City of Berkeley Concrete Building Inventory Validation Project

A report prepared by the Earthquake Engineering Research Institute

January 2018

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Final Report

1. Introduction

The Earthquake Engineering Research Institute was approached by the City of Berkeley to (1) review, refine and validate a list of older concrete buildings in Berkeley, and (2) provide recommendations to the City on possible ways to allocate mitigation funding to buildings in most need of further assessment and retrofit.

1.1 The Project Team

The project team was made up of a volunteer Expert Engineer Advisory Team (EEAT), EERI staff, and City of Berkeley staff. The Expert Engineer Advisory Team included senior engineers from Bay Area structural engineering firms. The EEAT was chaired by Marko Schotanus, Rutherford + Chekene, and included Marguerite Bello, Bello & Associates; Russell Berkowitz, Forell/Elsesser; David Bonowitz, S.E.; Saeed Fathali, Structural Technologies; Abe Lynn, Degenkolb; Joe Maffei, Maffei Structural Engineering; David Mar, Mar Structural Design; David McCormick, SGH; Erik McGregor, Holmes Structures; Karl Telleen, Maffei Structural Engineering; Clayton Riggins, Tipping Structural; and Bill Tremayne, Holmes Structures. Maggie Ortiz-Millan served as the EERI project manager with project support from EERI Post-Graduate Intern Marisa Araujo. EERI Executive Director, Heidi Tremayne, provided oversight for the project. Jonathan Cherry, Jenny McNulty, and Galadriel Burr were the main contacts from the City of Berkeley.

1.2 Preliminary List of Buildings

Since 2007, researchers and volunteers from the EERI Concrete Coalition have been compiling data on older (pre-1980) concrete buildings in several large California cities, including Los Angeles and San Francisco, to identify buildings that pose the most significant collapse hazards. From 2008-2011, EERI estimated the number of concrete buildings built prior to 1980 in the state of California. As a part of this effort, EERI volunteers developed a preliminary estimate of 275 older concrete buildings within the city limits of Berkeley, using Sanborn Maps, Tax Assessor records via a Map Quest database, knowledge from the City Building Official, and drive-by street surveys (EERI, 2011, Comartin et. al., 2011). Since 2015, the City of Berkeley refined this data through a more thorough review of Sanborn maps and parcel information, yielding a preliminary list of 222 buildings that included concrete buildings built prior to 1980 and added rigid wall - flexible diaphragm buildings built prior to 1997. This list was provided as an

Excel file to EERI in August 2017. The City of Berkeley also provided a detailed guide to the information sources for all data fields in the Excel sheet.

EERI intern Marisa Araujo reviewed the list and refined it by:

- Separating multiple buildings grouped into a single record into individual records (adding 61 buildings to the list);
- Identifying which buildings were likely concrete on property lots that contained multiple building structures; and
- Updating GPS coordinates to mark the center of each building.

The City of Berkeley also continued to update the list and added 60 buildings found through additional reviews of Berkeley's Sanborn maps. After refinement by EERI and additions from the City of Berkeley, the list, as of the survey date, included a total of 344 individual buildings.

1.3 Survey Methodology and Assessment Procedure

To validate the data in the refined building list, EERI organized a sidewalk survey in which volunteer engineers could make a visual assessment of each building on the list.

1.3.1 Survey Methodology

The EEAT guided the development of the survey form which was based on FEMA 154: Rapid Visual Screening of Buildings for Potential Seismic Hazards. The committee selected key questions from the FEMA 154 form and added questions tailored to the objective of this project - providing recommendations to the City of Berkeley. A complete version of the survey form is included in Appendix 1.

1.3.2 Survey Data Collection Tool

EERI staff chose the Fulcrum Data Collection app for the sidewalk survey. This online form-building app provided an intuitive platform for collecting data on a smartphone or tablet. Collecting the data digitally improved consistency, eliminated the need for data transcription, and allowed for the pre-population of known data and photos into the survey form for each building.

1.3.3 Survey Day

The sidewalk survey was held on Saturday, November 18, 2017 with 34 volunteer engineers and engineering students. Volunteers were assembled into teams of 3-4 people. Each team included one experienced engineer, one early-career engineer, and one or two graduate students. Each group was assigned a morning and afternoon walking route. Morning routes included approximately 15-16 buildings per group in West Berkeley. Afternoon routes included 8-12 buildings per group in Downtown, South, and North Berkeley.

The survey day began with a brief introduction about the project by Jenny McNulty from the City of Berkeley. EEAT Chair Marko Schotanus covered safety information, survey do's and don'ts, and reviewed the intent of several survey questions. Finally, Marisa Araujo conducted a short Fulcrum training to ensure that all engineers could successfully use the app. Once engineers completed the training, they set out on their walking routes to complete their assessments.

The survey day ended with a debrief discussion led by EEAT Chair Marko Schotanus. During the debrief discussion, volunteers provided key observations and also described any notable buildings.

1.3.4 Buildings Surveyed

Given the limited number of volunteers, not all 344 buildings included in the list were assigned for the survey. 283 buildings (222 from the original list plus 61 additional buildings on those property lots) were preliminarily assigned for the survey. In consultation with the City of Berkeley, 18 buildings from the 60 added by the City were added to the survey and 16 non-representative buildings from the preliminary assignment list of 283 were removed. This resulted in 285 buildings to be assigned for the survey. (Due to an error in the assignment process, only 283 buildings were actually assigned for the survey.)

During the survey day, 32 of the assigned buildings were not surveyed and nine additional buildings not on the list of 344 buildings were surveyed. While not all 344 buildings were surveyed, the project team believes that enough buildings were surveyed to provide meaningful recommendations.

1.3.5 Survey Day Follow-Up Call

A follow-up discussion was held by conference call on December 6, 2017. This provided the EEAT with another opportunity to discuss their observations, and more importantly, to provide their input on the development of the recommendations for the City of Berkeley.

1.3.6 Report Development

Members of the EEAT also reviewed the final report before its submission to the City of Berkeley and provided many useful comments and suggestions that greatly improved this report.

2. Survey Data

Data presented is not meant to be a conclusive assessment of individual buildings, but rather a screening tool to help identify potential vulnerabilities within the building stock. Survey assessment forms were completed by senior engineers based primarily on exterior views of the buildings. For each building, the teams indicated the level of confidence they had in their survey responses.

2.1 Data Compilation

The project data being delivered to the City of Berkeley is an aggregation of data originally provided by the City of Berkeley and the data from the November 18 Survey Day. The data package being provided to the City along with this report includes:

- Data in Excel Spreadsheet (including explanation of data fields)
- PDFs of building reports (Auto-generated PDF reports for each building that include all survey data and photos)
- Photos
  - Survey Day: All photos of buildings taken by volunteers during the survey day are included in a zip file.
  - Sanborn Maps: An undergraduate student volunteer from UC Berkeley, Mara Sio, took photos of physical copies of Sanborn Maps for each building on the list. These photos are also included as a reference in the zip file of photos.

2.2 Survey Results

This section presents survey data for important building characteristics including: building type, occupancy type, size, age, and structural characteristics.

2.2.1 Primary Building Type

Engineers selected the primary building type for each building from the FEMA 154 list. If necessary, engineers could also indicate a secondary building type along with notes on why a second building type was selected. The breakdown of primary building type, as identified by the survey engineers, for the surveyed buildings is shown in Table 1. Building types relevant to this project are highlighted.

Table 1. Building Types of Surveyed Buildings.

Primary Building Type	Total
C2 (SW RD) - Concrete Shear Wall Building with unspecified diaphragm	63
PC1 (TU) - Precast Concrete Tilt-up Building	42
RM1 (FD) - Reinforced Masonry Building with Flexible Diaphragm	30
C2 (SW FD) - Concrete Shear Wall Building with Flexible Diaphragm	56
C1 (MRF) - Concrete Moment Frame Building	13
URM - Unreinforced Masonry Building (see section 2.2.1.3)	11
C3 (URM INF) - Concrete Frame Building with URM Infill	5
W2 - Wood Building	5
S1(MRF) - Steel Moment Frame Building	5
W1 - Wood Building	4
RM2 (RD) - Reinforced Masonry Building with Rigid Diaphragm	3
S4 (RC SW) - Steel Building with Concrete Shear Walls	1
W1A - Wood Building	1
Unidentified	21
Grand Total	260

Of the 260 buildings surveyed, 21 have an “Unidentified” building type - most often because there were two records for a single building - and 30 were assigned primary building types that are not relevant to this project. The City of Berkeley will review these 30 buildings in more detail to determine if they can be removed from the building list. Figure 1 shows the building types of the remaining 209 buildings surveyed that are relevant to this project. Further discussions of survey data in this report will refer to this subset of 209 buildings as the relevant surveyed buildings. While this report focuses on the 209 buildings with building types C1, C2, C3, PC1, and RM1, this focus does not imply anything about the vulnerability of the buildings with building types not discussed in this report (URM, W1, W1A, W2, S1, S4, RM2).

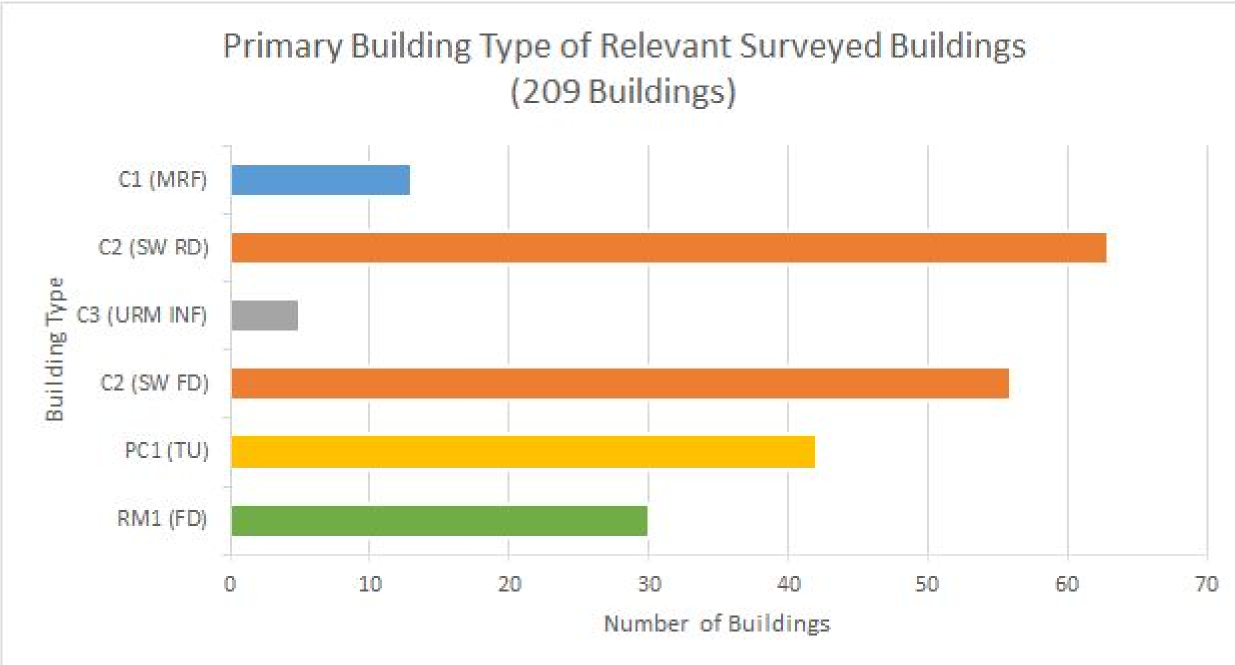


Figure 1.

