Bridge Construction: Reducing Disaster Risk

PROF MAHESH TANDON
MANAGING DIRECTOR, TANDON CONSULTANTS PVT LTD
GUEST PROFESSOR @ GANDHINAGAR
FORMER DISTINGUISHED VISITING PROFESSOR IITs @ KANPUR, ROORKEE
How the world has benefitted from the Japanese experience
EARTHQUAKE ENGINEERING: MAJOR MILESTONES FOR BRIDGES

- 1908: CRITERIA BASED ON HORIZONTAL STATIC FORCES APPLIED AT cg – ITALY
- 1939: DRAFT VSPECIFICATIONS FOR HIGHWAY BRIDGE—JAPAN
- 1943: ACCOUNTING FOR FLEXIBILITY OF STRUCTURE WHILE EVALUATING SEISMIC DEMAND – CALTRANS
- 1964: CONCEPT OF LIQUFACTION (Prof Mogami) AND LATERAL SPREADING – JAPAN
- 1975: RECOGNISING THAT STRUCTURES ENTER THE INELASTIC (POST-ELASTIC) STAGE AND THAT DUCTILITY IS OF SIGNIFICANCE – AASHTO
- 1981: CRITERIA OF INELASTIC DESIGN AND DUCTILITY REQUIREMENTS-- JAPAN
HANSHIN EXPRESSWAY
KOBE EARTHQUAKE 1995
CONFINEMENT OF CONCRETE BY CIRCULAR AND SQUARE HOOPS

(a) Confinement from spiral or circular hoop

(b) Forces acting on one-half spiral or circular hoop

(c) Confinement from a square hoop

CONFINEMENT OF CONCRETE BY CIRCULAR AND SQUARE HOOPS

COURTESY: PRIESTLEY
1964 Niigata earthquake. Shinano river, Niigata City

SHOWA BRIDGE COLLAPSE DUE TO LIQUEFACTION, LATERAL SPREADING
The post liquefaction phenomenon (few minutes after termination of main seismic action)

ICONIC EXAMPLE OF THE DETRIMENTAL EFFECTS OF LIQUEFACTION.

- The non-liquefied crust exerts passive earth pressure.
- The liquefied crust exerts passive earth pressure on the pile and the liquefied soil offers 30% of total overburden pressure.

CHECK FOR LATERAL SPREADING: ALTERNATIVE LOADING

\[ q_{NL} = \text{Passive earth Pressure} \]

\[ q_L = 30\% \text{ of overburden pressure} \]
INDIAN SCENARIO
<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Location</th>
<th>Year</th>
<th>Deaths</th>
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<tbody>
<tr>
<td>&gt;8.5</td>
<td>Assam</td>
<td>1897</td>
<td>1,542</td>
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<tr>
<td>8.0</td>
<td>Kangra (HP)</td>
<td>1905</td>
<td>20,000</td>
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<tr>
<td>6.5</td>
<td>Jabalpur</td>
<td>1927</td>
<td>?</td>
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<tr>
<td>7.1</td>
<td>Dhubri</td>
<td>1930</td>
<td>100</td>
</tr>
<tr>
<td>8.4</td>
<td>Bihar-Nepal</td>
<td>1934</td>
<td>14,000</td>
</tr>
<tr>
<td>8.3</td>
<td>Assam</td>
<td>1950</td>
<td>1,500</td>
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<tr>
<td>7.0</td>
<td>Anjar (Gujrat)</td>
<td>1956</td>
<td>100</td>
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<tr>
<td>6.5</td>
<td>Koyna</td>
<td>1967</td>
<td>200</td>
</tr>
<tr>
<td>6.6</td>
<td>Bihar-Nepal</td>
<td>1988</td>
<td>1,000</td>
</tr>
<tr>
<td>6.6</td>
<td>Uttarkashi</td>
<td>1991</td>
<td>700</td>
</tr>
<tr>
<td>6.4</td>
<td>Lattur</td>
<td>1993</td>
<td>10,000</td>
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<tr>
<td>6.1</td>
<td>Jabalpur</td>
<td>1997</td>
<td>?</td>
</tr>
<tr>
<td>6.8</td>
<td>Chamoli</td>
<td>1999</td>
<td>100</td>
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<tr>
<td>6.9</td>
<td>Bhuj</td>
<td>2001</td>
<td>13,805</td>
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<tr>
<td>7.8</td>
<td>Nepal</td>
<td>2015</td>
<td>9,000</td>
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Each increase of 1.0 in magnitude is a 10 fold increase in wave amplitude and a 30 fold increase in energy released. Over 60% of India is earthquake prone.
ASSAM BRIDGE

EARTHQUAKE, JUNE 12, 1897

MANSHAI BRIDGE

EASTERN BENGAL

STATE RAILWAY

Catalogue of major earthquakes and post disaster survey well documented
ASSAM BRIDGE
• North Lakhimpur, Bridge on Ranganadi

• Earthquake: Aug. 15, 1950

COURTESY SURVEY OF INDIA 1898
EXAMPLE OF LIQUEFACTION
(Fine sand can result in boiling)
STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

