Earthquake Safety and the Indian Subcontinent

SAARC Disaster Management Centre
GIDM Gandhinagar
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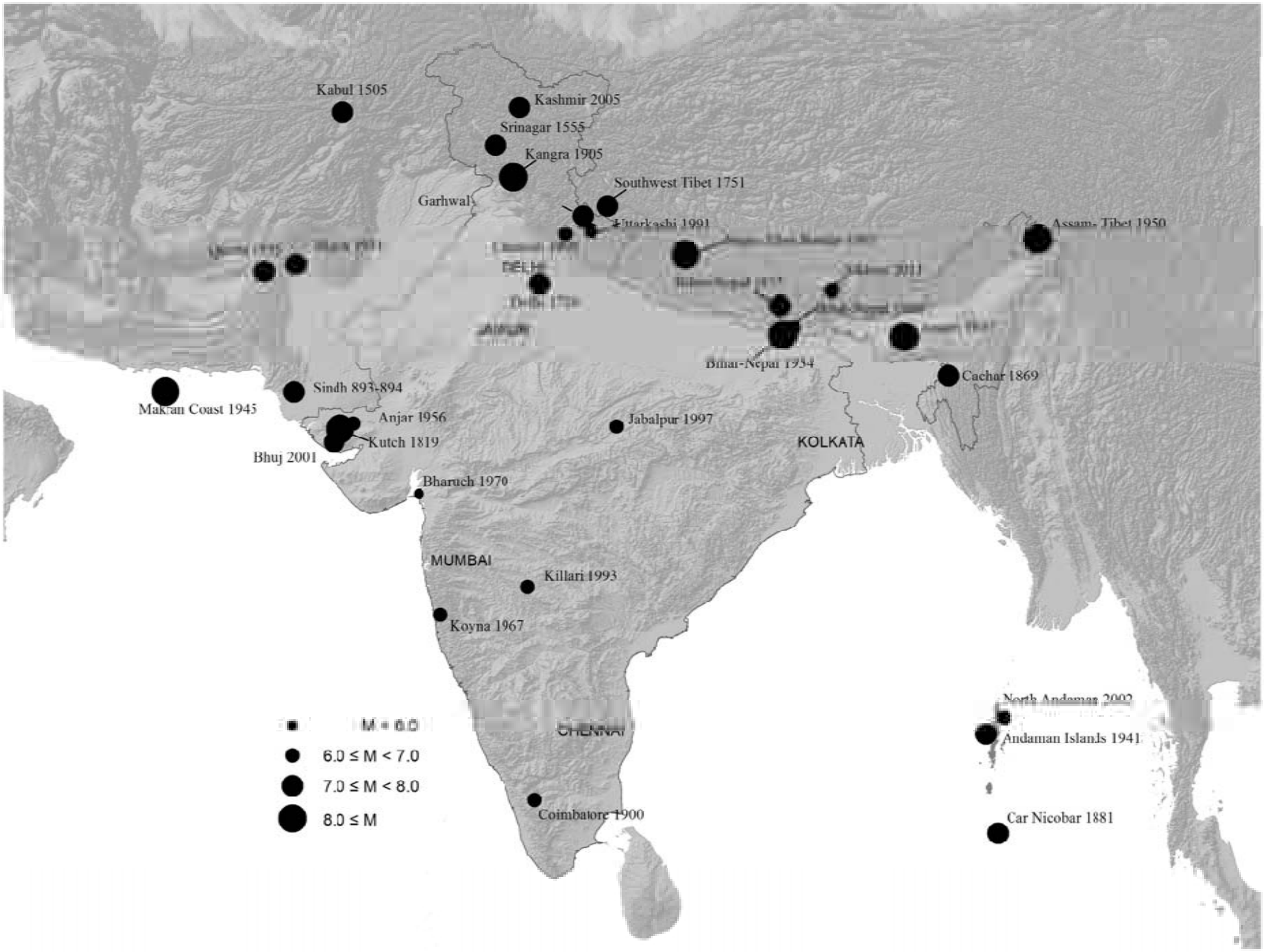
OUTLINE

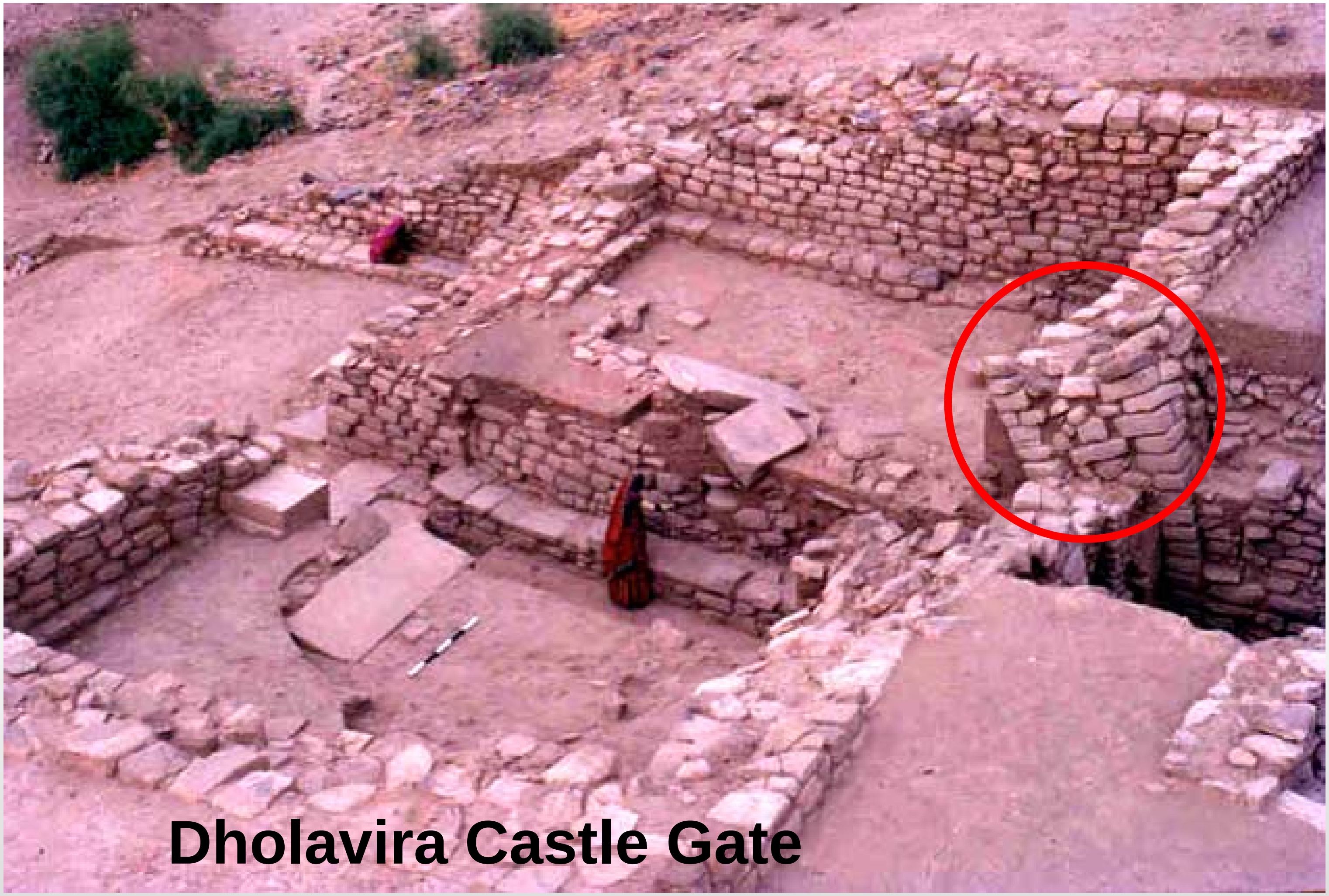
- The Earthquake Problem
- Three Examples of Local Solutions
- Capacity Building Initiatives in India
- The Way Forward and Concluding Remarks