2.2.1.1 C1, C2 (SW RD) , and C3 Buildings

In this report, C2 buildings with a flexible diaphragm are classified as C2 (SW FD) and are included in the RWFD building category described in the next section. C2 buildings with a rigid or unspecified diaphragm are classified as C2 (SW RD). Of the 260 relevant surveyed buildings, 81 buildings were identified as concrete building types C1, C2 (SW RD), and C3. Figure 1 also shows that among the concrete buildings, the frame structures (C1 and C3) are far less common than the wall structures C2.

2.2.1.2 Rigid Wall-Flexible Diaphragm (RWFD) Buildings

RWFD buildings are of special interest because many are eligible for a low-cost prescriptive retrofit approach. However, since FEMA 154 does not include RWFD as a specific building type, the survey form did not include options for this specific category. Most of the surveyed PC1 buildings, and many of the RM1 and C2 buildings (especially the one-story buildings with warehouse or industrial uses, and those that pre-date the development of precast tilt-up construction) are expected to be RWFD buildings.

This report categorizes PC1 (TU), RM1 (FD), and C2 (SW FD) buildings as RWFD as these building types are most commonly RWFD buildings. With this categorization, there are 128 buildings classified as RWFD. Due to this categorization, there are three RM1 (FD) buildings in the RWFD category taller than two stories. These taller RM1 (FD) buildings may not be similar to the other RWFD buildings surveyed.

2.2.1.3 Unreinforced Masonry Buildings (URMs)

11 of the 260 buildings surveyed appeared to be potential URM buildings based on the exterior views by the survey engineers. The City of Berkeley has reviewed these potential URM buildings and determined that only three of the 11 buildings require further analysis to determine if they are URM buildings. The remaining buildings have been confirmed to be either retrofitted or reinforced masonry or concrete buildings.

2.2.1.4 Wood Frame Buildings on Concrete Podium or Reinforced Masonry Perimeter Walls

In addition, there are some other residential buildings not included in the survey whose ground floor levels may be good candidates for grant funding. These buildings were surveyed previously by the City as part of the development of Berkeley's soft story ordinance, but are not subject to the mandatory retrofit requirements of the soft story ordinance because the ground floor level is not wood-framed. These buildings were typically built in the 1950s or 1960s and include 3-4 wood-framed stories over a parking level consisting of a concrete podium or reinforced masonry perimeter walls. These buildings contain an average of 30 units and have an average ground floor footprint of 8,500 square feet.

2.2.2 Occupancy Type

Survey engineers selected the occupancy type for each building from a list of FEMA 154 occupancy classes. Engineers were allowed to select multiple occupancy types for each building. Figure 2 shows the breakdown of occupancy for each building type. For the purposes of this report, buildings with multiple occupancy types listed were given a primary occupancy type that was assigned based on the following hierarchy: Assembly, School, Residential, Commercial, Office, Utility, Industrial, Warehouse. For example, if a building was marked as both Assembly and Commercial, the primary occupancy type is Assembly. These occupancy types do not necessarily match the occupancy groups defined in the Berkeley and California building codes.

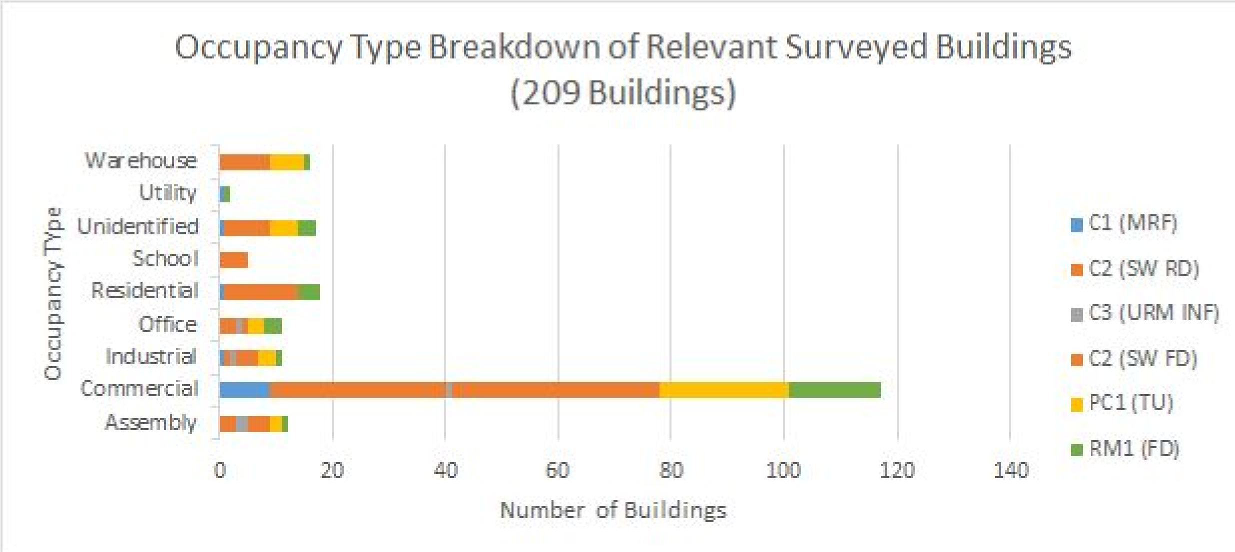


Figure 2.

Figure 2 shows that C1 buildings are mainly commercial with only three C1 buildings in other occupancy types. The majority of C2 buildings are also commercial, but there are a significant number of C2 buildings in all other occupancy types. Tilt-up buildings (PC1) are mainly commercial, warehouse, and industrial buildings.

2.2.3 Building Size

2.2.3.1 Building Height (Number of Stories)

Of the 209 relevant surveyed buildings, 122 (or 58%) were 1-story buildings. Figure 3 shows the height distribution of the relevant surveyed buildings broken down by building type.

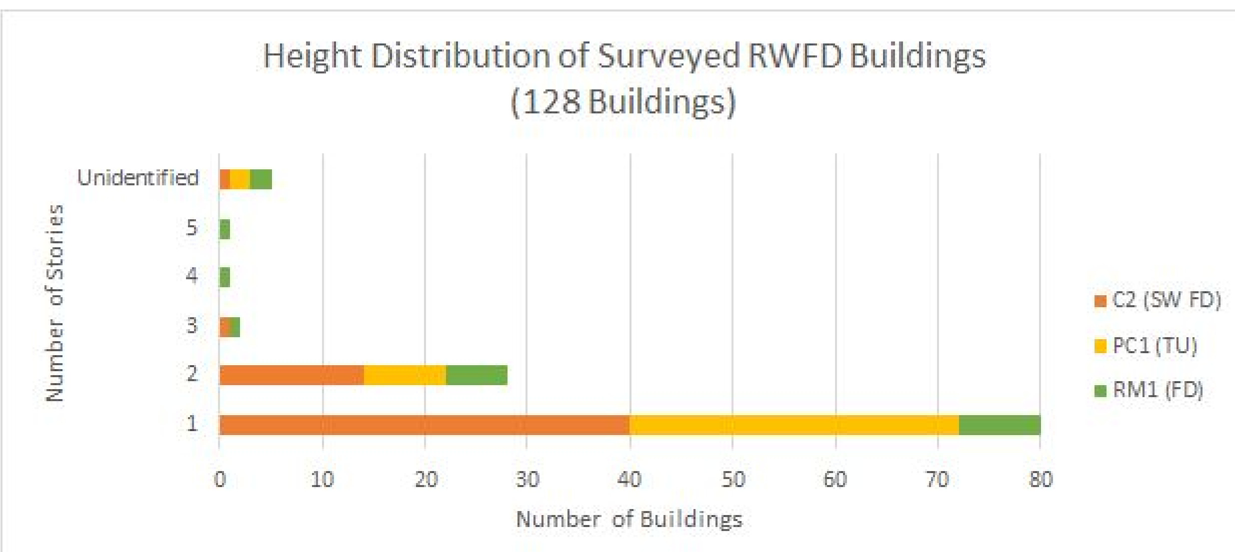


Figure 3.

Of the 81 C1 (MRF), C2 (SW RD), and C3 (URM INF) buildings surveyed, over 91% of buildings are 3 stories or less. All C1 buildings are 3 stories or less and all C3 buildings are 2 stories or less. Figure 4 shows the height distribution for these concrete building types only.

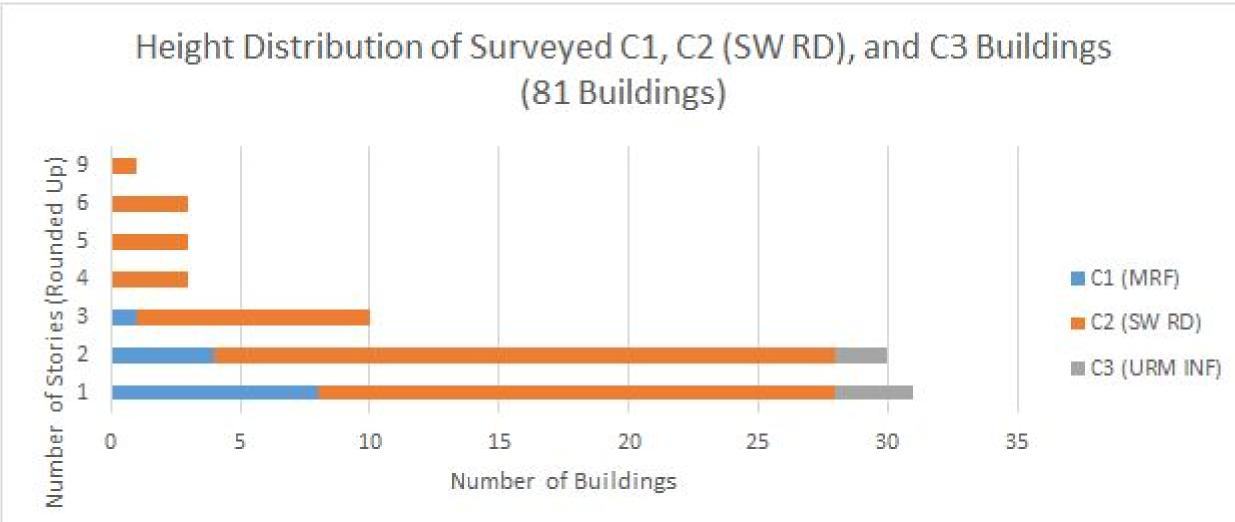


Figure 4.

Figure 5 shows the height distribution for RWFD building types. Of the 128 RWFD buildings surveyed, three RM1 (FD) and one C2 (SW FD) buildings are more than two stories.

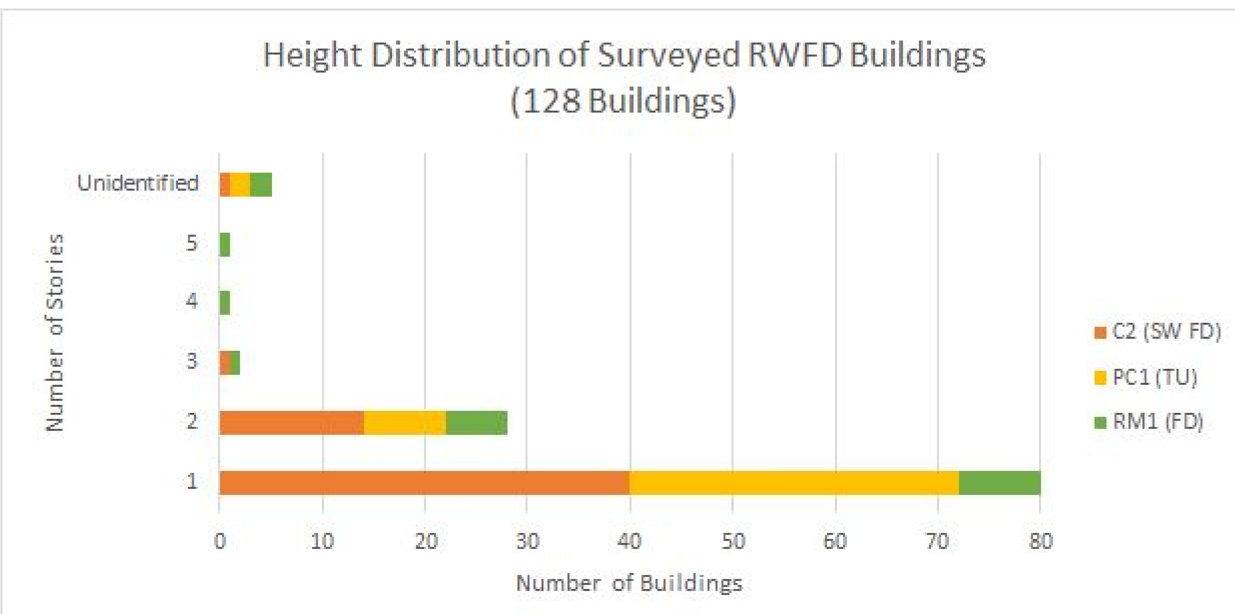


Figure 5.

