The Road to Seismic Safety

With Particular Reference to the Developing Countries

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Bhuj Earthquake of 2001

- **Magnitude 7.7, ~13,805 persons dead**
- **Ahmedabad**
  - Located ~ 250km from epicentre
  - 130 multistorey buildings collapsed; 805 persons killed in 70 buildings
  - All these were new (~ 10 years) residential RC buildings
    - **Designed by architects and engineers**
    - **Built by developers**
  - No collapses to very old buildings in town

Collapse of a 11-story apartment building in Ahmedabad in 2001 earthquake

Collapses in Ahmedabad

- **Maximum shaking intensity:**
  - Shaking intensity X in Bhuj
  - VII in Ahmedabad
- **Expected shaking intensity as per code**
  - IX and above in zone V (Bhuj)
  - VII in zone III (Ahmedabad)
- **It was not a case of unusually strong shaking in Ahmedabad**
  - It was due to unusually weak buildings in the city

Ahmedabad Scenario

- **Real estate boom**
- **Total disregard to**
  - Structural system,
  - Structural design principles, and
  - Quality of construction
- **Many buildings unsafe even to carry gravity loads!**
- **The collapses would not have been prevented even if we had more seismic instruments in place!**

Economic Losses

- Total losses in Bhuj earthquake: ~ Rs 25,000 crores (US$ 5 billion)
  - **Similar earthquake near Indo-Gangetic plains can be far more expensive.**
- As development takes place,
  - **Concern moves from number of deaths to economic losses**

Can instances such as Ahmedabad be avoided?

- **Has it been done elsewhere?**
- **Large earthquakes ~ 50 deaths in Calif**
- **India:**
  - Bhuj, 2001: 13,805 deaths
  - Latur, 1993: 7,928 deaths
  - Kashmir, 2005: ~ 95,000 deaths
- **Other developing countries, e.g., Iran, Turkey and Pakistan:**
  - Tens of thousands of deaths in major earthquakes.

Average Number of Deaths

Intensity	Latur (1993)	Bhuj (2001)
IX	188.6 per 1000	17.0 per 1000
VIII	15.4 per 1000	0.56 per 1000
VII	3.6 per 1000	0.057 per 1000

- Some villages in Latur (1993) ~35% deaths
- In Quetta (1935) ~40% deaths

Is it a Developing Country Problem?

- **What makes a developing country**
  - Poor governance (at all level)
  - Lack of team work
  - Poor utilization of available resources
- **Need to factor these into the strategy!**

Are there success storeys from India?

- **Yes. But, rather long time back!!**
  - 1930's in Baluchistan
  - 1897 Assam earthquake
  - 19th Century Srinagar in Kashmir

Let us go back in history!

- 1931 Mach earthquake (M7.4) in Baluchistan
- S L Kumar (28) designed earthquake resistant quarters for railway staff
- In 1933, Kumar presented a paper outlining:
  - Concept of EQ resistant constructions
  - Details of his design and cost implications
  - First ever seismic zone map of India
  - Seismic coefficients for two types of building
- Quetta earthquake (M7.6; max intensity X) in 1935: ~20,000 persons killed
- Performance of quarters designed by Kumar

Backdrop…

- Massive reconstruction after Quetta earthquake by military, railways, and civil
- Code developed; lintel, plinth and roof bands
- A new "Quetta Bond" developed!
- Highly acclaimed recovery project at that time:
  - *e.g.,* GSI report of Bihar-Nepal earthquake.
- Earthquake of 1941 (intensity VIII to IX) proved efficacy of these constructions

