Structural Design Practices in the Philippines

Looking Back and Looking Beyond.

Engr. Jose A. Sy
Sysquared & Associates, Inc.
President/Ceo
AGENDA

01. Marcos Regime
02. August 21, 1983: Ninoy Aquino’s Assassination
03. EDSA People Power Revolution
04. 1987: Key Projects
05. 1990 – 1997: Construction on the Rise
06. 1997: Asian Financial Crisis
07. 2000 Onwards: Moving Forward
08. Look Ahead
The collapse of Ruby Tower, a six-story condominium building, in the magnitude 7.3 1968 earthquake started the call for better design and construction practice in the Philippines.

That time, no structural design code is available in the Philippines.

Seismic lateral design force is proportional to the building weight.

\[ V = 0.10 \ W \]
Marcos Regime

National Structural Code for Buildings, 1st Edition

- Based on the Uniform Building Code (UBC 1970)
- Divided the Philippines into 3 zones with corresponding seismic zone factors
  \[ V = ZKCW \]
- Ductility requirements are still not included from 1971 San Fernando Earthquake
Marcos Regime

Cultural Center of the Philippines (CCP)
Folk Arts Theatre
Philippine International Convention Center (PICC)
Philippine Heart Center
AUGUST 21, 1983
Ninoy Aquino Assassination

- Economic Status

“The period shortly after the Aquino Assassination in August 1983 and the Debt Moratorium in October 1983 saw the severest economic contractions in the Philippines since after World War II.”
AUGUST 21, 1983
Ninoy Aquino Assassination

- Dollar Exchange Rate
  - The Philippines Peso to US Dollar Exchange rate was already suffering due to increasing debt, but it truly took a downfall almost immediately after the assassination.
  - The peso plunged 30% in 1983, and a further 50% in 1984, $1USD = 27 PHP
Rampant Protests and Rallies

165 rallies, marches, and other demonstrations took place between August 21 and September 30, 1983. Protest demonstrations continued into the following year, with more than 100 held between October 1983 and February 1984.
As a result, no construction activities were carried out

- Decrease in overall government spending
- Restrictive monetary policies became detrimental, especially in the industrial sector
- Majority of government led programs gave focus to the agricultural sectors only, failing to address the needs of other industries
- In effect, construction activities were at a standstill
AUGUST 21, 1983
Ninoy Aquino Assassination

Pacific Star (Nauru Building)

- Tallest building in the Philippines during the revolution
- 112.5 meters
- 29 stories with 4 basement levels
EDSA People Power Revolution
EDSA People Power Revolution

MARCOS’ LAST STAND
People’s army set for blitz

Cory gov’t formed today

MARCOS FLEES
Family, Ver off with him
Revolt’s last day: to dead

F.M. LEAVES R.P.
To seek asylum in US
EDSA People Power Revolution

It’s all over; Marcos flees!

By LUIS D. BELTRAN
Editor-in-Chief

Cory Aquino forms new government

Pro-Cory MIA forces stopping
1987 : Key Projects

**Pacific Plaza**

- Tallest building to be after the revolution
- 43 stories
- Designed using NSCP 1987 (based on UBC 1985)
  - Wind pressure, \( P = C_e C_q q_s l \)
  - Earthquake force, \( V = ZI KCSW \)
- First building in the Philippines to use 6000 psi concrete
- Dual system
1987: Key Projects

SM Megamall

- Largest shopping mall in Asia in 1991
- 330,000 square meters total floor area
- Also designed using NSCP 1987
- Utilized post-tensioning for long span beams
The Magnitude 7.7 Luzon Earthquake in 1990 reminded us to further improve the structural design practice in the Philippines.
1990 - 1997

National Structural Code for Buildings, 4\textsuperscript{th} Edition

- Based on the Uniform Building Code (UBC 1988)
- Inclusion of Seismic Zone Maps (Zone 2 and 4)
- Introduction of response modification factors or “R-Factors”

\[ V = \left( \frac{ZIC}{R_w} \right) W \]
1990 - 1997
Construction On the Rise

The country saw a boom in construction projects from the early to mid-90s
1990 - 1997
Construction On the Rise