2.2.3.2 Total Floor Area

Of the 209 buildings surveyed, 98% of buildings have a total floor area of 100,000 sq. ft. or less and 90% of buildings have a total floor area of 50,000 sq. ft. or less. There are 6 buildings with a floor area of greater than 100,000 sq. ft. The largest building has a floor area of 225,000 sq. ft. Figure 6 shows the distribution of floor area for all 209 relevant surveyed buildings.

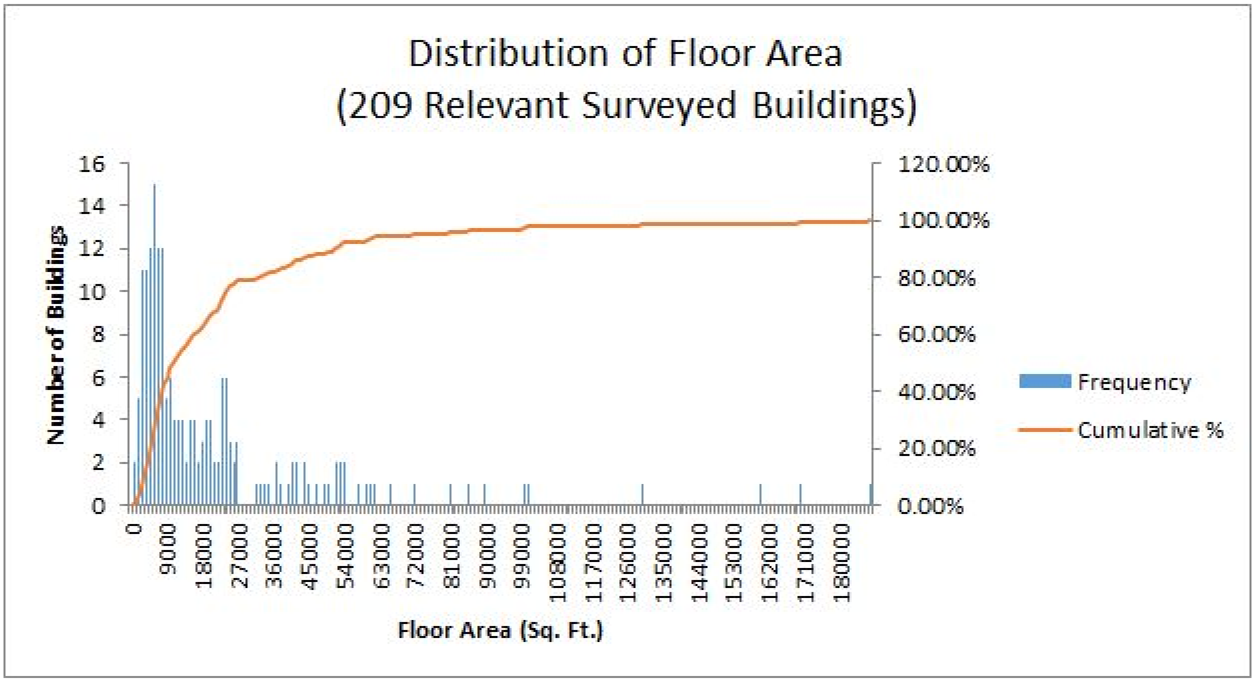


Figure 6.

2.2.4 Age

The year built for each buildings was provided by the City of Berkeley and survey engineers were asked to field verify that the year provided appeared reasonable. If the year built did not seem reasonable, survey engineers were asked to provide a better estimate. If multiple years were entered for year built, the earliest year built provided was selected. Year built is unknown for 17 of the relevant buildings surveyed. Figure 7 shows the age distribution for all 209 relevant surveyed buildings.

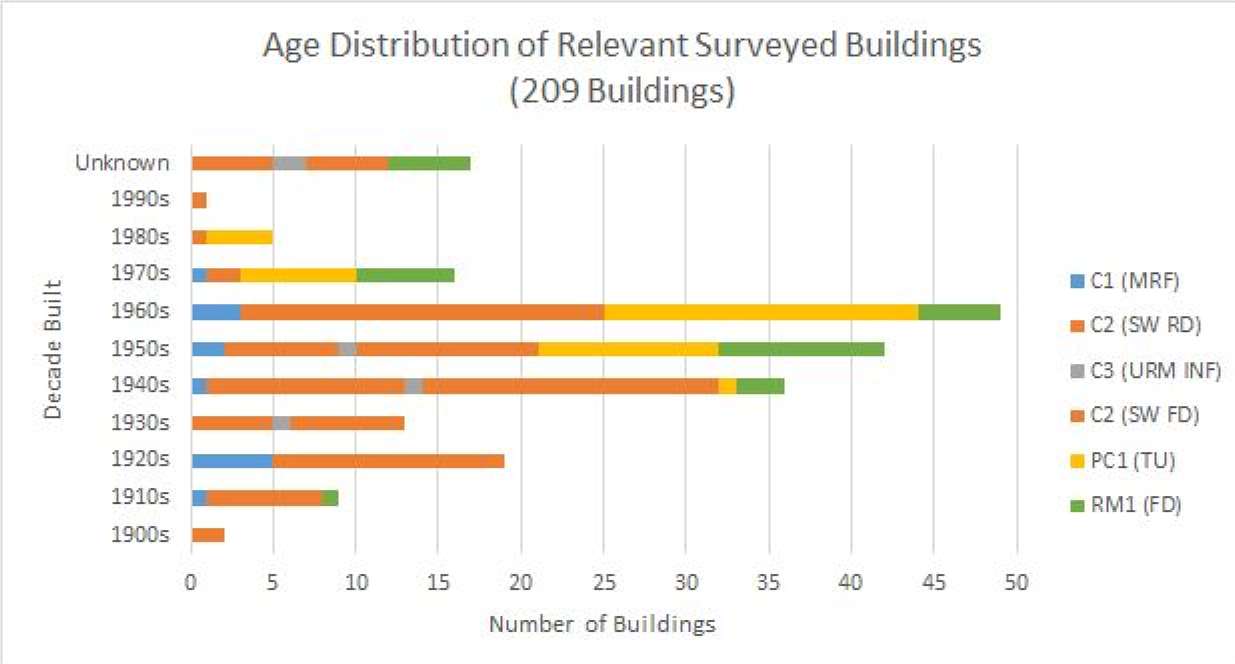


Figure 7.

Of the 81 C1 (MRF), C2 (SW RD), and C3 (URM INF) buildings surveyed, 77% were built between 1920-1969. All C1 buildings were built before 1980. Figure 8 shows the age distribution for the 81 C1 (MRF), C2 (SW RD), and C3 (URM INF) buildings surveyed.

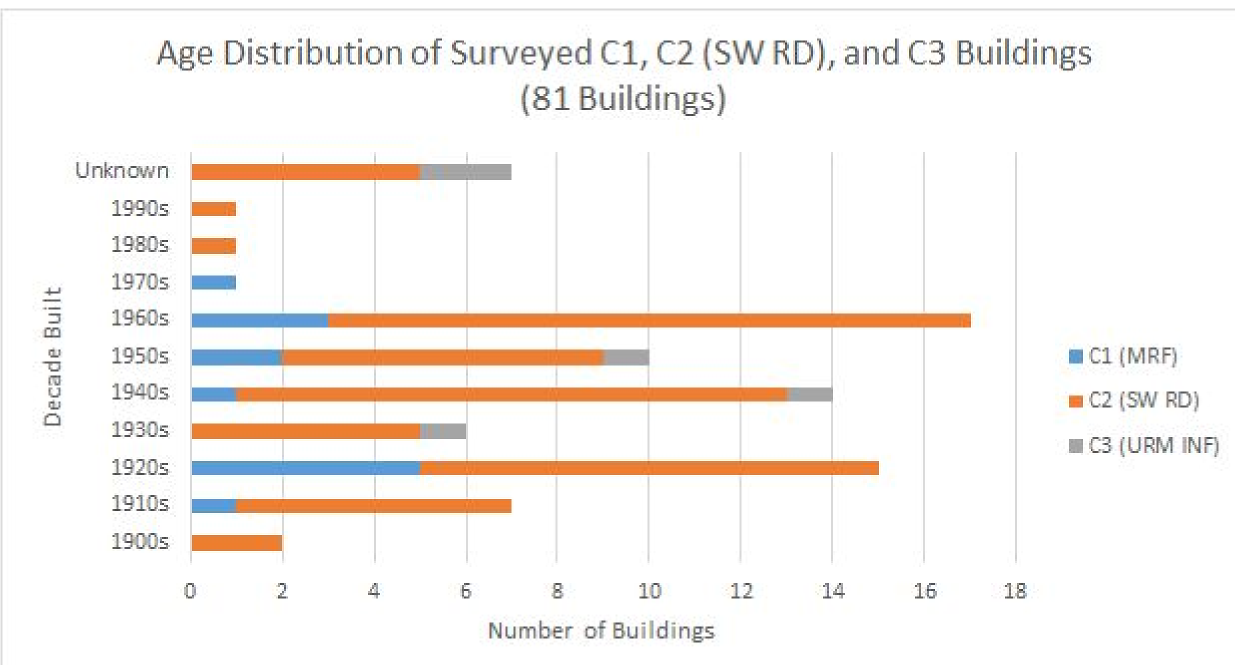


Figure 8.

With the exception of one RM1 (FD) and six C2 (SW FD) buildings, all other RWFD buildings surveyed were built in 1940 or later. Figure 9 shows the age distribution of the RWFD buildings surveyed.

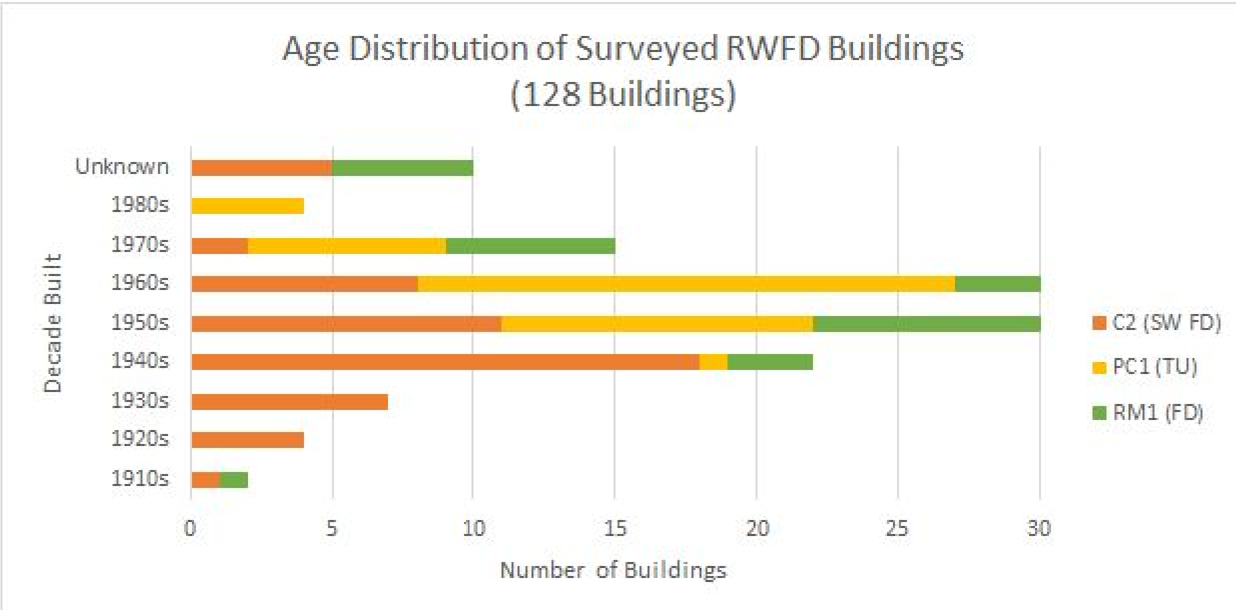


Figure 9.

