# 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 nonductile 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.)

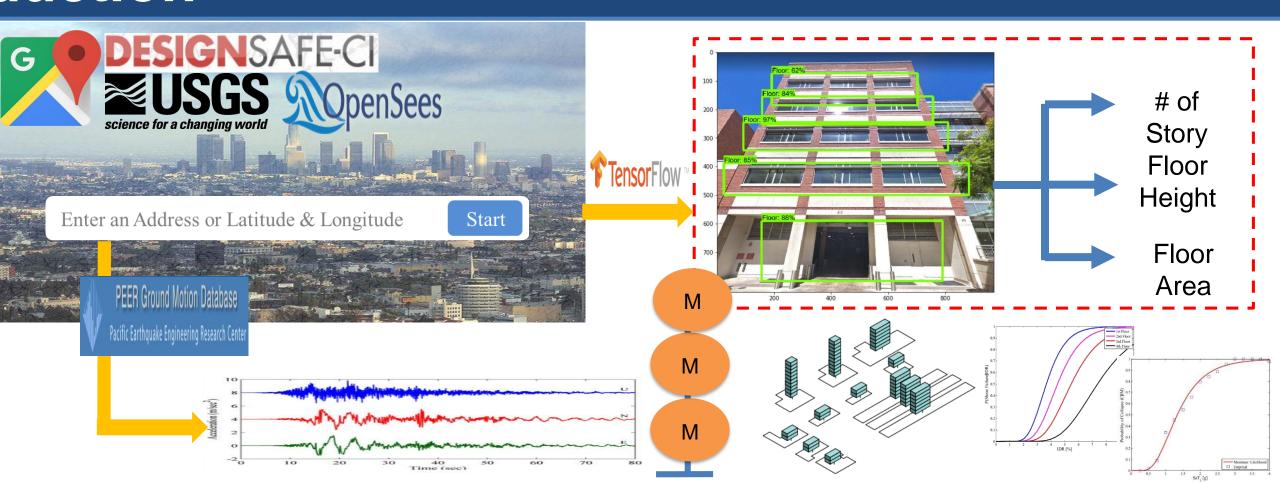


Figure 1. Overview of the proposed toolbox.

### 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.

### 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

 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.

