National Earthquake Hazard Reduction Program (NEHRP)

- - - - -

Advisory Committee on Earthquake Hazard Reduction (ACEHR)

Memphis Area Building Codes

Perspectives

Presented by

Richard W. Howe, PE

November 9, 2009

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RWH perspective

- **Practicing structural engineer in Memphis area for entire career**
  - **Projects of all kinds and construction media**
  - **Registered and practiced in as many as 42 states, including many designs in high seismic regions (West coast) as well as moderate seismic areas (East coast)**

- **a keen and involved observer of Memphis area perspectives**
  - **community at large**
  - **public and private sector officials, and**
  - **design and construction community**

and the major issues that impacts level of interest in seismic risk mitigation

- **perception of seismic hazard**
- **$$$$$$ $$$$$$ $$$$$$**

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RWH perspective

- **Frequent participant in peripheral activities that influence seismic design-related services**
  - **Code and standards development**
  - **Code consulting**
  - **Seismic hazard workshops – USGS**
  - **Seismic risk assessment and risk management**
  - **Structural and non-structural as well as infrastructure**
  - **Existing building performance evaluations**
  - **Due diligence property assessments**

BUT, I am not a seismologist/earth scientist and, *like all but the most truly expert*, lack the level of specialized expertise in seismic structural engineering for the various media and highly inter-related and sophisticated Code development issues to make any recommendations regarding Code changes to the technically uninformed under the (presumptuous) guise of them being well-informed and considered – a disservice to all.

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RWH perspective on Memphis area Codes focuses on several issues (three principle areas for discussion)

- **Appropriate approach for addressing safety – in this case building safety. Depends on who and what is at risk - whose safety is being considered and who has the prerogative to make unilateral input and how it .is presented**

- **$$$$ (cost issues) including parlance for discussion of such issues**

- **Providing an answer or solution to the issue**

  1 **Again, focus is on cost**
  2 **Meaningful expectations**
  3 **How to minimize – better optimize – addressing seismic-resistant design and construction provisions**

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APPROACH (and prerogative to decide/influence)

Appropriate approach

- **for addressing safety – in this case building safety**
- **and coincidentally, from a Katrina perspective – resiliency (the ability to return to life as normal in a reasonable time frame – instead of exposure to "if ever")**
- **disruption of services or business**
  - **continuity of operations (public sector) – not a personal choice**
  - **business continuity (private sector) – an owner option**

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APPROACH (and prerogative to decide/influence)

Depends on who and what is at risk - whose safety is being considered:

- **Yours personally** (your choice)
- **Your family and home** (your choice)
- **Your business and facilities (if you are the party responsible for safety and risk to that business or its employees) and its scale – one person business to large business or multi-billion corporation** (more than you - ??)
- **Or the public (i.e., others – whether group, city, or state is large or small)** It is not your prerogative to make unilateral decisions regarding their safety and welfare – Decisions regarding public safety and welfare are made in a broader consensus-driven process, often ultimately decided upon by responsible elected officials)

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APPROACH (and prerogative to decide/influence)

- **Perception of acceptable level of risk is often/generally driven by cost (especially, $$$ but also effort/time) Well off countries/states/groups have a different perspective than poorly off entities – and that can vary over time.**

- **Codes are the issue – Code address public safety and welfare, so latter category is under discussion**

- **The United States and most democratic societies have developed means of addressing public interests generally driven by quasi-democratic process where consensus is developed among experts, often with highly sophisticated input from highly specialize sub-committees where even the other experts are not fully qualified to made decisions and recommendations. (As opposed to a autocratic declaration of policy based on who knows what....and subject to change as powers that be change.)**

APPROACH (cont.)

- **This applies to the seismic issue in the three principal areas of interest (actually four)**

  1 - Defining seismic hazard

  2 - Addressing how buildings behave and what can be done to enhance performance (Engineering standards)

  3 - What should be done to address an appropriate level of safety – Codes

  And, fourth:
  4 - Final decision by elected officials/jurisdictional governments to adopt Codes and their provisions – perhaps with amendments deemed appropriate to meet special local interests and needs (e.g., Memphis cotton warehouses – considered unique among general U.S. jurisdictions)

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APPROACH (cont.)

