

## The Concrete Coalition: Building a Network to Address Nonductile Concrete Buildings

C.D. Comartin,<sup>1</sup> T. Anagnos,<sup>2</sup> H. Faison,<sup>3</sup> M. Greene,<sup>4</sup> and J.P. Moehle<sup>5</sup>

<sup>1</sup> President, CDComartin Inc., Stockton, California, USA

<sup>2</sup> Professor, General Engineering, San José State University, San José, California, USA

<sup>3</sup> Outreach Director, PEER, University of California, Berkeley, California, USA

<sup>4</sup> Special Projects Manager, EERI, Oakland, California, USA

<sup>5</sup> Director, PEER, University of California, Berkeley, California, USA

Email: ccomartin@comartin.net, tanagnos@email.sjsu.edu, hfaison@berkeley.edu, mgreene@eeri.org, moehle@berkeley.edu

### ABSTRACT :

Following a series of discussions among engineers, building officials, and other individuals with an interest in dangers posed by nonductile concrete buildings, a volunteer network called the Concrete Coalition was formed in 2006. The first goal of the Concrete Coalition is to assemble a database of case histories of concrete buildings that have been seismically assessed, including buildings that have been retrofitted. These case histories will be used to help inform research activities. A second goal is to assemble currently available community risk information into the database. This information will include data on local seismic shaking hazard and geologic conditions, public policy initiatives and, where available, building inventories. To facilitate the collection of both the case histories and the community risk information, online data collection forms have been created. Beyond the milestone of consolidated and improved data, an even more valuable product of this effort is the resulting “network” of individuals and organizations who share a common interest in identifying dangerous concrete buildings and fixing them. The network created through this project promises to be a valuable resource that can provide guidelines, checklists, and other assistance to those who are trying to identify truly dangerous buildings and fix them with economical retrofits. The network will provide a two-way conduit -- gathering information on the problems and distributing practical solutions. Sample ordinances, public policies, and creative ideas for funding and financing retrofits can also be developed and shared through this mechanism.

**KEYWORDS:** nonductile, concrete, mitigation, advocacy, retrofit, inventory

### 1. INTRODUCTION

Previous experience has shown that raising awareness among the public and decision makers about dangerous buildings is an important step in establishing policies and programs to mitigate the risks from these buildings. Awareness of the risk due to the potential collapse of unreinforced masonry buildings (URMs) led to the passage of SB 547 in 1986 in California. SB 547 required every jurisdiction in Seismic Zone 4 to inventory its URMs by 1990, to adopt a loss reduction program, and to report progress to the California Seismic Safety Commission. While many jurisdictions adopted a voluntary mitigation program, a number of major cities put mandatory programs in place. Consequently, in 2003 up to 90% of URMs in some jurisdictions had been brought into compliance with the 1991 Uniform Code for Building Conservation (UCBC) (EERI, 2006). Nonductile concrete buildings pose another major collapse risk in California, the United States, and throughout the world. Mitigating this risk poses a series of challenges because of the size of the problem and the variety of structural systems and configurations. It is imperative that the challenges of identifying and strengthening truly dangerous nonductile concrete buildings be addressed with state-of-the-art science and engineering, progressive public policies, and sound business practices.

A series of initial discussions among engineers, building officials, and other individuals with an interest in dangers posed by nonductile concrete buildings took place in early 2006 in both Southern and Northern California, as well as the Pacific Northwest. These meetings confirmed a strong consensus in favor of a volunteer



coalition with roots in the technical community to address challenges posed by nonductile concrete buildings. Participants also uniformly recognized the absolutely essential participation of non-technical stakeholders (e.g. building owners and managers, planners, economists, sociologists, public policy interests). Following these meetings, a Senior Advisory Panel was formed to begin to formulate a plan and objectives for the Concrete Coalition. The Concrete Coalition is a volunteer group of engineers, architects, building owners, and public officials with a common interest in identifying high risk concrete buildings susceptible to earthquake collapse damage and strengthening them to improve their earthquake safety. While initially formed with a substantial membership from California and the Pacific Northwest, the intention is that the Concrete Coalition be broadly based with membership from throughout the U.S. and the world.

