THRUST AREAS UNDER LANDSLIDES IN INDIA

सत्यमेव जयते
प्रो. आशुतोष शर्मा
Prof. Ashutosh Sharma

स्वच्छ भारत
एक कदम स्वच्छता की ओर

सचिव
भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
विज्ञान और प्रौद्योगिकी विभाग
Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

FOREWORD

Department of Science & Technology, Govt. Of India is supporting R&D activities in the area of landslide hazard mitigation over the last two decades. Over the years, research activities have been focused to prepare inventory of landslides, landslide hazard zonation mapping risk assessment, monitoring of critical landslides sites for developing slope stability models, design of site specific preventive measures and developing capacity and training at various levels. Considering the advancement of data acquisition techniques and improvement of software / modeling capabilities, the research activities in this area have been re-sharpened based on the Expert consultative meeting held in IIT, Mumbai on 20-21 May, 2016. Efforts have also been made to revise the thrust areas on landslide hazard mitigation so that wide range of research activities is considered for support including development of early warning system.

I am happy to note that Department of Science & Technology is working on such an important area of disaster management which is very crucial to provide relevant information / warning mechanism to larger stakeholders including government officials and citizens at large. I hope that thrust areas on landslide hazard mitigation will provide a broad spectrum to address various underlying causes of landslide through intensive research support and developing area specific models to control and minimize the landslide events.

Place : New Delhi
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(ASHUTOSH SHARMA)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
Tel: 00 91 11 26511439 / 26510068 • Fax: 00 91 11 26863847 • E-mail: dstsec@nic.in • website: www.dst.gov.in

सत्यमेव जयते

Telegram : Scienctech
दूरभाष/Tel : 26962819, 26567373,
26562134, 26562122 (EPBAX)
फैक्स/Fax : 26569908, 26864570,
26863847, 26862418
वेबसाइट/website : www.dst.gov.in

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विज्ञान और प्रौद्योगिकी मंत्रालय,
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टेक्नोलॉजी भवन, नया महरौली मार्ग,
नई दिल्ली-110 016

GOVERNMENT OF INDIA
MINISTRY OF SCIENCE AND TECHNOLOGY,
DEPARTMENT OF SCIENCE AND TECHNOLOGY,
TECHNOLOGY BHAVAN, NEW MEHRAULI ROAD,
NEW DELHI-110 016

PREFACE

Landslide hazard mitigation - a multi-disciplinary and multi-agency coordinated R&D programme of Department of Science & Technology is operational over more than two decades. During this long journey, the programme has gone through different phases of research and development activities. Initially, efforts were made to carry out landslide zonation mapping and risk assessment. Based on several pilot studies, a landslide Atlas of India has been brought out. With the advancement of computing models and improvement in satellite data interpretation, further refinement in the research areas have been made to address the slope monitoring and stability analysis, which lead to design of site specific control measures.

At present several critical sites are under constant monitoring which could lead to developing early warning system. The specific instrumentation for developing co-relation between threshold of rainfall and landslide triggering is being carried out in different environmental conditions to build up a criteria for deciding the warning mechanism of landslides.

As part of capacity building and training including dissemination of technologies for adoption is being given special attention with the participation of stakeholders. Uttarakhand State has been selected for carrying out damaged assessment and risk mapping as part of Kedarnath tragedy occurred in 2013. The results brought out under the project have been shared with the State Government to decide safe locations for infrastructure development. Further, studies are on to refine the models required for slope stability and developing design for preventive measures. The thrust areas identified through the expert consultations would be of great help to the young and talented scientific community to undertake relevant research.

Place : New Delhi
Date: 15th July, 2016

(Dr. Bhoop Singh)
Advisor / Head (NRDMS & NSDI)
Department of Science & Technology
New Delhi-110016

1.0 BACKGROUND

Landslides have become the most recurring phenomenon causing immense and irreparable damage to the man and properties all over the world. In the Indian sub-continent too, landslides which were once confined to the mighty Himalayan Mountains have now expanded to almost all the mountainous belts during last few decades. While the Geological Survey of India, the lead geo-exploration agency, has been studying landslides as a part of its nationwide geological mapping, the Disaster Management Support Programme (DMSP) of Department of Space, Govt. of India, has come out with the Landslide Hazard Zonation Mapping methodology to examine and validate the credentials of space borne satellite remote sensing for landslides. The other agencies like Central Road Research Institute (CRRI), Central Building Research Institute (CBRI) , Wadia Institute of Himalayan Geology (Dehradun) and defence related agencies like Boarder Roads Organization (BRO), Defense Research and Development Organization (DRDO), Snow and Avalanche Studies Establishment (SASE) etc., have been carrying out studies on landslides to minimize landslides vulnerabilities in their developmental projects and programs and also to provide solutions to others, wherever and whenever required.