Of course, all these processes are "quasi-democratic" in that there is always what some may deem special interests or unfair degrees of influence or simply the inertia of the mass body or machine. But it is as good a system as our democratic society can develop....always subject to refinement as part of the democratic process.

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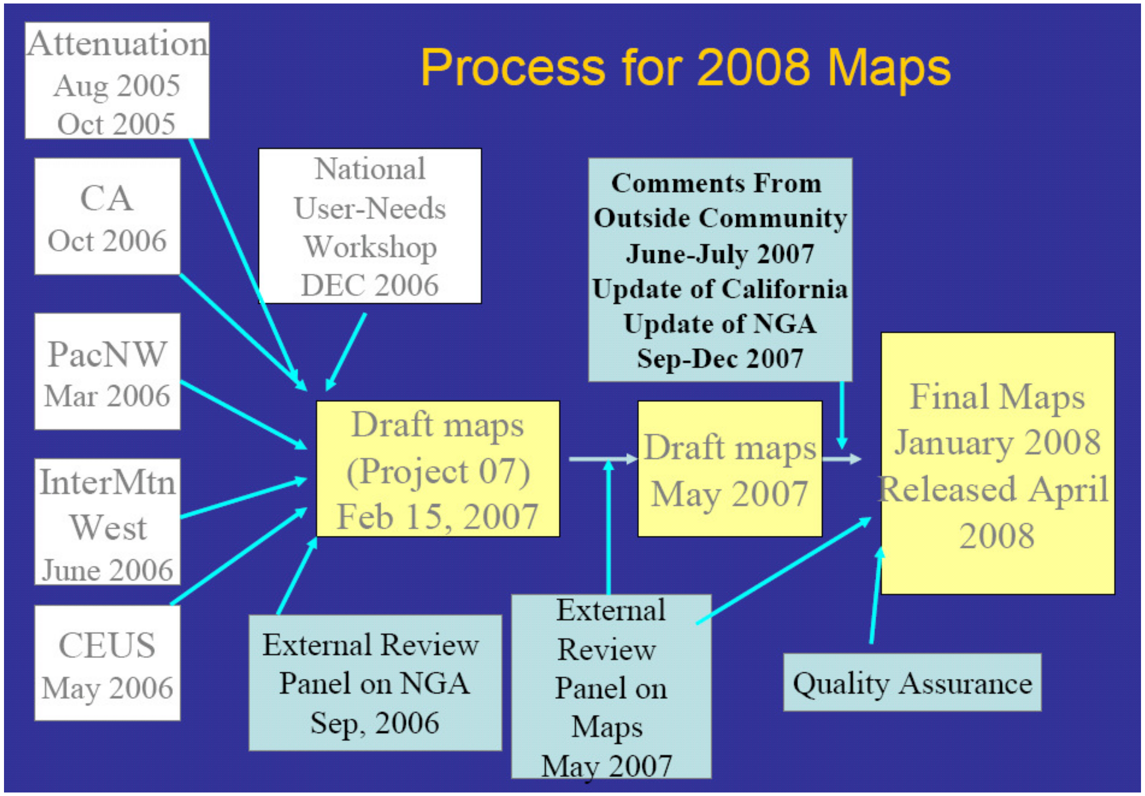
USGS national seismic hazard map development process
(Ref. Art Frankel presentation)



Yes, there are uncertainties – but best information available
Again, option to accept depends on "What is your prerogative?"

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Seismic Code developments

- **Process (USGS > NEHRP *Provisions* > ASCE 7 > IBC)**
- **2008 USGS national seismic hazard map developments** (done)
- **2009 NEHRP *Provisions* developments** (done)
- **ASCE 7-10 / IBC 2012 incorporation of 2009 NEHRP *Provisions*** (done)
- **IBC 2012** (in early stages of process – to be issued 2012)

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Seismic Code development

- **Process (USGS, NEHRP *Provisions*, ASCE 7, IBC)**

  All derived thru quasi-democratic development of consensus of expert and knowledgeable parties from broad and open representation of interests

