It's useful to note that automatically recording many of these defects, especially to this level of detail, while travelling at highway speeds is only achievable because of the scanning technology used.

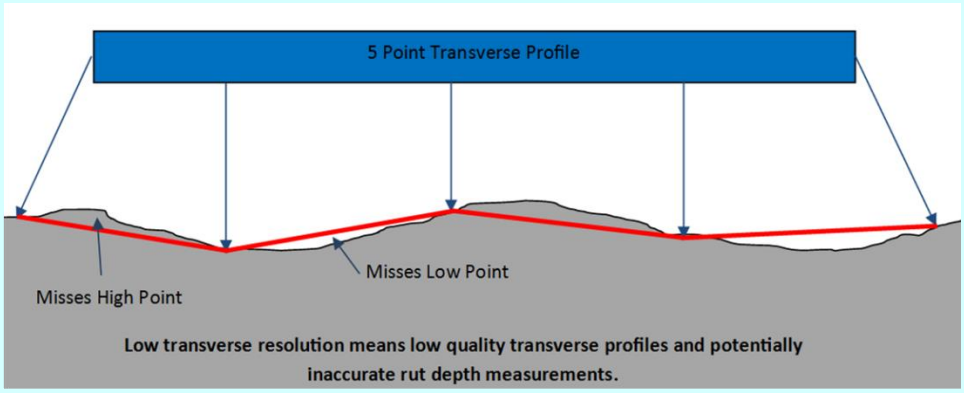
What has been used in the past and why is LCMS better?

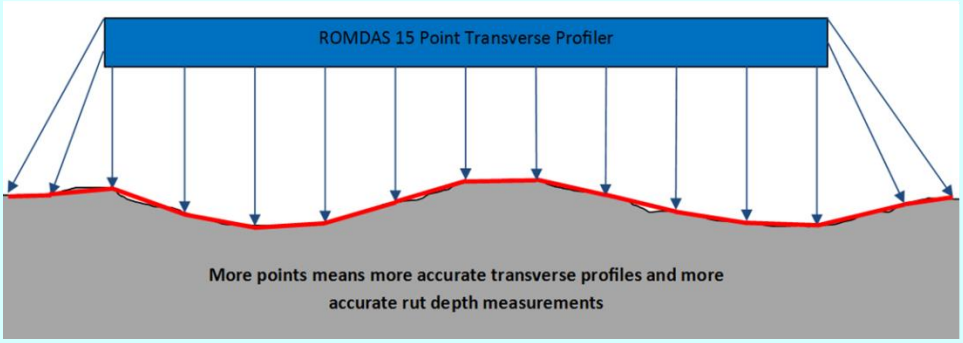
To understand how LCMS is different, it is important to understand the principles of how traditional devices normally work and how this contracts to the operational principle of LCMS.The following is a summary of commonly used equipment superseded by LCMS scanning lasers;

TRANSVERSE PROFILER

This device is mounted to the bumper and typically uses 5-20 'single point' lasers to collect a transverse profile across the lane. These profiles are then analyzed to calculate the depth of rutting in each wheel path.

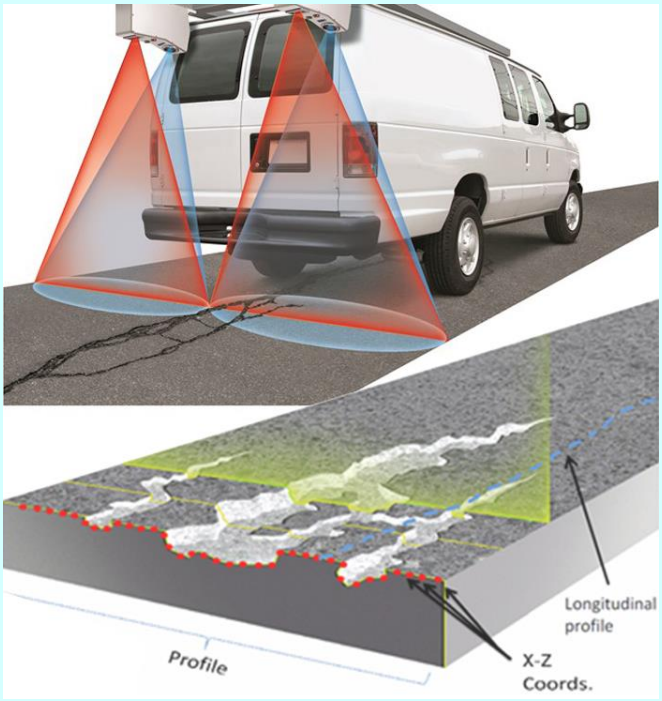
The limitation for this equipment arises from the use of 'single point' lasers. When it comes to collecting transverse profiles the more 'points' the better. More points mean higher resolution transverse profiles and therefore more accurate rut depth calculations. The diagram below shows the difference between a 5 and 15 point transverse profile.





Why is LCMS better?... 4,000 point transverse profile!

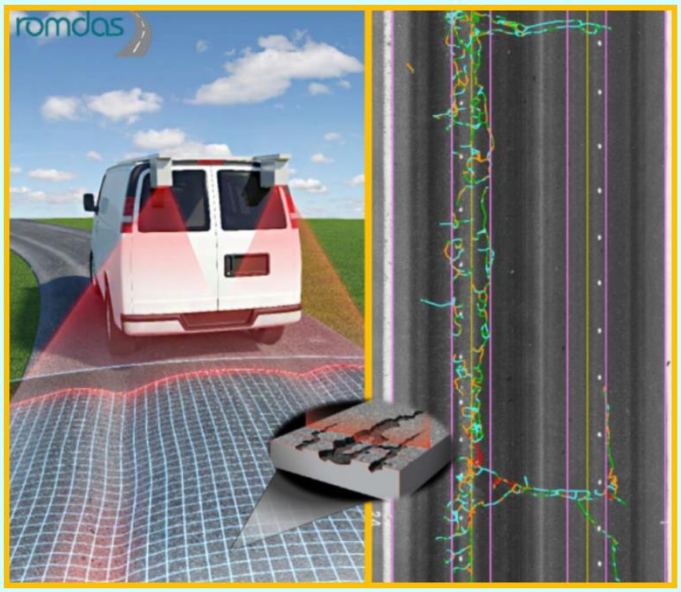
Even with 20 lasers, a transverse profiler would still have about 150-200m between each 'point'. This is acceptable to calculate rut depth, however these profiles are not detailed enough to detectother defects like cracking, potholes, rut width, rut cross-sectional area, raveling etc... By comparison, using 2 scanning lasers, rather than an array of 'single point' lasers, means LCMS can generate transverse profiles of +4,000 points. It is this resolution that allows LCMS to see and identify a wide variety of pavement defects present in its 3D profiles.



PAVEMENT CAMERAS USED FOR MANUAL EXTRACTION OF VISUAL DEFECTS,

2D pavement cameras have been used for many years to record pavement distresses; some even utilize software to extract visible defects from the images. Given the extreme demands of surveying at high-speed these systems tended to require high-end and expensive cameras, often needing significant lighting systems to overcome the influence of shadows or poor ambient light.

Why is LCMS better?... Images created from 3D profiles!



LCMS integrates laser light cameras and can therefore provide pavement imagery in any lighting conditions, even allowing operators to survey in complete darkness. During processing the pavement images are automatically imprinted with the cracking and defect data identified in the 3D profiles.
The other main advantage is the ability to accurately measure depth of specific defects. The scanning lasers measure a 3D profile and each 'point' (+4,000 per transverse profile) has a height resolution of 0.25mm. These height measurements allow for accurate depth and volume calculations, which 2D cameras are unable to achieve. For example LCMS can measure crack depth, pothole depth and volume, height of concrete joints/faulting and rut cross-sectional area.

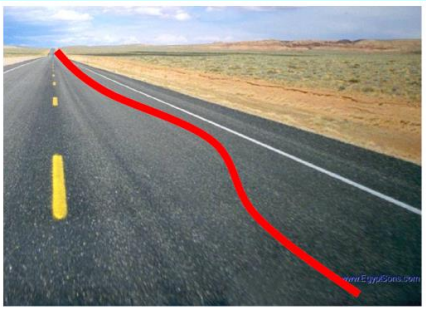
LASER PROFILOMETER

Typically Laser Profilometers are used to collect longitudinal profiles and calculate road roughness, normally in terms of International Roughness Index (IRI). These units tend to comply with ASTM950 and consist of a 'single point' elevation laser and inertial measurement unit (IMU) to output a profile and IRI in each wheel path. Some Laser Profilometers use higher frequency lasers to measure profiles with <1mm spacing. These higher resolution profiles are then used to calculate surface Macro-texture, normally in terms of Mean Profile Depth (MPD).

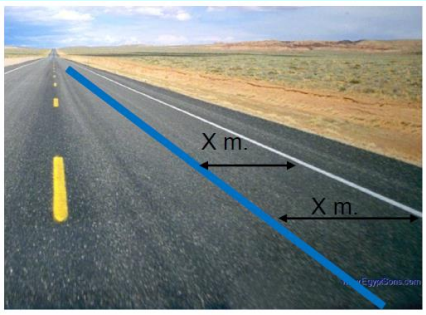
Similar to the nature of traditional transverse profilers, one limitation of Laser Profilometers is the use of a single point laser. This restricts the data collected to a thin line where the laser has directly measured. By definition, IRI is measured in the lane's 'wheel paths', if the vehicle wanders outside of the wheel paths then single point lasers cannot recognize this and it may affect the IRI results.Furthermore, if there are variations in Macro-texture outside where the laser has measured, then this is not recorded and results may not be a true reflection of the macro-texture across the whole lane.

Why is LCMS better?……..Full lane width profiles and Lane tracking to eliminate driver 'wander'!
When processing Macrotexture the LCMS can use its full lane width profiles to calculate MPD across the whole lane. Results are then summaries into 5 customizable bands to provide a truer understanding of the road's macrotexture condition.

Most manufacturers offer an upgrade to add IMUs the standard LCMS lasers, this then allows for the collection of longitudinal profiles and roughness (IRI) data in compliance with ASTM950; the same as Laser Profilometers. However, LCMS can go a step further than standard Laser Profilometers. By identifying the lane markings and then positioning the roughness profiles to always align with the 'wheel paths' essentially eliminatingthe effect of vehicle wander within the lane.



Classic system: Results depend on the trajectory of the vehicle (subject to variation based on driver's ability)



LCMS-IRI system: Erratic trajectory of the vehicle will still result in straight elevation profiles

This lane tracking feature also has benefits for other datasets, as it can exclude any measurements and anomalies outside the lane markings which might influence the accuracy of results.

ROAD GEOMETRY UNITS

Traditionally this device is used to measure the road's gradient, cross-slope/super elevation and radius of curvature. Like roughness, most manufacturers offer an upgrade to also output road geometry from LCMS. WhileLCMS doesn't offer many practical advantages over the traditional devices, it does mean that using the LCMS geometry upgrade eliminates the need for a dedicated Road Geometry device in the vehicle.

Example: Application of Rut Cross-sectional Area in New Zealand
In addition to the typical road condition indicators, this new scanning technology is providing engineers with levels of detail previously not available. The task now is to find practical ways of applying this new information which leads to increased efficiency and better decision making.

A good example of this comes from NewZealand during the construction of a 4 lane expressway near Auckland. The expressway was officially opened with a chip seal surface. It was trafficked for a full winter before the final AC layer was laid, giving the pavement time to settle.Before the AC was laid, Data Collection Limited (DCL) conducted a high speed condition survey with their ROMDAS brand LCMS system.

The general goal was to perform compliance testing aimed at identifying problematic areas that may require additional work before the final AC layer was applied.

Traditional methods only provide information on rut depth. The additional information (width and cross-section) helped give a truer understanding on how the pavement was performing.Specifically, the contractor obtained the cross-sectional area of each rut summarised at 1m intervals.

Knowing the cross-sectional area made it possible to calculate the volume of rutting along the road. This allowed the contractor to calculate how much additional AC was required to level the pavement surface before applying the final AC layer.

