# Development of a Regional Performance-Based Seismic Toolbox for Non-Ductile Reinforced Concrete Buildings in Los Angeles


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## 1. Introduction

- Develop a rapid, open-source, and scalable seismic assessment toolbox for non-ductile reinforced concrete buildings (NDRCBs).
- The toolbox will contain a scalable & editable inventory of building models and analysis functions.
- Build a matrix of models for each building to consider epistemic uncertainties in model parameters and provide fragility functions for decision makers.
- Automate the processes and produce results for general users (e.g. insurance companies, city officials, first responders, etc.)

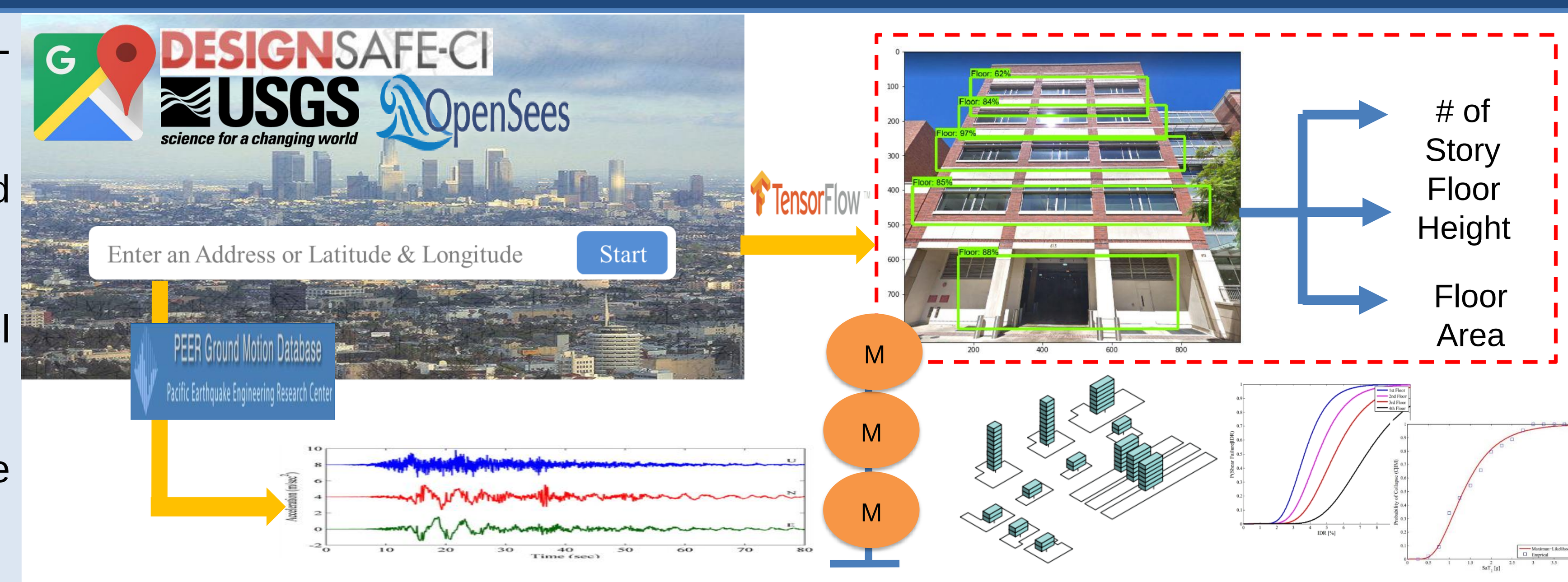


Figure 1. Overview of the proposed toolbox.

## 2. Data Harvest for Target Buildings

- Anagnos et al (2008) have investigated 1,600 potentially NDRCBs in Los Angeles, which has been reported and published as a database by Los Angeles Times in 2016.
- 1,229 NDRCBs' information have been validated through public databases such as LA GIS data portal, OpenStreetMAP, and Los Angeles Department of Building and safety.