  (a) *expert* sub-committee level

  (b) broader vote of *informed* voting organization membership

  Define the hazard: USGS national seismic hazard maps →

  Engineers recommend how to design for hazard: NEHRP/BSSC *Provisions* →

  Standardization into Code language: ASCE 7 Minimum Design Loads →

  Incorporation into model Code: IBC 2012

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Recent developments impacting forthcoming seismic model code design and construction provisions

- **USGS 2008 maps changed with somewhat diminished ground motions**

- **BSSC/NEHRP design procedures changed with net result of diminished design ground motions for Central US – specifically, for short period design ground motions**

Net impact on Memphis area thru Missouri bootheel – short period design ground motions down about 20-25% (but, in general, Seismic Design Category – SDC – is unchanged)

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Ground motions changing due to attenuation modeling

New Central and Eastern U.S. Source Models

- New analysis of magnitude distribution for earthquakes in the central and eastern U.S.
- New Madrid seismic zone: revised rates, added temporal cluster model
- New Charleston, SC zones: include offshore structures
- New CEUS attenuation relations (one of the new ground motion relations falls off faster with distance from earthquake than previous models}.

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2009 NEHRP *Provisions* developments

Proposal SDPRG-1R4

Approach and Key Components

- New USGS Maps - Proposal incorporates new seismic hazard data and related maps developed by the USGS
- Ground Motion Topics - Proposal includes technical changes to three ground motion topics:
  - ✓ Direction of ground motions (Maximum direction)
  - ✓ Near-fault (deterministic) ground motions
  - ✓ Risk-targeted ground motions
- Implementation – Proposal envisions that web-based software (i.e., USGS) will greatly simplify implementation of new design values maps and procedures

USGS science for a changing world · FEMA · Project '07 - Seismic Design Procedures Reassessment Group · Building Seismic Safety Council

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Probabilistic MCE Maps

- Current probabilistic MCE ground motions have a 2% probability of being exceeding in 50 years (i.e., they are of "uniform-<u>hazard</u>")

- But as recognized in ATC 3-06 (1978), …

  "It really is the probability of structural failure with resultant casualties that is of concern, and the geographical distribution of that probability is not necessarily the same as the distribution of the probability of exceeding some ground motion"

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- In other words, …

Designing for uniform-hazard (e.g., 2% in 50 years) ground motions does not necessarily result in buildings with uniform probability of collapse in 50 years (i.e., “uniform risk”).

- Proposed risk-targeted adjustments to uniform-hazard ground motions would result in expectation of uniform risk:

Collapse Risk Objective – 1% in 50 years

(Conditional Collapse Risk Objective – 10%|MCE)

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Comparison of proposed 1-second design ground motions (S_{D1}) and associated Seismic Design Category with current (*ASCE 7-05*) values CEUS city sites (Site Class D)

City (Site Location)	1997 *UBC*		*ASCE 7-05*		SDPRG-1R4	
	Zone	C_v	SDC	S_{D1} (g)	SDC	S_{D1} (g)
St. Louis			D	0.24	D	0.24
Memphis			D	0.42	D	0.40
Charleston			D	0.41	D	0.41
Chicago			B	0.096	B	0.100
New York			B	0.112	B	0.117
Weighted Mean				0.135		0.139

USGS Science for a changing world FEMA Project '07 - Seismic Design Procedures Reassessment Group Building Seismic Safety Council

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Comparison of proposed short-period design ground motions (S_{DS}) and associated Seismic Design Category with current (*ASCE 7-05*) CEUS city sites (Site Class D)

City (Site Location)	1997 *UBC*		*ASCE 7-05*		SDPRG-1R4	
	Zone	$2.5*C_a$	SDC	S_{DS} (g)	SDC	S_{DS} (g)
St. Louis			D	0.52	C	0.43
Memphis			D	0.93	D	0.74
Charleston			D	1.01	D	0.80
Chicago			B	0.18	A	0.14
New York			C	0.37	B	0.30
Weighted Mean				0.36		0.29

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Comparison of proposed short-period design ground motions (S_{DS}) and associated Seismic Design Category with current (*ASCE 7-05*) values and 1997 *UBC* coefficients (C_a) – S. California city sites (Site Class D)

