# Development of a Database for Ground Motion and Building Performance Data

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**SUMMARY**
Current information technology offers unprecedented opportunities to systematize post-earthquake field data collection, increase the amount of quantitative data collected in the field, and improve data preservation and dissemination. This paper describes the development of a prototype web-based data repository using new information-technology tools to classify, document, and disseminate field data collected after the 2010 Chile Earthquake.

The database has been designed with scalability and longevity in mind so that it can be expanded to collect data from other earthquakes and other disasters. In addition to the ability to ingest vast and varying types of information, the database also provides a simple interface, allowing the user to discover the data as he/she sees fit.

*Keywords: database, post-earthquake*

## 1. INTRODUCTION

Today, the types of media available for the purpose of recording observations after an earthquake (or other type of disasters) go far beyond printed journals and allow combining data in a wide range of formats varying from video to drawings. The 2010 Chile Earthquake was one of the seven largest recorded earthquakes in history and it is crucial to document the observations made after this earthquake. This paper discusses an effort being carried out to develop a pilot study using data collected following the 2010 Chile Earthquake by taking advantage of advances in information technology. This effort is funded by the National Institute of Standards and Technology (NIST). While the pilot study is being developed for one specific earthquake, it is expected that the same database technology and similar database architecture can be used for data collected from other types of disasters, such as wildfire, hurricanes, or tornadoes.

In general, the damage caused by the 2010 Chile Earthquake to building structures was limited, but there were exceptions. In Concepción, for example, a fifteen-story reinforced concrete building collapsed and approximately 7% of buildings with ten or more stories were scheduled for demolition after the earthquake. Understanding the causes of these failures is imperative. The earthquake engineering profession has benefitted much from careful examination of structures affected by strong ground motion. In fact, critical aspects of modern building codes for seismic areas have been conceived to respond to failures observed in the field.

Several databases have been created to date to document information collected following major earthquakes. While some are widely known and still used by the earthquake engineering community, it was found that none act as a depository for collecting information from new earthquakes, as they were designed to fill the need for a specific earthquake. The design of the prototype earthquake database was based on experience using other databases and on attempts on improving the usability of these databases.

## 2. SCOPE AND PURPOSE OF DATABASE

This database is designed to allow its users to: (1) explore photographic evidence of damage caused by the 2010 Chile Earthquake; (2) explore geotechnical and ground motion information; (3) associate photographs and performance data with building information (ranging from location and number of stories to, where available, seismic vulnerability indices, such as the ratio of wall area to total floor area); (4) associate damage information and information on recorded ground motion; (5) correlate level of damage and structural properties; (6) explore and export data in a variety of formats including text, kmz and kml (for use with the Google Earth software), and shp (for use with ESRI software); (7) download full-resolution photographs (one at a time or in groups); (8) search for entries associated with tags from a list of key terms; (9) download drawings (where available), numerical models, and reports for selected building structures; (10) compare damage caused by the 2010 Chile Earthquake and the 1985 Valparaiso Earthquake; (11) sort and select relevant information using multiple filters; and (12) if available, associate drawings, crack maps, and photographs.

In Chile, the vast majority of engineered buildings have reinforced concrete structures. Thus, the database concentrates on such structures, which allows for a reduction in the number of arguments needed to describe each structure. The data collected from structural drawings, crack maps, photographs, material properties, and soil reports were organized under 126 "fields" that describe the ground motion, the structure, and the response of the structure to the ground motion. These fields range from peak ground velocity to ratio of total cross-sectional area of walls to typical floor area. The fields selected are unlikely to be a complete list of relevant parameters. Rather, they are a compromise between the need for detailed information and the resources available today for data collection.

## 3. DATABASE STRUCTURE

The chosen parameters range from peak ground velocity recorded at the closest strong motion station to ratio of total cross-sectional area of columns to typical floor area. The data have been organized in five tables. In each table, information (numerical values or paths to binary files) is stored in text (ASCII) format. This format was chosen to ensure longevity: ASCII format has proven to be one of the most commonly used and lasting formats for character encoding. Entries are separated by commas to allow the use of spaces within each entry. A "parser" extracts data from the tables and stores it in the database (which is managed using an open-source system called MySQL (http://www.mysql.com/)). The data are organized as follows:

- *Building Data Table:* This table contains information regarding the geometric and structural properties of the buildings, such as building location, general building geometry, structural properties, and soil properties.

- *Earthquake Damage Data Table:* This table contains information on the damage caused in each building by a particular earthquake. This information includes: photos, crack maps (where available), a damage ranking (severe or not, based on guidelines established within the database), and information on the usability of the structure after the earthquake.

- *Station Data Table:* This table contains information on the measured ground motion and properties of sites where measurements were obtained. This table stores the records obtained at strong-motion stations operating in Chile in 1985 and 2010. Key information is given for each station including type of soil, if known, peak ground acceleration (PGA), peak ground velocity (PGV), network, coordinates, location within housing structure, if applicable, and orientation.

- *Data Sources Table:* This table contains information on references and authors of photographs and reports. This table lists the sources (references and individuals) that provided the information in the database.