2.2.5 Retrofit

Of the 209 relevant buildings surveyed, 27 buildings showed signs of seismic retrofit. No C1 buildings showed signs of retrofit. Figure 10 shows the relevant surveyed buildings with signs of retrofit broken down by building type and Figure 11 shows the age distribution of these buildings.

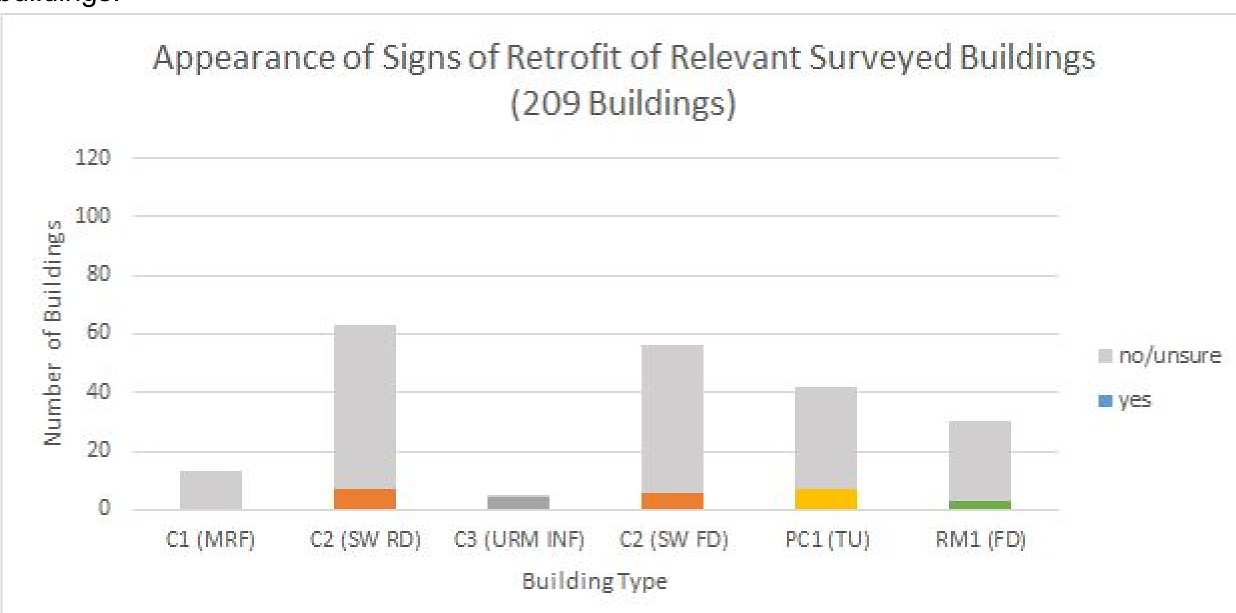


Figure 10.

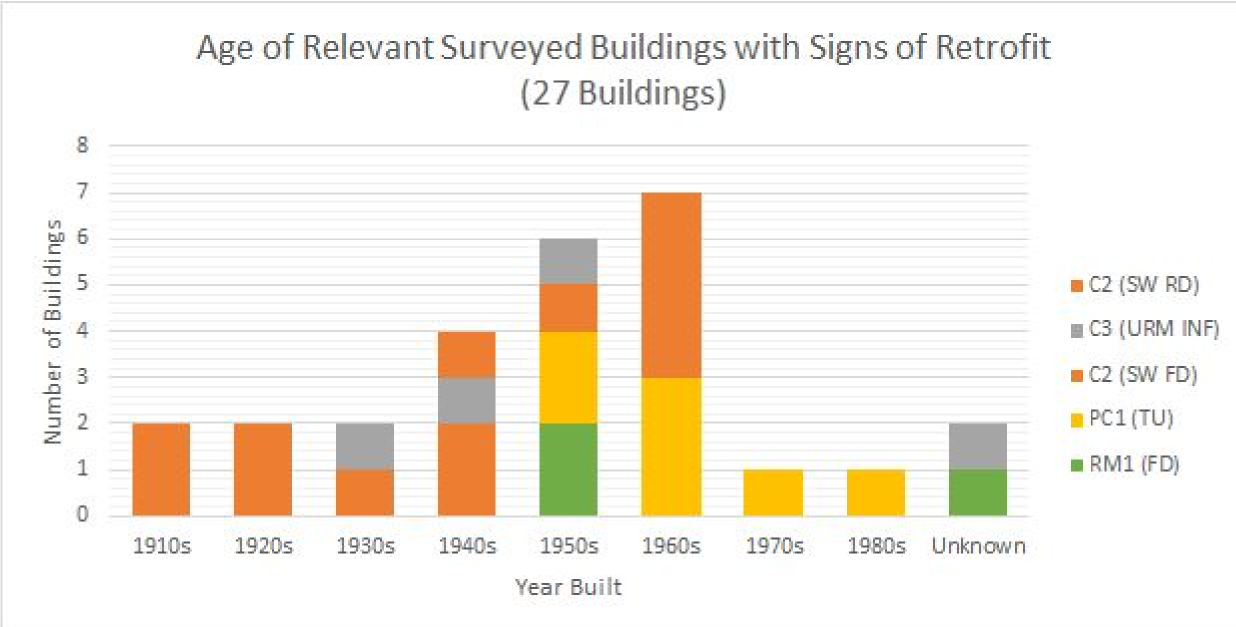


Figure 11.

Of the 27 buildings showing signs of retrofit, six PC1 (TU) and three RM1 (FD) buildings also showed visible roof ties.The presence of roof ties is suggestive of retrofit in RWFD buildings. Of the 128 RWFD buildings surveyed, 12 had visible roof ties. The presence of roof ties is typically hard to detect from an external survey, therefore, there are likely many more than 12 buildings with roof ties. Figure 12 show the RWFD buildings with the appearance of roof ties broken down by building type.

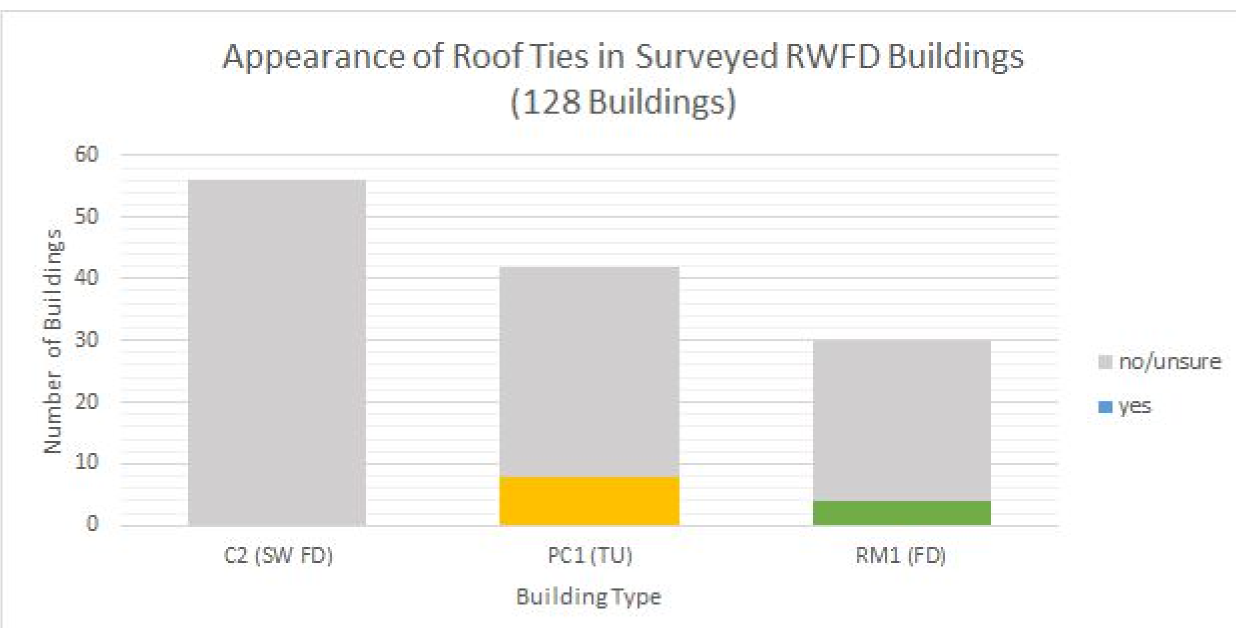


Figure 12.

2.2.6 Building Irregularities

Of the relevant buildings surveyed, 146 (or 69%) appeared to have at least one of the structural irregularities included in the survey. Figure 13 shows buildings with at least one structural irregularity broken down by building type. The percentage shown is the percent of buildings within each building type with the appearance of at least one irregularity. The irregularities included in the survey are:

- Pounding
- Lack of Redundancy
- Sloping Site
- Weak/soft story
- Setback
- Short column/pier
- Different roof levels
- Torsion
- Non-parallel system
- Reentrant corner
- Diaphragm opening
- Out-of-plane offset

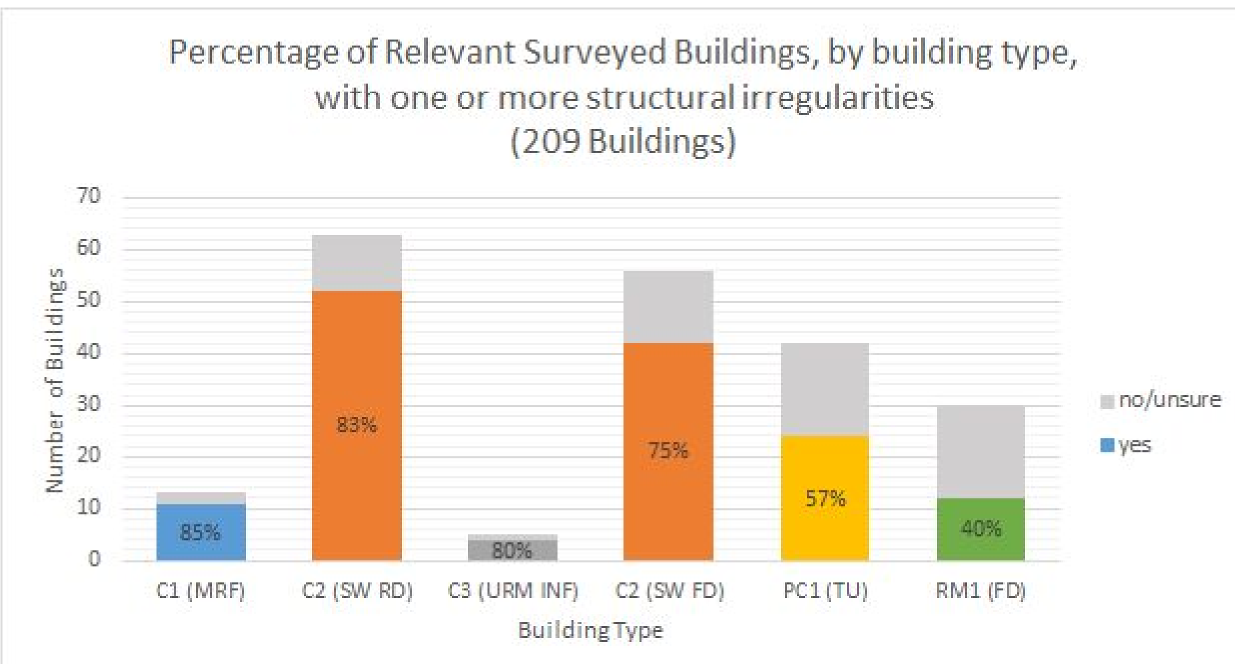


Figure 13.

