New Seismic Design Requirements in Louisiana

Mohsen Shahawy, PhD., PE

SDR Engineering Consultants, Inc.
January 11, 2011

2011 Louisiana Transportation Conference
**Seismic Zones.** Until relatively recently, seismic design criteria depended solely upon the seismic zone in which a structure was located. Zones were regions in which seismic ground motion, corresponding to a certain probability of occurrence, was within certain ranges.
New design requirements recognized that structure performance during a seismic event depends not only on the severity of sub-surface rock motion, but also on the type of soil upon which a structure is founded.
Earthquake Hazards Program

Louisiana
Seismic Hazard Map

Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)
The soil condition at the site is the additional variable that must now be dealt with.

While this adds another element to an already complicated procedure, it does incorporate established knowledge about the effect of soil properties during an earthquake into seismic design criteria.
In general, the process leading to the classification of the Seismic Design Category involves several steps and clearly, the procedure for establishing the seismic classification of a structure has become more complex.
Objectives

Develop the Seismic Zone classification map for Louisiana based on a study of all parishes in the state and accounting for the existing soil classification for each Parish.
Procedure

Step 1: Site Class Definitions

A site shall be classified as A though F in accordance with the site class definitions.

<table>
<thead>
<tr>
<th>Classifications</th>
<th>Seismic Zones</th>
<th>Seismic Site Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classifications</td>
<td>0, 1, 2, 3, 4</td>
<td>A, B, C, D, E, F</td>
</tr>
<tr>
<td>Criteria for Classification</td>
<td>Location</td>
<td>Location, Structure Use, &amp; Soil Type</td>
</tr>
</tbody>
</table>
E* INDICATES THE AREA IS IDENTIFIED AS SITE CLASS E WITH POSSIBLE AREA OF SITE CLASS F. REFER TO AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS TABLE 3.10.3.1-1 FOR THE DEFINITION OF SITE CLASS F. THE GEOFICAL ENGINEER SHALL BE CONSULTED FOR SITE CLASS F CONDITION.

LAWSIANSITECLASSMAP

(PER AASHTO LRFD BRIDGE DESIGN SPECIFICATION TABLE 3.10.3.1-1 SITE CLASS DEFINITIONS)
Procedure

Step 2: **Determine** Peak Ground Acceleration coefficient \( (PGA) \) and the short- and long period spectral acceleration coefficients \( (S_S \text{ and } S_I) \), respectively.

Step 3: **Determine** zero, short, and long-period site factors, \( F_{PGA}, F_a \), and \( F_v \).
Procedure

Step 4: Calculate the Response spectrum

\[ S_{D1} = F_s S_1 \quad (3.10.4.2-6) \]

where:

\[ S_1 = \text{horizontal response spectral acceleration coefficient at 1.0 sec period on rock (Site Class B)} \]

Figure 3.10.4.1-1 Design Response Spectrum.
For each Parish:

- Divide into 3 or 4 zones based on Zip code
- Perform analysis and determine $S_{D1} = F_v \times S_I$
- Determine Zone Classification
Seismic Performance Zones

Each bridge shall be assigned to one of the four seismic zones in accordance with Table 3.10.6-1