Backdrop…

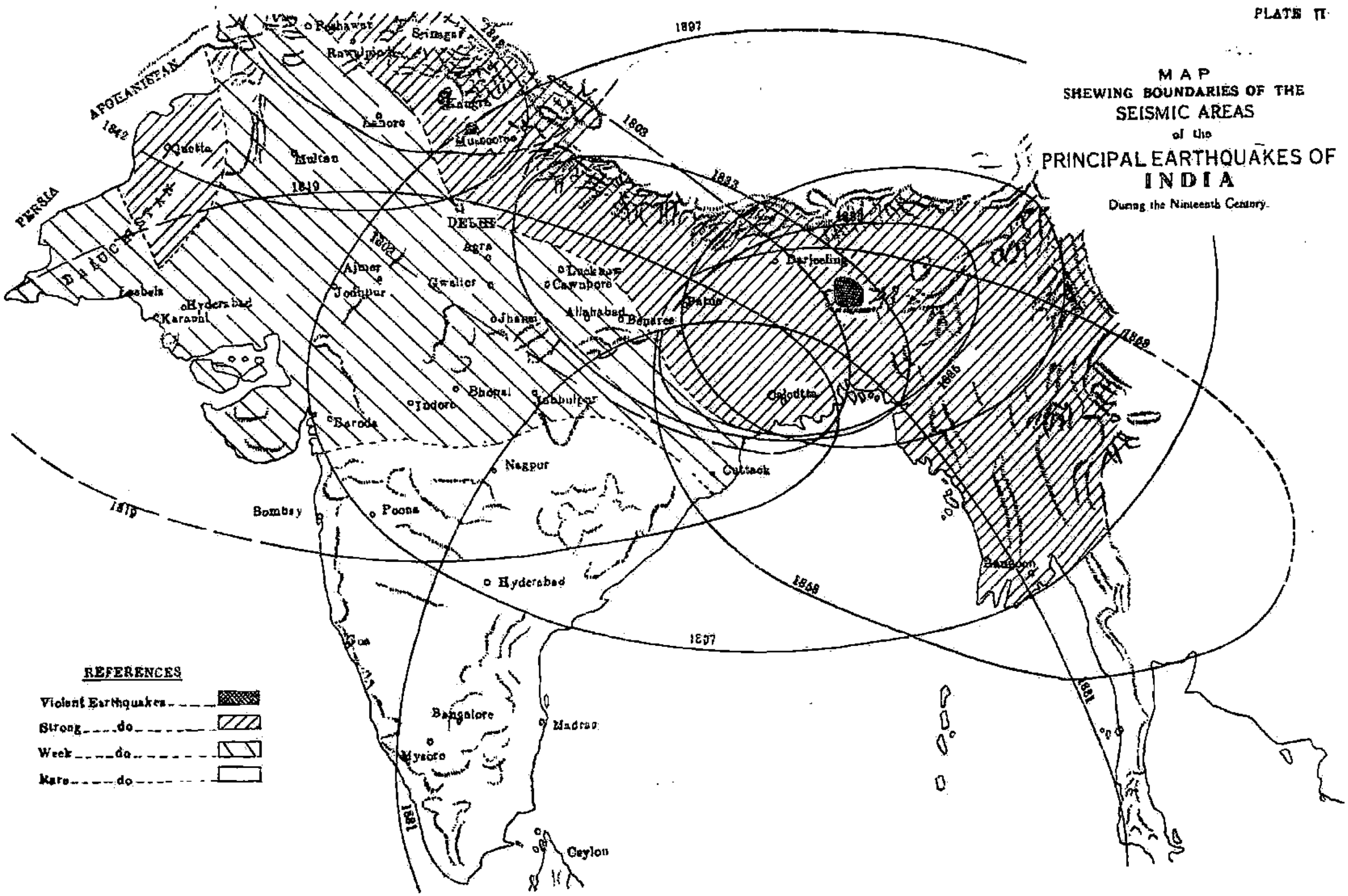