THE EARTHQUAKE PROBLEM

Some Significant Earthquakes



Ancient Earthquakes



Tilting of walls indicating an earthquake

Dholavira Castle Gate

Harrappan site in Kutch (2500 BCE)

Ancient India

- *Vedas* and *Puranas* refer to earthquakes
- Scholarly discussion on earthquakes by
  - Varaha Mihira in *Brihat Samhita*
    - 5th-6th century AD
  - Ballala Sena in *Adbhuta Sagara*
    - 10-11th century AD
  - Chamunda Raya in *Lokopakarakam*
    - 11th century AD

Ancient India

- Earthquake classification as per these:
  - *Agni* (fire)
  - *Vayu* (wind)
  - *Varuna* (water)
  - *Indra* (rain)
- Zones of occurrence of the four types
  - Well aligned with contemporary seismic zones

Some Significant Earthquakes

Earthquake	Magnitude	Deaths
1819 Kachchh	8.0	1,500
1897 Assam	8.7	1,500
1905 Kangra	8.6	19,000
1934 Bihar-Nepal	8.4	7,253 + 3,400
1950 Assam	8.7	1,500
1967 Koyna	6.5	180
1988 Bihar-Nepal	6.6	1,000
1991 Uttarkashi	6.4	768
1993 Killari, Latur	6.2	7,928
1997 Jabalpur	6.0	38
1999 Chamoli	6.6	63
2001 Bhuj	7.7	13,805
2004 Sumatra and Tsunami	9.0	250,000
2005 Kashmir	7.5	100,000

Building Collapses
(Without Earthquake Shaking)

Officials ignored complaints as illegal tower went up, and down

Toll 59, Cop, Civic Officer Suspended

COLLAPSE OF GOVERNANCE

WHO WILL ANSWER THESE QUESTIONS?

UNLUCKY BUILDING

Corporator, civic officers, cop, builders among 6 held for crash

State Govt Cracks The Whip As Bldg Toll Mounts To 75

INDIA'S WORST BUILDING COLLAPSE IN DECADES

Total Toll	Child	Children	Men	Women
	75	18	34	23

Act against Thane municipal chief Rajeev, oppn tells Chavan

THE HINDU

National » Other States

Published: April 5, 2013 | Updated: April 6, 2013 02:58 IST

Thane building collapse: Nine remanded in police custody

Municipal Corporation workers demolish illegal buildings in the wake of the

By our correspondent, Junagadh, 11 February 2013

After the collapse of a nine-storeyed building in Junagadh yesterday, the Municipal Commissioner of Junagadh has served notice to Monarch apartment's builder Vipul Kotecha to safely remove the other two buildings in same campus.

Yesterday, a newly constructed building Monarch-2 was collapsed killing two laborers while six persons were injured in this incident. The building was constructed by Mars developers before a year, along with two other buildings of same size in same campus.

After the collapse of "A" wing of the building, the Municipal Commissioner has asked developer to demolish "B" and "C" wings safely.

Two persons died yesterday were plaster of Paris artists from Rajasthan and Uttar Pradesh. Six others injured were also artists doing the work of plaster of Paris.

It is interesting to note that while one building collapsed, the other two buildings built with same material(according to developer) were standing strong.

April 04, 2013 |Thane building collapse

February 11, 2013 | Junagadh building

Developing Country Problem?

- Several countries have significantly reduced earthquake risk vis-à-vis number of deaths, e.g.,
  - New Zealand, US, Japan, Chile, …
- Earthquakes continue to cause a huge number of deaths elsewhere, e.g.,
  - India, Pakistan, China, Iran, Turkey, Haiti, …
- The gap between the two sets of countries in this respect has widened in the last fifty years

Two Categories of Problems

- “Engineered” Constructions
- Non-Engineered Constructions

2001 Bhuj Earthquake

- Magnitude 7.7, ~13,805 persons dead
- Ahmedabad City
  - 600 year old city; 250 km from epicentre
  - 130 multistory buildings collapsed
  - 805 persons killed
  - All were new residential RC buildings
  - Collapses due to unusually weak buildings

Two Pronged Approach

- Locally-appropriate building typologies
- Improvement in construction ecosystem

Indigenous Typologies

***Dhajji Diwari* construction in Srinagar area, Kashmir**

Patchwork of brick panels confined by timber members

Indigenous Typologies…

- Taq constructions in Kashmir
- Large wood horizontal runners embedded in masonry walls
  - Improves the lateral load resistance of the building

Assam Type House

- Developed after 1897 earthquake in Assam
- Became prevalent in the entire north-eastern India
  - Infills of Ikra panels made of local reeds caked in mud
  - Timber confining members
  - Lightweight roof, and no stone chimneys
- Currently being replaced by poorly-constructed RC and masonry buildings

Local Solutions

- Construction is very context specific
- Solutions must be found indigenously
  - Grounded in local culture and circumstances
- Three examples from Indian subcontinent