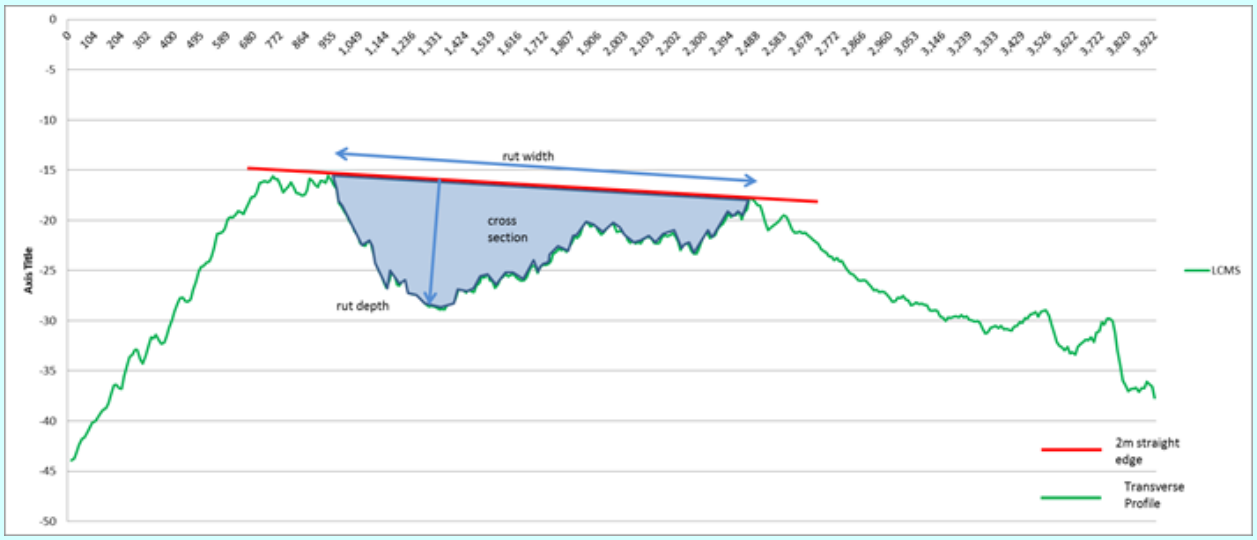


Figure 4: Graph of an LCMS transverse profile and how rutting attributes are determined.

CONCLUSION

Network Survey Vehicle is a comprehensive tool to evaluate the overall riding quality of the road. The parameters captured by the use of NSV, which include, but are not limited to crack measurement, rut measurement, macrotexture, raveling, potholes, bleeding etc also form an integral part of safety of roads. Today one can not dissociate Safety from Riding Quality. The riding quality parameters captured through Network survey vehicle however fail to address the important aspect of safety, which is usually associated with skidding under wet conditions.

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A Logical Approach For Performance Evalution of Bridge Expantion Joints

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Expansion joints are provided to accommodate all sorts of movements of bridge decks on account of traffic and environment effects. If not properly installed, these joints can be the potential source for problems for highway bridgescontributing towards riding discomfort and noise pollution. In India, a number of small to medium span bridges have traditional expansion joints, such as open gap joints, buried joints, sealed joints, sliding plate joints, strip seal joints and slab seal joints. Since the last 20-25 years, long span bridges such as balanced cantilever bridges, cable stayed bridges, cable suspension bridges,and extra-dosed bridges, have gained popularity. Designers are providing minimum number of joints to increase the passengers' comfort. Nowadays, large movement joint such as finger type joints, modular type joints, are more frequently used. Manufacturers are introducing innovative joints day by day. However, long term post-installation performance of such joints is not widely reported.

Performance of an expansion joint depends on – (i) proper design of joint fulfilling the functional and structural requirements, (ii) proper quality assurance during fabrication and assembling of the joint, (iii) proper installation of joint, (iv) proper maintenance of the joint.

Globally available guidelines suggest two types of performance evaluation criteria for bridges deck joints. The first type is the product specification criterion. In this criterion, the specifications of the product and its components are compared with the acceptable domain of specifications as per the governing standards. In this context, various tests are performed on the component materials as per the governing standards. Various tests which are to be conducted fall under the category of Routine Tests (Material Tests). The second type is the performance criterion. The focus of this criterion is on the performance of new and / or existing bridge deck joints which have exhibited good performance through successful installation and long term field trials. The criterion focuses on the critical components and actions in the joint, as these are the areas where failure is expected. In general, the tests needed for the evaluation of expansion joints may be broadly classified as those pertaining to elastomeric material or steel and those related to the entire assembly including anchorages.

The Routine (Material) tests are related to – hardness, specific gravity, tensile strength, compression set, creep, adhesion strength, accelerated aging, ash content, polymer content i.e. polymer identification test, crack detection i.e. dye penetration test.

The tests for expansion joint assemblies and their components fulfilling the performance criterion are – static strength test, fatigue test, braking test / traction test for shape stability, cyclic motion test, pull out test.

In Austria, the acceptance criteria for expansion joints are based on their actual testing. The tests like Pull out test, Debris expulsion test, are correlated with other major tests like Cyclic Motion test and Braking test respectively. TRB guidelines also suggest the acceptance criteria on the basis of the actual testing of expansion joints. In U.K., actual testing is carried out for acceptance purposes. However, in South Africa, the Routine tests (Material tests) and some minor performance tests like Water tightness test, are conduct on the joints. For major Performance tests like Fatigue test, Braking test, Cycling Motion test, the manufacturers are asked to produce Certificates from the independent laboratory where such tests have been carried out on the joints. In Germany, the Material tests and Minor Performance Tests are carried out on the joints by the manufacturers at their establishment. For major Performance tests like Fatigue test, Braking test, randomly selected specimens are tested in an independent laboratory. The quality assurance of the expansion joints manufacturing process is taken care of by the Routine Internal Supervision and the Periodic External Supervision.

The acceptance criteria as per IRC guidelines (IRC SP-69: 2011) suggest the actual testing of joints and their assemblies as far as Routine tests and the minor Performance tests like water tightness test, debris expulsion test, pull out test, cyclic motion test, anchorage bend test, are concerned. For major Performance test like fatigue test, the manufacturer is required to produce certificates from an independent laboratory (at present, the laboratories of the abroad universities / research institutes) as a proof of quality assurance. This is due to lack of availability of suitable testing facilities in our country.

A critical review of the available guidelines, especially the IRC guidelines (IRC: SP-69: 2011), gives the impression that the post installation evaluation of joint has not been addressed properly. Due to lack of an acceptance criteria based on the actual performance testing, a number of installed expansion joints have exhibited signs of early distresses in our country. The factors which affect the post-installation performance of expansion joints are–load v/s deformation behavior, water tightness, riding quality, noise / vibration. An optimal performance based evaluation criteria for expansion joints should include appropriate tests as per the available literature to give due consideration to these factorsappropriately thus avoiding early replacement of malfunctioning expansion joints involving significant financial implications and inconvenience to the road users due to traffic disruption. If the joint is to be installed on bridges located in seismically vulnerable sites, special tests such as earthquake resistance test, should also be included in the list of pre-installation performance test. Further, the specifications for all the tests (mentioned in the IRC guidelines (IRC: SP-69: 2011)) should be revised for the Indian loading conditions. In order to cater comprehensive testing requirements for expansion joints, state of the art testing facilities should be developed in our country. The outline of such comprehensive testing requirement for the performance based evaluation of expansion joints can be logically represented by the model as shown in Fig. 1.

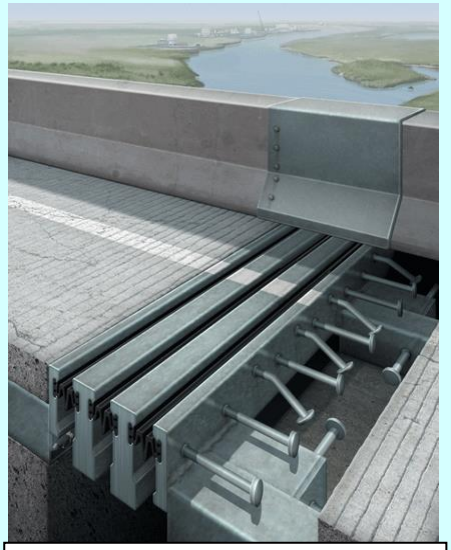

Photo 1: Modular Bridge Expansion Joint (MBEJ)

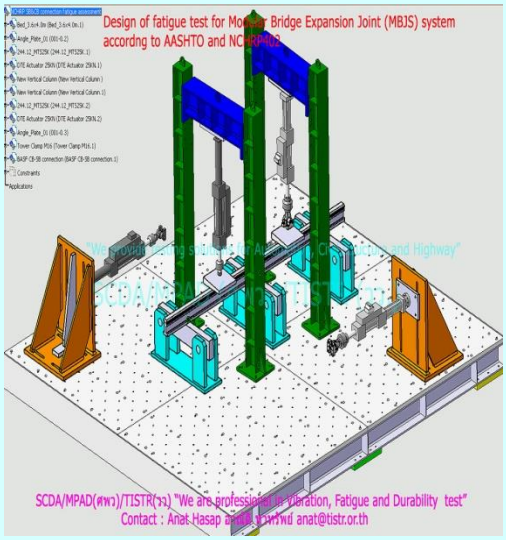

Photo 2: Fatigue Testing of Edge Beam of Expansion Joint

Comprehensive Testing Requirements

Pre-installation tests
Checking of design, Drawings, Dimensions, Material tests, Performance tests as per IRCGuidelines

Post installation Tests
Tests for load v/s deformation (load tests) behaviour, Riding Quality, Noise/Vibration (NVH Test)

Fig. 1: Comprehensive Testing Requirements

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Impediments To Implementation Project In Hill Area

(An Experience from the State of Mizoram)

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During the course of project execution, numerous problems have been encountered. With the benefit of hindsight, it is now clear that some of the problems are structural in nature and had not been addressed adequately at the pre-bidding stage. There are also problems which crop up during the course of construction and which could have been dealt with satisfactorily and expeditiously but for want of will. There are yet other problems associated with the contractor's lack of experience in hill road construction. Finally, problems such as extended monsoon and shortage in supply of construction materials are beyond the Employer's and Contractor's control.

The factors such as the geological formation, topography, transport system, communication system, social life etc. may never be thought of that they actually have an impact to the execution of the Project. The effects of these factors are long implementation period, poor quality of the final product, cost overrun and most importantly the adverse effect to the implementing Departmental reputation.

It is found that the impediments to be overwhelming and not likely to be easily and completely overcome. Nothing much could be done with respect to adverse climatic conditions, topographical restrictions and geological limitation and one is compelled to work within such constraints. However, some are surmountable and others could be considered as hindrances and considered for Project implementation Period.

The actual completion time required for completion of various major road projects that have been executed in the State of Mizoram mostly took more than double of the original scheduled completion time, and the extensions time were given on priority. The cost of execution had also ballooned on account of substantial increases in scope of work and high escalations. More importantly, the premature deterioration of the completed pavement gave rise to serious doubt as to the quality of the work. A quick question may be tempted to ask that if there were so many impediments, why were there no measures taken to address them during execution? The Answer is simple, Time, Financial and other constraints. Due to these various constraints, only ad hoc measures could be taken during the course of execution and these were far from adequate.

In the following section, the various problems and difficulties experienced in the project implementation are explained

A. Local/Location Problems: The Local problem may also be classified as:

i. **Supply of Construction Materials:**

Key construction materials such as cement, steel and bitumen are not produced in Mizoram and need to be procured from outside the State. Such procurement and delivery of the materials on site will require substantial lead time and are subject to logistical problems explained in the preceding Section of Mobilization of Plants and Equipment. Even though certain materials such as stones, aggregates and sand are available in the state, they are not available in processed and 'ready-to-use' form in any significant quantities.

The contractors need to identify suitable sources with appreciable yield and deploy the required manpower and equipment for extracting and processing the materials. The difficulties are compounded by the lack of adequate suitable sources. Much time has been expended in identifying and developing different sources of materials with low success rate. Such a scenario has not been foreseen by the contractors during the bidding stage and, the additional resources deployed and extra time expended have exerted great pressure on the contractors' financials, leading to lack of physical work progress and low progress billings.