PBCom Tower
- Tallest building in the Philippines
  - 259 meters
  - 52 storeys

GT International Tower
  - 217 meters
  - 47 storeys
1990 - 1997
Construction On the Rise

LKG Tower
• 180 meters
• 38 storeys

Ayala Tower One
• 160 meters
• 35 storeys
1997: Asian Financial Crisis

- The Peso dropped from 26.2 Pesos per US Dollar at the start of the crisis to 43.173 Pesos. In 1998, it was down to 54 Pesos per US Dollar.

- Investment in the Philippines declined as a result of the limitations of investors to accessing capital.

- In June 1997, office vacancy rates for Makati were extremely low at 0.9%, but by September 1998, the Makati area then had a vacancy rate of 5.8%.
2000 Onwards

The National Structural Code of the Philippines continued to develop.

Provisions of UBC 1997 are still being adopted.
Meanwhile, international practice also advanced at a rapid pace.

Seismic design is now based on mapped spectral accelerations.
Building codes are intended to establish minimum requirements for providing safety to life and property from hazards.

- Specification of a **Prescriptive** Criteria
  - Acceptable materials for construction
  - Approved structural and nonstructural systems
  - Required minimum levels of strength and stiffness
  - Details of how a building is to be put together

- A certain level of performance is **implied** without assessing the actual performance capability of the building

**Code Compliance or Achievement of Performance Objective?**

*Is code compliance enough?*
2000 Onwards

The development of seismic design criteria is a continuous process.

- **1933 Long Beach Earthquake**: Minimum levels of lateral strength
- **1971 San Fernando Earthquake**: Ability to deform without failure (Ductility)
- **1994 Northridge Earthquake buildings**: Damage can occur in code-compliant

**7.1M Mexico Earthquake**
Confining Reinforcement of Columns

The Code Approach for Columns of Special Moment Frames

Specify ductility requirements at yield zones.

Specify maximum spacing of ties, say 100.

Intent is confinement for adequate ductility and hysteretic behaviour.

If we provide 125, our design is not code compliant.

Does this mean failure?

Will this specific column yield?

Do we need to provide the same ductility for all columns?
2000 Onwards

Performance is not guaranteed by code conformance.

Performance can be achieved without code conformance.

208.1.1 Purpose

The purpose of the succeeding earthquake provisions is primarily to design seismic-resistant structures to safeguard against major structural damage that may lead to loss of life and property. These provisions are not intended to assure zero-damage to structures nor maintain their functionality after a severe earthquake.

Explicit verification of performance is a must.

Changes in the state of knowledge and development of new analytical tools should translate to evolution in structural design practice.
2000 Onwards

Alternative Systems and Methods of Analysis

101.4 Alternative Systems

The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been permitted and its use authorized by the Building Official (see Section 102).

Sponsors of any system of design or construction not within the scope of this code, the adequacy of which had been shown by successful use and by analysis and test, shall have the right to present the data on which their design is based to the Building Official or to a board of examiners appointed by the Building Official or the project owner/developer. This board shall be composed of competent structural engineers and shall authority to investigate the data so submitted, to require tests if any, and to formulate rules governing design and construction of such systems to meet the intent of this code. These rules, when approved and promulgated by the Building Official, shall be of the same force and effect as the provisions of this code.

104.3 Analysis

Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics that take in to account equilibrium, general stability, geometric compatibility and both short-term and long-term material properties. Members that tend to accumulate residual deformations under repeated service loads shall have included in their analysis the added eccentricities expected to occur during their service life. Such analysis shall result in a system that provides a complete load path capable of transferring all loads and forces from their point of origin to the load-resisting elements. The analysis shall include, but not be limited to, the provisions of Sections 104.3.1 through 104.3.3.
2000 Onwards

Alternative Systems and Methods of Analysis

No provisions for other structural systems appropriate for tall buildings

208.4.8.4 Alternative Procedures

208.4.8.4.1 General

Alternative lateral-force procedures using rational analyses based on well-established principles of mechanics may be used in lieu of those prescribed in these provisions.