2.2.6.1 Weak/Soft-Story

Three questions related to the presence of a weak/soft-story were included in the survey. Of the 209 relevant surveyed buildings, 18 appeared to have a weak/soft-story irregularity. Of the 18 buildings with a suspected weak/soft-tory irregularity, 12 are C2 buildings, two are C1 buildings, and four are RM1 buildings. Of these 18, two C2 (SW RD) buildings showed signs of seismic retrofit. Figure 14 shows the relevant surveyed buildings with the appearance of a weak/soft-story irregularity broken down by building type.

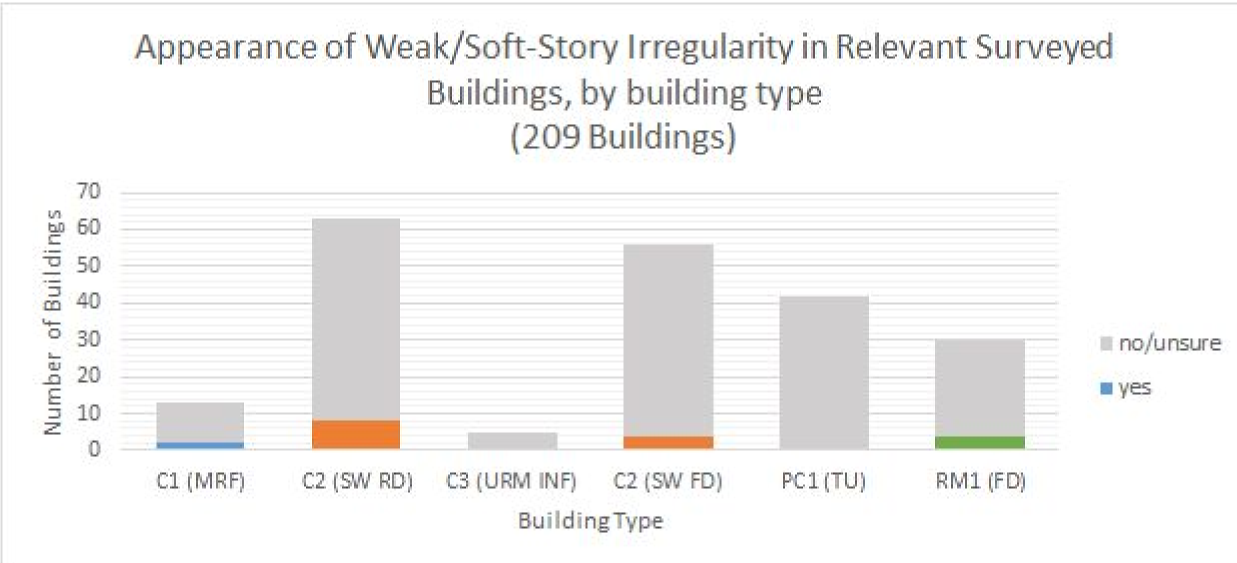


Figure 14.

2.2.6.2 Short Column/Pier

Two questions about the presence of a short column/pier irregularity were included in the survey. Of the 209 relevant surveyed buildings, 51 have a suspected short column/pier irregularity. Five of these 51 buildings, two C2 (SW RD), two C3, and one C2 (SW FD), showed signs of seismic retrofit. Figure 15 shows the relevant surveyed buildings with the appearance of a short column/pier irregularity broken down by building type.

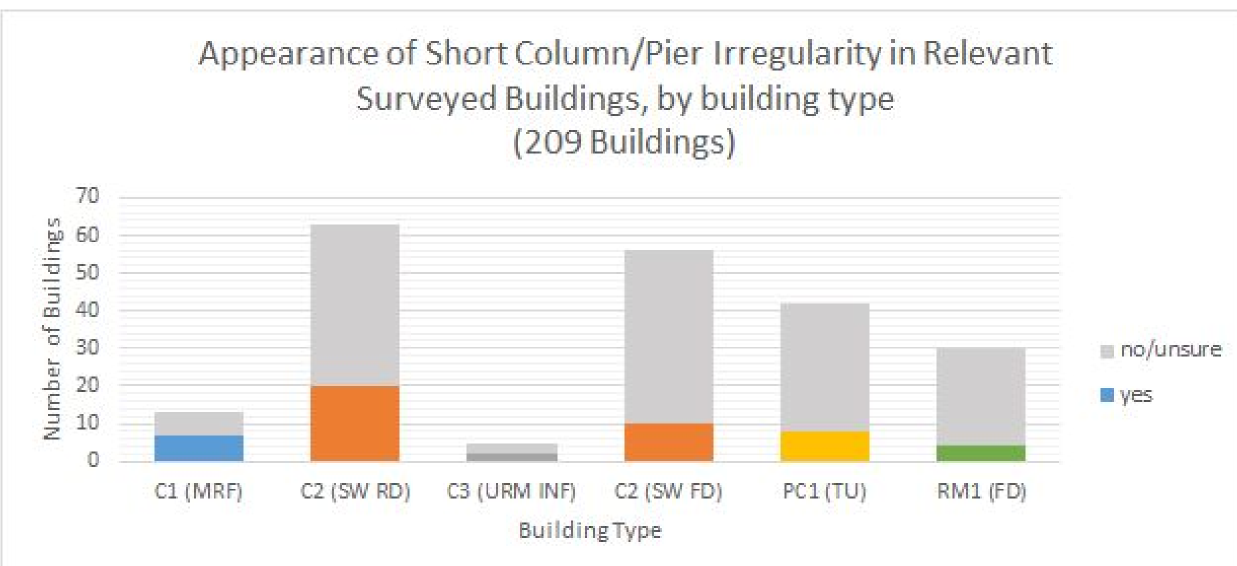


Figure 15.

2.2.6.3 Torsion

One question about the presence of a torsional irregularity was included in the survey. Of the 81 C1, C2 (SW RD), and C3 buildings surveyed, 28 were identified by engineers as having a torsional irregularity. Of these 28 buildings, four are C1, 23 are C2 (SW RD), and one is C3. Two of these 28 buildings showed signs of seismic retrofit. Figure 16 shows the relevant surveyed buildings with the appearance of a torsional irregularity broken down by building type. Figure 16 does not include RWFD buildings types as there may have been inconsistencies in how survey engineers responded to the torsional irregularity question in the survey for RWFD buildings.

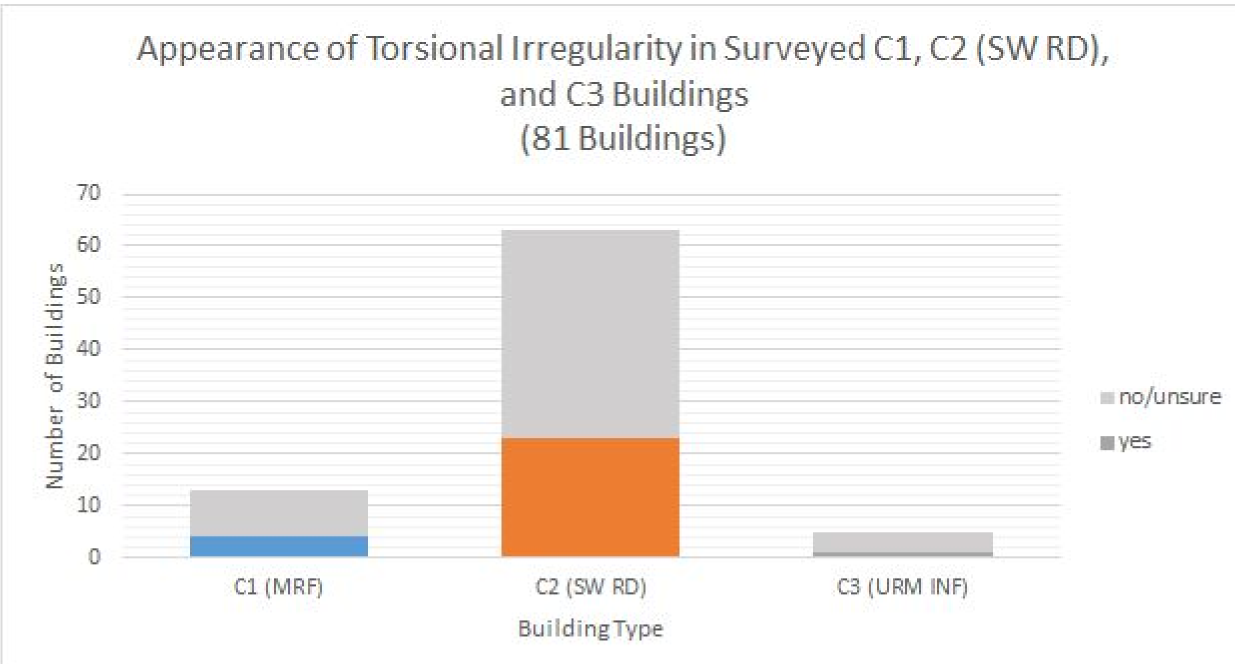


Figure 16.

2.2.6.4 Lack of Redundancy

Figure 17 shows the number of buildings with a lack of lateral system redundancy. The phrasing of the redundancy question in the survey is such that a “no” response indicates a lack of redundancy.

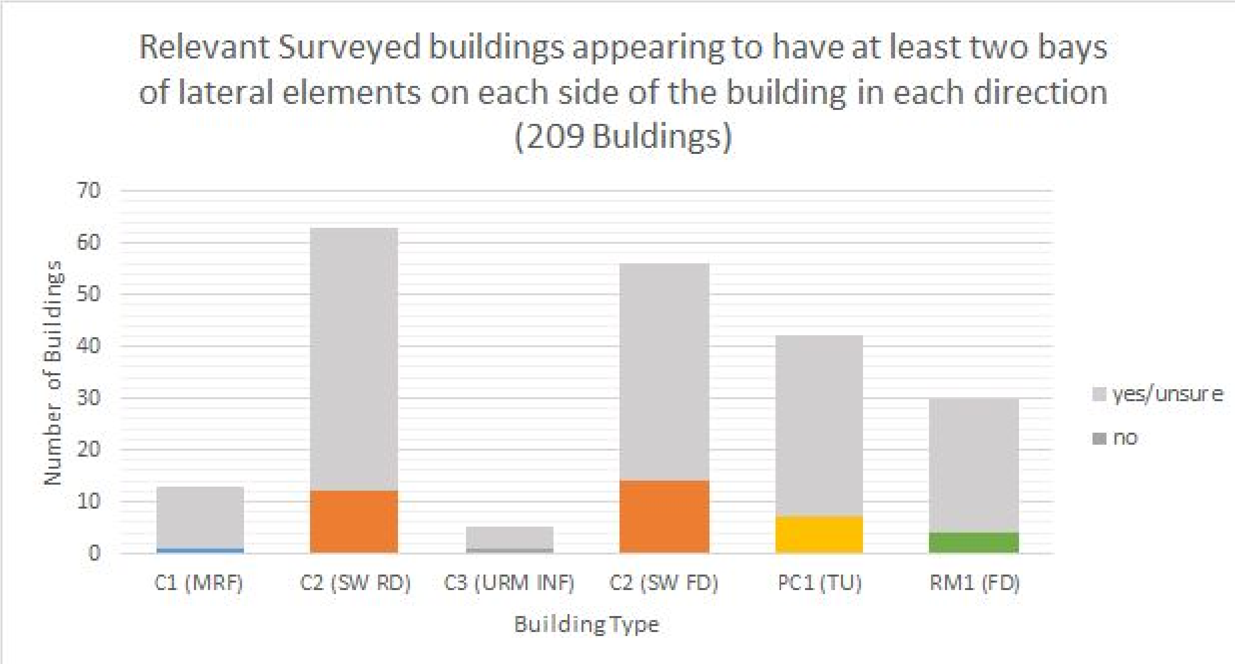


Figure 17.

