सत्यमेव जयते

PROCEEDINGS

NATIONAL CONSULTATIVE WORKSHOP ON

CLIMATE ADAPTATION POLICY AND GUIDELINES FOR RESILIENT HIGHWAY BRIDGES

Thursday, 03rd April 2025

Organized by:

National Institute of Disaster Management

(Ministry of Home Affairs, Government of India)

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सड़क परिवहन एवं राजमार्ग मंत्रालय
MINISTRY OF ROAD TRANSPORT AND HIGHWAYS

nidm
Resilient India - Disaster Free India

IIT Delhi

DTU

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Proceedings of National Consultative Workshop on Climate Adaptation Policy and Guidelines for Resilient Highway Bridges

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Plot No. 15, Block B, Pocket 3, Sector 29, Rohini, Delhi 110042

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Proceedings of National Consultative Workshop on Climate Adaptation Policy and Guidelines for Resilient Highway Bridges

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कार्यकारी निदेशक

Madhup Vyas, IAS
Executive Director

सत्यमेव जयते

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FOREWORD

It is my pleasure to present the proceedings of the National Consultative Workshop on "Climate Adaptation Policy and Guidelines for Resilient Highway Bridges," which convened specialists and practitioners to share knowledge, experiences and exemplary practices related to bridge resilience.

This proceedings represent a vital step forward in selection of climate adaptive measures for bridge infrastructure. The recommendations of the experts provide an insight for identifying climate risks, assessing vulnerabilities and integrating adaptation measures into the planning, design, maintenance and retrofitting of highway bridges.

Developed through collaboration with experts in climate science, bridge engineering and infrastructure planning, this document reflects both the current best practices and forward-looking strategies. It is designed to support engineers, planners, policymakers and all stakeholders involved in the highway transportation infrastructure with recommendations to enhance resilience in the face of a changing climate.

This workshop was genuinely enriching because of the insightful presentations and engaging discussions offered by keynote speakers, panelists and moderators. The workshop highlighted the importance of bridge resilience for ensuring the safety, sustainability and economic continuity of transportation systems. The valuable takeaways that will undoubtedly inform and improve practices in bridge design, construction, operation and maintenance. This workshop reminds us of our responsibility to ensure the safety and well-being of all individuals by mainstreaming sustainable and resilient developmental practices.

These proceedings compiles the key findings, insights and recommendations from the workshop, covering topics such as:

1. Understanding the Vulnerability of Bridges on National Highways due to Climate Hazards
2. Multi Hazard Risk Assessment for enhancing resilience of Road Bridge Structures from Climate Hazards
3. Adaptation Strategies for Alleviation of Risk to Bridges from Climate Hazards
4. Gaps and Challenges in Maintenance and Monitoring of Structural Health of Bridges Impacted from Climate Hazards
5. Gaps and Recommendations on Existing Codes, Standards and Guidelines for Climate Resilient Bridges

We hope that these proceedings will serve as a valuable resource for researchers, practitioners and policymakers in the field of bridge engineering and resilience. We look forward to continuing the collaboration and knowledge sharing efforts in the future.

(Madhup Vyas)

PREFACE

Climate change poses significant and evolving challenges to the resilience and sustainability of transportation infrastructure, particularly highway bridges, which serve as critical lifelines for mobility, commerce and emergency responses. Increasingly frequent extreme weather events, rising temperatures and changes in hydrological patterns require a proactive and structured approach to infrastructure planning and management.

This proceeding reflects the outcome of the discussions, presentations and results of the bridge resilience workshop, which gathered leading experts, researchers and professionals from the bridge field. The workshop provided a distinctive platform for sharing knowledge, collaborating and promoting innovation, emphasizing recent developments, challenges and effective methods for bridge resilience. It provides a comprehensive policy framework and practical guidelines for assessing climate risks; identifying vulnerabilities and incorporating adaptation measures into the design, construction, operation and maintenance of highway bridges.

This proceeding is intended to serve as a resource for researchers, practitioners and policymakers involved in bridge engineering and resilience. It is expected that the knowledge, insights and experiences shared in this document will help foster the creation of bridge infrastructure worldwide that would be more resilient, sustainable and safe.

Heartfelt thanks to distinguished experts and delegates for their role in ensuring the success of this workshop on climate adaptation policies and guidelines for resilient highway bridges. Their presence, participation and contributions have enriched the discussions and debates, providing invaluable insights and expertise to the bridge community. We appreciate the time and effort they took to share their knowledge, experiences and best practices. Their contributions have greatly improved the understanding of bridge resilience and its use. By adopting and implementing the principles outlined in this document, stakeholders at all levels can contribute to building more resilient and adaptive transportation networks.

I hope that this document will serve as a valuable resource and inspiration for bridge communities, promoting innovation, collaboration and knowledge sharing in the pursuit of bridge resilience.

Prof. Surya Parkash Gupta

ACKNOWLEDGEMENT

A one day National Consultative Workshop on "Climate Adaptation Policy and Guidelines for Resilient Highway Bridges" was organized by National Institute of Disaster Management (NIDM) on 03rd April 2025 at NIDM, Rohini, Delhi under the Project entitled "Development of National Highways Climate Adaptation Policy and Guidelines ", supported by Ministry of Road Transport and Highways (MoRTH), Government of India.

Our heartfelt thanks to Sh. Akil Ahmad, SE (S&R), MoRTH and Dr. S.L. Swamy, Chairman Institution of Civil Engineers, (ICE), for sharing their vision towards safer development practices highlighting the importance of bridges during inaugural session. We are grateful to Shri Rajendra Ratnoo, IAS, Former Executive Director, NIDM for his constant support and encouragement to organize this workshop. Sincere thanks to Mahesh Tandon, Chairman, Tandon Consultants Pvt. Ltd. for his guidance in shaping the workshop. We are also thankful to the collaborators and consortium partners of the project, Prof. Vimlesh Pant, IIT Delhi, Prof. Raju Sarkar, Delhi Technological University and Dr. Dericks Praise Shukla, IIT Mandi, for their presence and support in organizing the workshop.

