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Estimation of Natural Periods and Damping Ratios for Buildings

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Estimation of Natural Periods and Damping Ratios for Buildings

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Civil Engineering

by

Angie Angelique Harris

Thesis Committee:
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2016

DEDICATION

To

my mother, Carmen Harris

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ABSTRACT OF THE THESIS

Estimation of Natural Periods and Damping Ratios for Buildings

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Master of Science in Civil Engineering

University of California, Irvine, 2016

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This study is aimed at assessing modal parameters (e.g. natural periods and damping ratios) of existing buildings throughout California using system identification techniques. The data accumulated is then analyzed to provide generalized relationships between these modal parameters and building characteristics. The main focus has been on engineering applications, and addressing questions by the engineering community about building modal properties and how they are used to proportion structural components and seismic loss assessment.

The first part of this thesis discusses the estimated modal parameters for ten lateral force resisting systems. Correlations between the natural periods and damping are determined with respect to building heights and dominant building response characteristics. Comparisons are made between the data collected in this study and regressions for these parameters that have been provided by previous studies. There is an agreement in the natural periods estimated through system

identification and periods estimated through current code formulas. Likewise, damping values determined in this study remain within the range of current codes values.

The second part of this thesis discusses the application of system identification to the accurate estimation of loss. This portion of the study explores the comparison of natural periods provided through conventional analysis and that estimated through system identification for three lateral force resisting systems. The ratios derived from these comparisons result in the establishment of adjustment factors for natural periods. These adjustment factors are then applied to determine discrepancies in estimated lateral drift, and ultimately loss estimation.

CHAPTER 1:

1 INTRODUCTION

The earthquake engineering community has put forth a major effort to calculate loss of buildings when subject to ground shaking (Moehle and Deierlein, 2004; Song et al., 2014; Yang et al., 2009; Shoraka et al., 2013; Ramirez et al., 2012; Goulet et al., 2007; FEMA, 2012). Consequently, FEMA P-58-1 was created to provide a methodology of Performance-Based Earthquake Engineering (PBEE); which allows engineers to meet performance objectives for economic loss.

Studies of reconnaissance by the Multidisciplinary Center for Earthquake Engineering Research (MCEER) have explored and assessed damage due to seismic events which provided the basis of several models for loss estimation (Chang et al., 1999; Apostolakis et al., 2007; Tralli, 2000; Cimellaro et al., 2006). Models for loss estimation, such as HAZUS and MAEviz, have resulted from this need to quantify potential loss and alternatives for loss reduction (Schneider, 2006; Hampton et al., 2008).Loss estimation is heavily dependent on the accurate evaluation of lateral drift and acceleration of the building. It is important to perform the analysis of existing and proposed buildings with accurate modal parameters such as natural periods and damping ratios. Our current building engineering models, however, are not able to capture all sources of lateral stiffness, leading to inaccuracies in natural period. Furthermore, the guidance given by current codes on damping is not well-defined. As a result, uncertainties of these parameters lead to imprecisions in the calculation of drift and, ultimately, loss estimation.

The conventional methods being used to estimate dynamic response do not include the participation of all sources of stiffness. Current modeling techniques only take into consideration the stiffness of the building due to its structural components (i.e., beams, columns, walls, and braces). That assumption is accurate only when the magnitude of the seismic event is large enough to cause the nonstructural components, such as partitions and cladding, to detach, discontinuing its participation in the overall stiffness of the building. In a related topic, Poovarodom and Charoenpong (2008) and Memari (1999) have shown that nonstructural elements make up at least 40% of the building stiffness. Failing to capture such a large percentage of stiffness can result in skewed estimates of natural periods and building loss.

The damping ratios used in computational models are set based on the building type. However, buildings experience varying levels of energy dissipation that is dependent on its natural period and the intensity of ground motion experienced. Damping ratios have proven to be a difficult parameter to estimate. Therefore, uncertainties exist in the use of these parameters in design, causing uncertainties in the estimation of loss.

Performance-Based Assessment allows for existing buildings to be evaluated to determine if they will meet the requirements of loss after experiencing a given ground motion intensity. Similarly, Performance-Based Design allows engineers to design buildings to meet a specified loss after experiencing a given ground motion intensity. In both methodologies, the accurate modeling of the building, including accurate damping, natural periods, and stiffness values are necessary to provide the best estimate of the buildings response to a spectrum of ground motion intensities. In light of these current uncertainties, this thesis explores the accurate estimation of natural periods and damping ratios for the determination of building loss.

1.1 LITERATURE REVIEW

Over the past few decades, researchers have utilized modal analysis as a means to estimate the natural periods and damping ratios of structural systems. The civil engineering community has utilized experimental data from instrumented buildings and system identification to gain insight on the actual dynamic characteristics of existing buildings. Until the implementation of system identification, the estimates of these dynamic characteristics had been at best, meager estimates. The following sections provides a succinct review of previous research in engineering assessment of structural modal properties using system identification techniques.

1.1.1 Natural Periods

Several researchers have utilized system identification techniques to estimate natural periods to aid in the assessment of existing buildings and to evaluate the effectiveness of existing code period formulas. Cole et al. (1992) estimated the natural periods of 64 buildings using the transfer functions of the Fourier amplitude spectrum. These building periods were then compared to the code period formulas of the 1991 Uniform Building Code (UBC) and 1990 Structural Engineers Association of California (SEAOC) Blue Book. They concluded that in most cases, the measured periods are longer than those of the code periods for steel and concrete moment frames, but correlate well with the upper bound period formula. In addition, the measured periods for shear walls are usually shorter than that of the code formulas.

Following Cole et al. (1992), Chopra and Goel (1997 and 1998) performed system identification on 27 Reinforced Concrete Moment Resisting Frames (RCMRF), 42 Steel Moment Resisting Frames (SMRF), and 9 Reinforced Concrete Wall (RCW) buildings to determine their natural periods in comparison with the current code formulas of the Applied Technology Council (ATC) 1978, UBC 1997, SEAOC 1996, and National Earthquake Hazards Reduction Program (NEHRP) 1994. It was determined that the code formulas for the estimation of natural periods, at that time, were inadequate and led to shorter periods for RCMRFs and SMRFs, but longer periods than that identified for RCWs. New formulas were then derived, which have continued to be the basis for the current American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) approximate period formulas.

Similarly, Kwon and Kim (2010) evaluated the fundamental periods of RCMRF and SMRF buildings that depicted the lower bound of code formulas and the periods of RCWs were shorter than code predicted values. Hong and Hwang (2000) performed system identification with the autoregressive exogeneous (ARX) model of 21 RCMRF buildings in Taiwan and determined that the identified periods are less than that predicted in the UBC. Contrary to most studies, Lee et al. (2000) measured the natural periods of shear wall buildings, only to find that the periods determined from the code formulas are significantly less that of the measured periods.

One might wonder, why there are discrepancies in the findings of these studies which compare code estimated periods and identified periods. Code period formulas, as previously noted, are based on values estimated from existing buildings through system identification. The trends seen in estimated periods can be influenced by the method of estimation, type of building studied, changes in design methods and philosophy, and the ground motions used to estimate the periods. On the other hand, several studies have explored the discrepancies between the natural periods provided through finite element models (FEM) and those estimated through system identification. This discrepancy comes from the inability of engineers to capture all forms of building lateral stiffness. This additional lateral stiffness is the result of the nonstructural elements that participate in the actual building response.

Since conventional methods being used by typical engineers to estimate dynamic response do not include the participation of all sources of stiffness, several researchers have worked to create an FEM methodology that designates all known sources of stiffness for the determination of natural periods. Hatzigeorgiou and Kanapitsas (2013) modeled 20 existing buildings, incorporating the stiffness of infill walls and soil flexibility properties to determine the natural period through numerical analysis. They formulated an expression for the estimation of the natural period based on the results of the models that accounts for building height, building width, shear wall ratio, and subgrade modulus, providing a comparable estimate to current code formulas.

Amanat and Hoque (2006) explored the dependency of building periods on the percentage and distribution of infill walls by modeling diagonal struts to represent infill walls. They refined the UBC equation for the fundamental period to include building geometry and the presence of infill panels based on the computational analysis. Similarly, Kocak and Yildirim (2011) modeled varying percentages of infill walls in SAP 2000, determining that there is as much as 45 percent change in period for buildings modeled with infill as opposed to bare frames. Skolnik et al. (2007) utilized the subspace state space identification method (N4SID) to compare identified modal parameters to that determined through FEM analysis. It was determined that the participation of nonstructural components caused the natural period to be shorter for ambient vibration as opposed to low-to-moderate seismic excitation. As a result, the model was updated to account for the additional stiffness and mass using a modal-sensitivity based method.

Few studies have explored to what extent the nonstructural elements contribute to the overall stiffness of a building. Poovarodom and Charoenpong (2008) and Memari (1999) investigated the progression of the fundamental period of reinforced concrete and steel buildings (respectively) throughout its various stages of construction. The same study determined that as the completion of the building progressed and the percentage of nonstructural elements increased, the fundamental period decreased; proving the significance of the nonstructural elements' contribution to the building stiffness, and subsequently the estimation of natural periods and building performance.

1.1.2 Damping

The evaluation of building performance is not only dependent on the accurate estimation of its natural period, but also its damping. It is necessary for the energy dissipation of a building to be accurately modeled. However, damping continues to include much uncertainty and the ratios currently used in seismic design continue to be anything but well-defined. The Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-10, requires the use of %5 damping is used (ASCE/SEI 7-10). Whereas, the FEMA P-58-1 requires that equivalent viscous damping should lie within the range of %1 to %5 of the critical damping for the predominant modes (FEMA P-58-1). Similarly, the Los Angeles Tall Buildings Structural Design Council suggests that the additional modal or viscous damping should not exceed %2.5 of the critical damping for predominant modes (LATBSDC, 2014). It is evident that a damping value between %1 and %5 should be used; however, the respective damping values for differing Lateral Force Resisting Systems (LFRS) are not explicitly given, providing additional uncertainty into the design process.

The history of design has included the use of classical damping, Rayleigh damping, which is only based on known building mass and stiffness. As previously discussed, stiffness is not always clearly defined. Consequently, Rayleigh damping has resulted in unrealistically large and unconservative values.

Current seismic design methods use equivalent linear viscous damping to model energy dissipation. However, these linear models, like others, have proven to provide false damping values (Bernal, 1994), especially when analyzing nonlinear behavior. Furthermore, studies have estimated damping ratios of existing buildings through system identification to explore relationships between building modal parameters, such as forecast models of period and damping (Lagomarsino 1993). Although, Lagomarsino's damping formulas were based on a viscous damping model, they did not prove that structural damping is viscous in nature.

Buildings are complex and the damping of these structures cannot solely be determined from a linear model. Frictional damping must be taken into account. Wyatt (1977) introduced the term "stiction" (static friction), where non-linear range/increase in damping can be correlated to the imperfections of the material the building is comprised of, which is aligned with fracture mechanics. The imperfections in the material are mobilized when the structure is excited; thus, dissipating energy and increasing the structural damping.

Subsequently, several studies have elaborated on Wyatt's theory, choosing to estimate equivalent damping based on known seismic excitation and system identification, showing that damping is amplitude dependent, and resulting in a myriad of equations for damping (Jeary, 1997; Li, 1999; Davenport and Hill-Caroll, 1986; Fang et. al., 1999). It was found that at low amplitudes, damping seems to be remain constant. As the amplitude increases, damping increases as well, in a non-linear range, until it arrives at a plateau at the higher amplitude excitation (Jeary 1997).

Tamura (2008) further explored this concept and demonstrated that damping increases only until the amplitude corresponding to the critical tip ratio is reached. The corresponding amplitude to this ratio is the critical point at which the damping begins to decrease. This ideal corresponds to the assumption that as the amplitude of excitation increases, friction builds until it reaches a point when the components of the structure have “slipped” and the friction is constant, causing the damping relative to the friction forces to remain constant and eventually decrease.

Satake et. al (2003) performed an analysis of building periods and modal damping ratios obtained from a database of 137 steel-framed buildings, 25 reinforced concrete buildings, and 43 steel-framed reinforced concrete buildings. First mode damping was found to decrease with natural period (increasing with natural frequency). In addition, it was determined that the damping is amplitude dependent, increasing with mode, while first mode damping ratios in the small amplitude region increase linearly with natural frequency or vibration amplitude. Bernal (2012) similarly concluded that damping ratios, though they contained high amount of variability, increased with natural frequency.

On the other hand, damping studies have explored damping and its dependence on the dominant building response characteristics. Bentz and Kijewski-Correa (2008) discussed the prediction of damping based on the dominance of a structural systems deformation mechanisms, shear or cantilever action. Shear deformation takes precedence in frames where they deform from its generally square nature. Cantilever deformation usually occurs in shear wall systems and other systems where the structure behaves like a continuous cantilever and the aspect ratio of the structure aids in the determination of the level of cantilever action. In the research conducted, it was determined that damping values are more scattered for interactive systems (between the shear and cantilever-flexure condition). As systems become more cantilever, damping values collapse and decrease.

1.2 SCOPE OF THESIS AND ORGANIZATION OF MATERIAL

This thesis focuses on the estimation of natural periods and damping ratios for the application of Performance-Based methodology. Chapter 2 explores the application of adjustment factors to natural periods to aid in the determination of lateral drift for loss estimation. Chapter 3 then focuses on the estimation of natural periods and damping ratios to evaluate the usefulness of existing expressions for modal parameters. Chapter 4 then presents the conclusions of this study.

CHAPTER 2

2 ESTIMATION OF PERIODS AND DAMPING

2.1 BACKGROUND

Understanding building response to seismic excitation is key to designing buildings that perform best during and following seismic events. A vast amount of research in the past 20 years has been dedicated to understanding the behavior of buildings while undergoing seismic excitation (Lagomarsino, 1993; Chopra and Goel, 1997; Satake et al., 2003; Spence and Kareem, 2014). These studies have determined relationships between structural system types, ground motion intensity, and modal parameters, resulting in the creation of regression formulas for natural periods and damping ratios based on their estimation of these parameters using system identification. These regression formulas are based on the estimation of parameters for both domestic and international buildings.

The purpose of the study is to estimate the natural periods and damping ratios of ninety-one buildings throughout California to compare these parameters to existing regression formulas. Because these buildings have undergone recorded seismic excitation ranging from low to high intensity ground motions, building response under varying intensity can be observed.

2.2 METHODOLOGY

2.2.1 System Identification

Four Single Input Multiple Output methods were investigated including the Eigensystem Realization Algorithm with the Observer/Kalman filter – Input Output (ERA-OKID-IO), Auto-Regressive model with eXogenous terms (ARX), System Realization using Information Matrix (SRIM), and Numerical algorithms for Subspace State Space System Identification – Input Output (N4SID-IO) method.

Generally, system identification methods are based on a state space model, where dynamic systems are represented by first order differential equations:

$$x_{k+1} = Ax_k + Bu_k$$
$$y_k = Cx_k + Du_k , \qquad (2\text{-}1)$$

Where *x*, *u*, and *y* represent the system's current state, input data, and output data at each time step, *k*, respectively. The modal parameters of a system can be estimated based on the coefficient matrices [*A*, *B*, *C*, *D*].

The Structural Modal Identification Toolsuite was developed to perform system identification using a variety of both Output-Only and Input-Output methods using a graphical user interface within Matlab (Chang et al., 2012). In this study, four Input-Output methods presented in SMIT were utilized as a means to identify the modal parameters of each building. The following sections provide an overview of the methodology of each system identification method.

2.2.1.1 Eigensystem Realization Algorithm with Observer/Kalman Identification (ERA-OKID) Methodology

The ERA-OKID methodology is based on the approximation of the modal parameters based on the state-space model of a structural system. Within the general ERA methodology, the system can then be represented by the relationship between the current state (*x*), input (*u*), and output (*y*) of the system at each time step (*k*), where k is an integer (>0) in the following equations:

$$x_{k+1} = Ax_k + Bu_k$$
$$y_k = Cx_k + Du_k \tag{2-2}$$

Where constant matrices *A*, *B*, *C*, and *D* are constructed such that the measurement, y_k, is reproduced based on the input, u_k, and state, x_k, of the system. From these matrices, a Hankel matrix can be compiled of the system pulse response parameters, known as Markov parameters.

$$H(k) = \begin{bmatrix} Y_k & Y_{k+1} & \cdots & Y_{k+i-1} \\ Y_{k+1} & Y_{k+2} & \cdots & Y_{k+i} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{k+j-1} & u(k+p) & \cdots & Y_{k+j+i-2} \end{bmatrix} = \begin{bmatrix} CA^k B & CA^{k+1}B & \cdots & CA^{k+i-1}B \\ CA^{k+1}B & CA^{k+2}B & \cdots & CA^{k+i}B \\ \vdots & \vdots & \ddots & \vdots \\ CA^{k+j-1}B & CA^{k+j}B & \cdots & CA^{k+j+i-1}B \end{bmatrix} \tag{2-3}$$

Where *i* and *j* are integers that determine the size of the Hankel Matrix. Through the use of the singular value decomposition (SVD)

$$H(0) = U\Sigma V^T = \begin{bmatrix} U_1 & U_2 \end{bmatrix} \begin{bmatrix} S & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} V_1^T \\ V_2^T \end{bmatrix} = U_1 S V_1^T \tag{2-4}$$

where *U* and *V* are the unitary matrices, and *Σ* contains the singular values of *H(0)*. The number of non-zero singular values provides the order of the system. From the SVD, the system matrices are determined as

$$A = S^{-1/2} U_1^T H(1) V_1 S^{-1/2}, \tag{2-5}$$

$$B = S^{1/2} V_1^T E_r, \tag{2-6}$$

$$C = E_m^T U_1 S^{1/2} \tag{2-7}$$

where $E_r = \begin{bmatrix} I_{rxr} & 0 & 0 & \cdots & 0 \end{bmatrix}_{rxn_2}^T$ and E_m are defined analogously. The modal parameters can then be determined based on the matrices *A*, *B*, *C*, and *D*.

With an understanding of the general ERA method, we can appreciate how the OKID modifies the ERA methodology. The ERA-OKID method involves the use of an observer to stabilize the system and increase its accuracy. The original state space equation equations are rewritten to determine the so-called observer parameters using the previously stated process. The observer equations are written by adding and subtracting My_k in the state equation, where the following system is formulated

$$x_{k+1} = \hat{A}x_k + \hat{B}u_k \qquad (2\text{-}8)$$
$$y_k = Cx_k + Du_k$$

where

$$\hat{A} = (A + MC), \quad \hat{B} = \left[(B + MD), \quad (-M)\right],$$

Where M is an arbitrarily matrix that allows the system to become as stable as possible. Matrix M is chosen so that $\hat{A}^k \approx C\hat{A}^k\hat{B} \approx 0$ for $k \geq p$, where p is chosen such that is sufficiently large enough for the stabilization to occur.

For the condition that the initial condition is zero, it is possible to write the solution to the observer system as follows:

$$y_{q\times l} \approx \hat{Y}_{q\times[(q+m)(l-1)+m]} V_{[(q+m)(l-1)+m]\times l} \qquad (2\text{-}9)$$

where

$$y = \left[y(0) \quad \cdots \quad y(p) \quad \cdots \quad y(\ell - 1)\right]$$
$$\hat{Y} = \left[D \quad C\hat{A} \quad C\hat{A}\hat{B} \quad \cdots \quad C\hat{A}^{p-1}\hat{B}\right]$$

And the matrix V is comprised of the input and output data:

$$V = \begin{bmatrix} u(0) & u(1) & u(2) & \cdots & u(p) & \cdots & u(l) \\ & v(0) & v(1) & \cdots & v(p-1) & \cdots & v(l-1) \\ & & v(0) & \cdots & v(p-2) & \cdots & v(l-2) \\ & & & \ddots & \vdots & \cdots & \vdots \\ & & & & v(0) & \cdots & v(l-p-1) \end{bmatrix} \qquad (2\text{-}10)$$

The observer Markov parameters are the block partitions of matrix $\hat{Y}$. And they are obtained by determining the least-squares solution to Equation 2-9, $\hat{M} = YV^{\dagger}$ (where $V^{\dagger}$ is the pseudoinverse of *V*). Once the observer Markov parameters are determined, the system Markov parameters can be written in terms of the observer Markov parameters. The sequences are determined for:

$$Y_k = CA^k B \,, \tag{2-11}$$

$$Y_k^o = CA^k M \,, \tag{2-12}$$

The combined Markov parameter is formulated as

$$P_k = \begin{bmatrix} Y_k & Y_k^o \end{bmatrix} \tag{2-13}$$

where the Hankel Matrix is then created. The general ERA method can then be utilized to determine the matrices *A*, *B*, *M*, *C*, and *D*, and ultimately, the modal parameters of the system. Any details omitted can be found in Reference 26 and 27.

2.2.1.2 Auto-Regressive model with eXogeneous terms (ARX)

The ARX methodology is a specialized Autoregressive Moving Average method with eXogeneous terms (ARMAX) that is related to the Kalman filter through a state space model. The state space model is a discrete time model whose output is determined by the state of the system, which accounts for the noise and measurement error, of the system. The model is formulated as

$$\begin{aligned} x_{k+1} &= Ax_k + Bu_k + w_k \\ y_k &= Cx_k + v_k \end{aligned} \tag{2-14}$$

The sequence *w(k)* is the zero mean, white process noise and the sequence *v(k)* is the zero mean, white measurement noise. Both sequences are independent random variables.

Alternatively, the stochastic ARMAX model determines the system output directly from input and noise. The system is formulated with the following equations:

$$A(q^{-1})y_k = B(q^{-1})u_k + C(q^{-1})e_k \tag{2-15}$$

where

$$A(q^{-1}) = I_p + A_1 q^{-1} + \cdots + A_{na} q^{-na}$$

$$B(q^{-1}) = B_1 q^{-1} + \cdots + B_{nb} q^{-nb}$$

$$C(q^{-1}) = I_p + C_1 q^{-1} + \cdots + C_{nc} q^{-nc}$$

Where q^{-1} is a backward shift calculator ($(q^{-1})y_k = y_{k-1}$), I_p is a $p^x p$ identity matrix, and *na*, *nb*, and *nc* are the orders of the polynomials.

We can now relate the ARMAX and state space models through the Kalman filter. The Kalman filter determines the system output due to the state and input. The model is formulated through the following equations

$$\hat{x}_{k+1}^{-} = A\hat{x}_k^{-} + Bu_k + AK_k \pounds_k$$

$$y_k = C\hat{x}_k^{-} + \pounds_k \qquad (2\text{-}16)$$

where $\hat{x}_l^{-}$ is the best estimate of the state and ε_k is the residual, which is the difference of the predicted $C\hat{x}_k^{-}$ and the actual measurement, y_k. When the last two equations are combined one obtains the a priori state

$$\hat{x}_{k+1}^{-} = A(I_n - K_k C)\hat{x}^{-}{}_k^{-} + Bu_k + AK_k y_k \qquad (2\text{-}17)$$

The Kalman filter stabilizes and converges to its steady-state value independent of the initial conditions chosen. The a priori estimate is obtained with the inclusion of the Kalman filter gain, the output is formulated through the following equation:

$$\begin{aligned} y_k &= CAKy_{k-1} + C^{-}AAKy_{k-2} + \cdots + C^{-}A^{M-1}AKy_{k-M} \\ &\quad + CBu_{k-1} + C^{-}ABu_{k-2} + \cdots + C^{-}A^{M-1}Bu_{k-M} \\ &\quad + \pounds_k + C^{-}A\hat{x}_{k-M} \end{aligned} \qquad (2\text{-}18)$$

$$y_k = \sum_{i=1}^{M} C^{-}AA^{i-1}Ky_{k-i} + \sum_{i=1}^{M} C^{-}A^{i-1}By_{k-i} + \pounds_k + C^{-}A^{M}\hat{x}_{k-M} \qquad (2\text{-}19)$$

where

$${}^{-}A = A(I_n - KC)$$

For a stable filter, ${}^{-}A$ also becomes asymptotically stable. After shifting the terms of the last equation, the following ARX equation emerges:

$$y_k - \sum_{i=1}^{M} C^{-}AA^{i-1}Ky_{k-i} = \sum_{i=1}^{M} C^{-}A^{i-1}By_{k-i} + £_k + C^{-}A^{M}\hat{x}_{k-M} \quad (2\text{-}20)$$

Which now becomes a specialized version of the ARMAX formula, where the moving average term becomes the identity matrix, I_p. From this equation, a recursive least squares filter is utilized to determine the ARX coefficient matrices:

$$S_1 = \left[CAK, \quad C^{-}AAK, \quad \cdots, \quad C^{-}A^{M-1}AK\right] \quad (2\text{-}21)$$

$$S_2 = \left[CB, \quad C^{-}AB, \quad \cdots, \quad C^{-}A^{M-1}B\right] \quad (2\text{-}22)$$

These matrices are the system Markov parameters for the filter system that are driven by the output and input, respectively. Matrices S_1 and S_2 can be used to create two respective Hankel Matrices, where the realizations for [*A'*,*B'*,*C'*,*K'*] are determined through the ERA methodology, which are related to the system matrices [A,B,C,K]. The values of [*A'*,*B'*,*C'*,*K'*] are not all in the same coordinates. As a result, matrix *A'* is diagonalized, matrices *B'*, *C'*, and *K'* are normalized, and all are transformed to the modal coordinates so that the systems modal parameters can be determined. Further detail was omitted for brevity, and can be referenced in Reference 9.

2.2.1.3 System Realization Using Information Matrix (SRIM)

The SRIM method utilizes the information regarding the correlation of the input, output, state vectors determined through the state-space model in order to determine the system matrices *A*, *B*, *C*, and *D*. From the state-space model we have the following:

$$x(k+1) = Ax(k) + Bu(k) \quad (2\text{-}23)$$
$$y(k) = Cx(k) + Du(k)$$

There is an integer *p* chosen such that $p \geq (n/m)+1$ where n is the desired order of the system and m is the number of output values. The *x(k+1)* can be substituted into *y(k)* where you obtain the following equation:

$$\begin{bmatrix} y(k) \\ y(k+1) \\ y(k+2) \\ \vdots \\ y(k+p-1) \end{bmatrix} = \begin{bmatrix} C \\ CA \\ CA^2 \\ \vdots \\ CA^{p-1} \end{bmatrix} x(k) + \begin{bmatrix} D & & & & \\ CB & D & & & \\ CAB & CB & D & & \\ \vdots & \vdots & \vdots & \ddots & \\ CA^{p-2}B & CA^{p-3}B & CA^{p-4}B & \cdots & D \end{bmatrix} \begin{bmatrix} u(k) \\ u(k+1) \\ u(k+2) \\ \\ u(k+p-1) \end{bmatrix} \quad (2\text{-}24)$$

where

$$y_p(k) = \begin{bmatrix} y(k) \\ y(k+1) \\ y(k+2) \\ \vdots \\ y(k+p-1) \end{bmatrix} \qquad O_p = \begin{bmatrix} C \\ CA \\ CA^2 \\ \vdots \\ CA^{p-1} \end{bmatrix}$$

$$T_p = \begin{bmatrix} D & & & & \\ CB & D & & & \\ CAB & CB & D & & \\ \vdots & \vdots & \vdots & \ddots & \\ CA^{p-2}B & CA^{p-3}B & CA^{p-4}B & \cdots & D \end{bmatrix} \qquad u_p(k) = \begin{bmatrix} u(k) \\ u(k+1) \\ u(k+2) \\ \\ u(k+p-1) \end{bmatrix}$$

Where we can obtain the following equation

$$y_p(k) = O_p x(k) + T_p u_p(k) \quad (2\text{-}25)$$

The O_p matrix is the observability matrix and the T_p matrix is the Toeplitz matrix. In order to determine O_p and T_p, the Equation 2-25 must be expanded as the following:

$$Y_p(k) = O_p X(k) + T_p U_p(k) \quad (2\text{-}26)$$

where

$$X(k) = \begin{bmatrix} x(k) & x(k+1) & \cdots & x(k+N-1) \end{bmatrix}$$

$$Y_p(k) = \begin{bmatrix} y_p(k) & y_p(k+1) & \cdots & y_p(k+N-1) \end{bmatrix}$$

$$Y_p(k) = \begin{bmatrix} y(k) & y(k+1) & \cdots & y(k+N-1) \\ y(k+1) & y(k+2) & \cdots & y(k+N) \\ \vdots & \vdots & \ddots & \vdots \\ y(k+p+1) & y(k+p) & \cdots & y(k+N-2) \end{bmatrix}$$

$$U_p(k) = \lfloor u_p(k) \quad u_p(k+1) \quad \cdots \quad u_p(k+N-1) \rfloor$$

$$U_p(k) = \begin{bmatrix} u(k) & u(k+1) & \cdots & u(k+N-1) \\ u(k+1) & u(k+2) & \cdots & u(k+N) \\ \vdots & \vdots & \ddots & \vdots \\ u(k+p+1) & u(k+p) & \cdots & u(k+N-2) \end{bmatrix}$$

where the integer N must be large, whereas the rank of $U_p(k)$ and $Y_p(k)$ is at least that of O_p. From $U_p(k)$, $Y_p(k)$, and $x(k)$, correlation matrices can be developed for the creation of the information matrix, R. The correlation are calculated as follows:

$$\begin{aligned} R_{yy} &= (1/N)Y_p(k)Y_p^T(k) \quad R_{yu} = (1/N)Y_p(k)U_p^T(k) \\ R_{uu} &= (1/N)U_p(k)U_p^T(k) \quad R_{xu} = (1/N)X_p(k)U_p^T(k) \\ R_{xx} &= (1/N)X_p(k)X_p^T(k) \quad R_{yx} = (1/N)Y_p(k)X_p^T(k) \end{aligned} \tag{2-27}$$

Equation 2-26 can be postmultiplied by $U_p^T(k)$ and divided by N to produce:

$$R_{yu} = O_p R_{xu} + T_p R_{uu} \tag{2-28}$$

If R_{uu}^{-1} exists then:

$$T_p = [R_{yu} - O_p R_{xu}]R_{uu}^{-1} \tag{2-29}$$

Similarly, Equation 2-26 be postmultiplied by $Y_p^T(k)$ and divided by N to produce:

$$R_{yy} = O_p R_{yx}^T + T_p R_{yu}^T \tag{2-30}$$

and postmultiplying Equation 2-26 by $X_p^T(k)$ and divided by N to produce:

$$R_{yx} = O_p R_{xx} + T_p R_{xu}^T \tag{2-31}$$

If Equation 2-29 is substituted into Equation 2-30 and 2-31, for R_{yx} then Equation 2-30 produces

$$R_{yy} - R_{yu}R_{uu}^{-1}R_{yu}^T = O_p R_{xx} O_p^T - O_p R_{xu} R_{uu}^{-1} R_{xu}^T O_p^T \tag{2-32}$$

If the following are defined as

$$R_{hh} = R_{yy} - R_{yu}R_{uu}^{-1}R_{yu}^T \tag{2-33}$$

and

$$\tilde{R}_{xx} = R_{xx} - R_{xu}R_{uu}^{-1}R_{xu}^T \tag{2-34}$$

Then Equation 4 is

$$R_{hh} = O_p\tilde{R}_{xx}O_p^T \tag{2-35}$$

Matrices A and C can then be computed using the SVD of R_{hh} where

$$R_{hh} = U\Sigma^2U^T = \begin{bmatrix} U_n & U_0 \end{bmatrix}\begin{bmatrix} \Sigma_n^2 & 0 \\ 0 & 0 \end{bmatrix}\begin{bmatrix} U_n^T \\ U_0^T \end{bmatrix} = U_n\Sigma^2U_n^T \tag{2-36}$$

If Equation 4 is combined with Equation 6, the following is produced

$$R_{hh} = O_p\tilde{R}_{xx}O_p^T = U_n\Sigma_n^2U_n, \tag{2-37}$$

where

$$O_p = U_n$$

If the case arises where there are not any singular values that become zero due to noise and uncertainties in Σ, a partial decomposition method must be utilized, where $R_{hh}[;,1:(p-1)m]$ is decomposed. The O_p can be shifted into the following form

$$O_p(m+1:pm,:) = \begin{bmatrix} CA \\ CA^2 \\ CA^3 \\ \\ CA^{p-1} \end{bmatrix} = \begin{bmatrix} C \\ CA \\ CA^2 \\ \\ CA^{p-2} \end{bmatrix} A = O_p[1:(p-1)m,:]A \tag{2-38}$$

Thus A can be calculated by

$$A = O_p[1:(p-1)m,:]O_p^{\dagger}[1:(p-1)m,:] \tag{2-39}$$

where $O_p^{\dagger}$ is the pseudoinverse of O_p. Matrix A and C can then be computed from O_p where C is the first m rows.

A similar partition of the T_p matrix can also be done for the first r columns of the T_p, which is determined as

$$T[m+1;(p-1)m,1:r]=\begin{bmatrix} CB \\ CAB \\ \vdots \\ CA^{p-2}B \end{bmatrix}=\begin{bmatrix} C \\ CA \\ \vdots \\ CA^{p-2} \end{bmatrix}B=Op[1:(p-1)m,:]B \qquad (2\text{-}40)$$

Matrix B can then be calculated as

$$B=O_p^{\dagger}[1:(p-1)m,:]T[m+1;(p-1)m,1:r] \qquad (2\text{-}41)$$

Matrices B and D can be determined through the partitioning of T_p, where B and D is determined through

$$U_{0T}=U_{0n}\begin{bmatrix} D \\ B \end{bmatrix} \qquad (2\text{-}42)$$

or

$$O_{p\Gamma}=O_{pA}\begin{bmatrix} D \\ B \end{bmatrix} \qquad (2\text{-}43)$$

In addition, another method is useful where the output error is minimized from the following equation

$$y_N(0)=\Phi\Theta \qquad (2\text{-}44)$$

where

$$\Phi=\begin{bmatrix} C & U_m(0) & 0 \\ CA & U_m(1) & CU_n(0) \\ CA^2 & U_m(2) & CAU_n(0)+CU_n(1) \\ \vdots & \vdots & \vdots \\ CA^{N-1} & U_m(N-1) & \sum_{k=0}^{N-2} CA^{N-k-2}U_n(0) \end{bmatrix}$$

$$\Theta = \begin{bmatrix} x(0) \\ d \\ b \end{bmatrix}$$

From the realization of [A,B,C,D], the eigenvalues and eigenvectors are transformed into the modal coordinate space to determine the frequencies and damping ratios of the system. Further detail was omitted for brevity, and can be referenced in Reference 25.

2.2.1.4 Numerical Algorithm for Subspace State Space System Identification (N4SID)

The subspace identification methods are based on the use of the projections where the state sequences are determined based on the Kalman filter and are then minimized through the use of a least squares approximation, which is the opposite of most classical system identification methods. The N4SID method views the problem of system identification as both a deterministic and stochastic system. The combined system equations are formulated as the following

$$\begin{aligned} x_{k+1} &= Ax_k + Bu_k + w_k \\ y_k &= Cx_k + Du_k + v_k \end{aligned} \tag{2-45}$$

where

$$x_k = x_k^d + x_k^s$$

$$y_k = y_k^d + y_k^s$$

The superscripts d and s represent the contribution of the deterministic and stochastic system to the state and output variables, respectively. The sequence w_k is the zero mean, white process noise and the sequence v_k is the zero mean, white measurement noise. Both sequences are independent random variables and the following equation is true

$$E\left[\begin{pmatrix} w_k \\ v_k \end{pmatrix}\begin{pmatrix} w_l^t & v_l^t \end{pmatrix}\right] = \begin{bmatrix} Q^s & S^s \\ (S^s)^t & R^s \end{bmatrix}\text{¢}_{kl} \geq 0 \tag{2-46}$$

The deterministic subsystem is represented by the following equations

$$x_{k+1}^d = Ax_k^d + Bu_k$$
$$y_k^d = Cx_k^d + Du_k \qquad (2\text{-}47)$$

The x_{k+1} can be substituted into y_k where you obtain the following equations

$$Y_i(k) = \Gamma_i X_i + H_i^d U_i$$
$$X_i = A^i X_i^d + \Delta_i^d U_i \qquad (2\text{-}48)$$

where

$$\Gamma_i = \begin{bmatrix} C \\ CA \\ CA^2 \\ \vdots \\ CA^{i-1} \end{bmatrix} \quad , \quad \Delta_i^d = \begin{bmatrix} A^{i-1}B & \cdots & A^iB & B \end{bmatrix}$$

$$H_i^d = \begin{bmatrix} D & & & & \\ CB & D & & & \\ CAB & CB & D & & \\ \vdots & \vdots & \vdots & \ddots & \\ CA^{i-2}B & CA^{i-3}B & CA^{i-4}B & \cdots & D \end{bmatrix} \quad , \quad X_i^d(k) = \begin{bmatrix} x_i^d & x_{i+1}^d & \cdots & x_{i+j-1}^d \end{bmatrix}$$

$$U_{0/i-1} = \begin{bmatrix} u_0 & u_1 & u_2 & \cdots & u_{j-1} \\ u_1 & u_2 & u_3 & \cdots & u_{j-2} \\ u_2 & u_3 & u_4 & \cdots & u_{j-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ u_{i-1} & u_i & u_{i-1} & \cdots & u_{i+j-1} \end{bmatrix} \quad Y_{0/i-1} = \begin{bmatrix} y_0 & y_1 & y_2 & \cdots & y_{j-1} \\ y_1 & y_2 & y_3 & \cdots & y_{j-2} \\ y_2 & y_3 & y_4 & \cdots & y_{j-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{i-1} & y_i & y_{i-1} & \cdots & y_{i+j-1} \end{bmatrix}$$

The stochastic subsystem is represented by the following equations

$$x_{k+1}^s = Ax_k^s + w_k$$
$$y_k^s = Cx_k^s + v_k \qquad (2\text{-}49)$$

The covariance between the input and output data from Equations 2-49 is shown with the following formulas

$$P^s = E\left[x_k^s (x_k^s)^t\right] = AP^sA^t + Q^s \qquad (2\text{-}50)$$

$$G^s = E\left[x_k^s (y_k^s)^t\right] = AP^s C^t + S^s \tag{2-51}$$

$$\Lambda = E\left[y_k^s (y_k^s)^t\right] = CP^s C^t + R^s \tag{2-52}$$

The stochastic subsystem controllability, state, block Toeplitz covariance, and block Toeplitz cross-covariance matrices are the following

$$\Delta_i^s = \left[A^{i-1}G \quad \cdots \quad A^i G \quad G\right] \ , \ X_k^s(k) = \left[x_i^s \quad x_{i+1}^s \quad \cdots \quad x_{i+j-1}^s\right]$$

$$L_i^s = E\left[Y_{0/i} Y_{0/i-1}^t\right] = \begin{bmatrix} \Lambda_0 & \Lambda_{-1} & \cdots & \Lambda_{i-1} \\ \Lambda_1 & \Lambda_0 & \cdots & \Lambda_{i-2} \\ \vdots & \vdots & \ddots & \vdots \\ \Lambda_{i-1} & \Lambda_{i-2} & \cdots & \Lambda_0 \end{bmatrix} \quad \text{, and}$$

$$H_i^s = E\left[Y_{0/i} Y_{i/2i-1}^t\right] = \begin{bmatrix} \Lambda_i & \Lambda_{i-1} & \cdots & \Lambda_i \\ \Lambda_{i+1} & \Lambda_i & \cdots & \Lambda_2 \\ \vdots & \vdots & \ddots & \vdots \\ \Lambda_{2i-1} & \Lambda_{2i-2} & \cdots & \Lambda_i \end{bmatrix} = \Gamma_i \Delta_i^s$$

The past and future inputs are denoted by $U_{0/i-1}$ and $U_{i/2i-1}$, respectively. Similarly, the past and future output are denoted by $Y_{0/i-1}$ and $Y_{i/2i-1}$. The matrix input and output equations due to the deterministic and stochastic subsystems become

$$Y_{0/i-1} = \Gamma_i X_0^d + H_i^d U_{0/i-1} + Y_{0/i-1}^s, \tag{2-53}$$

$$Y_{i/2i-1} = \Gamma_i X_i^d + H_i^d U_{i/2i-1} + Y_{i/2i-1}^s \tag{2-54}$$

And

$$X_i^d = A^i X_0^d + \Delta_i^d U_{0/i-1} \tag{2-55}$$

Oblique projections are utilized to transform the future output, $Y_{i/2i-1}$, onto the past and future inputs, and the past outputs, $U_{0/i-1}$, $U_{i/2i-1}$ and $Y_{0/i-1}$, respectively. The projections aid in the simplification of the computational effort. A block Hankel matrix is derived by

$$H = \left.\begin{pmatrix} U_{0/2i-1} \\ Y_{0/i-1} \end{pmatrix}\middle/\sqrt{j}\right.$$

where $\sqrt{j}$ operator the denotes the Expected Value Operator.