Earthquake-Resistant Construction in Quetta in the 1930s

Seismic Retrofitting in Andaman Islands in the 1940s

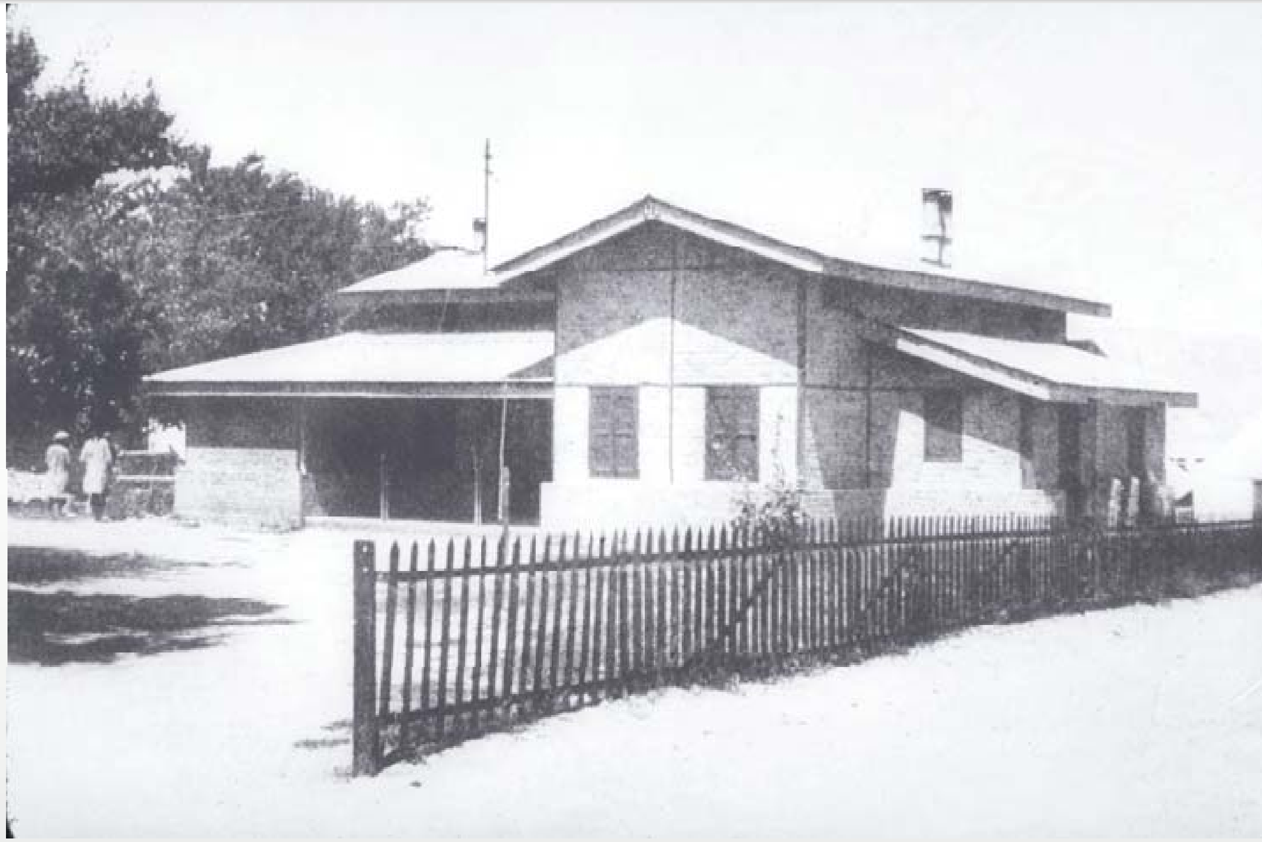
Confined Masonry in Gandhinagar in the 2010s

THREE EXAMPLES

EARTHQUAKE-RESISTANT CONSTRUCTION IN QUETTA

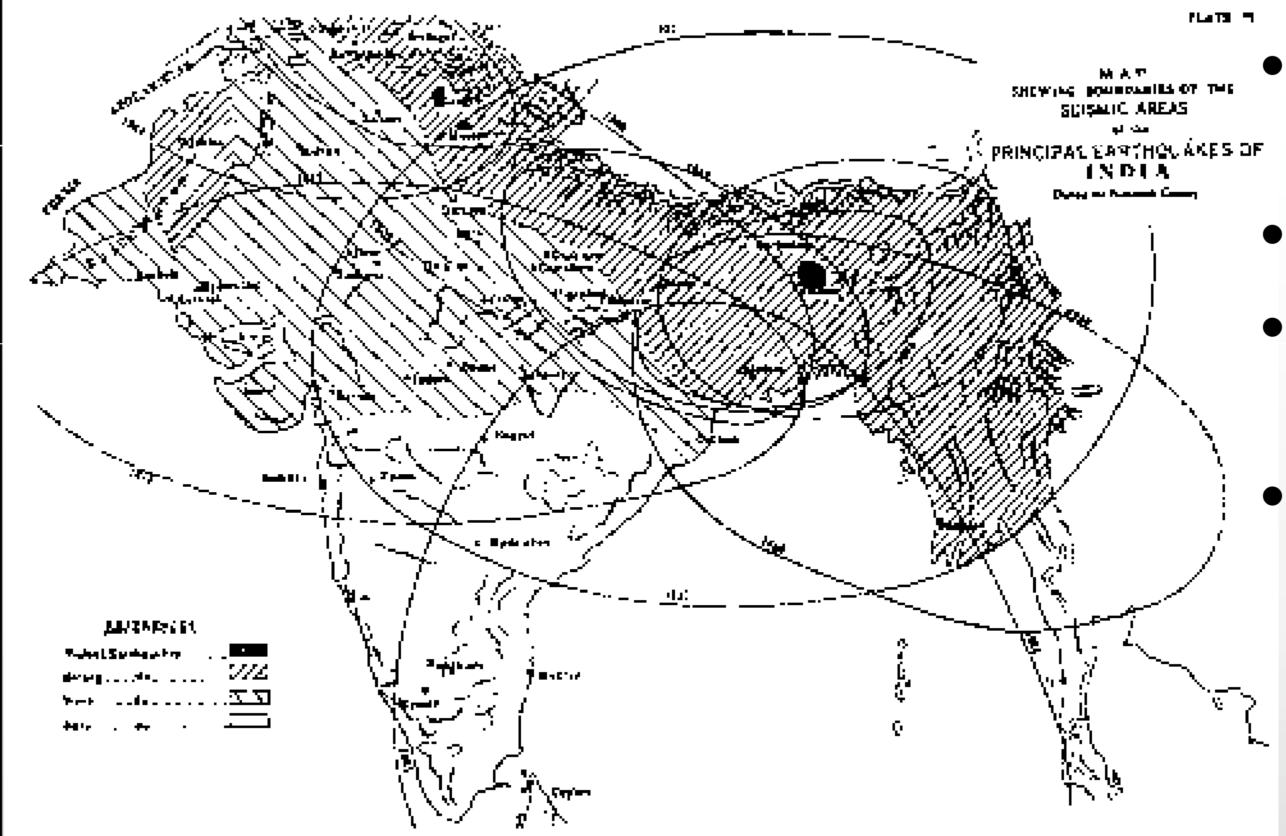
Developments in Baluchistan

- 1931 Mach EQ
  - M7.4; R.F. Intensity VIII
  - ~100 persons killed
- S L Kumar, 28 yrs, civil engineer with railways
  - Asked to undertake earthquake-resistant quarters for railway staff