Special thanks to Prof. Prem Krishna, Retd. Professor, IIT Roorkee for his kind contribution in successful implementation of the workshop. We are indebted to the experts and the participants from different reputed institutions/ organizations like NHAI, CSIR- CRRI, CSIR- SERC, ICE, MoRTH, University of Gour Banga, Ministry of Railways, IIT Roorkee and IIT Gandhinagar for sparing their time and contributing during the deliberations of the workshop. Their participation has been very useful and significant in drawing up the key outcomes of this important and strategic workshop.

We are grateful to Shri Madhup Vyas, IAS, Executive Director, NIDM; Col. Manoram Yadav, Joint Director, NIDM; Shri Randeep Kumar Rana, Senior Advisor, NIDM, for their support in publication of the proceedings. We also extend our thanks to Shri S.K. Tiwari, Librarian, NIDM and the entire publication cell of NIDM including Mr. Sanjay Kumar, Consultant (Rajbhasha) and Ms Karanpreet Kaur Sodhi, Jr Consultant, Publication for their help in printing and publication of the proceedings.

Further, we expresses gratitude to the NIDM Administration, IT team, Accounts team, Training Cell and other staff of NIDM, for providing administrative and logistic support in the workshop.

Prof. Surya Parkash Gupta

and Project Team

ABBREVIATIONS

ACI	American Concrete Institute
BIS	Bureau of Indian Standards
BMS	Bridge Management System
BRO	Border Roads Organisation
CPI	Chief Principal Investigator
CRRI	Central Road Research Institute
CSIR	Council of Scientific and Industrial Research
DIG	Deputy Inspector General
DTU	Delhi Technological University
FRP	Fibre Reinforced Polymer
GLOF	Glacial Lake Outburst Flood
GMR	Geo-Meteorological Risk
HighCAP	Development of National Highways Climate Adaptation Policy and Guidelines
ICE	Institution of Civil Engineers
IIT	Indian Institute of Technology
IRC	Indian Roads Congress
IRSC	Indian Road Safety Campaign
MBIUs	Mobile Bridge Inspection Units
MoRTH	Ministry of Road Transport and Highways
NASA	National Aeronautics and Space Administration

NDRF	National Disaster Response Force
NGO	Non-Governmental Organization
NHAI	National Highways Authority of India
NHIDCL	National Highways and Infrastructure Development Corporation Limited
NIDM	National Institute of Disaster Management
PARC	Project Appraisal and Review Committee
PD	Project Director
PM	Prime Minister
PWD	Public Works Department
RC-PSC	Reinforced Concrete – Pre-Stressed Concrete
S&R	Standards and Regulations
SE	Superintending Engineer
SERC	Structural Engineering Research Centre
SFDRR	Sendai Framework for Disaster Risk Reduction
SHM	Structural Health Monitoring
TMD	Tuned Mass Damper
WB	World Bank

CONTENTS

1. Introduction

A one-day national consultative workshop on "Climate Adaptation Policy and Guidelines for Resilient Highway Bridges" organized by the National Institute of Disaster Management (NIDM) on 3rd April 2025, was a pivotal initiative under the "Development of National Highways Climate Adaptation Policy and Guidelines (HighCAP)" project. This workshop aimed to enhance the understanding of the impacts of climate change on highway bridge infrastructure and promote the development and implementation of effective adaptation strategies. It sought to provide participants with practical knowledge on climate adaptation policies, technical guidelines, and innovative practices for building and maintaining resilient bridges. The workshop helped collate the key recommendations for updating existing codes, guidelines, and suggestions by bridge experts to build the capacity of decision-makers to integrate climate risk assessments into bridge design, maintenance and management processes. Furthermore, workshop encouraged collaboration between different highway sectors to ensure that highway bridges remain safe, functional and sustainable in the face of evolving climate challenges.

2. Background

In the context of India's ambitious journey towards a 5 trillion-dollar economy, the transport sector plays a pivotal role. India's extensive road and highway network, the second largest road network globally, plays a crucial role in economic development, connectivity and national security. The need for resilient infrastructure planning, risk assessment and adaptive strategies has never become more critical in becoming a developed nation by 2047. The country has witnessed devastating impacts on national highways due to climate extremes in recent disaster events such as catastrophic floods, which have washed away major highway segments, including bridges, disrupted transportation networks and economic activities. However, the increasing risk from climate change and associated climate hazards poses varied vulnerabilities to different highway assets owing to their material strength, location, condition and criticality.

Bridge structures are crucial in highway systems, allowing to overcome geographical barriers such as rivers and valleys, connecting communities enabling access to essential services, jobs, education and social connections for communities and economic development through smooth movement of goods and people promoting trade, commerce and economic growth. Bridges can be designed to accommodate high volumes of traffic, manage congestion, provide efficient movement within a road network and play a critical role in emergency response efforts by allowing access to disaster areas and facilitating the movement of aid supplies. Their resilience is essential for continued transport networks to avoid potential collapses, disruptions and long-term infrastructure degradation. The increasing intensity and frequency of climate-induced hazards threaten the sustainability of bridge infrastructures, often resulting in significant economic losses and humanitarian crises. Moreover, the long-term impacts of climate change, such as rising temperatures and changing hydrological patterns, accelerate material fatigue and structural weakening, rendering existing bridges more vulnerable over time (MoRTH 2023).

Achieving long-term resilience in bridge engineering requires a holistic approach that integrates lifecycle planning, risk assessment, resilient design principles, climate adaptation, research and innovation. By adopting proactive strategies and leveraging technological advancements, bridges can withstand tests of time and contribute to sustainable infrastructure development for future generations.