In particular, the sourcing of pavement aggregates has proven to be most challenging and time-consuming. There are no established quarries in Mizoram from which aggregates can be purchased. The contractors are compelled to devote much time and resources for identifying and developing suitable quarry sources along the project road corridor. Some of the difficulties encountered are: -

a. Lack of quarry sources with significant yield of stone meeting specifications - Rock in Mizoram are of relatively young geological formation. They' are mostly sedimentary deposits, highly foliated and laminated, and hard rock strata are interspersed with the soft rock and soil strata. Samples tested show that the stones are generally having high water absorption, high Los Angeles abrasion value and high combined flakiness and elongation index. These rules out most of the rock deposits are suitable sources of aggregates. Suitable sources are few and far in between and the search has proven to be laborious and time-consuming.

b. Long lead time required to develop quarry sources- It takes at least 3 months to develop a quarry source and even much longer time if the source is located away from the project road corridor. In some cases, quarry approach road up to 6 km long has been constructed. The difficult terrain, thick overburden and occurrence of soil and bad rock strata amongst good rock strata also mean that it will take much longer time before stone extraction can start.

c. Ownership Issues- In some quarry sources for which development work has been completed, disputes due to dual land ownership had resulted in stone extraction being stopped and the sources being abandoned for long period of time.

d. Extraction and logistical problems- Stone extraction has been slow due to difficult terrain and restricted working space. Transporting of stones to the crusher plant over bad road takes up much time and has to be suspended during the monsoon season. Extracted stones have also to be broken down into feed-sizes. Multiple handling has greatly limited the production of aggregates.

The production of adequate aggregates meeting specifications is deemed crucial to the successful implementation of the projects. As it is, the completion of the projects remains uncertain due to the above-mentioned problems.

ii. **Non – Availability of Experience Contractor:**
Due to lack of experience and Low Financial Turnover, Local Contractors are not qualified for larger contract packages. Contractors from outside the state are required to be sourced and they are mostly lack of experience in hill road construction, may be due to remote location of the State or other various reasons, only few capable contractors expressed interest to participate, resulting low number of bidder with high chances of higher bid price and final selection of low performing contractor. In fact, few Contractors who have already had work experienced in the State are mostly participating in the Bid Invitation and were awarded the work and become over loaded.

iii. **Adverse Climatic Conditions: Adverse Climatic Condition**:
On account of the annual monsoon season lasting at least 5 months but mostly much longer would appear to be the most serious impediment in the execution of road work in Mizoram. The adverse impact is fourfold as explained in the following paragraphs.
Firstly, monsoon season per se, shortens the working season and much more so if the monsoon season is an extended one. Short working seasons are the hallmark of road construction in Mizoram and one need to digest this hard fact.
Secondly, monsoon rains invariably trigger landslides, cause soil erosion and sedimentation as well as result in valley side slope failures. Clearing of landslide debris as well as debris from filled-up drains and catch pits, implementation of erosion control and slope stabilization measures, and construction of slope protection structures would increase the scope of works and construction time, substantially so if the monsoons were exceptionally adverse.
Thirdly, monsoon rains invariably result in damage to completed works including drainage and slope protection structures as well as the pavement. This again increases the scope of works and construction time.
Fourthly, monsoon rains would also result in compromising the quality of pavement work on account of ingress of water and degradation of sub-grade, prolonged exposure of pavement layers to monsoon rains, need for carrying out pavement work under wet conditions and lagging effect of drain construction. In fact, monsoon rains were identified as one of the major causes for the premature deterioration of the completed pavement.

iv. **Unseasonal Rains:**
Rains that come in the month of November, December/ January, February, March and April are usually called an Unseasonal rains, but these rains have the Mizo names such as, Ai-ruah (Oct. Nov.), Pawldelh-ruah (Dec/Jan.), Chapdelh-ruah (Feb.) and To-thli/ruah (Mar and April). These rains have the effect of shortening the already short working season and must be considered as an impediment in in execution of road works.

v. **Traffic During Construction:**
Several problems arose during construction especially while executing widening of existing single lane road to double/intermediate lane due to disruption of public traffic. Mostly the roads being executed are the only road the serve or the shortest and the best

road for the project area. The Contractor has no choice but to suspend his operation, move aside his excavator, truck, paver, loader etc, and allow the public vehicle ta pass through. This process was repeated numerous times each day and was complicated by the lack of lay-bys for moving aside the construction equipment. It did not help that some of the drivers were impatient and had no qualms in demanding that equipment be removed quickly to allow them to pass through. Summation of time loss for a month is considerable but difficult to present in numerical days.

vi. **Landslides and Collateral Damage to Completed Pavement:**

Mizoram receives very high rainfall annually, spread over at least 6 months with high intensity for short duration. Such rainfall pattern is ideal in triggering landslides at vulnerable areas such as freshly cut hill slopes. Landslides and the collateral damage to completed pavement would seem to be one of the main reasons why the pavement deteriorated so rapidly. This is explained in the following paragraphs.

Major landslides invariably occurred during heavy rains and long stretch of side drain would get filled up. Hill side water and surface runoff from the upper reach of the slide location would then flow along the surface course, sometimes for substantial distance before entering the side drain again or discharging on to valley side.

Clearing of major landslides during the monsoon season being a dangerous proposition and the Contractor would not agree to fully clear the slides, water would continue to flow along the same path whenever it rained causing damage to the surface course. Over time, mini nalahs and gullies down to the WMM base layer would be created.

At flattish stretches, water would tend to pond on the surface course adjacent to the debris heap, resulting in stripping of aggregates and cracking of the bituminous layer as well as water ingress into the underlying layer. The vehicular traffic would accentuate the damage and when the monsoon season was over, substantial damage to the pavement including large potholes, deep rutting, extensive cracking and excessive settlement could be observed.

In critical stretches such as with steep gradient and/or at sharp curve and low-lying locations, the damage to the surface course could be severe in that almost the entire surface course could be lost and the WMM base layer substantially damaged over a couple of monsoons.

The above problem is particularly serious when the monsoons happened to be exceptionally adverse. The constraint posed was that the Contractor would need to divert part of his resources for clearing landslide debris and making good the damage in the next working season

A major deficiency in the engineering design was the unavoidable steep batter of the finished cut slopes which rendered the slopes inherently unstable and prone to landslides. The adverse consequences of landslides were not just limited to the time expended and cost incurred in removing the debris but also the collateral damage inflicted on the completed pavement.

What is more pertinent is the need to recognize the destructive power of landslides during monsoon seasons which left many short pavement stretches in bad conditions and even led to some members of the public innocently ascribing the damage to use of substandard materials. There is no doubt that landslides were one of the main reasons why the completed pavement deteriorated so rapidly, though recognizing that this factor could not have been foreseen and considered at the procurement stage.

B. **Contractor's Shortfall/Problems**: The Contractor shortfall may be as follows:

i. **Problems Associated With Mobilization of Construction Plants and Equipment:** Construction plants and equipment are not available for lease or hire in Mizoram. The contractors therefore, need to source all the required plants and equipment from outside the State. This has given rise to several problems:-

a) Key construction plants and equipment are manufactured in states far away from Mizoram, such as Gujarat, Bangalore etc.
b) The current practice is for the contractors to receive mobilization advances from the Employer before placing order. Taking into account the manufacturing lead time, it will take at least three (3) months from the date of award of tender before a piece of equipment is ready for delivery.
c) As mentioned in (a) above the construction plants and equipment will need to be transported from the state of manufacture to Mizoram over long distances. Logistical problems are compounded by the need to traverse stretches of narrow roads with small bridges from Silchar to Mizoram and in Mizoram itself before reaching the sites.
d) Transporting of key construction plants and equipment during the monsoon seasons has been found to be hampered due to certain road stretches prone to floods and landslides.
e) Due to limited level space available in Mizoram, the selection of suitable sites, site preparation works and on-site installation of crusher, WMM and hot-mix plants have been found to take up much time.

ii. **Difficulties in Sourcing for Experienced Project Management Staff, Site Execution and Supervisory Staff and Skilled Manpower:**

The contractors have encountered great difficulties in sourcing for staff at project management, site execution and supervisory levels with adequate experience in hill road construction.
The large scale manual construction for side drain, cross drainage work, slope protection work, pavement work etc. calls for a large number of skilled labours. Such manpower is not readily available in Mizoram and the contractors are compelled to source it from outside the State (from as far as the southern states). Problems encountered include lack of adequate skilled manpower experienced in hill road construction and long lead time in identifying, negotiating and mobilizing labour gangs to site. These are compounded by the high labour turnover rate due to inability to adapt to local conditions, lack of communication facilities, late payments by the contractors and other problems.

The difficulties in sourcing for experienced staff and workers to work in Mizoram can be attributed to the following: -

a. The present pool of experienced project management personnel, engineers, supervisors and skilled manpower in the country appears to be inadequate to support the large scale of road projects currently under implementation across the country.

b. Construction personnel experienced in major hill road construction appear to be limited. They are hard to come by, most of the staff and workers recruited are inexperienced and need to be trained. The learning curve tends to be long and gentle.

c. Working conditions in Mizoram are perceived to be harsh, rightly or wrongly. Anecdotal evidence suggests the following: -
   - Living conditions on site are perceived to be tough due to lack of adequate basic amenities, lack of social amenities and difficulty in adapting to local conditions.
   - Commuting almost daily on narrow, winding and steep hill roads with potholed and undulating road surface in perceived by some to be tiring and unsafe.
   - Security situation in Mizoram has been wrongly perceived by some staff and workers to be not conducive due to isolated cases of social disorder in Mizoram and abduction in certain North-Eastern States.
   - With limited supply and perceived harsh conditions, it is become increasingly more difficult over time to engage experienced personnel and skilled workers from outside Mizoram to work in the State. Provision of monetary incentives has not improved the situation much.

iii. Contractor's Inexperience and Lack of Adequate Resources:

While many of the problems encountered during the construction are beyond the control of the Contractors, the Contractors themselves have also contributed to the delay. Some of the Contractors may have prior experience working in hilly terrain but this proved to be inadequate in handling the project in Mizoram. For "first-timer" Contractors, the construction experience in Mizoram may be a proved to be a long and painful learning curve.

The Contractors' work planning and site management are found to be grossly lacking and his inexperience in hill road construction shows up conspicuously and has a direct significant adverse impact on project implementation.

Most if not all, the Contractors have grossly under estimated the complexity of road construction in Mizoram. Lack of thorough insight and advanced work planning has led to the initial works programme being rendered unachievable within the 1st working season. The Contractors have also failed to appreciate the long period of mobilization and large initial working capital required, to their own peril.

While the Employer has recognized the various constraints impeding project implementation and generously granted extension of time and provided assistance, the Contractors' unwillingness to fully grasp the constraints and overcome the same is puzzling. Unencumbered works such as pavement and side drain are still falling behind schedule despite several revisions of the works programme. There is clearly a dire need for the Contractors to improve his site management and increase his resources and financing capacity.

C. Employer's/Consultant's Shortfall:

Design consultants engaged for Project preparation do not have much experience for the Design of Hill Road and various problems mention above and the Department also lacks experience and adequate resources in managing the large contract works, therefore, almost every large project there was design deficiency, which was found out

only during implementation stage only. Much time was spent for re-surveying and re-design of some stretches. To avoid such design issues:

- The Department needs to involve closely with the design consultant and contract management also has to look into the details of Contractor's work plan.
- In short the client need to involved in every stages of construction with the designer, Contractor and the supervision Consultants if any.

Having identified the impediments that almost sometimes derailed the implementation of the project, the future implementation of any major road project in Mizoram would face similarly high execution risks. This is because of certain external factors and ground realities which are beyond every party's control and may not be possible to mitigate even with detailed planning and comprehensive engineering design. However, better and realistic project planning may be able to achieve keeping in mind of these impediments.

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Roadside slope stabilization through soil bio-engineering methods in hill and mountain terrains of North India

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I. Introduction

Vegetation has been used for a very long time throughout the world in structures against soil erosion, as traces have been found dating back to the first century BC. Widely practiced in Western Europe during the eighteenth and nineteenth centuries, bioengineering was somewhat abandoned in the beginning of the twentieth century, before seeing a resurgence in recent times. Soil bioengineering can be traced to ancient peoples of Asia and Europe as early as 28 BC. It is said that use of soil bioengineering techniques for dike repair is recorded in Chinese history. Romans used fascines, bundles of willow poles, for hydro construction. A publication by Woltmann from 1791, illustrated use of live stakes for vegetating and stabilizing stream banks (Stiles, 1991,). About the same time, other early bioengineers working in Austria were developing live siltation construction techniques, planting rows of brushy cuttings in waterways for trapping sediment and reshaping channels. Use of indigenous materials and traditional methods was also consistent with developing soil-bioengineering techniques for hill slope stabilization. Hugo Shiechtl documented these techniques and in 1980 Schiechtl's "Bioengineering for Land Reclamation and Conservation was published in Canada. A new concept and introduction of soil bioengineering began. John Howell's works has been considered to be exemplary in roadside soil bioengineering of Himalayan region. Over 100 slope, protection works were carried out along Jogbani-Basantapur road from 1986 to 1998 under Department of Road (DoR), Nepal mainly focusing on appropriate soil bioengineering measures combined with civil engineering techniques and it was considered to be the most effective measures for the region.