Six bungalows constructed by Kumar
Brick walls braced with vertical and horizontal iron rails

Sardari Lal Kumar



1933 paper by Kumar:

- Concept of earthquake resistant constructions
- Details of his design
- First seismic zone map of India
- Seismic coefficients for design

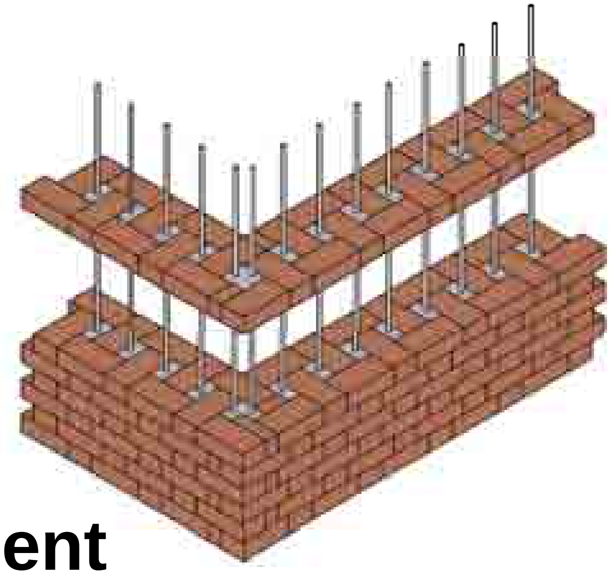
Quetta Earthquake

- 1935 Quetta earthquake
  - M7.6; max intensity X;
  - 20,000 to 30,000 persons killed (~ 40-50% population)

- **Exemplary performance of Railway quarters designed by Kumar**

Reconstruction in Baluchistan

- Massive reconstruction by
  - Military
  - Railways, and
  - Civil authorities
- Seismic codes developed, implemented and enforced
  - **First time in Indian sub-continent**



- "Quetta Bond" developed
- Earthquake of 1941 (intensity VIII to IX) proved efficacy of these

In Contrast!

- Bihar-Nepal (1934) earthquake
  – M8.4; intensity X on MM Scale
  – Deaths: 7,253 in India and 3,400 in Nepal
  – No efforts for earthquake-resistant construction!
  – Had similar earthquake in 1833 as well
- GSI report (1939) on this earthquake:
  – *In the Quetta area an excellent building code has recently been drawn up, and reconstruction has been rigidly enforced in terms of that code…. It is, perhaps, not too much to hope that the rest of Northern India will some day follow Quetta's lead.*