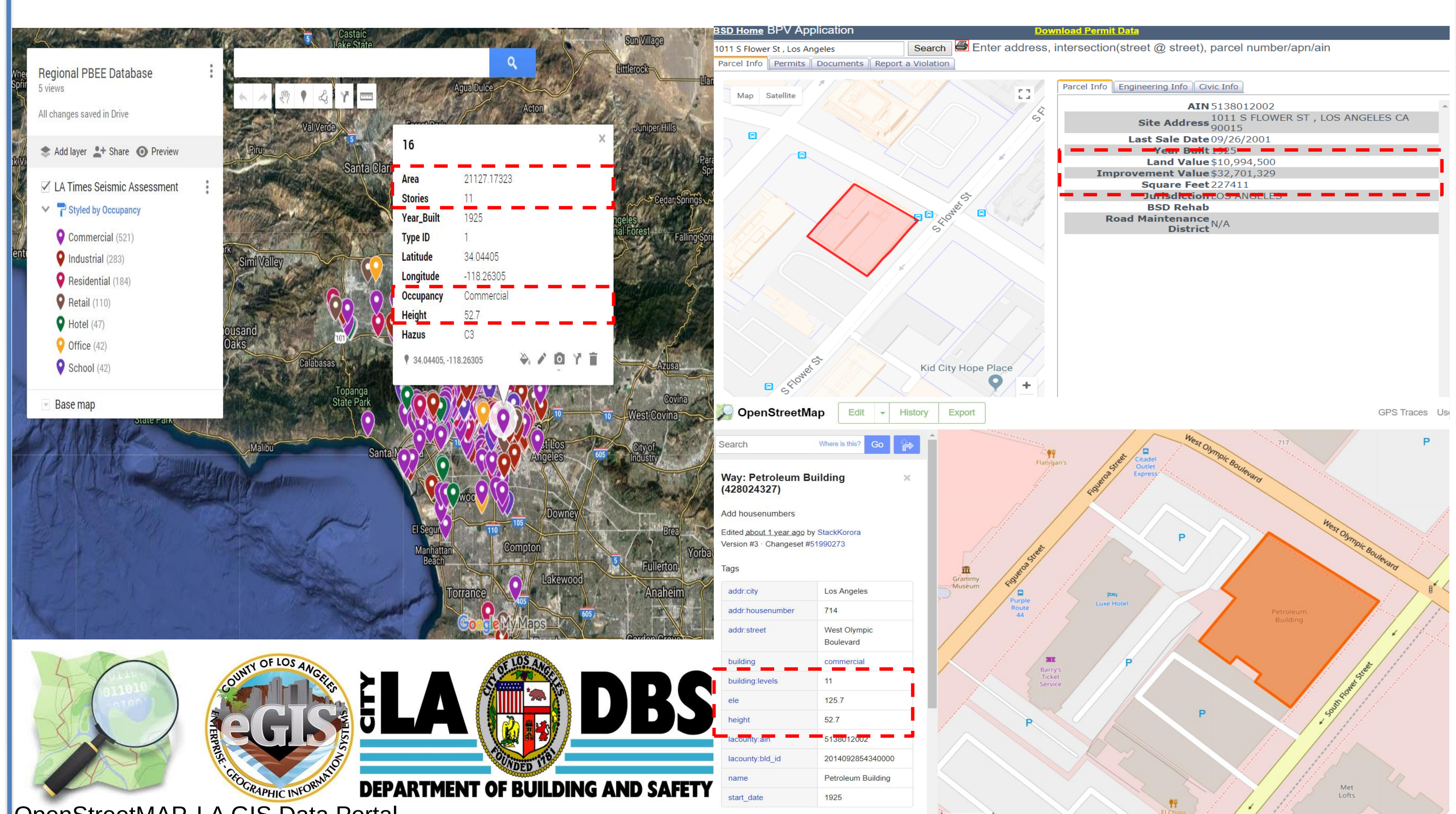


Figure 2. Data harvest for the proposed toolbox.