- *Earthquake Information Table:* This table describes the location and time of each of the earthquakes considered (Valparaiso, Chile, 1985 and Maule, Chile, 2010) and, for larger databases, should be expanded to include detailed information about magnitude and the seismic source.

## 4. IMPROVEMENTS OFFERED BY THE DATABASE

### 4.1 Access to Information

The database has two main features for accessing the information in the data repository: Data Views for exploring building, earthquake, and ground motion data, and a Photo Gallery Viewer for searching the photograph collection.

The database can be searched and sorted using Data Views. Columns (fields) can be filtered for text or numbers, and any data view can be downloaded as a spreadsheet. Links in data views allow the user to download files (drawings, analysis files, general files, and ground motion records) and access the Photo Gallery Viewer for a specific building.

Data views include maps that show locations of buildings, recording stations, and cameras. Building and recording station markers display additional information when selected. Five data views are provided in the database. Four of these have been specifically developed for the following uses:

- Essential data view includes only attributes deemed most important by the project development team (Figure 1)

- Full data view includes all fields in the database

- Stations information data view includes only information pertaining to ground motion recording stations

- Earthquake damage data view includes building-specific map views of earthquake data

A fifth data view, Flex View, can be used to create customized views by the user.

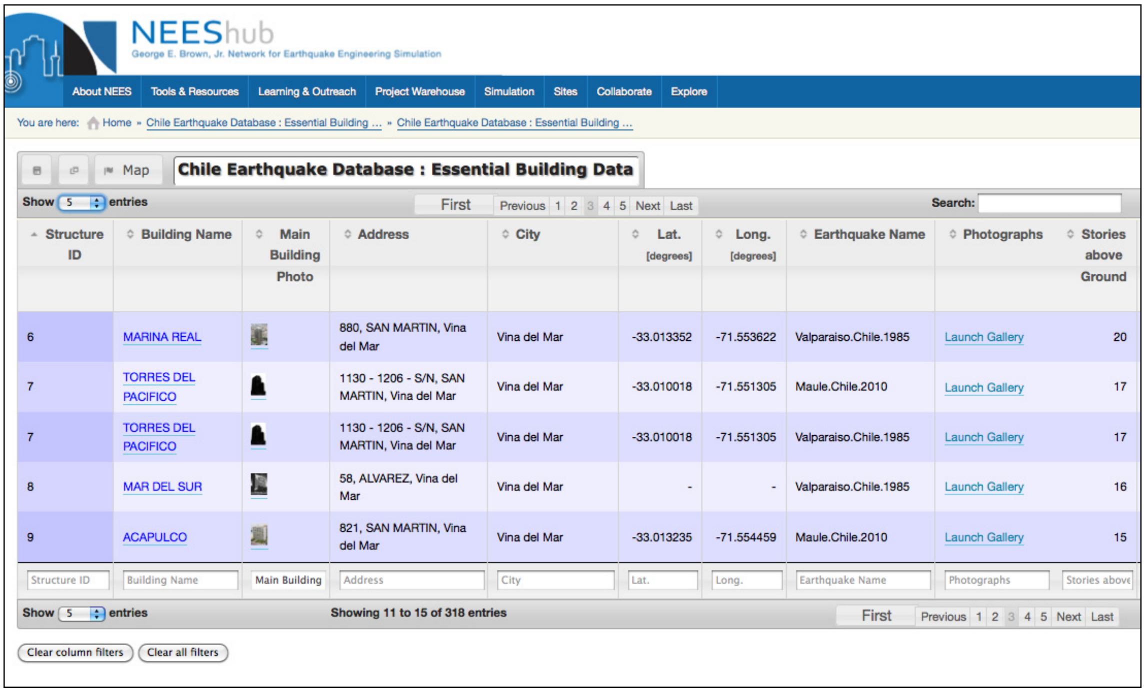


**Figure 1.** Sample page of Essential Building Data View.

The Photo Gallery Viewer provides the capability to search through tens of thousands of photographs of impacted buildings. The photos in the database are annotated with descriptive keywords. As shown in Figure 2, the map interface on which available data (photos) can be linked to their geographical location provides ease of navigation. It also provides a way for identifying geographical areas that are in need of more data collection.

