American Concrete Institute®
Advancing concrete knowledge

The Art of Designing Ductile Concrete in the Past 50 Years: The Impact of the PCA Book and Mete A. Sozen, Part 2

ACI Fall 2012 Convention
October 21 – 24, Toronto, ON

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WEB SESSIONS

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Drift Control as the Goal
the case of the Colombian Code

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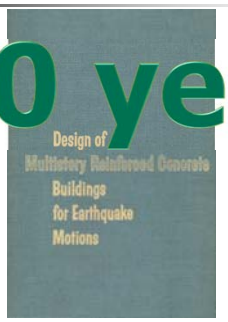
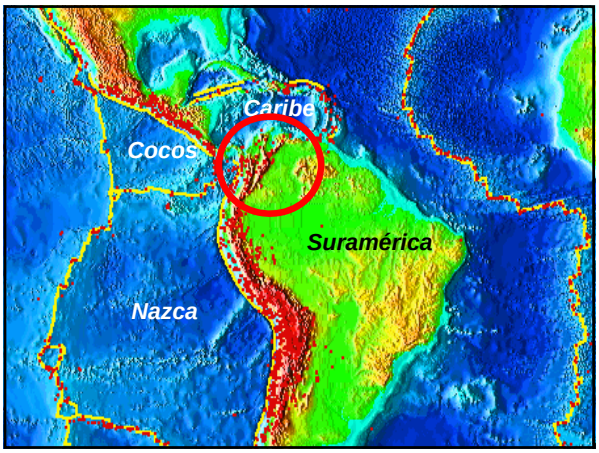
Professor of Civil Engineering, Universidad de los Andes
Bogotá, Colombia

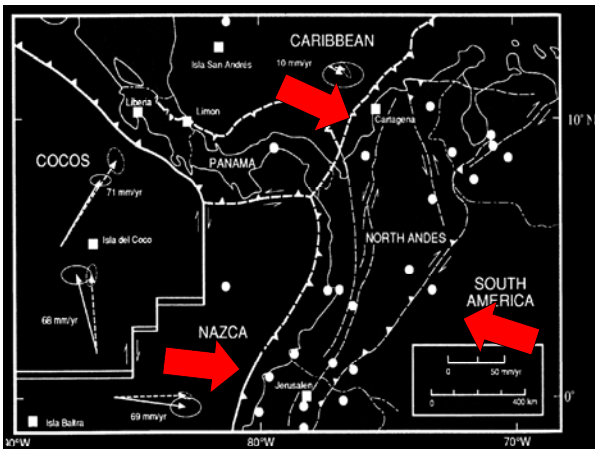
We are celebrating

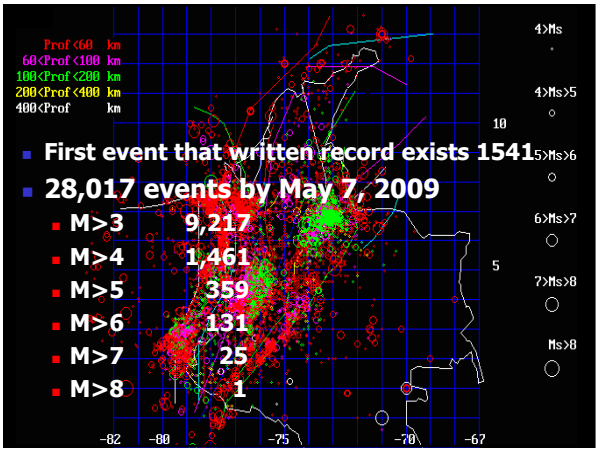
50 years



The Colombian case







Good news also spread fast!

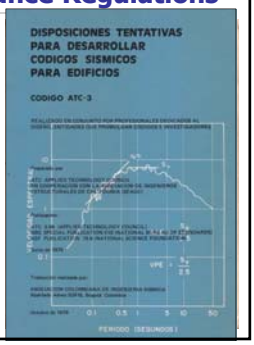
- By mid 1960s Prof. Alberto Sarria was teaching earthquake resistant basics for reinforced concrete structures at the Universidad de los Andes in Bogotá using PCA Newmark, Blume, Corning book.

Development of the Colombian Earthquake Resistance Regulations

- In 1975 **AIS (Colombian Association for Earthquake Engineering)** translated into Spanish the **1974 Blue Book** (**SEAOC**).
- The emphasis was making sure that the main feature was **detailing**

Development of the Colombian Earthquake Resistance Regulations

- When **ATC 3-06** was published in 1978, **AIS** made the decision to **translate** into **Spanish** the document for possible adoption as Earthquake Resistance Regulations for Colombia.
- This translation was widely distributed in Colombia and the rest of Latin America.