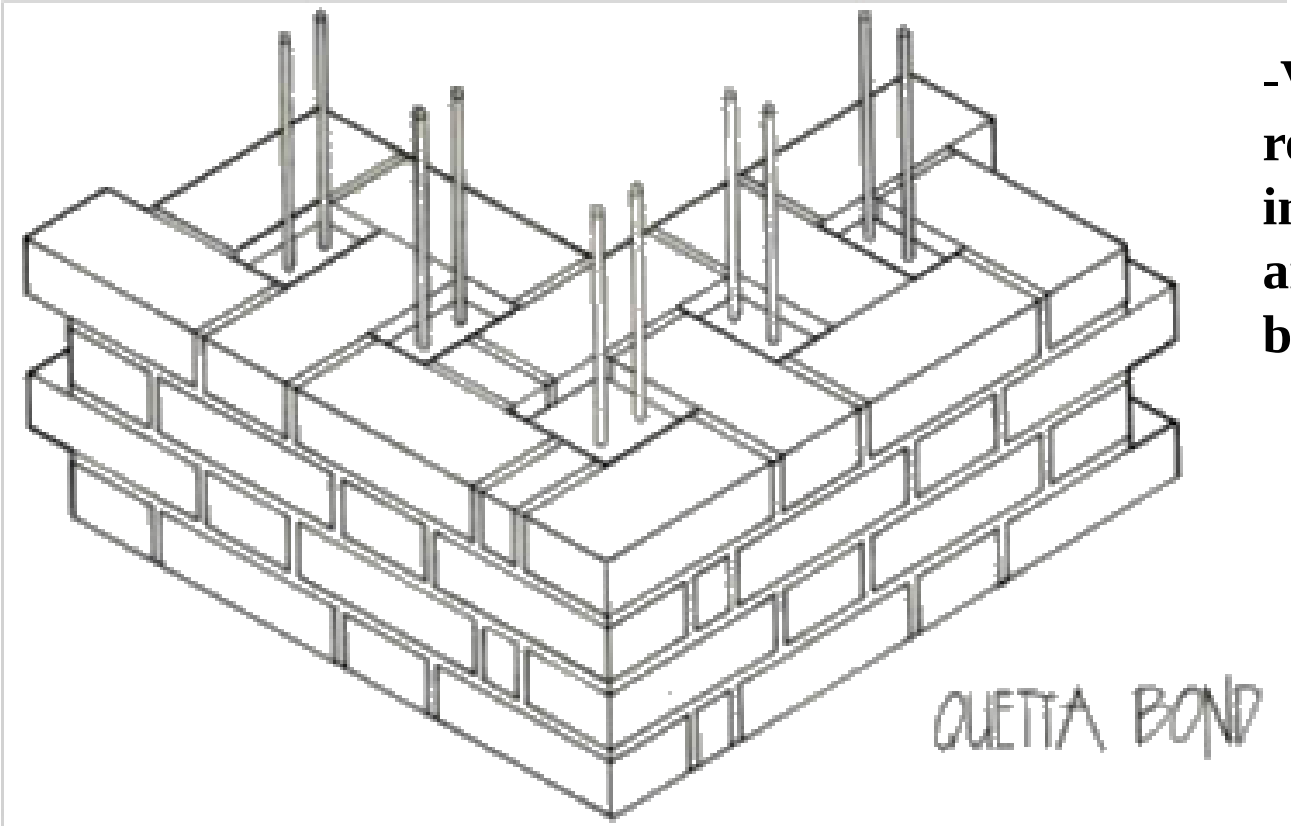