SEISMIC RETROFITTING IN ANDAMAN ISLANDS

Retrofitting in 1941: A&N Islands

Jama Masjid in Port Blair

Brick masonry with arches, domes and minarets

Iron angle for anchoring the tie rods

1941 Retrofit of Jama Masjid

Tie-rods placed in both directions

The Story of Ross Island

Church in good days **Church today**

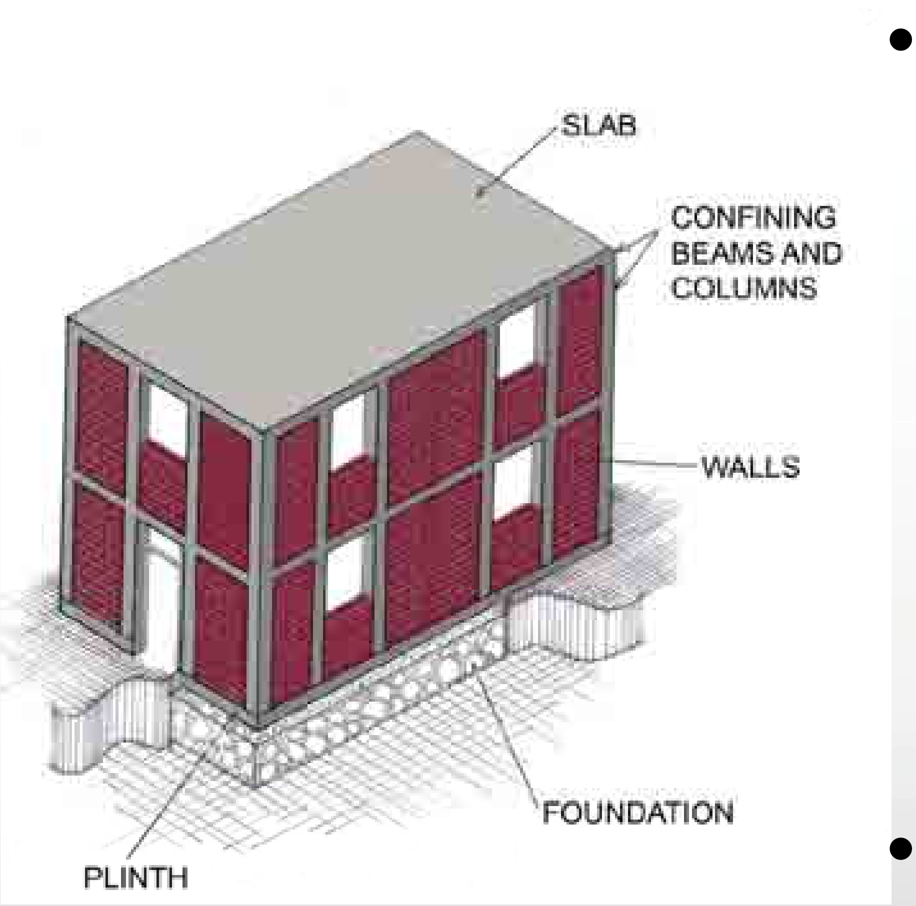
Retrofitting in the Church

Tie rods in church ruins

Anchor bolts

CONFINED MASONRY IN IIT GANDHINAGAR CAMPUS

Confined Masonry

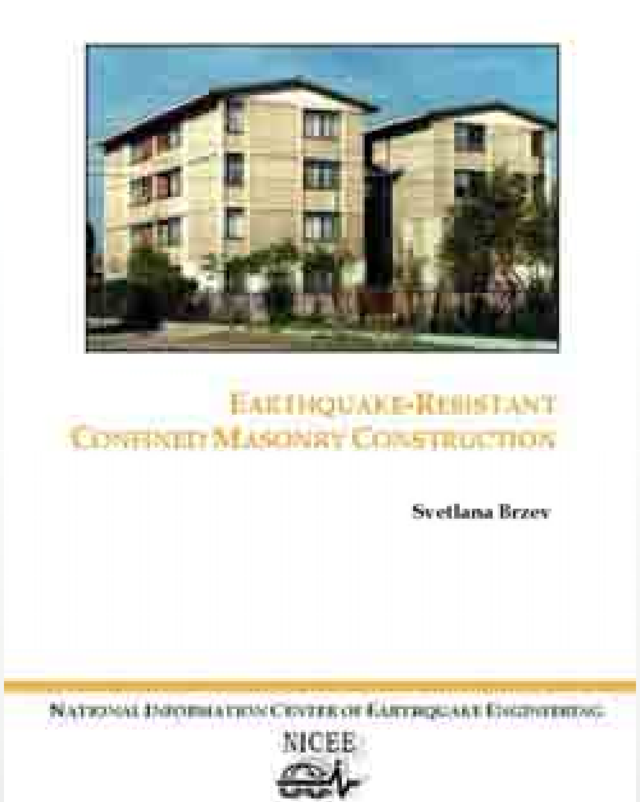


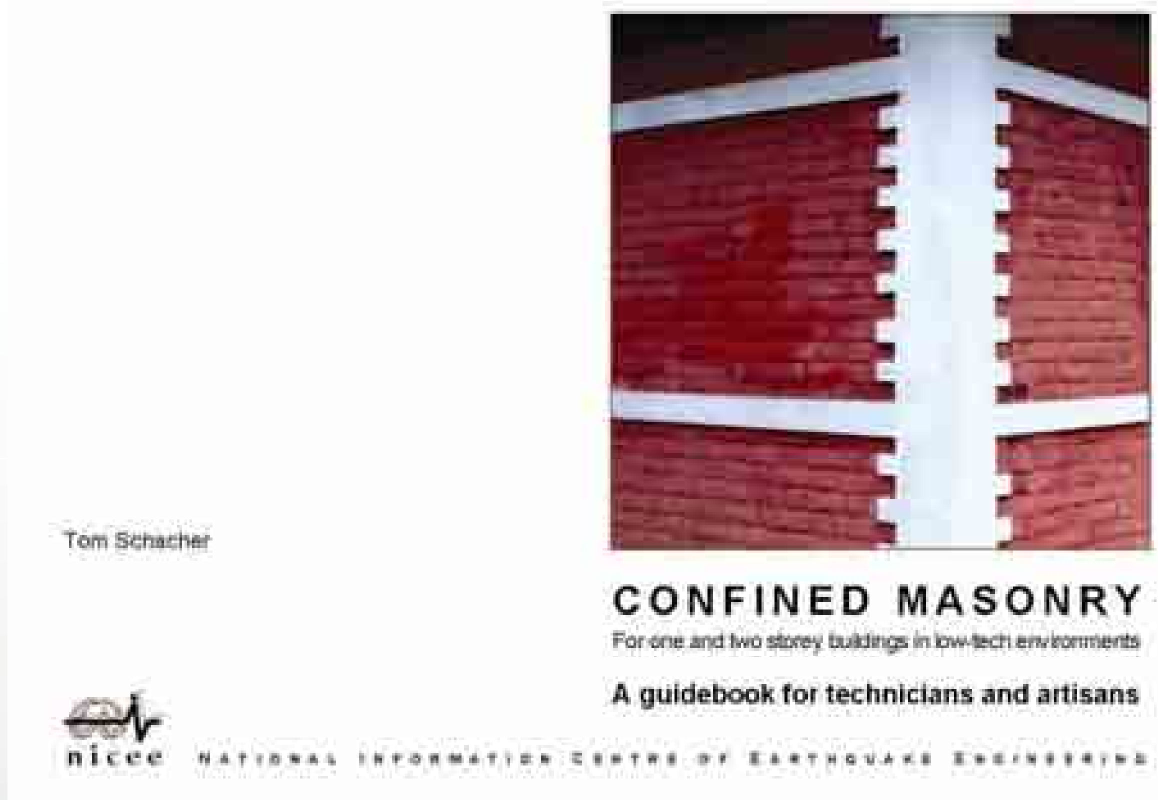
- Proven record of good seismic performance
  - Excellent features for seismic areas
  - Close to traditional construction practices
    - Masonry construction, and
    - RC frame buildings
  - Low in engineering intricacies
- Efforts in last 10 years to propagate in India

Confined Masonry Initiative

- International Strategy Workshop at IIT Kanpur in January 2008
  - Creation of a confined masonry network

Resource Materials by NICEE





Monograph by Brzev (2007)

Manual by Schacher (2009) for Technicians, homeowners, masons

Campus of IIT Gandhinagar

- 400 acre campus
- Student hostels and faculty apartments in confined masonry
  - Small size rooms
  - High wall density
  - 3 and 4 storey
  - 10-15% cost savings over RC frames

Confined Masonry at IITGN Campus

- First large-scale application in India
- Design challenges
  - Architects/structural design team not familiar
  - Many debates about process and provisions
- Construction challenges
  - High strength bricks in large quantity
  - Manufacturing plant for Fly Ash Lime Gypsum bricks at site

Housing under Construction

Constructed Housing

Student Hostel under Construction

Constructed Hostel

Implications

- IITGN project a showcase for confined masonry
  - Constructed by Central Public Works Department of the Government of India
  - May lead CPWD specifications to now include CM
  - Will help acceptance in formal construction sector

Continuing Education Programmes

National Information Centre of Earthquake Engineering (NICEE)

National Prog. of Earthquake Engineering Education (NPEEE)

Interventions towards architects

Earthquake Tips

CAPACITY BUILDING INITIATIVES

An Opportunity for CEP

Inaugural programme to kick-start formal activities at the new IIT at Guwahati

- Assam Accord in 1985
- Foundation Stone of an IIT in Assam in 1992
- 3-day short course in October 1992 under the banner of IIT Guwahati
  - On seismic design
  - For structural engineers
- Encouraging response

Continuing Education

- Massive CEP for professionals by Jain and Murty
- During 1992 to 2001
  - Numerous one-week training programmes
    - Seismic design of RC buildings
    - Seismic design of bridges
  - In different cities of India (and in Nepal and Bhutan)
  - Class size of ~100 engineers, sometimes ~200
  - About 2,000 professional engineers trained
- By 2001, considerable expertise was available in the profession