In 1980 a cooperative effort

University of Illinois
Urbana-Champaign

Universidad de los Andes
Colombia

for making an adaptation of ATC 3-06 to the Colombian environment.

Develo… Earthq… …mbian …Regulations

- Mete A. Soz… …the help of some of Me… …a, French, Moehle, and… …n an evaluation … …ced concrete buildings ur…
- A draft of te… …as made.
- Besides detailing problems derived from not having a mandatory code, **strict control of story drift was needed** to improve frame stiffness.

Development of the Colombian Earthquake Resistance Regulations

- In March 1983 a 5.5 Magnitude shallow earthquake produced intensive structural damage and more than 200 victims in Popayán.

Development of the Colombian Earthquake Resistance Regulations

- In June 1984 the **"Colombian Code for Earthquake Resistance"** was enacted by Presidential **Decree 1400 of 1984**
- It used the draft made at the U of I.

Development of the Colombian Earthquake Resistance Regulations

- June 1984 first Colombian Code.
- In 1997 Colombian Congress approves **Law 400 of 1997** defining all issues related to Seismic Resistance including creation of the Code Commission.
- In 1998 **NRS-98 Code** is enacted (Decree 33, 1998)
- In 2010 **NSR-10 Code** is enacted (Decree 926, 2010)

28 years

1987 - US Advisory Committee on the International Decade for Natural Hazard Reduction*

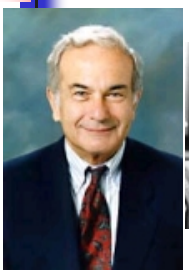
"... The Applied Technology Council (ATC) developed recommended building practices for earthquake resistant design for use in the United States. **One of the first implementers – even before the United States – was Colombia.**

...

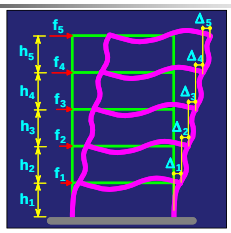
Fortunately, contacts between Colombian and U. S. engineers involved in the ATC effort are strong. **The Colombian engineers were able to adapt the guidelines – with advice from the U. S. developers – to their circumstances**."

* Advisory Committee on the International Decade for Natural Hazard Reduction, Commission on Engineering and Technical Systems, National Research Council, U.S. National Academy of Sciences and U.S. National Academy on Engineering, " CONFRONTING NATURAL DISASTERS - AN INTERNATIONAL DECADE FOR NATURAL HAZARD REDUCTION", National Academy Press, Washington, 1987.

This advice came from ...



The story drift case

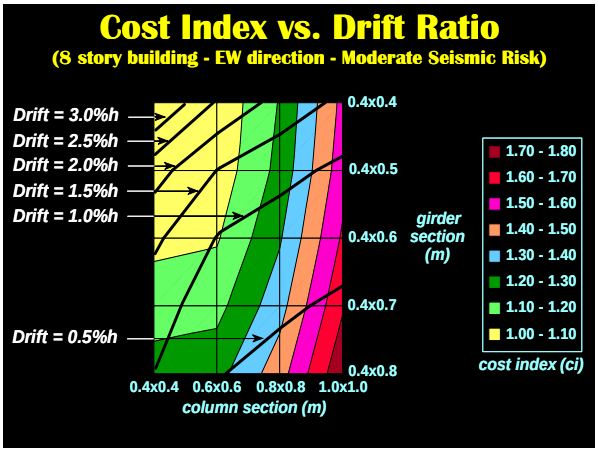






Methodology

A series of studies were performed to prove to the Colombian building industry that the increase in cost to make structures stiffer was marginal.



What was proven?

- For **frames**, important story drift reductions could be accomplished with **marginal structure cost increase**.
- Using **walls** the story drift could be reduced to less of one third with a structure **cost** increase of **less than 5%.**
- **Maximum story drift is currently**:
  - **0.5%** of story height for masonry structures
  - **1%** for all other structures.

Moderate Seismic Design Category (SDC) Requirements in the Colombian Code

Moderate Seismic Design Category (SDC) Requirements

- For the 1984 Colombian Code the reinforced concrete detailing requirements for Moderate SDC were changed to provide **more toughness** than what is required in ACI 318 Code were introduced.