Therefore, enhancing the resilience of bridges is not just an engineering necessity but also a strategic imperative for disaster preparedness, economic stability and sustainable development. Recognizing the urgency of this issue, the National Institute of Disaster Management (NIDM) has taken the opportunity to facilitate knowledge sharing by organizing a national consultative workshop on "Climate Adaptation Policy and Guidelines for Resilient Highway Bridges" under the project entitled "Development of National Highways Climate Adaptation Policy and Guidelines (HighCAP)". This workshop brought together experts, policymakers, engineers and stakeholders to deliberate on the vulnerabilities, challenges and solutions to enhance the resilience of bridges on roads and highways in India against climate threats. The event covered aspects such as vulnerability mapping, risk assessment, climate-resilient engineering, policy frameworks and innovative technological solutions.

3. Objectives

The main objective of the workshop was to promote discussions and exchange knowledge among participants, including the consortium partners, to create standardized parameters for vulnerability assessments related to multi-hazard risk mapping along national highways. More precisely, the workshop focused on the following aspects:

a) To brainstorm on climate adaptive resilience of bridges

b) To explore innovation in bridges technologies and materials

c) To discuss maintenance and retrofitting of existing bridges

d) To find ways for structural health monitoring of bridge structures

e) To discuss risk-based decision making

4. Workshop Aim and Scope

The workshop aimed to enhance the understanding, preparedness and adaptation measures to reduce the vulnerability of bridges to climate hazards, ultimately contributing to sustainable and disaster-resilient road infrastructure in India. The scope of the workshop included the following:

a) Impact of climate-induced hazards on bridges

b) Structural vulnerability assessment methodologies

c) Climate adaptation and resilience in bridge design, planning, maintenance and retrofitting

d) Case studies of past bridge failures and lessons learned

e) Role of geospatial data and advanced technology in vulnerability mapping

f) Identify policy gaps, provide policy recommendations and best practices for resilient

g) Infrastructure planning

5. Target Groups

a) Officials from the Ministry of Road Transport and Highways (MoRTH), NHAI, NHIDCL, BRO, CRRI, SERC and state PWDs

b) Engineers and Infrastructure Planners

c) Disaster management professionals and scientific researchers

d) Representatives from urban and rural development authorities

e) Academicians from civil engineering, disaster management and climate science backgrounds

f) Representatives from multilateral agencies, institutes, NGOs and industry experts related to the bridge infrastructure

6. Session-wise Summary

The national consultative workshop on "Climate Adaptation Policy and Guidelines for Resilient Highway Bridges" started with the introduction of all the participants. The workshop was conducted in the hybrid mode. The inaugural session was chaired by Prof. Surya Parkash Gupta (PD/CPI, HighCAP & Head of the GMR Division, NIDM). Esteemed dignitaries like Prof. Mahesh Tandon (Chairman, Tandon Consultants Pvt. Ltd.), Prof. Prem Krishna (Prof. Retd., IIT Roorkee), Sh. Akil Ahmad (SE (S&R), MoRTH), Dr. S.L. Swamy (Chairman, ICE) and Sh. Randeep Kumar Rana (Senior Advisor, NIDM) graced the occasion, underscoring collaborative effort and commitment towards building bridge resilience.

6.1 Inaugural Session

6.1.1 Prof. Surya Parkash Gupta, PD/CPI HighCAP

- Prof. Surya Parkash Gupta emphasised that highways are essential connectivity for socio-economic growth of our country, but they also become high-risk zones owing to the regular impact of various hazards. Lacunas in their durability have been observed due to emerging disasters driven by climate change.
- India's connectivity has been continuously impacted in past due to bridge's location, design constraints and poor maintenance. It has been observed during recent disasters in various parts of India such as on 5th Aug 2010 at Leh, on 16th June 2013 in Kedarnath, on 7th Feb 2021 in Chamoli district, in 2023 at Himachal Pradesh and Jammu &

Photo 1: Prof. Surya Parkash Gupta, PD/CPI, HighCAP & Head of GMR Division, NIDM provided overview of the objectives of workshop

Kashmir, etc. A focus on region-specific hazard risk, as per their physiography and climate zones, is needed.

- The WB took initiative with MoRTH to bridge the gap and NIDM was approached to contribute to the development of policy and guidelines for climate adaptation in the NH. Expert recommendations will help formulate the policy and guidelines that would be placed in parliament. Further, if any alteration is required in codes and standards that would also be recommended.

6.1.2 Dr. S.L. Swamy, Chairman, ICE

- Dr. Swamy emphasised the importance of infrastructure preparedness to face the risks and uncertainties in order to make India self-resilient as per Hon'ble Prime Minister's vision for 2047.
- India is affected by extreme weather events which can wipe out key transport links. The climate threats are real present day challenges. The SFDRR guides to build resilient infrastructure from the beginning. Life cycle based approach should address long term climate risk such as for structural fatigue.
- Exposure to hazards varies with terrain, therefore, climate-resilient design standards be adopted accordingly.
- Existing bridges can be strengthened by retrofitting.

Photo 2: Dr. S.L. Swamy, Chairman, ICE as special guest of inaugural session highlighted the importance of infrastructure preparedness, climate threats and climate-resilient design standards

- Technology plays a greater role in present times and geospatial tool is one of the technological tools useful in engineering. Many engineers lack clear guidance of climate adaptation in engineering which needs to be addressed.

6.1.3 Shri Akil Ahmad, SE (S&R), MoRTH

- Shri Akil Ahmad mentioned that India has taken the challenge of becoming *Viksit Bharat* by 2047 and stated that the initiative of NIDM in taking up discussions for bridge resilience would contribute in making India *Viksit Bharat*.
- He highlighted several steps taken by MoRTH in policy strengthening for

Photo 3: Sh. Akil Ahmad, SE (S&R), MoRTH discussed the several steps taken by MoRTH in policy strengthening for bridge construction

bridge construction addressing impacts from high-intensity seismic and wind loads on bridges. These include the use of eco-friendly materials, such as jute in construction and monitoring of projects through Intelligent Monitoring Systems. He added that capacity building of relevant target audience can be achieved by partnering with CRRI and NIDM.