Two Workshops at Kanpur

- Round-table brain storming workshops
  - 1996: EQ Resistant Construction in Civil Engg Curriculum
  - 1998: Developing Earthquake Engineering Industry in India
- Valuable for
  - Subsequent creation of NICEE and NPEEE
  - Developing earthquake engineering community in academia and industry

National Information Centre of Earthquake Engineering

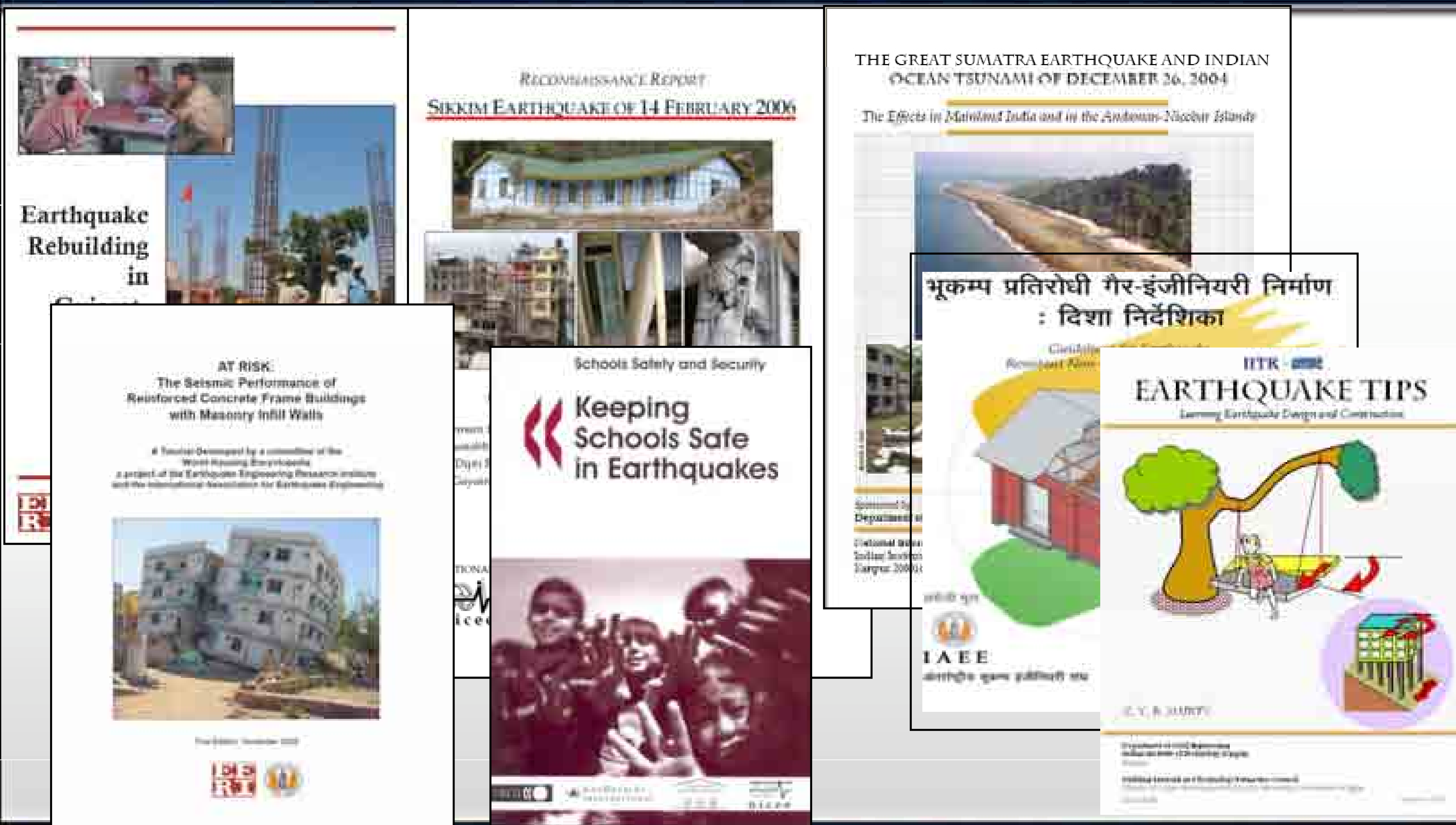
- Inception
  - 1996: Workshop at Kanpur identified the need
  - 1997: Proposal for raising funds
  - 1999: First donation received
  - 2001: Major impetus by Bhuj earthquake
- Key Words for Objectives
  - Information and capacity building
  - Earthquake safety
  - India and developing countries

2013 Literature review workshop for post-graduate students

NICEE Activities

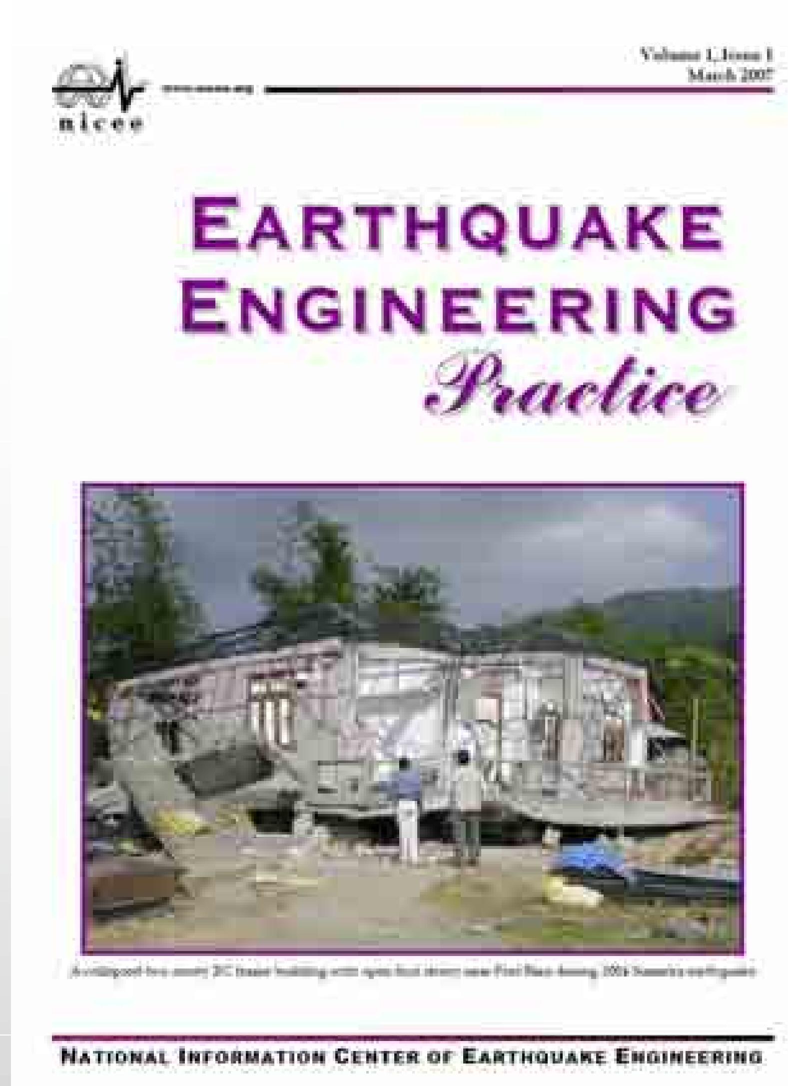
- Acquisition and dissemination of publications
- Publication of monographs & distance education products
- Translations into local languages
- Earthquake Engineering Practice – A quarterly periodical
- Distribution of ETABS and SAP to colleges
- Workshops, meetings, conferences, e-conferences
  - Post-graduate students, architecture students, ….
- Inter-school quiz for school children
- Web Site; Electronic Newsletter; Strong Email Listing
- World Conference Proceedings