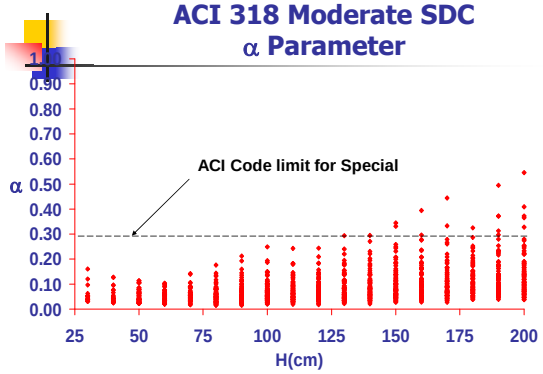
Confinement efficiency

- 1200 columns were studied:
  - **h** from 12 to 80 in.
  - section aspect ratios (**h/b**) of 1.0, 0.5 and 0.33
  - concrete strength 3000 to 5000 psi, and
  - longitudinal bar diameters No. 5 to No. 18
- Each column meeting the corresponding requirements

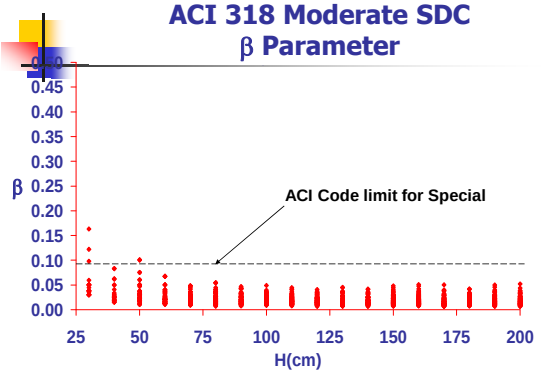
$$\alpha = \frac{A_{sh} f_{yt}}{s b_c f'_c \left(\frac{A_g}{A_{ch}} - 1 \right)}$$

$$\beta = \frac{A_{sh} f_{yt}}{s b_c f'_c}$$

Confinement provided ACI 318 Moderate SDC α Parameter



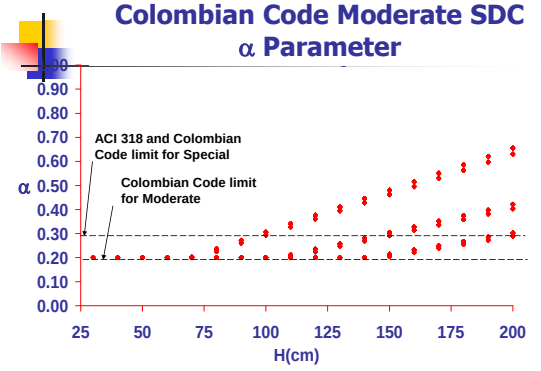
Confinement provided ACI 318 Moderate SDC β Parameter



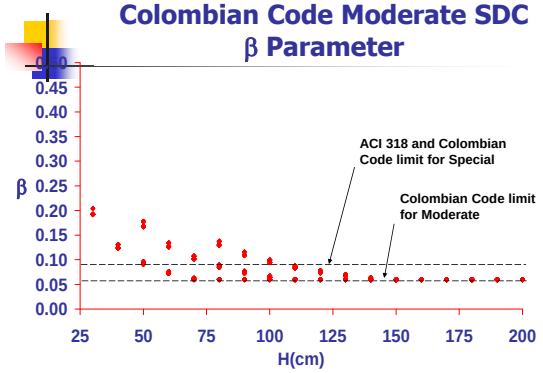
Moderate SDC requirements in the Colombian Code

- The Colombian Code **Moderate SDC** column confinement requirements correspond to **60% of the requirements in ACI Special SDC**.
  - Values for constants α and β were fixed at **0.20** and **0.06** respectively.
  - Crossties, or legs of overlapping hoops must be **horizontally spaced no more than 350 mm**.
  - Maximum vertical spacing is **1/2 of smaller cross section dimension**, **8db** longitudinal reinforcement, **16db** transverse reinforcement, or **6 in.**