- MoRTH is developing a bridge management system using a scour resistance foundation, taking geo-technical steps to control erosion of embankments, promoting green and eco-friendly highways and updating policy codes whenever a new durable technology is introduced.

6.1.4 Prof. Mahesh Tandon, Chairman, Tandon Consultants Pvt. Ltd.

- Prof. Tandon highlighted the need for clarity between the concept of resilience and sustainability in the context of bridges.
- Resilience proposes robustness, redundancy and reparability of the bridge, rapid restoration of functionality after suffering extreme event or long-term durability deterioration and stringent requirements for collapse resistance and ductility.
- Sustainability has three pillars - economic, social and environmental factors. The workshop must highlight a combination of all these three.

Photo 4: Prof. Mahesh Tandon, Chairman, Tandon Consultants Pvt. Ltd. highlighted the concept of resilience and sustainability in the context of bridges

6.1.5 Shri Randeep Rana, Sr. Advisor, NIDM

- Shri Randeep Rana shared his practical experience as DIG operations, NDRF underlining the fact that during crisis the bridges become lifeline for relief and response.
- He recalled the Kashmir Floods from 2014 when NH was submerged and rendered non - motorable. NDRF faced problems of movement during golden hours to reach the victims due to roads being fully jam packed with traffic and there was lack of information on alternate routes. He cited another experience from the Kedarnath disaster in 2013 during which relief workers had to halt their work for 26 hours due to damage of major bridges.
- He suggested to learn from the conventional wisdom of villagers for

Photo 5: Sh. Randeep Kumar Rana, Senior Advisor, NIDM shared his experiences on Kashmir floods and highlighted the major issues related to damage of bridges

contingency measures in tackling disasters. Ideas of local people can be imbibed for designing of highway bridges.

- He highlighted the importance of prepositioning of raw material kits near bridges in anticipation of disasters. Those kits can be used in the event of disaster to repair the bridges in shorter duration of time as compared to conventional method.

6.2 Technical Session: Enhancing Bridge Resilience against Climate Disasters

Chair: Prof. Surya Parkash Gupta
Co-Chair: Prof. Raju Sarkar

6.2.1 Session 1: Understanding the vulnerability of bridges on national highways due to climate hazards

Dr. Rajeev Goel, Chief Scientist & Head, Bridge Engineering and Structures Division, CRRI

- Dr. Goel discussed the different types of loads considered in bridge design.
- Human activities have caused the warming of the world faster than at any time. The average temperature of the Earth's surface is now about 1.2 degree Celsius warmer than it was in the late 1800s and warmer than at any time in the last 100,000 years. This is causing more and intense extreme weather events.

Photo 6: Dr. Rajeev Goel, Chief Scientist & Head, Bridge Engineering and Structures Division, CRRI highlighted the vulnerability of bridges on national highways due to climate hazards

- As a result bridges are exposed to different kind of loads – Snow load, Wind load, Impact due to floating bodies or vehicles, Vehicle collision load, Wave pressure to name a few.
- Bridges are designed for 100 years return period of floods. However, it is anticipated that frequency of return period may reduce to 20 years in next 30-40 years. Thus, there is higher risk of crossing high flood level very frequently.
- Climate change also increases the risk of landslides/slope failure due to precipitation, higher scour depth due to higher average annual run – off, additional loads on foundation, higher risk of damages to bridges due to avalanches, higher thermal stress in the bridges, damages to bridge bearings at expansion joints due to higher expansion of bridge and reduction in remaining fatigue life of bridge.
- Other climate change related risks include the risk of instability of cable stayed bridges due to higher wind speeds, accelerated deterioration of concrete and steel due to higher values of temperatures, rainfall, relative humidity and carbon dioxide and higher corrosion probability in those substructures which were earlier not in splash zones due to rise in sea levels.

- He highlighted the research gaps and underscored the need of studies on creep and shrinkage on the basis of changed climate conditions and relative humidity, studies on the effective temperature and temperature gradients and studies on various properties of materials such as fatigue, strength, corrosion etc.
- He informed that a new document on the Hydraulics of Bridges is being prepared by the IRC, considering the effects of climate change.

6.2.2 Session 2: Multi hazard risk assessment for enhancing resilience of road bridge structures from climate hazards

Prof. Vasant Matsagar, Head, Department of Civil Engineering, IIT Delhi

- Prof. Matsagar started his discussion by citing examples of failure of lifeline structures such as bridge pier or deck damage during the Kobe earthquake and the pounding of deck girders caused by the 2001 Bhuj earthquake.
- He highlighted the significance of Performance-Based Seismic Design (PBSD) of structures such as service life multi-hazard risk assessment of bridges, infrastructure design for beyond loads and load combinations and multi-hazard risk evaluation of infrastructure.
- He highlighted the importance of studying effects of multi-hazard on infrastructure and discussed the Arizona bridge collapse in 2015. He mentioned heavy rains cause scouring by washing away riverbed materials.