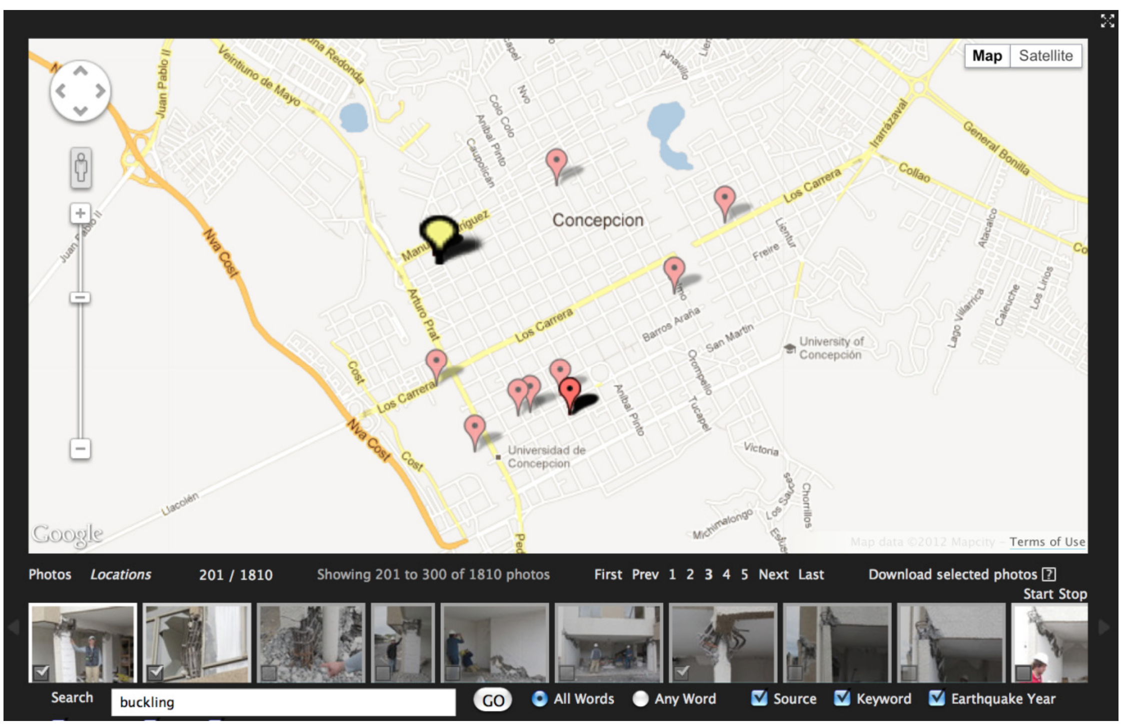


**Figure 2.** Sample page of Photo Gallery Viewer utilizing the map interface.

**4.2 Crediting Contributors and Tagging with Metadata**

A key to the success of a central data repository is to provide adequate credit to the contributors of information. This is achieved by embedding the name of the author in file names and file headers, including fields in the database to specify sources, and providing readily available and complete citation information.

The bulk of the data consists of photographs (more than 20,000). To make this information accessible, each photograph was described with keywords (also called tags) and these tags were inserted into the headers of the photographic files. The tags are displayed in the system by the Photo Gallery Viewer that also allows the user to locate the points where photographs were taken using interactive maps (Figure 2).

The tags used in this process are listed in Table 1. The list of chosen tags is not exhaustive, however, tagging of photos has not been automated and is, therefore, costly and time consuming.

**Table 1**. Tags (Keywords)

| Keyword Number | Keyword (or Tag) |
|---|---|
| 1 | Building |
| 2 | Building elevation |
| 3 | Surroundings |
| 4 | Nonstructural |
| 5 | Reinforced concrete |
| 6 | Precast concrete |
| 7 | Steel |
| 8 | Wood |
| 9 | Masonry |
| 10 | Coupling beam |
| 11 | Truss |
| 12 | Column |
| 13 | Wall |
| 14 | Slab |
| 15 | Beam |
| 16 | Stairs |
| 17 | Boundary zone |
| 18 | Tie |
| 19 | Bar splice |
| 20 | Discontinuous bar |
| 21 | Wall buckling |
| 22 | Bar buckling |
| 23 | Bar fracture |
| 24 | Drawings |
| 25 | Captive column |
| 26 | Reentrant corner |

In addition, and to ensure correct use of the information in the database, the headers of all photographic files were also modified to include name of photographer, building name, building coordinates, address, and earthquake name/date. A customized "processor" was written for this purpose. The processor uses the location of the file in the directory structure described to determine information about the building (name, ID, address, and coordinates) and the photographer. The specifics about the photographer are stored in the sources spreadsheet. Any standard file browser can be used to access photo headers after download.

### 4.3 Usability Studies

During the development phase, usability studies were undertaken. These were conducted by providing selected users with specific assignments to complete, such as reporting the percentage of buildings that were severely damaged following the 2010 Chile Earthquake or downloading a specific set of ground motion station recordings. The development of the database was informed by these studies and necessary improvements were made.

### 4.4 Scalability and Expandability

The pilot database was developed with expandability and scalability in mind. While the current database is limited to information from the 2010 Chile Earthquake, the underlying database technology can accommodate multiple earthquakes, additional data fields, and additional data. It is also possible to use this pilot database as a guide for developing data repositories for other natural or man-made hazards, such as wildfires, hurricanes, and tornadoes. It is recognized that while each hazard will its own specific data needs, the database structure can be modified and used for each of these.

## 5. CONCLUSIONS

As population centers expand and the exposure of the built environment increases, new earthquakes are bound to keep challenging the state of the art in seismic design. To update design methods in response to those challenges, the profession needs to keep documenting field observations. A central data repository is necessary for this purpose. With this need in mind, a pilot database, focusing on the findings from the 2010 Chile Earthquake, has been developed. It is necessary to support the use of this database as a tool in the earthquake engineering community and to continue thinking about how to expand this database to cover multiple earthquakes and multiple hazards.


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