The block Hankel is factored using the RQ decomposition to simplify the system

$$\begin{bmatrix} U_{0/i-1} \\ U_{i/i} \\ U_{i+1/2i-1} \\ Y_{0/i-1} \\ Y_{i/i} \\ Y_{i+1/2i-1} \end{bmatrix} = \begin{bmatrix} R_{11} & & & & & \\ R_{21} & R_{22} & & & & \\ R_{31} & R_{32} & R_{33} & & & \\ R_{41} & R_{42} & R_{43} & R_{44} & & \\ R_{51} & R_{52} & R_{53} & R_{54} & R_{55} & \\ R_{61} & R_{62} & R_{63} & R_{64} & R_{65} & R_{66} \end{bmatrix} \begin{bmatrix} Q_1^T \\ Q_2^T \\ Q_3^T \\ Q_4^T \\ Q_5^T \\ Q_6^T \end{bmatrix} \tag{2-56}$$

The projection of the future outputs onto the past and future inputs and the past outputs are determined by

$$Z_i = Y_{i/2i-1} \Big/ \begin{bmatrix} U_{0/i-1} \\ U_{i/2i-1} \\ Y_{0/i-1} \end{bmatrix} = \begin{bmatrix} L_i^1 & L_i^2 & L_i^3 \end{bmatrix} \begin{bmatrix} U_{0/i-1} \\ U_{i/2i-1} \\ Y_{0/i-1} \end{bmatrix} \tag{2-57}$$

$$Z_{i+1} = Y_{i+1/2i-1} \Big/ \begin{bmatrix} U_{0/i} \\ U_{i+1/2i-1} \\ Y_{0/i} \end{bmatrix} = \begin{bmatrix} L_{i+1}^1 & L_{i+1}^2 & L_{i+1}^3 \end{bmatrix} \begin{bmatrix} U_{0/i} \\ U_{i+1/2i-1} \\ Y_{0/i} \end{bmatrix} \tag{2-58}$$

where

$$L_i^1 = \Gamma_i([A^i - Q_i\Gamma_i]S(R^{-1}) + \Delta_i^d - Q_i H_i^d),$$

$$L_i^2 = H_i^{d+}\Gamma_i[A^i - Q_i\Gamma_i]S(R^{-1}), \text{ and}$$

$$L_i^3 = \Gamma_i Q_i$$

The projections Z_i are used to create new state space equations

$$Z_i = \Gamma_i \hat{X}_i + H_i^d U_{i/2i-1}$$

$$Z_{i+1} = \Gamma_{i-1} \hat{X}_{i+1} + H_{i-1}^d U_{i+1/2i-1} \tag{2-59}$$

The Singular Value Decomposition is performed on the portion of Z_i that contains the past inputs and outputs

$$\begin{bmatrix} L_i^1 & L_i^3 \end{bmatrix} \begin{bmatrix} U_{0/i-1} \\ Y_{0/i-1} \end{bmatrix} = \begin{bmatrix} U_1 & U_2 \end{bmatrix} \begin{bmatrix} \Sigma_1 & 0 \\ 0 & 0 \end{bmatrix} V^t \tag{2-60}$$

Where the system order is determined by the number of nonzero singular values in Σ_1. The observability matrix Γ_i can be determined since it has the same number of column space at L_i

$$\Gamma_i = U_1 \Sigma_1^{1/2} \text{ and } \Gamma_{i-1} = \underline{U}_1 \Sigma_1^{1/2}$$

Where the underlined value represents the augmented matrix whose last row is deleted. Due to the projections, the system can then be described as a linear system, where Z_{i+1} can be found due to Z_i using the general Kalman filter equations

$$X_{i+1} = A\hat{X}_i + BU_{i/i} + K_i(Y_{i/i} - C\hat{X}_i - DU_{i/i})$$

$$Y_i = C\hat{X}_i + DU_{i/i} + (Y_{i/i} - C\hat{X}_i - DU_{i/i}) \tag{2-61}$$

where $£_i = (Y_{i/i} - C\hat{X}_i - DU_{i/i})$, which is the residual.

From Equations 2-61) and Equations 2-59 the following system of equations is determined

$$\begin{bmatrix} \hat{X}_{i+1} \\ Y_{i/i} \end{bmatrix} = \begin{bmatrix} A \\ C \end{bmatrix} \hat{X}_i + \begin{bmatrix} B \\ D \end{bmatrix} U_{i/i} + \begin{bmatrix} U_{0/2i-1} \\ Z_i \\ \hat{X}_i \end{bmatrix}^{\perp} \tag{2-62}$$

$$\begin{bmatrix} \Gamma_{i-1}^{\dagger} Z_{i+1} \\ Y_{i/i} \end{bmatrix} = \begin{bmatrix} A \\ C \end{bmatrix} \hat{X}_i + \begin{bmatrix} K_{12} \\ K_{22} \end{bmatrix} U_{i/i} + \begin{bmatrix} U_{0/2i-1} \\ Z_i \\ \hat{X}_i \end{bmatrix}^{\perp}$$

We now have a linear equation in which the least approximation can be used

$$\min \left\| \begin{bmatrix} \Gamma_{i-1}^{\dagger} Z_{i+1} \\ Y_{i/i} \end{bmatrix} - \begin{bmatrix} A & K_{12} \\ C & K_{22} \end{bmatrix} \begin{bmatrix} \Gamma_i^{\dagger} Z_i \\ U_{i/2i-1} \end{bmatrix} \right\|_F^2 \tag{2-63}$$

The system matrices, A, B, C, D, Q^s, S^s, and R^s can then be determined. Further detail was omitted for brevity, and can be referenced in Reference 41 and 42.

2.2.2 CSMIP Database

The CSMIP database provides accelerometer layout for each building along with the acceleration, velocity, and displacement data for each seismic event. The sensor data at the base of the building was used to represent the seismic excitation, whereas the sensor data from the remaining floors represented the building response to the excitation. The sensor locations were used to describe the building height and geometry of the building geometry as nodes.

The sampling frequency of the accelerometer given for each data set was given and the Type I Chebyshev filter was utilized to filter out the high frequency noise of each recording to increase the accuracy in the estimation of the modal parameters.

2.2.3 System Identification Method Evaluation

When comparing the reliability of the four available system identification methods within SMIT, it became apparent the SRIM method provided the most stable convergence of modal parameters with the highest efficiency in processing time. As a result, it was decided that SRIM would be used to estimate the modal parameters (e.g. natural period and damping) for all buildings in the database.

2.3 RESULTS AND DISCUSSION

This section provides an overview of the results provided by the system identification that was performed on each building. The results are analyzed and grouped into ten types of lateral force resisting systems (LFRS) chosen for this study. The system types include Reinforced Concrete Walls (RCW), Steel Moment Resisting Frames (SMRF), Reinforced Concrete Moment Resisting Frames (RCMRF), Eccentric Braced Frames (EBF), Concentric Braced Frames (CBF), Reinforced Block Masonry Walls (MAW), Precast Concrete Walls (PCW), Reinforced Concrete Tilt-up Walls (RCTUW), Unreinforced Masonry Walls (URM), and Wood Shear Walls (WOOD).

2.3.1 Natural Periods

Generally, it was shown that regardless of the LRFS, as a building increases in height, the natural period increases accordingly, as shown in Figures 2-1 through 2-10. This observation coincides with the general consensus of the relationship between natural period and height. In addition, it can be seen that as the ground motion intensity increases, building's period also increases. As the ground motion intensity increases, the nonstructural components of a building become damaged; thus, decreasing the overall stiffness of the structure, and increasing the natural period. In addition, when comparing the natural periods with respect to the intensity measure (IM), it was seen that the higher the Peak Ground Acceleration (PGA), the higher the period, which coincides with the theory set forth in previous studies. This trend could not be detected within the group of RCTUW (Figure 2-8) and WOOD (Figure 2-10) buildings due to the lack of available data.

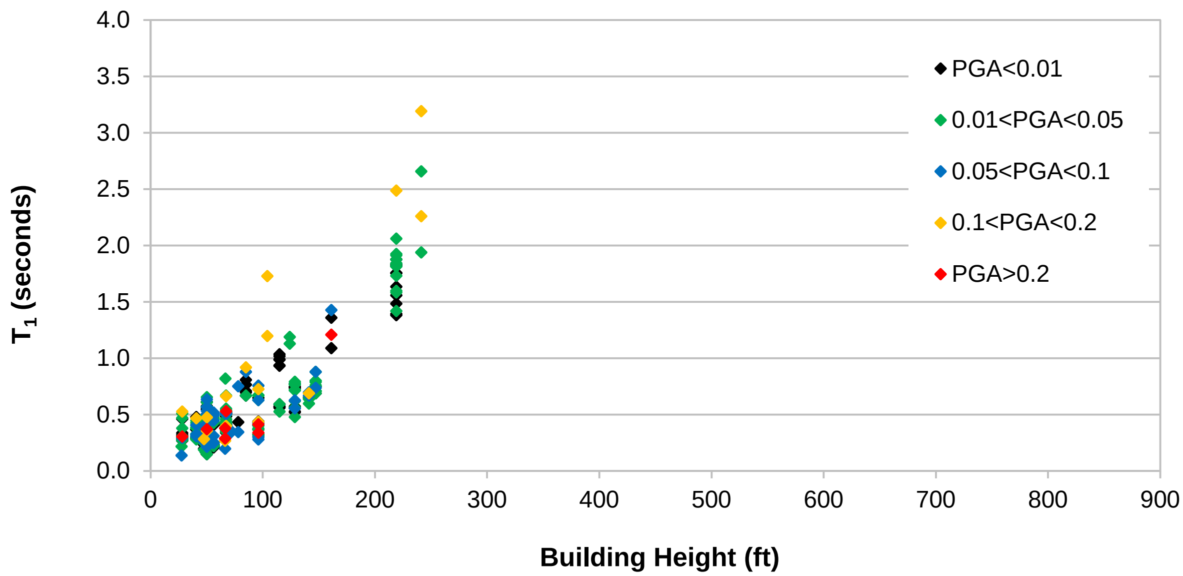


Figure 2-1: Variation of Fundamental Period with Height (RCW)

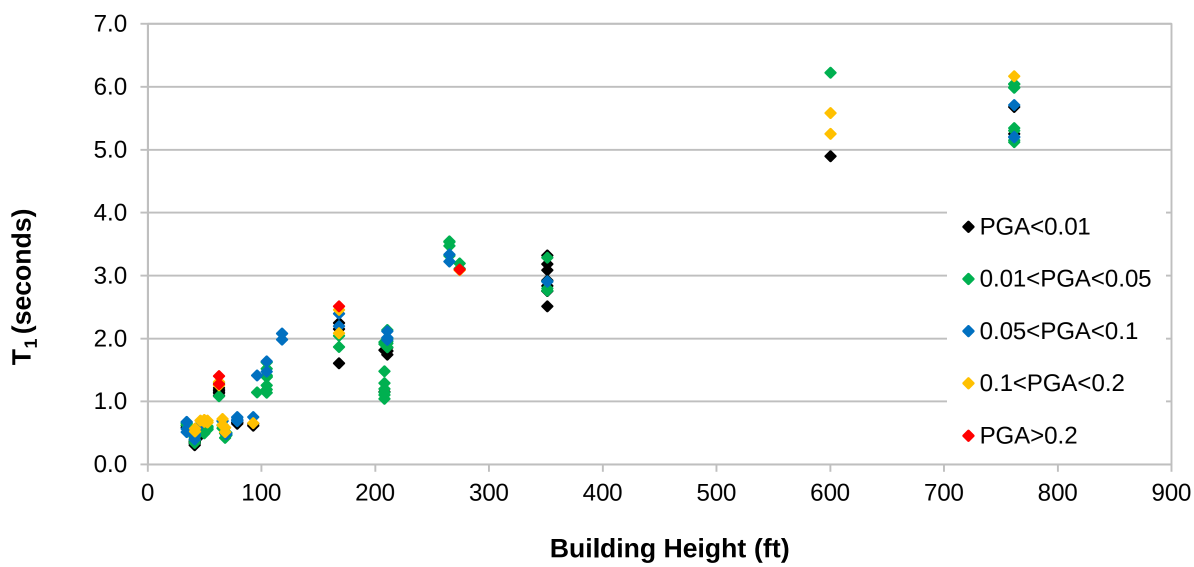


Figure 2-2: Variation of Fundamental Period with Height (SMRF)

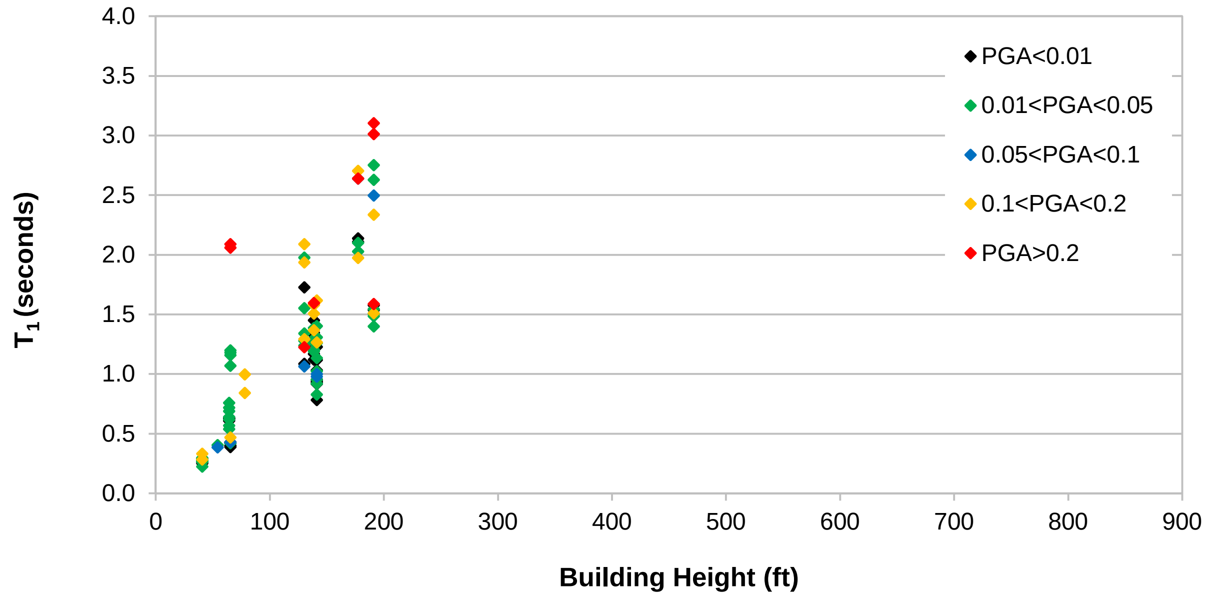


Figure 2-3: Variation of Fundamental Period with Height (RCMRF)

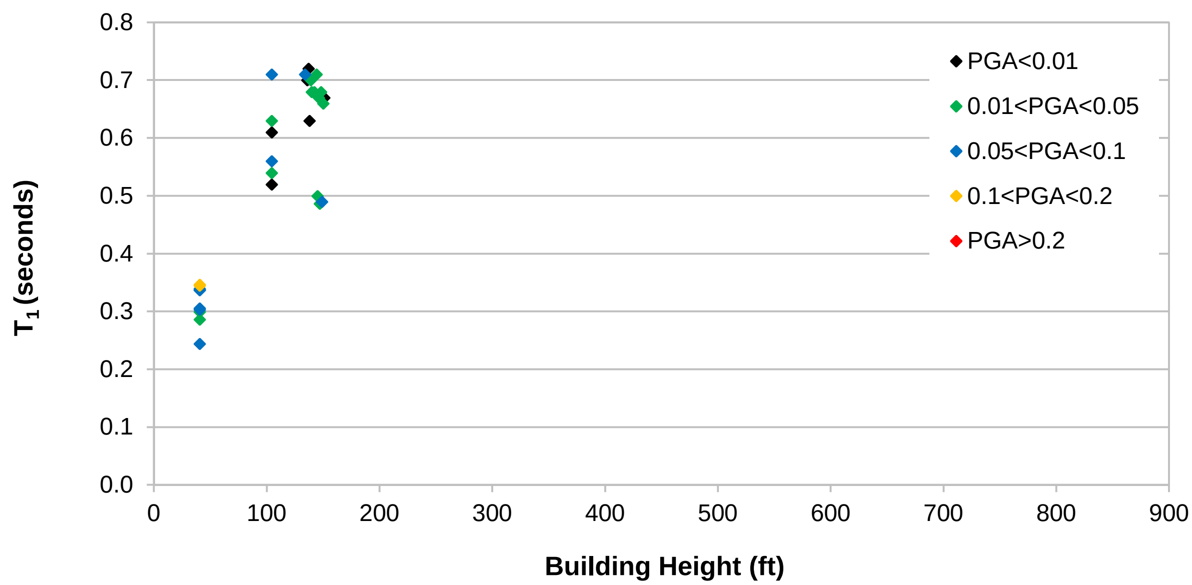


Figure 2-4: Variation of Fundamental Period with Height (EBF)

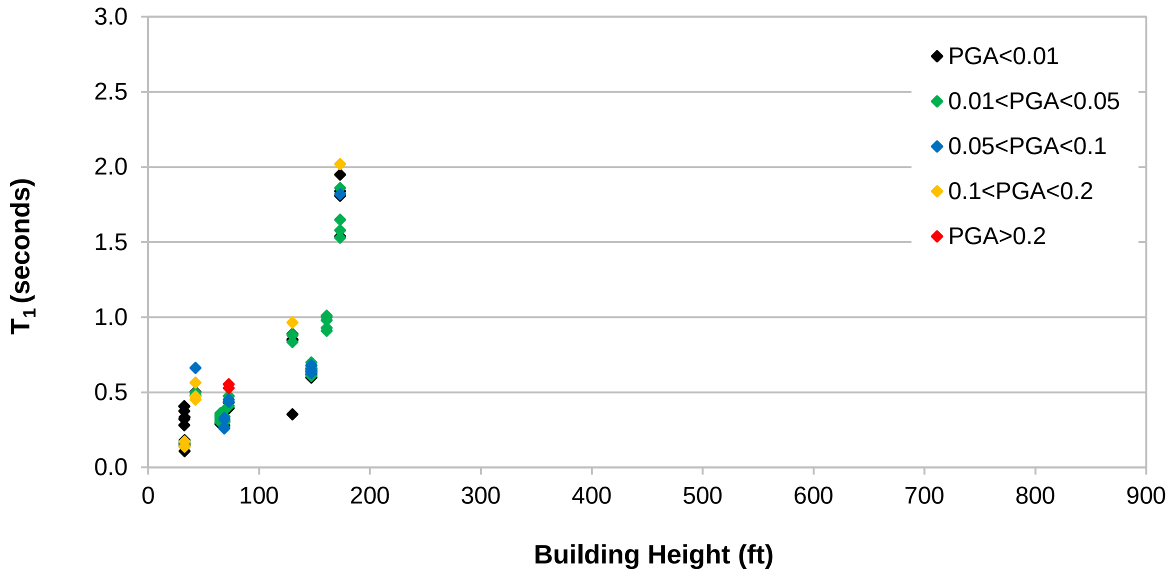


Figure 2-5: Variation of Fundamental Period with Height (CBF)

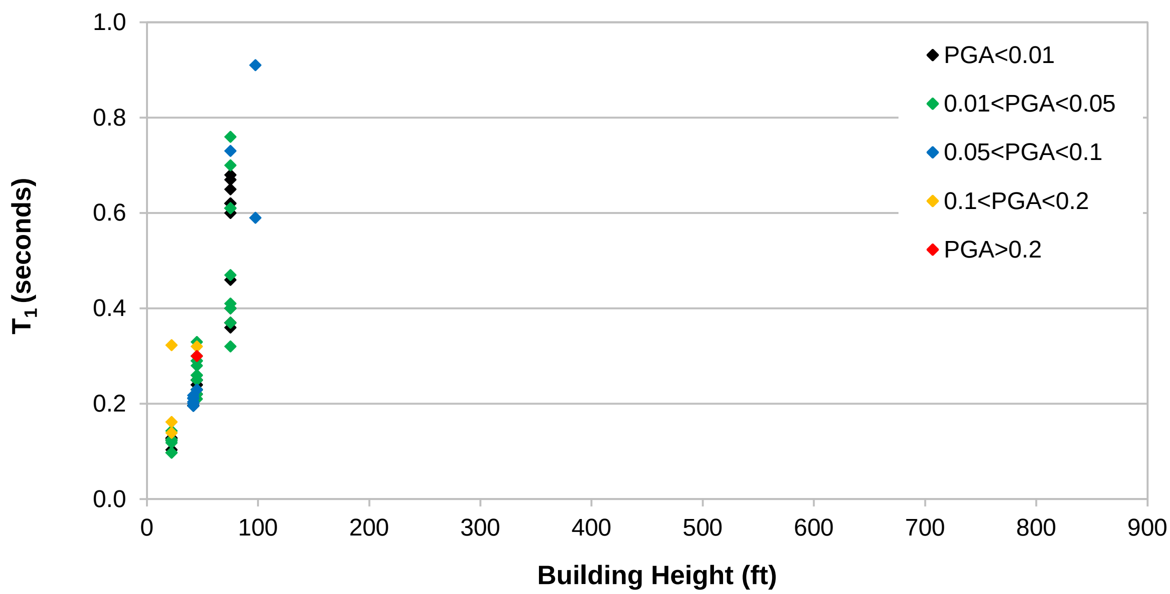


Figure 2-6: Variation of Fundamental Period with Height (MAW)

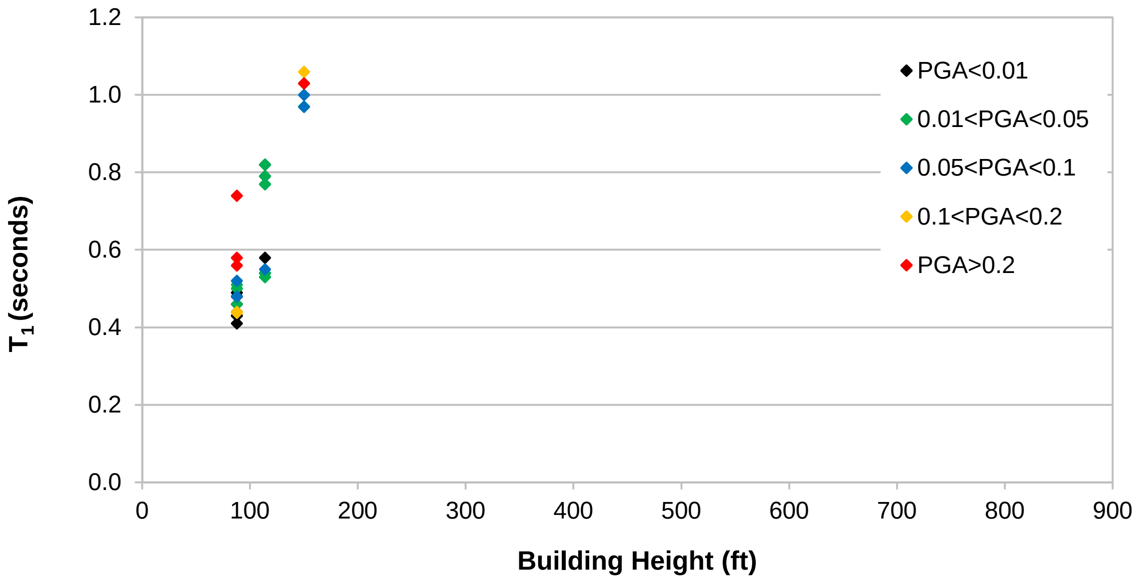


Figure 2-7: Variation of Fundamental Period with Height (PCW)

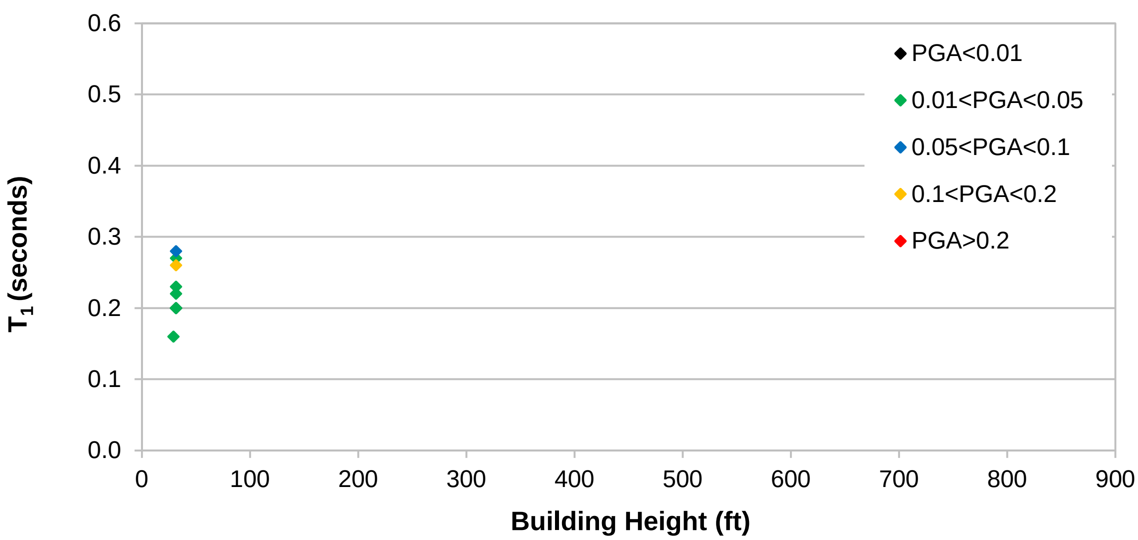


Figure 2-8: Variation of Fundamental Period with Height (RCTUW)

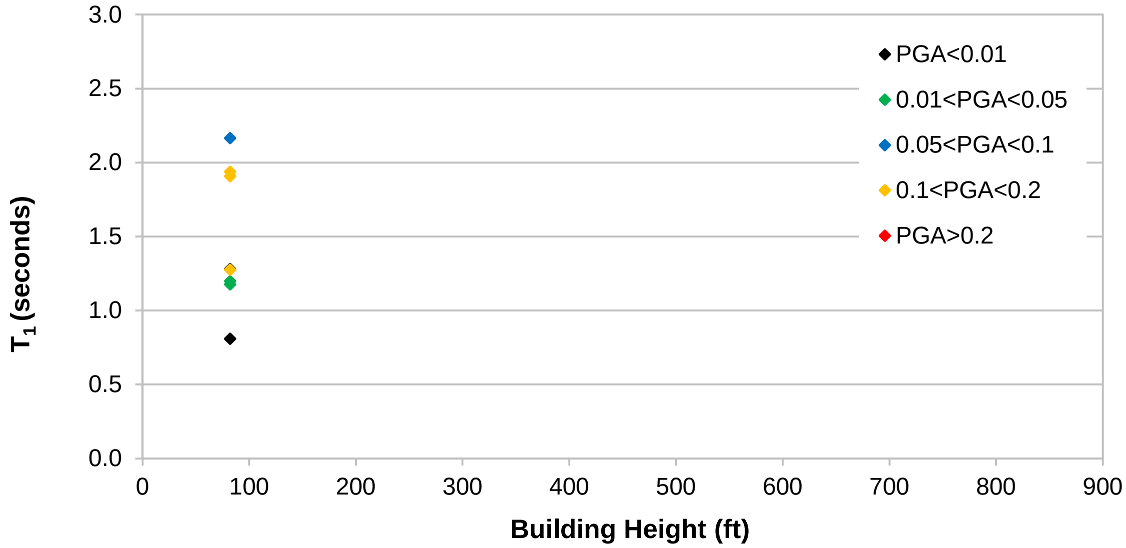


Figure 2-9: Variation of Fundamental Period with Height (URM)

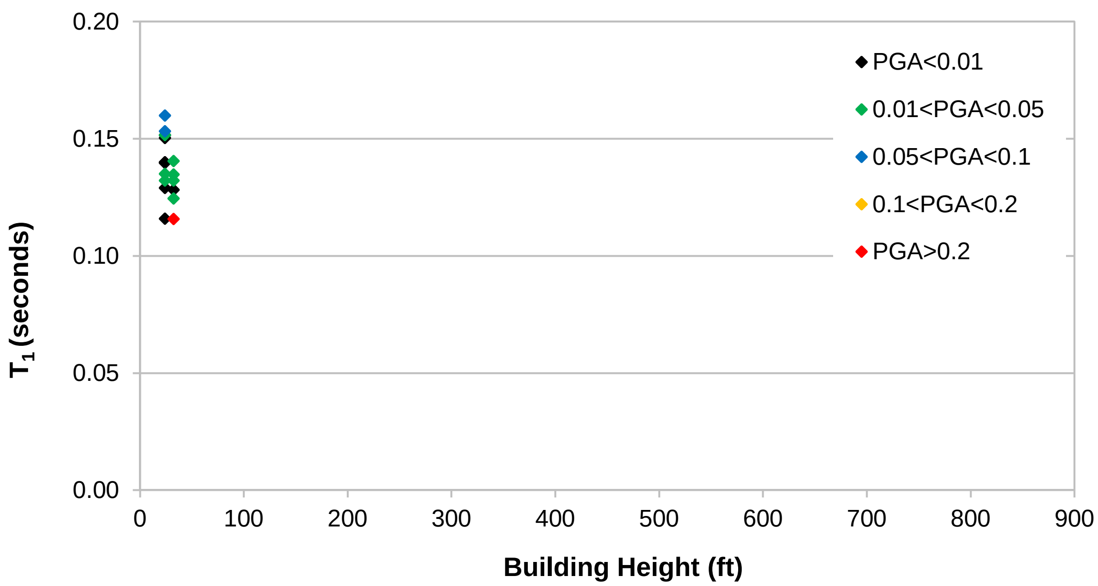


Figure 2-10: Variation of Fundamental Period with Height (WOOD)

Chopra (2012) suggests that the ratio of the beam to column stiffness dictates, not only the building response behavior, but also the ratio of subsequent periods to the fundamental period. Based on the suggestion, as this stiffness ratio increases, a building transitions from flexural dominant to shear dominant behavior; thus, increasing the period ratio. However, this trend was not evident in this study due to the high variation of the 2nd mode period. Similar to Lagomarsino (1993), we discovered the period ratio for most LFRS ranged between 0.2 and 0.4, averaging around 0.3, which is characteristic of prismatic shear cantilever beams. Buildings below 150 feet experienced higher variability in the 2nd mode periods, which cause further variability in the ratio of the 2nd mode period to the 1st mode period (Figures 2-11 through 2-20). This may be the result of low-rise buildings experiencing low intensity ground motions which do not fully excite the 2nd mode. As a result, the response behavior of individual LFRS types could not be concluded, making it difficult to predict subsequent mode period values based on the fundamental period.

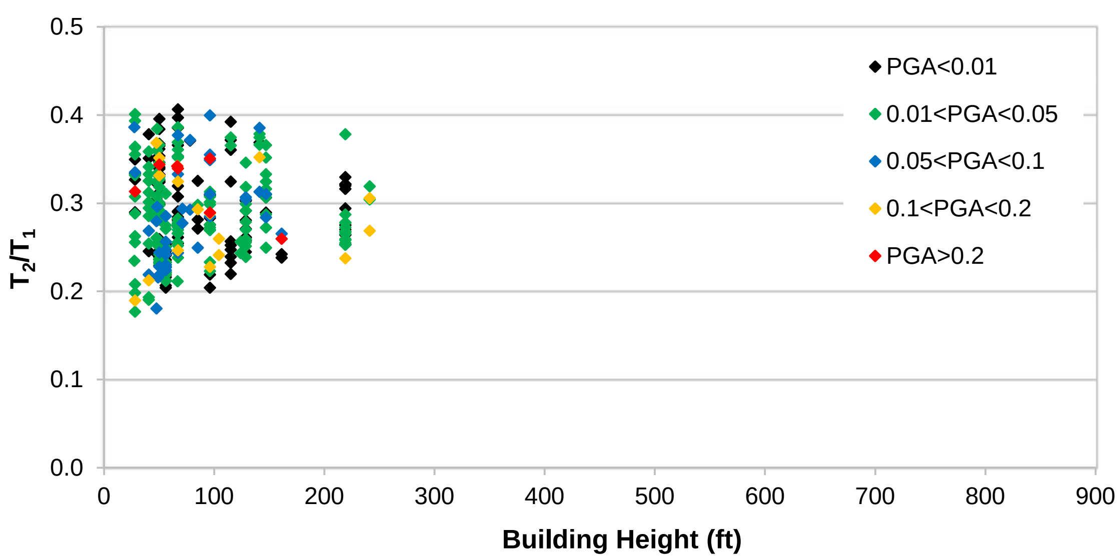


Figure 2-11: Variation of Period Ratio with Height (RCW)

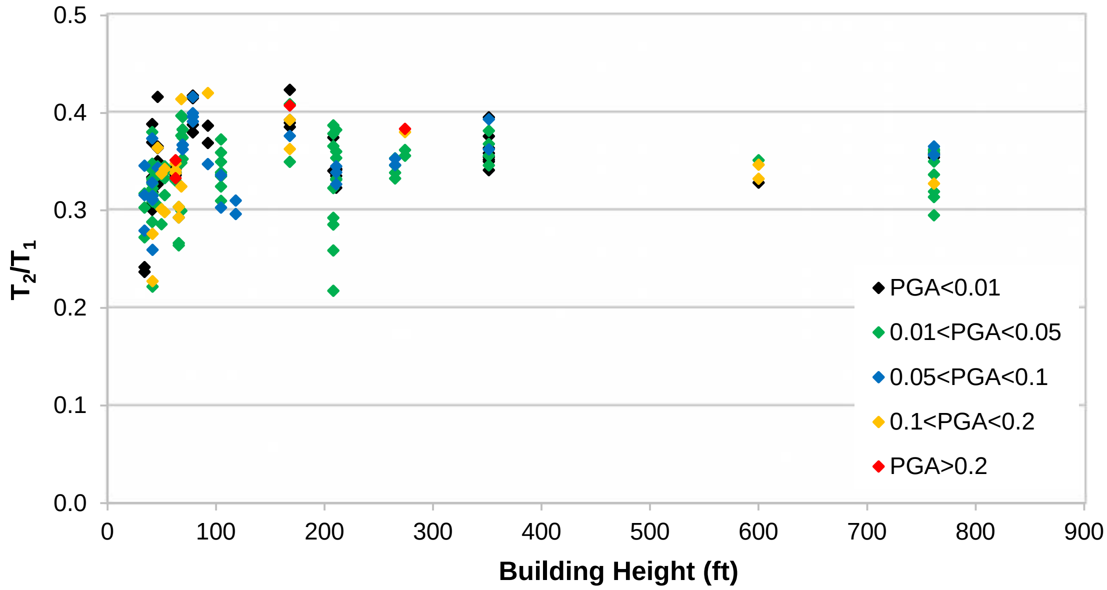


Figure 2-12: Variation of Period Ratio with Height (SMRF)

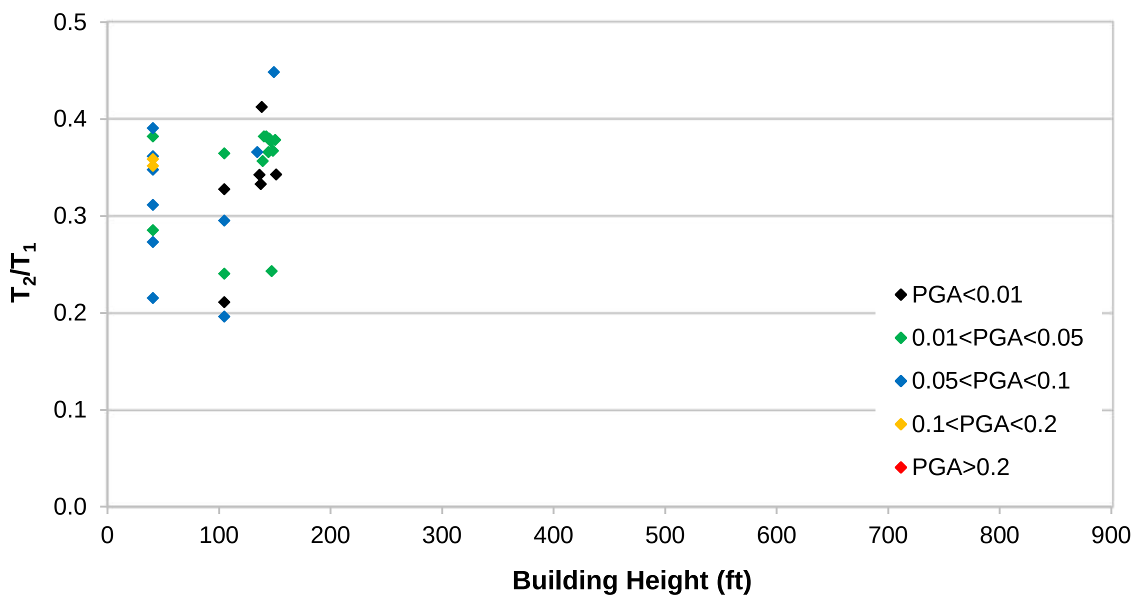


Figure 2-13: Variation of Period Ratio with Height (EBF)

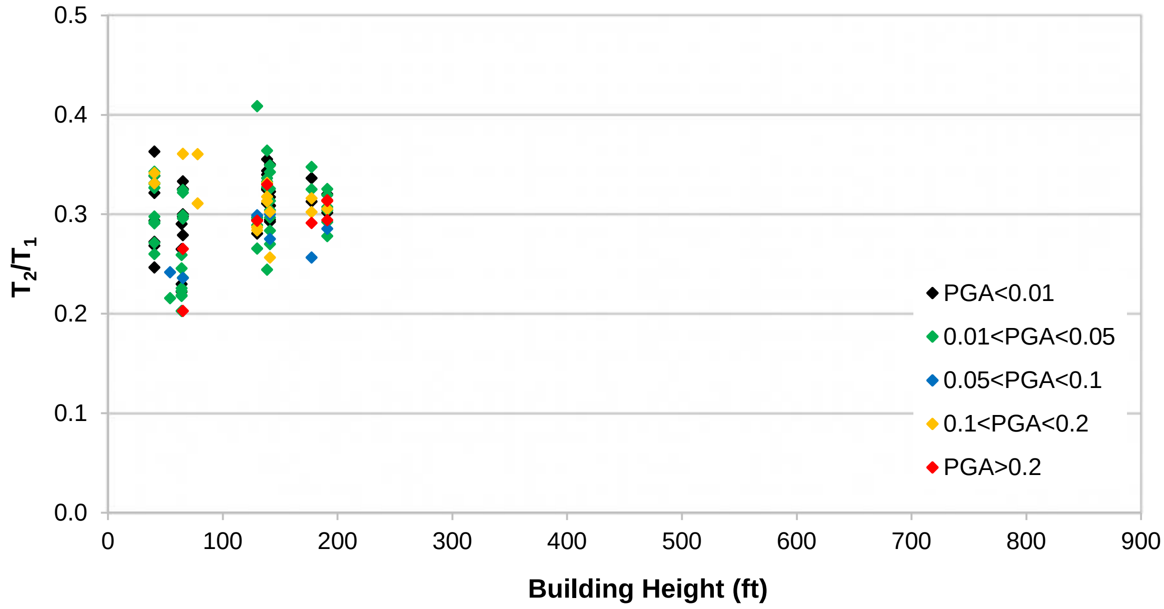


Figure 2-14: Variation of Period Ratio with Height (RCMRF)

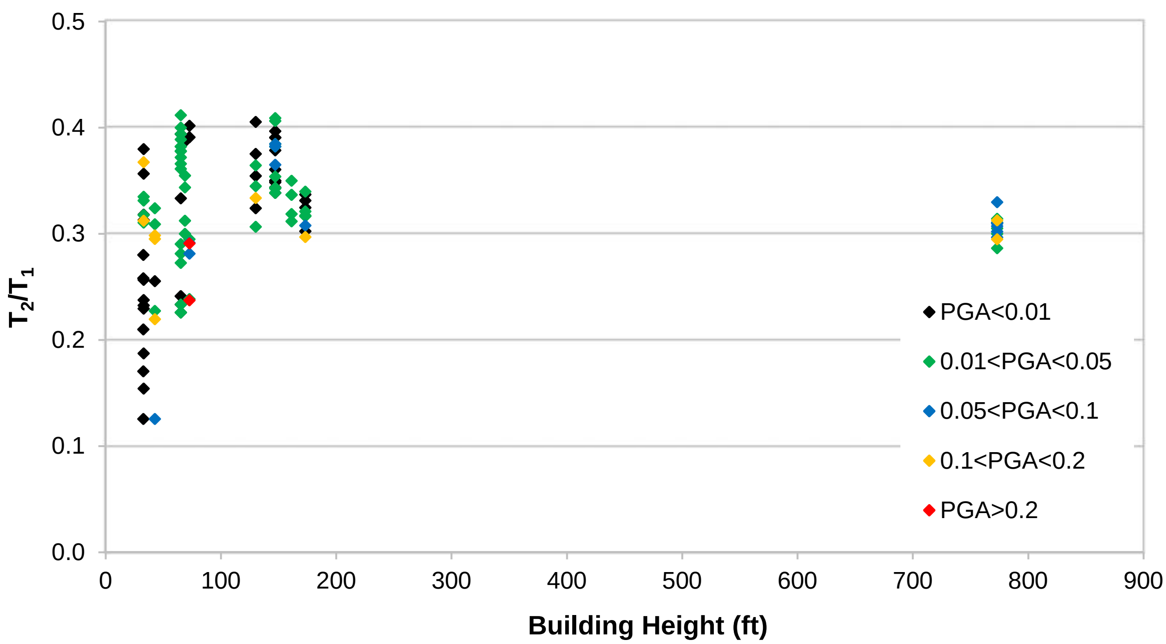


Figure 2-15: Variation of Period Ratio with Height (CBF)