208.4.8.4.2 Seismic Isolation

Seismic isolation, energy dissipation and damping systems may be used in the analysis and design of structures when approved by the building official and when special detailing is used to provide results equivalent to those obtained by the use of conventional structural systems.
2000 Onwards

Alternative Systems and Methods of Analysis

208.5.3.6.3.1 Nonlinear Time History Analysis

Nonlinear time history analysis shall meet the requirements of Section 208.4.4, and the time histories shall be developed and results determined in accordance with the requirements of Section 208.5.3.6.1. Capacities and characteristics of nonlinear elements shall be modeled consistent with test data or substantiated analysis, considering Importance Factor. The maximum inelastic response displacement shall not be reduced and shall comply with Section 208.6.5.

Time-history analysis provides an evaluation of dynamic structural response under loading which may vary according to the specified time function.

The nonlinearity comes from material and geometric nonlinearity, including P-delta and large-displacement effects.
The performance-based seismic design process explicitly evaluates how a building is likely to perform given the potential hazard it is likely to experience.

Assess performance of buildings under multiple seismic events

Provide higher performance for critical structures than intended by the building code.

Deliver standard performance at a reduced cost

Can be applied to both new and existing buildings
For Risk Category II tall buildings, two performance objectives are investigated explicitly:

<table>
<thead>
<tr>
<th>Level of Earthquake</th>
<th>Performance Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Level Earthquake (SLE):</strong></td>
<td>Negligible damage in once-in-a-lifetime earthquake. Structure to remain essentially</td>
</tr>
<tr>
<td>50% probability of exceedance in 30 years (43-year return</td>
<td>elastic with minor damage to structural and non-structural elements.</td>
</tr>
<tr>
<td>period)</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum Considered Earthquake (MCE):</strong> 2% probability</td>
<td>Response without loss gravity-load-carrying capacity; without inelastic straining</td>
</tr>
<tr>
<td>of exceedance in 50 years (2,475-year return period)</td>
<td>of important lateral-force-resisting elements; and without experiencing excessive</td>
</tr>
<tr>
<td></td>
<td>permanent lateral drift or development of global structural instability.</td>
</tr>
</tbody>
</table>
## Standard Structural Performance Objectives

<table>
<thead>
<tr>
<th>Earthquake Level</th>
<th>Frequent (43 years)</th>
<th>Occasional (72 years)</th>
<th>Rare (475 years)</th>
<th>Very Rare (2475 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operational</td>
<td>Immediate Occupancy</td>
<td>Life Safety</td>
<td>Collapse Prevention</td>
</tr>
<tr>
<td>Frequent (43 years)</td>
<td>Basic Objective</td>
<td>Unacceptable</td>
<td>Unacceptable</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>Occasional (72 years)</td>
<td>Essential Objective</td>
<td>Basic Objective</td>
<td>Unacceptable</td>
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</tr>
<tr>
<td>Rare (475 years)</td>
<td>Safety-Critical Objective</td>
<td>Essential Objective</td>
<td>Basic Objective</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>Very Rare (2475 years)</td>
<td>Not Feasible</td>
<td>Safety-Critical Objective</td>
<td>Essential Objective</td>
<td>Basic Objective</td>
</tr>
</tbody>
</table>
2000 Onwards

PEER TBI

LATBSDC

ASCE 41
2000 Onwards

Why PBD?

Integrating Aesthetics, Integrity, and Economy

Aesthetics

The art that exist within the built environment

Integrity

The backbone of structural engineering
Stability, Strength, and Stiffness

Economy

Enhancing the quality without sacrificing cost
2000 Onwards

Why PBD?

Buildings are getting taller.