## 3. Image to Model (Deep Learning)

- Transfer Learning is the state-of-the-art Deep Learning technique that can be utilized to train an image classification and object detection model within a short time.
- One can use different pre-trained model (e.g., VGG16, VGG19, and Inception) to train their predictors for different categories. Since the basic features (e.g., edge, corner) have been learned in the lower layers of neural network, the total training time can be reduced significantly.
- In this research, the training set, the validation set and the test set are summarized in Table 1 and Table 2. More images will be implemented into the training process to improve the performance.

Table1. Dataset for image classification

| | Reinforced Concrete | Steel | Wood |
|---|---|---|---|
| Training Set | 86 | 104 | 36 |
| Validating Set | 11 | 13 | 4 |
| Testing Set | 11 | 13 | 4 |

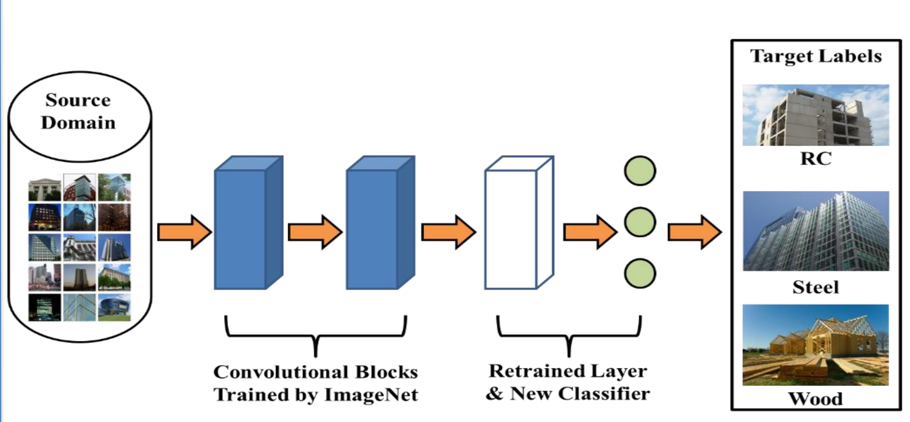


Figure 3. Architecture of transfer learning

Table2. Dataset for Object detection

| | Floor Detection |
|---|---|
| Training Set | 544 |
| Validating Set | 68 |
| Testing Set | 68 |

Figure 4. Image classification example

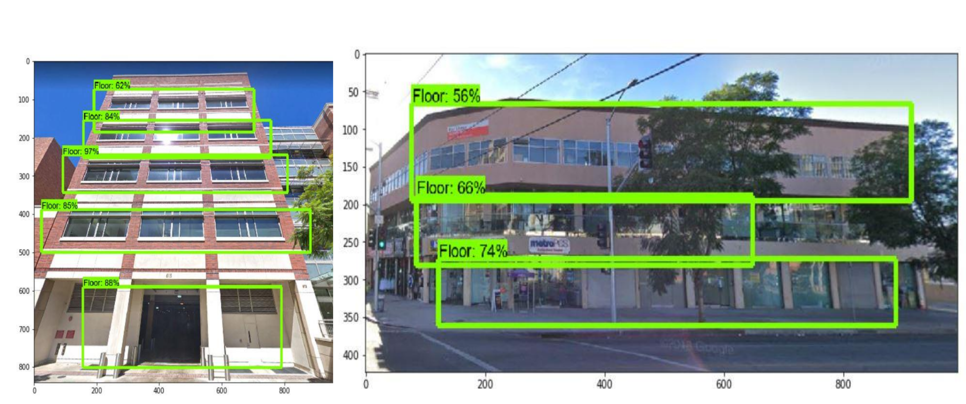

Figure 5. Object detection example

## 4. Regional PBEE Workflow

- A regional PBEE workflow developed by NHERI SimCenter was implemented in the proposed toolbox to perform Incremental Dynamic Analysis (IDA). In IDA, 22 sets of ground motion are required to evaluate the uncertainties of seismic hazard. As a result, a ground motion selection module was introduced into the toolbox.
- Simplified Multi-Degree-of-Freedom (MDOF) nonlinear shear building model provided by the workflow was utilized for the nonlinear time history analysis. A hysteretic nonlinear material model was defined for each floor with a story-force relationship defined by using HAZUS data.