PLATE II
MAP
SHEWING BOUNDARIES OF THE
SEISMIC AREAS
of the
PRINCIPAL EARTHQUAKES OF
INDIA
During the Nineteenth Century.
REFERENCES
Violent Earthquakes
Strong do
Week do
Rare do
AFGHANISTAN
PERSIA
BALUCHISTAN
Peshawar
Srinagar
Rawalpindi
Lahore
Quetta
Multan
DELHI
Agra
Ajmer
Jodhpur
Gwalior
Lucknow
Cawnpore
Allahabad
Benares
Darjeeling
Jhansi
Hyderabad
Karachi
Bhopal
Jabbulpur
Indore
Baroda
Calcutta
Nagpur
Cuttack
Bombay
Poona
Hyderabad
Rangoon
Bangalore
Madras
Mysore
Ceylon
1897
1842
1819
1868
1833
1869
1885
1881

Quetta Bond

Quetta Bond in Masonry Buildings

- Developed as a result of 1935 earthquake



-Vertical reinforcement used to improve horizontal and vertical bond between walls

Assam Type House

-Developed after the Great 1897 earthquake in Assam
-Prevalent in `the entire north-eastern India
-Called *Ikra construction* in Sikkim

Dhajji-Dewari

-Prevalent around Srinagar

-**One cannot find any such houses elsewhere in J&K, including in Muzaffarabad**

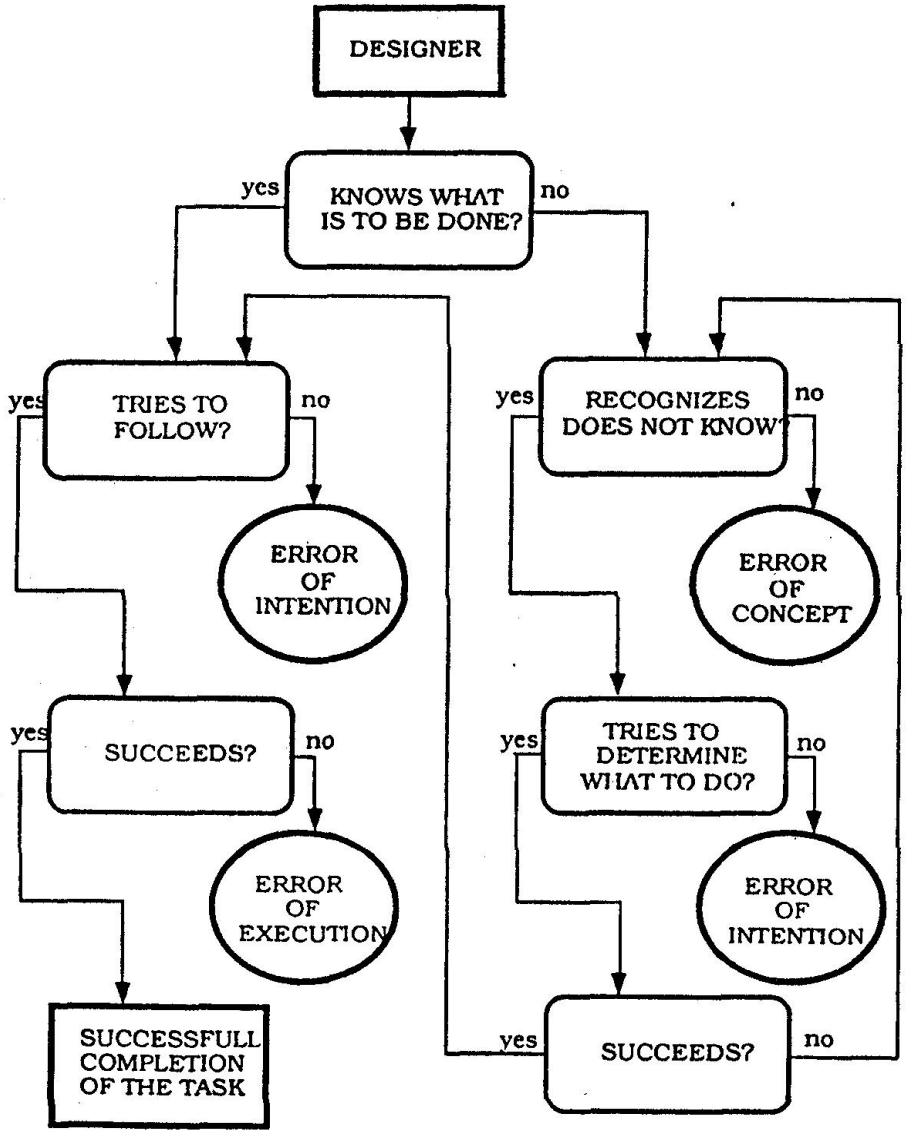
-Developed by local people after damaging earthquakes in 19th Century in Srinagar