Table 3.10.6-1  Seismic Zones

<table>
<thead>
<tr>
<th>Acceleration Coefficient, $S_{D1}$</th>
<th>Seismic Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{D1} \leq 0.15$</td>
<td>1</td>
</tr>
<tr>
<td>$0.15 &lt; S_{D1} \leq 0.30$</td>
<td>2</td>
</tr>
<tr>
<td>$0.30 &lt; S_{D1} \leq 0.50$</td>
<td>3</td>
</tr>
<tr>
<td>$0.50 &lt; S_{D1}$</td>
<td>4</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
</tr>
<tr>
<td>Acadia</td>
<td>70543</td>
</tr>
<tr>
<td></td>
<td>70578</td>
</tr>
<tr>
<td></td>
<td>70526</td>
</tr>
<tr>
<td>Allen</td>
<td>70648</td>
</tr>
<tr>
<td></td>
<td>70655</td>
</tr>
<tr>
<td></td>
<td>71463</td>
</tr>
<tr>
<td>Ascension</td>
<td>70737</td>
</tr>
<tr>
<td></td>
<td>70778</td>
</tr>
<tr>
<td></td>
<td>70797</td>
</tr>
<tr>
<td></td>
<td>70769</td>
</tr>
<tr>
<td></td>
<td>70346</td>
</tr>
<tr>
<td>Assumption</td>
<td>70390</td>
</tr>
<tr>
<td></td>
<td>71355</td>
</tr>
<tr>
<td>Beauregard</td>
<td>70634</td>
</tr>
<tr>
<td></td>
<td>70653</td>
</tr>
<tr>
<td></td>
<td>70652</td>
</tr>
<tr>
<td></td>
<td>70660</td>
</tr>
<tr>
<td>Bienville</td>
<td>71068</td>
</tr>
<tr>
<td></td>
<td>71016</td>
</tr>
<tr>
<td></td>
<td>71008</td>
</tr>
<tr>
<td></td>
<td>71028</td>
</tr>
<tr>
<td>Bossier</td>
<td>71064</td>
</tr>
<tr>
<td></td>
<td>71006</td>
</tr>
<tr>
<td></td>
<td>71051</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Caddo</td>
<td>71082</td>
</tr>
<tr>
<td></td>
<td>71107</td>
</tr>
<tr>
<td></td>
<td>71047</td>
</tr>
<tr>
<td></td>
<td>70661</td>
</tr>
<tr>
<td></td>
<td>70665</td>
</tr>
<tr>
<td></td>
<td>70611</td>
</tr>
<tr>
<td></td>
<td>70607</td>
</tr>
<tr>
<td></td>
<td>71418</td>
</tr>
<tr>
<td></td>
<td>71435</td>
</tr>
<tr>
<td></td>
<td>70631</td>
</tr>
<tr>
<td></td>
<td>70643</td>
</tr>
<tr>
<td></td>
<td>70630</td>
</tr>
<tr>
<td></td>
<td>70645</td>
</tr>
<tr>
<td></td>
<td>71343</td>
</tr>
<tr>
<td></td>
<td>71340</td>
</tr>
<tr>
<td></td>
<td>71368</td>
</tr>
<tr>
<td></td>
<td>71038</td>
</tr>
<tr>
<td></td>
<td>71040</td>
</tr>
<tr>
<td></td>
<td>71003</td>
</tr>
<tr>
<td></td>
<td>71354</td>
</tr>
<tr>
<td></td>
<td>71334</td>
</tr>
<tr>
<td></td>
<td>70753</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Desoto</td>
<td>71063</td>
</tr>
<tr>
<td></td>
<td>71046</td>
</tr>
<tr>
<td></td>
<td>71052</td>
</tr>
<tr>
<td>East Baton Rouge</td>
<td>70791</td>
</tr>
<tr>
<td></td>
<td>70810</td>
</tr>
<tr>
<td></td>
<td>70815</td>
</tr>
<tr>
<td>East Carroll</td>
<td>71254</td>
</tr>
<tr>
<td></td>
<td>71286</td>
</tr>
<tr>
<td></td>
<td>71276</td>
</tr>
<tr>
<td>East Feliciana</td>
<td>70761</td>
</tr>
<tr>
<td></td>
<td>70722</td>
</tr>
<tr>
<td></td>
<td>70777</td>
</tr>
<tr>
<td>Evangeline</td>
<td>70554</td>
</tr>
<tr>
<td></td>
<td>70586</td>
</tr>
<tr>
<td>Franklin</td>
<td>71295</td>
</tr>
<tr>
<td></td>
<td>71336</td>
</tr>
<tr>
<td></td>
<td>71232</td>
</tr>
<tr>
<td>Grant</td>
<td>71432</td>
</tr>
<tr>
<td></td>
<td>71467</td>
</tr>
<tr>
<td></td>
<td>71454</td>
</tr>
<tr>
<td></td>
<td>71417</td>
</tr>
<tr>
<td>Iberia</td>
<td>70538</td>
</tr>
<tr>
<td></td>
<td>70560</td>
</tr>
<tr>
<td></td>
<td>70563</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Iberville</td>
<td>70788</td>
</tr>
<tr>
<td></td>
<td>70740</td>
</tr>
<tr>
<td></td>
<td>70764</td>
</tr>
<tr>
<td>Jackson</td>
<td>71251</td>
</tr>
<tr>
<td></td>
<td>71226</td>
</tr>
<tr>
<td></td>
<td>71268</td>
</tr>
<tr>
<td></td>
<td>71238</td>
</tr>
<tr>
<td>Jefferson</td>
<td>70904</td>
</tr>
<tr>
<td></td>
<td>7072</td>
</tr>
<tr>
<td></td>
<td>7036</td>
</tr>
<tr>
<td></td>
<td>70067</td>
</tr>
<tr>
<td>Jefferson</td>
<td>70549</td>
</tr>
<tr>
<td>Davis</td>
<td>70591</td>
</tr>
<tr>
<td></td>
<td>70532</td>
</tr>
<tr>
<td>Lafayette</td>
<td>70520</td>
</tr>
<tr>
<td></td>
<td>70592</td>
</tr>
<tr>
<td></td>
<td>70529</td>
</tr>
<tr>