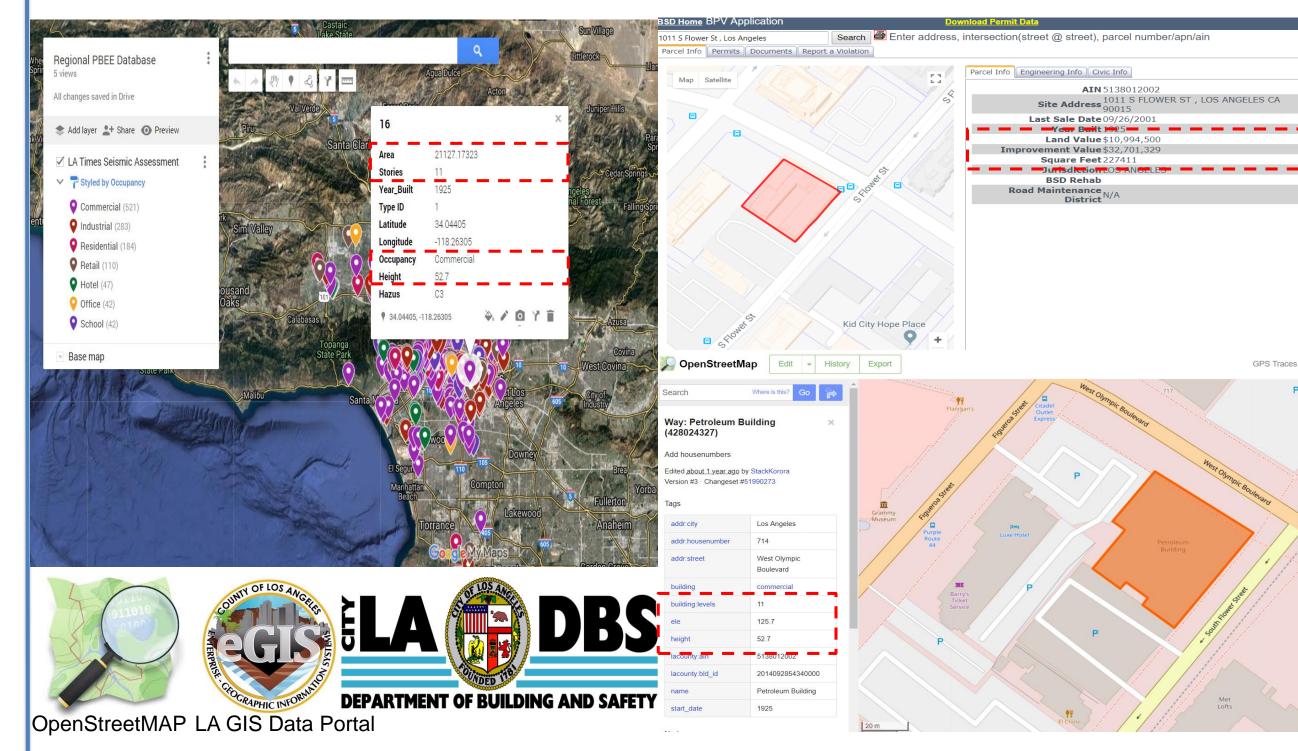


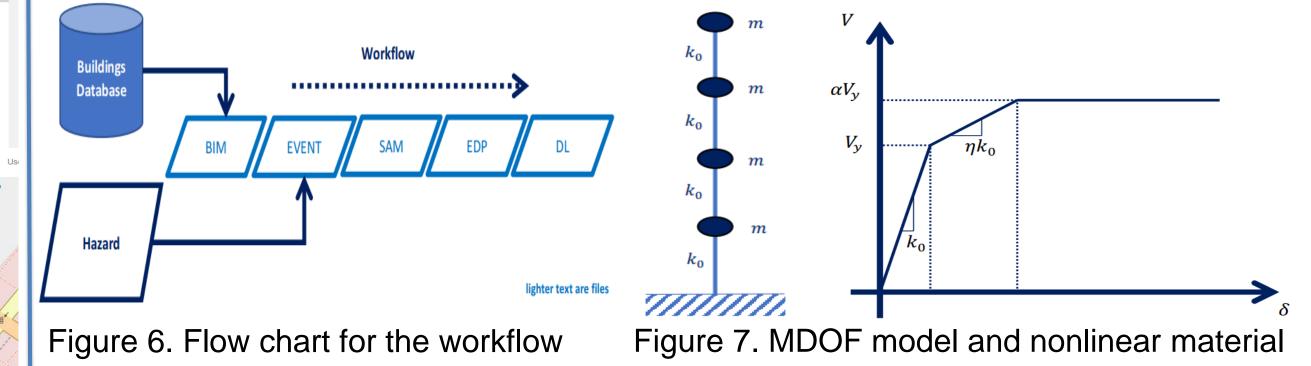
Figure 2. Data harvest for the proposed toolbox.

#### 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

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.



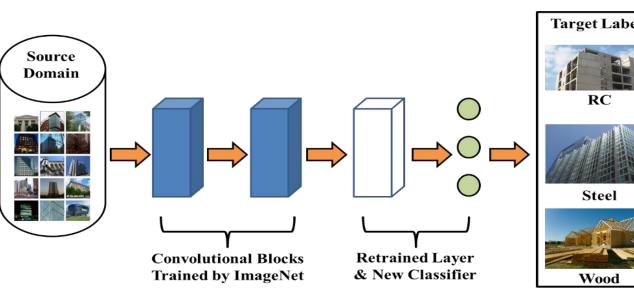
### **5. Application of NDRCBs' Metadata**

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

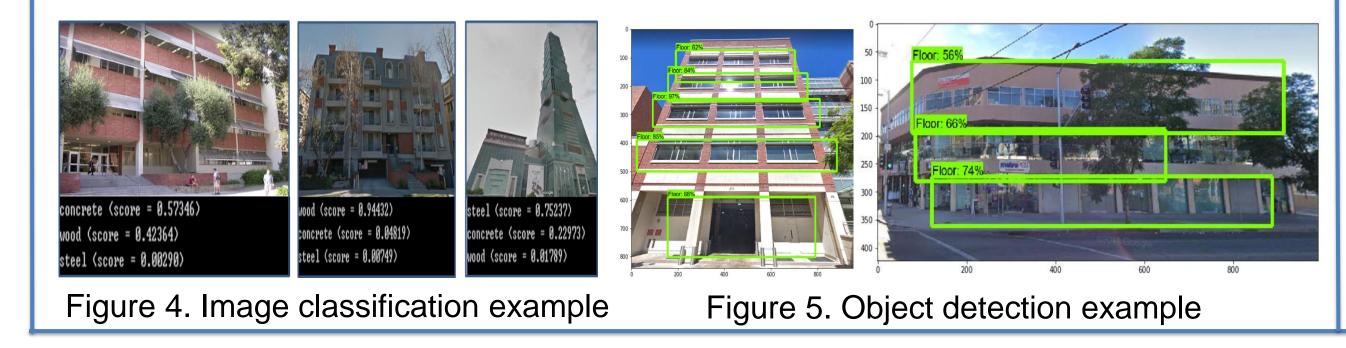
their predictors for different categories. Since the basic features (e.g., edge, corner) have been learned in the lower layers of neural network, the total training time can be reduced significantly.