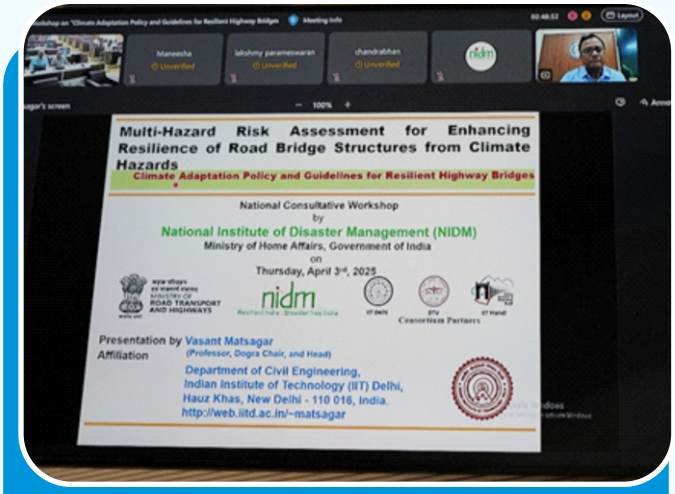

Photo 7: Prof. Matsagar discussing resilience of road bridge structures from climate hazards

- Multi-hazard impacts under earthquake and scour (earthquake and flood induced scouring) is a major concern for lifeline bridge engineering research communities.
- He discussed multiple hazards to which structures are vulnerable, dynamic response control in bridges, dynamic control for highway bridges, practical applications of control devices, Tuned Mass Dampers (TMDs) in real-life bridges and enhanced resilience under multi-hazard scenarios.
- He advised multi-hazard risk assessment for enhancing the resilience of road bridge structures from climate-induced hazards and vulnerability can be addressed through appropriate structural design mandates through codes and specifications.

6.2.3 Session 3: Case study on bridge failure due to climate related disasters

Dr. Rajeev Kumar Garg, Prof. Emeritus, DTU

- Prof. Garg highlighted climate variables (CO_2 concentration, temperature, sea-level rise precipitation patterns, relative humidity, and chloride levels) and discussed how they affect infrastructure.

- He presented failure bridge database for India from 1977 to 2017. In four decades, 2130 bridges failed in service. The average age of failure of the bridge is calculated to be 34.5 years. He also informed that during construction stage 123 bridges failed in India from 1977 to 2017.
- He attributed the failure of bridges to overloading deterioration, natural disasters, design & construction and human-made disasters like accidents/ blasts. In addition, extreme weather events and their impact on bridge was discussed.

Photo 8: Dr. Rajeev Kumar Garg, Prof. Emeritus, DTU discussed the bridge failure due to climate related disasters

- He suggested that vulnerability can be addressed by using several approaches, such as performance-based, resilience – based, life-cycle by economics consideration and life- cycle by environmental considerations (carbon – management).

6.3 Panel Discussion (Policy, Regulations & Institutional Frameworks in India in the context of Bridges)

Chair – Prof. Mahesh Tandon
Co-chair- Prof. Prem Krishna

6.3.1 Prof. Mahesh Tandon, Chairman Tandon Consultants, Pvt., Ltd.

Prof. Tandon focussed his discussion on following key codes and standards:

- Fib model code for concrete structures (2020).
- Code requirements for environmental engineering concrete structure (ACI 350) and commentary (ACI 1350R-01).
- Standard guide for community resilience planning for building & infrastructure (E3350-22) International standard.

Photo 9: Prof. Mahesh Tandon, Chairman Tandon Consultants, Pvt. Ltd. chairing the panel discussion

6.3.2 Dr. Alok Bhowmick, CEO, B&S Engineering Consultants Pvt., Ltd.

- Dr. Bhowmick discussed the evolution of codes & standards over the years from the code of Hammurabi to present day codes. He also shed light on code making bodies in India.

- He highlighted the need for the codes and standards as they have societal impact and provide feedback mechanism as well as verification of structural adequacy.
- Current codes lack the climate considerations and therefore, revisions are required for sustainability and resilience of infrastructure.
- New codes must address the following to reduce the impact of climate change on bridges:
  - » Social performance-robustness, structural resilience, health & quality of built environment and aesthetics, safety, durability, and serviceability.
  - » Environmental performance-CO_2 emissions, resource use, energy use, waste generation and impact on bio-diversity. Economic performance- Construction cost, operation cost, maintenance cost, refurbishment cost, demolition cost and capital cost.
- Until India develops its own updated codes, international standards can be followed.

Photo 10: Dr. Alok Bhowmick, CEO, and B&S Engineering Consultants Pvt. Ltd. spoke on relevance of current codes and policies

6.3.3 Prof. Prem Krishna, Retd. Professor, IIT Roorkee

- Prof. Prem Krishna reiterated the urgency of updating the codes.
- He informed that IRC codes such as IRC: 5 (General Features of Design of Highway Bridges), IRC: 6 (Load & Stresses) and IRC: 112 (Concrete Road Bridges) have been widely adopted.
- He advised that bridges must undergo regular inspections under IRC guidelines (typically annual or biennial). Specialized audit of structures after natural calamities or audit of older structures must be undertaken.

6.3.4 Dr. Sanjeev Kumar Garg, Executive Director (Urban and Rapid Regional Transport), Ministry of Railways

- Dr. Sanjeev Kumar Garg discussed the relevance of current codes & policies, designing resilient bridges, role of codes and policies in risk reduction and ensuring implementation of policies and regulations for resilient bridges.
- He suggested that the critical actions required during and after construction should be recorded in drawing.

Photo 11: Dr. Sanjeev Kumar Garg, Executive Director (Urban and Rapid Regional Transport), Ministry of Railways discussed the institutional frameworks in India in the context of bridges

- The restoration strategy for bridges outlined by Dr. Garg included designing resilient bridges, availability of design and drawing, use of standard size spans-modular bridges and buffer of trained man power.
- He advised to integrate the updated codes into education and training.

6.3.5 Mr. G.K. Sahu, Chief Scientist, CSIR-CRRI

- Mr. G.K. Sahu highlighted the important role of structured inspections, advanced instrumentation and effective regulatory implementation in ensuring the long-term resilience of highway bridges in India. He also discussed on the operational challenges and the systemic gaps in bridge maintenance practices.