<td>Lafourche</td>
<td>70301</td>
</tr>
<tr>
<td></td>
<td>70374</td>
</tr>
<tr>
<td></td>
<td>70357</td>
</tr>
<tr>
<td>LaSalle</td>
<td>71371</td>
</tr>
<tr>
<td></td>
<td>71465</td>
</tr>
<tr>
<td></td>
<td>71342</td>
</tr>
<tr>
<td>Lincoln</td>
<td>71270</td>
</tr>
<tr>
<td></td>
<td>71275</td>
</tr>
<tr>
<td></td>
<td>71235</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Livingston</td>
<td>70785</td>
</tr>
<tr>
<td></td>
<td>70449</td>
</tr>
<tr>
<td></td>
<td>70754</td>
</tr>
<tr>
<td></td>
<td>71282</td>
</tr>
<tr>
<td>Madison</td>
<td>71232</td>
</tr>
<tr>
<td></td>
<td>71264</td>
</tr>
<tr>
<td></td>
<td>71220</td>
</tr>
<tr>
<td></td>
<td>71250</td>
</tr>
<tr>
<td></td>
<td>71070</td>
</tr>
<tr>
<td></td>
<td>71457</td>
</tr>
<tr>
<td></td>
<td>71468</td>
</tr>
<tr>
<td>Natchitoches</td>
<td>710129</td>
</tr>
<tr>
<td></td>
<td>70131</td>
</tr>
<tr>
<td></td>
<td>70124</td>
</tr>
<tr>
<td>Orleans</td>
<td>71203</td>
</tr>
<tr>
<td></td>
<td>71202</td>
</tr>
<tr>
<td></td>
<td>71292</td>
</tr>
<tr>
<td></td>
<td>71225</td>
</tr>
<tr>
<td></td>
<td>71291</td>
</tr>
<tr>
<td>Ouachita</td>
<td>70083</td>
</tr>
<tr>
<td></td>
<td>70037</td>
</tr>
<tr>
<td></td>
<td>70091</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Pointe Coupee</td>
<td>70715</td>
</tr>
<tr>
<td></td>
<td>70762</td>
</tr>
<tr>
<td></td>
<td>70753</td>
</tr>
<tr>
<td>Rapides</td>
<td>71328</td>
</tr>
<tr>
<td></td>
<td>71430</td>
</tr>
<tr>
<td></td>
<td>71409</td>
</tr>
<tr>
<td></td>
<td>71360</td>
</tr>
<tr>
<td>Red River</td>
<td>71019</td>
</tr>
<tr>
<td></td>
<td>71068</td>
</tr>
<tr>
<td>Richland</td>
<td>71292</td>
</tr>
<tr>
<td></td>
<td>71259</td>
</tr>
<tr>
<td></td>
<td>71232</td>
</tr>
<tr>
<td>Sabine</td>
<td>71429</td>
</tr>
<tr>
<td></td>
<td>71419</td>
</tr>
<tr>
<td></td>
<td>71449</td>
</tr>
<tr>
<td>St. Bernard</td>
<td>70085</td>
</tr>
<tr>
<td></td>
<td>70042</td>
</tr>
<tr>
<td></td>
<td>70067</td>
</tr>
<tr>
<td></td>
<td>70057</td>
</tr>
<tr>
<td></td>
<td>70087</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td>St. Helena</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70441</td>
</tr>
<tr>
<td></td>
<td>70422</td>
</tr>
<tr>
<td></td>
<td>70453</td>
</tr>
<tr>
<td>St. James</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70090</td>
</tr>
<tr>
<td></td>
<td>70086</td>
</tr>
<tr>
<td></td>
<td>70723</td>
</tr>
<tr>
<td>St. John</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70068</td>
</tr>
<tr>
<td></td>
<td>70049</td>
</tr>
<tr>
<td></td>
<td>70051</td>
</tr>
<tr>
<td>St. Landry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70358</td>
</tr>
<tr>
<td></td>
<td>70570</td>
</tr>
<tr>
<td></td>
<td>70512</td>
</tr>
<tr>
<td>St. Martin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70582</td>
</tr>
<tr>
<td></td>
<td>70517</td>
</tr>
<tr>
<td>St. Mary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70538</td>
</tr>
<tr>
<td></td>
<td>70392</td>
</tr>
<tr>
<td></td>
<td>70544</td>
</tr>
<tr>
<td>St. Tammany</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70461</td>
</tr>
<tr>
<td></td>
<td>70431</td>
</tr>
<tr>
<td></td>
<td>70447</td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td><strong>2</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Parish</td>
<td>Zip code</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>Webster</td>
<td>71072</td>
</tr>
<tr>
<td></td>
<td>71073</td>
</tr>
<tr>
<td>Webster</td>
<td>71055</td>
</tr>
<tr>
<td>West Baton Rouge</td>
<td>70767</td>
</tr>
<tr>
<td></td>
<td>71263</td>
</tr>
<tr>
<td></td>
<td>71266</td>
</tr>
<tr>
<td></td>
<td>71237</td>
</tr>
<tr>
<td>West Feliciana</td>
<td>70775</td>
</tr>
<tr>
<td>Winn</td>
<td>71422</td>
</tr>
<tr>
<td></td>
<td>71473</td>
</tr>
<tr>
<td></td>
<td>71483</td>
</tr>
</tbody>
</table>
The following Parishes are designated Seismic Zone 2:

- East Carroll
- Franklin
- Madison
- Morehouse
- Richland
- Tensas
- West Carroll

All bridges located in these parishes shall be designed using the provisions under Extreme I.
Seismic Zone Classification Map

2011 Louisiana Transportation Conference
Summary:
The structural analysis and design for the earthquake loads are specified in LRFD specification as for four seismic zones, i.e. seismic zone 1, zone 2, zone 3 and zone 4.

Bridges in LA State shall be designed for seismic zone 1 and zone 2.
Summary:

LA Bridges in seismic zone 1 need not be analyzed for seismic loads, regardless of their operational classification and geometry except for the minimum requirements as specified in Articles 3.10.9 and A4.7.4.4.
Summary:

Bridges in Seismic Zone 2 shall be analyzed and designed in accordance with the minimum requirements specified in LRFD design specification, and the latest version of “AASHTO guide specifications for LRFD seismic bridge design”
Summary:

The structural analysis and structural design, respectively, shall be taken into consideration for bridges located in seismic zone 2.

Bridges shall be analyzed and designed in accordance with the minimum requirements specified in LRFD design specification, and the latest version of “AASHTO guide specifications for LRFD seismic bridge design”
Summary:

The SEISMIC design requirements of Article 5.10.11.4 (for Seismic Zones 3 and 4) shall be taken to apply to bridges in Seismic Zone 2 except that the area of longitudinal reinforcement shall not be less than 0.01 or more than 0.06 times the gross cross-section area, $A_g$. 
Table 4.7.4.3.1-1—Minimum Analysis Requirements for Seismic Effects

<table>
<thead>
<tr>
<th>Seismic Zone</th>
<th>Single-Span Bridges</th>
<th>Multispan Bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Other Bridges</td>
<td>Essential Bridges</td>
</tr>
<tr>
<td></td>
<td>regular</td>
<td>irregular</td>
</tr>
<tr>
<td>1</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>SM/UL</td>
<td>SM</td>
</tr>
</tbody>
</table>

* = no seismic analysis required
SM = single-mode elastic method
UL = uniform load elastic method
MM = multimode elastic method

Regularity is a function of the number of spans and the distribution of weight and stiffness.

Regular bridges have less than seven spans; no abrupt or unusual changes in weight, stiffness, or geometry; and no large changes in these parameters from span to span or support-to-support.
In general, the upper boundary for Zone 2 in the current edition is significantly higher than in the previous edition due to the increase in the return period for the design earthquake.
LAUGH PARADE®
BY BUNNY HOEST AND JOHN REINER

“Let me see those blueprints again!”

2011 Louisiana Transportation Conference