## **2. PROBLEM STATEMENT**

Poor seismic performance of concrete buildings was demonstrated dramatically in recent earthquakes in Turkey, Taiwan, Sumatra, Pakistan, China, and in the U.S.' moderate Northridge earthquake in 1994. Unfortunately, at present, building officials in the major metropolitan areas of seismic regions in the U.S. and Canada do not know how many of these buildings there are in their jurisdictions. The potential safety problems posed by vulnerable concrete buildings constructed on the U.S. west coast prior to the 1970's are generally well known among structural engineers and building officials practicing in seismically active areas. Public policy makers are somewhat less aware and the general public is not informed adequately of the potential risks. The scenario based on a repeat of the San Francisco 1906 event in the Bay Area today confirms that a large proportion of the deaths and serious injuries would be attributable to the collapse of nonductile concrete buildings.

Nonductile concrete buildings are widespread in California. They were a prevalent construction type in the western U.S. prior to enforcement of codes for ductile concrete in the mid-1970s. Los Angeles County Assessor roles suggest that about 1,600 of them exist in LA City alone; and the California Seismic Safety Commission estimates there are 40,000 throughout California (OES, 2004, p. 97). The California Seismic Safety Commission states that "many older concrete frame buildings are vulnerable to sudden collapse and pose serious threats to life." The exposure to life and property loss in a major earthquake is immense. Many nonductile concrete buildings have high occupancies, including residential, commercial, and critical services. Severe damage can lead to critical loss of building contents and risk of ruin for business occupants and partial or complete collapse can result in large numbers of casualties.

## **3. CONCRETE COALITION CONCEPT**

The Concrete Coalition, a joint project of the Earthquake Engineering Research Institute (EERI), the Pacific Earthquake Engineering Research Center (PEER) and Applied Technology Council (ATC), aims to generate a concerted effort to advocate the identification of dangerous nonductile concrete buildings and the development of sensible solutions to reduce the collapse hazard associated with these buildings. This effort is focused in three main areas: assembling a online database that assesses the current status of at-risk communities and inventories their infrastructure, developing a human network comprised of individuals and organizations interested in addressing this risk, and providing leadership to communities by assisting in the development of mitigation plans and strategies to reduce the risk associated with these buildings.

The first goal of the Concrete Coalition is to assemble currently available information on potentially dangerous concrete buildings into a database for access by all stakeholders. This information will include data on local seismic shaking hazard and geologic conditions, and where available, data on building inventories. Information on public policy initiatives will also be included. To facilitate this effort a Community Risk Profile will be developed for gathering data from local jurisdictions and community groups, as well as various state agencies and other organizations with pertinent data. These Community Risk Profiles will be disseminated through a network of local volunteers who will assist in gathering the information. The results of this effort will be placed into a



searchable web-based data repository. The outcome will be a picture of the currently available information related to the seismic risk associated with concrete buildings for major metropolitan areas with a significant seismic risk. This will enable an improved ability on the part of state and local jurisdictions and agencies to quantify risks and prioritize mitigation actions.

Beyond this digital repository of consolidated and improved data, an even more valuable product of this effort is the resulting “network” of individuals and organizations who share a common interest in finding dangerous concrete building and fixing them. This network comprising members from the technical community including structural engineers, building officials, retrofit contractors, etc., as well as non-technical stakeholders (e.g. building owners and managers, planners, economists, sociologists, public policy interests), will provide a two-way conduit -- gathering information on the problems and distributing practical solutions. It will be a valuable resource that can provide guidelines, checklists, and other assistance to those who are trying to identify truly dangerous buildings and fix them with economical retrofits. Sample ordinances, public policies, and creative ideas for funding and financing retrofits can also be developed and shared through this mechanism, as can technical documents and research results from projects done by PEER, ATC, and others.

The Concrete Coalition realizes that this effort can not be successful unless the risks of these buildings are successfully mitigated. An important part of this effort is to meet regularly with elected officials and other policy makers to inform them of the risks and encourage action. The Concrete Coalition is in a unique position to help develop mitigation plans and has the collective experience and technical knowledge to provide guidance on effective strategies. An important element of this project is linking policy makers interested in developing community action plans with other jurisdictions that have similar goals, have had successful mitigation efforts in the past, or are currently instituting mitigation programs.