2.2.6.5 Pounding

Figure 18 shows the number of relevant surveyed buildings for which pounding is expected to be an issue.

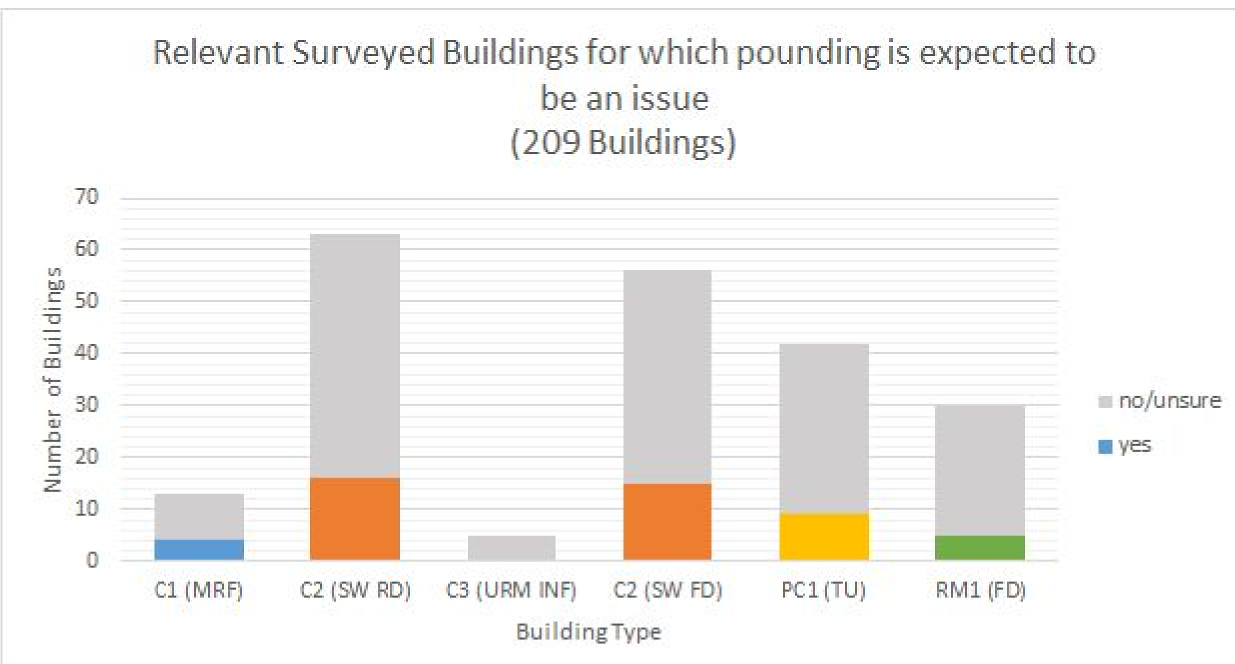


Figure 18.

2.2.6.6 Reentrant Corner

Figure 19 show the number of relevant surveyed buildings which appear to have a reentrant corner.

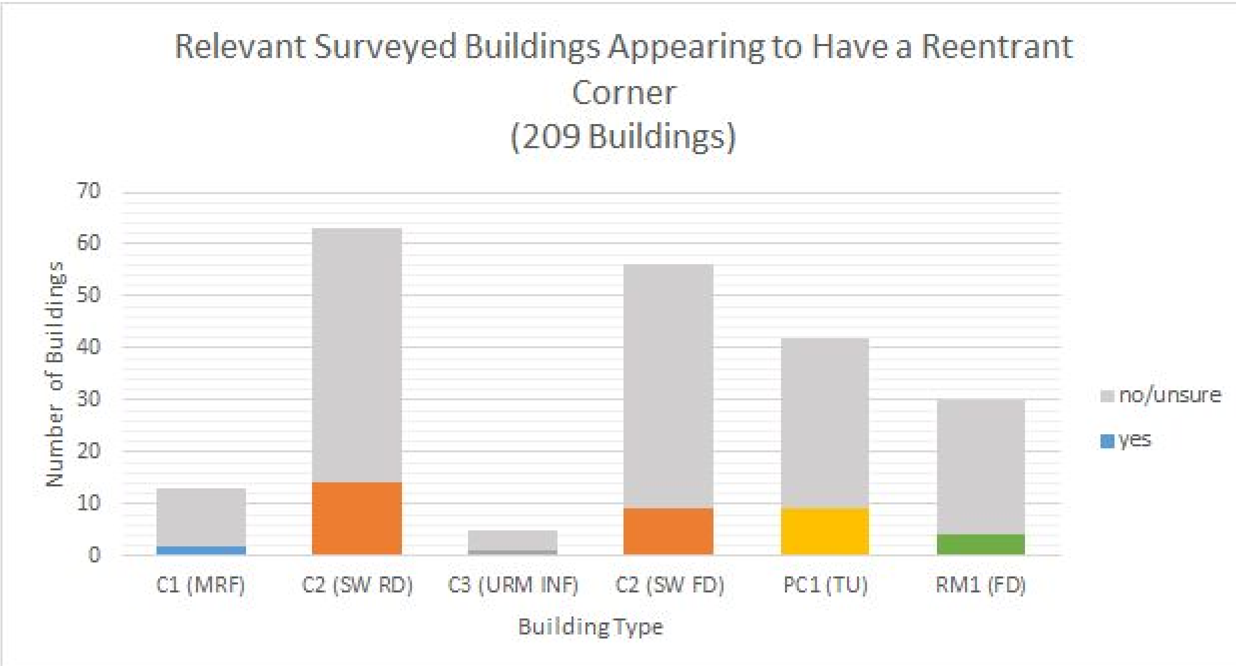


Figure 19.

3. Recommendations for Allocation of Mitigation Funding

3.1 Factors to Consider

The survey included a question asking engineers to make a professional judgement about the importance of capturing each building in a mandatory retrofit ordinance. While each response to this question does not necessarily indicate an individual building's vulnerability, the question did provide the opportunity for engineers to identify what factors they considered when making their judgement.

From the survey data and two post-survey debrief discussions, the factors that led engineers to mark buildings as "High Importance" to capture in an ordinance are shown in Table 2 below:

Table 2.

Factor	**Values leading to "High Importance" response**
Occupants/Occupancy	Children, Assembly, residential, School, Public
Occupant Load	High number of occupants
Building Size	Height (Multi-Story), Total Floor Area
Age	Historic value, Age (as a proxy for structural inadequacy)
Retrofit	No retrofit, Unclear extent of seismic retrofit
Structural Irregularity	Weak/soft story, Short Columns, Torsional, multiple, open front
Other structural inadequacy	Insufficient shear walls, lack of redundancy, slender lateral system, questionable lateral system, absence of roof ties, connection between roof diaphragm and walls, no wall anchors, lack of lateral resistance
Falling Hazards	Masonry or concrete parapet without obvious anchorage/bracing, heavy cladding or glazing
Location	Commercial street front or adjacent to other public way (especially with high foot traffic)
Adjacent building	Adjacent/attached to vulnerable building (URM)
Building Type	URM, CMU, Concrete Frame
Other	Bridge between buildings, hazardous materials

From the list in Table 2, the factors most frequently cited by survey engineers as important were: occupancy type, critical structural irregularities, location in a commercial corridor, and high number of occupants.

The EEAT focused on buildings that pose a higher risk either because of perceived weakness of the building or higher population exposure. Therefore, the EEAT recommends considering the following factors when allocating limited mitigation funding:

3.1.1 Factor 1: Buildings with one or more structural irregularities or deficiencies recognized as predictors of collapse

Not all structural irregularities included in the survey are necessarily predictors of collapse. This option would consider only the subset of structural irregularities that are recognized as predictors of collapse.

- Number of surveyed buildings with one or more structural irregularity or deficiency recognized as a predictor of collapse:
  - C1, C2 (SW RD), C3: 60 (of 81 surveyed)
  - RWFD: 83 (of 128 surveyed)
- Structural irregularities or deficiencies recognized as predictors of collapse:
  - Weak/Soft-story irregularity: 18 (of 209)
  - Short column/pier irregularity: 51 (of 209)
  - Torsional irregularity: 28 (of 81)
  - Lack of Redundancy: 39 (of 209 buildings)
  - Pounding: 49 (of 209 buildings)
  - Reentrant Corner: 39 (of 209 buildings)
  - RWFD deficiency (not quantified by this survey)

Pros

- Address buildings expected to pose the largest collapse risk

Cons

- Buildings may be most expensive to retrofit

3.1.2 Factor 2: Buildings along commercial corridors

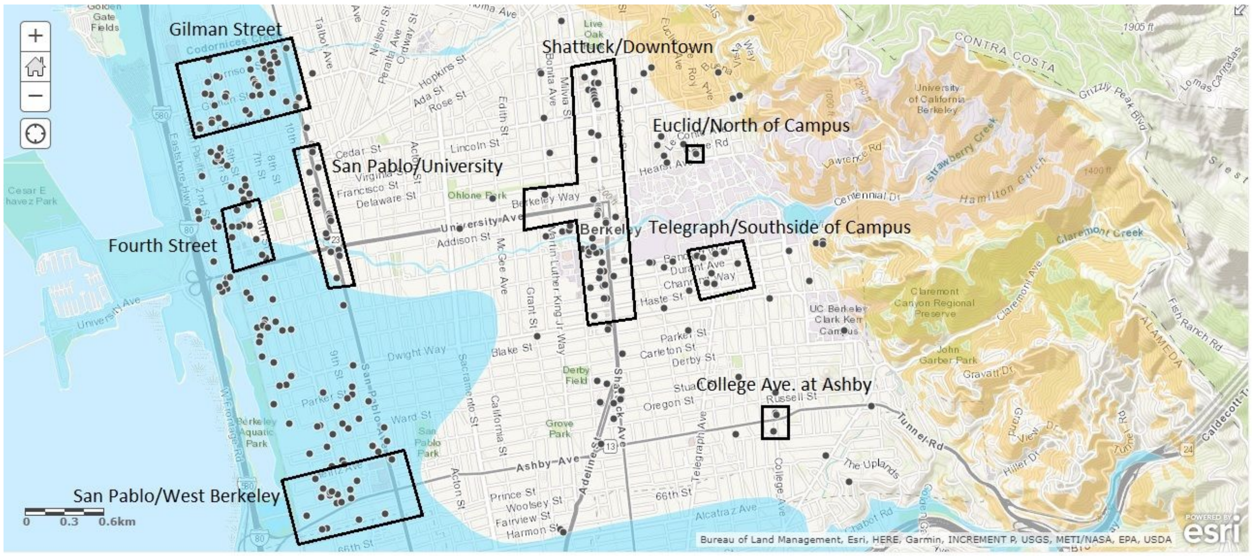


Figure 20. Map showing all 353 buildings (surveyed and non-surveyed) in Berkeley along with the boundaries of commercial districts defined by EERI

- Number of relevant surveyed buildings in commercial corridors:
  - C1, C2 (SW RD), C3 (URM INF): 40 (of 81 surveyed)
  - RWFD: 45 (of 128 surveyed)
  - Unidentified: 10 (of 21 surveyed)
- Areas defined as Commercial Corridors and the number of buildings in each:
  - Fourth St: 7 (of 209 surveyed)
  - San Pablo/University: 5 (of 209 surveyed)
  - Telegraph/Southside of Campus: 10 (of 209 surveyed)
  - Shattuck Ave/Downtown: 16 (of 209 surveyed)
  - College Ave at Ashby: 3 (of 209 surveyed)
  - Gilman Street: 37 (of 209 surveyed)
  - Euclid/Northside of Campus: 2 (of 209 surveyed)
  - San Pablo/West Berkeley: 15 (of 209 surveyed)

Pros
- Address buildings in areas with highest population exposure
- Potential to increase resilience of commercial areas

Cons
- Resilience is dependent on the number of owners who retrofit their buildings
- Retrofit will likely lead to closure of businesses, putting owners at disadvantage when neighboring buildings don't have same downtime

3.1.3 Factor 3: Buildings with Occupancy Types: Assembly, School, Residential (rent controlled housing)

This option would prioritize buildings with higher numbers of occupants, with occupants from vulnerable populations, and whose occupants may assume a building is safe (buildings with public access, rent controlled housing). In this case, occupancy type could be used as an indicator of occupant load.