Photo 12: Mr. G K Sahu, Chief Scientist, CSIR-CRRI, discussing operational gaps in maintenance of bridges

- He emphasized the need for special attention to bridges situated near river, as well as suspension and cable-stayed structures, which demand the use of specialized equipment such as drones, underwater scanning robots, Mobile Bridge Inspection Units (MBIUs) and man lifters.
- Mr. Sahu proposed a national initiative focused on the systematic cleaning and maintenance of key bridge components, including expansion joints, drainage spouts, bearings, piers and cables. He strongly advocated for mandatory instrumentation in all critical bridge projects, referencing successful implementations of sensor-based monitoring systems on the Ganga Bridge in Varanasi, the ITO Bridge in Delhi and the Jamshedpur railway bridge.
- He advised that without consistent policy enforcement and the adoption of modern technologies, the goal of achieving sustainable and climate-resilient bridge infrastructure will remain out of reach.

6.3.6 Dr. Vipul Prakash, Professor of Structural Engineering, IIT Roorkee

- Dr. Vipul Prakash emphasized the climate-induced vulnerabilities affecting bridge infrastructure and pointed out fundamental shortcomings in existing design and codal provisions, especially those rooted in the Limit State Method (LSM). He critically assessed the adequacy of Indian bridge design

Photo 13: Dr. Vipul Prakash, Professor of Structural Engineering, IIT Roorkee, discussing review and revision of existing codes

standards-such as IRC: 112, IRC: 18, and IRC: SP: 65 in addressing durability and resilience challenges posed by changing climate conditions.

- He recommended a comprehensive review and revision of IRC codes, with specific attention to:
  - » Distinct treatment of RCC and PSC structures (not a unified design approach)
  - » Strengthened detailing provisions for high-compression elements
  - » Integration of climate-based thermal stress considerations in structural safety checks

6.4 Session 5: Adaptation strategies for alleviation of risk to bridges from climatic hazards

Shri V. N. Heggade, Vice President (West)-IA StructE and Founder of DECon Complete Solutions

- Shri Heggade discussed the serviceability, durability, geo-technical and operational effects of climate change events on bridges.
- He advised that codes be re-calibrated to incorporate updated standards considering higher temperatures, increased rainfall, floods and stronger winds.
- High-performance concrete, corrosion-resistant steel and fibre-reinforced polymers can withstand moisture, temperature variation and salinity.
- Bridges should be designed with efficient drainage to prevent water accumulation and reduce hydrostatic pressure.

Photo 14: Shri V. N. Heggade, Vice President (West)-IA StructE and Founder of DECon Complete Solutions shared the adaption strategies for alleviation of risk to bridges from climatic hazards

- More frequent inspections of bridges are required, especially after extreme weather events.
- Use asset management systems to prioritize adaptation investments based on bridge vulnerability assessment.
- Use future climate models during project planning of bridges and not just historical data.

6.5 Session 6: Gaps and challenges in maintenance and monitoring of structural health of bridges impacted from climate hazards

Dr. Srinivas V., Chief Scientist CSIR-SERC

- Dr. Srinivas V. emphasized that most bridges in India, especially rural or older ones, lack sensors or automated systems to detect damages.
- He informed that many state and local bridges are not fully documented in national databases. (e.g., MoRTH BMS).

- He remarked that the difficulty in forecasting the scale and type of hazard (e.g., changing flood zones) leads to inadequate planning for bridges maintenance.
- National, state and local bodies often have unclear roles in bridge maintenance, leading to delayed actions.
- Many authorities lack formal response plans for rapid inspection and repair following climate-related incidents.

Photo 15: Dr. Srinivas V, Chief Scientist CSIR-SERC discussed the gaps and challenges in maintenance and monitoring of structural health of bridges

6.6 Session 7: Gaps and recommendations on existing codes, standards and guidelines for climate resilient bridges

Dr. Lakshmy Parameswaran, Chief Scientist (Retd.) CSIR-CRRI, Member of the Executive Committee, ING-IABSE

- Dr. Lakshmy Parameswaran pointed out that existing standards (e.g., IRC codes) primarily use historical climate data and do not account for future projections (e.g., increased rainfall, floods, and temperature extremes).
- Current standards largely focus on new construction, and there is little guidance for up grading of existing bridges to withstand future climate stressors.
- Bridge design codes (IRC: 5, IRC: 6, IRC: 112, etc.) do not explicitly integrate risk assessments for climate hazards such as cyclones, sea level rise, or Glacial Lake Outburst Floods (GLOFs).
- There is a need to introduce a dedicated national guideline or supplement to IRC codes focusing on the design criteria for climate-adaptive bridges (materials, elevation, drainage, etc.).
- She recommended to update standards to encourage climate-resilient materials (e.g., FRPs and corrosion-resistant steel) and digital tools such as Structural Health Monitoring (SHM) systems and remote sensing.
- She advised to provide training to engineers and officials of bridge authorities to apply updated codes and assess climate risks during all project phases.

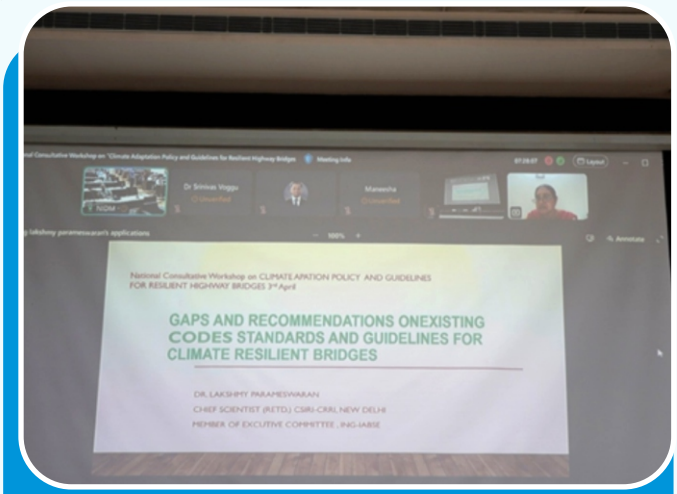

Photo 16: Dr. Lakshmy Parameswaran, Chief Scientist (Retd.) CSIR-CRRI, Member of the Executive Committee, ING-IABSE shared gaps and recommendations on existing codes, standards and guidelines for climate resilient bridges