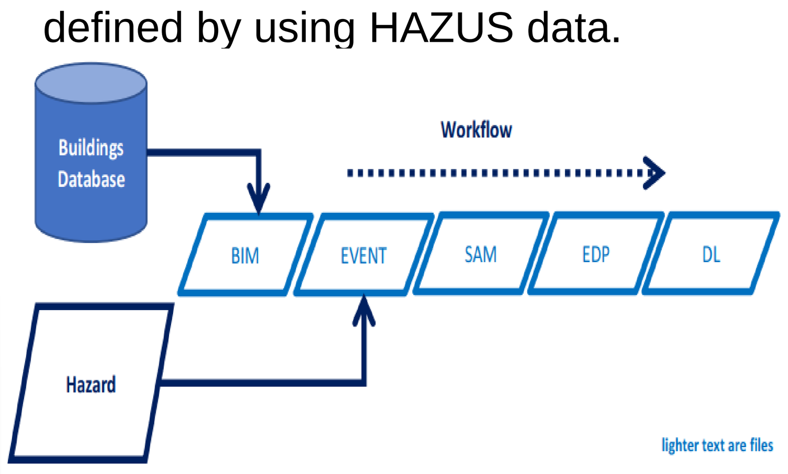


Figure 6. Flow chart for the workflow

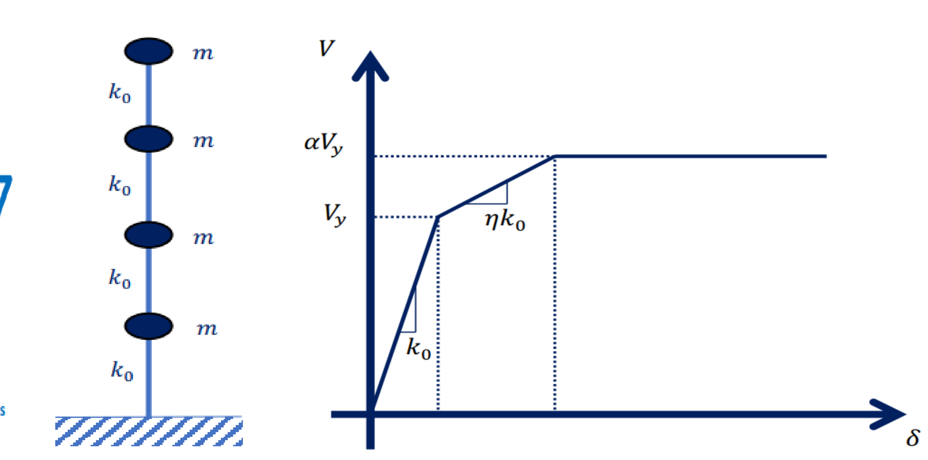


Figure 7. MDOF model and nonlinear material

## 5. Application of NDRCBs' Metadata

- Seismic assessment of 1,229 NDRCBs have been done through IDA. Due to the simplified MODF model, each nonlinear time history analysis performed by OpenSees can be finished in few seconds.
- The output of the toolbox including Engineering Demand Parameters (e.g., peak floor displacement and peak floor acceleration), and collapse fragility.
- The metadata can be utilized to evaluate the collapse probability of buildings subjected to a scenario, which is shown in Figure 9 (M7.2 reverse-slip earthquake).