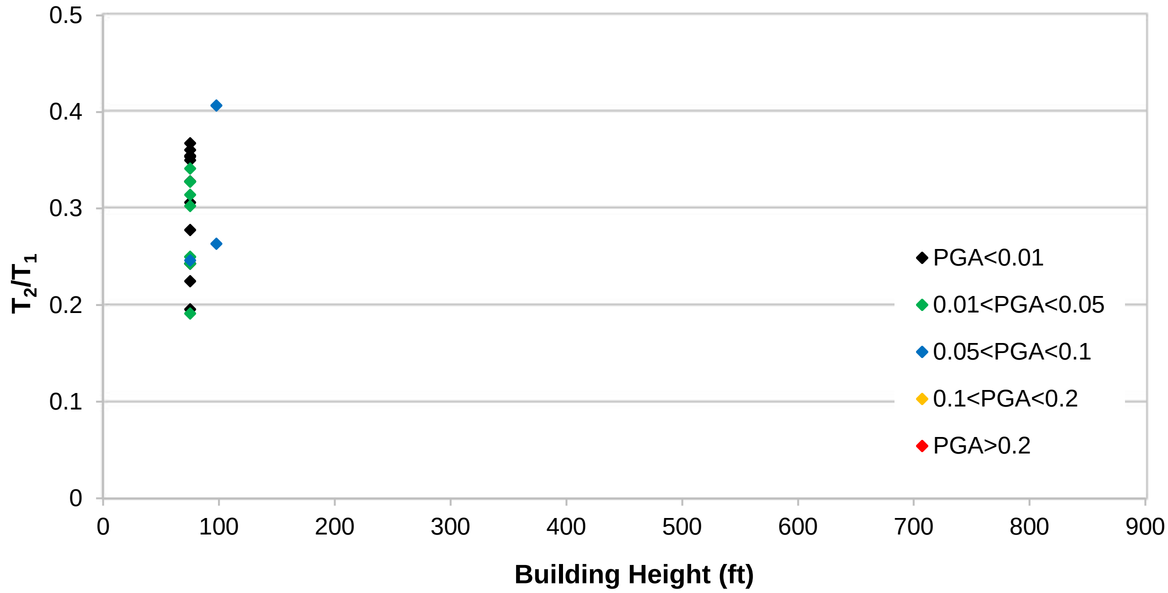


Figure 2-16: Variation of Period Ratio with Height (MAW)

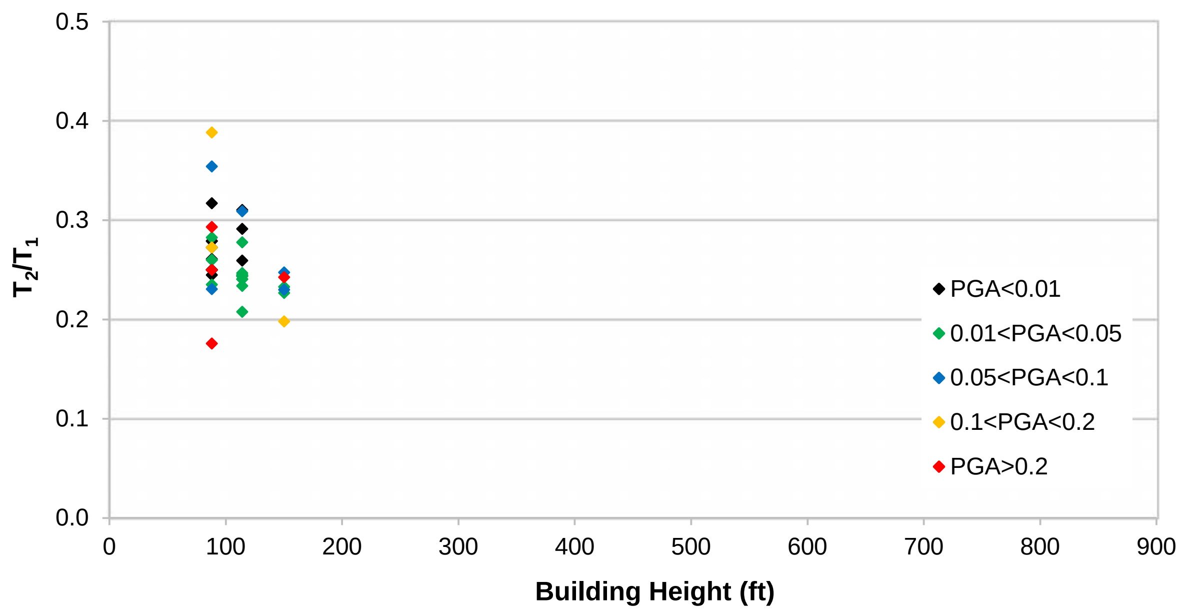


Figure 2-17: Variation of Period Ratio with Height (PCW)

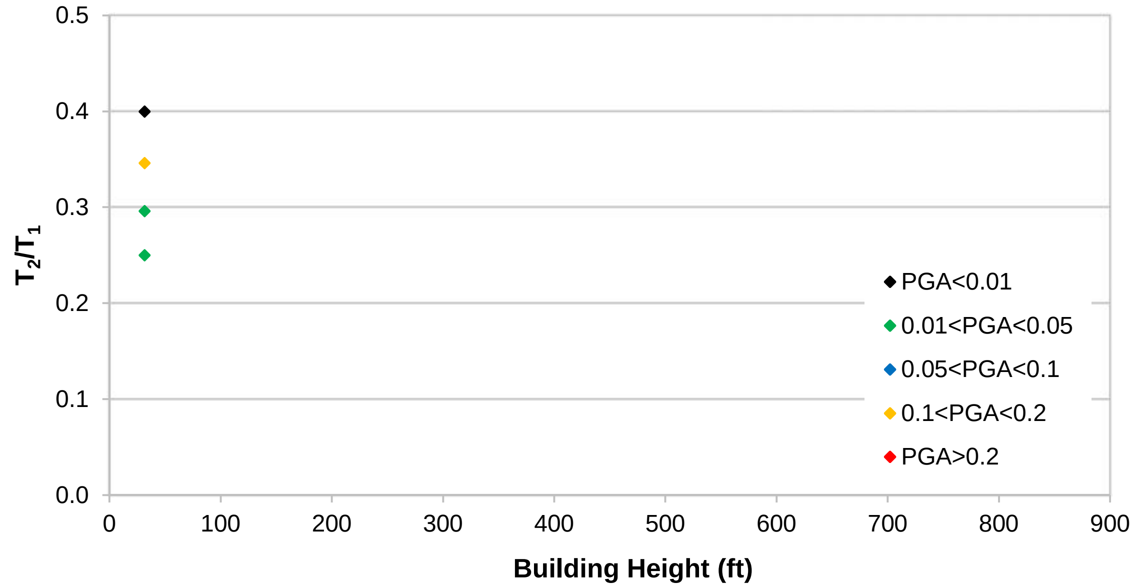


Figure 2-18: Variation of Period Ratio with Height (RCTUW)

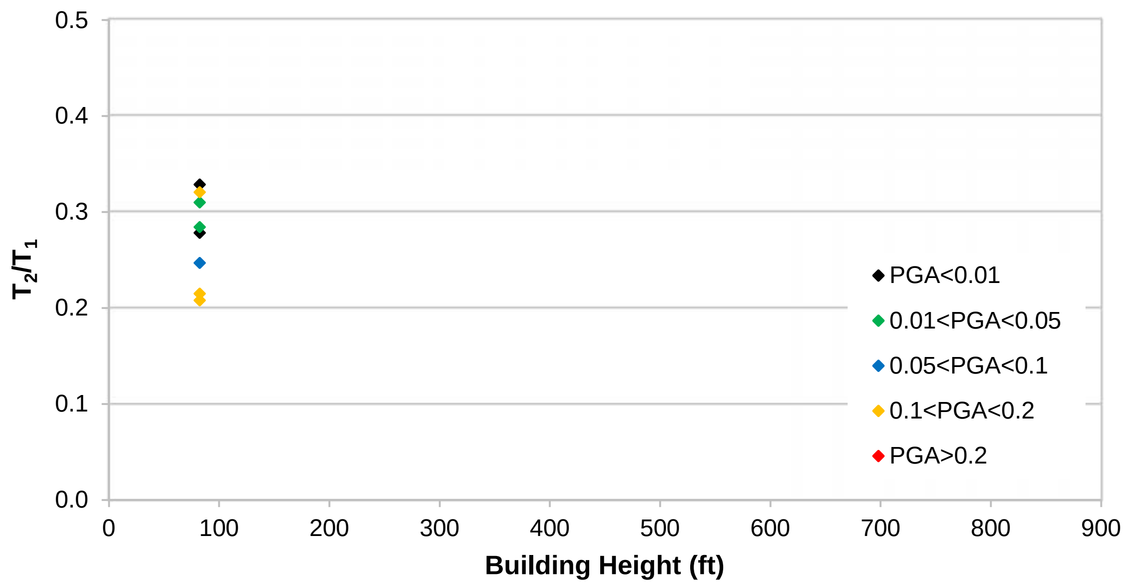


Figure 2-19: Variation of Period Ratio with Height (URM)

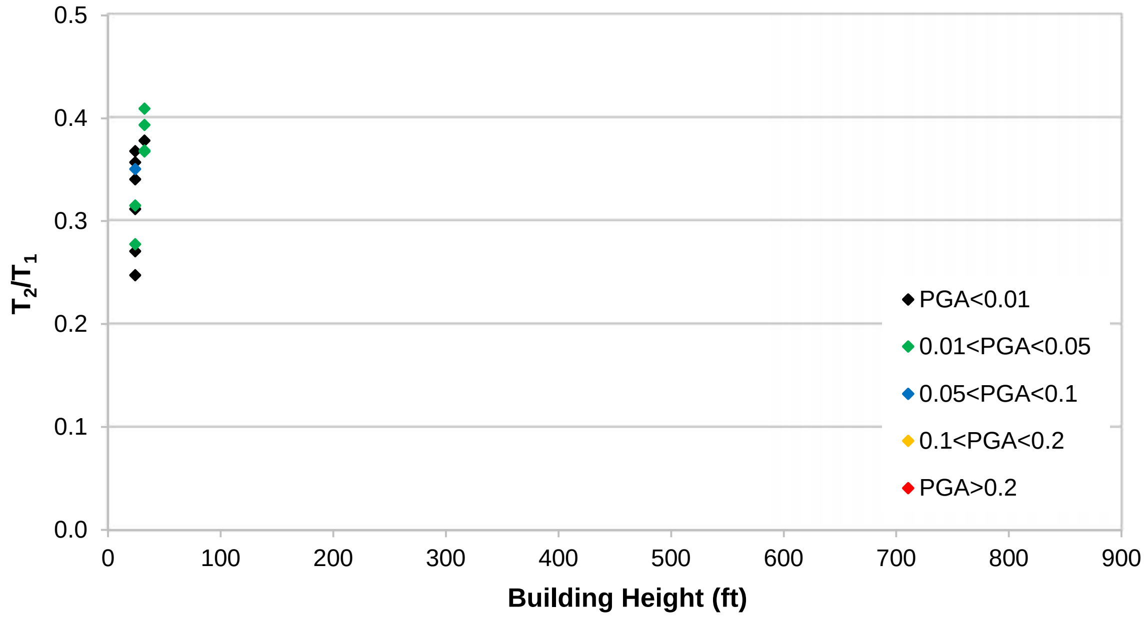


Figure 2-20: Variation of Period Ratio with Height (WOOD)

In the past, system identification has proven to be a reliable method of period estimation. As a result, codes equations have been formulated based on previous system identification studies. These codes and standards have been developed to simplify the approximation of building periods prior to the use of computational software. The Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-10, approximates building periods based on the LRFS type and building height using the following equation

$$T_a = C_t h_n^x \tag{2-64}$$

where h is the building height and C_t and x are parameters defined based on the LRFS type as shown in Table 2-21.

Structure Type	C_t	x
Moment-resisting frame systems in which the frames resist 100% of the required seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting where subjected to seismic forces:		
Steel moment-resisting frames	0.028 (0.0724)[a]	0.8
Concrete moment-resisting frames	0.016 (0.0466)[a]	0.9
Steel eccentrically braced frames in accordance with Table 12.2-1 lines B1 or D1	0.03 (0.0731)[a]	0.75
Steel buckling-restrained braced frames	0.03 (0.0731)[a]	0.75
All other structural systems	0.02 (0.0488)[a]	0.75

[a]Metric equivalents are shown in parentheses.

Figure 2-21: Values of Approximate Period Parameters C_t and x (ASCE/SEI 7-10)

As shown in Figures 2-22 through 2-31, when comparing the coefficient, C_t, provided in the ASCE/SEI 7-10 and that derived from the estimated periods of this study, one can see that the code provided C_t is generally the average of the C_t values determined for the RCW, SMRF, RCMRF, CBF, MAW, and PCW buildings. However, the remainder of the LRFS types either have average C_t values either higher or lower than that of the C_t suggested by the ASCE 7-10. This may be due to the fact that RCMRF, SMRF, and EBF buildings are the only LRFS types with specific C_t and x parameters; whereas the remaining LFRS types have blanket C_t and x parameters of 0.02 and 0.75, respectively. One can assume that these blanket parameters may not be applicable to all remaining LRFS types.

In addition, the discrepancy in C_t may due to the lack of available data for EBF, RCTUW, URM, and WOOD buildings. These systems have significantly less buildings compared to that of the RCW, RCMRF, CBF, MAW, and PCW buildings. Additional data is necessary to determine the applicability of C_t to these systems. However, C_t is satisfactory parameter when approximating periods based on the building LRFS and height for RCW, RCMRF, CBF, MAW, and PCW building types.

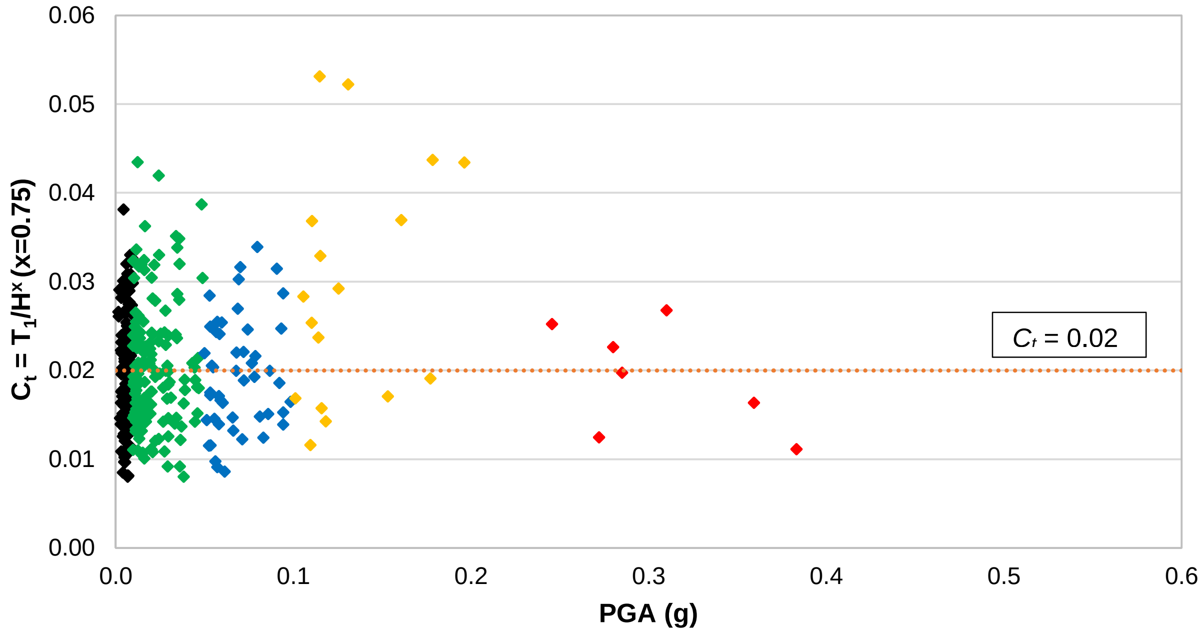


Figure 2-22: Variation of Code C_t with PGA (RCW)

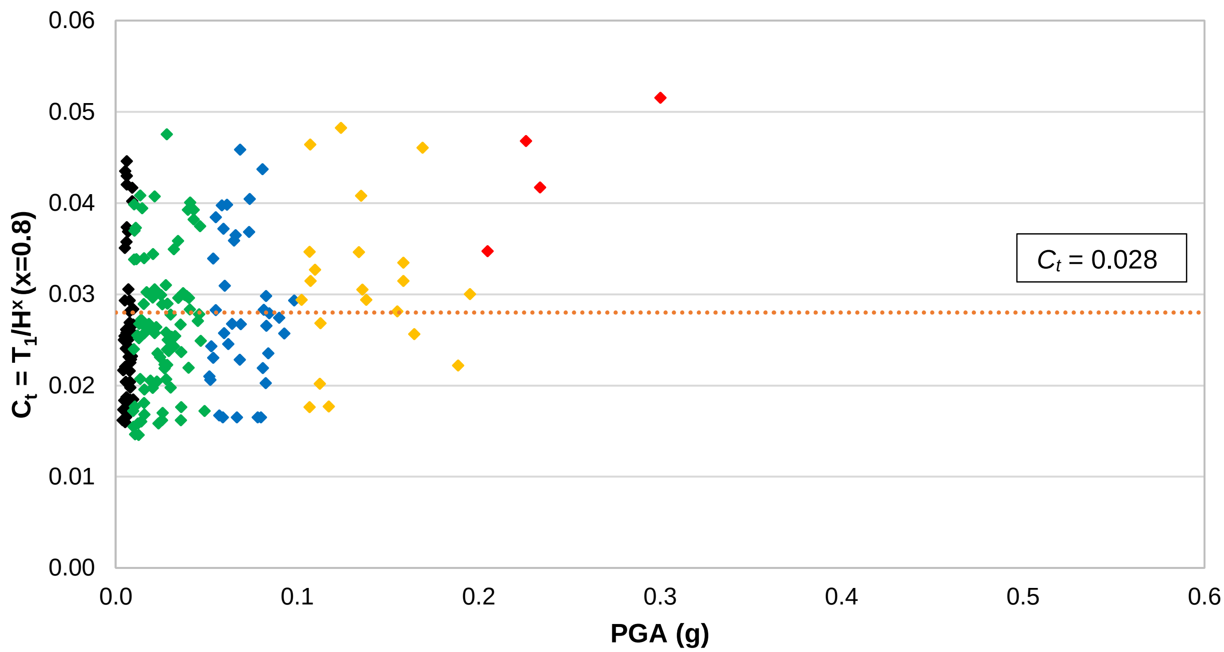


Figure 2-23: Variation of Code C_t with PGA (SMRF)

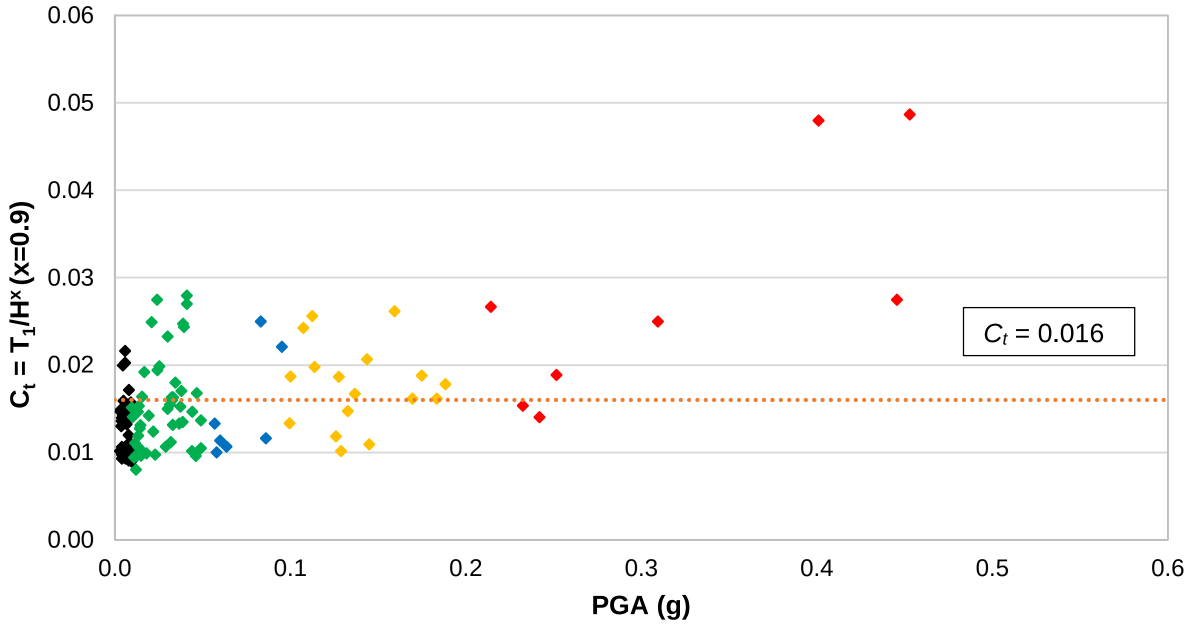


Figure 2-24: Variation of Code C_t with PGA (RCMRF)

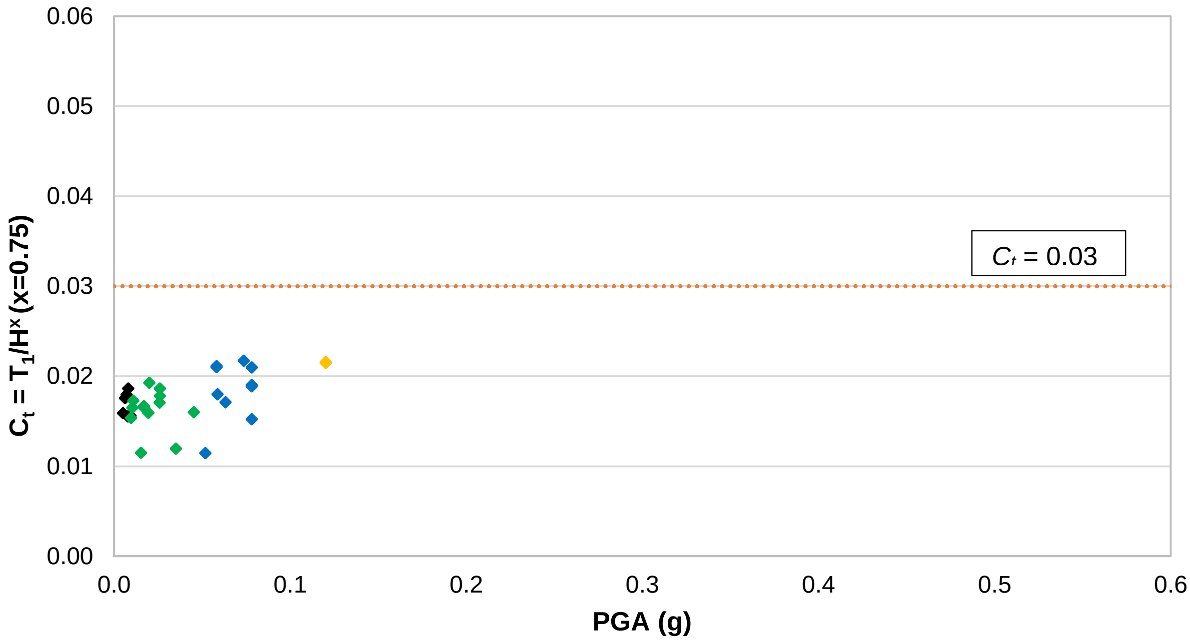


Figure 2-25: Variation of Code C_t with PGA (EBF)

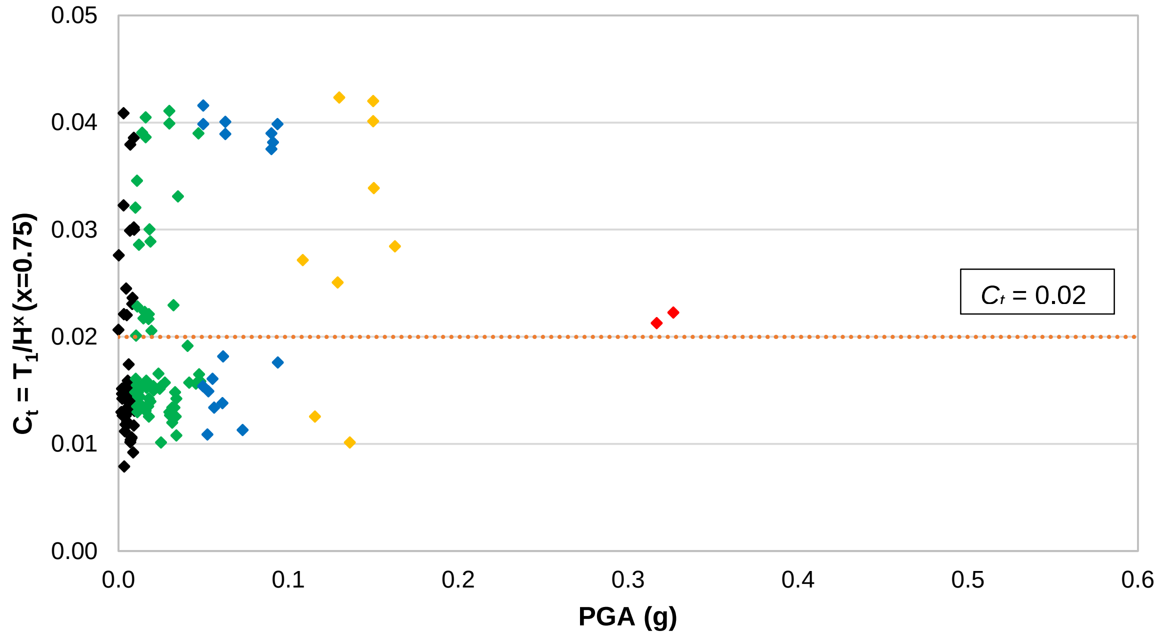


Figure 2-26: Variation of Code C_t with PGA (CBF)

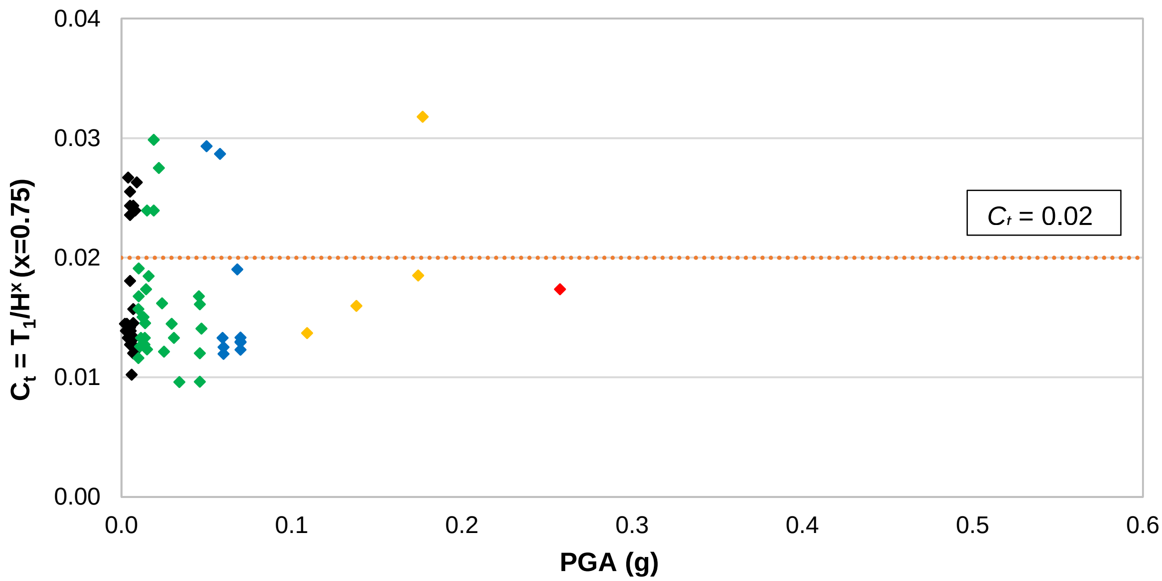


Figure 2-27: Variation of Code C_t with PGA (MAW)

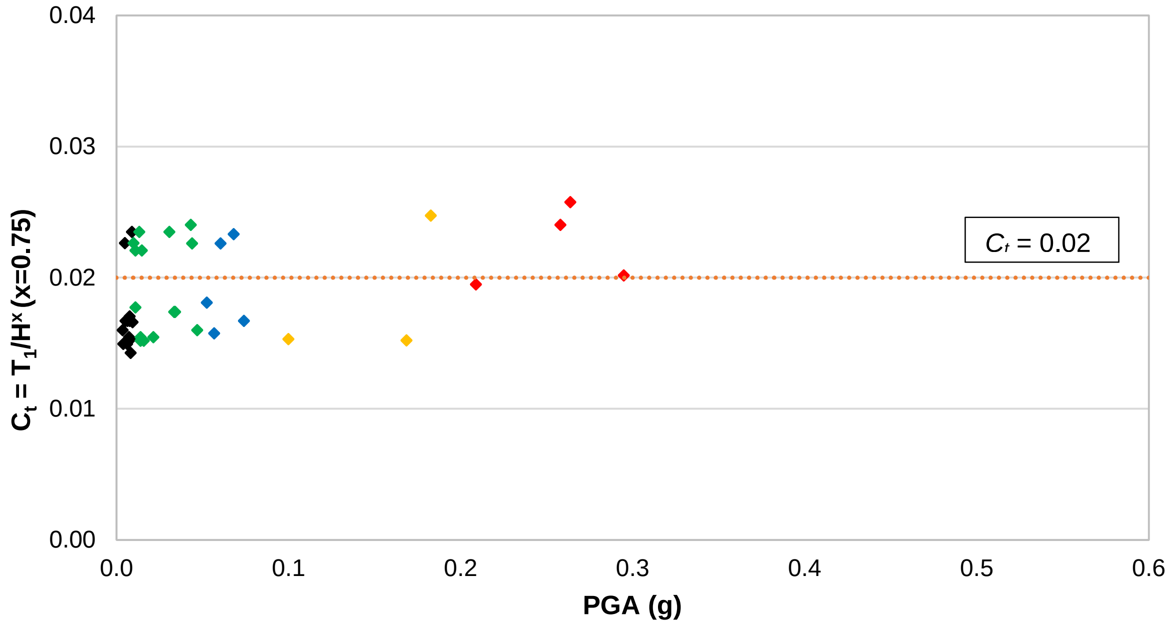


Figure 2-28: Variation of Code C_t with PGA (PCW)

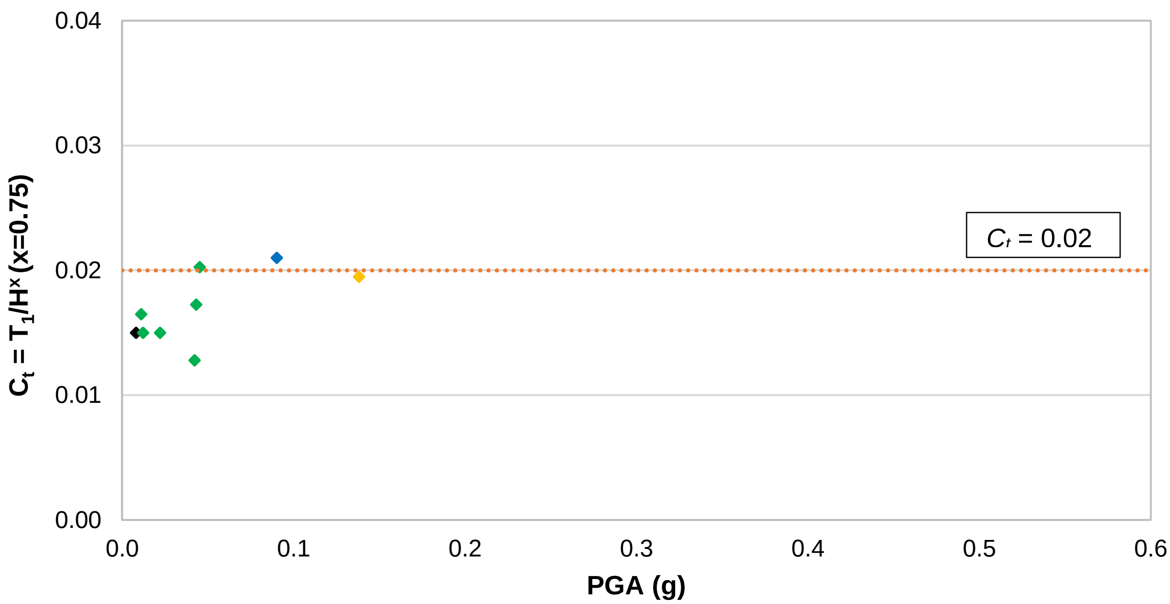


Figure 2-29: Variation of Code C_t with PGA (RCTUW)

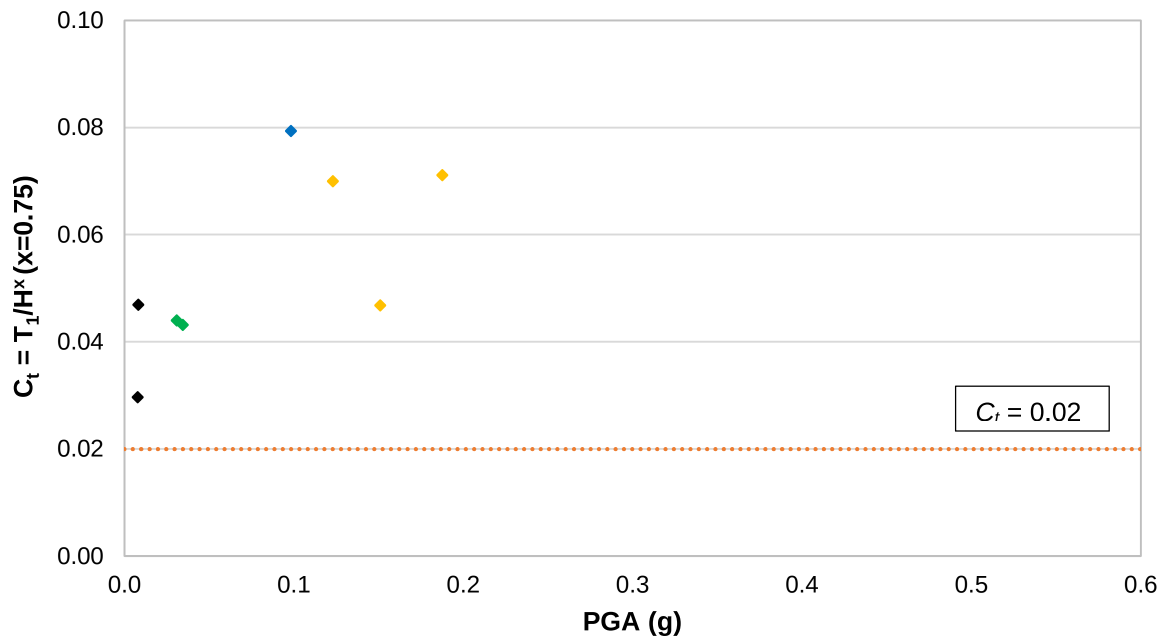


Figure 2-30: Variation of Code C_t with PGA (URM)

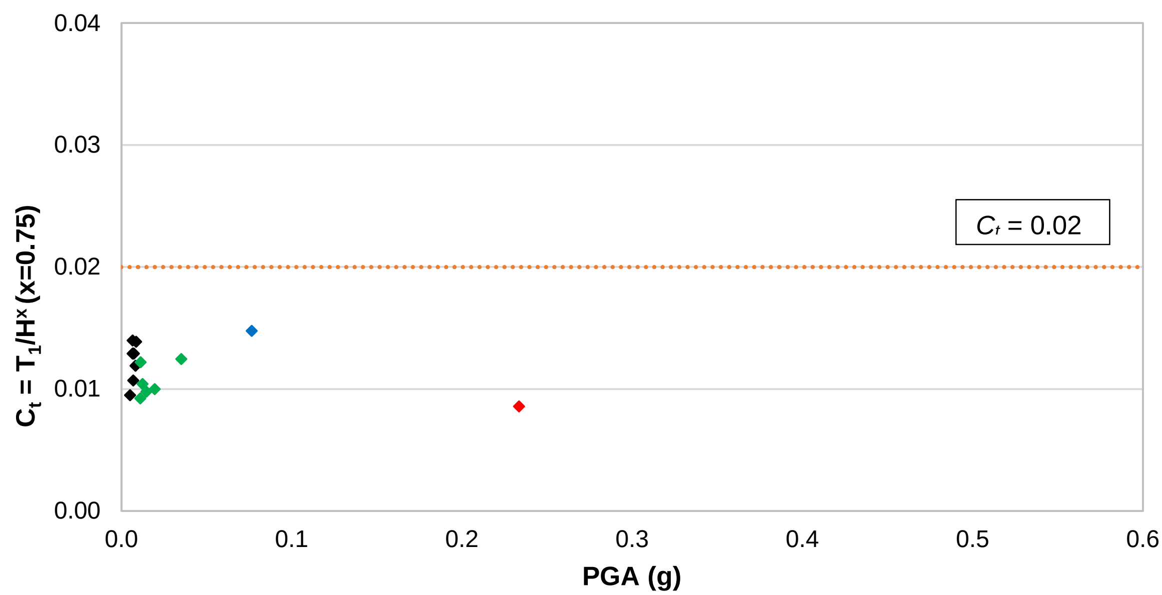


Figure 2-31: Variation of Code C_t with PGA (WOOD)

2.3.2 Damping

The damping ratios estimated through system identification were in most cases variable. The damping ratios generally range between %1 and %7 for most LFRSs. The average damping values for RCW, SMRF, RCMRF, EBF, CBF, MAW, PCW, RCTUW, URM, and WOOD structures are %2.8, %3.7, %3.4, %2.4, %2.4, %2.1, %2.6, %3.0, %5.8, and %2.5, respectively. These values are consistent with the damping values recommended by the ASCE/SEI 7-10 and the FEMA 58-1 between %1 and %5. Figures 2-32 through 2-41 shows the variation of ζ_1 to building height. It is evident from the figure that estimation of the modal values is associated with high level of variability. Nevertheless, the damping ratio, ζ_1, of RCW, SMRF, and EBF buildings decrease with height as observed in previous research (Satake et al., 2003; Bernal et al., 2012). The damping ratios of the remaining LFRS types remain constant due to the majority of low-rise buildings within those building categories.