SECTION: II
LOADS AND LOAD COMBINATIONS (SEVENTH REVISION)
(incorporating all amendments and errata published upto March, 2017)

INDIAN ROADS CONGRESS
2017

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

RDSO GUIDELINES
ON
SEISMIC DESIGN of RAILWAY BRIDGES

JANUARY, 2015

BRIDGE & STRUCTURES DIRECTORATE
RESEARCH DESIGNS AND STANDARDS ORGANISATION
LUCKNOW – 226011

IRC: 6-2017
HIGHWAY BRIDGES

RDSO GUIDELINES- 2015
RAILWAY BRIDGES
GENERAL PROVISIONS AND BUILDINGS

IS 1893 Part 3: 2014
BRIDGES AND RETAINING WALLS

PERFORMANCE BASED DESIGN NOT YET IMPLEMENTED
SEISMIC ZONE OF INDIA
-IS:1893 (PART I)
-IRC:6
CURRENT INDIAN SCENARIO

GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES  (July 2006)

National Centre for Seismology  (August 2014)

• THE SEISMOTECTONIC ATLAS OF INDIA SHOWS EXISTENCE OF OVER 66 NEOTECTONIC/ ACTIVE FAULTS. THE HIMALAYAN BELT, EXTENDING FOR 2400 KM, IS DISSECTED BY 15 MAJOR ACTIVE FAULTS.

• AS PER SEISMIC ZONING OF THE COUNTRY, OVER 59% OF INDIA’S LAND MASS IS UNDER THREAT OF MODERATE TO SEVERE SEISMIC HAZARD, I.E. PRONE TO SHAKING OF MSK INTENSITY VII & ABOVE. SEVERAL IMPORTANT CITIES LYING IN SEISMIC ZONE III, IV AND V ARE VULNERABLE TO EARTHQUAKES.
PRESENT DAY TECTONIC PLATES
The four known instrumentally recorded great (M *8.0–8.7) earthquakes in the foothills of the Himalaya in India, from west to east – the **1905 Kangra, 1934 Bihar, 1897 Shillong** and the **1950 Assam**
ENERGY DISSIPATION / SHARING

\[ E_{\text{seismic}} = E_{\text{structure}} + E_{\text{dissipated}} \]
Our codal provisions are still prescriptive. AASHTO (2012) stipulates the design basis as a 975 year return period (5% possibility of exceedance in 50 years).

Many building codes accept 500 year return period for buildings.

AASHTO (2012) stipulates design basis as a 975 year return period (5% possibility of exceedance in 50 years).

**FIG. 26:**

Relation between return period $t_s$, design life $t$, and probability of exceedence $p$.

$$ t_s = \frac{1}{1-(1-p)^{1/t}} $$
BASIC ISSUE: PREVENTION OF DISLODGEMENT (UNSEATING)

TWO OPTIONS:
- USE REACTION BLOCKS
- SELECT INTEGRAL BRIDGES

MANDATORY REQUIREMENT:
- PROVIDE ADEQUATE SUPPORT LENGTHS
OLD SURAJBARI BRIDGE
EXAMPLE OF LONGITUDINAL SEISMIC RESTRAINER FOR CONTINUOUS BRIDGES
BRITANIA CHOWK FLYOVER
ELEVATION OF RESTRAINED PIER
LONGITUDINAL TIE BARS

HOLDING-DOWN BARS

PREVENTION OF DISLODGEMENT
SEISMIC REACTION
BLOCKS: PERSPECTIVE VIEW

APPLIED FORCES ON PIER (t) :

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<tr>
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<td>162</td>
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<td>LONGITUDINAL</td>
<td>120</td>
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CAPACITY OF SEISMIC RESTRAINERS (t) :

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</thead>
<tbody>
<tr>
<td>TRANSVERSE</td>
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<td>256</td>
</tr>
<tr>
<td>LONGITUDINAL</td>
<td>NA</td>
<td>512</td>
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* BASIS : $\alpha_h = 0.126$
INTEGRAL BRIDGES

SUB-STRUCTURE AND SUPERSTRUCTURE ARE MONOLITHIC

---NO BEARINGS!!
---FEW EXP JTS!!
SURAJBARI OLD BRIDGE
METTALIC BEARINGS DESTROYED
PADSHAHI BAGH (J & K) : DAMAGED PIER CAP, BEARINGS & SUPERSTRUCTURE

DISASTER REDUCTION FROM TERRORIST THREAT:
HARDEN THE STRUCTURE
PANCHSHEEL CLUB FLYOVER: INTEGRAL CONSTRUCTION, HIGH DURABILITY, LOW MAINTENANCE, INCREASED SAFETY DURING EARTHQUAKES
DAMPERS, STUs

REDUCING

SHARING
$STU \text{ FORCE (ULTIMATE)} = 650t$

NHAI’s GANGA BRIDGE AT ALLAHABAD
SHOWING APPLICATION OF STUs.
NHAI’s ALLAHABAD BRIDGE: APPLICATION OF STUs
THANK YOU!
JAI HIND!!