Stratford Residences

Trump Tower

Gramercy Residences
2000 Onwards
Why PBD?

Buildings are getting more complicated.

The Spire
2000 Onwards

Why PBD?

Buildings are getting complex.

The Proscenium
Ayala Triangle Gardens
Park Central Towers
<table>
<thead>
<tr>
<th>2000 Onwards</th>
<th>80 PBD Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon Tower-2</td>
<td>Green Residences</td>
</tr>
<tr>
<td>Beacon Tower-3</td>
<td>Sequoia at Two Serendra</td>
</tr>
<tr>
<td>Park Terraces Tower-1</td>
<td>The Suites</td>
</tr>
<tr>
<td>Park Terraces Tower-2</td>
<td>Kirov Tower</td>
</tr>
<tr>
<td>Gramercy Residences</td>
<td>Sakura Tower</td>
</tr>
<tr>
<td>Milano Residences</td>
<td>Lorraine Tower</td>
</tr>
<tr>
<td>Niagara Tower</td>
<td>Lincoln Tower</td>
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<tr>
<td>Anchor Skysuites</td>
<td>Proscenium Tower</td>
</tr>
<tr>
<td>One Shangri-la Place</td>
<td>Dettifoss Tower</td>
</tr>
<tr>
<td>Admiral Baysuites</td>
<td>Trump Tower</td>
</tr>
<tr>
<td>Stratford Residences</td>
<td>Sutherland Tower</td>
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<tr>
<td>Blue Residences</td>
<td>Garden Tower-1</td>
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<tr>
<td>Ascott Residences</td>
<td>Garden Tower-2</td>
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<tr>
<td>Discovery Primea</td>
<td>Spire Tower</td>
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<tr>
<td>Edades Tower</td>
<td>Shangri-la at the Fort</td>
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<tr>
<td>One World Place Building</td>
<td>Livingstone Tower</td>
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<tr>
<td>BDO Tower</td>
<td>Two Roxas Triangle</td>
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<tr>
<td>M Place @ Ortigas</td>
<td>Iguazu Tower</td>
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<tr>
<td>Shang Salcedo Place</td>
<td>The Rise</td>
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<tr>
<td>Knightsbridge Residences</td>
<td>East Gallery Place</td>
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<tr>
<td>128 Nivel Hills Tower 1</td>
<td>Sonata Premier Residential Tower</td>
</tr>
<tr>
<td>128 Nivel Hills Tower 2</td>
<td>Sonata Premier Hotel Tower</td>
</tr>
<tr>
<td>128 Nivel Hills Tower 3</td>
<td>Olive Residences</td>
</tr>
<tr>
<td>Air Residences</td>
<td>Ayala Triangle Garden Hotel</td>
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<tr>
<td>Anchor Grandsuites</td>
<td>Ayala Triangle Garden Office</td>
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<tr>
<td>Sonata Premier Residential Tower</td>
<td>Fame Residences</td>
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<tr>
<td>Anchor Grandsuites</td>
<td>Portico Tower 1</td>
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<td>Sonata Premier Residential Tower</td>
<td>Menarco Tower</td>
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<td>Olive Residences</td>
<td>West Gallery Place</td>
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<tr>
<td>Ayala Triangle Garden Hotel</td>
<td>Nova Manila</td>
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<tr>
<td>Ayala Triangle Garden Office</td>
<td>Emerald North Tower</td>
</tr>
<tr>
<td>Fame Residences</td>
<td>Emerald South Tower</td>
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<td>Portico Tower 1</td>
<td>Two Serendra Building</td>
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<td>Menarco Tower</td>
<td>Azure North</td>
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<tr>
<td>West Gallery Place</td>
<td>Mandani Bay Ph. 1 Tower 1</td>
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<tr>
<td>Nova Manila</td>
<td>Mandani Bay Ph. 1 Tower 2</td>
</tr>
<tr>
<td>Emerald North Tower</td>
<td>STRC Apartment Ridge</td>
</tr>
<tr>
<td>Emerald South Tower</td>
<td>The Connor</td>
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<tr>
<td>Two Serendra Building</td>
<td>Glas Office Development</td>
</tr>
<tr>
<td>Azure North</td>
<td>Mandani Bay Ph. 2 Tower 1</td>
</tr>
<tr>
<td>Mandani Bay Ph. 1 Tower 1</td>
<td>Mandani Bay Ph. 2 Tower 2</td>
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<td>Mandani Bay Ph. 2 Tower 3</td>
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<td></td>
<td>Mandani Bay Ph. 2 Tower 4</td>
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<td></td>
<td>Sixth Tower at Proscenium</td>
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<td>Proscenium Performance Hall</td>
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<td></td>
<td>Shang Residences</td>
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<td>Landmark BGC Office Tower</td>
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<td>NAIA Terminal 1</td>
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<td>GSIS Building</td>
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<td>Alphaland Makati Tower</td>
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<td>Vertis North</td>
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<td>Estancia</td>
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<td>Frontera Verde</td>
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<td>Benpres</td>
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<td>Innoland Makati Tower</td>
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</tbody>
</table>
2000 Onwards