A few Austrian students as part of their Master's Thesis introduced bamboo crib walls in Thankot village of Kathmandu, Nepal in 2000. This initial research has helped immensely both in terms of labor, cost and easy use of locally available materials throughout Nepal. Now the crib wall technique has been successfully working in many parts of Nepal and Himachal Pradesh in India while this has been recently introduced in Mizoram in India as well. The acceptance and willingness of people's to use this technology and the people's participation has provided beautification of the surroundings. This can be visualized with the photographs that have been taken before and after the techniques were used (Plate No. 1).

Before: Bamboo crib wall construction

After: Result in next few months

Plate No. 1: Construction of bamboo crib wall using locally available materials in Padampuri, Uttarakhand

Soil bioengineering is a sustainable approach where the combination of living and dead plants and plant parts are used as building materials for reduction and prevention of soil erosion and upland slope protection based on an engineering concept. Live plants are used in various soil bioengineering techniques, either alone or in conjunction with civil engineering structures and non-living plant materials to increase slope stability against shallow mass waste. The combination of vegetative engineering and civil engineering systems normally offers the most complete natural and cost effective solutions to variety of instability problems of any effective sites. The duration for implementing vegetation for slope stabilization work depends on the technique of soil bioengineering measures and the type of the plants that has been used. Locally available indigenous plants are recommended to be used extensively because it is readily available and creates to a nearly natural environment which blends with its surroundings.

Soil bioengineering techniques have shown excellent results for stabilizing loose landfill sites and areas of surficial erosion in the Himachal Pradesh State Road Projects (Plate No. 2). Similarly, the application of soil bioengineering measures has been initiated in stabilizing dumping yards in Champhai-Zokhawthar (C-Z) and Chhumkhum-Chawngte (C-C) state road projects and have shown good results. Soil bioengineeering methods have been used alone, or in combination with civil engineering structures.

Before: Brush layers with palisades and fascine

After: Rows of brush layers using mainly *Ipomia* sp. (Ranital-Kotla state road, HP)

Before: Bamboo crib wall and brush layering techniques

Result after one year (Barsar-Jahu state road, HP)

Plate No. 2: Loose dumps slope stabilization works with application of soil bioengineering techniques

II. Background Information

The Public Works Department (PWD) of Himachal Pradesh and Mizoram have decided to improve the road network throughout the state in order to uplift the present economic growth of the state. The PWD has introduced a state road up-gradation project with financial support made

by the World Bank for the overall economic development of the State. One of the major focuses of the project is to build sustainable environment friendly roads with appropriate application of soil bioengineering. The method is considered as an important and integral part of road construction. Appropriate locations for debris disposal sites are planned, identified and being stabilized by using proper soil bioengineering methods. The slopes are stabilized where the top portion are made into an additional flat land for economic purpose (Plate No. 3).

III. Overall Objective

The overall objective is to contribute towards establishment of improved sustainable and environment friendly road transport system so as to facilitate the economic growth of the region. The other objectives are,

- to build the capacity/skills in understanding the concept of appropriate soil bioengineering technology and
- to create awareness among the grass root level beneficiary groups in the communities on the use of and/or application of the technology

In this context, there is an urgent need to introduce soil bioengineering in all the road under construction to maintain a safe, sustainable and an eco-friendly road construction method.

Km 7+500 (Govt.)

Km 8+160 (Govt.)

Km 10+620 (Govt.)

Km 13+370 (Private)

Km 13+950 (Govt.)

Km 16+620 (Private)

Km 18+650 (Private)

Km 20+200 (Private)

Km 22+000 (Govt.)

Km 23+720 (Private)

Km 26+000 (Private

Km 27+550 (Private)

IV. Concept, Approach and Practicable Techniques of soil bioengineering

Concept of Soil bioengineering

Wood and living plants have remained the main materials for maintaining the hill and slope stabilization works since last couple of centuries. These days some of the old techniques have been modified and applied, which mainly uses live material such as willow branches, willow cuttings, and rooted deciduous trees. The duration for implementing vegetation for slope stabilization works depend on the technique of soil bioengineering measure and the type of the plant that has been used.

Specifically soil bioengineering concept is adapted with a view to

i) Examine soil bioengineering needs of project,
ii) Monitor existing road system regarding their slope stabilization works.
iii) Study plant species compositions and plant species which can be used for future soil bioengineering purpose.
iv) Survey a plan of soil bioengineering activities.
v) Test plant species in combination with different soil bioengineering techniques for its suitability in winter plantations.
vi) Stabilize the unstable slopes through a suitable application of vegetation in different soil-bioengineering methods, either alone or in combination with civil engineering structures.
vii) Use indigenous materials, low capital costs compared to civil engineering structures.

Soil bioengineering is totally labor based approach providing benefits to the local people. It focuses on minimizing the damage to the natural environment as well as reducing the future maintenance costs. Major portion of the cost of the road construction goes toward the payment of wages to the local labors. The approach incorporates social, environmental and technical issues. Due to these facts, it is getting increasingly prioritized by national and international organizations in hill road construction. The people's participation is most essential for the success of slope conservation works. The use of local materials motivates local people's participation.

There are numerous different hillside slope stabilization methods, which utilize plants in combination with construction of wood, bamboo, stone and wire such as timber crib wall, live bamboo crib walls, vegetated stone walls and vegetated gabions. Choosing the right method depends on various factors such as the position of slope, ground and available materials.

The techniques adopted currently in the road projects are bamboo crib wall, brush layer, drainage fascines, palisades, single tree planting and grass planting.

Bamboo crib wall: It can be termed as a form of gravity-retaining structure generally used on-site fill materials. The timbers required for the construction of crib walls are not easily available in the region, therefore, the idea to use bamboo for the construction of the crib wall was developed (Plate No. 4).

Before: Bamboo crib wall with brush layers,

After: Result in a few months with good coverage

Plate No. 4: Soil bioengineering in Gorkha, Nepal

- Bamboos can be propagated by seed, off-cut stumps with root sections, and nodal cuttings.
- Nodal cuttings from a single culm are potentially the cheapest and best method of propagation.
- Bamboo crib wall structure technology has been tested and has shown successful results at sites with very good roots and shoots performance and has contributed to great to stabilize loose soil and slopes along hill road.
- There is a need to scale up this technology in embankments and landfill sites for erosion control and slope stabilization.

Brush Layer consists of placing live branch cuttings laid nearly flat in shallow trench across the slope and covered in soil (Plate No. 5). The cuttings are at right angles to the line of the trench, with their tops protruding from the slope. The surface of the bench slope should be constructed in such a manner that the outside edge is higher than the inside part.

Before: Laying of cuttings in C-Z road

After: Result in 12 weeks period

Plate No. 5: Brush layering in Mizoram

The cuttings should normally be 45 to 60 cm long with three-fourth buried and placed at the rate of 20 cuttings per running meter of trench. Live materials should be 1.25 to 5 cm in diameter. The cuttings are oriented perpendicular to slopes. This is more effective for earth reinforcement and mass stability of slope. It is also recommended on slopes up to 2:1 in steepness. It serves as tensile inclusions or reinforcing units adding significant resistance to sliding or shear resistance. It assists in retarding runoff and reducing surface erosion. The technique also acts as horizontal drain by redirecting and mitigating adverse slope seepage. The backfill is placed on top of the branches and compacted to eliminate air spaces. The brush tips should extend slightly beyond the fill to filter sediment. Each lower bench is backfilled with soil obtained from excavating the bench above. The main engineering functions are to catch debris and to armour and reinforce the slope.

Drainage fascines are used for a variety of slope stabilization purposes. Hardwood cuttings (live branches or stems) of approximately 20 to 40 cm in diameter are laid in bundles tied together with jute or coir string every 50 cm and fixed into the ground every meter by wooden pegs or live stacks along shallow trenches across the slope and completely buried. After burial in the trenches, they put out roots and shoots, forming a strong line of vegetation. The main engineering functions are to catch debris, and to armour and reinforce the slope due to rooting. The cuttings should normally be 1 to 2 meters long, bundled together into a continuous length, usually with 8 cuttings throughout the fascine. Fascines can also be angled to provide drainage.

***Before**: An appropriate place for fascine*

***Before**: fascines being laid as bundle on rill*

***Before**: fascines after burial*

After: Result in few months

Plate No. 6: Fascine work in Padampuri, Bhimtal

Drainage fascines in particular stabilize and drain slopes and is built into rills or small gullies (Plate No. 6). Immediately after establishment they have a draining effect because the water is channelled through the straight branches (Plate No. 7). With shoot and root development they form a strong line of vegetation. Additionally they achieve water-removal due to transpiration of plants. The branches are placed with the butt ends pointing at the same direction into existing rills or dug trenches following the contour or desired angle precisely.

Plate No. 7: Fascine construction for gully stabilization (C-Z road, Mizoram).

Vegetated palisade construction are ancient techniques, which were already used by the first people in central Europe. Palisades are used for protection of small but deeper, narrow gullies and shallow V-shaped rills. Immediately after construction they provide mechanical protection by catching debris, armouring and reinforcing gully floors. These effects are increasing after shoot development of cuttings. As a result of plant transpiration, they achieve water-removal from soil. (FLORINETH and RAUCH, 2001; SCHIECHTL, 1992). Huge live poles are driven or dug half of their length, vertically into the ground (Plate No. 8). Twenty live poles per running meter should be used. The hardwood cuttings are normally 20 to 50 mm in diameter and 1000 mm in length. On their top they are fixed by wire on one or two cross beams, which have been anchored into the sides of the gully. The distance between the palisades depend on the steepness of the gully slope and profile of the gully floor. On slopes with less than 30° inclination 2 m are convenient, of slopes with an inclination between 30° and 60° a distance of 1 m is recommended. (FLORINETH and RAUCH, 2001; HOWELL, 1999a; SDC, 1990). Growing shrubs and trees form a dense network of roots in the soil. Reinforcing and in the longer term anchoring, are the main engineering functions. Shrub and tree planting can be applied on almost every slope.

Plate No. 8: Establishment of Palisades in Gorkha for gully stabilization after the earthquake in Nepal

Plantation: Rooted plants from the nursery (usually raised as polypot seedlings) are planted in off-set rows or in other specific pattern on the slope. One plant per m^2 should be enough. Main considerations are the costs of establishment and the period in which a dense plantation is required. The plants are put into a pit large enough for the rooting system. After filling soil carefully around the cylinder of roots and soil from the polypot, the soil is firmed gently around the plant. Stump-sprouting species should be preferred. Mulching, with for instance compost or chopped grass helps the young plants to grow faster by regulating the moisture and suppressing competing vegetation (HOWELL, 1999a; SCHIECHTL, 1992; SDC, 1990).

Grass slip cuttings, or clumps grown from seed are planted in lines or at random on the slope (Plate No. 9).

Plate No. 9: Grass slip plantation in between brush layers in C-Z road, Mizoram

Grass plantations protect the slope, due to rooting by providing a surface cover. They reduce the speed of runoff, catch debris and armour the slope (HOWELL, 1999a). A planting bar is used to make holes and the grass slips or cuttings are placed into it. The soil is filled around it and firmed gently. Grass planting is started from the top of the slope working downwards. Different patterns of grass lines can be used as given below:

- Contour/horizontal lines: Reduce speed of runoff and catch debris thereby armoring the slope.
- Down-slope/vertical lines: Armour, reinforce and drain the slope. Used for damp sites and poorly drained materials where an intensified infiltration can lead to liquefaction of the soil.
- Diagonal lines: Main functions are armoring and reinforcing. Secondary they catch debris and drain the slope. It is the best compromise of horizontal and vertical planting.
- Random planting: Often used in combination with jute netting on very steep harsh slopes, where complete surface protection is needed.
-

VI. Conclusion

- Applied stabilization measures are affordable
- The measures are highly effective and generally have been successful for more than a decade
- Local capability is developed for design and construction of such stabilization works
- The measures can be successfully replicated in other similar road sections

Provision of watering on a temporary basis should be carried out until the plants can revive well.