Confinement provided Colombian Code Moderate SDC α Parameter

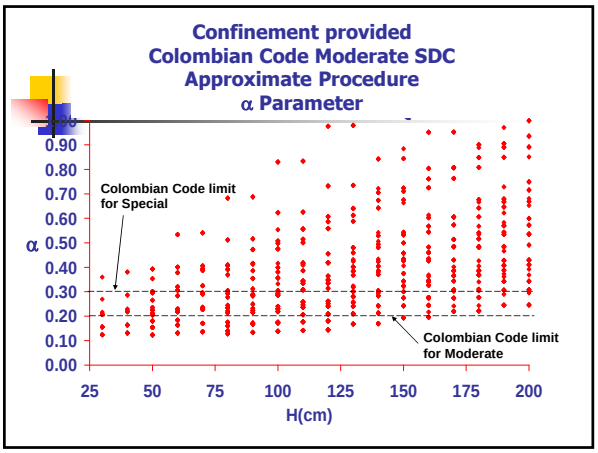


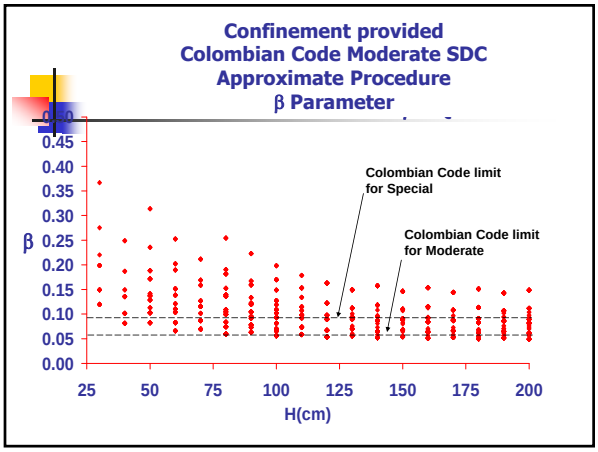
Confinement provided Colombian Code Moderate SDC β Parameter



Simplified Moderate SDC column confinement requirements in the Colombian Code

- The Colombian Code established since 1984 a **simplified approximate procedure for column confinement**.
  - **No. 3 bars** (f_y = 60 ksi) hoops and crossties
  - Spaced vertically **s = 4 in**.
  - Spaced **horizontally** no more than 1/2 of the least dimension of the column or **8 in.**