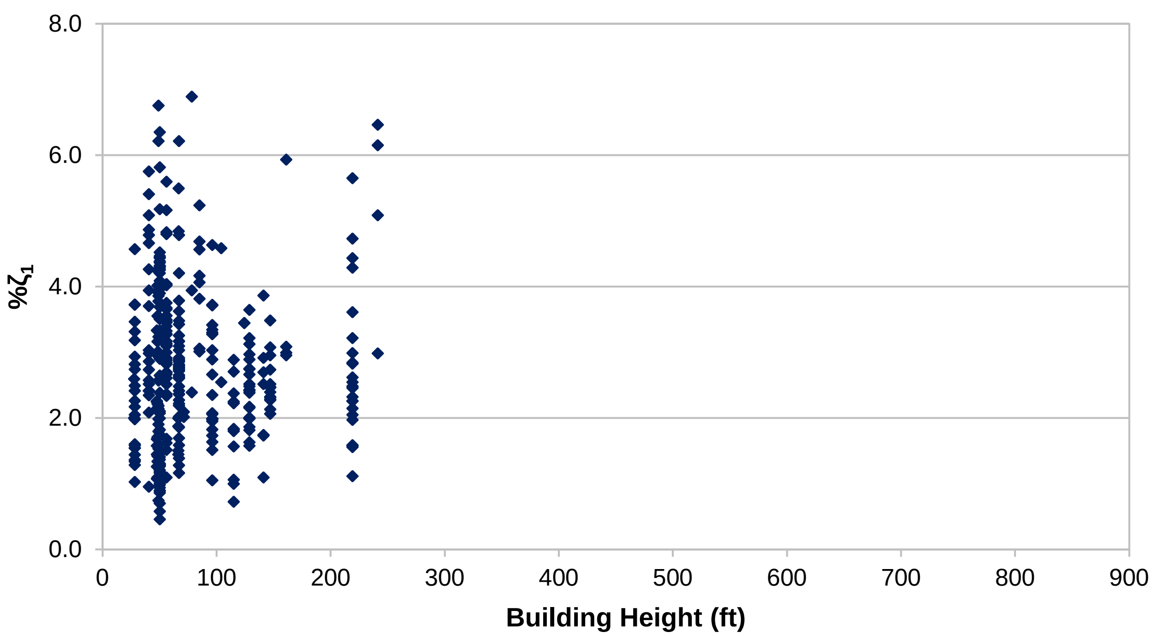


Figure 2-32: Variation of First Mode Damping with Height (RCW)

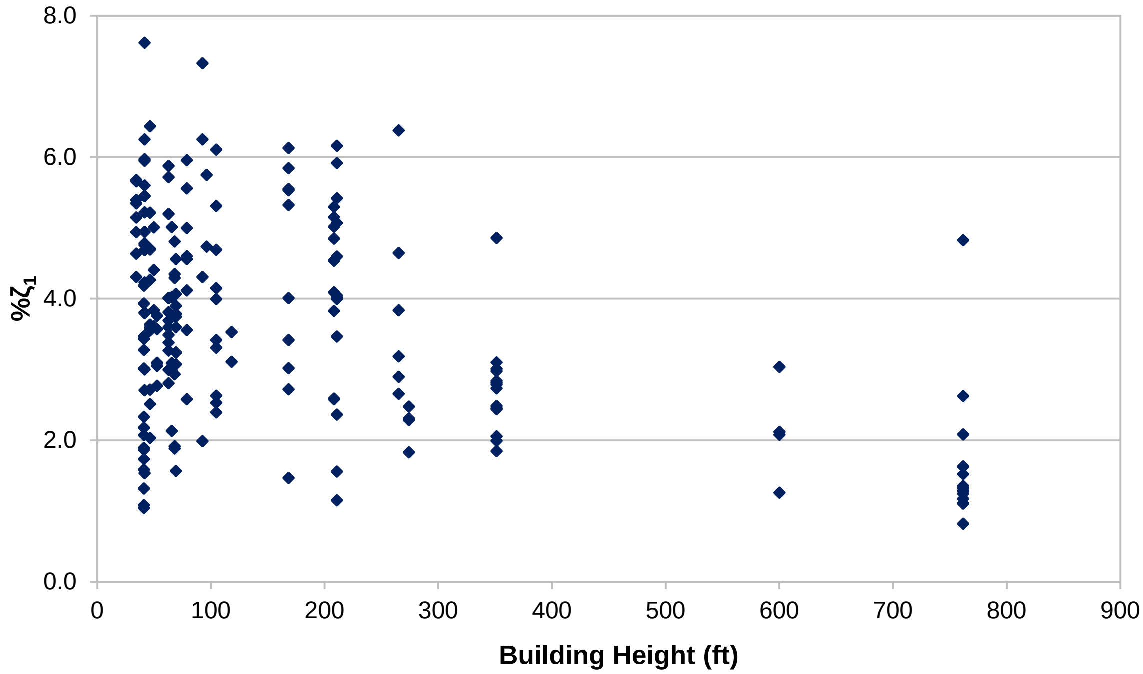


Figure 2-33: Variation of First Mode Damping with Height (SMRF)

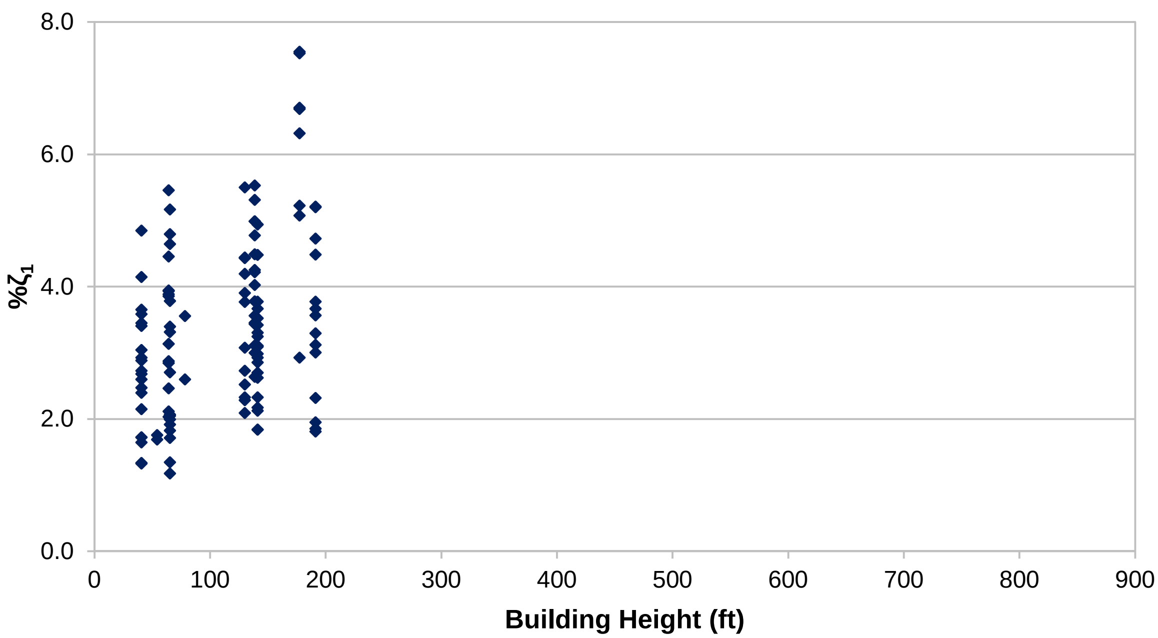


Figure 2-34: Variation of First Mode Damping with Height (RCMRF)

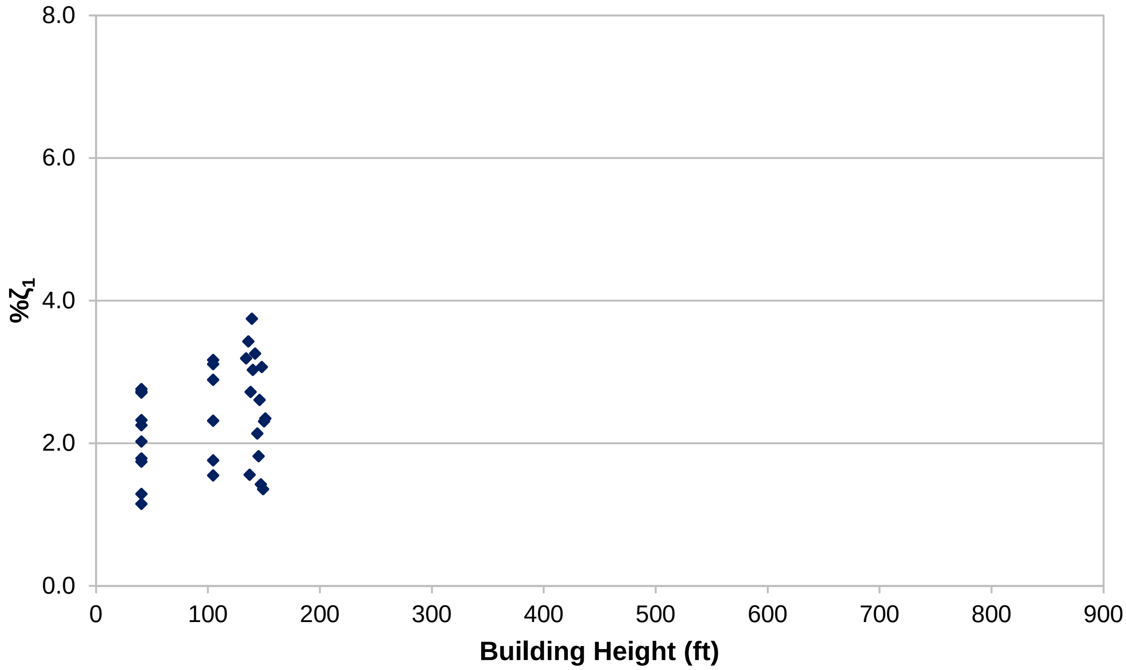


Figure 2-35: Variation of First Mode Damping with Height (EBF)

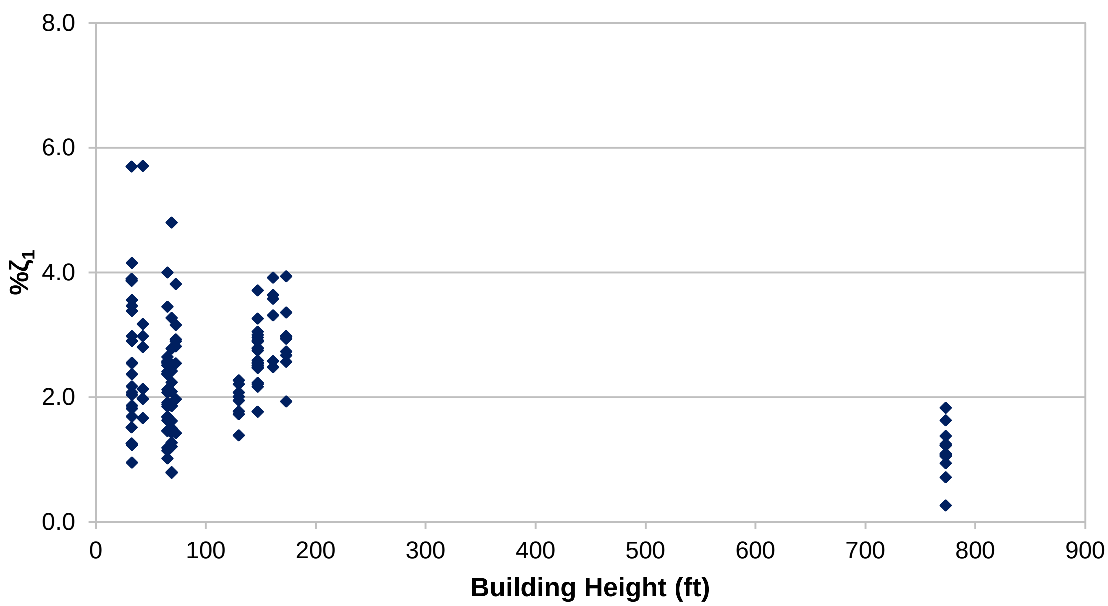


Figure 2-36: Variation of First Mode Damping with Height (CBF)

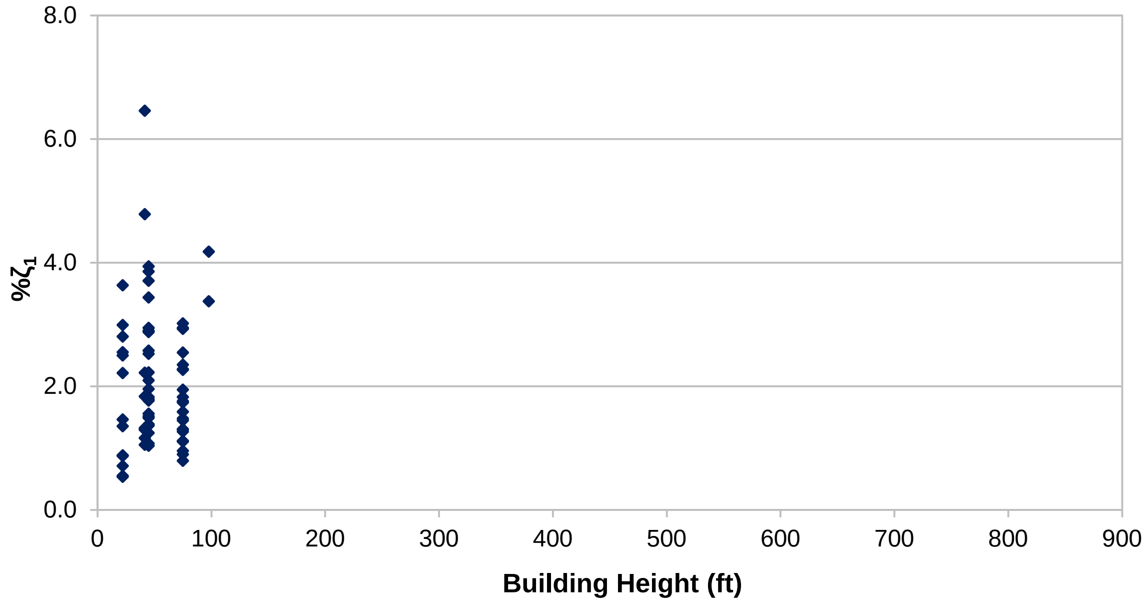


Figure 2-37: Variation of First Mode Damping with Height (MAW)

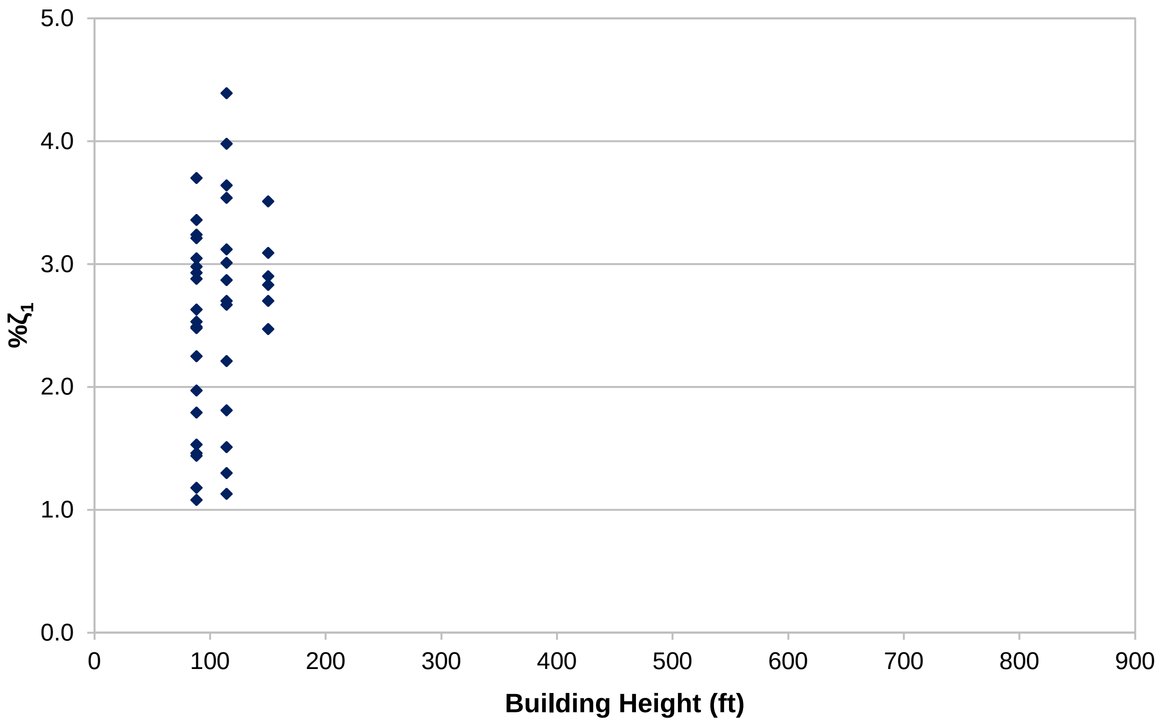


Figure 2-38: Variation of First Mode Damping with Height (PCW)

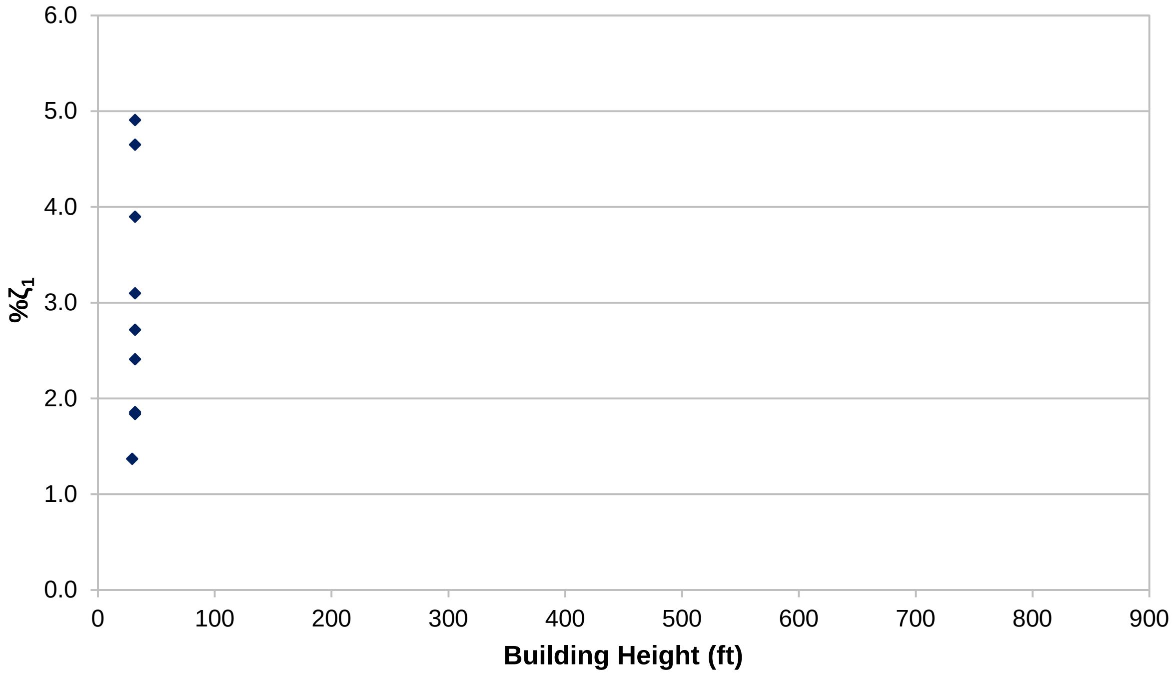


Figure 2-39: Variation of First Mode Damping with Height (RCTUW)

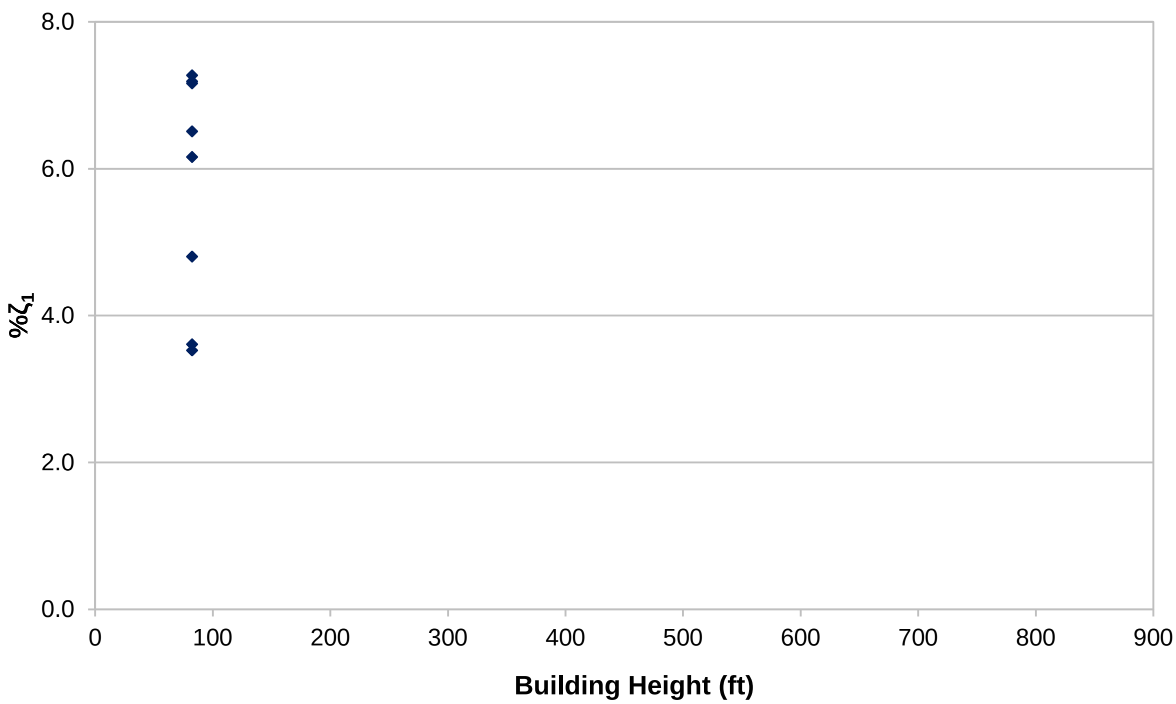


Figure 2-40: Variation of First Mode Damping with Height (URM)

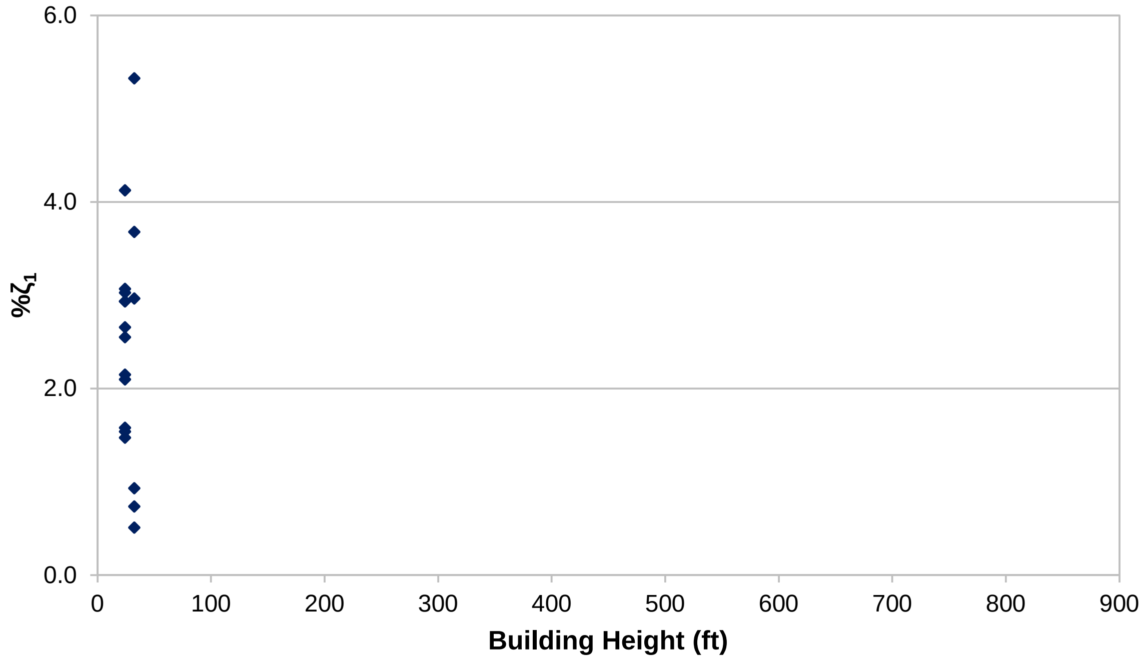


Figure 2-41: Variation of First Mode Damping with Height (WOOD)

When comparing the estimated damping ratios with suggested expressions given in Table 2-1, the trends are in general agreement. Similarly, the damping ratio, ζ_1, decreases with the increase in natural period for the SMRF and CBF data sets (Figures 2-43 and 2-46), which is concurrent with previous studies (Satake et al., 2003; Lagomarsino 1993; Zhang & Cho, 2009; Sasaki, 1998). This trend could not be fully detected for the RCW, RCMRF, EBF, PCW, and RCTUW buildings (Figures 2-42, 2-44, 2-45, 2-48, and 2-49, respectively). Regression expressions specifically formulated for masonry structures are not available, which explains the lack of adherence of the MAW, URM, and WOOD (Figures 2-47, 2-50, and 2-51, respectively) to the general expression for damping ratios provided by Zhang and Cho (2009).

Table 2-1: Damping Expressions from Previous Studies

Expression	Source
$\varsigma_1 = 0.013 f_1$ (Steel) $\varsigma_1 = 0.014 f_1$ (Concrete)	Satake (2003)
$\varsigma_1 = \alpha' T_1 + \beta' / T_1$ $\alpha' = 0.3192$, $\beta' = 0.7813$ (Steel) $\alpha' = 0.7238$, $\beta' = 0.7026$ (RC)	Lagomarsino (1993)
$\varsigma_1 = 1.945 + 0.195 T_1^{-3.779}$	Zhang & Cho (2009)
$\varsigma_1 = 0.013 f_1 + 0.0029$	Sasaki (1998)

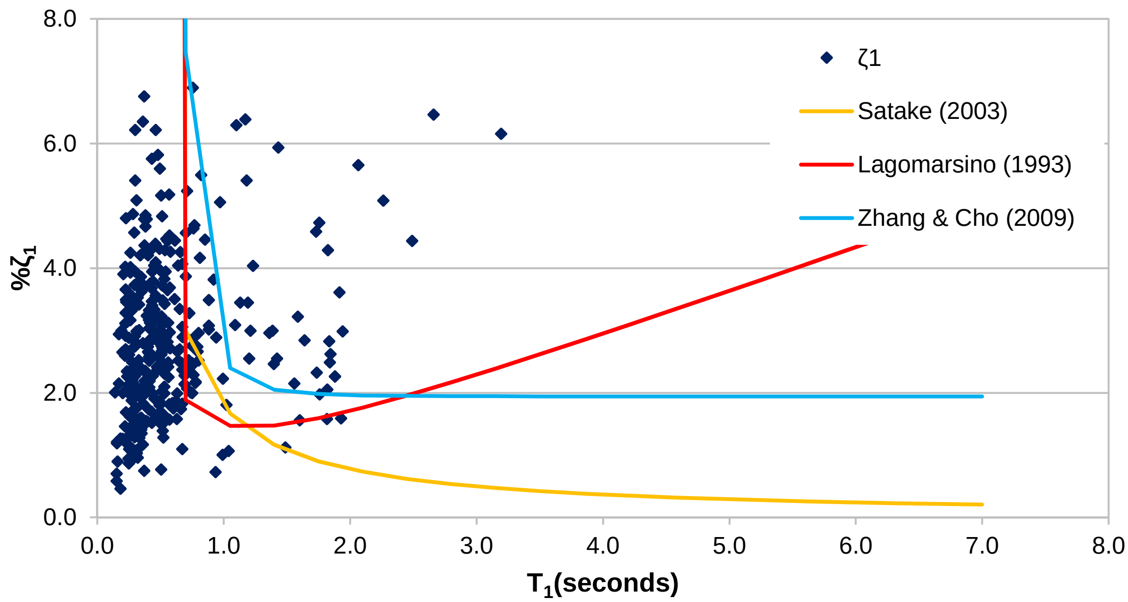


Figure 2-42: Variation of First Mode Damping with the Fundamental Period (RCW)

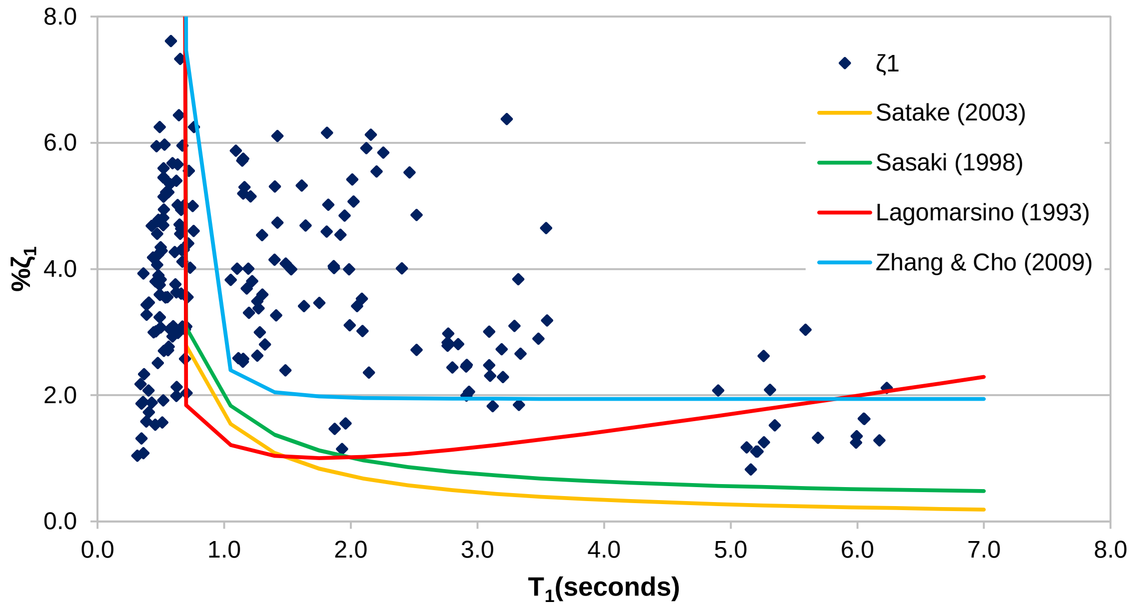


Figure 2-43: Variation of First Mode Damping with the Fundamental Period (SMRF)

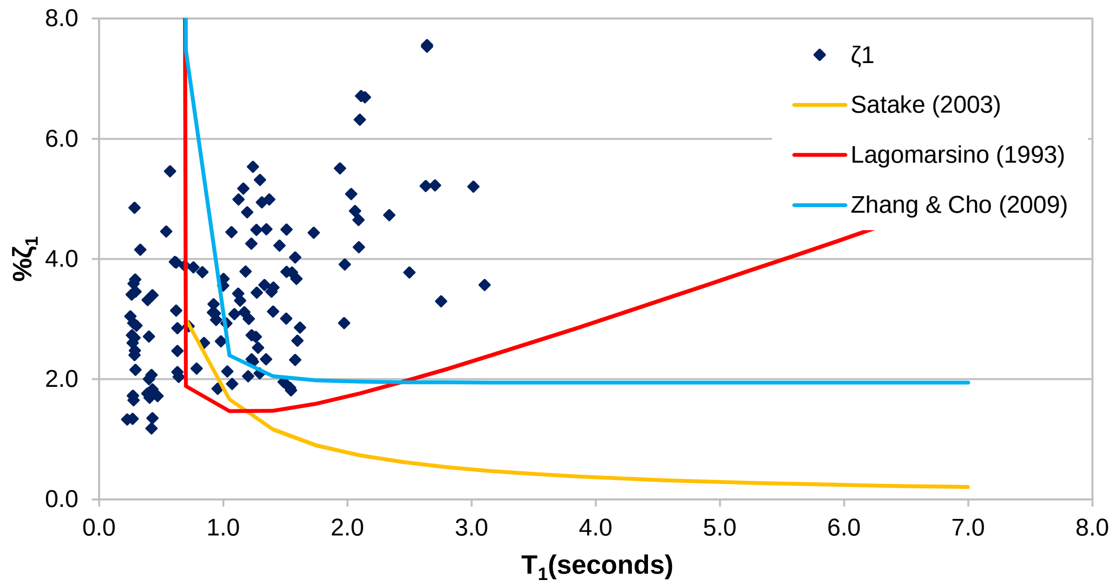


Figure 2-44: Variation of First Mode Damping with the Fundamental Period (RCMRF)

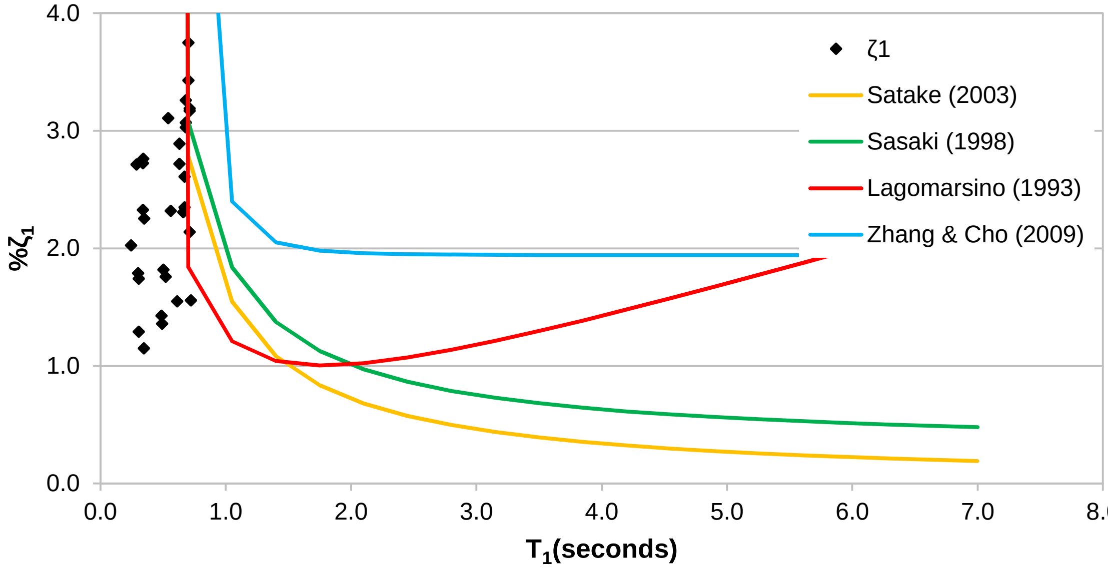


Figure 2-45: Variation of First Mode Damping with the Fundamental Period (EBF)

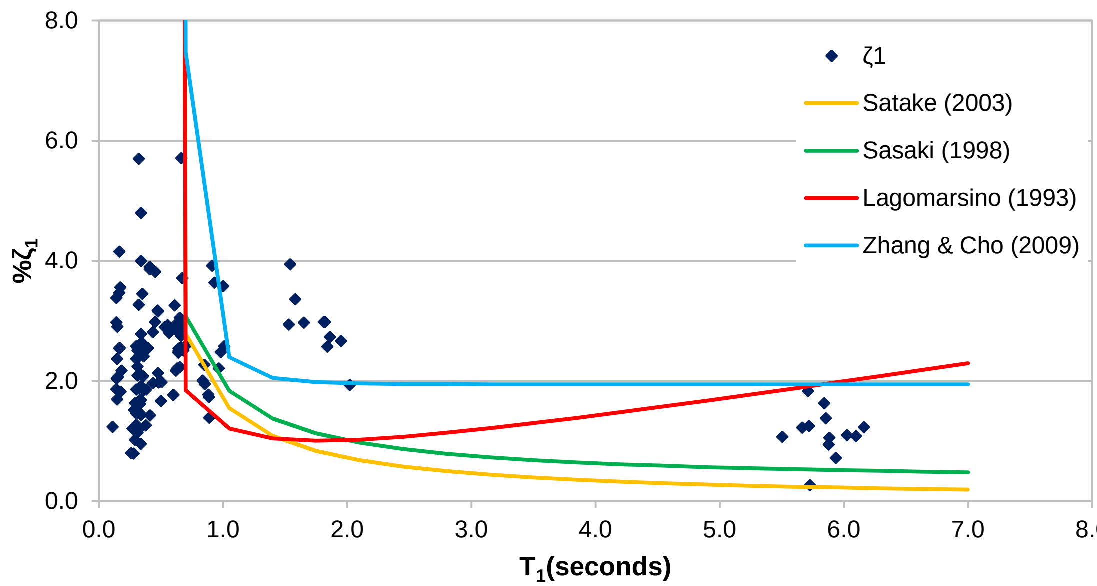


Figure 2-46: Variation of First Mode Damping with the Fundamental Period (CBF)

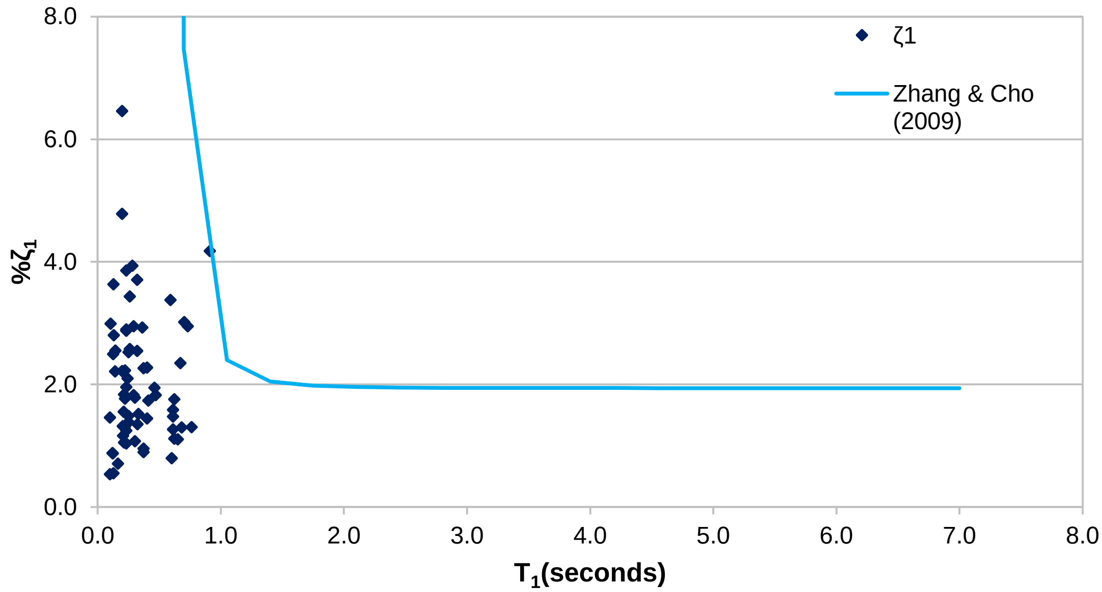


Figure 2-47: Variation of First Mode Damping with the Fundamental Period (MAW)

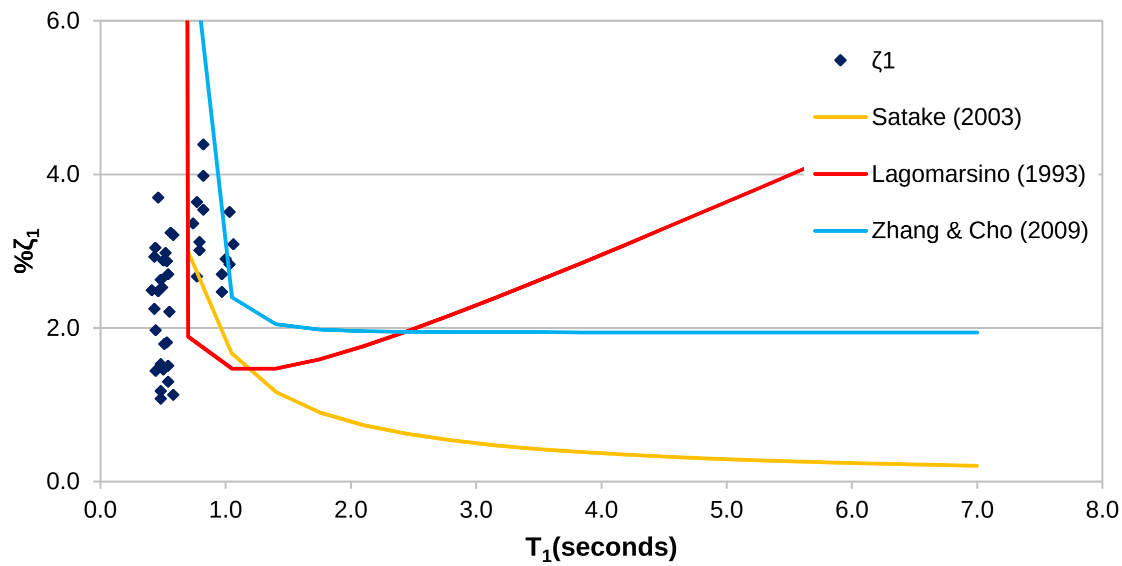


Figure 2-48: Variation of First Mode Damping with the Fundamental Period (PCW)

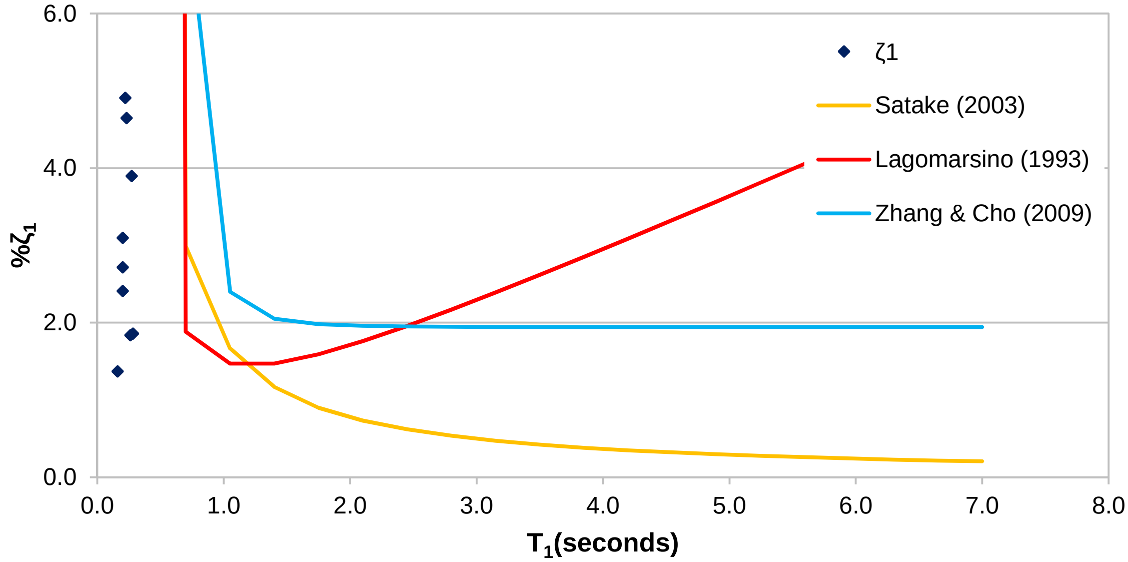


Figure 2-49: Variation of First Mode Damping with the Fundamental Period (RCTUW)

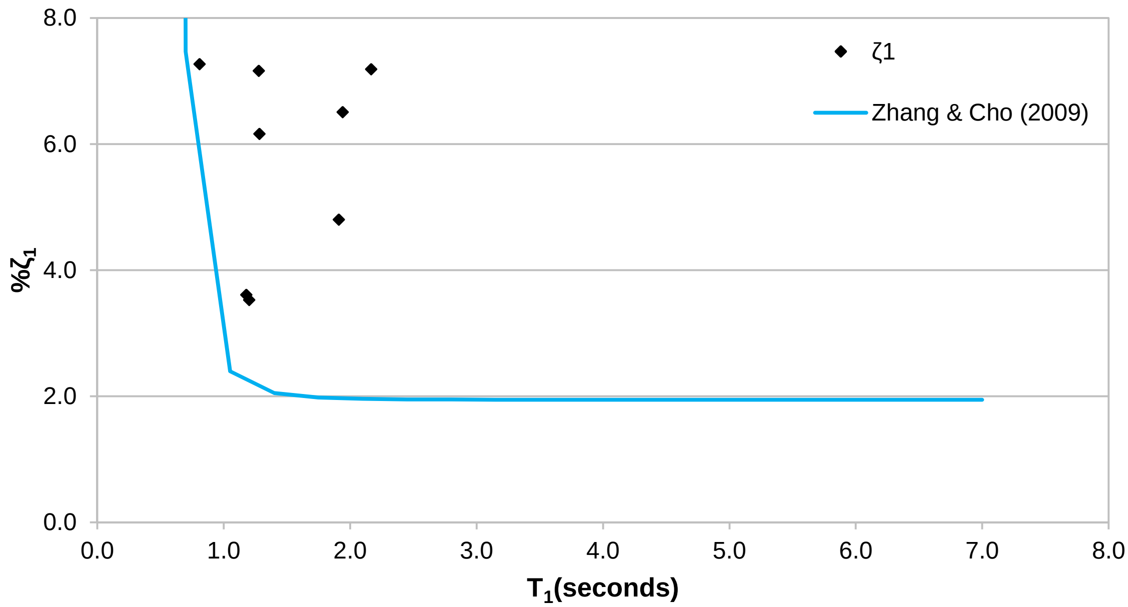


Figure 2-50: Variation of First Mode Damping with the Fundamental Period (URM)

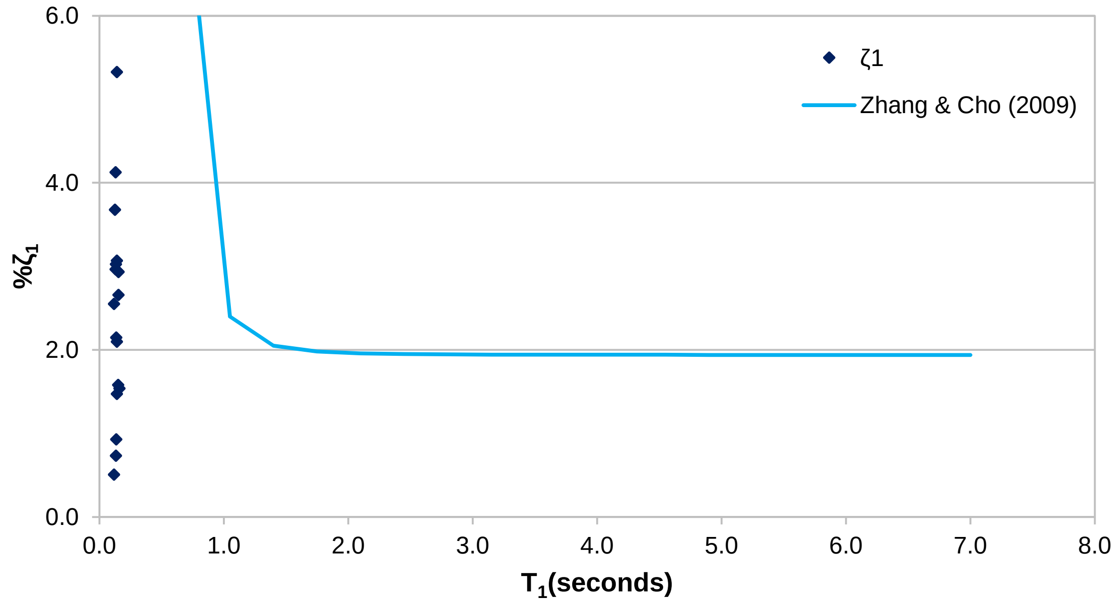


Figure 2-51: Variation of First Mode Damping with the Fundamental Period (WOOD)

Contrary to the suggestion by Satake et al. (2003), the results obtained in this research indicate that on average, the damping ratio of higher modes is smaller than the damping ratio of the first mode. Bernal et al. (2012) suggests that ζ_n / ζ_1 is a function of the lateral load resisting systems behavior; it is expected that buildings with dominant flexural response (e.g. shear wall buildings, tall frame buildings) have a different trend in ζ_n / ζ_1 compared with buildings with dominant shear response (e.g. short frame buildings). In this study, relative contribution of flexural and shear response is measured with T_2/T_1 ratio; small values of T_2/T_1 (e.g. $T_2/T_1 < 0.3$) represents high levels of contribution from flexural mode to the building response, and otherwise. Figures 3-52 through 3-61 show the variation of ζ_2/ζ_1 with T_2/T_1. It is evident for most plots (Figures 2-52 through 2-61) that there is a positive correlation between ζ_2/ζ_1 with T_2/T_1. Large T_2/T_1 represents dominance of the shear mode of response to the total response and leads to further engagement of mechanisms that result in energy dissipation in higher modes. The plots of RCTUW and URM (Figures 2-59 and 2-60) do not display this trend; however, the data available for these building types is very limited.