The lack of significant references/ research work reveals that no systematic landslide hazard mitigation studies have been carried out in India before 1980. However the available information shows that the studies carried out on landslides in India prior to 1990 were totally on ad-hoc basis and proper coordinated efforts were made neither from funding part nor from the studies point of view. Duly realizing the need, the Department of Science & Technology, Govt. India, launched a multi-disciplinary and multi-institutional coordinated programme on landslide hazard mitigation with the key objectives as to:

- Evolve methodologies for landslide hazard zonation
- Carry out landslide hazard zonation mapping in selected areas.
- Develop suitable preventive measures
- organize training sessions/programmes for the stake holders

2.0 MAJOR MALPA LANDSLIDE IN SEPTEMBER 1998

During the initial period, the major landslide took place in Malpa in Sept, 1998 along the Kali River (district Pithoragarh, Uttarakhand) which is also a prominent route for the Indian pilgrimage visiting the holy shrine in Mansarovar, China. Afterwards this area was studied. In this study efforts were made to map the landslide prone areas, because during the 1998 event 201 devotees, who were sleeping along the road below the slope were killed. This event has further stimulated the Govt. of India to re-look into the various R&D efforts being made by different agencies on landslide mitigation, besides the above mentioned multi-disciplinary and multi-institutional programme. In this connection, a meeting was organized under the Chairmanship of Secretary, DST, which took stock of the status of our preparedness and the research capabilities of different institutions concerned with landslides. Based on this, the following three Task Forces were constituted to draw a detailed action plan for Research and Development on landslides:

1. Task Force on “landslide hazard zonation” coordinated by GSI

2. Task Force on “geotechnical investigations” coordinated by DST

3. Task Force on “land use regulations and planning” coordinated by MoEF.

During 2000-01, the first two Task Forces had submitted their reports, except the Task Force (3).

Task Forces on landslide hazard zonation and geotechnical investigations have done commendable work to prioritize the research activities. However, in spite

of all this, not much attention was paid by the agencies concerned with implementation of the recommendations of the Task Forces. However concurrent to the Malpa studies , the Department of Science & Technology, Govt. of India, New Delhi, being the authorized agency for promoting Science & Technological research in India, has come out with an exclusive "mission mode programme on Landslides" through the NRDMS Division . Thus, during the last more than two decades, DST /NRDMS has supported more than 100 projects to various R&D institutions/universities and CSIR labs through a standard mechanism , such as peer review of the proposals, presentation by the proponents of these projects and thoroughly wetting them during the meetings of Project Advisory Committees (PAC) ,finally the financial supports etc. As a result, huge amount of data has been gathered by different scientists from different parts and different geological provinces of the country related:

i. Landslide Hazard Zonation Mapping using traditional techniques as well as advanced tools like Remote Sensing, GIS, GPS, Photogrammetry, SAR interferometry, Resistivity Tomography, etc.
ii. Large scale mapping and geotechnical investigations of major and recurring landslides
iii. Rock mechanics, factor of safety and numerical modeling
iv. Risk assessment and mitigation strategies
v. Instrument based early warning systems etc.

3.0 NEED FOR INTEGRATED STUDIES

But the concurrent synthesis of these studies carried out under the funding of NRDMS and other agencies showed that different workers followed different methods, used varying geological and geotechnical parameters, that too each parameter having differing degree and depth of information, different tools, etc. all leading to the development of models and concepts with greater

variance in Landslides mapping, mitigation and management. Again, such a synthesis has also indicated perceptible spatial and technological gaps. Lack of organized data base on the studies carried out on landslides was also inferred during the synthesis. Further there is no agency in the country working exclusively on landslides and which could own the responsibility and provide solutions. It was further inferred that critical manpower required to face the landslides is lacking in India. So, DST, New Delhi, felt it essence to organize a series of "Brainstorming Sessions on Landslides", inviting the leading scientists and other researchers from different parts of the country to share their findings through key note addresses / discussions and finally carve out a road map for the future comprehensive studies on landslides and necessary funding by DST.