City (Site Location)	1997 *UBC*		*ASCE 7-05*		SDPRG-1R4	
	Zone	2.5^*C_a	SDC	S_{DS} (g)	SDC	S_{DS} (g)
Los Angeles	4	1.10	D	1.44	E	1.60
Century City	4 (NF)	1.32	D	1.22	E	1.44
Northridge	4	1.10	D	1.09	D	1.13
Long Beach	4 (NF)	1.43	D	1.20	D	1.10
Irvine	4	1.10	D	1.00	D	1.03
Riverside	4	1.10	D	1.00	D	1.00
San Bernardino	4 (NF)	1.32	D	1.13	E	1.58
San Luis Obispo	4	1.10	D	0.83	D	0.78
San Diego	4 (NF)	1.43	D	1.07	D	0.84
Santa Barbara	4 (NF)	1.43	E	1.38	E	1.89
Ventura	4 (NF)	1.43	E	1.64	E	1.59
Weighted Mean		1.25		1.16		1.22

USGS science for a changing world · FEMA · Project '07 - Seismic Design Procedures Reassessment Group · Building Seismic Safety Council

Point of reference: High seismic West Coast areas higher design ground motions than Memphis x2 to x3

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- On-Going Process
  - ✓ Proposal ground motions (SDPRG-1R4) must first be approved by the BSSC (for the 2009 *NEHRP Provisions*) before consideration by the SSC for *ASCE 7-10*
- A Word of Caution
  - ✓ New USGS hazard maps should not be used directly with current design procedures (e.g., *ASCE 7-05*)
- User Friendly
  - ✓ GIS tools (Google) and web-based software (USGS) will greatly simplify implementation of new design values maps and procedures

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ASCE 7-10 / IBC 2012 incorporation of 2009 NEHRP *Provisions*

- ***ASCE 7-10 Minimum Structural Design Loads for Buildings and Other Structures*** **has been issued**

- **ICC adopts ASCE 7-10 into IBC 2012 (anticipated, 2012)**

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Memphis Code adoption status

Local amendment or Code variance option

Memphis has historically adopted local amendments, in effect, diminishing seismic design and construction provisions of the model building code

- **Conformance to 2009 NEHRP *Provisions* (and subsequent revision to ASCE 7-10 and IBC 2012 seismic provisions, as issued)**
- **Excludes critical and essential facilities (conform to more conservative provisions/design ground motion of present Code for such facilities)**

NOTE: Memphis adoption of ASCE 7-10 (future IBC 2012) as local amendment vaults Memphis from position of national perception as Code-defying to advanced state of the art.

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Underlying issue: $$$$$ $$$$$ $$$$$ $$$$$ $$$$$

If cost were zero, or minimal, there would likely be no issue

And an answer or solution

Given that there is now a general perception – even acceptance - in the Memphis area of there is, in fact, a level of seismic hazard that should be dealt with and
If costs were perceived as nominal or, at least, reasonable

- **Public and private sector responsible parties would demand it**

- **Only resistance would come from design community, who arguably is not paid added cost of dealing with it….**(cost on the order of 25% max increase in structural fees which typically are on order of 0.50% to 0.75% of cost of construction or about 0.12 to 0.18 per cent of project construction cost)

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So, effectively addressing the cost issue is paramount – from two perspectives:

- **Meaningfully accurate expectations**
- **Meaningfully controlling those costs**

A new paradigm for addressing costs

What should costs (premiums as carefully defined) of conformance to Code seismic provisions be they be and how can we achieve them or, control them, to maximum extent/degree practical?

Proposed: Address costs/premiums analytically for typical range of building types and grades (Grade A, B, C, etc), publish guidelines, including do's and don't's to best achieve them – i.e., enlightened design.

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Importance of parlance

I.e., consistent and well understood terminology & definitions

RWH white paper on parlance

Used here/generally recommended:

- **(Cost) Premium – cost of certain Code-required seismic-resistant design, construction (and administrative) provisions ÷ certain project costs**

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Importance of parlance (cont.)

- **Seismic costs**
  - **Structural**
  - **Non-structural**
  - **QA (quality assurance)**
    - **Design**
    - **Construction**
    - **Equipment performance ratings**
  - **Administrative (enforcement, documentation)**
  - **Design and project administration**
  - **Total (of interest to whoever pays for it)**

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Importance of parlance (cont.)