Road Map to Seismic Safety

- Community awareness
- Legal framework
- Technical competence
- Professional ambience
- Enforcement by local authorities
- Research and development
- Appropriate building typologies

Challenges towards Safe Construction

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



Factors for Seismic Performance

- Architectural configuration
- Structural design
- Non-structural elements
- Quality of construction

Plan of Action

- **Recognize the problem (correctly)**
  - Have intent to fix it
  - Information campaigns
  - Humans tend to deny existence of very difficult problems
- **Capacity building activities:**
  - Currently too few experts in a large country such as India
- **Enforcement framework for code compliance**
  - With appropriate incentives and punitive measures
  - Seat belts in cars!!

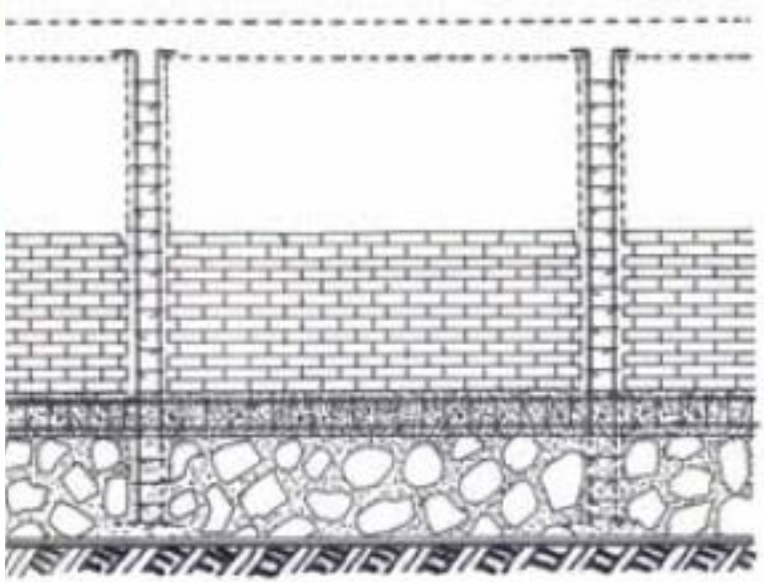
Enforcement of Codes

- **Legal clarity on code enforcement**
- **Licensing of structural engineers based on competence**
  - Not based on degree or years of experience
- **Municipal authorities to ensure compliance**
  - Municipal engineers to ensure drawings comply
  - Develop systems for on-site inspections

What about informal sector?

- **Develop new building typologies that are inherently safer against earthquakes, e.g.,**
  - Quetta Bond, Assam Type House, Dhajji Diwari…
- **Confined masonry**
  - Can be good for small and medium size buildings, upto 4-5 storeys.
  - Must be extensively tested full-scale for Indian typology
- **Need good replacements of brick-masonry infills.**

Confined Masonry Construction



Caution

- **Earthquake safety is a long and hard struggle**
- **No instant results**
  - Unlike CNG campaign in Delhi a few years back
- **Need to focus on new constructions: over the years, more percentage of buildings will be safe**
- **California started earthquake safety programmes ~70 years back**
  - Seismic retrofit of flyovers and bridges started in 1971; still continues

Concluding Remarks

- **Mega earthquake disasters await India and other developing countries**
- **Most constructions generally deficient**
- **Solution lies in "buildings"**
  - And not in "earthquakes" as such!
- **Need urgent interventions in building industry**

Long Term Human Response to Earthquakes

(Key, 1988)

Stage	Time	Event	Reaction	
			Positive	Negative
1	0-1min	Major EQ		Panic
2	1min to 1week	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	1year 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	

Thank you!!