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Roadside Slope Protection Measures: Prevailing Practice in Nepal Himalayas

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1 Background

1.1 Introduction

Slope stability is a major concern in hilly and mountainous roads. In case of roadside slopes, the slope instability is affected by combination of both natural as well as artificial factors. Among the causes of the slope instability, steep slope, saturation / pore pressure build-up, steep road cut or loading by the road embankment and retaining structures are the primary causes. The slopes are subject to wetting during the wet monsoon season which reduces effective stresses and hence shear strength at the potential slip surfaces. In case of the Himalayan ranges, the slope stability is further critical owing to the fragile young geological formations. This article describes roadside slope instabilities in colluvial soil slopes which are susceptible to sliding during the wet period.

Physio-graphic Condition

Nepal is situated in the southern lap of the Himalayas between China to the north and India to the south. The country is elongated east-west with length of 880 km and width of 240 km with surface area of 147,181 km^2. Geographically, the country is situated between latitudes 26 to 30 degrees and longitudes 80 to 88 degrees. The altitude of the land rises from 70 m elevation at southern border at Kechana to 8848 m at northern border at Mount Everest (highest peak in the world). The topography is rugged and deeply incised and drained by more than 6000 rivers and tributaries. The country is divided into three main physio-graphic belts: Himalayan ranges (15%), mountains and hills (68%) and Terai plains (17%). Most of the settlements are situated in Terai and a few in hills. The physio-graphiic belts are presented in Figure 1.

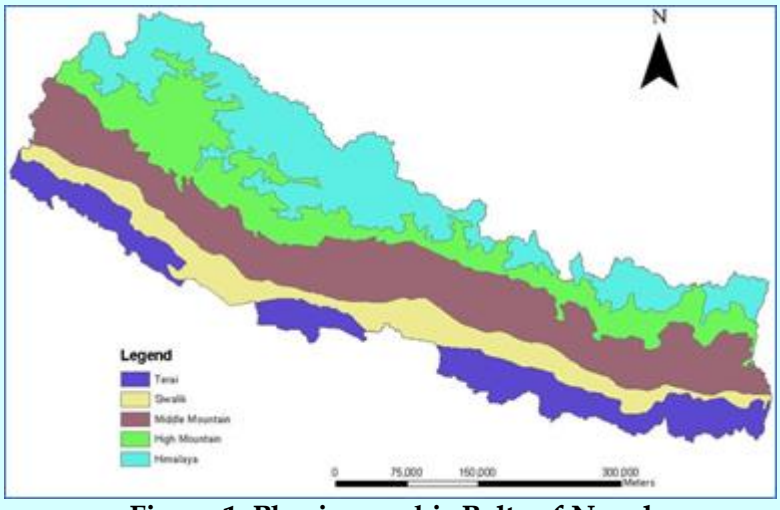

Figure 1: Physio-graphic Belts of Nepal

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Geological Condition

Nepal Himalayas are uplifted from Tethys sea some 50 million year ago as a result of continued collision between the Eurasian Plate and Indian Plate. The rock formations are relatively young, weak, jointed and fragile. A number of thrusts demarcate the geological belts. Among them, Himalayan Frontal Thrust (HFT) is the most active tectonically. Other important thrusts include Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Tibetan Techyan System. The geological belts of Nepal are presented in Figure 2. Apart from basal rock formations, many of the mountain faces are covered by quaternary deposits such as residual, colluvial and alluvial deposits.

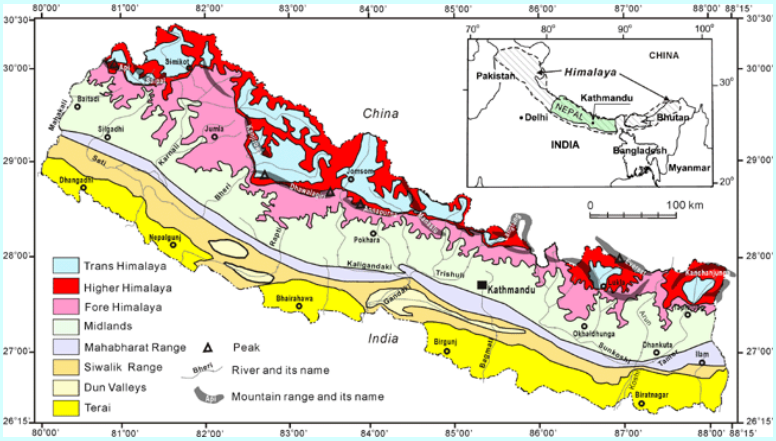

Figure 2: Geological Map of Nepal (Dahal and Hasegawa, 2008)

Seismicity Condition

Nepal falls under seismic zones IV and V as per IS seismicity zones which is generally followed in the design of the structures. More detailed seismicity map is recently being developed with contours of gals as indicated in Figure below.

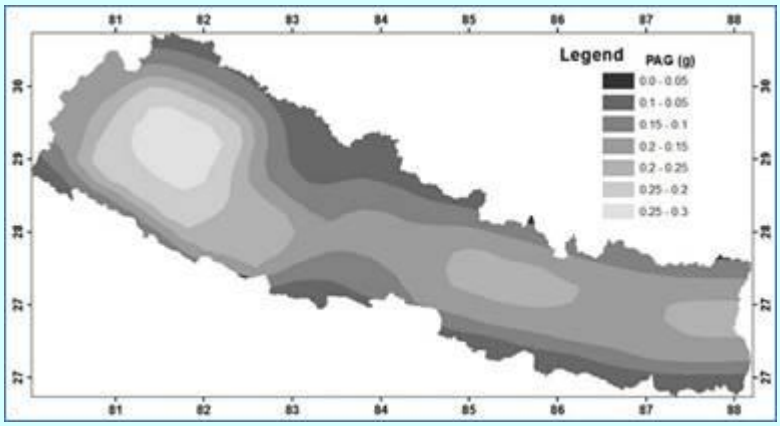

Figure 3: Seismicity Map of Nepal

Road Network Development

The development of road network in Nepal had started in 1924 with the construction of Amlekhganj-Bhimphedi section of Tribhuwan Rajpath. Since then, a gradual expansion of road network has taken place with more than 15,000 km of strategic roads (national highways and feeder roads) and more than 55,000 km of local roads (district roads, urban roads, rural roads and agricultural roads). Road infrastructures in Nepal were implemented in the past through technical and financial assistance of multilateral donors (WB and ADB) and bilateral agencies (India, China,

US, UK, SDC, GIZ, JICA etc) apart from national development funding. The road network is presented in Figure 3. It is evident that about one third of the road network traverses through hills and mountains. It is estimated that about five percent of the slope failures are caused due to road construction in mountainous and hilly terrain of Nepal.

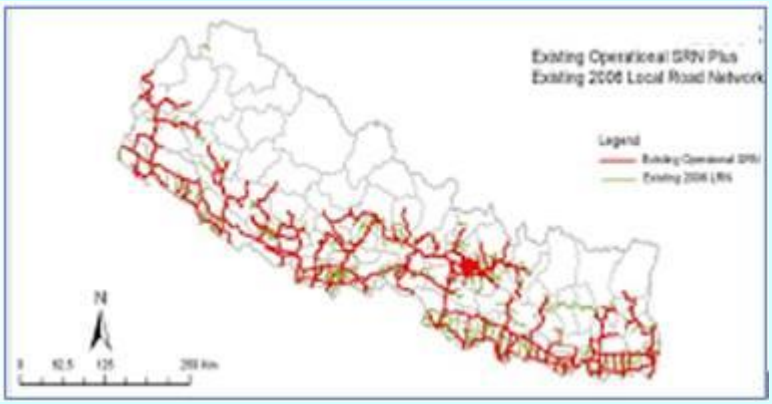

Figure 4: Nepal Road Network Map

During the early decades of road construction, environmental and geotechnical aspects were often neglected. After roads construction started full-fledged in the mountainous terrain, the problems of slope instability became evident. The awareness on the need of geotechnical and environmental aspects was commenced through the pioneering works in Dharan-Dhankuta road (DfID funded) and Lamosangu-Jiri road (SDC funded).

Dharan-Dhankuta road marked the beginning of environment-friendly road design and construction practices in Nepal. Extensive researches were conducted during its construction on bio-engineering and slope stability measures. The stabilization measures included bio-engineering solutions such as brush layers, grass plantation, tree/shrub plantation, wattle fences, brushwood check dams, hedge layers, jute netting, brush matting etc. and geotechnical solutions such as retaining walls, rock bolts, soil nails, subsurface drains, check dams, cascades, trap walls etc. Extensive use of flexible gabion structures was made in the off-road structures.

Similarly, Lamosangu-Jiri road pioneered in environment-friendly road construction practices in fragile mountainous environment. The bio-engineering, drainage and geotechnical measures were extensively used along the road combined with labour-intensive construction practices. Apart from general enhancement of environment friendly practice along the roadside, Charnawati Rehabilitation Project (CHRP) is considered as an important milestone in extensive use of innovative slope stabilization measures. The slope stabilization measures applied in the valley included French drains, horizontal drains (up to 45m), rock bolts, passive ground anchors / soil nails (up to 20m long 32mm diameter passive steel bar with yield strength of 830 MPa), catch drains, composite check dams, composite cascades, composite chutes, composite spurs, flexibly placed concrete armoured blocks at river bed and banks in combination with extensive drainage and bioengineering measures. While the soil nails were inspired from snow avalanche protection works in the Alps, the concrete armoured blocks were designed from the model studies performed in ETH Zurich.

Later on, implementation of environment-friendly road construction practice was continued in Bardibas-Sindhuli-Banepa road under JICA's assistance. In addition to multitude of environment friendly practices, the road also applied extensive cut and fill side slope stability measures such as reinforced earth and soil nails as well as road safety measures.

After capacity development from these pioneering projects, similar geotechnical solutions were later on replicated in other road corridors such as Arniko Highway Project (AHP), Thankot-Naubise road, Prithvi highway, Narayanghat-Mugling road, Bhainse-Hetauda road, Malekhu-Dhadingbesi road, Butwal-Narayanghat road, Hetauda-Narayanghat road etc. by the national experts. In addition to the replication of successful measures from Dharan-Dhankuta and Lamosangu-Jiri roads, further innovative geotechnical solutions applied in the roads included various forms of composite revetment structures, various types of spurs with face block protection, launching aprons with composite frames or articulated concrete blocks, boulder riprap, boulder armouring using interconnected boulders, rock fall netting etc.

For the gully control works, gabion works are extensively used due to their flexible and free draining capabilities instead of rigid masonry and concrete structures. Gabions are used as walls, check dams, mattresses or even drains. For filter purpose, extensive use of geotextile is made as replacement of graded filter due to difficulty of its haulage to landslides. Recently, geogrid material as reinforced earth has been extensively used in Sindhuli-Banepa road, Kathmandu Bhaktapur Road and at grade separated intersections.

2 Investigation and Design Practices

2.1 Engineering Geological and Hazard Mapping

Engineering geological mapping was initiated during the Dharan-Dhankuta and Lamosangu-Jiri roads. A more extensive mapping exercise was initiated during the preparation of Mountain Risk Engineering Project undertaken by the ICIMOD which created a set of comprehensive Mountain Risk Engineering Handbook in 1991. The document recommended developing a series of mapping including topographic map, slope map, aspect map, engineering geological map, morpho-structural map, land use map and hazard map. Apart from field based mapping, further initiatives were undertaken in Arniko Highway Rehabilitation Project to apply air photo interpretation to develop larger scale (1:10,000) orthophoto and contoured maps as the base map for further land use, engineering geological and hazard maps. Later on, a DfID study has recommended use of latest satellite imageries in addition to air photo to prepare base map. Recent efforts are directed towards digital processes to develop and implement hazard maps. For the preparation of digital terrain model, Lidar survey method is recently introduced for mapping of irrigation command areas, hydropower sites as well as road corridors, while drone photography is used to prepare site specific detailed contour maps and 3D models.