7. Key Takeaways

Discussions and deliberations during national consultative workshop on climate adaptation policies for resilient highway bridges emphasized the urgent need to assess and manage risks from climate change impacts, such as flooding, sea-level rise, heat waves and extreme storms. All the experts have unequivocally advised to promote the integration of climate considerations into every stage of infrastructure planning, design, construction, maintenance and operation. Some of the key takeaways include-

- **Design Standards Update:** It has been suggested that bridge design codes should be revised to incorporate future climate conditions based on historical data on past disaster impacts (e.g., increased loadings from floods and thermal expansion).
- **Vulnerability Assessment:** Evaluating a bridge's structural and functional weaknesses under various hazard scenarios is key to identify critical failure points.
- **Bridge Age and Condition:** Older bridges are more vulnerable to climate hazards owing to outdated design codes, deterioration over time and wear and tear. Regular inspection and maintenance are critical to identify vulnerabilities.
- **Resilient Infrastructure:** Move towards a performance-based design approach that emphasizes bridge performance during extreme events, rather than solely meeting static criteria.
- **Mainstreaming Adaptation:** Climate considerations should be integrated into all phases including planning, design, construction, maintenance and retrofitting.
- **Adaptive Capacity:** Bridges should be designed flexibly to allow for future adjustments and enhancements as climate conditions change.
- **Use of Climate Projections:** It has been recommended that engineers and planners should utilize multiple climate scenarios instead of depending on one forecast.
- **Cost Benefit Analyses:** It is good to use economic tools to weigh the initial investment in resilience against potential future losses.
- **Training and Education:** It has been emphasized to build technical capacity of engineers, planners and decision-makers.
- **Data-sharing platforms:** Centralized access to climate data and best practices be promoted to support informed decision-making.
- **Adaptation Strategies:** Adaptation measures include retrofitting bridges with enhanced materials, elevating decks, strengthening foundations and incorporating climate-resilient features, such as improved drainage or flood barriers.
- **Long-Term Planning and Monitoring:** Given the dynamic nature of climate risks, continuous monitoring and long-term planning are necessary to keep national highway bridges resilient to evolving climate threats.

8. Programme Agenda

सड़क परिवहन एवं राजमार्ग मंत्रालय
MINISTRY OF ROAD TRANSPORT AND HIGHWAYS
सत्यमेव जयते

nidm
Resilient India - Disaster Free India

IIT Delhi | DTU | IIT Mandi
Consortium Partners

National Consultative Workshop

on

"Climate Adaptation Policy and Guidelines for Resilient Highway Bridges"

Date: 3rd April, 2025

Chanakya Hall, Ground Floor, NIDM,
(Ministry of Home Affairs, Government of India),
Plot no. 15, Pocket-3, Block-B, Sector-29, Rohini, Delhi -110042

https://maps.app.goo.gl/CZrmo8AUr5uXP1vD7

Time	Session Title & Details	Resource Persons
10:30 AM-11:15 AM	Inaugural Session	Prof. Surya Parkash Gupta, PD/CPI HighCAP Shri Randeep Rana, Sr. Advisor, NIDM Shri Akil Ahmed, Senior Official, MoRTH Dr. S.L. Swamy, Chairman, ICE, Special Guest Ms. Bindu Aggarwal, Project Manager, Vote of Thanks
11.15 AM-11.30 AM	Group Photo and High Tea	
Technical Session: Enhancing Bridge Resilience against climate disasters Chair - Prof. Surya Parkash Gupta, Co- Chair - Prof. Raju Sarkar		
11:30 AM-12:00 PM	**Session 1**: Understanding the Vulnerability of Bridges on National Highways Due to Climate Hazards	Dr. Rajeev Goel
12:00 PM-12:30 PM	**Session 2**: Multi Hazard Risk Assessment for Enhancing Resilience of Road Bridge Structures from Climate Hazards	Prof. Vasant Matsagar
12:30 PM-1:00 PM	**Session 3**: Case Studies - "Bridge Failure Due to Climate Change"	Dr. Rajeev Kumar Garg

Time	Session Title & Details	Resource Persons
1:00 PM- 2:00 PM	**Session 4: Panel Discussion** Policy, Regulations & Institutional Frameworks in India in the context of Bridges	
	Chair : Prof. Mahesh Tandon, **Co-Chair** : Prof. Prem Krishna	**Panelists**
	1) Relevance of Current Codes & Policies 2) Designing Resilient Bridges 3) Role of Codes and Policies in Risk Reduction 4) Ensuring Implementation of Policies and Regulations for Resilient Bridges	1. Dr. Alok Bhowmick 2. Dr Sanjeev Kumar Garg 3. Prof.Vipul Prakash 4. Mr. GK Sahu 5. NHAI
02:00 PM- 03:00 PM	Lunch	
03:00 PM- 03:30 PM	**Session 5:** Adaptation strategies for alleviation of risk to bridges from climatic hazards	Shri V. N. Heggade
03:30 PM- 04:00 PM	**Session 6:** Gaps and challenges in maintenance and monitoring of structural health of bridges impacted from climate hazards	Dr. Srinivas V
03:30 PM- 04:00 PM	**Session 6:** Gaps and challenges in maintenance and monitoring of structural health of bridges impacted from climate hazards	Dr. Srinivas V
04:00 PM- 04:20 PM	**Session 7:** Gaps and Recommendations on Existing Codes, Standards and Guidelines for Climate Resilient Bridges (Online)	Dr. Lakshmy Parameswaran
4:20 PM- 4:30 PM	**Summary by Chair and Co-Chair of Technical Session**	
04:30 PM- 04:45 PM	Way Forward: Developing Climate Adaptation Policy and Guidelines through Resilient Bridge Infrastructure	PD, HighCAP
04:45 PM- 04:55 PM	Valedictory Address	Shri Rajendra Ratnoo (IAS), Former ED, NIDM
04:55 PM- 05:00 PM	Vote of Thanks	Project Director, HighCAP
05:00 PM- 05:30 PM	Tea Break	

Glimpses of the Workshop

Photo 17: Inaugural session: Prof. Surya Parkash Gupta, PD/CPI, HighCAP & Head of GMR division provided the overview of the objectives of the consultative workshop.