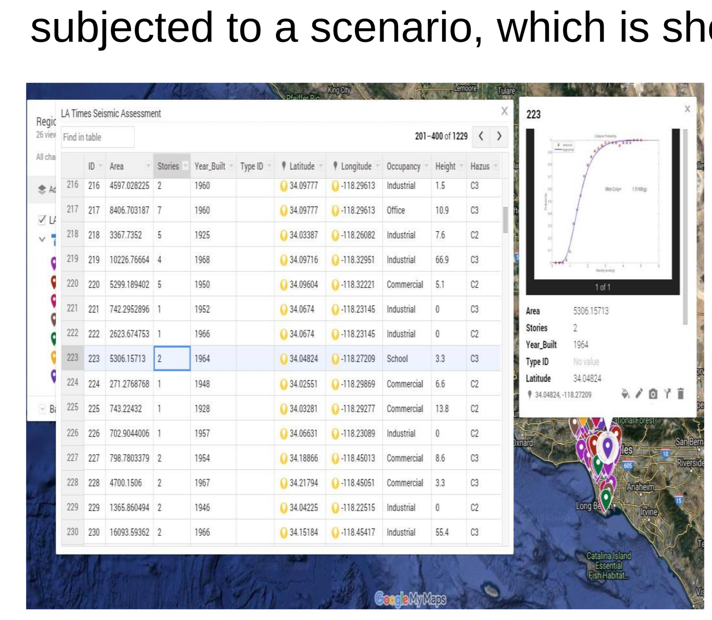

Figure 8. Demonstration of the metadata

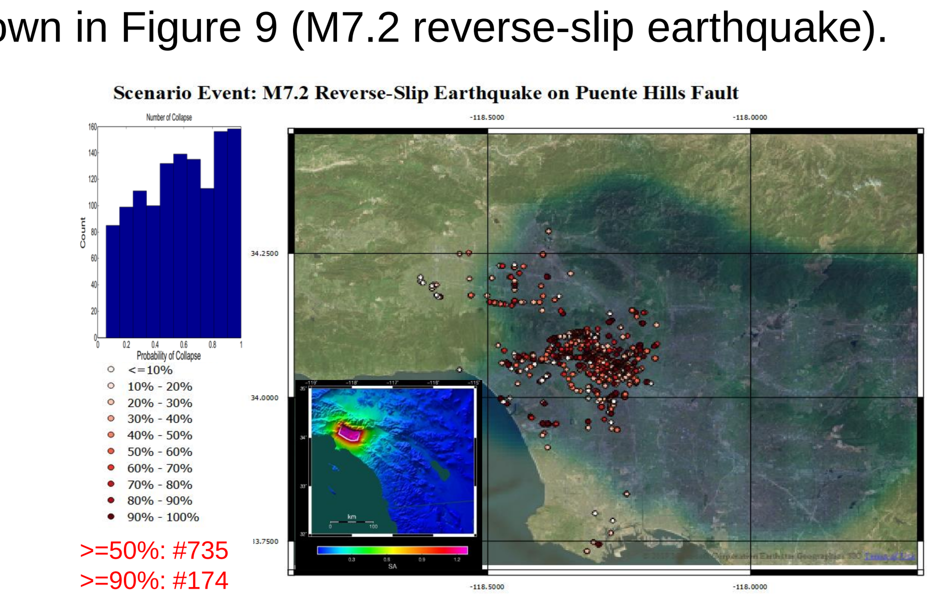


Figure 9. Collapse Probability of a Scenario

## 6. Summary

- Multiple databases have been utilized to validate and update the existing database for regional seismic assessment.
- Image classification and object detection techniques have been implemented for generating simplified structural analysis model.
- A module for selecting ground motions was implemented based on site-specific parameters.
- Through the combination of NHERI SimCenter workflow and IDA, several fragility functions can be generated efficiently to evaluate the seismic performance of NDRCBs.
- 1 million nonlinear time history analysis have been performed through the proposed toolbox and the corresponding metadata can be utilized to calculate the collapse probability of buildings subject to a scenario earthquake.


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