#### **4. MODEL PROJECT**

EERI intends to use its successful project on the safety of international housing types as a long term model for the Concrete Coalition. The World Housing Encyclopedia (WHE) is a web-based global project that has brought together over 200 architects and engineers from around the world (<http://www.world-housing.net/>). Volunteers prepare reports on various construction types in each of their countries. Authors use a standard format, which includes photos and drawings, and provide information on 11 categories, including architectural features, the structural system, earthquake performance and vulnerability, the construction process and costs, and seismic strengthening techniques. Each of the reports is peer-reviewed, and then posted to the website. To date, there are 113 reports from 40 different countries. The project is managed by an all-volunteer editorial board, which currently has representatives from 17 countries, led by a volunteer editor-in-chief. Table 4.1 indicates the parallels between these two projects.

The network created by the WHE project is perhaps its most successful feature. Engineers from very diverse countries are now talking via e-mail to each other and occasionally gather at global meetings. The network, guided by the leadership of the editorial board, has decided to place a stronger focus on implementation, by promoting change in construction practices around the world. The website that they have all contributed to, and that they use to share information, is the tool that they can each use in communicating with builders and government officials.

The web-based framework for the project allows for fast, efficient and inexpensive communication among many participants, and the standard reporting framework ensures the ability to draw comparisons and pull out basic conclusions. These same features will be equally advantageous for the Concrete Coalition, encouraging exchange and collaboration within a growing network of engineers and building officials committed to reducing seismic risks of nonductile concrete buildings.

Table 4.1 Comparison of World Housing Encyclopedia to Concrete Coalition

	<b><i>WHE</i></b>	<b><i>Concrete Coalition</i></b>
<b><i>Focus</i></b>	Risks associated with housing around the world	Risks associated with nonductile concrete buildings
<b><i>Objectives</i></b>	Awareness of risks and tools for mitigation	Documentation of risks and local action for mitigation
<b><i>Geographic scope</i></b>	Multiple countries	Multiple jurisdictions and agencies within State
<b><i>Participants</i></b>	In-country volunteers	Local community volunteers
<b><i>Initial product</i></b>	Detailed description of housing types by country	Summaries of local inventories, hazards and policies
<b><i>Ongoing efforts</i></b>	Guidelines on practical mitigation techniques	Bulletins on: <ul style="list-style-type: none"> <li>• Technical developments</li> <li>• Community fact sheets</li> <li>• Model ordinances</li> <li>• Cost effective retrofit</li> <li>• Financing</li> </ul>
<b><i>Quality Assurance</i></b>	Editorial Board	Senior Advisory Panel
<b><i>Governance</i></b>	Editor-in-Chief and Editorial Board	Project Director and Steering Group

## 5. TANGIBLE ACTIVITIES AND OUTCOMES

This project has developed a series of activities to date that will be necessary steps for the Concrete Coalition. These activities are in varying stages of completion but progress is currently underway.

### 5.1. Top Ten Deficiencies Survey

In collaboration with a PEER project called *Mitigation of Collapse Risk in Older Concrete Buildings*, the Concrete Coalition has established a web-based Top Ten Deficiencies Survey on the Concrete Coalition website at [http://www.concretecoalition.org/top\\_ten\\_deficiencies.php](http://www.concretecoalition.org/top_ten_deficiencies.php). This survey endeavors to rank the most commonly encountered collapse mechanisms for nonductile concrete structures. The survey respondents are practicing engineers who complete the survey form based on their engineering judgment and experience. When results and conclusions are generated from these surveys, the responses will be weighted based on the respondent's years of expertise and the quantity of buildings of this type they have encountered during their career. The survey is intended to be applicable to a particular geographic region so as to capture any regional construction trends.

The ten deficiency mechanisms in the survey are shown in Table 5.1.1. Most of the buildings of this construction vintage will have columns, beams, walls, or other elements with widely-spaced hoops/stirrups with 90-degree hooks; beam-column joints without hoops; poorly located or confined splices; etc. Therefore, these conditions are not specifically called out as a particular "Deficiency" category. Instead, they likely occur along with the particular geometric conditions identified in the deficiency mechanisms.