 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.



		Reinforce	d	Steel	Wood				
		Concrete	<b>;</b>						
oels	Training Set	86		104	36				
	Validating Set	11		13	4				
	Testing Set	11		13	4				
	Table2. Dataset for Object detection								
			Floor Detection						
	Trainin	g Set	544						
	Validati	ng Set	68						
	Testing	g Set	68						

Figure 3. Architecture of transfer learning



subjected to a scenario, which is shown in Figure 9 (M7.2 reverse-slip earthquake).

26 view	Find in table 201–400 of 1229 < >											
All cha		ID -	Area 👻	Stories *	Year_Built •	Type ID 👻	🕴 Latitude 🔄	V Longitude	Occupancy *	Height •	Hazus - la	
🌲 Ad	216	216	4597.028225	2	1960		0 34.09777	0-118.29613	Industrial	1.5	C3 MeCoby 15H	10
₹ L4	217	217	8406.703187	7	1960		0 34.09777	0-118.29613	Office	10.9	C3 C3	
v -	218	218	3367.7352	5	1925		0 34.03387	0-118.26082	Industrial	7.6	C2	
ç	219	219	10226.76664	4	1968		0 34.09716	0 -118.32951	Industrial	66.9	C3	
Q	220	220	5299.189402	5	1950		0 34.09604	0-118.32221	Commercial	5.1	C2 1 of 1	
9	221	221	742.2952896	1	1952		0 34.0674	0-118.23145	Industrial	0	C3 Area 5306.15713	
G	222	222	2623.674753	1	1966		0 34.0674	0-118.23145	Industrial	0	C2 Stories 2	
ç	223	223	5306.15713	2	1964		0 34.04824	0-118.27209	School	3.3	C3 Year_Built 1964 C3 Type ID No value	
Q	224	224	271.2768768	1	1948		0 34.02551	0-118.29869	Commercial	6.6	C2 Latitude 34.04824	10 Y
B	225	225	743.22432	1	1928		0 34.03281	0-118.29277	Commercial	13.8	C2	
	226	226	702.9044006	1	1957		0 34.06631	0 -118.23089	Industrial	0	C2	rest
	227	227	798.7803379	2	1954		0 34.18866	0-118.45013	Commercial	8.6		10-
-	228	228	4700.1506	2	1967		0 34.21794	0-118.45051	Commercial	3.3	C3	neim
E	229	229	1365.860494	2	1946		0 34.04225	0 -118.22515	Industrial	0	C2 Long Ba	rvine,
	230	230	16093.59362	2	1966		0 34.15184	0-118.45417	Industrial	55.4	C3	

Figure 8. Demonstration of the metadata

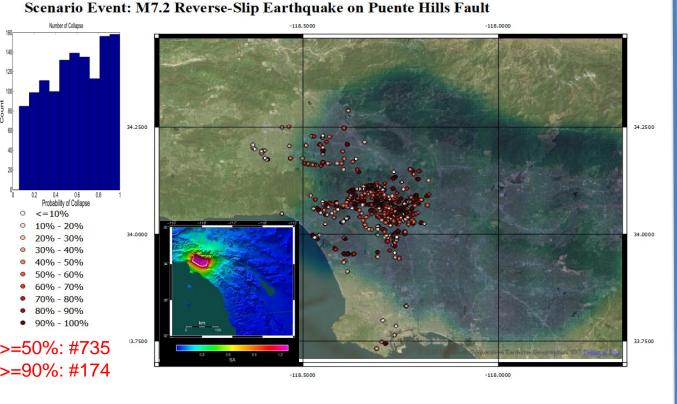


Figure 9. Collapse Probability of a Scenario

## 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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