Publications



Earthquake Engineering Practice

- A Quarterly Periodical
- Reprints high-quality articles from other journals
  - In arrangement with EERI and NZSEE
- Distributed free-of-charge to individuals; Nominal charge to libraries
  - Except in US and Canada



National Programme on Earthquake Engg Education

- Inception:
  - 1996: Workshop at Kanpur brainstormed need
  - 2001: Earthquake caused concern in Govt of India; proposal developed
  - 2003: Funding released
- To develop Earthquake Engineering capacity in
  - Engineering colleges, schools of architecture, and polytechnics
  - India had ~1,000 such colleges/institutes at that time
- Funded by the Ministry of Human Resource Development, Govt of India
  - Rs 13.5 crores (US$ 3 million) in 4 years (2003-07)

National Programme on Earthquake Engg Education…

Participants at launch workshop in 2003

- Executed by 7 IITs and IISc
  - With IIT Kanpur coordinating
- Open to all colleges, government or private
  - Focus on training of faculty and curriculum development

NPEEE: Components

- Faculty development through training
  - Short courses of one and two week duration
  - Semester long programmes
  - Semester long post-doctoral work overseas
- Curriculum and resource material development
- Workshops and conferences
- International visitors to IITs and IISc
- Support for participation in conferences abroad
- Support for laboratory and library development

Interventions Towards Architects

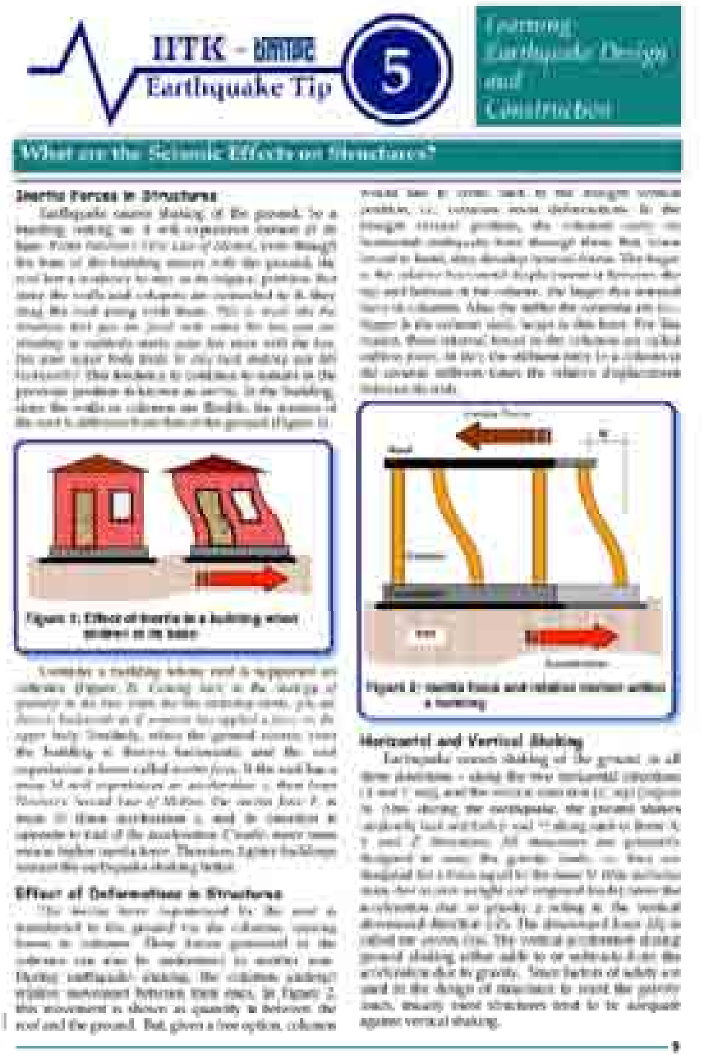
Students presenting their design to the jury

- One-day seminars
  - Ministry of Home Affairs and Indian Institute of Architects
  - 21 seminars in different cities
- Annual workshop for architectural students
  - NICEE in IIT Kanpur
  - Nearly 400 students participated to date

Interventions Towards Architects…

- Earthquake design in curricula of architecture
- Resource materials
  - 600 PPT slides for 28 lectures in classroom
  - Indian version of RESIST

Earthquake Tips



IITK - BMTPC Earthquake Tip 5

Learning Earthquake Design and Construction

What are the Seismic Effects on Structures?

Inertia Forces in Structures

Figure 1: Effect of inertia in a building when shaken at its base

Figure 2: Inertia force and relative motion within a building

Horizontal and Vertical Shaking

Effect of Deformations in Structures

Figure 3: Principal directions of a building

Flow of Inertia Forces to Foundations

Figure 4: Flow of seismic inertia forces through all structural components

Figure 5: Importance of designing walls/columns for horizontal earthquake forces

Reading Material

- Simplified explanations of concepts in earthquake engineering
- 24 Tips (now 32)
- Published in newspapers, journals, available for download
- Translated into Hindi and Marathi