- Number of surveyed buildings with occupancy type Assembly, School, or Residential (rent controlled housing):
  - C1, C2 (SW RD), C3 (URM INF): 15 (of 81 surveyed)
  - RWFD: 10 (of 128 surveyed)

Pros

- Address buildings with highest number of occupants
- Address buildings with occupants from vulnerable population groups

Cons

- Occupancy type does not directly correlate to risk
- These buildings are likely to be more expensive to retrofit (larger concrete buildings, as opposed to RWFD)

3.1.4 Factor 4: Larger buildings

- Number of relevant surveyed buildings with 3 or more stories or a total floor area of 20,000 square feet or greater:
  - All relevant buildings: 67 (of 209 surveyed)
  - C1, C2 (SW RD), C3 (URM INF): 36 (of 81 surveyed)
  - RWFD: 31 (of 128 surveyed)
- Number of relevant surveyed buildings with 3 or more stories:
  - C1, C2 (SW RD), C3 (URM INF): 20 (of 81 surveyed)
  - RWFD: 4 (of 128 surveyed)
- Number of relevant surveyed buildings with a total floor area of 20,000 square feet or greater:
  - C1, C2 (SW RD), C3 (URM INF): 31 (of 81 surveyed)
  - RWFD: 30 (of 128 surveyed)

Pros

- Larger buildings are likely to have higher numbers of occupants

Cons

- Retrofit of these buildings may be more expensive

3.1.5 Factor 5: RWFD buildings without wall anchorage

- Sidewalk survey was not sufficient to determine how many RWFD buildings surveyed lacked wall anchorage
- Number of surveyed buildings with visible roof/wall ties:
    - RWFD: 12 (of 128 surveyed)

Pros
- Retrofit of these buildings may be less expensive.

Cons
- These buildings are generally in industrial areas with fewer occupants, so they present a less direct safety risk.

4. Conclusion

The factors suggested by the EEAT are based on professional experience, survey day observations, and the survey data presented in this report. The factors described are not meant to be an exhaustive list for making decisions about funding allocation. There may be other ways to prioritize funding and in all likelihood, the most rational prioritization will involve some combination of two or more of the factors presented.

Additionally, from a community resilience perspective, the highest priority building cohorts would be those whose expected recovery times most exceed their reoccupancy and recovery goals (NIST, 2015). We recommend such an analysis, but we have not made it here. (Considering retail businesses along commercial streets, for example, such an analysis would assess *all* retail facilities as a group, not just those in concrete buildings, and would then ask what disproportionate impact the subset of concrete, or URM, or tilt-up, or soft story wood buildings might have.)

References

EERI, 2011. *The Concrete Coalition California Inventory Project: Background and Final Report*, Earthquake Engineering Research Institute, available at: http://www.concretecoalition.org/california-inventory-project/

Comartin, C., D. Bonowitz, M. Greene, D. McCormick, P. May, and E. Seymour, 2011. The Concrete Coalition and the California Inventory Project: An Estimate of the Number of Pre-1980 Concrete Buildings in the State, Earthquake Engineering Research Institute, available at: http://www.concretecoalition.org/wp-content/uploads/2013/11/concrete_coalition_final-revise-0512.pdf

NIST, 2015. Community Resilience Planning Guide, National Institute of Science and Technology, available at: https://www.nist.gov/topics/community-resilience/community-resilience-planning-guide

Acknowledgements

This project would not have been successful without the participation of the Expert Engineering Advisory Team and Survey Day volunteers who generously donated their time to support this effort. Special thanks to UC Berkeley undergraduate student Mara Sio, who volunteered many hours to digitize City of Berkeley Sanborn Maps that provided incredibly useful background information for volunteers during the sidewalk survey. The dedication of EERI Post-Graduate Intern Marisa Araujo in completing this project is greatly appreciated.

Appendix 1: Survey Form

Field Survey

- Notes from City of Berkeley
- Address
- Other Identifiers
- Building Name
- Latitude
- Longitude
- No. Stories
- Year Built
- Year Built Seems Reasonable?
- Estimated Year Built
- Total Floor Area (sq. ft)
- Floor Area Reasonable?
- Estimated Total Floor Area (sq. ft)
- Addition
- Addition Year(s) Built

- Other Modifications
- Any sign of seismic retrofit?
- Occupancy
- Residential, # units
- Building Type
  - Building Type 1
  - Building Type 2 (if applicable)
  - If you selected 2 types, clarify why:
  - Rigid or Flexible Diaphragm at Roof?
  - Rigid or Flexible Diaphragm at other floors?
  - Are there roof ties that are visible?
- Exterior Falling Hazards
- Pounding
- The floors of any adjacent buildings do not align vertically within 2 feet.
- One adjacent building is 2 or more stories taller than the other.
- The building is at the end of the block.

The building is at the end of the block.

Building is separated from an adjacent structure by less than 1.5% of the height of the shorter of the building or adjacent structure

Do you think pounding is an issue for this building?

Redundancy

The building has at least two bays of lateral elements on each side of the building in each direction.

Vertical Irregularity

Sloping Site

There is at least a full story grade change from one side of the building to the other.

Weak and/or Soft Story

Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.

Height of any story is more than 2.0 times the height of the story above.

Length of lateral system at any story is between 50% and 75% of that at story above.

Height of any story is between 1.3 and 2.0 times the height of the story above.

Setback

Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.

Vertical elements of the lateral system at upper stories are inboard of those at lower stories.

There is an in-plane offset of the lateral elements that is greater than the length of the elements.

Short Column/Pier

At least 20% of columns (or piers) have clear height less than or equal to 50% of the story height.

The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten column.

Different Levels of Roof?

Plan Irregularity

Does the building have torsional irregularity? (Torsional Irregularity: Lateral System does not appear relatively well distributed in plan in either or both directions.)

Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.

Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.

Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.

Building out-of-plane offset: the exterior beams do not align with the columns in plan.

Were you able to see the building from all sides?

Were you able to access this building?

Comments

Photos

Confidence Check

How confident are you with your findings?

If not very confident, Why?

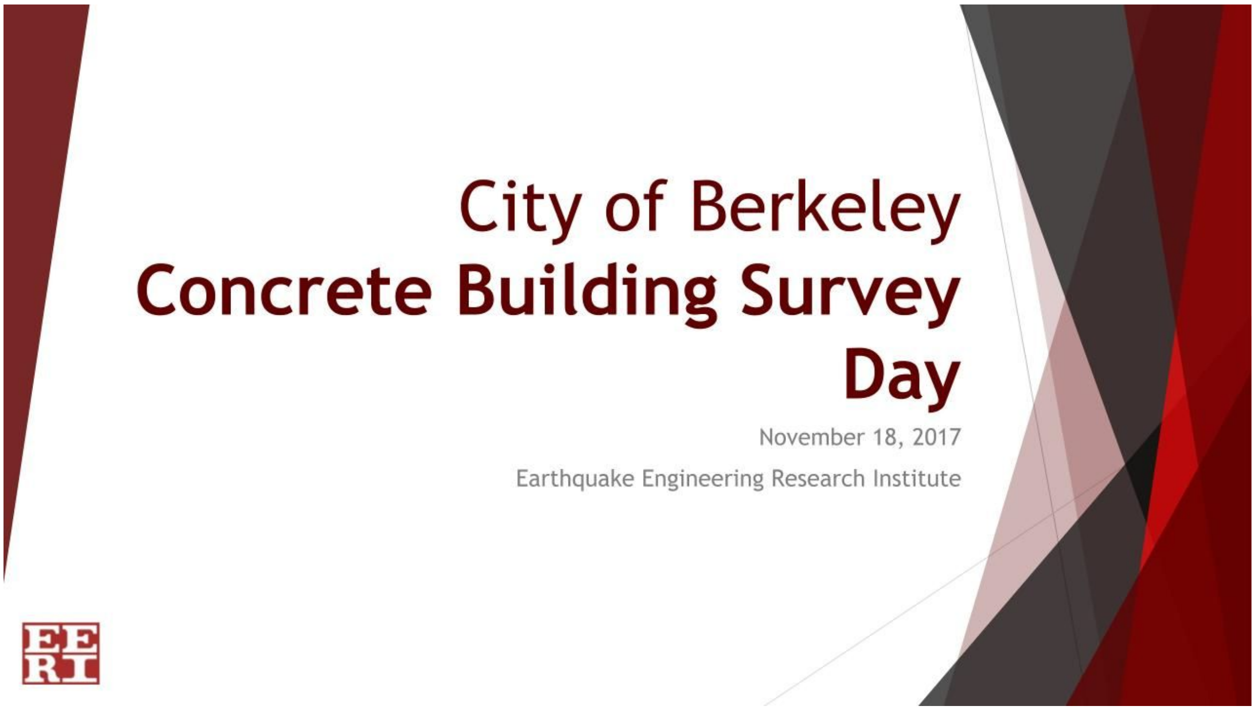
Would you recommended more detail evaluation of structure?

How important would it be to capture this building in an ordinance?

If it is Very Important, Why?

Appendix 2: Survey Day Materials

Survey Day Presentation Slides



Agenda

- 8:00 am – 8:15 am Breakfast and Check-in[1]
- 8:15 am – 8:30 am Intro & Training[1]
- 8:30 am – 12:30 pm Building surveys in West Berkeley
- 12:30 pm – 1:00 pm Lunch[1]
- 1:00 pm – 4:00 pm Building surveys in Downtown Berkeley
- 4:00 pm – 5:30 pm Debrief Discussion/Dinner[2]

[1]**Mar Structural Engineers:** 2629 Seventh Street, Suite C, Berkeley, CA 94710

[2]**North Berkeley Senior Center:** 1901 Hearst Ave, Berkeley, CA 94709

Project Objectives

- Refine the existing list of non-ductile concrete buildings compiled by the City of Berkeley
- Verify characteristics of the buildings on the list
- Make some broad recommendations to the City of Berkeley on the vulnerability of these structures

Survey Day Objectives

- Conduct exterior surveys of 285 buildings
- Discuss observations during end of day debrief discussion

EERI

Survey Day Procedures

- Teams of 3-5 people (one senior engineer, one early career engineer, and one engineering graduate student)
- Data collection using Fulcrum App (short training after this presentation)
- A group packet was given to each team leader, which contains:
  - Agenda with EERI staff contact information and meeting locations
  - List of assigned buildings (25-30)
  - City of Berkeley Letter to Property Owners
  - FEMA 154 Appendix sections
  - Map with liquefaction and landslide zones

EERI

Survey Day Procedures

- Data Collection using Fulcrum
  - One account for each group leader with buildings assigned
  - Forms pre-populated with data from City of Berkeley's list
  - Photos: aerial view, google street view, and image of sanborn maps are included in the Fulcrum form for nearly all buildings. In most cases, you do not need to take additional photos of the building, unless google street view of building is obstructed, etc.
  - Data will be stored on your phone until you sync your data. This can be done at lunch.
  - More info during Fulcrum training

EERI

Health & Safety

- Please exercise caution while conducting building surveys. Do not enter unsafe areas and be mindful of traffic.
- EERI carries volunteer insurance that may supplement your primary insurance if an injury occurs during the survey day.
- If there are any incidents during the survey, please contact Maggie Ortiz-Millan (209) 819-9317.