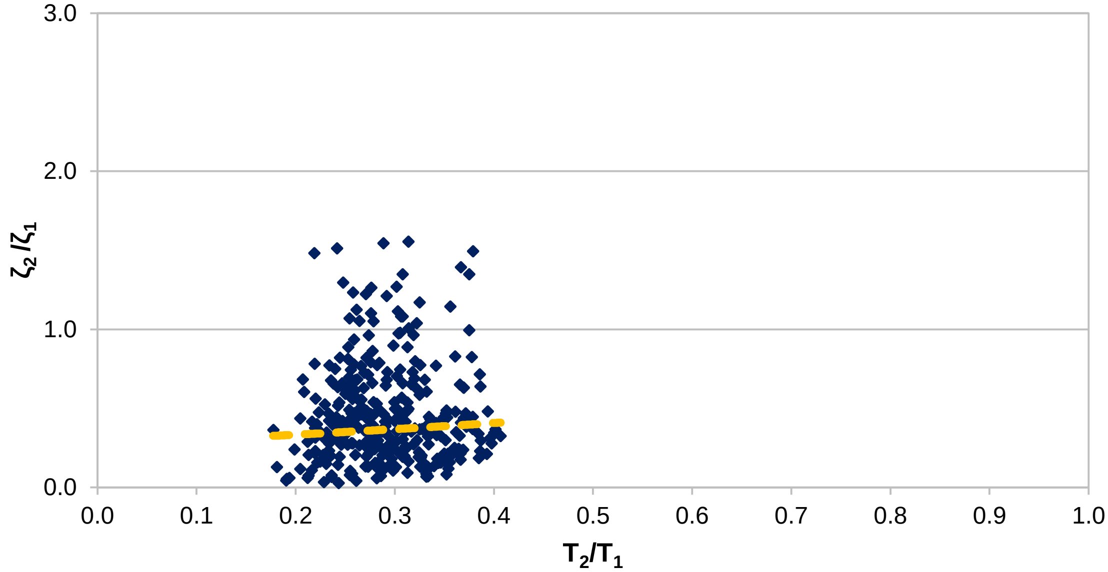


Figure 2-52: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (RCW)

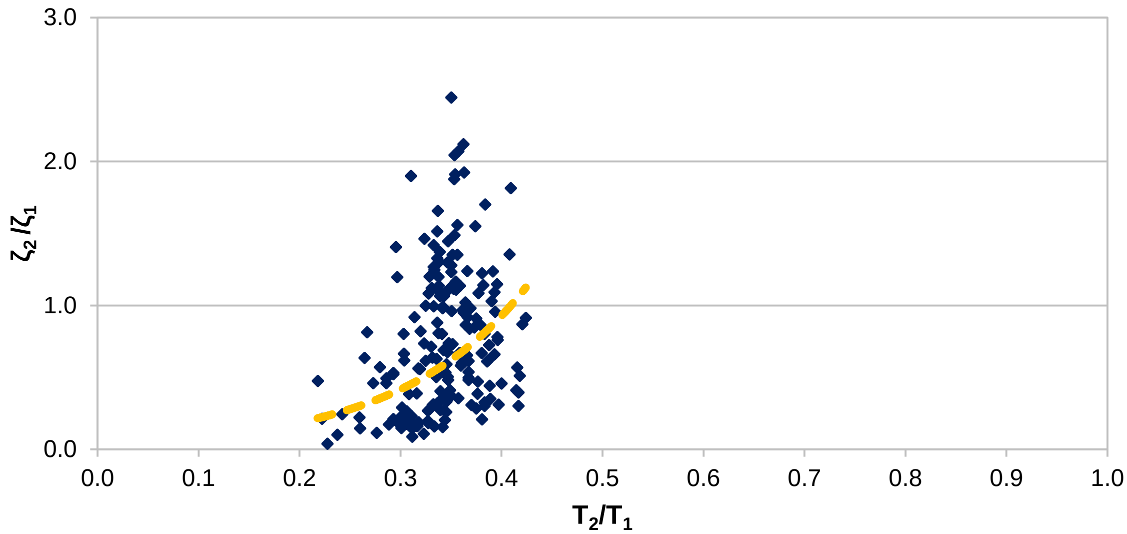


Figure 2-53: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (SMRF)

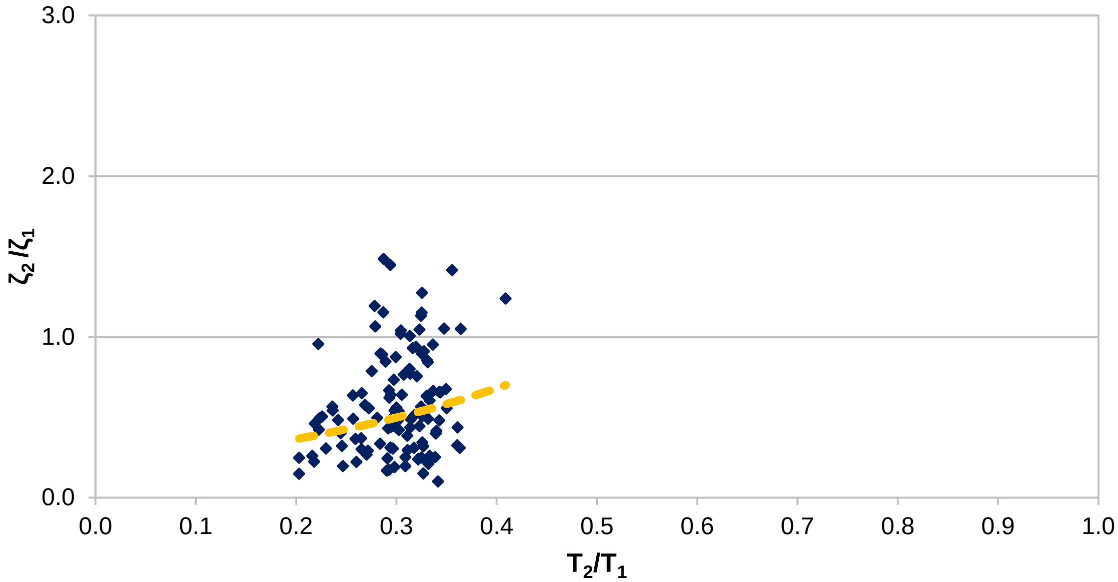


Figure 2-54: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (RCMRF)

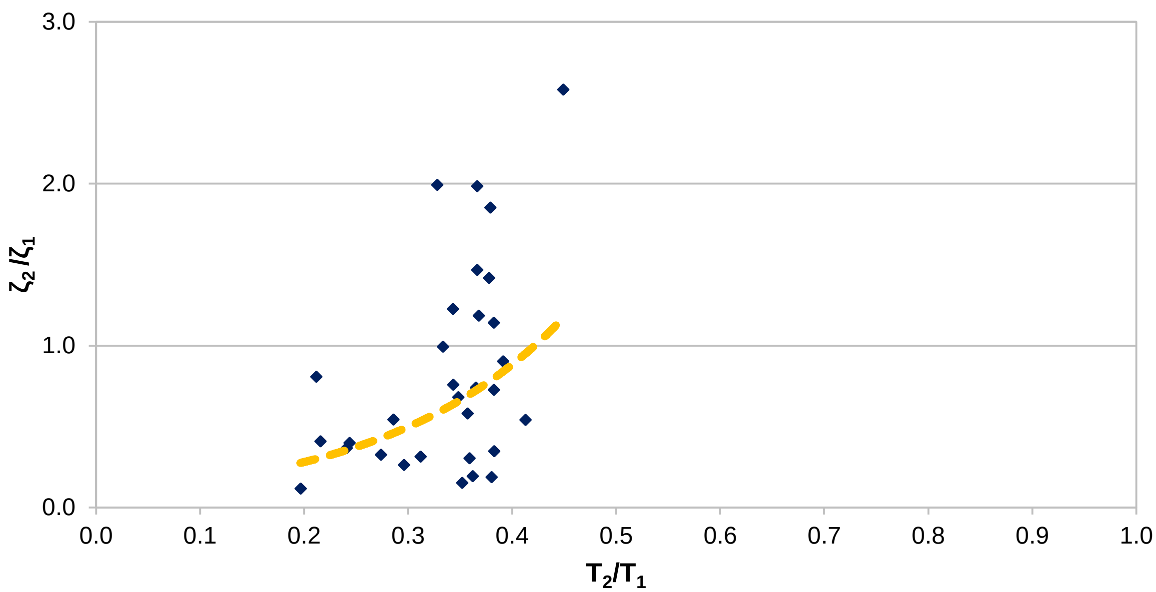


Figure 2-55: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (EBF)

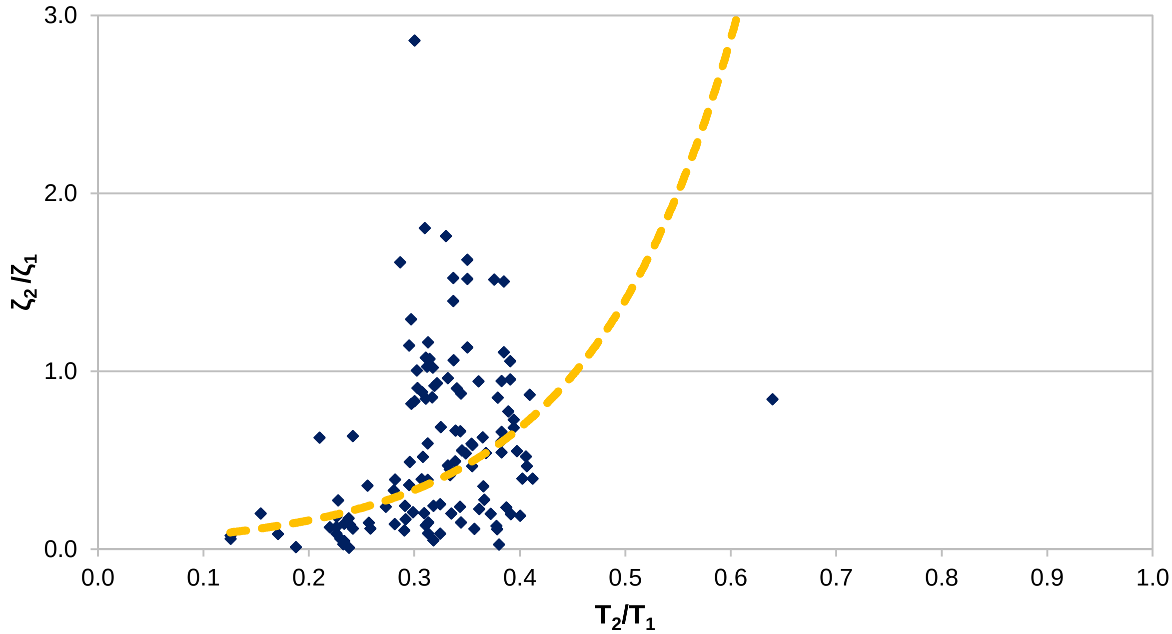


Figure 2-56: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (CBF)

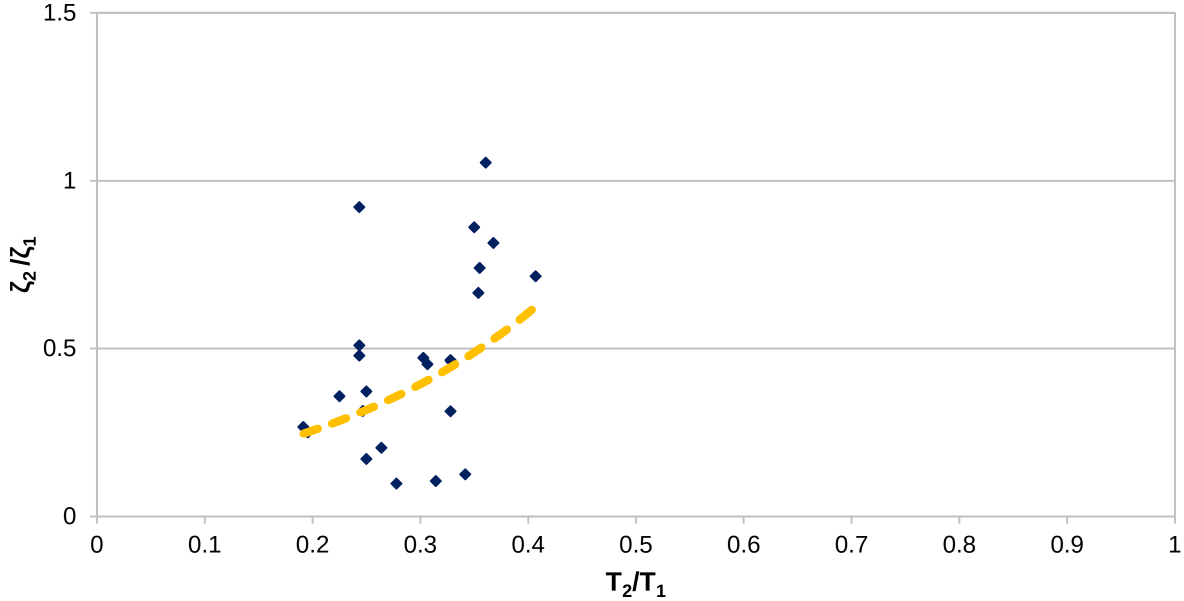


Figure 2-57: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (MAW)

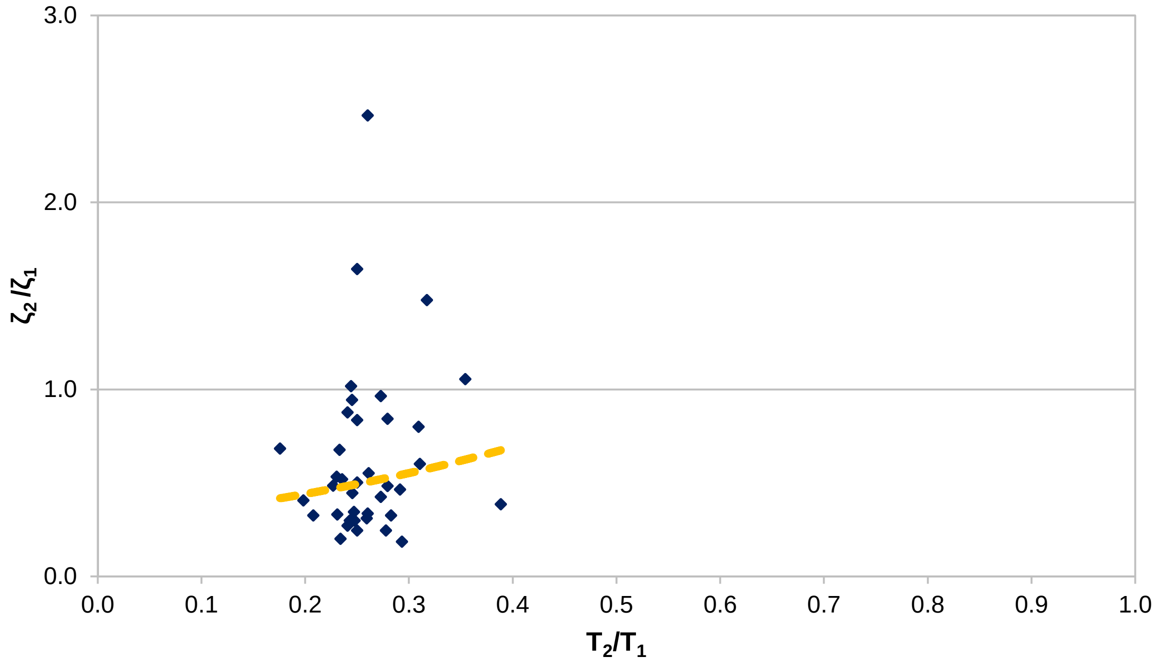


Figure 2-58: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (PCW)

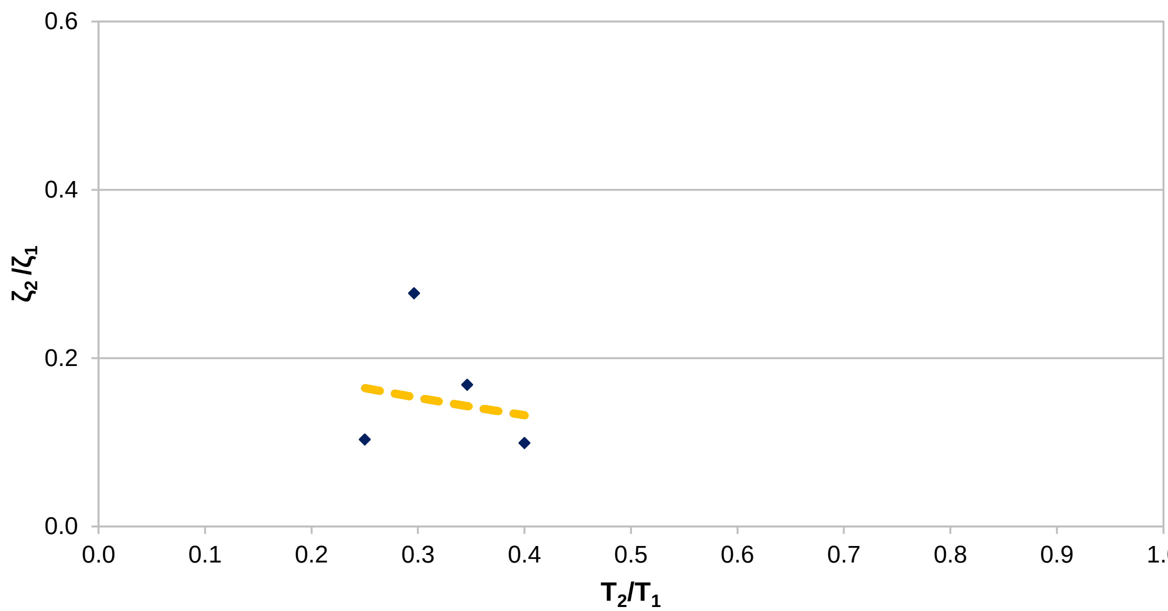


Figure 2-59: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (RCTUW)

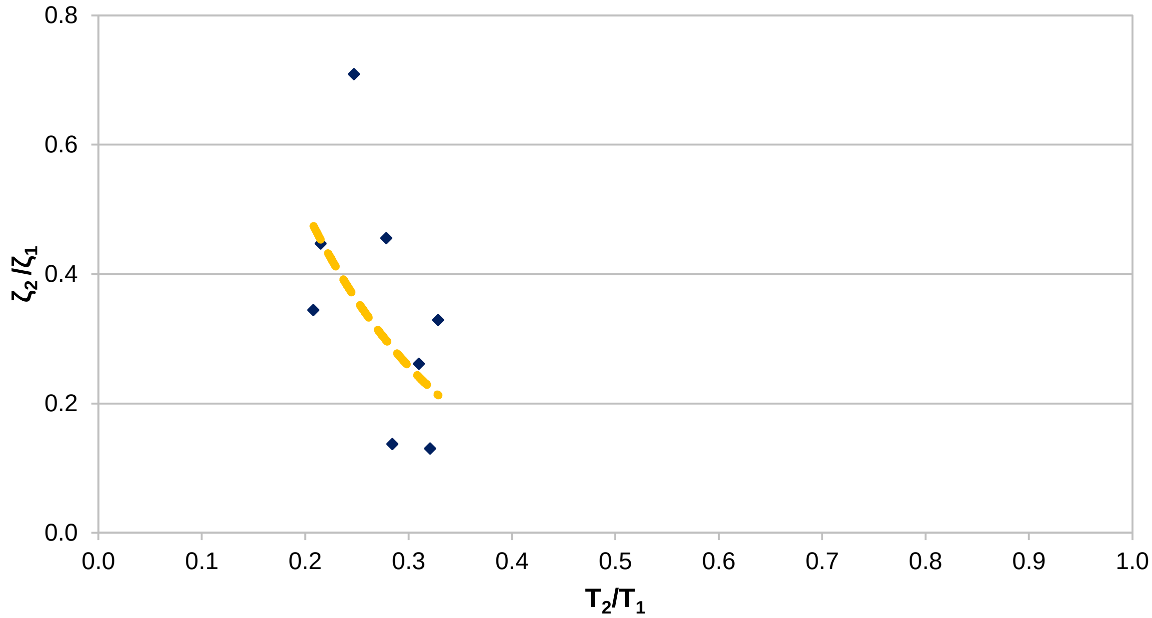


Figure 2-60: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (URM)

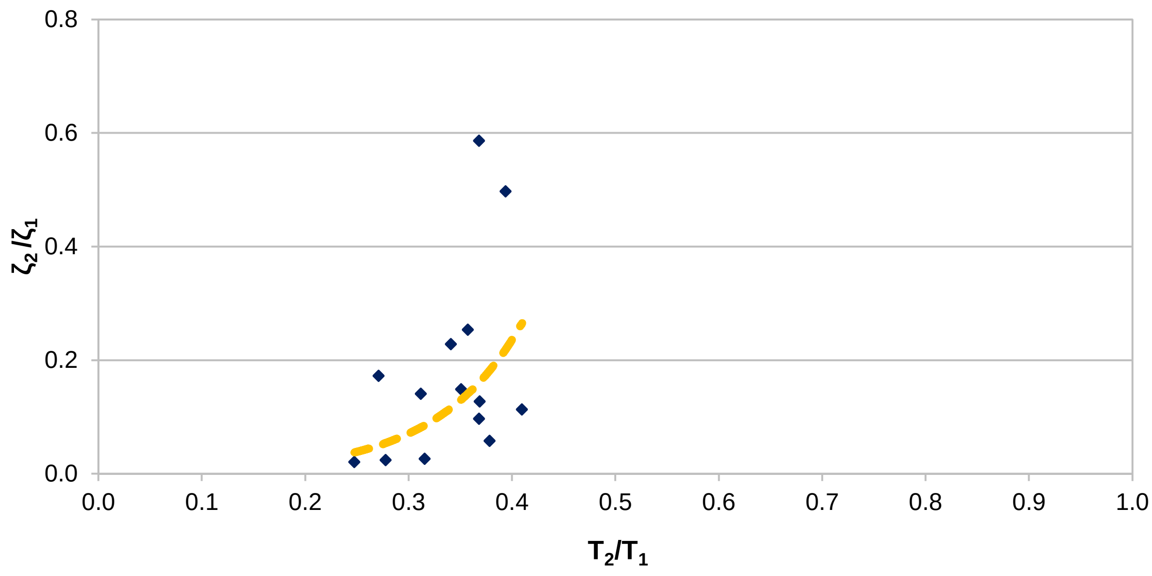


Figure 2-61: Variation of Modal Damping Ratio to Contribution of Flexural vs. Shear Dominant Response (WOOD)

CHAPTER 3:

3 DEVELOPMENT OF FUNDAMENTAL PERIOD ADJUSTMENT FACTORS

3.1 BACKGROUND

The current studies on enhancing performance-based earthquake engineering are focusing on the accurate estimation of loss due to ground shaking. Currently, the conventional methods being used to estimate loss in a building do not include the participation of additional sources of stiffness. Current modeling techniques only take into consideration the stiffness of the building due to its structural components (i.e., beams, columns, walls, and braces). Because all sources of stiffness are not accounted for in the structural analysis of a building, the estimated losses to that structure are inaccurately depicted.

The purpose of this study is also to provide a practical approach in adjusting the fundamental period and lateral stiffness of the computational model of a building's structural system, which aid in further research that will provide a more realistic estimation of seismic loss. To that end, we have utilized a database of instrumented buildings that have experienced ground shaking in past earthquakes in California– through California Strong Motion Instrumentation Program (CSMIP) –and estimated their natural periods through System Identification, and conventional analysis methods used in industry. The natural periods were then compared to identify adjustment factors.

3.2 METHODOLOGY

Seven buildings (Table 3-1) were chosen from the building database to compare natural periods estimated through system identification versus conventional analysis used in industry. System identification was performed for each building to identify its natural period during each recorded seismic event. Then, the natural period of each building was provided through use of a computational model, ETABS. The natural periods provided through system identification and the computational model were then compared to identify the discrepancy in the natural periods given for each structure. From this comparison, adjustment factors were created for the natural periods based on the ratio of the natural period provided through system identification to the natural period provided through the computational model (T_{SID}/T_{ETABS}).

Table 3-1: Building Summary

No.	CSMIP ID	Name	Floors above	Floors below	# of Sensors	Plan Shape	Primary VSFRS
1	12299	Palm Springs - 4-story Hospital	4	1	13	Rectangular	SMRF
2	12284	Palm Desert - 4-story Office Bldg.	4	0	9	Rectangular	RCW
3	24463	Los Angeles 5-story Warehouse	5	1	13	Rectangular	RCMRF
4	23287	San Bernardino - 6-story Hotel	6	0	9	Rectangular	RCW
5	24571	Pasadena - 9-story Commercial Bldg.	9	1	15	Rectangular	RCMRF
6	24322	Sherman Oaks 13-story Commercial Bldg.	13	2	15	Rectangular	RCMRF
7	54388	Bishop-2-story Office Bldg.	2	0	13	Rectangular	SMRF

3.2.1 Structural Model

A computational model of each building was created in ETABS using the drawings provided by CSMIP. The material properties designated in the model were either explicitly given or assumed based on industry standards. Structural dimensions were explicitly stated in the drawings or measured to scale. The loading assumptions utilized in this study were based on average values used in industry. Therefore, the additional dead loads of the office, hospital, and warehouse buildings were designated as 25 psf, 40 psf, and 50 psf, respectively, and a global cladding load was assumed as 25 psf.

The effective values of member moments of inertia (I_{eff}) for the RCMRF and RCW buildings were provided in the American Concrete Institute (ACI) 318-11 and the LATBSDC manuals (ACI 2011, and Brandow et al. 2014). Using the ACI and LATBSDC, for beams, I_{eff} = 0.35Ig and 0.7Ig, respectively; for columns, I_{eff} = 0.7Ig and 0.9Ig, respectively; shear walls, I_{eff} = 0.35Ig and 0.75Ig, respectively; and basement walls, I_{eff} = 1.0Ig, where Ig is the moment of inertia of the gross section. Because the ACI 318-11 is more widely used, its values were used for most of the analyses.

The steel panel zone offsets for the SMRF building was based on industry standards and designated as %0, %50, and %100.

3.2.2 Comparison of Natural Periods

Four Single Input Multiple Output methods were used including the ERA-OKID-IO, Auto- ARX, SRIM, and N4SID-IO methods. It was found that the periods provided through each method of system identification were generally in agreement. As a result, the periods of each seismic event were averaged among the four methods. In some analyses, the identified period of all seismic events were averaged to determine a single period for each building.

The natural periods provided through system identification and the computational model were then compared to identify the discrepancy in the natural periods given for each structure. From this comparison, adjustment factors were created for the natural periods and stiffness based on the ratio of the natural period provided through system identification to the natural period provided through the computational model (T_{SID}/T_{ETABS}). The following equation was used to identify the adjustment factor's relationship to both the natural periods and stiffness:

$$Adjustment\ \ Factor = \frac{T_{SID}}{T_{ETABS}} = \sqrt{\frac{k_{ETABS}}{k_{SID}}} \tag{3-1}$$

3.3 RESULTS AND DISCUSSION

3.3.1 Reinforced Concrete Walls

Table 3-2: RCW Analysis LATBSDC vs. ACI (With Participation of Both Lateral and Gravity System)

Station	LATBSDC			ACI		
	Period (T_{ETABS})	**Direction**	**Ratio (T_{SID}/T_{ETABS})**	**Period (T_{ETABS})**	**Direction**	**Ratio (T_{SID}/T_{ETABS})**
12284	0.51	Transverse	1.12	0.65	Transverse	0.87
23287	0.262	Longitudinal	1.70	0.291	Longitudinal	1.53

Table 3-3: RCW Analysis LATBSDC vs. ACI (Without Participation of Gravity System)

Station	LATBSDC			ACI		
	Period (T_{ETABS})	**Direction**	**Ratio (T_{SID}/T_{ETABS})**	**Period (T_{ETABS})**	**Direction**	**Ratio (T_{SID}/T_{ETABS})**
12284	0.55	Transverse	1.03	0.74	Transverse	0.76
23287	0.264	Longitudinal	1.68	0.294	Longitudinal	1.51

Each building was analyzed to determine the level of participation that the gravity system plays in the determination of the natural period of each building. In the case of the 6-story building (Station 23287), the walls resist loading in both the lateral and vertical direction. In addition, there are columns placed only on the first floor to provide additional support to the gravity system in addition to the walls. As seen in Table 3-2 and 3-3, the reduction in stiffness of the columns (gravity-only elements) in Station 23287 cause only an insignificant increase in the period (T_{ETABS}).

Alternatively, in the case of the 4-story building (Station 12284), the walls provide most of the lateral resistance. However, the beam-column frame also provides some lateral resistance with its moment connections. The decrease in stiffness of the gravity frame in Station 12284 causes an increase in the natural period because the stiffness of the frame is not taken into account for the determination of the natural period. As a result, in the analysis of reinforced concrete wall buildings, the additional gravity elements that provide moment resistance should be taken into account for the determination of the period. In moving forward, the natural period found that includes both the participation of the lateral and gravity system (Table 3-2) will be used to determine the adjustment factor.

Based on the comparison of actual and estimated RCW building periods, it is apparent that there is a dissimilarity in the number of structural elements in the model contributing to the building stiffness and period. The estimated period of Station 23287 is significantly shorter than Station 12284. Accordingly, the adjustment factor for Station 23287 is higher and ranges from 1.50 to 1.70; whereas, the adjustment factor for Station 12284 ranges from 0.90 and 1.10. This occurrence is unusual for buildings of the same structural type.

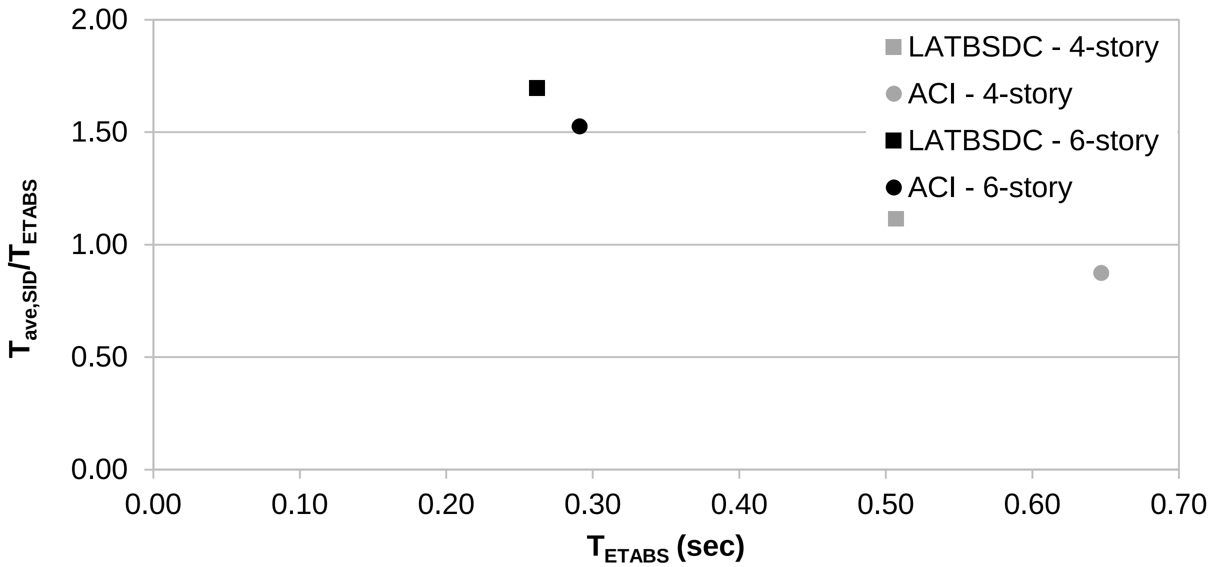


Figure 3-1: Variation of Adjustment Factor with Period (RCW)

The inconsistency in the adjustment factor is the result of the buildings' differing design. Station 12284 is a conventional office building whose perimeter is comprised of concrete walls with only a minimal number of interior concrete shear walls designated in the model. Alternatively, Station 23287 is a hotel that has several interior structural concrete walls designated in the computational model.

Station 23287 is atypical and its stiffness is larger than most conventional RCW buildings, causing base flexibility to play a larger role in the actual building behavior. A computational model, such as ETABS, considers the base of a concrete wall as a fixed support. Therefore, as the number of concrete walls that are designated in the model increases, the stiffness of the building will proportionally increase, causing the period to decrease. In actuality, a building with shear walls experiences base flexibility during ground shaking, and the assumption of a fixed base does not apply (Grib and Mamedov, 2004). In the case of Station 23287, the superstructure is much stiffer

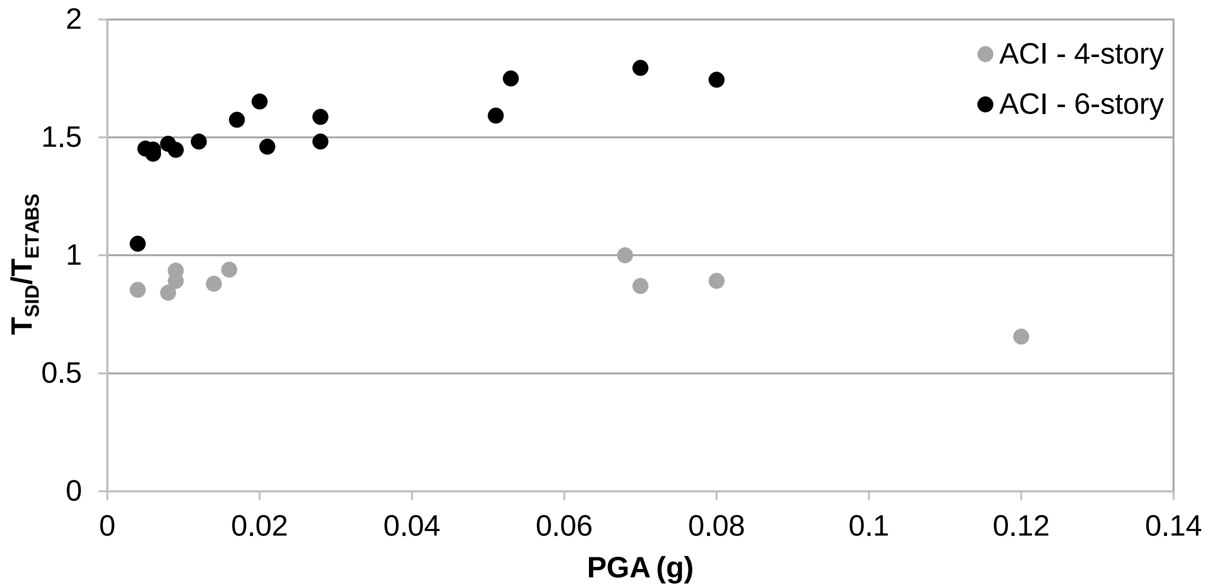


Figure 3-2: Variation of Adjustment Factor with PGA (RCW)

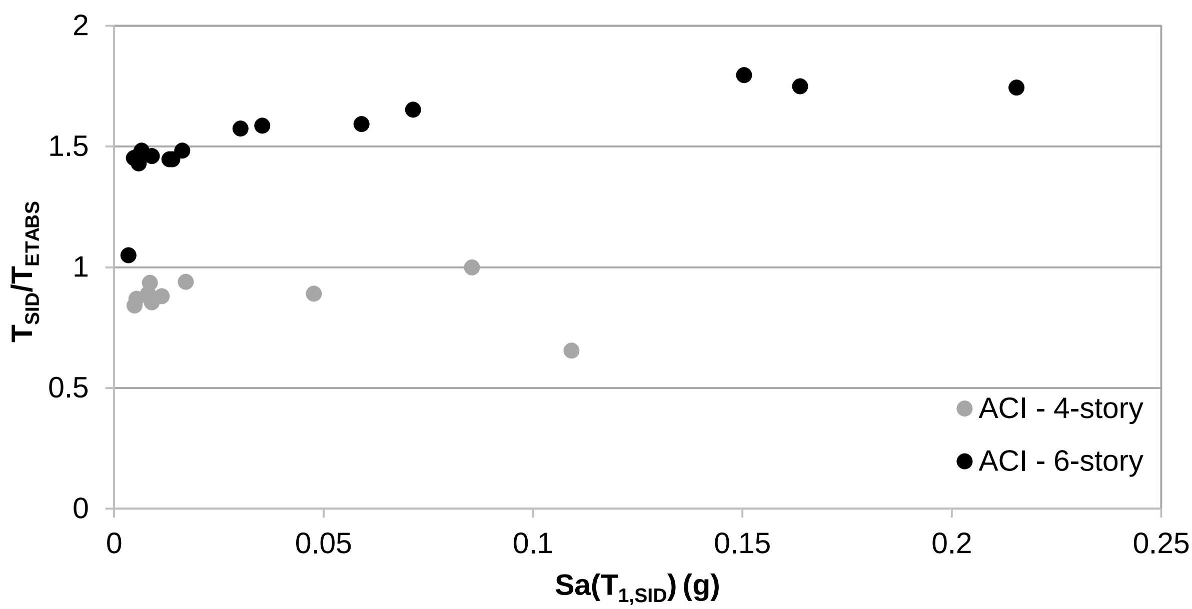


Figure 3-3: Variation of Adjustment Factor with S_a (RCW)

than that of the surrounding soil, causing rocking to take place, taking on the behavior of a pinned base, and causing the period to increase (Hong et al., 2009).

When comparing the adjustment factors to the IM, PGA and spectral acceleration (S_a), of each seismic event, it is seen that there is a steady increase of the adjustment factor with respect to the IM for low to moderate intensity. Since there is not much data for IMs over 0.2g, there is not an adequate representation of adjustment factors for buildings experiencing moderate-to-high ground shaking. However, Figures 3-2 and 3-3 illustrate how the stiffness decreases with increasing IM for low-to-moderate ground shaking, satisfying our original assumption.

For Station 12284, it was determined the average adjustment factor is 0.90 for most seismic events with PGA under 0.2g. In addition, for Station 23287 the average adjustment factor is 1.6. Currently, most conventional shear wall buildings are being designed to have minimal shear walls. Therefore, Station 23287 is not applicable for proposed buildings and its corresponding data will not be used in the derivation of the adjustment factor for RCMRFs. Consequently, it is recommended that all RCW buildings have an adjustment factor of 0.9.