- 179 meters
- 53 storeys
- Designed using displacement-based design approach
- Utilized Tuned Liquid Column Sloshing Dampers to resist wind
2000 Onwards

Designed more 250m using the Performance-Based Design approach

Shangri-La at the Fort

Trump Tower

Gramercy Residences
2000 Onwards

The Proscenium

THE PROSCENIUM RESIDENCES

NORTH GARDEN VILLAS
5 PHYSICAL FLOORS
5 OFFICE LEVELS
3 RESIDENTIAL LEVELS

EAST/WEST GARDEN VILLAS
5 PHYSICAL FLOORS
5 OFFICE LEVELS
3 RESIDENTIAL LEVELS

SIXTH TOWER
37 PHYSICAL FLOORS
56 ACCOMMODATION LEVELS
1 POWER LEVEL
6 OUTLETS & 6 CON

PERFORMANCE HALL
1 PERFORMANCE LEVEL
6 THEATER LEVELS
2000 Onwards

The Spire

Vertical Irregularities
Asymmetrical Framing System of the Crown

Vertical Irregularities
Mushrooming Column Diagonally Outward at Different Levels

Cladding Axometric
2000 Onwards

Nova Manila
2000 Onwards

Nova Manila
2000 Onwards

Started the application of energy-dissipating devices such as BRBs

- Park Terraces
- First Application of Buckling-Restrained Brace (BRB) in the Philippines
<table>
<thead>
<tr>
<th>Project</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Suites</td>
<td>![Image of The Suites]</td>
</tr>
<tr>
<td>Sonata Premier</td>
<td>![Image of Sonata Premier]</td>
</tr>
<tr>
<td>East Gallery Place</td>
<td>![Image of East Gallery Place]</td>
</tr>
</tbody>
</table>
2000 Onwards

... until Viscoelastic Coupling Damper (VCD) was introduced in 2016.

- Consists of Two High-Rise Residential Towers
- South Tower (70-story, 235m) & North Tower (58-story, 197m)
- First application of Viscoelastic (VE) dampers in the Philippines
2000 Onwards

... until Viscoelastic Coupling Damper (VCD) was introduced in 2016.

Park Central Towers (Emerald)

First application of viscoelastic (VE) damper in the
2000 Onwards

... until Viscoelastic Coupling Damper (VCD) was introduced in 2016.

Park Central Towers
(Emerald)
Look Ahead

- The Philippines has the same earthquake risk as California, Japan, New Zealand, Haiti, etc. However, our practice of earthquake engineering is not at par with theirs.
- We believe that we should not be bounded by the limitations of the codes.
- We believe that we should take advantage of available powerful hardware and software in doing alternative approaches to ensure better performing buildings against earthquakes.
- Code compliance is not enough.
- Innovative approach is a must.
Challenges Inspire Innovations.