2.2 Landslide Investigation

In consideration of the multi-disciplinary nature of the slope stability, efforts were initiated to combine related expertise in the investigation, design and implementation of landslide stabilization measures. Apart from field reconnaissance, photographic illustration and engineering geological mapping, further investigations such as geophysical exploration, core drilling, instrumentation and monitoring, field and laboratory testing are carried out.

The subsurface geophysical exploration may include electrical resistivity tomography (ERT), seismic refraction tomography (SRT), seismic reflection (SR) sounding, ground penetrating radar (GPR), multi-channel analysis of surface waves (MASW), microtremor array measurement (MAM) etc. The measures are applied in complex slopes and underground works. For road bank stability,

ERT and SRT are the most useful methods. The geophysical findings should however be confirmed with core drillings and in-situ / laboratory testing.

The core drilling is often prescribed in soil exploration for bridges, heavy retaining walls and foundations. The procedure is also applicable to landslide studies. The procedure was applied in a number of active landslides along Lamosangu-Jiri road, Arniko highway and Thankot-naubise road. The borehole logs were referred while deciding on the depth of bearing strata, fixed anchor zones for soil nails and aquifer locations for piezometers and horizontal drains.

The practice of geotechnical instrumentation is yet to mature in road bank stabilization. A range of geotechnical instrumentations applied in CHRP include standpipe piezometers, discharge meters, rain gauge, rainfall intensity meter, rod extensometers, rock bolt tension gauges etc. Similarly, standpipe piezometers were installed and monitored in landslides in Arniko highway.

Movement monitoring is crucial to assess the effectiveness of the applied measures in the landslides, drains, walls and check dams. Instrumental monitoring of the levels and positions of the monitoring points were carried out at CHRP and AHP. The monitoring results provided useful hints on the status of stabilization or impending dangers. The monitoring works included movement monitoring, subsidence monitoring, cracks monitoring, stress monitoring, discharge monitoring, river stage monitoring etc.

In the recent road design and construction projects, basic field testing such as trial pitting, DCP testing, material sampling etc. have become routine practice for road pavement investigation. The tests are performed following IS, ASTM or AASHTO specifications. Similarly, laboratory testing for USCS classification, gradation, LAA, AIV, Proctor compaction, CBR etc. are also routinely performed. For slope stability purpose, testing for soil strength parameters (c and ϕ), unit weights (γ_d, γ and γ_{sat}), unconfined compression, triaxial strength, point load test, joint friction etc. are also performed as per requirement for the geotechnical designs.

2.3 Slope Stability Analysis

The procedures for stability analysis are usually considered separately for soil slopes and rock slopes. The soil slopes are commonly analysed by limit equilibrium or finite element methods of the soil mass and the latter by a combination of kinematics and limit equilibrium methods with an emphasis on discontinuity behaviour.

The use of an appropriate factor of safety (FoS) is important. In practice, the FoS prescribed by guidelines of Hong Kong GCO or those specified by TRL Road Note 16 are generally followed. Other references including MRE Handbook and Indian Standards usually prescribe high FoS for both soil and rock slope stability. For preliminary slope stability analysis reference is made to appropriate chart solutions such as Hoek & Bray Charts for soil slopes as well as weathered heavily jointed / fractured rocks.

	Risk to Life Category		
Economic Risk Category	1	2	3
A	1.4	1.4	1.4
B	1.4	1.2	1.2
C	1.4	1.2	>1.0

Figure 5: Prescribed FoS for Slope Stability Analysis, GCO, Hong Kong

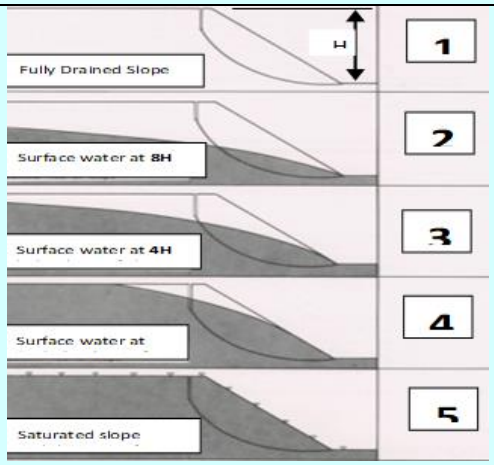

Figure 6: Hoek and Bray Stability Chart Numbers

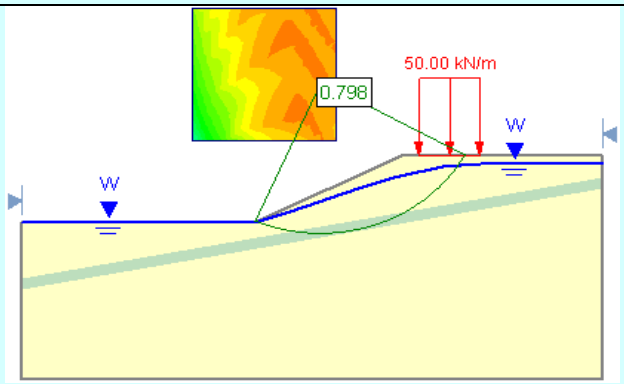

Figure 7: Example of Slope Stability Analysis of a Simple Slope

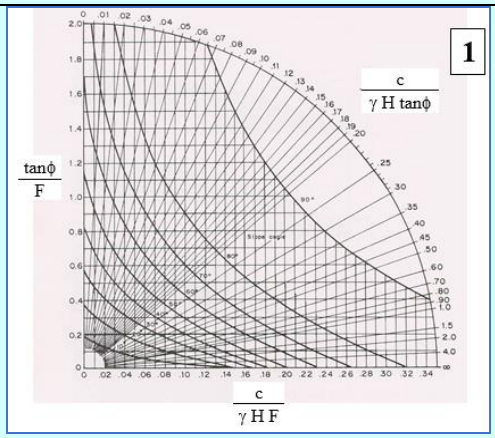

Figure 8: Hoek and Bray Stability Chart for Case 1

The use of slope stability software was initiated from CHRP where CUBUS LARIX BS software was extensively used. Later, geotechnical experts applied software of their own choice such as SB-SLOPE, STABL, FLAC etc. Recently, there has been a breakthrough in the software capabilities, versatilities and speed. Latest versions of SLIDE or RS2, for example, offer most capabilities for soil slope stability analysis including windows compatibility, non-circular slip surface, effective stress analysis, back analysis, sensitivity analysis, graphic interface etc. With the advance of user-friendly software, the analysis part has become mechanical but it demands for a sound judgement of geotechnical engineers to obtain information and to eliminate uncertainties on subsoil layers, water table and pressure, soil strength parameters, possible slip surface, pre-sliding condition etc.

There is currently a wide range of computer software available for use in the analysis of soil slopes, rock slopes and related support structures. Their relative usefulness in the Himalayan context is very much a function of their adaptability to the particular geotechnical management requirements. The software used in the region are: SLIDE, Swedge, RS2, RocPlane, RockFall, RocTopple, Dips etc. For soil nail wall designs, SNAP-2 software developed by FHWA is often used.

Quality assurance is a fundamental aspect in the management of geotechnical investigations, if cost effective solutions for dealing with roadside stability problems, are to be identified. Quality assurance has a particular importance where investigation, analysis or design is being undertaken through contracts. The engineers of the designated road agency need to assume an active quality control role with regards to outputs from the contracted parties. Key issues to be considered in quality assurance include: reliability and accuracy of field and laboratory data, appropriateness of analysis and design, selection of appropriate computer software and overall professional competence of the contracted parties.

2.4 *Applied Codes of Practices and Standards*

During the early decades of road construction, the DoR had generally adopted codes of practice and standards such as BS, ASTM, AASHTO, TRL, DIN, SIA, IRC, Chinese and USSR codes and standards. With the introduction of Nepal Road Standards and DoR Standard Designs, more uniformity was accomplished in the design and construction of roadside structures. As a part of institutional strengthening of the DoR, a series of guidelines such as Guide to Road Slope Protection Work, Roadside Bio-engineering (reference manual and site handbook), Environmental Management Guidelines, Reference Manual for Environmental and Social Aspects of Integrated Road Development, Traffic Safety Manuals, Guideline for Inspection and Maintenance of Bridges, Roadside Geotechnical Problems: A Practical Guide to Their Solution etc. are prepared and adopted.

2.5 *Reference / Guidance Documents*

Extensive reference exists in Nepal on slope stability related geotechnical problems in the form of reports and guidelines as indicated in **Table 1**. There is also a significant body of professional engineers, engineering geologists and geologists with experience in roadside slope stability or landslide issues.

Table 1 Geotechnical Guidance Documents

Document	Summary
Landslide Risk Assessment in the Rural Access Sector – Scott Wilson; 2004	Summarises procedures on the assessment of landslide risk, remote sensing and mapping of geomorphological and geological issues. Targeted to engineering geologist and rural road engineers.
Guide to Road Slope Protection Works, GESU/DoR, Nepal; 2003	Provides guidance and proposals for the general ongoing management of roadside slopes both at DoR's DROs and GESU level.
Principles of Low Cost Road Engineering in Mountainous Regions, ORN 16, TRL UK; 1997	Summarises the geological and geotechnical background related to construction of road in mountainous regions and provides guidelines on possible engineering options for design and protection of slopes.
Mountain Risk Engineering Handbook – ICIMOD; 1991	The comprehensive document provides extensive information on all aspects of road engineering in mountainous terrain.

Roadside Geotechnical Problems: A Practical Guide to Their Solution, GESU/DoR, Nepal, 2009	The document includes main text, problem definition formats, standard geotechnical procedures and solutions for geotechnical problems along with extensive bibliography. This is among the most practical guide intended to be used by engineers with modest exposure to geotechnical problems.
Roadside Bio-Engineering – Reference Manual and Site Handbook, DoR, Nepal, 1996	The documents are exhaustive references in roadside bioengineering developed through extensive practice in the developing countries. The documents are among the pioneering resources in the field.

3 Options for Slope Protection Works

The design process involves four stages, namely, consideration of possible general options to satisfy the requirements, preliminary outline designs for the identified options, selection of an optimum solution based on comparison of costs, effectiveness, availability of expertise or technology, and environmental impact, and developing detailed design for the optimal solution option.

Table 2 below indicates a matrix to identify the options available for stabilization of slopes. In most cases these options are generally chosen. In special problem areas, however, a combination of multiple measures or entirely new solutions is recommended by the geotechnical experts.

Table 2 Matrix of Geotechnical Problems and Solution Options

A. Problem Avoidance	B. Reduction of Driving Force	C. Increase of Internal Strength	D. External Restraint	E. Slope Protection	F. Debris Control	B. Bank Protection	General Options	Earthfall	Rockfall / Topples	Rock Slide	Debris Slide	Soil Slide (Rotational)	Soil Slide (Translational)	Debris Flow	Earth Flow (Soil Creep)	River Erosion	Slope Erosion
●							**Removal**	♦	♦	◊	◊	◊	◊	◊			
●						●	**Realignment**	♦	♦	◊	◊	◊	◊	◊	◊	♦	
	●	●					**Earthwork**	♦	♦	◊	◊	◊	◊				
	●	●		●			**Drainage**			◊	♦	♦	♦	♦	◊		♦
			●		●	●	**Retaining Wall**			◊	◊	◊	♦	◊	♦	♦	
				●	●		**Revetment Wall**			◊	◊	♦	♦	◊	◊		♦
		●		●	●	●	**Bio-engineering**				◊	◊	◊	◊	♦	◊	♦
					●		**Check Dams**				♦			♦			◊
			●			●	Tie-back Wall			♦	♦	♦	♦	◊	◊	♦	
			●			●	Pile Wall			◊	♦	♦	♦	◊	◊	♦	
			●				Buttress	♦	♦	◊	◊						
						●	**River Training**			◊	◊	◊	◊			♦	
			●				Anchors / Bolts	♦	♦	◊		◊	◊				
●					●		**Catch Work**	◊	◊	◊	◊						
				●	●		**Surface Protection**	◊	◊	◊							♦

B, C, D – Primary Slope Stabilization Measures
A, E, F, G – Slope Protection / Control Measures
• - Applicable Solution
♦ - Principal Option to be Considered for Solution of the Problem
◊ - Secondary Option

Source: Roadside Geotechnical Problems: A practical Guide to Their Solution, GESU / DOR, Nepal, 2009

4 Illustrative Examples of Applied Measures

Various types of slope stability measures are applied in road bank stabilization in the Himalayan region. The solutions show varying degree of success. Overall, the solutions seem to be cost effective and appropriate to cater for the requirement of the low to medium traffic volume. The photographic illustrations are presented in section below.