THE WAY FORWARD AND CONCLUDING REMARKS

2-Pronged Approach

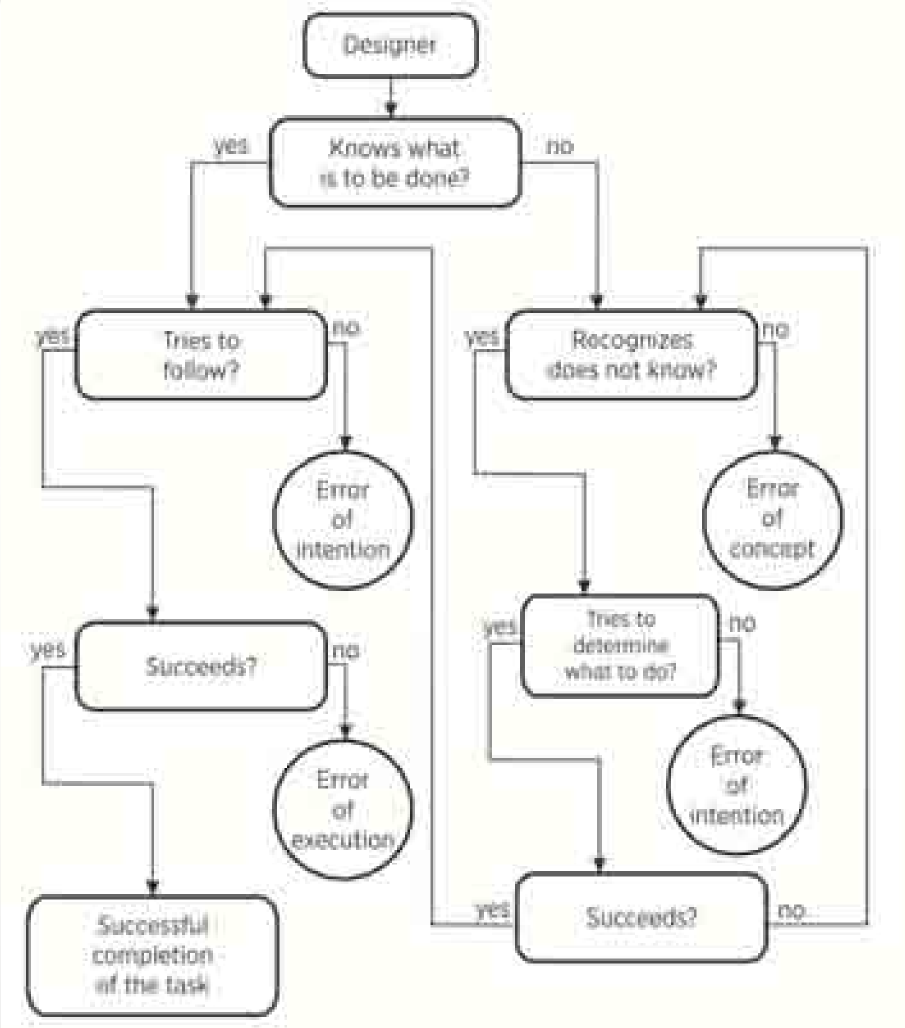
- Local solutions and construction typologies
- Improve ecosystem for quality construction

Our Challenge

- Civil Engineering Structures
  - Large and expensive
  - Unique (one-of-a kind; unlike aircrafts or cars)
- Civil Engineering Profession
  - Limited time for design and development
- Based on trust
  - No scope for testing of real structures
- Ethics is critical for safe constructions

Challenge of Safe Construction

- Error of intention
- Error of concept
- Error of execution



Alternative paths with regard to acceptable practice (Novak and Arafah, 1994)

Critical Needs

- Awareness and creating demand
- Capacity building at all levels
- Competence-based licensing
- Professionalization
- Ethical enforcement of codes
- R&D for construction typologies

Plan of Action

- Recognize the problem (correctly)
  - Have intent to fix it
  - Humans tend to deny existence of very difficult problems
- Capacity building activities:
  - A lot has been done but a lot more needs to be done
- Enforcement framework for code compliance
  - With appropriate incentives and punitive measures
  - Seat belts in cars!!

Where we stand today?

- Tremendous awareness after 2001 earthquake
- Awareness of seismic codes
- Problem Areas
  - Basics of structural engineering
  - Ethical professional conduct
- **Solution**
  - Competence-based licensing of engineers
  - Enforcement of codes by the municipal authorities

Licensing of Engineers

- Competence Based
  - As against degree or experience based
- Critical where inherent trust needed
  - For example, civil engineering industry
  - Not for cell phone or car industry
- *Grandfather clause* initially
- **Licensing in other professions**
  - Architects, medicine, legal
  - Chartered accountants

Gujarat Initiative

- The Gujarat Professional Civil Engineers Bill, 2006
- Gujarat Council of Professional Civil Engineers
  - Two meetings in 2011
  - No progress since !
- Not enough sensitization of WHY we need to do this

Enforcement of Codes

- Municipal authorities to ensure compliance
  - Municipal engineers to ensure drawings comply
  - Develop systems for on-site inspections
- Already done for Fire Safety

Policy Issues

- Science *versus* engineering of earthquakes
- Retrofitting *versus* ensuring safe new constructions
- Propagating right construction typologies
- Who is to champion seismic safety?

Human Response to Earthquakes

(Key, 1988)

Stage	Time	Event	Reaction	
			Positive	Negative
1	0-1min	Major EQ		Panic
2	1min to 1 week	Aftershocks	Rescue and Survival	Fear
3	1week to 1month	Diminishing Aftershocks	Short term repairs	Allocation of blame to builders, designers, officials, etc
4	1month to 1year		Long term repairs, **Action for higher standards**	
5	1 year to 10years			Diminishing interest
6	10yrs to next EQ			Reluctance to meet costs of seismic provisions, etc., Increasing non-compliance with regulations
7	The next EQ	Major EQ	Repeat stages 1-7	

Window of Opportunity

- Damaging earthquakes provide a window of opportunity, e.g.,
  - NICEE and NPEEE in India
- It is a rather short window
  - Not enough time to develop new strategies after the disaster
  - Planning to be done in ‘peacetime’

Earthquakes *versus* Buildings

- For earthquake safety
  - Entire chain of construction industry must be robust
    - E.g., safe food in a restaurant!
  - Can only be achieved if there is a safety culture
- Earthquake engineering must be better integrated into civil engineering
  - And not seen as a super specialty
- Earthquake problem *versus* building problem
  - Focus must shift from “earthquakes” to “buildings"

To Conclude

- Indian subcontinent has a huge stock of unsafe buildings
  - And, we continue to build many unsafe buildings
  - And, we have a huge construction boom ahead
- To meet our aspirations on quality of life and economic development
  - We must address problem of seismic risk
- A major earthquake in a vulnerable area could set back development by decades

To Conclude

- Earthquake problem has no quick fixes
  - Requires sustained attention and tremendous effort
  - On multiple fronts
  - By a diverse set of stakeholders
  - Over decades
- A lot has been achieved in recent years
  - But, much remains to be done

THANK YOU