3.3.2 Reinforced Concrete Moment Frames

Table 3-4: RCMRF Analysis LATBSDC vs. ACI (With Participation of Both Lateral and Gravity System)

Station	LATBSDC			ACI		
	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})
24322	2.7	Transverse	0.98	3.44	Transverse	0.76
24463	1.83	Longitudinal	0.57	2.15	Longitudinal	0.49
24571	2.05	Transverse	0.79	2.3	Transverse	0.7

Table 3-5: RCMRF Analysis LATBSDC vs. ACI (Without Participation of Gravity System)

Station	LATBSDC			ACI		
	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})
24322	2.7	Transverse	0.98	3.44	Transverse	0.76
24463	3.84	Longitudinal	0.27	3.85	Longitudinal	0.27
24571	2.21	Transverse	0.73	2.47	Transverse	0.66

Each building was analyzed to determine the level of participation that the gravity system plays in the determination of the natural period of each building. In the case of the 13-story building (Station 24322), the gravity system did not have any participation in the determination of the period because only the lateral resisting frames were modeled in ETABS originally.

The 5-story building (Station 24463) is comprised of a large number of structural elements that could be attributed to the gravity system. As seen in Table 3-4, the period is 1.83 and 2.15 seconds for the LATBSDC and ACI scenarios, respectively, if we assume all the elements are part of lateral load resisting system. However, the reduction in stiffness of so called gravity beams and columns causes a large reduction in the overall stiffness of the structure, causing the natural period to become significantly longer. The period is determined to be 3.84 and 3.85 seconds (Table 3-5), for the LATBSDC and ACI scenarios, respectively. Because this is the case, we can only come to the understanding that the so called gravity beams and columns, along with the flat slab, provides some moment resisting capacity due to the monolithically poured elements. As a result, the participation of the stiffness of gravity design elements must be included to determine an accurate natural period for the structure.

In the case of the 7-story building (Station 24571), it was determined that the inclusion of the gravity elements does not make a significant difference in the determination of the natural period provided through analysis when the number of gravity columns does not exceed the number of columns designed for lateral resisting behavior. As seen in Table 3-4, the original period is 2.05 and 2.30 seconds for the LATBSDC and ACI scenarios, respectively. The reduction in stiffness of such a small number of the gravity beams and columns causes a smaller reduction in the overall stiffness of the structure and small effect on the period. As seen in Table 3-5, the period is determined to be 2.21 and 2.47 seconds, for the LATBSDC and ACI scenarios, respectively. Because this is the case, we can only come to the understanding that the gravity beams and columns, along with the flat slab, provides some moment resisting capacity due to the monolithically poured elements. However, since the participation of the stiffness of gravity design elements is low, the inclusion of such a minimal number of gravity element do not necessarily need to be included to determine an accurate natural period for the structure.

Furthermore, the participation of the gravity elements in the determination of the natural period is significant if the number of gravity elements exceeds the number of lateral resisting elements, where the gravity system still provides some moment resisting capacity. As a result, the natural periods provided in Table 3-4 must be used for the further analysis of the RCMRF buildings.

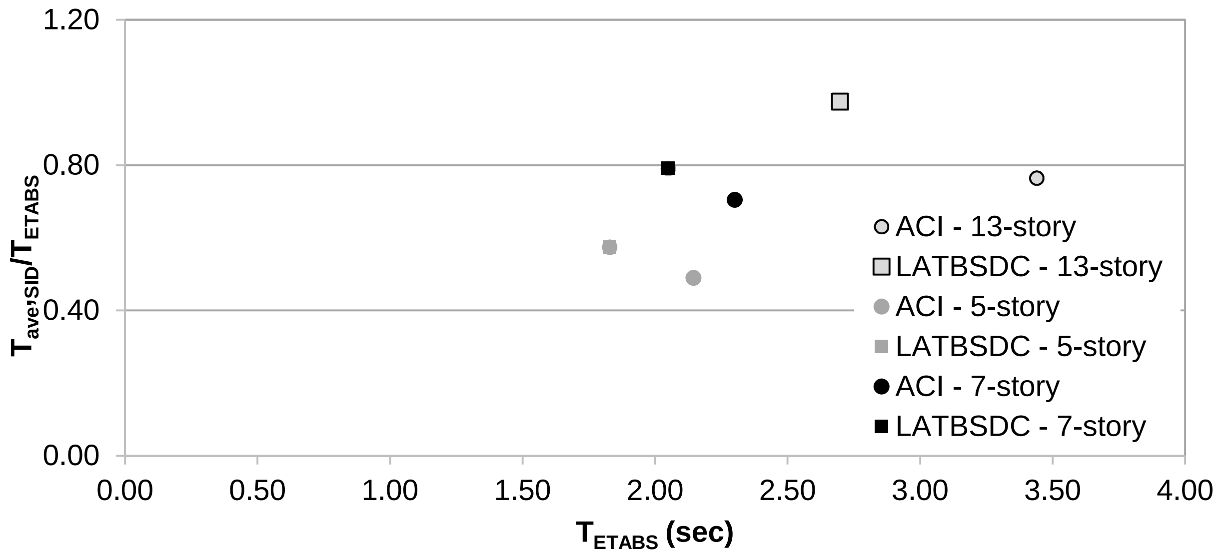


Figure 3-4: Variation of Adjustment Factor with Period (RCMRF)

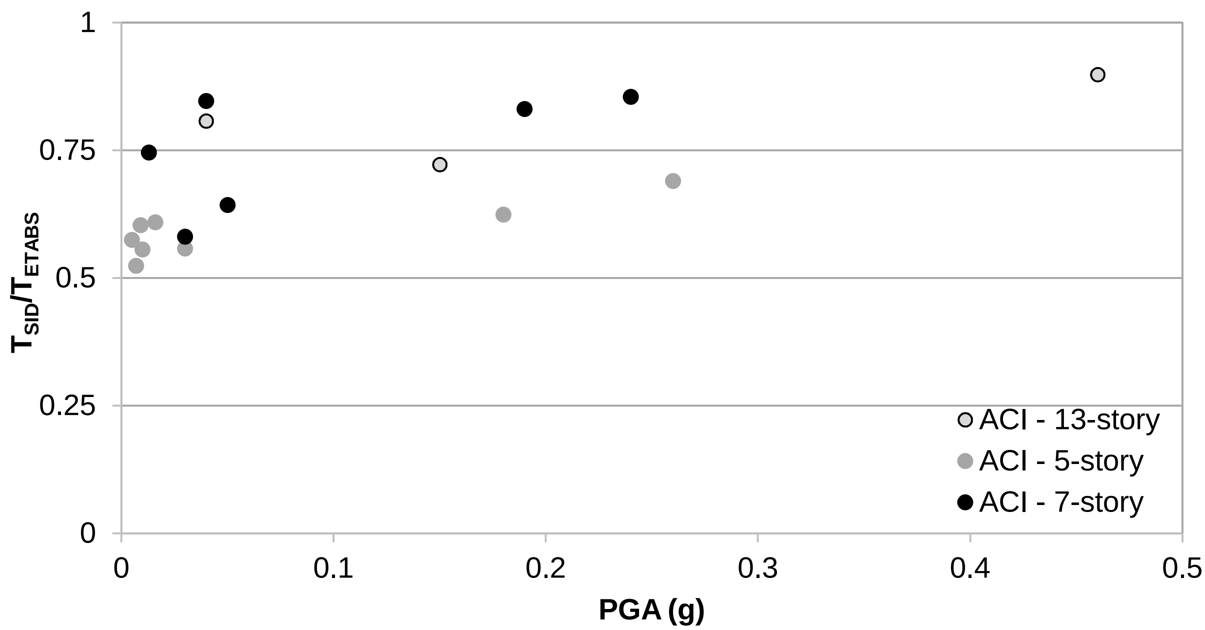


Figure 3-5: Variation of Adjustment Factor with PGA (RCMRF)

In the analysis of RCMRF buildings, it was determined that the actual periods for RCMRF buildings are heavily dependent on the stiffness of its nonstructural elements. In the case of Station

24322, 24571, and 24463, the attachments range from glass with minimal cladding to the use of precast concrete panels as the cladding. As a result, the adjustment factor for Stations 24322, 24571, and 24463 ranged from 0.8 to 1.0, 0.7 to 0.8, and 0.5-0.6, respectively. As the stiffness of the infill and exterior attachments increased, the difference between the actual and estimated period increased, causing the decrease in the adjustment factor at low-to-moderate ground shaking.

When comparing the adjustment factors for Stations 24322, 24463, and 24571 to the IMs, PGA and S_a, of each seismic event, once again there is generally a steady increase of the adjustment factor with respect to the increase in IM. As shown in the Figures 3-5 and 3-6, the adjustment factor approaches 1 for IMs greater than 0.2g. This illustration is in agreement with the assumption that as the seismic intensity increases, the participation of nonstructural elements decreases; therefore elongating the fundamental period.

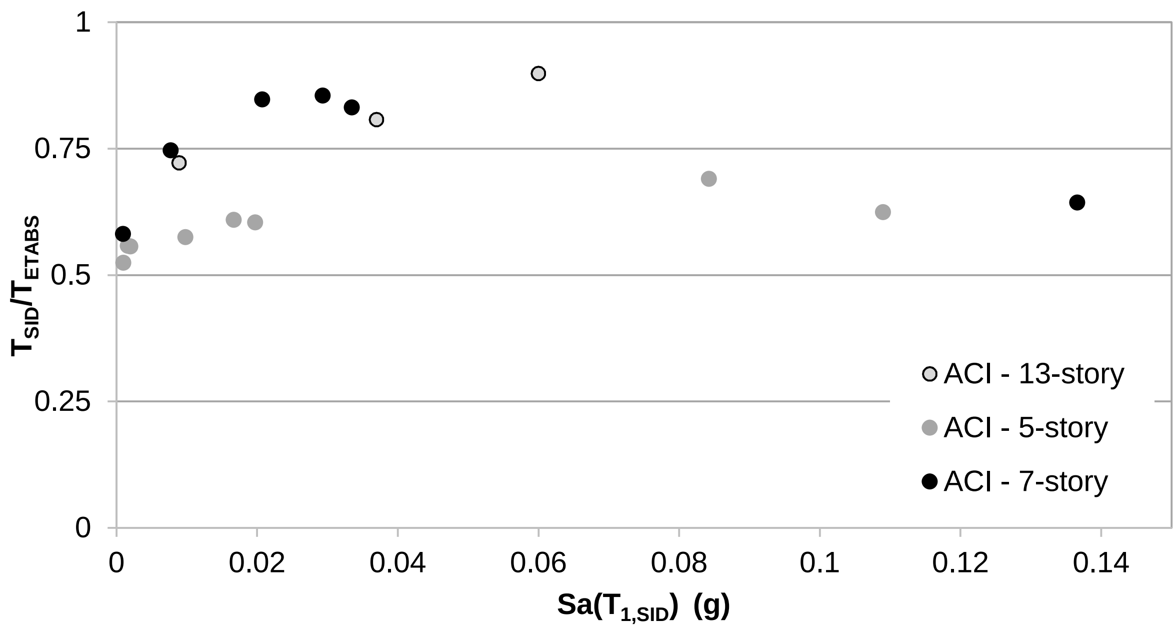


Figure 3-6: Variation of Adjustment Factor with S_a (RCMRF)

3.3.3 Steel Moment Resisting Frames

Table 3-6: SMRF Analysis (With Participation of Both Lateral and Gravity System)

Station	Stiffness Property	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})
12299	Panel Zone Offset = 0	1.10	Transverse	0.57
	Panel Zone Offset = 0.5	1.011	Transverse	0.62
	Panel Zone Offset = 1	0.94	Transverse	0.67
54388	Panel Zone Offset = 0	1.15	Transverse	0.23
	Panel Zone Offset = 0.5	1.146	Transverse	0.23
	Panel Zone Offset = 1	1.15	Transverse	0.23

Table 3-7: SMRF Analysis (Without Participation of Gravity System)

Station	Stiffness Property	Period (T_{ETABS})	Direction	Ratio (T_{SID}/T_{ETABS})
12299	Panel Zone Offset = 0	1.13	Transverse	0.56
	Panel Zone Offset = 0.5	1.048	Transverse	0.60
	Panel Zone Offset = 1	0.97	Transverse	0.65
54388	Panel Zone Offset = 0	1.15	Transverse	0.23
	Panel Zone Offset = 0.5	1.146	Transverse	0.23
	Panel Zone Offset = 1	1.15	Transverse	0.23

Each building was analyzed to determine the level of participation that the gravity system plays in the determination of the natural period of each building. In the case of the 4-story and 2-story buildings (Stations 12299 and 54388), the gravity elements or the elements with fully pinned connections did not participate much in the determination of the natural period. As a result, the values of the periods with the participation of the stiffness of the gravity system shown in Table 3-6 has less than five percent difference in the period as opposed to the analysis excluding the participation of the gravity elements in Table 3-7. It was determined that the participation of the gravity system is insignificant. As a result, the natural periods provided in Table 2-6 will be used for the further analysis of the SMRF buildings.

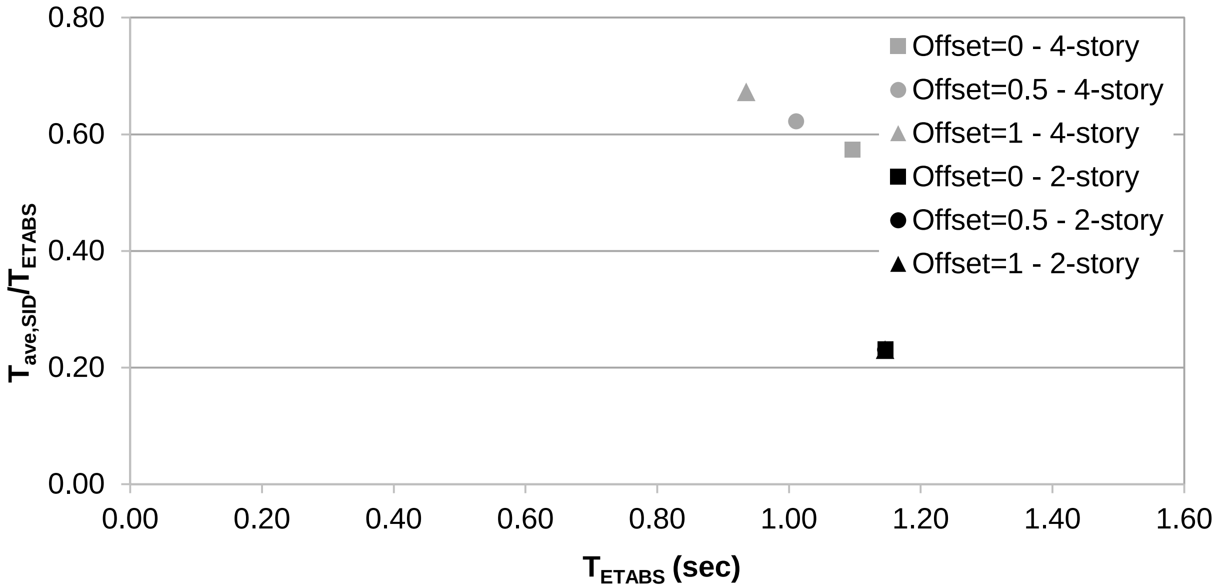


Figure 3-7: Variation of Adjustment Factor with Period (SMRF)

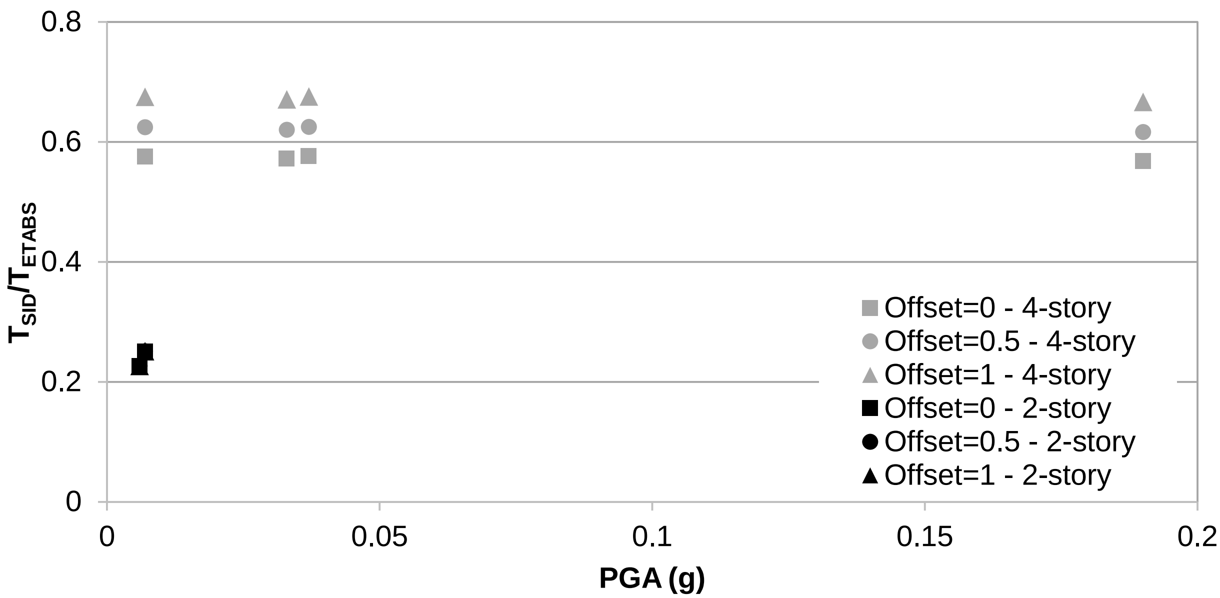


Figure 3-8: Variation of Adjustment Factor with PGA (SMRF)

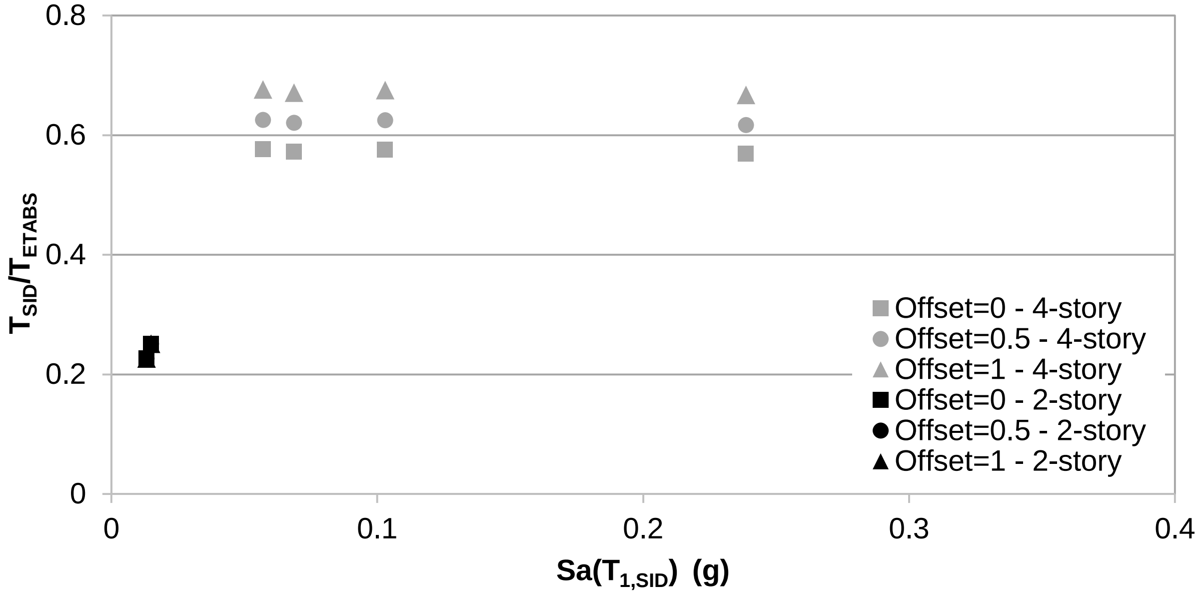


Figure 3-9: Variation of Adjustment Factor with S_a (SMRF)

Based on the analysis of Station 12299, it is determined that the stiffness of the entire panel zone of steel buildings must be taken into account. As shown in Figure 3-7, the adjustment factor for Station 12299 increases from 0.60 and 0.70 when the offset of the panel zone increases from a factor of 0 to 1. However, the 2-story SMRF (Station 54388) remains at 0.23 even with the variance of the stiffness properties. In the case of Station 12299, the period identified through system identification is more closely related to the period provided in the computational model. Station 12299 is a typical SMRF where the lateral force resisting elements are the beams and columns. On the other hand, Station 54388 has trusses, is not a typical SMRF, and its results are considered an outlier.

When comparing the adjustment factors for Station 12299 with respect to the IMs, PGA and S_a, of each seismic event, it is seen that the adjustment factor remains constant even with the increase in IM (Figures 3-8 and 3-9). As a result, SMRF buildings maintain the stiffness from its nonstructural elements at low-to-moderate ground shaking.

3.3.4 Adjustment Factor

In the interest of this research study, a generalized adjustment factor was generated for each structural system based on the average of adjustment factors for conventional designs. As a result, the application of an adjustment factor to natural period provided in computational models are necessary to achieve an accurate depiction of the economic loss a building will experience during ground shaking. It is recommended that that the adjustment factors noted in Table 2-8 be used.

Table 3-8: Adjustment Factors

System	RCW	RCMRF	SMRF
Adjustment Factors for T_{ETABS}	0.9 T_{ETABS}	0.7 T_{ETABS}	0.6 T_{ETABS}

An adjustment factor can also be applied to estimate actual drift values. Using the natural period derived from a computational model, the adjusted period, and the response spectrum to determine the S_a for both periods, lateral drift can also be derived based on the design spectral response

$$S_D = \omega^2 S_a \text{,} \tag{3-2}$$

Subsequently, the adjustment factor (α_δ) is determined by:

$$\alpha_\delta = \frac{\delta_{SID}}{\delta_{ETABS}} = \frac{S_D(T_{SID})}{S_D(T_{ETABS})} \tag{3-3}$$

Accordingly, (α_δ) can be applied to the drift determined through computational analysis to aid in the determination of actual loss.

4 CONCLUSION

This study is focused on utilizing building modal parameters, assessed via system identification techniques, for engineering applications. The previous chapters have addressed the estimation of natural periods and damping ratios for several buildings types using system identification. Four methods of system identification were examined to determine the most efficient and accurate methods of system identification using the SMIT Toolsuite (Chang et al., 2012). The SRIM method was then determined to be the prime method of estimation for the natural periods and damping ratios of our database of CSMIP buildings. These estimated parameters were then compared to existing expressions for modal parameters that were derived in previous studies.

Of the ninety-one buildings examined, seven buildings were modeled in ETABS to examine the discrepancies between natural periods estimated using computational analysis and that estimated based on recorded seismic excitation with system identification. The ratios of the periods determined through system identification and ETABS were then used to provide period and stiffness adjustment factors for the refinement of current methods of loss estimation.

4.1 ANALYSIS OF NATURAL PERIODS AND DAMPING RATIOS

The estimation of natural periods was found to be a stable parameter and was consistent across system identification methods. The natural periods estimated in this study displayed similar trends to that of previous research studies. As anticipated, the periods increased with height, as well as, with intensity of the ground motion. It was found that the code formula for the approximation of periods was adequate for most structural types when only the building height and LFRS is known. The general coefficients (C_t = 0.02 and x = 0.75) was not adequate for EBF, RCTUW, URM, and WOOD buildings.

Damping ratios have been proven to be generally in agreement with previous research studies. The high variability of damping values prevents the determination of a deterministic value for each structural system. Generally, for low- to mid-rise buildings, a clear trend cannot be detected. As a result, the average of the values might be a crude, but practical method to assess the damping values for each structural type.

Previous studies have shown that damping usually decreases with the increase in period, which is reflected in most expressions for the determination of damping (Table 3-1). It should be noted that some expressions of previous studies were not based on the same database of buildings, where most were built outside of the United States, and using other methods of excitation, such as ambient vibration. These variables, among others, can cause differing results for buildings that seem very similar. At this time, we can conclude that damping is consistent across low- to mid-rise buildings, and providing an average damping value is adequate. Further research is necessary to investigate mid- to high-rise buildings to gain a better understanding of the behavior of these modal parameters.

4.2 DEVELOPMENT OF FUNDAMENTAL PERIOD ADJUSTMENT FACTORS

It was determined that the absence of nonstructural elements and other attachments (e.g., partitions and cladding, etc.) from the computational models result in overestimation of the period of the structure. Alternatively, if foundation flexibility is not taken into account in the computational model, the resultant period will be shorter than the actual period of the building. In an effort to maintain the current industry modeling practices, adjustment factors for the fundamental period, stiffness, and drift were derived.

Adjustment factors were provided for three structural types, RCW, SMRF, and RCMRF, which are 0.9, 0.6, and 0.7, respectively. The application of these factors provides a practical and simple approach to determining the actual building response, and can be directly applied to the estimation of economic loss.

4.3 FUTURE WORK

In several instances of our analysis, it is seen that a lack of data prevents the identification of relationships between natural periods, damping ratios, and other building characteristics. In most cases, there is a lack of buildings within a specific LFRS group. In that case, it is impractical to draw generalized conclusions about the behavior of a structural system based on the behavior of 2 or 3 buildings. In other instances, there is a lack of data ranging from mid- to high-rise buildings. As a result, the continued estimation of natural periods and damping ratios is necessary to provide regression formulas for the estimation of these parameters for each type of LFRS.

REFERENCES

1. ACI Committee, American Concrete Institute, and International Organization for Standardization, 2014. *Building code requirements for structural concrete and commentary*, ACI 318-11, American Concrete Institute.

2. Amanat, K. M., & Hoque, E. (2006). A rationale for determining the natural period of RC building frames having infill. *Engineering Structures*, *28*(4), 495-502.

3. Apostolakis, G., Qu, B., Ecemis, N., & Dogruel, S. (2007). Field reconnaissance of the 2007 Niigata-Chuetsu Oki earthquake. *Earthquake Engineering and Engineering Vibration*, *6*(4), 317-330.

4. ASCE-American Society of Civil Engineers (2010). *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 7–10). American Society of Civil Engineers: Reston, VA.

5. Bentz, A., & Kijewski-Correa, T. (2008). Predictive models for damping in buildings: the role of structural system characteristics. In *Proceedings of the 2008 Structures Congress, 18th Analysis and Computation Specialty Conference, Vancouver, Canada*.

6. Bernal, D. (1994). Viscous damping in inelastic structural response. *ASCE Journal of Structural Engineering*, **120**(4): 1240-1254.

7. Bernal, D., Mozaffari Kojidi, S., Kwan, K., Döhler, M. (2012). Damping identification in buildings from earthquake records. *SMIP12 Seminar on Utilization of Strong-Motion Data, p. 39 - 56*.

8. Brandow, G., Carpenter, L., Cochran, M. B. L., Hart, G. C., Huang, S. C., Lew, M., ..., and Somerville, P., 2014. *An Alternative Procedure For Seismic Analysis And Design of Tall Buildings Located in The Los Angeles Region*, Los Angeles, CA.

9. Chang, M., Leonard, R.L., Pakzad, S.N. (2012). Structural Modal Identification Toolsuite (SMIT). Lehigh University.

10. Chang, S. E., Shinozuka, M., & Svekla, W. (1999). Modeling post-disaster urban lifeline restoration. In *Optimizing Post-Earthquake Lifeline System Reliability* (pp. 602-611). ASCE.

11. Chen, C. W., Huang, J. K., Phan, M., & Juang, J. N. (1992). Integrated system identification and state estimation for control of flexible space structures. *Journal of Guidance, Control, and Dynamics*, *15*(1), 88-95.

12. Chopra, A.K (2012). *Dynamics of structures*. Fourth Edition. Prentice Hall.

13. Cimellaro, G. P., Reinhorn, A. M., & Bruneau, M. (2006, April). Quantification of seismic resilience. In *Proceedings of the 8th US National Conference on Earthquake Engineering. Presented at the 8th US National Conference on Earthquake Engineering, San Francisco, California, USA* (p. 10).

14. Cole, E. E., Tokas, C. V., & Meehan, J. F. (1992). Analysis of recorded building data to verify or improve 1991 Uniform Building Code (UBC) period of vibration formulas. *Proc. SMIP92. Strong Motion Instrumentation Program, Division of Mines and Geology, California Department of Conservation*. Sacramento, Calif.

15. Davenport, A. G., & Hill-Carroll, P. (1986). Damping in tall buildings: its variability and treatment in design. In *Building motion in wind* (pp. 42-57). ASCE.

16. Fang, J. Q., Jeary, A. P., Li, Q. S., & Wong, C. K. (1999). Random damping in buildings and its AR model. *Journal of Wind Engineering and Industrial Aerodynamics*, *79*(1), 159-167.

17. Federal Emergency Management Agency (FEMA), 2012. *Seismic Performance Assessment of Buildings Volume 1 – Methodology, Tech. Rep. P-58-1*, Washington, D.C.

18. Ghrib, F., and Mamedov, H., 2004. Period formulas of shear wall buildings with flexible bases, *Earthquake engineering & Structural Dynamics*, 33(3), 295-314.

19. Goel, R., Chopra, A.K. (1997). "Period formulas for moment-resisting frame buildings". *Journal of Structural Engineering*; **123**(11): 1454 – 1461.

20. Goel, R., Chopra, A.K. (1998). "Period formulas for concrete shear wall frame buildings". *Journal of Structural Engineering*; **124**(4): 426 – 433.

21. Hampton, S. D., Lee, J. S., Tolbert, N. L., McLaren, T. M., Navarro, C. M., Myers, J. D., ... & Elnashai, A. S. (2008, December). MAEviz: bridging the time-from-discovery gap between seismic research and decision making. In *eScience, 2008. eScience'08. IEEE Fourth International Conference on* (pp. 414-415). IEEE.

22. Hatzigeorgiou, G. D., and Kanapitsas, G., 2013. Evaluation of fundamental period of low-rise and mid-rise reinforced concrete buildings *Earthquake Engineering & Structural Dynamics*, 42(11), 1599-1616.

23. Hong, A. L., Betti, R., and Lin, C. C., 2009. Identification of dynamic models of a building structure using multiple earthquake records, *Structural Control and Health Monitoring*, 16(2), 178-199.

24. Hong, L. L., & Hwang, W. L. (2000). Empirical formula for fundamental vibration periods of reinforced concrete buildings in Taiwan. *Earthquake engineering & structural dynamics*, *29*(3), 327-337.

25. Jeary, A. P. (1997). Damping in structures. *Journal of Wind Engineering and Industrial Aerodynamics*, 72: 345 – 55.

26. Jeary, A.P. (1986). "Damping in tall buildings – a mechanism and a predictor". Earthquake Engineering and Structural Dynamics; 14: 733 – 750.

27. Juang, J. (1997). Identification of linear structural systems using earthquake induced vibration data. *Journal of Guidance, Control, and Dynamics*, **20**(3): 492-500.

28. Juang, J. N. (1997). System realization using information matrix. *Journal of Guidance, Control, and Dynamics*, *20*(3), 492-500.

29. Juang, J. N., & Pappa, R. S. (1985). An eigensystem realization algorithm for modal parameter identification and model reduction. *Journal of guidance, control, and dynamics*, *8*(5), 620-627.

30. Juang, J. N., Phan, M., Horta, L. G., & Longman, R. W. (1993). Identification of observer/Kalman filter Markov parameters-Theory and experiments. *Journal of Guidance, Control, and Dynamics*, *16*(2), 320-329.

31. Koçak, A., & Yıldırım, M. K. (2011). Effects of infill wall ratio on the period of reinforced concrete framed buildings. *Advances in Structural Engineering*, *14*(5), 731-743.

32. Kwon, O. S., & Kim, E. S. (2010). Evaluation of building period formulas for seismic design. *Earthquake Engineering & Structural Dynamics*, *39*(14), 1569-1583.

33. Lagomarsino, S. (1993). Forecast models for damping and vibration periods of buildings. *Journal of Wind Engineering and Industrial Aerodynamics*, *48*(2), 221-239.

34. Lee, L. H., Chang, K. K., & Chun, Y. S. (2000). Experimental formula for the fundamental period of RC buildings with shear-wall dominant systems. *The Structural Design of Tall Buildings*, *9*(4), 295-307.

35. Li, Q. S., Liu, D. K., Fang, J. Q., Jeary, A. P., & Wong, C. K. (2000). Damping in buildings: its neural network model and AR model. *Engineering Structures*, *22*(9), 1216-1223.

36. Luş, H., Betti, R., Longman, R. W. (1999). Identification of linear structural systems using earthquake induced vibration data. *Earthquake Engineering and Structural Dynamics*, 28:1449-1467.

37. Memari, A. M., Aghakouchak, A. A., Ashtiany, M. G., and Tiv, M., 1999. Full-scale dynamic testing of a steel frame building during construction, *Engineering Structures*, 21(12), 1115-1127.

38. Poovarodom, N., and Charoenpong, K., 2008. Identification of Dynamic Properties of Low-Rise RC Building by Ambient Vibration Measurements During Construction, in *Proceedings, 14th World Conference on Earthquake Engineering*, 12–17 October, 2008, Beijing, China.

39. Sasaki, A., Suganuma, S., Suda, K., & Tamura, Y. (1998). Full-scale database on dynamic properties of buildings-Frequency and amplitude dependencies of buildings. In *Proc., Annual Meeting of the Architectural Institute of Japan (AIJ)* (pp. 379-380).

40. Satake, N., Suda, K. I., Arakawa, T., Sasaki, A., & Tamura, Y. (2003). Damping evaluation using full-scale data of buildings in Japan. *Journal of structural engineering*, *129*(4), 470-477.

41. Skolnik, D., Yu, E., Wallace, J., & Taciroglu, E. (2007). Modal System Identification & Finite Element Model Updating of a 15-story Building using Earthquake & Ambient Vibration Data. In *Structural Engineering Research Frontiers* (pp. 1-14). ASCE.

42. Schneider, P. J., & Schauer, B. A. (2006). HAZUS—its development and its future. *Natural Hazards Review*, *7*(2), 40-44.

43. Spence, S., Kareem, A. (2014). Tall Buildings and Damping: A Concept-Based Data-Driven Model. *J. Struct. Eng.*, **140**(5): 04014005.

44. Tamura, Y., & Yoshida, A. (2008). Amplitude dependency of damping in buildings. In *Proceedings of the 18th Analysis and Computation Speciality Conference* (Vol. 315).

45. Tralli, D. M. (2000). *Assessment of advanced technologies for loss estimation*. Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo

46. Van Overschee, P., & De Moor, B. (1994). N4SID: Subspace algorithms for the identification of combined deterministic-stochastic systems. *Automatica*, *30*(1), 75-93.

47. Van Overschee, P., & De Moor, B. L. (2012). *Subspace identification for linear systems: Theory—Implementation—Applications*. Springer Science & Business Media.

48. Wyatt, T. A. (1977, May). Mechanisms of damping. In *Proceeding of a Symposium of Dynamic Behavior of Bridges at the Transpor and Road Research Laboratory, Crowthorne, Berkshire, England, May 19, 1977.* (No. TRRL Rpt. 275 Proceeding).

49. Zhang, Z., & Cho, C. (2009). Experimental study on damping ratios of in-situ buildings. *World Acad Sci Eng Technol*, *50*, 614-618.

APPENDIX A: SYSTEM IDENTIFICATION SUMMARY

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
13698	CBF	42.5	2	Calexico 04 Apr 2010	X-Direction	0.025	0.012	1.549	2.128	0.48	0.15		2.13	0.43	
13698	CBF	42.5	2	Calexico 04 Apr 2010	Z-Direction	0.014	0.009	2.927	3.372	0.50	0.13		1.98	0.71	
13698	CBF	42.5	2	Chino Hills 29 July 2008	X-Direction	0.225	0.163	6.570	0.550	0.47	0.14	0.06	3.17	0.66	0.42
13698	CBF	42.5	2	Chino Hills 29 July 2008	Z-Direction	0.021	0.094	2.134	0.096	0.66	0.08	0.04	5.71	0.34	0.14
13698	CBF	42.5	2	La Habra 28 Mar 2014	X-Direction	0.016	0.019	0.872	0.048	0.48	0.16	0.06	1.97	0.50	0.09
13698	CBF	42.5	2	La Habra 28 Mar 2014	Z-Direction	0.023	0.018	0.921	0.055	0.50	0.11		1.67	0.46	
13698	CBF	42.5	2	Lake Elsinore 02 Sep 2007	X-Direction	0.043	0.150	4.164	0.195	0.56	0.17	0.06	2.80	1.37	0.47
13698	CBF	42.5	2	Lake Elsinore 02 Sep 2007	Z-Direction	0.047	0.108	2.244	0.103	0.45	0.10		2.98	0.37	
13702	CBF	161	7	Anza 12 Jun 2005	Z-Direction	0.008	0.018	0.884	0.087	1.00	0.35		3.58	4.06	
13702	CBF	161	7	Borrego Springs 07 Jul 2010	X-Direction	0.013	0.019	1.418	0.153	0.93	0.29		3.64	3.74	
13702	CBF	161	7	Borrego Springs 07 Jul 2010	Z-Direction		0.024	1.144	0.114		0.34		3.31	3.06	
13702	CBF	161	7	La Habra 28 Mar 2014	X-Direction	0.006	0.010	0.525	0.049	0.91	0.29		3.92	3.60	
13702	CBF	161	7	La Habra 28 Mar 2014	Z-Direction	0.008	0.016	0.726	0.093	1.01	0.34		2.58	3.60	
13702	CBF	161	7	Lake Elsinore 02 Sep 2007	Z-Direction	0.003	0.018	0.577	0.042	0.98	0.33		2.48	3.78	
14654	CBF	173	14	Borrego Springs 07 Jul 2010	X-Direction	0.004	0.003	0.382	0.086	1.54	0.50		3.94	2.71	
14654	CBF	173	14	Borrego Springs 07 Jul 2010	Z-Direction	0.002	0.003	0.409	0.082	1.95	0.59		2.67	2.42	
14654	CBF	173	14	Calexico 04 Apr 2010	X-Direction	0.028	0.011	9.308	8.629	1.65	0.53		2.97	2.77	
14654	CBF	173	14	Calexico 04 Apr 2010	Z-Direction	0.019	0.009	5.407	5.070	1.84	0.62		2.57	2.73	
14654	CBF	173	14	Inglewood 17 May 2009	X-Direction	0.005	0.035	1.546	0.197	1.58	0.50		3.36	2.87	
14654	CBF	173	14	Inglewood 17 May 2009	Z-Direction	0.002	0.047	1.824	0.104	1.86	0.59		2.73	2.79	
14654	CBF	173	14	La Habra 28 Mar 2014	X-Direction	0.016	0.010	1.315	0.312	1.53	0.52		2.94	2.66	
14654	CBF	173	14	La Habra 28 Mar 2014	Z-Direction	0.005	0.007	1.191	0.317	1.81	0.60		2.98	2.87	
14654	CBF	173	14	Northridge 17 Jan 1994	X-Direction	0.078	0.091	10.197	2.697	1.82	0.56		2.98	1.55	
14654	CBF	173	14	Northridge 17 Jan 1994	Z-Direction	0.048	0.130	11.513	3.200	2.02	0.60		1.93	1.58	
24248	CBF	147	9	Barstow 05 Dec 2008	X-Direction	0.004	0.002	0.182	0.035	0.64	0.25	0.16	2.47	2.36	2.34
24248	CBF	147	9	Barstow 05 Dec 2008	Z-Direction	0.006	0.002	0.252	0.037	0.62	0.21	0.11	2.17	1.45	0.38
24248	CBF	147	9	Borrego Springs 07 Jul 2010	X-Direction	0.010	0.005	0.496	0.125	0.66	0.25	0.16	2.78	2.37	0.50
24248	CBF	147	9	Borrego Springs 07 Jul 2010	Z-Direction	0.012	0.005	0.419	0.133	0.63	0.25	0.11	2.21	1.22	0.33
24248	CBF	147	9	Calexico 04 Apr 2010	X-Direction	0.039	0.010	3.500	5.006	0.68	0.26	0.16	2.51	1.37	0.81
24248	CBF	147	9	Calexico 04 Apr 2010	Z-Direction	0.025	0.009	2.671	3.200	0.66	0.23	0.11	2.56	1.38	3.71
24248	CBF	147	9	Chino Hills 29 July 2008	X-Direction	0.038	0.055	3.612	0.723	0.68	0.26	0.17	3.00	2.84	0.91
24248	CBF	147	9	Chino Hills 29 July 2008	Z-Direction	0.060	0.048	2.716	0.319	0.67	0.23	0.10	3.71	2.46	0.27
24248	CBF	147	9	Encino 17 Mar 2014	X-Direction	0.010	0.046	1.055	0.090	0.66	0.27	0.17	2.75	2.39	1.39
24248	CBF	147	9	Encino 17 Mar 2014	Z-Direction	0.009	0.024	0.588	0.030	0.64	0.26	0.12	2.54	1.19	0.70
24248	CBF	147	9	Inglewood 17 May 2009	X-Direction	0.007	0.012	0.441	0.075	0.65	0.25	0.16	2.23	2.47	0.45
24248	CBF	147	9	Inglewood 17 May 2009	Z-Direction	0.011	0.006	0.454	0.081	0.64	0.22	0.11	2.50	2.19	0.23
24248	CBF	147	9	La Habra 28 Mar 2014	X-Direction	0.036	0.023	2.725	0.562	0.70	0.24	0.17	2.59	0.62	1.17
24248	CBF	147	9	La Habra 28 Mar 2014	Z-Direction	0.025	0.025	1.415	0.325	0.65	0.23	0.16	3.05	1.81	0.56
24248	CBF	147	9	Newhall 1 Sep 2011	X-Direction	0.002	0.004	0.099	0.011	0.60	0.21	0.11	1.77	2.88	0.42
24248	CBF	147	9	Newhall 1 Sep 2011	Z-Direction	0.003	0.004	0.147	0.013	0.60	0.21	0.11	1.77	2.69	0.42
24248	CBF	147	9	Rowland Heights 29 Mar 2014	X-Direction	0.007	0.020	0.634	0.044	0.65	0.22	0.17	2.89	1.43	2.28
24248	CBF	147	9	Rowland Heights 29 Mar 2014	Z-Direction	0.003	0.012	0.408	0.018	0.61	0.39	0.12	3.26	2.75	0.30
24248	CBF	147	9	Whittier Narrows 16 Mar 2010	X-Direction	0.009	0.050	1.319	0.052	0.65	0.25	0.17	2.79	4.20	1.14
24248	CBF	147	9	Whittier Narrows 16 Mar 2010	Z-Direction	0.010	0.053	1.226	0.075	0.63	0.23	0.10	2.96	1.05	0.37
24248	CBF	147	9	Yorba Linda 07 Aug 2012	X-Direction	0.003	0.009	0.250	0.015	0.64	0.25	0.16	2.47	2.61	1.30
24248	CBF	147	9	Yorba Linda 07 Aug 2012	Z-Direction	0.002	0.009	0.232	0.012	0.61	0.22	0.16	2.91	2.75	0.72
24332	CBF	72.5	3	Encino 17 Mar 2014	X-Direction	0.041	0.041	1.769	0.108	0.48	0.11		3.16	0.44	
24332	CBF	72.5	3	Encino 17 Mar 2014	Z-Direction	0.093	0.094	3.660	0.250	0.44	0.12		1.97	0.77	
24332	CBF	72.5	3	Northridge 17 Jan 1994	X-Direction	0.469	0.327	16.071	4.490	0.55	0.16		2.93	0.72	
24332	CBF	72.5	3	Northridge 17 Jan 1994	Z-Direction	0.420	0.317	29.640	4.912	0.53	0.13		2.90	0.51	
24332	CBF	72.5	3	View Park Windsor Hills 12 Apr 2015	X-Direction	0.002	0.006	0.108	0.005	0.43	0.17		2.81	0.56	
24332	CBF	72.5	3	View Park Windsor Hills 12 Apr 2015	Z-Direction	0.005	0.005	0.234	0.013	0.40	0.16		2.54	1.01	
24332	CBF	72.5	3	Whittier 01 Oct 1987	X-Direction	0.101	0.062	4.162	0.467	0.45	0.13		3.82	0.65	
24332	CBF	72.5	3	Whittier 01 Oct 1987	Z-Direction	0.108	0.047	3.787	0.518	0.41	0.12		1.43	0.52	
24602	CBF	773	57	Big Bear 28 Jun 1992	X-Direction	0.003	0.030	4.170	1.034	6.02	1.73	0.96	1.09	1.77	1.51
24602	CBF	773	57	Big Bear 28 Jun 1992	Z-Direction	0.003	0.030	3.409	1.196	5.85	1.82	0.97	1.38	1.48	1.32
24602	CBF	773	57	Chino Hills 29 July 2008	X-Direction	0.001	0.063	2.429	0.436	5.88	1.82	0.94	0.94	1.70	1.38
24602	CBF	773	57	Chino Hills 29 July 2008	Z-Direction	0.001	0.063	5.201	0.858	5.71	1.77	0.96	1.83	1.55	1.28
24602	CBF	773	57	Encino 17 Mar 2014	X-Direction	0.000	0.014	0.288	0.063	5.73	1.75	0.90	0.26	0.87	1.43
24602	CBF	773	57	Encino 17 Mar 2014	Z-Direction		0.014	0.245	0.058		1.73	0.99		0.55	1.45
24602	CBF	773	57	La Habra 28 Mar 2014	X-Direction	0.001	0.016	1.348	0.353	5.93	1.78	0.95	0.72	2.05	1.61
24602	CBF	773	57	La Habra 28 Mar 2014	Z-Direction	0.001	0.016	1.536	0.451	5.66	1.78	0.94	1.22	1.31	1.40
24602	CBF	773	57	Landers 28 Jun 1992	X-Direction	0.018	0.050	6.614	4.754	6.10	1.81	0.94	1.08	1.40	1.35