4.1 Demonstrated Examples in Nepal

Lamosangu Jiri Road

Cost effective environment-friendly solutions were applied along the Lamosangu Jiri road (110 km) right from the first earthwork stage of the road. Later on at Charnawati valley (km 43 to km 46), various types of slope protection works were applied subsequent to the devastative debris flow event of 1987. These included innovative solutions like soil nails, rock bolts, concrete armour blocks, check dams, French drains, bioengineering measures etc. The solutions were applied during 1988 to 1992 and are exceptionally successful. The measures are serving well even after major earthquake of 7.8 Mw and 7.3 Mw (Gorkha earthquake and its aftershocks).

Figure 9: Charnawati Valley After 1987 Disastrous Event

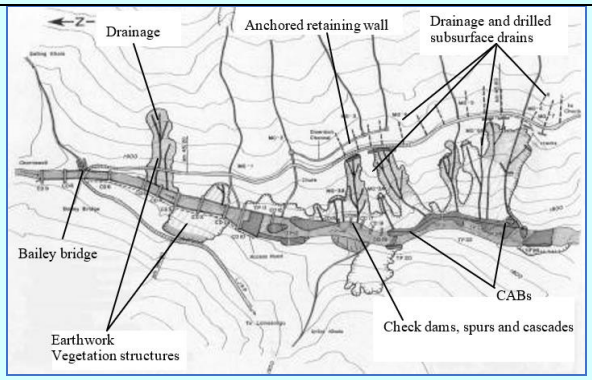

Figure 10: General Slope Protection Works Applied in Charnawati Valley

Figure 12: Extensive River Control Work Using

Figure 11: Disastrous Condition of Charnawati Left Bank in 1988

Check Dams and Guide Walls and Landslide at Right Bank

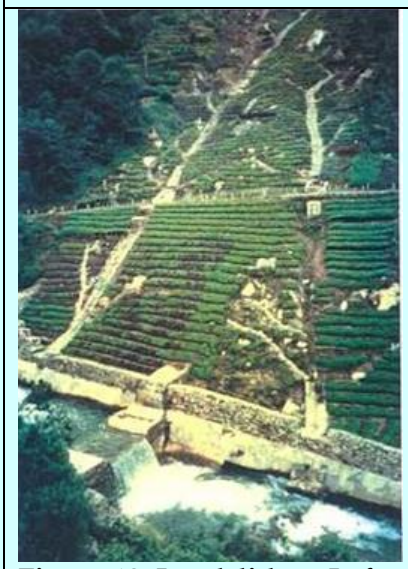

Figure 13: Landslide at Left Bank of Charnawati Valley

Figure 14: Extensive Use of Flexible Concrete Armored Blocks for Bed Protection

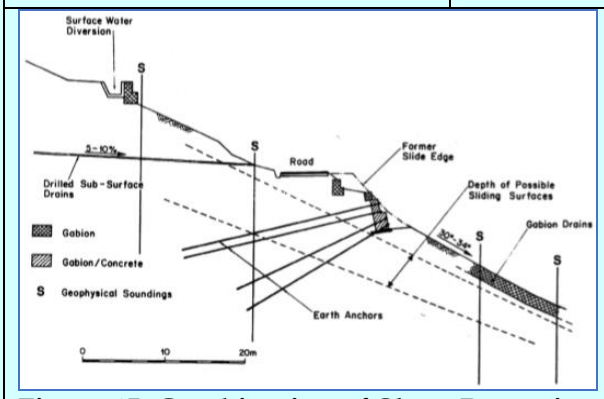

Figure 15: Combination of Slope Protection Measures at Landslide MG-3

Figure 16: Bioengineering Nursery Established Near Project Site

Figure 17: Check Dam, Guide Wall, French Drains and Bioengineering Measures at Landslide at Charnawati Left Bank

Figure 18: Thick Forest Has Grown After 28 Years

Figure 19: Stabilized Slide Remains Intact After 28 Years

Figure 20: Gabion Check Dams Have Remained Intact After 28 Years

Figure 21: Concrete Armor Blocks After 28 Years

Arniko Highway

Similar cost-effective slope protection works were applied along Arniko Highway (km 30 to km 88) after 1987 disastrous flood event. Later on, CHRP types of slope protection works were applied including soil nails, rock bolts, RCC blocks, check dams, French drains, bioengineering measures etc. The solutions were applied during 1990 to 1992 and are highly successful. The measures are serving well even after major Gorkha earthquake. The solutions applied at km 69, km 72, km 73.5, km 78 and km 82 are among the most exemplary ones.

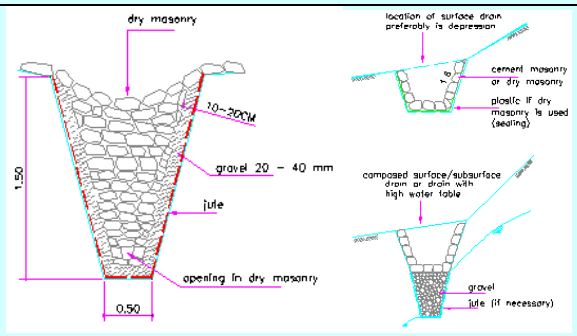

Figure 22: Typical French Drains

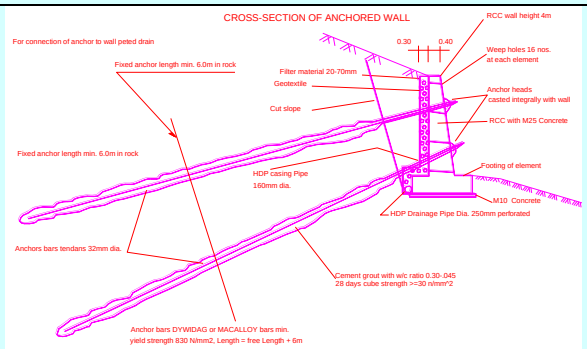

Figure 23: Typical Soil Nail Wall at km 70.2

Figure 24: Network of French Drains at km 69

Figure 25: Gabion Wall Supported by Anchored RCC Slices at km 70

Figure 26: Horizontal Drains Draining Effectively at km 69

Figure 27: Landslide Converted into Thick Forest. River Training Intact at km 69

Thankot Naubise Road

Similar slope protection works were applied all along the Thankot Naubise road (at 15 critical sites) destroyed by 1987 flood event. The slope protection works included soil nails, rock bolts, concrete armour blocks, check dams, French drains, RCC cascades, composite cascades, bioengineering measures etc. The solutions were applied during 1993 to 1995 and are serving well without much distress even after major Gorkha earthquake the soil nail works applied at TN4 and TN 10A (Khatripauwa) are exemplary.

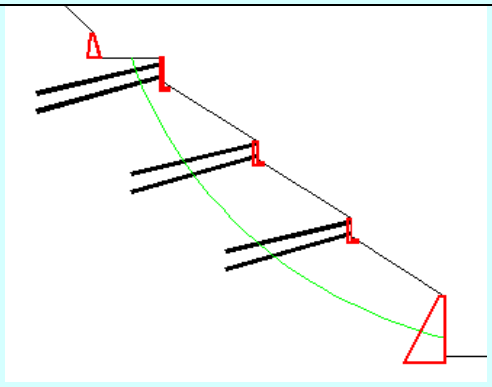

Figure 28: Soil Nail Wall Tiers

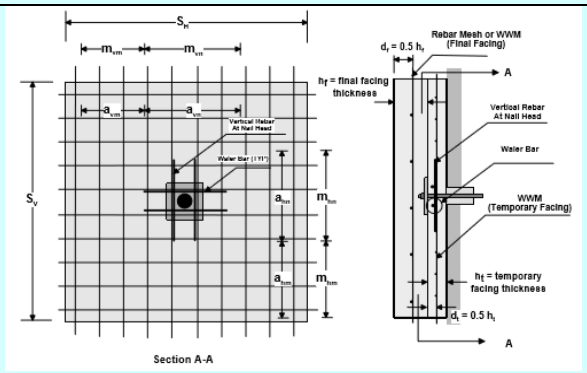

Figure 29: Typical Details of Soil Nail Walls

Figure 30: Gabion Toe Wall and Three Tiers of Soil Nail Walls at TN10A

Figure 31: Soil Nailed Wall at Road Edge is Intact at TN10A

Prithvi Highway

Various type of slope stability measures were applied along Naubise Mugling section after widening of the road in 1992-1994. In particular cost-effective drainage and bioengineering solutions applied at Krishnabhir slide are notable. The protection measures applied in the major slide included catch drains, storm water drains, French drains, sediment flow channels, toe walls, bioengineering measures etc. The applied solutions have greatly mitigated the slide activity and allowed uninterrupted traffic flow. The measures are serving well for over 20 years.

Narayanghat Mugling Highway

Following the heavy cloudburst of 2003, the road was severely affected at numerous sections. Various types of mitigation measures were applied at all damaged locations by the DoR and DWIDM. The protection woks included French drains, horizontal drains, soil nails, retaining walls, toe walls, block protection works, sabo engineering works and bioengineering works. The slope condition was excellent for more than 12 years. In particular, chronic problems of km 24 and km 17 were greatly improved.

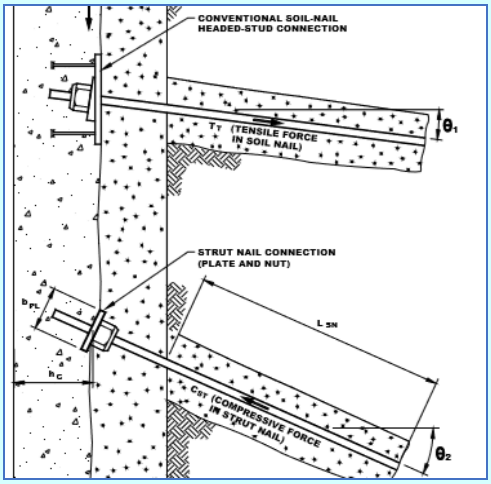

Figure 32: Typical Section of Soil Nails and Wall

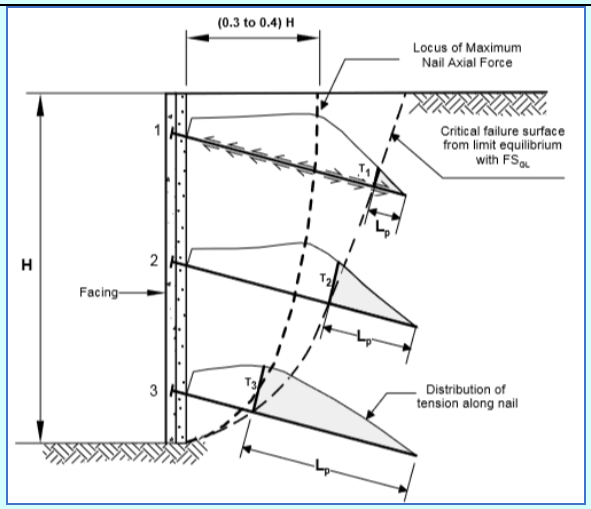

Figure 33: Typical Load Transfer in Soil Nail Wall

Figure 34: Pavement Condition Intact on Embankment Supported by Soil Nail Wall at km 17

Figure 35: Soil Nail Wall at km 17 Intact

Tribhuwan Rajpath

After the exceptionally cloud burst and debris flow of 1993, numerous sections of the road were devastated. Most of the problems were mitigated using low cost solutions such as bioengineering, catch drains, French drains and toe walls. The slide at Lamidanda hairpin bend is of particular importance which was stabilized using gabion walls, check dams, shotcrete and bioengineering measures. The measures are serving well for over 15 years.