There are two primary sections of the survey. In the first section users are asked to rank each of the ten deficiencies according to the frequency of occurrence and the criticality of the collapse mechanism. "Frequency" identifies how frequently the respondent structural engineer encounters the deficiency mechanism when they review older nonductile concrete buildings. It does not mean how frequently this condition is associated with collapse. "Criticality" on the other hand, is based on the criticality of this condition as a contributor to building collapse when it is encountered. A simple rating system of very high, high, moderate and low is used. Identification and rating of deficiencies will be used by researchers at a later date to understand the construction trends for each region. This type of data collection will allow the Coalition to provide guidance based on validated data to policy makers so that they can focus their mitigation efforts on the most dangerous and frequently occurring collapse hazards in their region.

Table 5.1.1 Top Ten Deficiency Mechanisms

Mechanism ID	Mechanism Title & Description
A	<b>Flexurally weak column mechanism:</b> Weak-column, strong-beam moment frame or similar system prone to story collapse from flexural failure of weak columns.
B	<b>Shear-critical column:</b> Shear and axial failure of columns in a moment frame.
C	<b>Captive columns:</b> Shear and axial failure of columns due to partial-height infills or other walls.
D	<b>Other concrete moment frames:</b> Moment frames having typical era details with collapse mechanisms other than mechanisms A, B, or C (i.e. splice failures, joint failures, etc.).
E	<b>Weak first story:</b> Weak first story prone to side-sway collapse due to discontinuous concrete or masonry infill in stories above.
F	<b>Discontinuous wall:</b> Columns prone to crushing from overturning of discontinuous concrete or masonry infill wall, as distinct from mechanism E.
G	<b>Severe plan irregularity:</b> Conditions (including some corner buildings) leading to torsional-induced demands.
H	<b>Deformation Compatibility:</b> Gravity system collapse under imposed lateral drifts, including slab-column, beam-column, lift slab, and other framing.
I	<b>Pounding:</b> Collapse caused by pounding of adjacent buildings with non-coincident story heights.
J	<b>Foundation failure:</b> Inadequate foundation conditions, including ground failure, ground settlement.

In the second section of this survey, each respondent ranks the deficiency mechanisms from one to ten, one being the most likely to cause a collapse resulting in life loss. From this ranking, the Concrete Coalition hopes to generate industry-wide consensus on the most dangerous collapse mechanisms for nonductile concrete buildings. Once a consensus is reached from the survey data, the results will be displayed on the website and will be a useful educational reference for engineers in other regions and countries struggling with nonductile concrete structures in their own communities as well as young engineers trying to understand the principles of earthquake engineering and collapse. In this way, the survey is being used as a consensus building tool, a data collection tool and an educational tool.

### 5.2. Community Risk Profiles

Development of the Community Risk profiles is underway. These profiles are intended to be a snapshot of the status of a jurisdiction's nonductile concrete building stock, and its resources and policies in regards to this construction type. The current version of the Community Risk Profile is still in its infancy but some of its conceptual categories are discussed in the following paragraphs.

The profile contains sections on basic community information, contacts, existing inventory information, and seismic policies. The basic information portion includes population statistics, housing statistics, seismic zone, fault information and other information from census data and other sources. The profile needs to contain names and contact information for critical people in the community including building officials, engineers, building owners, and government representatives and staff members that may be instrumental in providing technical information, supplemental community data, or developing or implementing mitigation efforts.

Existing Building Inventory information is an important and lengthy portion of the profile. It contains information about the community's nonductile concrete structures including any existing inventory data, and estimates of prevalence of these buildings in various functional use categories like government buildings, housing, industrial, etc. In the first stages of this process, much of this information may be unavailable, incomplete or just random approximations. Knowing that information is missing or approximated is still useful

to communities because it shows them where they need to place their focus. For this reason, inventory data fields require the specification of the data source and an expression of the quality of the data from “guess by an individual opinion” to “guess by group, substantiated by group discussion” to “direct data.”

The other primary element of the profile relates to seismic policies and awareness. This section provides mitigation codes and ordinances for nonductile concrete as well as for other structural systems that may be used as templates or guides for new ordinances. It also looks at post-earthquake repair policies and the status of the community’s multi-hazard mitigation plan.