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
24602	CBF	773	57	Landers 28 Jun 1992	Z-Direction	0.019	0.050	8.699	9.813	5.84	1.79	0.95	1.63	1.44	1.42
24602	CBF	773	57	Northridge 17 Jan 1994	X-Direction	0.011	0.150	7.974	4.035	6.16	1.82	0.98	1.23	1.41	1.32
24602	CBF	773	57	Northridge 17 Jan 1994	Z-Direction	0.005	0.150	10.986	1.971	5.88	1.84	1.00	1.05	1.23	1.47
24602	CBF	773	57	Sierra Madre 28 Jun 1991	X-Direction	0.002	0.090	2.824	0.581	5.72	1.73	0.91	1.25	1.26	1.21
24602	CBF	773	57	Sierra Madre 28 Jun 1991	Z-Direction	0.001	0.090	5.073	0.881	5.50	1.81	0.95	1.07	1.88	1.65
24713	CBF	130	8	Big Bear City 22 Feb 2003	X-Direction	0.014	0.009	0.505	0.046	0.36	0.12	0.06	2.08	0.18	0.11
24713	CBF	130	8	Big Bear City 22 Feb 2003	Z-Direction	0.003	0.003	0.226	0.023	0.85	0.35	0.17	1.95	1.01	0.46
24713	CBF	130	8	Borrego Springs 07 Jul 2010	X-Direction	0.009	0.008	0.472	0.078	0.89	0.33	0.16	1.39	2.10	0.82
24713	CBF	130	8	Borrego Springs 07 Jul 2010	Z-Direction	0.006	0.005	0.490	0.077	0.85	0.30	0.14	2.27	1.06	0.63
24713	CBF	130	8	Chino Hills 29 July 2008	X-Direction	0.066	0.129	9.024	0.975	0.97	0.32	0.15	2.21	0.93	0.89
24713	CBF	130	8	Chino Hills 29 July 2008	Z-Direction	0.024	0.032	1.914	0.410	0.88	0.30	0.16	1.73	0.96	0.50
24713	CBF	130	8	Encino 17 Mar 2014	X-Direction	0.003	0.011	0.419	0.031	0.88	0.32	0.15	1.77	1.12	0.22
24713	CBF	130	8	Encino 17 Mar 2014	Z-Direction	0.004	0.015	0.529	0.038	0.84	0.26	0.17	2.01	0.79	0.58
47796	CBF	65	3	Alum Rock 30 Oct 2007	X-Direction	0.024	0.008	0.966	0.157	0.32			1.88		
47796	CBF	65	3	Alum Rock 30 Oct 2007	Z-Direction	0.017	0.011	1.070	0.172	0.34	0.13	0.10	1.91	1.16	0.48
47796	CBF	65	3	Aromas 2 Jul 2007	X-Direction	0.013	0.019	0.486	0.025	0.32	0.09		1.19	0.17	
47796	CBF	65	3	Aromas 2 Jul 2007	Z-Direction	0.022	0.021	0.713	0.044	0.35	0.14	0.08	3.45	0.65	0.35
47796	CBF	65	3	Gilroy 13 May 2002	X-Direction	0.023	0.012	0.666	0.109	0.33	0.09		1.46	0.35	
47796	CBF	65	3	Gilroy 13 May 2002	Z-Direction	0.031	0.013	1.207	0.157	0.33	0.13	0.05	1.69	1.23	0.15
47796	CBF	65	3	Hollister 21 Dec 2008	X-Direction	0.007	0.004	0.150	0.013	0.29	0.07		1.63	0.19	
47796	CBF	65	3	Hollister 21 Dec 2008	Z-Direction	0.007	0.003	0.174	0.021	0.33	0.13	0.06	2.12	1.45	0.26
47796	CBF	65	3	Parkfield 28 Sep 2004	X-Direction	0.021	0.011	1.506	0.304	0.31	0.07		1.14	0.10	
47796	CBF	65	3	Parkfield 28 Sep 2004	Z-Direction	0.031	0.011	1.701	0.277	0.36	0.13		2.08	0.58	
47796	CBF	65	3	San Juan Bautista 05 Dec 5 2014	X-Direction	0.015	0.009	0.320	0.034	0.30	0.10		2.58	1.16	
47796	CBF	65	3	San Juan Bautista 05 Dec 5 2014	Z-Direction	0.046	0.042	1.634	0.103	0.36	0.14	0.08	2.41	1.87	0.32
47796	CBF	65	3	San Juan Bautista 12 Jan 2011	X-Direction	0.037	0.016	0.965	0.118	0.30	0.07		2.37	0.11	
47796	CBF	65	3	San Juan Bautista 12 Jan 2011	Z-Direction	0.069	0.027	1.165	0.120	0.36	0.13		1.85	0.42	
47796	CBF	65	3	San Juan Bautista 27 Jun 2013	X-Direction	0.023	0.018	0.642	0.038	0.31	0.07		2.51	0.46	
47796	CBF	65	3	San Juan Bautista 27 Jun 2013	Z-Direction	0.015	0.021	0.585	0.040	0.34	0.13		2.56	0.29	
47796	CBF	65	3	San Juan Bautista 15 Mar 2004	X-Direction	0.008	0.006	0.458	0.119	0.30	0.07		1.46	0.21	
47796	CBF	65	3	San Juan Bautista 15 Mar 2004	Z-Direction	0.019	0.012	0.930	0.174	0.34	0.13	0.08	2.64	0.35	0.38
47796	CBF	65	3	San Juan Bautista 19 Nov 2014	X-Direction	0.004	0.002	0.099	0.008	0.29	0.07		1.02	0.65	
47796	CBF	65	3	San Juan Bautista 19 Nov 2014	Z-Direction	0.013	0.010	0.356	0.028	0.34	0.13	0.08	1.68	1.11	0.39
47796	CBF	65	3	San Juan Bautista 19 Nov 2014	X-Direction	0.021	0.008	0.597	0.080	0.31	0.07		2.38	0.30	
47796	CBF	65	3	San Juan Bautista 19 Nov 2014	Z-Direction	0.064	0.033	1.877	0.189	0.34	0.14		4.00	1.59	
47796	CBF	65	3	San Simeon 22 Dec 2003	X-Direction	0.025	0.014	2.784	0.923	0.31	0.09		2.55	0.27	
47796	CBF	65	3	San Simeon 22 Dec 2003	Z-Direction	0.025	0.017	2.979	0.807	0.35	0.13		2.51	0.50	
54331	CBF	32.8	1	Mammoth Lakes 12 Jun 2007	X-Direction	0.208	0.136	3.784	0.210	0.14	0.05		1.86	1.01	
54331	CBF	32.8	1	Mammoth Lakes 12 Jun 2007	Z-Direction	0.147	0.116	4.189	0.216	0.17	0.05		3.56	1.39	
54331	CBF	32.8	1	Mammoth Lakes 21 Oct 2013	Z-Direction	0.010	0.005	0.132	0.007	0.16	0.04		4.16	0.63	
54331	CBF	32.8	1	Mammoth Lakes 24 Oct 2013	X-Direction	0.047	0.025	0.460	0.016	0.14	0.04		2.98	0.73	
54331	CBF	32.8	1	Mammoth Lakes 24 Oct 2013	Z-Direction	0.037	0.032	0.388	0.020	0.16	0.05		3.47	0.47	
54331	CBF	32.8	1	Mammoth Lakes 25 Oct 2013	X-Direction	0.015	0.008	0.177	0.012	0.14	0.05		1.69	0.20	
54331	CBF	32.8	1	Mammoth Lakes 25 Oct 2013	Z-Direction	0.016	0.004	0.136	0.008	0.16	0.05		2.54	0.13	
54331	CBF	32.8	1	Toms Place 15 Oct 2011	X-Direction	0.013	0.008	0.175	0.004	0.15	0.03		2.37	0.07	
54331	CBF	32.8	1	Toms Place 15 Oct 2011	Z-Direction	0.004	0.004	0.116	0.003	0.34	0.05		0.95	0.19	
54331	CBF	32.8	1	Toms Place 26 Nov 2006	X-Direction	0.012	0.007	0.119	0.004	0.14	0.04		3.38	0.51	
54331	CBF	32.8	1	Toms Place 26 Nov 2006	Z-Direction	0.016	0.004	0.082	0.003	0.15	0.04		2.07	0.13	
54331	CBF	32.8	1	Toms Place 28 Jun 2008	X-Direction	0.056	0.034	0.784	0.029	0.15	0.05		2.90	0.59	
54331	CBF	32.8	1	Toms Place 28 Jun 2008	Z-Direction	0.067	0.030	0.604	0.017	0.17	0.06		1.82	0.86	
54331	CBF	32.8	1	Toms Place 29 Mar 2013	X-Direction	0.016	0.007	0.093	0.005	0.14	0.03		2.04	0.02	
54331	CBF	32.8	1	Toms Place 29 Mar 2013	Z-Direction	0.007	0.005	0.183	0.009	0.17	0.05		2.55	0.23	
54331	CBF	32.8	1	Tonopah Jnctn 12 Feb 2013	X-Direction	0.011	0.003	0.120	0.011	0.11	0.04		1.23	0.03	
54331	CBF	32.8	1	Tonopah Jnctn 12 Feb 2013	Z-Direction	0.010	0.004	0.144	0.009	0.18	0.03		2.17	0.03	
57948	CBF	32.5	2	Gilroy 13 May 2002	X-Direction	0.029	0.008	0.536	0.065	0.32	0.08		5.70	0.67	
57948	CBF	32.5	2	Gilroy 13 May 2002	Z-Direction	0.029	0.009	0.485	0.055	0.41	0.07		3.86	0.34	
57948	CBF	32.5	2	Morgan Hill 07 Jan 2011	Z-Direction	0.014	0.007	0.325	0.034	0.41	0.05		3.90	0.30	
57948	CBF	32.5	2	South Napa 24 Aug 2014	X-Direction	0.000	0.000	0.001		0.28	0.08		1.52	0.50	
57948	CBF	32.5	2	South Napa 24 Aug 2014	Z-Direction	0.000	0.000	0.024	0.008	0.38	0.08		1.26	0.79	
58196	CBF	68.7	5	Alamo 5 Sept 2008	X-Direction	0.041	0.018	0.925	0.057	0.30	0.09	0.06	1.86	1.55	0.45
58196	CBF	68.7	5	Alamo 5 Sept 2008	Z-Direction	0.014	0.009	0.289	0.019	0.28			0.79		
58196	CBF	68.7	5	Berkeley 20 Oct 2011	X-Direction	0.041	0.034	0.931	0.061	0.34			4.80		
58196	CBF	68.7	5	Berkeley 20 Oct 2011	Z-Direction	0.042	0.033	1.137	0.068	0.32	0.10	0.06	3.27	1.95	0.39

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
58196	CBF	68.7	5	Berkeley 5 Sept 2003	X-Direction	0.025	0.030	0.738	0.039	0.31			2.09		
58196	CBF	68.7	5	Berkeley 5 Sept 2003	Z-Direction	0.067	0.034	1.233	0.051	0.30			1.27		
58196	CBF	68.7	5	El Cerrito 05 Mar 2012	X-Direction	0.040	0.018	1.376	0.091	0.34			2.78		
58196	CBF	68.7	5	El Cerrito 05 Mar 2012	Z-Direction	0.082	0.032	0.661	0.069	0.32	0.11	0.07	2.52	0.38	0.24
58196	CBF	68.7	5	Lafayette 01 Mar 2007	X-Direction	0.124	0.056	2.405	0.127	0.32			2.42		
58196	CBF	68.7	5	Lafayette 01 Mar 2007	Z-Direction	0.177	0.052	3.342	0.203	0.26			0.80		
58196	CBF	68.7	5	Morgan Hill 07 Jan 2011	X-Direction	0.008	0.002	0.084	0.005	0.34			1.43		
58196	CBF	68.7	5	Morgan Hill 07 Jan 2011	Z-Direction	0.008	0.002	0.076	0.006	0.31	0.12	0.06	2.24	0.53	0.21
58196	CBF	68.7	5	Piedmont 20 July 2007	X-Direction	0.127	0.061	2.422	0.228	0.33			1.62		
58196	CBF	68.7	5	Piedmont 20 July 2007	Z-Direction	0.210	0.073	3.075	0.183	0.27			1.21		
58196	CBF	68.7	5	South Napa 24 Aug 2014	X-Direction	0.040	0.016	1.185	0.329	0.38			1.86		
58196	CBF	68.7	5	South Napa 24 Aug 2014	Z-Direction	0.049	0.011	0.748	0.323	0.31	0.11		1.50	0.88	
24249	EBF	136	8	Borrego Springs 07 Jul 2010	X-Direction	0.010	0.006	0.515	0.150	0.700	0.240	0.110	3.430	4.210	0.150
24249	EBF	137	8	Borrego Springs 07 Jul 2010	Z-Direction	0.009	0.007	0.571	0.132	0.720	0.240	0.110	1.560	1.550	0.720
24249	EBF	138	8	Calexico 04 Apr 2010	X-Direction	0.023	0.009	2.738	3.186	0.630	0.260	0.110	2.720	1.470	0.170
24249	EBF	139	8	Calexico 04 Apr 2010	Z-Direction	0.039	0.011	3.365	4.989	0.700	0.250	0.160	3.750	2.180	1.100
24249	EBF	134	8	Chino Hills 29 July 2008	X-Direction	0.064	0.059	2.912	0.326	0.710	0.260	0.160	3.190	4.680	0.400
24249	EBF	140	8	Encino 17 Mar 2014	X-Direction	0.007	0.017	0.504	0.029	0.680	0.260	0.160	3.030	3.460	1.550
24249	EBF	142	8	Inglewood 17 May 2009	Z-Direction	0.007	0.010	0.515	0.079	0.680	0.260	0.170	3.260	2.370	0.320
24249	EBF	144	8	La Habra 28 Mar 2014	X-Direction	0.030	0.026	1.528	0.350	0.710	0.260	0.170	2.140	4.250	0.200
24249	EBF	145	8	La Habra 28 Mar 2014	Z-Direction	0.047	0.035	2.591	0.521	0.500	0.190	0.120	1.820	0.340	0.770
24249	EBF	146	8	Rowland Heights 29 Mar 2014	X-Direction	0.003	0.019	0.514	0.024	0.670	0.253	0.092	2.610	3.700	0.513
24249	EBF	147	8	Rowland Heights 29 Mar 2014	Z-Direction	0.013	0.015	0.716	0.045	0.486	0.118	0.092	1.427	0.569	0.473
24249	EBF	148	8	Whittier Narrows 16 Mar 2010	X-Direction	0.010	0.045	1.310	0.070	0.680	0.250	0.160	3.070	3.640	0.790
24249	EBF	149	8	Whittier Narrows 16 Mar 2010	Z-Direction	0.021	0.052	1.729	0.055	0.490	0.220	0.170	1.360	3.510	0.590
24249	EBF	150	8	Yorba Linda 07 Aug 2012	X-Direction	0.002	0.010	0.221	0.014	0.660	0.250	0.160	2.310	4.280	0.710
24249	EBF	151	8	Yorba Linda 07 Aug 2012	Z-Direction	0.003	0.008	0.290	0.021	0.670	0.230	0.080	2.350	1.780	0.110
57594	EBF	104.5	5	Alum Rock 30 Oct 2007	X-Direction	0.084	0.074	5.728	0.674	0.710	0.210		3.170	0.830	
57594	EBF	104.5	5	Alum Rock 30 Oct 2007	Z-Direction	0.045	0.063	3.051	0.315	0.560	0.110		2.320	0.270	
57594	EBF	104.5	5	Gilroy 13 May 2002	X-Direction	0.008	0.020	0.746	0.081	0.630	0.230		2.890	2.140	
57594	EBF	104.5	5	Gilroy 13 May 2002	Z-Direction	0.016	0.017	0.809	0.101	0.540	0.130		3.110	1.140	
57594	EBF	104.5	5	Milpitas 07 Jan 2010	X-Direction	0.005	0.008	0.395	0.042	0.610	0.200		1.550	3.090	
57594	EBF	104.5	5	Milpitas 07 Jan 2010	Z-Direction	0.004	0.005	0.152	0.037	0.520	0.110		1.760	1.420	
58496	EBF	40.5	3	Berkeley 20 Oct 2011	X-Direction	0.114	0.078	2.548	0.145	0.337	0.117		2.727	1.856	
58496	EBF	40.5	3	Berkeley 20 Oct 2011	Z-Direction	0.112	0.078	2.072	0.114	0.305	0.119	0.036	1.291	1.166	0.364
58496	EBF	40.5	3	Berkeley 20 Oct 2011	X-Direction	0.081	0.058	1.689	0.095	0.337	0.073		2.327	0.949	
58496	EBF	40.5	3	Berkeley 20 Oct 2011	Z-Direction	0.050	0.058	1.186	0.061	0.339	0.106	0.074	2.763	0.866	0.364
58496	EBF	40.5	3	Berkeley 27 October 2011	X-Direction	0.026	0.026	0.654	0.029	0.286	0.109		2.713	0.940	
58496	EBF	40.5	3	Berkeley 27 October 2011	Z-Direction	0.021	0.026	0.504	0.027	0.300	0.086	0.039	1.790	0.970	0.564
58496	EBF	40.5	3	El Cerrito 05 Mar 2012	X-Direction	0.131	0.078	3.003	0.155	0.303	0.083		1.744	0.568	
58496	EBF	40.5	3	El Cerrito 05 Mar 2012	Z-Direction	0.129	0.078	2.113	0.109	0.245	0.089	0.053	2.028	0.393	0.138
58496	EBF	40.5	3	Loma Prieta 17 Oct 1989	X-Direction	0.222	0.120	6.410	0.919	0.345	0.124		1.151	0.349	
58496	EBF	40.5	3	Loma Prieta 17 Oct 1989	Z-Direction	0.273	0.120	17.563	2.752	0.347	0.122		2.256	0.340	
23544	MAW	97.5	6	Landers 28 Jun 1992	X-Direction	0.082	0.068	11.103	3.106	0.590	0.240		3.380	2.420	
23544	MAW	97.5	6	Landers 28 Jun 1992	Z-Direction	0.070	0.050	9.668	2.419	0.910	0.240		4.180	0.860	
24517	MAW	41.5	3	Calexico 04 Apr 2010	X-Direction	0.007	0.007	2.476	2.726	0.196			6.461		
24517	MAW	41.5	3	Calexico 04 Apr 2010	Z-Direction	0.010	0.007	1.671	1.545	0.196			4.785		
24517	MAW	41.5	3	Landers 28 Jun 1992	X-Direction	0.105	0.070	5.814	2.695	0.218			1.300		
24517	MAW	41.5	3	Landers 28 Jun 1992	Z-Direction	0.169	0.070	8.424	3.620	0.201			1.324		
24517	MAW	41.5	3	Northridge 17 Jan 1994	X-Direction	0.108	0.070	8.636	2.632	0.212			1.840		
24517	MAW	41.5	3	Northridge 17 Jan 1994	Z-Direction	0.104	0.070	9.912	2.428	0.211			1.054		
24517	MAW	41.5	3	Whittier 01 Oct 1987	X-Direction	0.114	0.060	2.928	0.187	0.195			2.223		
24517	MAW	41.5	3	Whittier 01 Oct 1987	Z-Direction	0.174	0.060	2.683	0.165	0.205			1.164		
58492	MAW	74.9	8	Alamo 5 Sept 2008	X-Direction	0.007	0.005	0.299	0.027	0.650	0.230	0.110	1.110	0.740	0.740
58492	MAW	74.9	8	Alamo 5 Sept 2008	Z-Direction	0.015	0.007	0.370	0.030	0.370	0.090	0.050	2.270	1.090	0.100
58492	MAW	74.9	8	Alum Rock 30 Oct 2007	X-Direction	0.014	0.004	0.531	0.113	0.680	0.250	0.120	1.300	1.060	0.460
58492	MAW	74.9	8	Alum Rock 30 Oct 2007	Z-Direction	0.012	0.005	0.564	0.111	0.360	0.100		2.930	0.290	
58492	MAW	74.9	8	Berkeley 20 Oct 2011	X-Direction	0.030	0.019	1.020	0.101	0.610	0.200	0.110	1.480	0.690	0.250
58492	MAW	74.9	8	Berkeley 20 Oct 2011	Z-Direction	0.030	0.014	0.690	0.059	0.370	0.090		0.960	0.490	
58492	MAW	74.9	8	Berkeley 20 Oct 2011	X-Direction	0.026	0.015	1.148	0.086	0.610	0.200	0.100	1.590	0.500	0.670
58492	MAW	74.9	8	Berkeley 20 Oct 2011	Z-Direction	0.028	0.016	0.989	0.059	0.470	0.090		1.830	0.490	
58492	MAW	74.9	8	Berkeley 20 Oct 2011	X-Direction	0.013	0.008	0.429	0.039	0.610	0.220	0.110	1.270	1.340	1.240
58492	MAW	74.9	8	Berkeley 20 Oct 2011	Z-Direction	0.019	0.010	0.484	0.039	0.400	0.100	0.040	2.280	0.850	0.090

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
58492	MAW	74.9	8	Concord 03 May 2015	X-Direction	0.006	0.005	0.247	0.026	0.620	0.190	0.120	1.760	0.800	0.830
58492	MAW	74.9	8	Concord 03 May 2015	Z-Direction	0.008	0.007	0.274	0.026	0.400	0.090	0.050	1.450	0.520	0.800
58492	MAW	74.9	8	El Cerrito 05 Mar 2012	X-Direction	0.012	0.007	0.524	0.040	0.620	0.220	0.110	1.120	0.830	0.860
58492	MAW	74.9	8	El Cerrito 05 Mar 2012	Z-Direction	0.025	0.007	0.506	0.032	0.370	0.090	0.040	0.900	0.830	0.050
58492	MAW	74.9	8	Loma Prieta 17 Oct 1989	X-Direction	0.194	0.058	7.827	2.118	0.730	0.180		2.950	0.930	
58492	MAW	74.9	8	Loma Prieta 17 Oct 1989	Z-Direction	0.133	0.046	6.881	1.823	0.410	0.140		1.740	0.220	
58492	MAW	74.9	8	Piedmont 20 July 2007	X-Direction	0.007	0.009	0.492	0.053	0.670	0.220	0.110	2.350	1.090	0.960
58492	MAW	74.9	8	Piedmont 20 July 2007	Z-Direction	0.039	0.011	0.567	0.057	0.320	0.080		2.550	0.440	
58492	MAW	74.9	8	Piedmont Area 20 Dec 2006	X-Direction	0.009	0.005	0.367	0.030	0.600	0.210	0.100	0.800	0.690	0.110
58492	MAW	74.9	8	Piedmont Area 20 Dec 2006	Z-Direction	0.016	0.005	0.384	0.031	0.460	0.090		1.950	0.490	
58492	MAW	74.9	8	South Napa 24 Aug 2014	X-Direction	0.029	0.019	1.588	0.462	0.760	0.230	0.150	1.310	0.620	0.260
58492	MAW	74.9	8	South Napa 24 Aug 2014	Z-Direction	0.054	0.022	1.893	0.509	0.700	0.220		3.020	0.320	
89473	MAW	22	1	Bayview 11 Oct 2013	X-Direction	0.106	0.109	1.302	0.098	0.139			2.218		
89473	MAW	22	1	Eureka Offshore 05 Oct 2010	X-Direction	0.016	0.008	0.217	0.012	0.127			3.636		
89473	MAW	22	1	Fendale 04 Feb 2010	X-Direction	0.115	0.034	0.987	0.105	0.098			1.466		
89473	MAW	22	1	Ferndale 01 Jan 2014	X-Direction	0.028	0.010	0.204	0.009	0.118			0.883		
89473	MAW	22	1	Ferndale 09 Mar 2014	X-Direction	0.241	0.046	2.075	1.424	0.122			0.878		
89473	MAW	22	1	Ferndale 17 Dec 2013	X-Direction	0.017	0.015	0.267	0.011	0.125			0.554		
89473	MAW	22	1	Ferndale 28 Jan 2015	X-Direction	0.100	0.047	2.183	0.227	0.143			2.555		
89473	MAW	22	1	Humboldt Hill 02 Aug 2013	X-Direction	0.012	0.006	0.144	0.009	0.104			2.995		
89473	MAW	22	1	Petrolia 25 Apr 1992	X-Direction	0.324	0.138	17.543	4.867	0.162			0.713		
89473	MAW	22	1	Petrolia Aftershock 26 Apr 1992	X-Direction	0.608	0.177	11.585	2.305	0.323			1.356		
89473	MAW	22	1	Petrolia Offshore 15 Nov 2008	X-Direction	0.023	0.046	0.454	0.028	0.098			0.539		
89473	MAW	22	1	Petrolia Offshore 26 Oct 2008	X-Direction	0.029	0.008	0.327	0.023	0.123			2.500		
89473	MAW	22	1	Riodell 14 Sep 2012	X-Direction	0.029	0.006	0.179	0.009	0.128			2.808		
89494	MAW	44.7	5	Bayview 11 Oct 2013	X-Direction	0.093	0.045	1.665	0.152	0.290			2.950		
89494	MAW	44.7	5	Bayview 11 Oct 2013	Z-Direction	0.077	0.059	2.016	0.187	0.230			1.960		
89494	MAW	44.7	5	Fendale 04 Feb 2010	X-Direction	0.033	0.010	0.901	0.232	0.290			1.830		
89494	MAW	44.7	5	Fendale 04 Feb 2010	Z-Direction	0.022	0.012	1.104	0.151	0.230			1.040		
89494	MAW	44.7	5	Ferndale 09 Jan 2010	X-Direction	0.643	0.174	11.850	2.465	0.320			3.710		
89494	MAW	44.7	5	Ferndale 09 Jan 2010	Z-Direction	0.563	0.258	33.003	7.900	0.300			1.080		
89494	MAW	44.7	5	Ferndale 09 Mar 2014	X-Direction	0.049	0.024	2.263	1.571	0.280			3.940		
89494	MAW	44.7	5	Ferndale 09 Mar 2014	Z-Direction	0.084	0.030	2.362	1.710	0.250			1.390		
89494	MAW	44.7	5	Ferndale 17 Dec 2013	X-Direction	0.026	0.013	0.468	0.021	0.260			2.580		
89494	MAW	44.7	5	Ferndale 17 Dec 2013	Z-Direction	0.033	0.014	0.682	0.051	0.300			1.790		
89494	MAW	44.7	5	Ferndale 26 Feb 2007	X-Direction	0.013	0.008	0.689	0.092	0.230			1.250		
89494	MAW	44.7	5	Ferndale 26 Feb 2007	Z-Direction	0.050	0.013	0.984	0.130	0.220			1.770		
89494	MAW	44.7	5	Ferndale 28 Jan 2015	X-Direction	0.012	0.005	0.409	0.081	0.240			2.100		
89494	MAW	44.7	5	Ferndale 28 Jan 2015	Z-Direction	0.013	0.005	0.396	0.052	0.220			2.230		
89494	MAW	44.7	5	Humboldt Hill 02 Aug 2013	X-Direction	0.013	0.012	0.602	0.042	0.260			3.440		
89494	MAW	44.7	5	Humboldt Hill 02 Aug 2013	Z-Direction	0.018	0.010	0.491	0.037	0.330			1.520		
89494	MAW	44.7	5	Petrolia 20 Jul 2012	X-Direction	0.008	0.002	0.091	0.008	0.250			2.530		
89494	MAW	44.7	5	Petrolia 20 Jul 2012	Z-Direction	0.008	0.003	0.119	0.006	0.240			1.370		
89494	MAW	44.7	5	Petrolia Offshore 26 Oct 2008	X-Direction	0.009	0.004	0.143	0.019	0.230			2.880		
89494	MAW	44.7	5	Petrolia Offshore 26 Oct 2008	Z-Direction	0.010	0.003	0.166	0.025	0.250			1.490		
89494	MAW	44.7	5	Trinidad 16 Aug 2008	X-Direction	0.028	0.014	0.661	0.075	0.230			3.860		
89494	MAW	44.7	5	Trinidad 16 Aug 2008	Z-Direction	0.053	0.025	1.550	0.105	0.210			1.560		
89494	MAW	44.7	5	Trinidad 24 Jun 2007	X-Direction	0.072	0.031	1.820	0.132	0.230			2.900		
24385	PCW	88	10	Borrego Springs 07 Jul 2010	X-Direction	0.013	0.006	0.523	0.095	0.480	0.120	0.070	2.630	2.200	1.700
24385	PCW	88	10	Borrego Springs 07 Jul 2010	Z-Direction	0.010	0.004	0.458	0.074	0.430	0.120	0.080	2.930	1.420	0.300
24385	PCW	88	10	Calexico 04 Apr 2010	X-Direction	0.017	0.008	1.647	1.613	0.480	0.120	0.070	1.180	1.940	0.150
24385	PCW	88	10	Calexico 04 Apr 2010	Z-Direction	0.016	0.005	2.006	2.883	0.480	0.120	0.070	1.530	0.770	0.300
24385	PCW	88	10	Chatsworth 09 Aug 2007	X-Direction	0.003	0.008	0.215	0.026	0.410	0.130	0.070	2.490	3.680	0.200
24385	PCW	88	10	Chatsworth 09 Aug 2007	Z-Direction	0.003	0.011	0.294	0.020	0.510	0.120	0.060	1.790	0.930	0.250
24385	PCW	88	10	Chino Hills 29 July 2008	X-Direction	0.067	0.033	2.360	0.240	0.500	0.130	0.070	1.460	3.600	0.910
24385	PCW	88	10	Chino Hills 29 July 2008	Z-Direction	0.095	0.034	5.337	0.460	0.500	0.130	0.070	2.880	0.970	0.640
24385	PCW	88	10	Encino 24 Mar 2014	X-Direction	0.021	0.052	1.393	0.099	0.520	0.120	0.070	2.980	0.990	0.970
24385	PCW	88	10	Encino 24 Mar 2014	Z-Direction	0.022	0.047	1.530	0.081	0.460	0.130	0.090	3.700	1.210	0.580
24385	PCW	88	10	Newhall 1 Sep 2011	X-Direction	0.003	0.003	0.137	0.013	0.460	0.120	0.060	2.480	1.370	1.880
24385	PCW	88	10	Newhall 1 Sep 2011	Z-Direction	0.004	0.006	0.145	0.015	0.430	0.120	0.070	2.250	1.900	0.500
24385	PCW	88	10	Northridge 17 Jan 1994	X-Direction	0.244	0.264	11.545	2.953	0.740	0.130		3.360	2.300	
24385	PCW	88	10	Northridge 17 Jan 1994	Z-Direction	0.461	0.295	20.334	3.506	0.580	0.170		3.210	0.600	
24385	PCW	88	10	Sierra Madre 28 Jun 1991	X-Direction	0.097	0.074	8.401	0.891	0.480	0.170		1.080	1.140	

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
24385	PCW	88	10	Sierra Madre 28 Jun 1991	Z-Direction	0.243	0.100	4.621	0.671	0.440	0.120		1.970	0.840	
24385	PCW	88	10	Whittier 01 Oct 1987	X-Direction	0.235	0.209	10.974	0.999	0.560	0.140		3.240	0.800	
24385	PCW	88	10	Whittier 01 Oct 1987	Z-Direction	0.191	0.168	8.449	1.055	0.438	0.170		3.047	1.180	
24385	PCW	88	10	Whittier Narrows 16 Mar 2010	X-Direction	0.006	0.007	0.229	0.014	0.490	0.120	0.070	2.530	2.390	1.490
24385	PCW	88	10	Whittier Narrows 16 Mar 2010	Z-Direction	0.007	0.008	0.302	0.018	0.440	0.120	0.070	1.440	1.390	0.940
24601	PCW	150	17	Landers 28 Jun 1992	X-Direction	0.093	0.043	7.291	6.527	1.030	0.240	0.110	2.830	1.920	0.770
24601	PCW	150	17	Landers 28 Jun 1992	Z-Direction	0.087	0.044	11.495	7.596	0.970	0.220	0.080	2.470	1.200	0.130
24601	PCW	150	17	Northridge 17 Jan 1994	X-Direction	0.210	0.258	23.333	3.783	1.030	0.250	0.130	3.510	1.050	0.480
24601	PCW	150	17	Northridge 17 Jan 1994	Z-Direction	0.229	0.182	18.381	3.549	1.060	0.210	0.090	3.090	1.260	0.510
24601	PCW	150	17	Sierra Madre 28 Jun 1991	X-Direction	0.069	0.068	5.237	0.713	1.000	0.230	0.110	2.900	1.550	0.740
24601	PCW	150	17	Sierra Madre 28 Jun 1991	Z-Direction	0.071	0.060	4.743	0.969	0.970	0.240	0.080	2.700	0.810	0.430
58639	PCW	114	13	Alum Rock 30 Oct 2007	X-Direction	0.014	0.009	0.830	0.133	0.820	0.200	0.090	4.390	1.330	0.690
58639	PCW	114	13	Alum Rock 30 Oct 2007	Z-Direction	0.013	0.009	0.537	0.065	0.580	0.180	0.060	1.130	0.680	0.110
58639	PCW	114	13	Bolinas 18 Aug 1999	X-Direction	0.007	0.010	0.637	0.075	0.790	0.190	0.090	3.120	2.740	1.100
58639	PCW	114	13	Bolinas 18 Aug 1999	Z-Direction	0.011	0.014	0.550	0.048	0.540	0.130	0.060	1.510	0.410	0.180
58639	PCW	114	13	El Cerrito 05 Mar 2012	X-Direction	0.005	0.011	0.521	0.042	0.770	0.180	0.080	2.670	0.540	0.470
58639	PCW	114	13	El Cerrito 05 Mar 2012	Z-Direction	0.011	0.021	0.758	0.067	0.540	0.150		1.300	0.320	
58639	PCW	114	13	Gilroy 13 May 2002	X-Direction	0.005	0.005	0.306	0.031	0.790	0.230	0.080	3.010	1.400	0.220
58639	PCW	114	13	Gilroy 13 May 2002	Z-Direction	0.008	0.007	0.369	0.035	0.540	0.140		2.700	0.840	
58639	PCW	114	13	Lafayette 01 Mar 2007	X-Direction	0.005	0.015	0.563	0.056	0.770	0.190	0.080	3.640	1.260	0.390
58639	PCW	114	13	Lafayette 01 Mar 2007	Z-Direction	0.011	0.016	0.743	0.060	0.530	0.130	0.060	1.810	0.810	0.190
58639	PCW	114	13	Piedmont 20 July 2007	X-Direction	0.012	0.031	1.548	0.115	0.820	0.200	0.080	3.980	4.050	0.500
58639	PCW	114	13	Piedmont 20 July 2007	Z-Direction	0.021	0.056	2.232	0.141	0.550	0.170	0.060	2.210	1.770	0.670
58639	PCW	114	13	South Napa 24 Aug 2014	X-Direction	0.015	0.013	1.538	0.330	0.820	0.200	0.100	3.540	1.040	0.500
58639	PCW	114	13	South Napa 24 Aug 2014	Z-Direction	0.026	0.014	1.056	0.265	0.530	0.110		2.870	0.940	
12493	RCMRF	64	4	Borrego Springs 07 Jul 2010	X-Direction	0.052	0.039	3.460	0.664	0.570	0.140		5.460	1.760	
12493	RCMRF	64	4	Borrego Springs 07 Jul 2010	Z-Direction	0.056	0.033	3.309	0.805	0.690	0.140		3.890	0.580	
12493	RCMRF	64	4	BorregoSprings 12 Jun 2010	X-Direction	0.006	0.014	0.769	0.043	0.540	0.140		4.460	1.630	
12493	RCMRF	64	4	BorregoSprings 12 Jun 2010	Z-Direction	0.008	0.013	0.379	0.037	0.620	0.140		3.940	1.990	
12493	RCMRF	64	4	Brawley 26 Aug 2012	X-Direction	0.008	0.003	0.447	0.095	0.630	0.140		2.850	1.210	
12493	RCMRF	64	4	Brawley 26 Aug 2012	Z-Direction	0.006	0.003	0.518	0.153	0.620	0.180		3.140	0.530	
12493	RCMRF	64	4	Calexico 04 Apr 2010	X-Direction	0.092	0.035	5.522	4.596	0.760	0.166		3.860	0.865	
12493	RCMRF	64	4	Calexico 04 Apr 2010	Z-Direction	0.076	0.038	6.550	6.665	0.720	0.161		2.880	1.423	
12493	RCMRF	64	4	Chino Hills 29 July 2008	X-Direction	0.019	0.008	0.738	0.103	0.610	0.140		3.950	1.210	
12493	RCMRF	64	4	Chino Hills 29 July 2008	Z-Direction	0.009	0.010	0.470	0.090	0.640	0.140		2.040	0.940	
12493	RCMRF	64	4	Ocotillo 14 Jun 2010	X-Direction	0.015	0.005	0.560	0.135	0.630	0.140		2.120	2.030	
12493	RCMRF	64	4	Ocotillo 14 Jun 2010	Z-Direction	0.009	0.006	0.534	0.143	0.630	0.167		2.470	0.914	
23511	RCMRF	40.5	3	Anza 11 March 2013	X-Direction	0.009	0.004	0.264	0.039	0.261	0.084		3.409	0.816	
23511	RCMRF	40.5	3	Anza 11 March 2013	Z-Direction	0.008	0.003	0.186	0.034	0.284	0.103		2.687	0.834	
23511	RCMRF	40.5	3	Borrego Springs 07 Jul 2010	X-Direction	0.039	0.015	1.539	0.242	0.273	0.091		2.932	0.620	
23511	RCMRF	40.5	3	Borrego Springs 07 Jul 2010	Z-Direction	0.045	0.018	1.256	0.247	0.278	0.091		1.651	0.529	
23511	RCMRF	40.5	3	Calexico 04 Apr 2010	X-Direction	0.022	0.011	2.871	2.971	0.264	0.086		2.733	0.416	
23511	RCMRF	40.5	3	Calexico 04 Apr 2010	Z-Direction	0.029	0.014	4.170	4.918	0.292	0.086		2.154	0.374	
23511	RCMRF	40.5	3	Chino Hills 29 July 2008	X-Direction	0.124	0.129	12.253	2.358	0.285	0.094		2.401	0.529	
23511	RCMRF	40.5	3	Chino Hills 29 July 2008	Z-Direction	0.236	0.126	11.940	2.695	0.332	0.113		4.152	0.426	
23511	RCMRF	40.5	3	Pomona 19 Sep 2013	X-Direction	0.066	0.044	1.343	0.081	0.284	0.083		4.854	1.192	
23511	RCMRF	40.5	3	Pomona 19 Sep 2013	Z-Direction	0.054	0.049	1.291	0.076	0.294	0.101		3.457	1.668	
23511	RCMRF	40.5	3	San Bernardino 08 Jan 2009	X-Direction	0.029	0.013	0.323	0.031	0.270	0.070		2.604	0.583	
23511	RCMRF	40.5	3	San Bernardino 08 Jan 2009	Z-Direction	0.016	0.007	0.534	0.058	0.286	0.077		2.478	1.428	
23511	RCMRF	40.5	3	Whittier 01 Oct 1987	X-Direction	0.130	0.007	2.928	0.352	0.271	0.092		1.726	0.438	
23511	RCMRF	40.5	3	Whittier 01 Oct 1987	Z-Direction	0.099	0.046	2.078	0.143	0.270	0.091		1.341	0.536	
23511	RCMRF	40.5	3	Whittier Narrows 16 Mar 2010	X-Direction	0.034	0.015	0.330	0.015	0.271	0.081		1.726	0.330	
23511	RCMRF	40.5	3	Whittier Narrows 16 Mar 2010	Z-Direction	0.034	0.012	0.582	0.032	0.226	0.075		1.333	1.141	
23511	RCMRF	40.5	3	Yorba Linda 13 June 2012	X-Direction	0.009	0.009	0.467	0.025	0.252	0.069		3.047	1.700	
23511	RCMRF	40.5	3	Yorba Linda 13 June 2012	Z-Direction	0.017	0.009	0.207	0.010	0.291	0.085		3.658	1.141	
23511	RCMRF	40.5	3	Yorbalinda 29 August 2012	X-Direction	0.019	0.007	0.218	0.011	0.277	0.068		3.589	0.711	
23511	RCMRF	40.5	3	Yorbalinda 29 August 2012	Z-Direction	0.020	0.013	0.365	0.028	0.299	0.081		2.890	0.844	
24322	RCMRF	191	13	Calexico 04 Apr 2010	X-Direction	0.011	0.004	2.425	3.088	1.578	0.476	0.263	2.323	1.125	1.257
24322	RCMRF	191	13	Calexico 04 Apr 2010	Z-Direction	0.013	0.004	2.415	2.802	1.537	0.492	0.312	1.860	1.406	0.433
24322	RCMRF	191	13	Chatsworth 09 Aug 2007	X-Direction	0.002	0.022	0.528	0.049	1.401	0.431	0.266	3.126	2.393	1.099
24322	RCMRF	191	13	Chatsworth 09 Aug 2007	Z-Direction	0.003	0.015	0.674	0.046	1.486	0.475	0.294	1.955	1.835	0.670
24322	RCMRF	191	13	Chino Hills 29 July 2008	X-Direction	0.011	0.037	2.397	0.212	1.506	0.458	0.267	3.009	3.071	2.383
24322	RCMRF	191	13	Chino Hills 29 July 2008	Z-Direction	0.015	0.049	2.601	0.269	1.546	0.503	0.309	1.813	2.311	1.771