4.0 CONSULTATIVE MEETING ON 20 – 21st May, 2016

The recent brainstorming session was conducted on 20 – 21st May, 2016 at IIT Bombay, Mumbai. Prof. T. N. Singh, Department of Earth Sciences coordinated the proceedings. The final recommendations for thrust areas for undertaking Research activities under the landslide programme are as below:

4.1 Reactivated landslide - Failure mechanism and probability of failure in past landslides

- Investigate known landslides
- Possible causes of reactivation
- Investigate possibilities for reactivation
- Role of drainage systems in landslide probable areas

4.2 Landslide hazard zonation mapping and Risk Assessment

- Application of Geospatial technologies for mapping and characterization with respect to associated risk

- High resolution satellite data and its ability for visualization of landslide hazard

4.3 Instrumentation and monitoring of critical landslides

4.4 Real time monitoring and development of early warning systems

- Scope for complete monitoring at slide prone areas
- Rainfall – soil – geological conditions monitoring
- Identify relations among different soil properties with rainfall patterns (lab to field scale)
- Monitoring using acoustic emission technique for rockslides
- Angle shift or geometrical modification leading to stabilization
- Physical demonstration of slope monitoring systems

4.5 Earthquake triggered landslides

- Slides induced by ground movements due to seismic activities
- Dynamic slope stability investigation – numerical modelling
- Role of liquefaction and PGA in triggering slides
- Relation between seismic and rain pattern induced slides
- Investigate impact of low magnitude quakes (4 and above) on slides
- Influence of active tectonic related structures and activities on slides
- Past earthquakes leading to landslides in tectonically active areas

4.6 Basic and Advanced Remote Sensing and GIS Tools

- Algorithm development
- Remote sensing acquisition, processing and analysis for landslides
- Support LiDAR related monitoring, investigation and data analysis

- Investigate the rate of movement
- Integration of remote sensing data with field and geotechnical investigation
- Development of protocol for of acquisition and interpretation of big data

4.7 Characterization of slope materials and its relation with landslide occurrences

- Mixed characterization of soil/rock
- Determination of correct values – particularly in-situ values
- Determining the factor of safety using rock mass data
- Equivalent material characterization and up scaling
- Debris flow mechanics – process in a physical laboratory
- Rockfall analysis, prediction, prevention and mitigation

4.8 Multiple types of landslides and debris flow

4.9 Geo-statistics in geotechnical engineering relevant to landslide studies

4.10 Numerical simulation

- Slope stability investigation using Geomechanical modelling
- Simulation of deposition profile and distance travel to calculate the associated risk
- 2D and 3D numerical models
- Numerical modelling schemes like limit equilibrium method (LEM), finite element method (FEM), finite difference method (FDM), discrete element method (DEM) and integral equations
- Software development and utility for data processing

- Big data analytics from soft computing for prediction of landslides

4.11 Geological structures and their relation with landslides

- Shear matrix of joints including role of the overburden
- Persistence and non-persistence of discontinuities
- Variable lithology controls on slides
- Geologic sections along bedding and joints and across contours
- Profiling of the rear end of a slide – ground-to-toe calculations
- Estimation of volume of slided materials
- Quaternary sediments deposition profile and its relation with landslide triggering
- Geochemical analysis and modelling with respect to landslides
- Clay Mineralogy and other weak materials

4.12 Geophysical Investigation for landslide mapping and analysis

- Ground Penetrating Radar (GPR) survey – vertical profiling of sub-surface materials
- Resistivity survey: demarcation of water/rock bodies
- Tomography, mapping – to determine bedrock profiles

4.13 Reinforcement and stabilization methods – site specific control methods

- Geometrical scaling
- Biostabilization
- Geomechanical stabilization
- Soil nailing design and field tests
- Geo-grid and geotextile applications

- Development of new materials for stabilization
- Chemical grouting with fibers for improving the factor of safety

4.14 Climate impact on landslides

- Water rock interactions in variable climatic conditions

4.15 Hydrological factors influencing the landslides including glacial melts

4.16 Rockfall and landslides around archaeological structures

4.17 Coastal landslide investigations

5.0 OTHER RECOMMENDATIONS

5.1 Benchmark study of a selected landslide

- Before and after remedial measures
- Projects in the networking mode

5.2 Identify zonal experts for training – e.g. NE India, Uttarakhand Himalaya, etc.

5.3 Monitoring at hydro-power stations – avail the industrial support

5.4 Nation-wide standardization vs corresponding values

5.5 Administrative Suggestions for expansion

- Proposed (Virtual) Centre for Advanced Studies in Landslides and Rockfall (National coordination mode)
- DST National Chair for Landslides (Geo hazards) – 05 (One in each region)
- Two year post-doctoral fellowships in the areas of landslides and natural hazards (DST can initiate 10 fellowships each year)
- Capacity building in the form of workshop, training programme, schools and discussion - 02 per year
- Dedicated website for landslide data sharing, inventory and technology information dissemination – preferably in standard data format including maps