The final format of these Community Risk Profiles is unknown at the time of this paper’s publication; however the end product will likely be web-based with the following components. A database will contain the profile data for each jurisdiction or community. This database will be interactive and adaptable with the ability to be modified as more information is uncovered about a community (i.e. a better quality building inventory data is obtained) or as progress is made in their community efforts at mitigation. A website will display some of the non-sensitive profile information to the public. This will allow viewers to compare different communities and may encourage a friendly competition between communities to effect change in their locality. Ideally, a password protected web-based user interface will allow Coalition volunteers to update the profile as more information becomes available, and will automatically and push the information live and update the website at the same time as it updates the back-end database.

### **5.3. Detailed Building Inventory**

The PEER Grand Challenge project is developing an inventory of nonductile concrete buildings in the City of Los Angeles. The inventory is being compiled using tax assessor’s records, sidewalk surveys, aerial photos, and other online databases (Anagnos et al., 2008). As a joint effort with the Grand Challenge project, the Concrete Coalition has created a web-based *basic building form* to assist the inventory effort. Forms are intended to be completed by structural engineering firms with expertise in existing building analysis and retrofit. The form contains information about building size, configuration, functional use, lateral forces resisting system, soil and foundation information, etc. It also has a portion that discusses the results of the firm’s engineering analysis and retrofit. These sections summarize the analysis codes and methodologies used, the primary deficiencies uncovered, the expected performance prior to and post retrofit, etc. The complete version of the form is found on the website at: [http://www.concretecoalition.org/basic\\_building\\_profile.php](http://www.concretecoalition.org/basic_building_profile.php).

The primary purpose of these forms is to help supplement existing inventory data that is obtained from tax assessor’s data and other sources. These data are often limited to building age, size, use, and location, lacking structural information. When structural information is available from tax assessor’s records it only gives structural material (wood, steel, concrete) but not structural system. The long term intent of the project is develop a set of rules that assign structural deficiencies to buildings in the inventory based on, for example, the year they were built, their size, and specific architectural features. With these data, statistical techniques can be used to develop probabilistic rules and associated uncertainties that more accurately estimate which buildings are the truly “killer” buildings.

The focus of this form so far has been the region of Los Angeles, California. The primary reason for this is that the Coalition is piloting a new system of involving volunteers: using each firm’s summer interns to complete the online forms on behalf of the senior engineers in the firm. The concept is to have the intern interview the senior engineers about which buildings are good candidates for the forms. Once the intern gathers the appropriate information (building drawings and reports) and makes a first pass at the form, the senior engineer will review the responses and fill in any gaps in the data. The final step is for the intern to submit the form online. Through this process the intern learns from the senior engineer’s insights and gets a good feel for a sample concrete building analysis and retrofit process. This process is still underway at the time of this paper’s completion and the effectiveness of this approach is not yet evident.



## **5. CALL TO ACTION**

According to a 2006 scenario that estimated losses from a repeat of the 1906 earthquake (Kircher et al., 2006), 50% of the casualties will result from the failure of 5% of the buildings. We have seen repeatedly in past earthquakes that the majority of deaths occur in buildings that collapse. Identifying these “killer” buildings is a key step in developing mitigation priorities, strategies, and policies. Currently available earthquake evaluation procedures for older concrete buildings tend to err on the side of conservatism. This can result in costs to correct deficiencies that in a specific building do not contribute necessarily to a collapse risk. California has hundreds of thousands of nonductile concrete buildings, and to declare them all unsafe would result in an intractable problem that would be difficult to address both economically and politically. Instead we need to realize that while concrete buildings constructed prior to the mid-1970s generally have nonductile detailing, not all of the buildings are collapse hazards. We need to develop tools to identify those with a high probability of collapse, as well as develop targeted design and construction strategies that result in cost effective mitigation solutions. By involving local engineers who are familiar with the design and construction practices in their communities, the Concrete Coalition can assemble the type of information needed to understand the true scope of the problem. Using the power of its member network, the Concrete Coalition can provide leadership in solving the problem by informing decision makers and advocating for practical solutions.

The Concrete Coalition plans to expand its networking and advocacy beyond California to include members from active seismic areas throughout the United States and around the world. We invite all those who are interested in mitigating nonductile concrete building collapse to visit the Concrete Coalition web site ([www.concretecoalition.org](http://www.concretecoalition.org)) and join the effort.

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