Photo 18: Inaugural session dignitaries (left to right): Ms. Bindu Aggarwal, Project Manager, HighCAP, Prof. (Retd.) Prem Krishna, Mr. Akil Ahmad, SE (S&R) MoRTH, Prof. Surya Parkash Gupta, PD, CPI, HighCAP, Dr. S.L. Swamy, Chairman, ICE and Prof. Mahesh Tandon, Chairman Tandon consultants Pvt. Ltd.

Photo 19: Shri Rajendra Ratnoo, IAS, Former ED, NIDM interacted with experts during the valedictory session

Photo 20: Prof. Surya Parkash Gupta, PD/CPI, HighCAP and Rajendra Ratnoo, IAS, Former ED, NIDM felicitated Shri Akil Ahmad, SE (S&R), MoRTH

Photo 21: Group Photo of the delegates and organising team present in the National Consultative Workshop on Climate Adaptation Policy and Guidelines for Resilient Highway Bridges held on 3rd April 2025

Photo 22: Group Photo of the delegates and organising team with ED, NIDM after valedictory session

Workshop Flyer

11. List of Participants

S. No.	Name	Designation
1.	Prof. Mahesh Tandon	Chairman, Tandon Consultants Pvt Ltd, Guest faculty IIT Gandhinagar
2.	Dr. Rajeev Goel	Chief Scientist and Head Bridge Engineering and Structure Division CSIR-CRRI
3.	Prof. Rajeev Kumar Garg	Professor Emeritus, Department of Civil Engineering, Delhi Technological University
4.	Mr. Alok Bhowmick	Adjunct Professor,VR Siddhartha Engineering College & Owner of B&S Engineering Consultants Pvt. Ltd.
5.	Prof. Vipul Prakash	Professor, Structural Engineering, IIT Roorkee
6.	Dr. Sanjeev Kumar Garg	Executive Director (Urban and Rapid Regional Transport), Ministry of Railways, earlier on deputation to DMRC and IRSE officer
7.	Dr. Srinivas V.	Chief Scientist, CSIR- SERC
8.	Mr. Ganesh Kumar Sahu	Senior Principal Scientist, Bridge Engineering and Structures Div. CSIR-CRRI
9.	Prof Vasant Matsagar,	Professor, Dogra Chair, and Head, Department of Civil Engineering, IIT Delhi
10.	Prof. Prem Krishna	Retd. Professor, IIT Roorkee
11.	Prof. Yogendra Singh	Professor, Civil Engineering, IIT Roorkee
12.	Dr. Rakesh Ranjan	Assistant Professor, Civil Engineering, IIT Roorkee
13.	Dr. Shivang Shekhar	Assistant Professor, Structural Engineering, IIT Mandi
14.	Dr. Lakshmy Parameswaran	Retd. Chief Scientist, Bridge Engineer, CSIR-CRRI
15.	Dr. Vivek Gupta	Assistant Professor, School of Civil and Environmental Engineering, IIT Mandi
16.	Prof. Raju Sarkar	Department of Civil Engineering, Delhi Technological University
17.	Dr. Dericks P. Shukla	Associate Professor, School of Civil and Environmental Engineering, IIT Mandi
18.	Dr. Sunil Saha,	Department of Geography, University of Gour Banga
19.	Prof. Vimlesh Pant	Centre For Atmospheric Sciences, Block VI Indian Institute of Technology, Delhi
20.	Shri V. N. Heggade	Vice President (West) - IAStructE and Former CEO, STUP Consultants & founder of DEC on Complete Solutions, HOD of Technical Mgt. at Gammon India Limited

S. No.	Name	Designation
21.	Shri Pankaj Menawat	EE, MoRTH
22.	Shri Vipin Kumar Gupta	Institutional Development Expert from Project Monitoring Consultant
23.	Shri Satyam Chokkapu	Team Leader cum Infrastructure Expert from Project Management Consultancy Services
24.	Shri Akil Ahmad	SE (S&R), MoRTH
25.	Dr. S.L Swamy	Chairman, ICE(I)
26.	Col. Rohini Kumar	Pathak (Retd), ICE (I)
27.	Ms Mahi Swami	Intern (ICE)
28.	Shri Sanjay Nawani	Manager (Tech.), NHAI
29.	Dr. Pankaj Kumar	Assistant Professor, NIDM
30.	Dr. Arkaprabha Sarkar	Assistant Professor, NIDM

12. Programme Team

Patron

Shri Rajendra Ratnoo, IAS, Former Executive Director, NIDM

Programme Chair

Prof. Surya Parkash Gupta, Project Director/CPI HighCAP & Head, GMR Division

Programme Convenor

Ms. Bindu Aggarwal, Project Manager, HighCAP

Supporting Team

Ms. Yogita Garbyal, Project Scientist-II, HighCAP, NIDM

Dr. Aditya Kumar Anand, Project Scientist-II, HighCAP, NIDM

Mr. Gautam Pathare, Sr. Project Associate, HighCAP, NIDM

Dr. Nirbhav, Sr. Project Associate, HighCAP, NIDM

ABOUT THE INSTITUTE

The National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its re-designation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management. Both as a national Centre and then as the national Institute, NIDM has performed a crucial role in bringing disaster risk reduction to the forefront of the national agenda. The Institute believes that disaster risk reduction is possible only through promotion of a "Culture of Prevention" involving all stakeholders. The Institute works through strategic partnerships with various ministries and departments of the central, state and local governments, academic, research and technical organizations in India and abroad and other bi-lateral and multi-lateral international agencies.

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