- **Project costs - unless clearly stated otherwise, % of total project construction contract cost (specifically, building/facility exclusive of site work)**
  - **building/facility construction contract cost (exclusive of site work)**

- **Could consider "total facility development cost" (not only building construction cost but also including cost of land, project development fees, design fees, even finance costs, etc.) since that is the real investment on the part of the Owner/community and that being protected by added cost of seismic-resistant design**

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Importance of parlance (cont.)

- **Also perhaps of interest: <u>component/system</u> construction contract cost**
  - **structure (typically taken as structure <u>and</u> foundations)**
  - **non-structural (or individual systems: plumbing, HVAC, electrical, or even communications/IT/computer system)**

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Cost issues

RWH analysis of multiple building types

- **Added cost of construction for conformance to IBC 2006 seismic code provisions (vs. SBC 99) – here, again, be careful with parlance - should be on order of 1-2% (ideally less than 1%) (varies somewhat with type and grade of construction)**
- **Analytical determination of what cost premiums *__should be__***

RWH <u>SAMPLE</u> ANALYSIS FOLLOWS

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IBC 2006/2008 Seismic cost premium evaluation		SUMMARY - MEMPHIS	
Updated 8/19/09			
		DRAFT for REVIEW and COMMENT ONLY	
STRUCTURAL (see NON-STRUCT tab for non-structural)			
Variables			**Comments**
Applicable Code			
SBC 1999 (also 1994, 1997 - BOCA 1993, 1996, 1999)			All 1991 NEHRP *Provisions* -based codes
IBC 2003/2006/2009			1997-2005 NEHRP *Provisions* -based codes
IBC 2012/ASCE 7-10			2009 NEHRP *Provisions* -based
Building type			
Office building		OB	
Warehouse/industrial		WH	
Parking structure		PS	
Retail		RET	
Hospital		HOSP	
Multi-family residential (apt/condo/hotel)		RES	
Type construction			
Steel frame		STL	
Load-bearing masonry		LBM	
Cast-in-place concrete		CIP	
Pre-cast concrete		PC	Includes site precast tilt-up
Wood frame		WD	

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Building height - terminology applicable to this study only - not necessarily consistent with general building vernacular.		
Single story	1-sty	
Low rise (2-4 stories)	LR	
Mid rise (5-8 stories)	MR	
High rise (9-12 stories)	HR	
Lateral force-resisting system		
Shear wall	SW	
Moment-resisting frame	MRF	
Braced frame	BF	
Project size		**Area (sf) varies with project type**
Small	SM	Less than $2M in total project cost
Medium	MED	$3M to $6M in total project cost
Large	LG	$10M to $20M in total project cost
Project location		
Geographic - all projects Memphis, TN		Seismic hazard varies with project location
Site soil conditons - all projects assumed to be Memphis typical soil classification D		Site soil class varies

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SUMMARY - MEMPHIS, TN

	Low	High	Typical	Comments
Case A - Office Building - OB - STL - LR (2-4 stories) - BF - MED (30,000-60,000± sf)				
Seismic lateral force-resisting system cost premium (over SBC 99) as percentage of project cost	0.0%	1.3%	0.2%	
CUMULATIVE SEISMIC PREMIUM (IBC 2003 seismic vs. SBC 99 wind only)	0.0%	2.6%	0.6%	
Case B - Office Building - OB - STL - MR (5-8 stories) - BF - LG (100,000-200,000± sf)				
Seismic lateral force-resisting system cost premium (over SBC 99) as percentage of project cost	0.0%	3.0%	0.5%	
CUMULATIVE SEISMIC PREMIUM (IBC 2003 seismic vs. SBC 99 wind only)	0.2%	6.0%	1.1%	
Case C - Warehouse - WH - STL/PC - 1-sty - SW - MED (75,000-200,000± sf)				
Seismic lateral force-resisting system cost premium (over SBC 99) as percentage of project cost	0.1%	3.1%	0.4%	
CUMULATIVE SEISMIC PREMIUM (IBC 2003 seismic vs. SBC 99 wind only)	0.3%	6.3%	1.2%	