Figure 36: Mitigated Major Slide at Lamidanda Hairpin Bend, TRP

Figure 37: Modified Hairpin Bend at Lamidanda, TRP

4.2 Outside Nepal

Lateral Highway and Farm Roads, Bhutan

Low-cost and environment-friendly solutions such as bioengineering, French drains, catch drains etc. were applied at dozens of unstable slopes along the Lateral Highway (550 km) in Bhutan. Simultaneously, training and capacity building was carried to impart hands-on skill to the DEs and SOs of the DoR Bhutan. The protection measures applied along the slopes were largely successful. In the subsequent years, Bhutanese engineers were skilled enough to apply such measures on their own. Later on, similar solutions were applied in farm roads. The reference manuals and practical handbooks on roadside bioengineering were extensively referred to apply bioengineering measures in Bhutan.

Ramban Banihal Section of Jammu Kashmir Highway, India

The cost-effective and environment-friendly slope protection works were later designed for Ramban Banihal section (36 km four lane road) of Jammu Kashmir Highway. Solutions such as rock bolts, soil nails, French drains, catch drains, toe walls, shotcrete etc. are being implemented by the EPC Contractor. Further, the guidelines prescribed by the Mountain Risk Engineering Handbook (Deoja et. al., 1991) is the reference material referred while developing hill road guidelines in India.

5 Conclusions

The concept of low-cost and environment-friendly road construction practices were developed during the eighties mainly from Dharan Dhankuta and Lamosangu Jiri roads. Later the experience was documented in the form of reference manuals and site handbooks which was continually disseminated to wider audience though annual bioengineering training. Simultaneously, various cost-effective innovative solutions for slope stabilization and gully control works were developed through experimentation in CHRP and AHP. The experiences were very well documented in the "Mountain Risk Engineering Handbook". Later other references such as "Guide to Slope Protection Works", "Landslide Risk Assessment in Rural Road Corridor", "Roadside Geotechnical Problems: A Practical Guide to Their Solution" and "Principles of Low Cost Roads, TRL Road Note 16" etc. were published.

The slope protection solutions applied in Dharan Dhankuta Road, Lamosangu Jiri Road and Arniko Highway were later replicated by Nepalese geotechnical experts to Thankot Naubise Road, Prithvi Highway, Narayanghat Mugling Highway, Tribhuwan Rajpath, Ilam Road, Okhare Mines Road, Narayanghat Butwal Highway etc. and the performance of the measures are seen to be highly effective.

The slope protection work including bioengineering, small scale drainage solutions and proven soil nails and rock bolts were later replicated in Lateral Highway and Farm Roads of Bhutan. Recently, the successful such measures are being considered for implementation in Ramban Banihal section of Jammu Kashmir Highway.

As the entire Himalayan region consists of fragile young geology in conjunction with steep topography, the slope stability problems are acute and more research needs to be conducted to determine the most cost effective solutions.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transport Officials
ADB	Asian Development Bank
AHP	Arniko Highway Project
AIV	Aggregate Impact Value
ASCE	American Society of Civil Engineers
ASTM	American Standards for Testing Materials
BS	British Standards
CBR	California Abrasion Ratio
CHRP	Charnawati Rehabilitation Project
DCP	Dynamic Cone Penetration
DE	Divisional Engineers
DfID	Department for International Development
DIN	German Institute for Standardization
DoR	Department of Roads
DRO	Division Roads Offices
DWIDM	Department of Water Induced Disaster Management
EPC	Engineering Procurement and Construction
ERT	Electrical Resistivity Tomography

ETH	Swiss Federal Institute of Technology
FHWA	Federal Highway Administration
FoS	Factor of Safety
GCO	Geotechnical Control Office
GESU	Geo-environmental and Social Unit
GIZ	German International Cooperation
GPR	Ground Penetrating Radar
HFT	Himalayan Frontal Thrust
ICIMOD	International Center for Integrated Mountain Development
IRC	Indian Roads Congress
IS	Indian Standards
JICA	Japan International Cooperation Agency
km	kilometers
LAA	Los Angeles Abrasion
m	meters
MAM	Microtremor array measurement
MASW	Multi-Channel Analysis of Surface Waves
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MPa	Mega Pascals
MRE	Mountain Risk Engineering
Mw	Moment Magnitude Scale
NS	Nepalese Standards
ORN	Overseas Road Notes
RCC	Reinforced Cement Concrete
SDC	Swiss Agency for Development Cooperation
SIA	Swiss Engineering and Architectural Standards
SO	Section Officers
SR	Seismic Reflection
SRT	Seismic Refraction Tomography
TRL	Transport Research Laboratory
UK	United Kingdom
US	United States
USSR	Union of Soviet Socialist Republic
WB	World Bank

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FROM THE DESK OF
CHAIRMAN
SOUVENIR SUB-COMMITTEE

Greetings and a warm welcome to all from the Souvenir Sub- Committee of IRC 215th Mid Term Council Meeting organized in Aizawl, Mizoram on 4th & 5th May, 2018.

The Indian Roads Congress is the Apex technical body of Engineers and Scientist across the Country which has contributed significantly to the quality standards and specifications for Highway sector including its maintenances.

On this auspicious occasion of IRC 215th Mid Term Council Meeting, a Souvenir is being published to enhance the value and commemorate the event.

I am pleased to thank all the high dignitaries for their messages, distinguished and eminent authors for their valuable technical articles, all the advertising sponsors/ donors for their best compliments.

My sincere thanks to all officials in the IRC Secretariat, New Delhi for their guidance and co-operations for the publication of this Souvenir.

My deepest-felt thanks to members of the Souvenir Committee for their dedicated helps and efforts rendered for bringing out of this Souvenir into a final shape.

My heartfelt thanks also go to the Local Organizing Committee for the advice, suggestions and inputs given towards the success of this Souvenir.

I wish the IRC 215th Mid Term Council Meeting a grand success.

Thank you.

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Aizawl, Mizoram.

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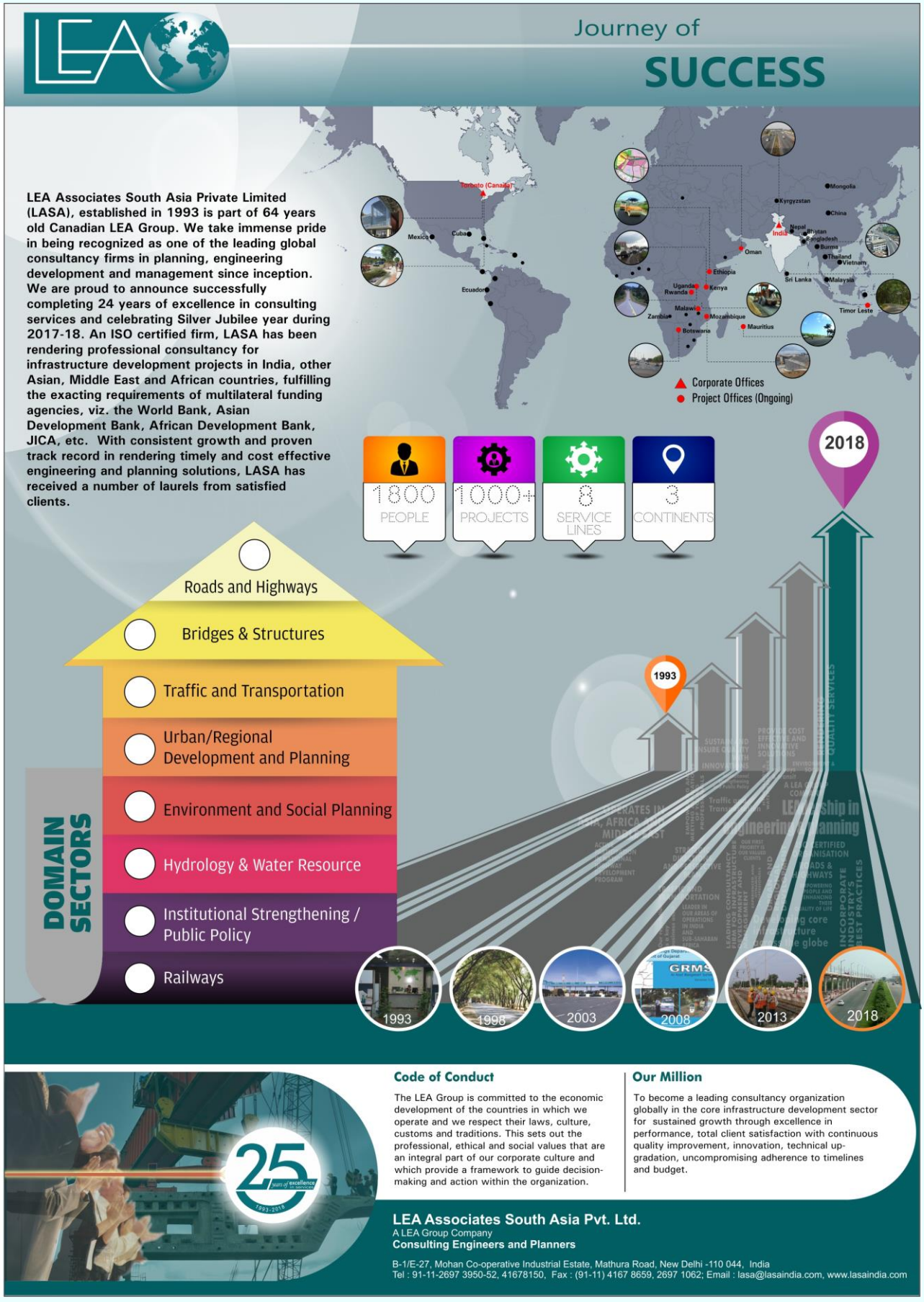
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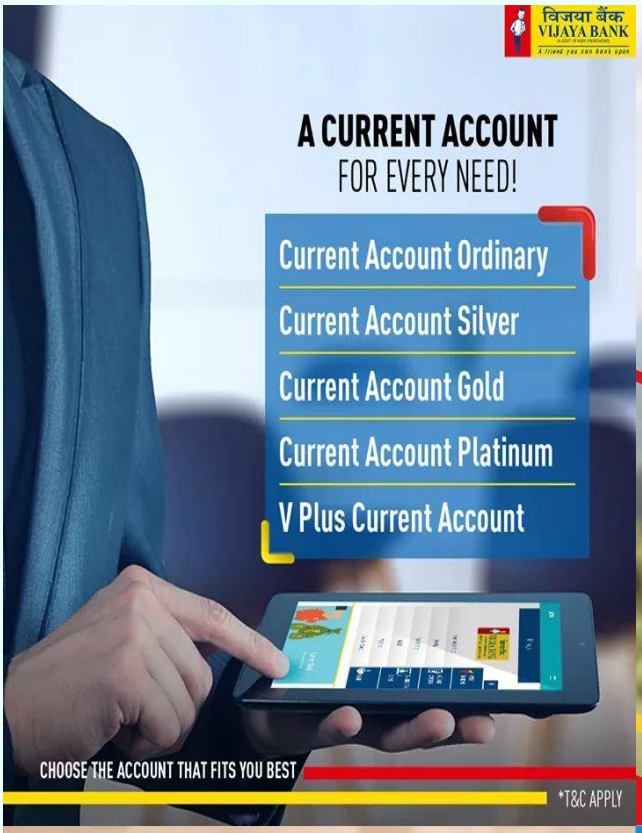

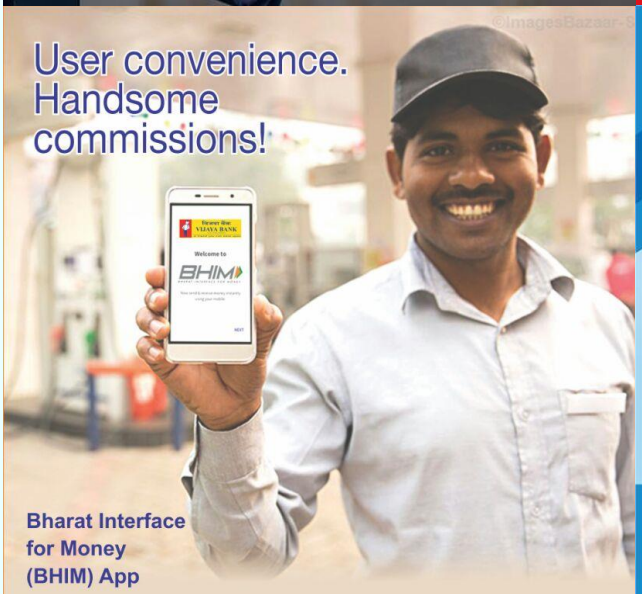

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