EERI

Should I enter a property to complete the survey?

- **NO**. Complete the survey to the best of your ability from the sidewalk or from other public vantage points.
- Do **NOT** enter garages or go through gates, even if open.
- Do **NOT** climb on walls, mail boxes, or your car to get a better view.
- Do **NOT** ask owners or tenants to provide access.

- In some cases owners have stated that they are willing to provide access to their building. If this is applicable to any of the buildings on your list, you will see that information in your group packet. In this case, call owners as early as possible to arrange a time to access building

What should I say to building owners, tenants, or others who ask about their building?

- Refer to the letter sent to property owners by the City of Berkeley.
- If pressed, you may discuss issues within the limits of your expertise, but you should avoid representing your views as those of EERI or the City of Berkeley.

May I share the data I collect?

- No, though the data will eventually be the property of the City.
- A report containing generalized summaries of the survey will be available when completed (end of 2017).
- You may share a blank survey form.

WHAT TO KEEP IN MIND WHEN COMPLETING THE FORMS

We are looking for consistent, high quality data

- Complete **ALL** questions. A 'No' can also be a 'N/A'. Type NA in fields that don't apply.
- Use judgment, but don't guess.
- Move on if something is unclear.

Am I liable for any mistakes I make?

- No, though you should compile the surveys to your best ability.
- The data will be used to help the City of Berkeley develop a mitigation strategy and no judgment of individual buildings will be made.
- Each group is led by an experienced structural engineer.
- Each survey allows you to indicate your confidence level for the information you provide for each building and you can provide an explanation.

What if I see a falling hazard from an adjacent building?

- Only identify falling hazards at the surveyed building. An ordinance would not fix the building next door.

What if I see a concrete building that is not on the list?

- Use one of the blank forms in your Fulcrum building list to complete a survey for that building.

What if a building on my list is actually more than one building?

- Use one of the blank forms in your Fulcrum building list to complete a survey for that building.

EERI

What if a building on my list is not a concrete building?

- Mark the appropriate building type on the survey form and move on.

EERI

What if the building has walls and frames?

- You can select up to two 'Model Building Types'.
- A second model building type may also apply to an addition (use judgement; lean on sheds or small additions may be ignored).

EE
RI

How to respond to the last question?

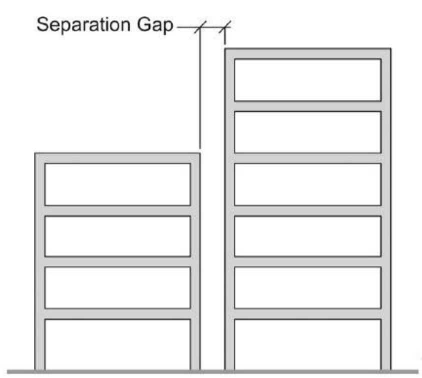
- "How important would it be to capture this building in an ordinance?"
- This is a judgment question. Is the building more or less likely to sustain damage...
- Very important = more vulnerable
- Somewhat important = average
- Not important = less vulnerable

EE
RI

FEMA 154 Clarifications

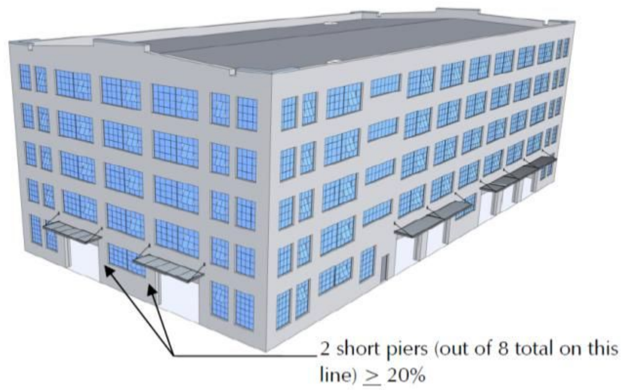
Pounding

- Building is separated from an adjacent structure by less than 1.5% of the height of the shorter of the building or adjacent structure.



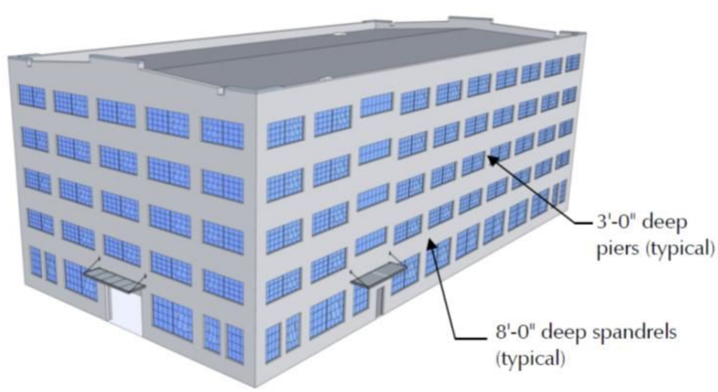
Short Column/Pier

- At least 20% of columns (or piers) have clear height less than or equal to 50% of the story height.



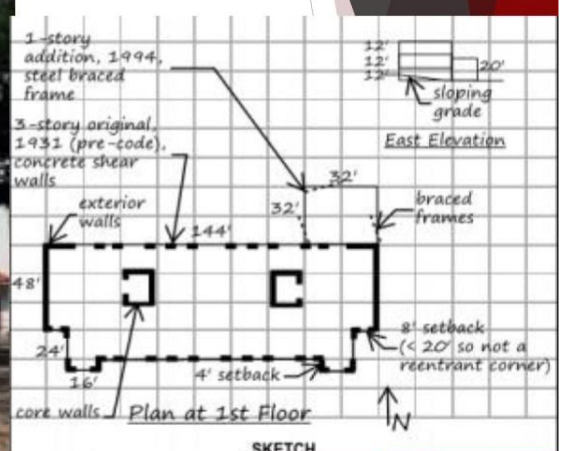
Short Column/Pier

- The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten columns.



Fulcrum Training

Demonstration Building



List of Survey Day Participants

Name	Role	Affiliation
Saeed Fathali	Experienced Engineer	Structural Tec
Elide Pantoli	Early Career Engineer	WJE Associates, Inc.
Jamie Brownell	Graduate Student	Cal Poly SLO
Karl Tellen	Experienced Engineer	Maffei Structural Engineering
Karl Eid	Early Career Engineer	Degenkolb
Carlene Chow	Graduate Student	UC Berkeley
Clayton Riggins	Experienced Engineer	Tipping Structural
Angela Hu	Graduate Student	UC Berkeley
Eleanor Siow	Graduate Student	UC Berkeley
Marko Schontanus	Experienced Engineer	Rutherford + Chekene
Mara Minner	Early Career Engineer	Forell Elsesser
Shan Shan Wang	Graduate Student	UC Berkeley
Fendy Setiawan	Graduate Student	UC Berkeley
David Bonowitz	Experienced Engineer	David Bonowitz, S.E.
Nicole Paul	Early Career Engineer	ARUP
Mara Sio	Graduate Student	UC Berkeley
David Mar	Experienced Engineer	Mar Structural Engineer
Mary Kretschmar	Early Career Engineer	Holmes Structural
Yin Yin	Graduate Student	UC Berkeley
Jiawei Chen	Graduate Student	UC Berkeley
Russell Berkowitz	Experienced Engineer	Forell Elsesser
Chiara McKenny	Early Career Engineer	E Structures
Marissa Gelms	Graduate Student	UC Berkeley
Bill Tremayne	Experienced Engineer	Holmes Structures
Matthew Thomas	Early Career Engineer	Thornton Tomasetti
Pearl Ranchal	Graduate Student	UC Berkeley
Abe Lynn	Experienced Engineer	Degenkolb
Sam Richardson	Early Career Engineer	Paradigm Structural Engineers, Inc.
Aditya Pandey	Graduate Student	UC Berkeley
Marguerite Bellos	Experienced Engineer	Bello & Associates
Brenna Marcoux	Early Career Engineer	FTF Engineering
Tracy Donoghue	Graduate Student	UC Berkeley
Erik McGregor	Experienced Engineer	Holmes Structures
Jeffery Sun	Graduate Student	UC Berkeley
Katherine Brody	Graduate Student	UC Berkeley
Jonathan Cherry	City of Berkeley	Dept of Planning & Development, Community Services Specialist

Jenny McNulty	City of Berkeley	Building & Safety Division, Program & Administration Manager
Galadriel Burr	City of Berkeley	Intern
Chandra Vogt	City of Berkeley	Intern
Giselle Aikenhead	City of Berkeley	Intern

Survey Day Flyer (Prepared by the City of Berkeley)

Building and Safety

Why are we visiting the exterior of your property?

On Saturday, November 18th, between 9am and 5pm, a team of volunteer structural engineers working with the Earthquake Engineering Research Institute (EERI) will be conducting a "sidewalk survey" of numerous buildings.

This visual survey includes two construction types:

a) Older concrete buildings built prior to ~1979 and

b) Buildings with concrete or reinforced masonry walls and flexible floor or roof diaphragms (generally wood sheathing or metal decking) built prior to ~1997

Based on experience from past earthquakes around the world, buildings of these construction types that were not designed to current code standards and have not been sufficiently retrofitted may be prone to significant damage in a major earthquake.

Letter to Building Owners (Template prepared by the City of Berkeley)

Planning & Development Department
Building and Safety Division

November 7, 2017

«**Name**»
«**Address**»
«**CITY_ST_ZIP**»

RE: Visual Field Survey and Potential Retrofit Grant for «**STRNBR**» «**STRNAME**», APN: «**APN**»

Dear Property Owner:

The City of Berkeley is working to enhance its existing seismic safety programs and wants to make you aware of two items related to your property.

Sidewalk Survey

On **Saturday, November 18th**, a team of volunteer structural engineers working with the Earthquake Engineering Research Institute (EERI) will be conducting a "sidewalk survey" of the exterior of numerous buildings. The survey will occur between **9am and 5pm**.

This survey includes buildings that are of construction types that may be vulnerable in the event of a major earthquake. One or more buildings at the above address has been identified as either:

a) An older concrete building built prior to approximately 1979 or
b) A building with concrete or reinforced masonry walls and flexible roof or floor diaphragm (generally wood sheathing or metal decking) built prior to approximately 1997

Based on experience from past earthquakes in the United States and around the world, buildings of these construction types that were not designed to current code standards and have not been sufficiently retrofitted are generally considered prone to significant damage in a major earthquake. The seismic adequacy of structural detailing in these buildings varies, and cannot be determined without a detailed assessment by a structural engineer.

The sidewalk survey will be a brief visual survey of each building, not a detailed assessment. In most cases, the engineers will be surveying the buildings' exterior, but if you (or your tenant) would like to grant access to portions of the interior of the building to better view the structure, please either contact Jonathan Cherry at the contact information below prior to November 18th or speak directly with the survey team.

The City will use the information gathered for analytical purposes to help better understand the community's potential vulnerability in a major earthquake. The City also intends to use the data collected to develop priorities for available grant funding.

1947 Center Street, Berkeley, CA 94704
http://www.cityofberkeley.info/RetrofitGrants