	Low	High	Typical	Comments
Case D - Warehouse - WH - STL/PC - 1-sty - SW - LG (400,000-750,000± sf)				

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- **Analytical case studies**
    - **(Ghosh et all 2003)**
    - **Belz – Memphis tilt up warehouse**
    - **Medtronics - Memphis**

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SEISMIC DESIGN COMPARISONS:

Summary of Comparative Designs of Buildings Based on the Structural Provisions of the 1999 SBC and the 2003 IBC

Prepared for the Building Seismic Safety Council by S. K. Ghosh Associates, Inc., with funding from the Federal Emergency Management Agency of the Department of Homeland Security

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Table 10 Summary of Design Seismic and Wind Base Shears

Building Type			Location	Seismic			Wind (max.)		
				1999 SBC	2003 IBC	IBC/ SBC	1999 SBC	2003 IBC	IBC/ SBC
Office buildings	3 stories		Memphis, TN	277	337	1.22	89	88	0.99
	6 stories	N-S		928	942	1.02	268	228	0.85
		E-W		480	407	0.85	104	89	0.86
Warehouse facilities	100,000 sq ft	N-S	Atlanta, GA	276	325	1.18	114	104	0.91
		E-W		251	325	1.30			
	1,000,000 sq ft	N-S		1,874	2,210	1.18	344	314	0.91
		E-W		1,666	2,210	1.33			
Retail shopping center			Memphis, TN	117	149	1.27	26	26	1.00
School			Birmingham, AL	55	314	5.71	32	32	1.00
Parking structure			Charleston, SC	1,119	3,798	3.39	333	283	0.85
Condominium			St. Louis, MO	832	957	1.15	213	181	0.85

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Table 20 Summary of Material Quantities

Building Type			Location	Seismic Base Shear IBC/SBC	Material Quantity Ratio* IBC/SBC	
Office buildings	3 stories		Memphis, TN	1.22	Total weight of structural steel in LFRS	1.12
					Total weight of structural steel	1.04
	6 stories	N-S		1.02	Total weight of structural steel in LFRS	0.81
		E-W		0.85	Total weight of structural steel	0.93
					Gravity framing (NP) / Weight of reinforcing steel in walls	1.00 / 1.04
Retail shopping center			Memphis, TN	1.27	Roof framing members (NP)	1.00
					Volume of CMU in walls	1.00
					Weight of reinforcing steel in walls	1.05
					Roof framing members (NP)	1.00
Parking structure			Charleston, SC	3.39	Volume of concrete	1.00
					Weight of post-tensioned reinforcing steel (NP)	1.00
					Weight of reinforcing steel in shear walls	1.64
					Total weight of nonprestressed reinforcing steel	1.02
					Volume of concrete	1.00

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Concept of "enlightened approach"
to design and costing of seismic provisions

- **Acknowledge seismic is an issue**
  "If you live or develop on the Coast, then the wind might blow" or
  "If you live or develop in the Mid-South, then the ground might shake"

- **Qualified consultants involved from onset -provide guidance on appropriate seismic performance objectives, what the Code provides, and what the seismic cost/premium should be and how to optimize it**

- **Engage structural engineer early in actual building design process** (instead of post conceptual/schematic design in a competitive low-bid environment – here, Mr. Structural Engineer…make this meet Code…and good luck….COSTS ⬆)

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“Enlightened approach” (cont.)

- Ensure that non-structural is approached in a manner that does not invite CYA bids (MEP, typically performance-spec’ed - uncertainty invites conservative costs by second and third tier specialty subcontractors

- Ensure that bidders and all understand project QA provisions (and, hence, bids include appropriate $$ thus avoiding exposure to costly disputes and change orders, etc)

- Establish a process for assessing seismic premium, if that is done, that invites the most competitive/streamlined determination of such costs rather than one the invites/introduces multiple levels of conservatism in costing

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Cost impacts

Technical code requirements – impact construction costs x1 (should be on order of = 1% or less impact for typical building construction)

Absence of "enlightened approach" can impact costs by factors of 2, 3, 4 and more (and therefore inflate costs by 1 to 4 or more %).

The sleeper in the cost premium discussion is enforcement of IBC QA provisions – not only from perspective of cost of QA services but also potential impact on contractor pricing.

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