6.0 Creation of Indian Institute for Landslide Studies (IILS):

An “Indian Institute of Landslide Studies” (IILS) will be established in a suitable location in India. This will have the state of art facilities for Landslides studies like (i) rock mechanics lab and Lab for estimating factor of safety (ii) labs for developing and studying physical and experimental models on landslides (iii) labs and equipment for developing and experimenting early warning systems on landslides (iv) remote sensing and GIS laboratory, etc. The proposed institute will focus on the followings:

- to have a core scientific team to carry out studies on the above aspects of landslides and in addition will facilitate the research scholars, scientists and technocrats to carry out laboratory studies,
- to have data bases and Archives on all Landslides and Landslide studies in India including Geospatial data bases,
- conducting periodical training to the research scholars, field level Scientists, Supervisory Officers and Planners/ Administrators for different time duration,
- to bring out Quarterly Newsletter on “Landslides in India”,
- to organize one National Conference every year in different parts of the country & will bring out the proceedings of the deliberations in the form of state of art publication at international standards by a leading publisher.

Annexure-I

List of Institutions involved in Landslide studies:

- Indian Institute of Technology Roorkee
- Central Building Research Institute, Roorkee.
- Central Road Research Institute, New Delhi
- Central Soil and Material research station, New Delhi
- Indian Institute of Technology Kharagpur
- Indian Institute of Technology Bombay, Mumbai
- Indian Institute of Technology Delhi
- Department of Geology, University of Delhi
- North Eastern Hill University, Shillong.
- Bharthidasan University, Trichi.
- Border Roads Organisation.
- Geological Survey of India
- Punjab University, Chandigarh
- Wadia Institute of Himalayan Geology, Dehradun
- Global Hydrogeological Solutions, New Delhi
- National Institute of Technology, Hamirpur.
- National Geotechnical Facility, Dehradun
- Pune University, Pune
- Snow and Avalanche Studies Establishment, Chandigarh
- HNB Garhwal University, Srinagar
- University of Jammu, Jammu

- Manipur University, Imphal
- Imphal Science College, Manipur
- Manipur State Remote Sensing Centre, Imphal
- Nagaland University, Kohima
- Mizoram University, Aizawl
- Directorate of Geology and Mines, Govt. of Mizoram
- Presidency College, Chennai
- Lucknow University, Lucknow
- Benaras Hindu University, Varanasi
- Indian School of Mines, Dhanbad
- SASTRA Deemed University, Thanjavur
- Periyar University, Salem, Tamil Nadu
- Amrita University, Amritapuri, Kerala
- Defence Terrain and Research Laboratory, Delhi.
- Deptt. Of Information Technology, New Delhi
- National Remote Sensing Centre, Hyderabad.
- Indraprastha University, New Delhi
- Kumaon University, Nainital
- Punjab Technical University, Chandigarh
- G.B. Pant Institute for Himalayan Eco-system Development, Almora

Annexure-II

List of the participants of Brainstorming Session held on 20-21st May, 2016:

1. Dr. Bhoop Singh, DST, New Delhi
2. Prof. R. N. Gupta, former Director, NIRM, KGF
3. Dr. Rajbal Singh, Former joint Director, CSMRS, New Delhi
4. Dr. Ram Avtar Singh, Pithoragarh, UK
5. Prof. Y. P. Sundriyal, Srinagar Garhwal, UK
6. Dr. D. P. Mohanty, Pune University
7. Dr. Raj Shekhar, Genesis International, Mumbai
8. Dr. Sunayana Sarkar, MPSTME, Mumbai
9. Dr. K. Ravi Verma, MPSPS, Navi Mumbai
10. Dr. V. Joshi, Indraprastha University, New Delhi
11. Dr. V. Vishal, IIT Bombay, Mumbai
12. Dr. A. Kainthola, IIT Bombay, Mumbai
13. Dr. Prakash Singh, IIT Bombay, Mumbai
14. Dr. J. S. Rawat, Dextra, Mumbai
15. Mr. Mashud Ahmad, Dr. Fixit, Mumbai
16. Mr. Prashant Singh, ONGC, Mumbai
17. Mr. Bankim Mohanta, IIT Bombay, Mumbai
18. Mr. Ashutosh Tripathy, IIT Bombay, Mumbai
19. Mr. Mrityunjay Sharma, IIT Bombay, Mumbai
20. Mr. Lakshmi Kant Sharma, IIT Bombay, Mumbai
21. Mr. Ratan Das

22. Mr. Ved Prakash

23. Mr. Tariq Anwar Ansari

24. Mr. J. S. Shrikant, IIT Bombay, Mumbai

25. Prof. T. N. Singh, IIT Bombay, Mumbai

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