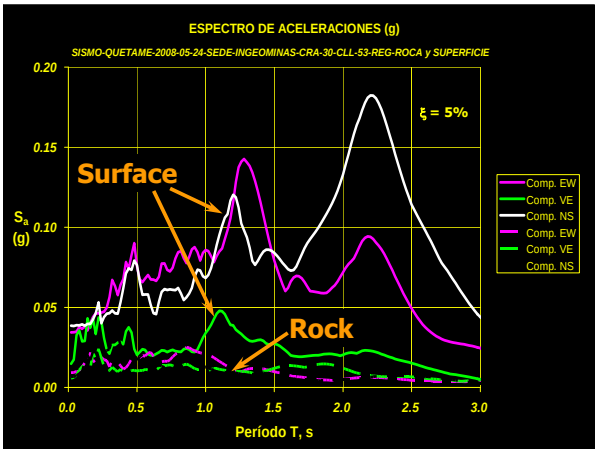


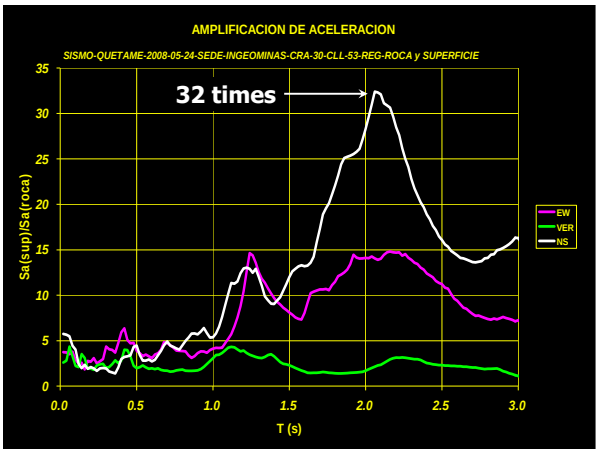


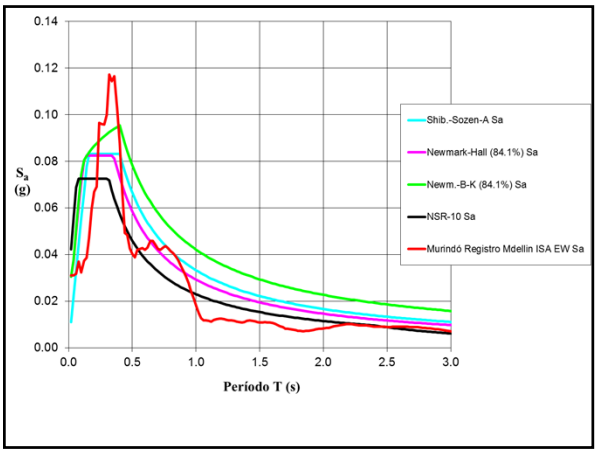
Design ground motions

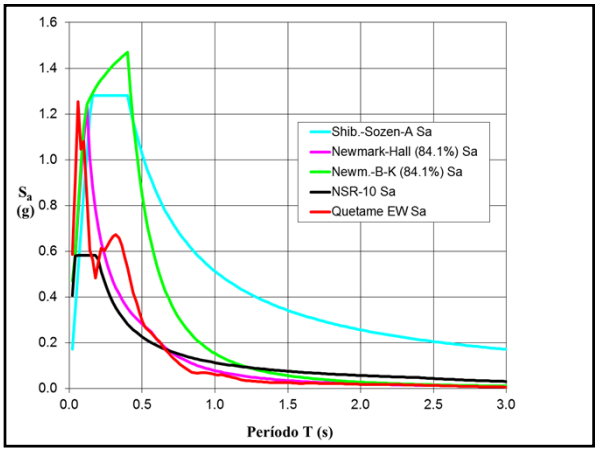
The big concerns in 1980 when the Colombian Code was being developed

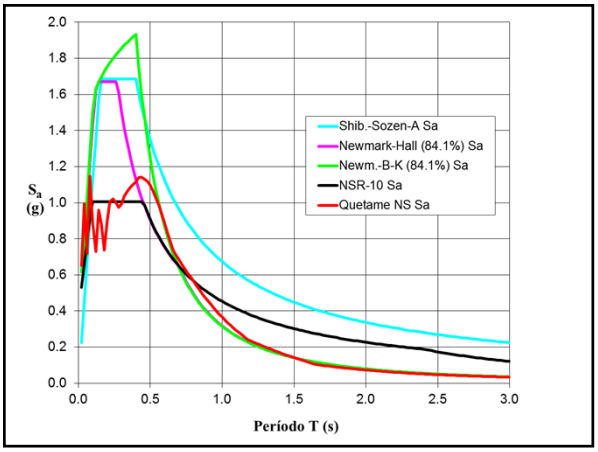
- Just a few strong motion instruments.
- Two not-too-strong "strong motion records" obtained more than 150 km away from the epicenter.
- Would the spectra as defined in ACT 3 work for the Colombian tectonics and type of faulting?

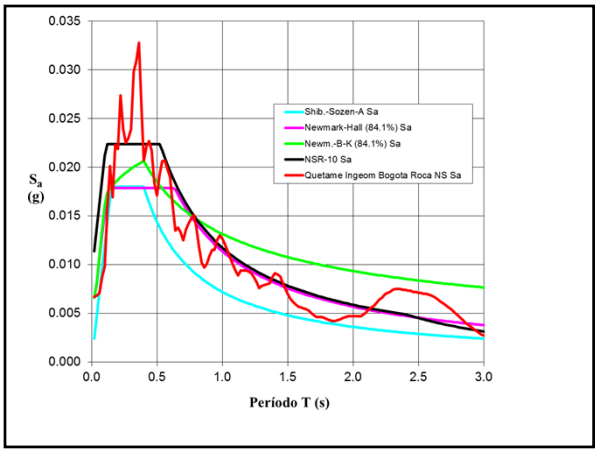




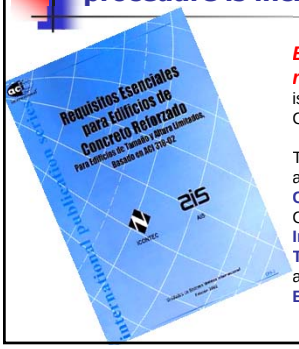








A simplified structural concrete procedure is included

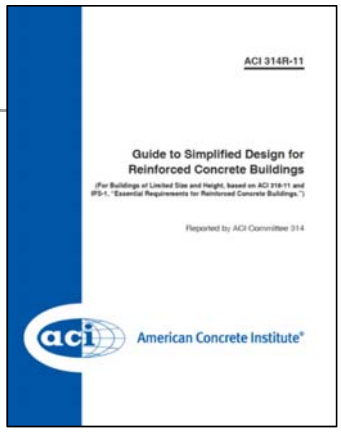


Essential requirements for reinforced concrete buildings is included as part of the Colombian Code.

This is a result of a cooperation agreement between the **American Concrete Institute** and two Colombian institutions: **Instituto Colombiano de Normas Técnicas y Certificación (Icontec)** and the **Colombian Association for Earthquake Engineering – AIS.**

And now...

ACI 314R-11



September 17, 1985

THE END

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ASOCIACIÓN COLOMBIANA DE INGENIERÍA SÍSMICA

The Colombian Association for Earthquake Engineering – AIS presents this
Special Recognition to

METE A. SOZEN

for his brilliant and continuous support in making the Colombian earthquake-resistant codes and standards, practical and effective in defending Colombians from threatening earthquakes

Luis Enrique Aycardi
President

Alberto Sarria
Honorary President

Luis E. García
Honorary President

October 21, 2013