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
24322	RCMRF	191	13	Encino 17 Mar 2014	X-Direction	0.004	0.100	2.435	0.132	1.510	0.474	0.278	4.491	3.469	1.732
24322	RCMRF	191	13	Encino 17 Mar 2014	Z-Direction	0.011	0.242	7.499	0.588	1.588	0.499	0.328	3.672	1.790	1.759
24322	RCMRF	191	13	Landers 28 Jun 1992	X-Direction	0.052	0.030	5.640	2.022	2.630	0.769	0.433	5.214	3.486	1.609
24322	RCMRF	191	13	Landers 28 Jun 1992	Z-Direction	0.039	0.039	5.785	2.226	2.753	0.766	0.434	3.298	3.935	1.854
24322	RCMRF	191	13	Northridge 17 Jan 1994	X-Direction	0.109	0.214	29.378	8.712	3.013	0.887	0.473	5.203	3.332	1.482
24322	RCMRF	191	13	Northridge 17 Jan 1994	Z-Direction	0.059	0.446	54.904	13.134	3.104	0.973	0.568	3.570	3.591	1.357
24322	RCMRF	191	13	Whittier 01 Oct 1987	X-Direction	0.010	0.144	5.894	0.498	2.337	0.714	0.383	4.730	3.033	2.760
24322	RCMRF	191	13	Whittier 01 Oct 1987	Z-Direction	0.009	0.095	9.351	1.039	2.498	0.714	0.433	3.778	3.365	2.739
24386	RCMRF	65.2	7	Big Bear 28 Jun 1992	X-Direction	0.045	0.024	3.912	0.695	1.180	0.380	0.210	3.790	0.920	0.880
24386	RCMRF	65.2	7	Big Bear 28 Jun 1992	Z-Direction	0.036	0.021	3.016	0.745	1.070	0.320	0.130	1.920	0.890	0.590
24386	RCMRF	65.2	7	Borrego Springs 07 Jul 2010	X-Direction	0.011	0.004	0.565	0.133	0.420	0.140	0.060	2.070	0.540	0.200
24386	RCMRF	65.2	7	Borrego Springs 07 Jul 2010	Z-Direction	0.010	0.004	0.540	0.125	0.400	0.120		2.000	0.870	
24386	RCMRF	65.2	7	Chino Hills 29 July 2008	Z-Direction	0.088	0.023	1.155	0.192	0.420	0.136		1.180	0.670	
24386	RCMRF	65.2	7	Encino 17 Mar 2014	X-Direction	0.087	0.145	2.325	0.158	0.470	0.170	0.057	1.720	0.753	0.510
24386	RCMRF	65.2	7	Encino 17 Mar 2014	Z-Direction	0.056	0.058	5.036	0.294	0.430	0.102	0.058	3.400	1.925	1.163
24386	RCMRF	65.2	7	Landers 28 Jun 1992	X-Direction	0.078	0.041	10.303	6.954	1.160	0.343	0.200	5.170	2.308	0.610
24386	RCMRF	65.2	7	Landers 28 Jun 1992	Z-Direction	0.142	0.041	16.683	13.778	1.200	0.284	0.134	2.050	1.115	0.237
24386	RCMRF	65.2	7	Newhall 1 Sep 2011	X-Direction	0.006	0.004	0.161	0.015	0.430	0.120	0.070	1.350	1.440	0.290
24386	RCMRF	65.2	7	Newhall 1 Sep 2011	Z-Direction	0.009	0.006	0.206	0.023	0.400	0.130	0.050	2.710	0.680	0.040
24386	RCMRF	65.2	7	Northridge 17 Jan 1994	X-Direction	0.223	0.453	35.321	11.956	2.090	0.554	0.200	4.650	1.407	0.570
24386	RCMRF	65.2	7	Northridge 17 Jan 1994	Z-Direction	0.275	0.401	50.931	7.908	2.060	0.418	0.240	4.800	1.191	1.020
24386	RCMRF	65.2	7	Westwood Village 01 June 2014	X-Direction	0.004	0.008	0.199	0.018	0.430	0.140	0.070	1.830	1.640	1.060
24386	RCMRF	65.2	7	Westwood Village 01 June 2014	Z-Direction	0.004	0.009	0.250	0.021	0.390	0.116	0.060	3.320	1.803	1.090
24454	RCMRF	54	4	Whittier Narrows 16 Mar 2010	X-Direction	0.026	0.032	0.950	0.060	0.406	0.088	0.067	1.694	0.443	0.339
24454	RCMRF	54	4	Whittier Narrows 16 Mar 2010	Z-Direction	0.066	0.064	2.439	0.134	0.387	0.094	0.057	1.760	0.850	0.633
24463	RCMRF	138.5	5	Borrego Springs 07 Jul 2010	X-Direction	0.010	0.004	0.501	0.130	1.238	0.410	0.276	5.532	4.666	1.133
24463	RCMRF	138.5	5	Borrego Springs 07 Jul 2010	Z-Direction	0.008	0.005	0.653	0.117	1.347	0.437	0.128	4.494	5.090	0.353
24463	RCMRF	138.5	5	Calexico 04 Apr 2010	X-Direction	0.021	0.009	3.987	4.049	1.331	0.434	0.277	3.567	1.812	0.674
24463	RCMRF	138.5	5	Calexico 04 Apr 2010	Z-Direction	0.019	0.008	4.892	6.372	1.452	0.452	0.148	4.225	1.255	0.554
24463	RCMRF	138.5	5	Encino 17 Mar 2014	X-Direction	0.002	0.010	0.225	0.019	1.191	0.397	0.279	4.778	2.893	2.366
24463	RCMRF	138.5	5	Encino 17 Mar 2014	Z-Direction	0.001	0.007	0.508	0.041	1.226	0.417	0.074	4.257	1.772	0.282
24463	RCMRF	138.5	5	La Habra 28 Mar 2014	X-Direction	0.017	0.014	1.939	0.540	1.296	0.436	0.323	5.318	3.535	1.173
24463	RCMRF	138.5	5	La Habra 28 Mar 2014	Z-Direction	0.018	0.016	2.003	0.686	1.387	0.505	0.262	3.458	3.633	0.749
24463	RCMRF	138.5	5	Northridge 17 Jan 1994	X-Direction	0.084	0.188	15.337	2.042	1.509	0.473	0.343	3.784	3.038	0.651
24463	RCMRF	138.5	5	Northridge 17 Jan 1994	Z-Direction	0.072	0.252	14.263	1.807	1.597	0.527	0.117	2.643	1.671	0.351
24463	RCMRF	138.5	5	Whittier 01 Oct 1987	X-Direction	0.102	0.170	12.899	1.944	1.369	0.454	0.309	4.990	2.457	1.274
24463	RCMRF	138.5	5	Whittier 01 Oct 1987	Z-Direction	0.069	0.128	9.033	1.608	1.579	0.502	0.147	4.028	2.064	0.395
24463	RCMRF	138.5	5	Whittier Narrows 16 Mar 2010	X-Direction	0.002	0.019	0.838	0.045	1.205	0.395	0.122	3.006	2.737	0.966
24463	RCMRF	138.5	5	Whittier Narrows 16 Mar 2010	Z-Direction	0.002	0.030	0.956	0.049	1.268	0.310	0.195	3.438	1.386	2.035
24463	RCMRF	138.5	5	Yorba Linda 07 Aug 2012	X-Direction	0.001	0.007	0.258	0.023	1.121	0.386	0.277	4.990	3.276	1.778
24463	RCMRF	138.5	5	Yorba Linda 07 Aug 2012	Z-Direction	0.001	0.007	0.309	0.024	1.169	0.416	0.144	3.118	4.414	1.167
24464	RCMRF	177.25	20	Calexico 04 Apr 2010	X-Direction	0.008	0.006	1.642	2.443	2.140	0.670	0.380	6.690	5.340	3.680
24464	RCMRF	177.25	20	Calexico 04 Apr 2010	Z-Direction	0.004	0.005	2.061	2.202	2.110	0.710	0.400	6.710	6.400	2.630
24464	RCMRF	177.25	20	Chino Hills 29 July 2008	X-Direction	0.004	0.017	1.022	0.161	2.030	0.660	0.380	5.080	5.850	4.910
24464	RCMRF	177.25	20	Chino Hills 29 July 2008	Z-Direction	0.003	0.025	2.149	0.266	2.100	0.730	0.400	6.320	6.650	4.170
24464	RCMRF	177.25	20	Northridge 17 Jan 1994	X-Direction	0.041	0.113	11.871	2.923	2.705	0.818	0.451	5.227	2.822	1.670
24464	RCMRF	177.25	20	Northridge 17 Jan 1994	Z-Direction	0.062	0.309	34.840	7.207	2.640	0.770	0.479	7.557	3.259	1.746
24464	RCMRF	177.25	20	Whittier 01 Oct 1987	X-Direction	0.006	0.083	6.226	0.808	2.640	0.678	0.418	7.533	4.793	2.548
24464	RCMRF	177.25	20	Whittier 01 Oct 1987	Z-Direction	0.015	0.100	4.626	0.574	1.974	0.624	0.421	2.933	2.730	1.635
24571	RCMRF	130	9	Big Bear 28 Jun 1992	X-Direction	0.052	0.031	3.791	0.768	1.238	0.358	0.188	2.288	1.939	1.076
24571	RCMRF	130	9	Big Bear 28 Jun 1992	Z-Direction	0.018	0.039	4.384	0.790	1.977	0.525	0.306	3.908	2.539	2.479
24571	RCMRF	130	9	Calexico 04 Apr 2010	X-Direction	0.008	0.005	1.624	2.538	1.088	0.320	0.172	3.083	1.359	1.074
24571	RCMRF	130	9	Calexico 04 Apr 2010	Z-Direction	0.007	0.006	2.225	2.682	1.728	0.485	0.285	4.437	2.211	2.713
24571	RCMRF	130	9	Landers 28 Jun 1992	X-Direction	0.100	0.047	6.156	1.788	1.343	0.398	0.187	2.334	0.717	0.392
24571	RCMRF	130	9	Landers 28 Jun 1992	Z-Direction	0.118	0.033	6.243	2.015	1.279	0.523		2.524	3.126	
24571	RCMRF	130	9	Northridge 17 Jan 1994	X-Direction	0.070	0.184	8.880	1.269	1.293	0.371	0.197	2.096	3.114	0.552
24571	RCMRF	130	9	Northridge 17 Jan 1994	Z-Direction	0.026	0.159	10.014	0.822	2.091	0.600	0.337	4.199	4.842	3.000
24571	RCMRF	130	9	Sierra Madre 28 Jun 1991	X-Direction	0.103	0.233	7.505	0.738	1.227	0.360	0.174	2.734	3.959	0.698
24571	RCMRF	130	9	Sierra Madre 28 Jun 1991	Z-Direction	0.029	0.107	19.966	2.140	1.938	0.551		5.506	4.943	
24571	RCMRF	130	9	Whittier Narrows 16 Mar 2010	X-Direction	0.004	0.057	0.745	0.039	1.065	0.319	0.159	4.447	3.896	1.113
24571	RCMRF	130	9	Whittier Narrows 16 Mar 2010	Z-Direction	0.001	0.024	1.969	0.115	1.554	0.462	0.182	3.775	2.771	2.786
24579	RCMRF	141	10	Borrego Springs 07 Jul 2010	X-Direction	0.006	0.004	0.444	0.066	1.120	0.346	0.162	3.427	0.863	0.381
24579	RCMRF	141	10	Borrego Springs 07 Jul 2010	Z-Direction	0.006	0.005	0.474	0.148	1.228	0.360		2.333	1.451	

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
24579	RCMRF	141	10	Chino Hills 29 July 2008	X-Direction	0.029	0.033	2.581	0.286	1.134	0.370	0.172	3.309	1.137	1.131
24579	RCMRF	141	10	Chino Hills 29 July 2008	Z-Direction	0.034	0.037	3.541	0.861	1.311	0.354		4.943	1.329	
24579	RCMRF	141	10	Landers 28 Jun 1992	X-Direction	0.068	0.044	6.274	2.970	1.261	0.358	0.176	2.705	0.909	0.546
24579	RCMRF	141	10	Landers 28 Jun 1992	Z-Direction	0.045	0.032	7.174	5.343	1.403	0.416		3.527	1.762	
24579	RCMRF	141	10	Los Angeles Airport 25 Jul 2012	X-Direction	0.001	0.008	0.192	0.008	0.784	0.249	0.130	2.180	0.675	0.712
24579	RCMRF	141	10	Los Angeles Airport 25 Jul 2012	Z-Direction	0.001	0.008	0.182	0.009	1.033	0.319		2.130	0.420	
24579	RCMRF	141	10	Northridge 17 Jan 1994	X-Direction	0.130	0.133	9.433	3.116	1.266	0.383	0.228	4.482	1.887	0.723
24579	RCMRF	141	10	Northridge 17 Jan 1994	Z-Direction	0.112	0.175	16.748	2.720	1.618	0.416		2.860	1.404	
24579	RCMRF	141	10	View Park Windsor Hills 12 Apr 2015	X-Direction	0.001	0.007	0.258	0.013	0.941	0.304	0.157	2.990	1.333	0.473
24579	RCMRF	141	10	View Park Windsor Hills 12 Apr 2015	Z-Direction	0.001	0.009	0.278	0.011	0.954	0.334		1.843	1.028	
24579	RCMRF	141	10	Whittier Narrows 16 Mar 2010	X-Direction	0.001	0.011	0.259	0.018	0.954	0.327	0.158	1.843	1.212	0.598
24579	RCMRF	141	10	Whittier Narrows 16 Mar 2010	Z-Direction	0.001	0.013	0.431	0.020	1.025	0.322		2.930	1.283	
57355	RCMRF	141	10	Loma Prieta 17 Oct 1989	X-Direction	0.132	0.086	18.111	9.927	1.000	0.300		3.670	2.060	
57355	RCMRF	141	10	Milpitas 07 Jan 2010	X-Direction	0.005	0.004	0.336	0.049	0.917	0.270		3.109	1.520	
57355	RCMRF	141	10	Morgan Hill 07 Jan 2011	X-Direction	0.005	0.012	0.441	0.044	0.830	0.290		3.780	2.560	
57355	RCMRF	141	10	Morgan Hill 30 March 2009	X-Direction	0.005	0.009	0.455	0.041	0.930	0.301		3.096	3.242	
57355	RCMRF	141	10	Morgan Hill 24 Apr 1984	X-Direction	0.174	0.060	12.281	3.381	0.980	0.270		2.630	2.070	
57355	RCMRF	141	10	Mt. Lewis 31 Mar 86	X-Direction	0.045	0.029	4.502	1.484	0.920	0.280		3.250	3.380	
58490	RCMRF	78	6	Loma Prieta 17 Oct 1989	X-Direction	0.363	0.137	16.160	2.655	0.843	0.304	0.174	2.603	0.848	0.654
58490	RCMRF	78	6	Loma Prieta 17 Oct 1989	Z-Direction	0.202	0.114	14.602	3.497	0.998	0.310	0.229	3.559	1.377	0.864
23540	RCTUW	29	1	Northridge 17 Jan 1994	Z-Direction	0.094	0.042	2.920	0.328	0.160			1.370		
57502	RCTUW	31.6	2	Loma Prieta 17 Oct 1989	X-Direction	0.392	0.138	20.660	10.019	0.260	0.090		1.840	0.310	
57502	RCTUW	31.6	2	Loma Prieta 17 Oct 1989	Z-Direction	0.249	0.090	30.767	24.161	0.280			1.860		
57502	RCTUW	31.6	2	Milpitas 07 Jan 2010	X-Direction	0.057	0.045	1.230	0.066	0.270	0.080		3.900	1.080	
57502	RCTUW	31.6	2	Milpitas 07 Jan 2010	Z-Direction	0.090	0.043	1.781	0.153	0.230			4.650		
57502	RCTUW	31.6	2	Morgan Hill 07 Jan 2011	X-Direction	0.046	0.022	0.957	0.050	0.200	0.050		3.100	0.320	
57502	RCTUW	31.6	2	Morgan Hill 07 Jan 2011	Z-Direction	0.031	0.011	0.504	0.040	0.220			4.910		
57502	RCTUW	31.6	2	South Napa 24 Aug 2014	X-Direction	0.015	0.008	1.253	0.396	0.200	0.080		2.720	0.270	
57502	RCTUW	31.6	2	South Napa 24 Aug 2014	Z-Direction	0.016	0.012	1.144	0.437	0.200			2.410		
12267	RCW	48	4	Anza 11 March 2013	X-Direction	0.012	0.009	0.252	0.032	0.278	0.090		1.102	0.330	
12267	RCW	48	4	Anza 11 March 2013	Z-Direction	0.010	0.011	0.338	0.025	0.260	0.080		4.250	4.600	
12267	RCW	48	4	Calexico 04 Apr 2010	X-Direction	0.150	0.037	3.679	4.545	0.250	0.090		1.430	0.360	
12267	RCW	48	4	Calexico 04 Apr 2010	Z-Direction	0.048	0.027	2.831	3.105	0.260	0.100		3.930	0.730	
12267	RCW	48	4	Hemet 02 Sept 2014	X-Direction	0.008	0.046	0.605	0.012	0.277	0.070		1.713	1.520	
12267	RCW	48	4	Hemet 02 Sept 2014	Z-Direction	0.030	0.081	1.627	0.033	0.270	0.080		3.560	0.650	
12267	RCW	48	4	Idyllwild 28 Oct 2012	X-Direction	0.007	0.019	0.302	0.007	0.276	0.080		2.220	0.270	
12267	RCW	48	4	Idyllwild 28 Oct 2012	Z-Direction	0.011	0.044	0.376	0.013	0.260	0.080		4.020	5.420	
12267	RCW	48	4	San Jacinto 6 May 2015	X-Direction	0.006	0.014	0.151	0.005	0.269	0.090		1.344	0.600	
12267	RCW	48	4	San Jacinto 6 May 2015	Z-Direction	0.011	0.017	0.236	0.009	0.260	0.080		3.170	2.090	
12284	RCW	50	4	Big Bear Lake 05 Jul 2014	X-Direction	0.009	0.012	0.321	0.023	0.461	0.107		4.095	1.346	
12284	RCW	50	4	Big Bear Lake 05 Jul 2014	Z-Direction	0.005	0.007	0.476	0.025	0.567	0.140		5.184	1.657	
12284	RCW	50	4	Borrego Springs 07 Jul 2010	X-Direction	0.059	0.053	2.182	0.311	0.535	0.117		4.292	1.615	
12284	RCW	50	4	Borrego Springs 07 Jul 2010	Z-Direction	0.045	0.080	3.734	0.521	0.638	0.156		4.046	3.324	
12284	RCW	50	4	BorregoSprings 12 Jun 2010	X-Direction	0.011	0.006	0.292	0.027	0.470	0.110		4.016	3.103	
12284	RCW	50	4	BorregoSprings 12 Jun 2010	Z-Direction	0.008	0.008	0.388	0.023	0.576	0.150		4.264	2.010	
12284	RCW	50	4	Calexico 04 Apr 2010	X-Direction	0.132	0.069	3.992	3.333	0.507	0.116		3.229	1.061	
12284	RCW	50	4	Calexico 04 Apr 2010	Z-Direction	0.085	0.036	4.582	2.985	0.655	0.159		4.259	2.208	
12284	RCW	50	4	Calexico 30 Dec 2009	X-Direction	0.005	0.003	0.458	0.108	0.436	0.103		4.322	1.747	
12284	RCW	50	4	Calexico 30 Dec 2009	Z-Direction	0.009	0.004	0.429	0.108	0.554	0.143		4.442	1.240	
12284	RCW	50	4	Chino Hills 29 July 2008	X-Direction	0.016	0.014	0.675	0.126	0.457	0.109		4.392	1.813	
12284	RCW	50	4	Chino Hills 29 July 2008	Z-Direction	0.011	0.010	0.585	0.093	0.572	0.145		3.693	2.576	
12284	RCW	50	4	Ocotillo 10 Apr 2010	X-Direction	0.008	0.005	0.279	0.016	0.497	0.114		3.967	2.090	
12284	RCW	50	4	Ocotillo 10 Apr 2010	Z-Direction	0.009	0.009	0.426	0.025	0.613	0.156		4.445	1.911	
12284	RCW	50	4	Ocotillo 14 Jun 2010	X-Direction	0.019	0.013	0.770	0.124	0.492	0.115		4.312	2.017	
12284	RCW	50	4	Ocotillo 14 Jun 2010	Z-Direction	0.017	0.016	0.917	0.166	0.610	0.155		3.509	3.754	
12284	RCW	50	4	Palm Springs 08 Jul 1986	X-Direction	0.128	0.110	8.663	2.410	0.478	0.168		5.823	0.899	
12284	RCW	50	4	Palm Springs 08 Jul 1986	Z-Direction	0.084	0.069	7.461	2.392	0.570	0.189		4.529	0.398	
12284	RCW	50	4	San Bernardino 08 Jan 2009	X-Direction	0.007	0.007	0.226	0.017	0.450	0.108		3.337	1.379	
12284	RCW	50	4	San Bernardino 08 Jan 2009	Z-Direction	0.005	0.008	0.304	0.015	0.545	0.131		4.469	1.506	
13329	RCW		8	Calexico 04 Apr 2010	X-Direction	0.017	0.009	0.319	4.935	1.100	0.330	0.200	6.300	3.130	0.790
13329	RCW		8	Calexico 04 Apr 2010	Z-Direction	0.014	0.008	1.799	1.561	1.230	0.330	0.200	4.040	1.920	0.870
13329	RCW		8	Chino Hills 29 July 2008	X-Direction	0.011	0.050	2.196	0.191	1.170	0.340	0.210	6.390	4.120	2.140
13329	RCW		8	Chino Hills 29 July 2008	Z-Direction	0.012	0.029	1.019	0.234	1.180	0.360	0.210	5.410	5.300	4.010

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
13329	RCW		8	Laguna Niguel 23 Apr 2012	X-Direction	0.000	0.009	0.162	0.005	0.850	0.270	0.170	4.460	3.260	1.600
13329	RCW		8	Laguna Niguel 23 Apr 2012	Z-Direction	0.001	0.009	0.174	0.013	0.970	0.293	0.189	5.060	3.563	3.345
13589	RCW	146.9	11	Borrego Springs 07 Jul 2010	X-Direction	0.007	0.003	0.552	0.157	0.690	0.200	0.130	2.140	0.760	0.490
13589	RCW	146.9	11	Borrego Springs 07 Jul 2010	Z-Direction	0.007	0.004	0.383	0.113	0.750	0.230	0.150	2.480	1.410	0.730
13589	RCW	146.9	11	Calexico 04 Apr 2010	X-Direction	0.031	0.017	3.450	1.910	0.710	0.260	0.140	2.070	0.450	0.460
13589	RCW	146.9	11	Calexico 04 Apr 2010	Z-Direction	0.026	0.016	3.891	4.537	0.790	0.250	0.160	2.740	1.790	0.720
13589	RCW	146.9	11	Chino Hills 29 July 2008	X-Direction	0.050	0.029	2.774	0.681	0.710	0.250	0.140	2.320	1.130	0.330
13589	RCW	146.9	11	Chino Hills 29 July 2008	Z-Direction	0.060	0.039	4.131	0.925	0.800	0.260	0.160	2.520	1.480	1.320
13589	RCW	146.9	11	Inglewood 17 May 2009	X-Direction	0.010	0.011	0.517	0.040	0.690	0.230	0.160	2.280	0.910	1.350
13589	RCW	146.9	11	Inglewood 17 May 2009	Z-Direction	0.011	0.011	0.668	0.087	0.750	0.230	0.140	2.470	1.100	0.610
13589	RCW	146.9	11	La Habra 28 Mar 2014	X-Direction	0.034	0.012	2.055	0.519	0.710	0.220	0.120	2.400	1.130	0.690
13589	RCW	146.9	11	La Habra 28 Mar 2014	Z-Direction	0.037	0.012	1.515	0.330	0.800	0.230	0.110	2.960	1.050	0.070
13589	RCW	146.9	11	Landers 28 Jun 1992	X-Direction	0.134	0.047	12.253	6.795	0.760	0.190	0.130	2.290	0.880	0.880
13589	RCW	146.9	11	Landers 28 Jun 1992	Z-Direction	0.132	0.043	6.446	2.775	0.880	0.240	0.170	3.080	1.060	0.590
13589	RCW	146.9	11	Northridge 17 Jan 1994	X-Direction	0.107	0.053	5.803	1.365	0.740	0.230	0.130	2.330	0.970	0.910
13589	RCW	146.9	11	Northridge 17 Jan 1994	Z-Direction	0.109	0.076	5.304	1.761	0.880	0.250	0.160	3.490	2.750	0.470
13620	RCW	27.5	2	Northridge 17 Jan 1994	X-Direction	0.078	0.053	3.917	0.698	0.139	0.054		2.009	0.598	
13620	RCW	27.5	2	Northridge 17 Jan 1994	Z-Direction	0.147	0.046	3.202	0.360	0.218	0.051		2.600	0.520	
14311	RCW	71	5	Chino Hills 29 July 2008	Z-Direction	0.088	0.066	11.034	1.149	0.360	0.100		2.100	0.830	
14311	RCW	71	5	Whittier 01 Oct 1987	Z-Direction	0.249	0.094	6.145	0.715	0.340	0.100		2.020	0.550	
23285	RCW	67	5	Barstow 05 Dec 2008	X-Direction	0.005	0.004	0.284	0.040	0.408	0.119		3.173	0.726	
23285	RCW	67	5	Barstow 05 Dec 2008	Z-Direction	0.008	0.003	0.242	0.040	0.515	0.143		2.723	2.354	
23285	RCW	67	5	Big Bear Lake 05 Jul 2014	X-Direction	0.013	0.020	0.429	0.036	0.413	0.111		3.039	1.105	
23285	RCW	67	5	Big Bear Lake 05 Jul 2014	Z-Direction	0.014	0.012	0.654	0.028	0.528	0.144		2.421	2.331	
23285	RCW	67	5	Borrego Springs 07 Jul 2010	X-Direction	0.013	0.008	0.651	0.113	0.419	0.118		2.862	0.746	
23285	RCW	67	5	Borrego Springs 07 Jul 2010	Z-Direction	0.022	0.009	0.652	0.112	0.516	0.147		3.487	1.223	
23285	RCW	67	5	Calexico 04 Apr 2010	X-Direction	0.027	0.010	4.079	5.608	0.428	0.114		1.700	0.866	
23285	RCW	67	5	Calexico 04 Apr 2010	Z-Direction	0.058	0.014	2.435	3.517	0.535	0.149		2.876	1.340	
23285	RCW	67	5	Chino Hills 29 July 2008	X-Direction	0.044	0.029	1.257	0.211	0.431	0.115		2.612	1.211	
23285	RCW	67	5	Chino Hills 29 July 2008	Z-Direction	0.023	0.014	2.075	0.214	0.532	0.147		3.432	2.271	
23285	RCW	67	5	Fontana 15 Jan 2014	X-Direction	0.015	0.012	0.577	0.076	0.438	0.104		2.277	0.707	
23285	RCW	67	5	Fontana 15 Jan 2014	Z-Direction	0.017	0.011	0.571	0.082	0.542	0.150		2.895	3.190	
23285	RCW	67	5	Inglewood 17 May 2009	X-Direction	0.006	0.005	0.295	0.023	0.401	0.123		2.660	0.520	
23285	RCW	67	5	Inglewood 17 May 2009	Z-Direction	0.010	0.004	0.213	0.019	0.512	0.141		2.027	1.609	
23285	RCW	67	5	Landers 28 Jun 1992	X-Direction	0.108	0.078	6.298	2.131	0.507	0.124		2.619	0.509	
23285	RCW	67	5	Landers 28 Jun 1992	Z-Direction	0.154	0.105	7.763	3.463	0.664	0.164		2.488	1.639	
23285	RCW	67	5	Loma Linda 23 Jun 2008	X-Direction	0.004	0.006	0.169	0.011	0.409	0.119		3.173	1.234	
23285	RCW	67	5	Loma Linda 23 Jun 2008	Z-Direction	0.004	0.008	0.232	0.017	0.507	0.143		2.759	2.140	
23285	RCW	67	5	Northridge 17 Jan 1994	X-Direction	0.079	0.034	2.183	0.362	0.554	0.157		2.819	0.838	
23285	RCW	67	5	Northridge 17 Jan 1994	Z-Direction	0.088	0.035	3.565	0.526	0.670	0.169		2.371	0.643	
23285	RCW	67	5	Ocotillo 14 Jun 2010	X-Direction	0.009	0.003	0.271	0.048	0.413	0.164		2.194	0.611	
23285	RCW	67	5	Ocotillo 14 Jun 2010	Z-Direction	0.008	0.003	0.245	0.038	0.522	0.139		1.286	0.714	
23285	RCW	67	5	Redlands 13 Feb 2010	X-Direction	0.003	0.007	0.131	0.005	0.407	0.149		2.639	0.465	
23285	RCW	67	5	Redlands 13 Feb 2010	Z-Direction	0.003	0.006	0.164	0.008	0.486	0.156		1.593	0.596	
23285	RCW	67	5	San Bernardino 08 Jan 2009	X-Direction	0.016	0.072	0.940	0.042	0.518	0.195		1.392	1.150	
23285	RCW	67	5	San Bernardino 08 Jan 2009	Z-Direction	0.011	0.046	1.761	0.094	0.501	0.177		2.923	0.626	
23285	RCW	67	5	Yucaipa 02 Oct 2008	X-Direction	0.003	0.008	0.166	0.009	0.400	0.110		2.228	0.479	
23285	RCW	67	5	Yucaipa 02 Oct 2008	Z-Direction	0.002	0.009	0.148	0.005	0.488	0.128		1.868	1.050	
23287	RCW	56	6	Banning 11 Jan 2010	X-Direction	0.005	0.005	0.175	0.009	0.424	0.105		3.176	1.324	
23287	RCW	56	6	Banning 11Jan 2010	Z-Direction	0.008	0.005	0.219	0.013	0.210	0.048		2.673	0.845	
23287	RCW	56	6	Beaumont 14 Sept 2011	X-Direction	0.016	0.020	0.734	0.032	0.434	0.109		3.003	1.825	
23287	RCW	56	6	Beaumont 14 Sept 2011	Z-Direction	0.030	0.027	0.551	0.027	0.223	0.047		2.703	0.559	
23287	RCW	56	6	Beaumont 16 Jan 2010	X-Direction	0.006	0.006	0.200	0.016	0.418	0.105		3.758	1.447	
23287	RCW	56	6	Beaumont 16 Jan 2010	Z-Direction	0.009	0.005	0.283	0.021	0.223	0.049		3.662	0.799	
23287	RCW	56	6	Borrego Springs 07 Jul 2010	X-Direction	0.166	0.053	3.021	0.401	0.511	0.115		4.835	0.790	
23287	RCW	56	6	Borrego Springs 07 Jul 2010	Z-Direction	0.051	0.024	4.605	0.574	0.252	0.069		1.100	0.358	
23287	RCW	56	6	Calexico 04 Apr 2010	X-Direction	0.069	0.019	3.072	3.025	0.473	0.105		2.370	0.860	
23287	RCW	56	6	Calexico 04 Apr 2010	Z-Direction	0.030	0.020	6.507	7.248	0.226			1.689		
23287	RCW	56	6	Chino Hills 29 July 2008	X-Direction	0.063	0.050	2.235	0.357	0.449	0.111		4.047	1.700	
23287	RCW	56	6	Chino Hills 29 July 2008	Z-Direction	0.132	0.036	2.425	0.288	0.249	0.068		2.887	0.565	
23287	RCW	56	6	Devore 28 Apr 2012	X-Direction	0.051	0.017	0.422	0.024	0.460	0.106		3.563	1.242	
23287	RCW	56	6	Devore 28 Apr 2012	Z-Direction	0.015	0.010	0.984	0.071	0.227	0.050		4.806	0.757	
23287	RCW	56	6	Inglewood 17 May 2009	X-Direction	0.013	0.008	0.414	0.038	0.423	0.102		3.275	1.459	

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
23287	RCW	56	6	Inglewood 17 May 2009	Z-Direction	0.012	0.008	0.364	0.026	0.234	0.048		3.142	1.371	
23287	RCW	56	6	Landers 28 Jun 1992	X-Direction	0.217	0.074	15.058	7.996	0.504	0.116		5.167	0.776	
23287	RCW	56	6	Landers 28 Jun 1992	Z-Direction	0.146	0.083	16.943	9.578	0.255			1.626		
23287	RCW	56	6	Loma Linda 04 Mar 2013	X-Direction	0.007	0.007	0.237	0.015	0.434	0.107		3.402	1.191	
23287	RCW	56	6	Loma Linda 04 Mar 2013	Z-Direction	0.025	0.012	0.422	0.024	0.225	0.070		3.498	0.871	
23287	RCW	56	6	Loma Linda 23 Jun 2008	X-Direction	0.009	0.013	0.394	0.020	0.427	0.100		3.681	1.025	
23287	RCW	56	6	Loma Linda 23 Jun 2008	Z-Direction	0.017	0.021	0.596	0.019	0.222	0.049		2.919	2.286	
23287	RCW	56	6	Loma Linda 26 Feb 2013	X-Direction	0.006	0.005	0.273	0.017	0.430	0.104		3.473	2.209	
23287	RCW	56	6	Loma Linda 26 Feb 2013	Z-Direction	0.008	0.008	0.197	0.012	0.232	0.048		2.344	1.603	
23287	RCW	56	6	Northridge 17 Jan 1994	X-Direction	0.144	0.060	6.404	1.020	0.520	0.126		3.102	0.444	
23287	RCW	56	6	Northridge 17 Jan 1994	Z-Direction	0.127	0.071	5.980	0.699	0.251	0.064		2.613	0.230	
23287	RCW	56	6	Ocotillo 14 Jun 2010	X-Direction	0.014	0.006	0.536	0.094	0.417	0.101		2.826	1.040	
23287	RCW	56	6	Ocotillo 14 Jun 2010	Z-Direction	0.011	0.006	0.582	0.133	0.220	0.052		3.116	0.210	
23287	RCW	56	6	Ontario 20 Dec 2011	X-Direction	0.002	0.004	0.122	0.006	0.409	0.104		3.329	1.635	
23287	RCW	56	6	Ontario 20 Dec 2011	Z-Direction	0.009	0.004	0.106	0.006	0.219	0.051		4.027	0.939	
23287	RCW	56	6	Redlands 13 Feb 2010	X-Direction	0.033	0.028	1.034	0.082	0.469	0.104		2.849	1.140	
23287	RCW	56	6	Redlands 13 Feb 2010	Z-Direction	0.052	0.020	1.642	0.103	0.228	0.048		3.460	0.999	
23287	RCW	56	6	San Bernardino 08 Jan 2009	X-Direction	0.096	0.058	3.309	0.232	0.493	0.112		5.601	1.154	
23287	RCW	56	6	San Bernardino 08 Jan 2009	Z-Direction	0.169	0.094	8.346	0.678	0.313	0.089		1.518	0.733	
23287	RCW	56	6	Yorba Linda 07 Aug 2012	X-Direction	0.008	0.009	0.176	0.011	0.411	0.100		2.518	0.784	
23287	RCW	56	6	Yorba Linda 07 Aug 2012	Z-Direction	0.008	0.003	0.339	0.023	0.223	0.048		3.284	1.366	
24514	RCW	96	6	Borrego Springs 07 Jul 2010	X-Direction	0.010	0.006	0.661	0.124	0.323	0.100		1.957	0.390	
24514	RCW	96	6	Borrego Springs 07 Jul 2010	Z-Direction	0.010	0.005	0.577	0.113	0.370	0.105		2.080	0.332	
24514	RCW	96	6	Newhall 1 Sep 2011	X-Direction	0.019	0.015	0.459	0.036	0.330	0.090		3.420	0.450	
24514	RCW	96	6	Newhall 1 Sep 2011	Z-Direction	0.013	0.022	0.519	0.042	0.370	0.100		3.720	0.500	
24514	RCW	96	6	Newhall 28 Oct 2012	X-Direction	0.019	0.016	0.346	0.019	0.310	0.086	0.080	1.060	1.340	0.650
24514	RCW	96	6	Newhall 28 Oct 2012	Z-Direction	0.006	0.013	0.498	0.029	0.378	0.117		2.359	0.962	
24514	RCW	96	6	Northridge 17 Jan 1994	X-Direction	0.998	0.383	71.076	18.415	0.342	0.120		2.065	0.620	
24514	RCW	96	6	Northridge 17 Jan 1994	Z-Direction	2.057	0.798	112.139	28.298	0.414	0.120		3.125	0.570	
24514	RCW	96	6	Whittier 01 Oct 1987	X-Direction	0.169	0.057	3.129	0.528	0.280	0.099		1.640	0.262	
24514	RCW	96	6	Whittier 01 Oct 1987	Z-Direction	0.164	0.056	3.681	0.561	0.300	0.120		1.990	0.690	
24655	RCW	67	6	Borrego Springs 07 Jul 2010	X-Direction	0.008	0.005	0.478	0.076	0.340	0.120		2.365	0.433	
24655	RCW	67	6	Borrego Springs 07 Jul 2010	Z-Direction	0.007	0.003	0.432	0.103	0.400	0.102		2.740	0.289	
24655	RCW	67	6	Calexico 04 Apr 2010	X-Direction	0.016	0.009	5.075	4.628	0.360	0.139		2.800	0.644	
24655	RCW	67	6	Calexico 04 Apr 2010	Z-Direction	0.012	0.006	3.632	4.300	0.430	0.175		3.100	1.011	
24655	RCW	67	6	Chino Hills 29 July 2008	X-Direction	0.156	0.059	4.141	0.442	0.390	0.130		4.790	1.550	
24655	RCW	67	6	Chino Hills 29 July 2008	Z-Direction	0.054	0.025	2.710	0.516	0.460	0.170		6.220	3.930	
24655	RCW	67	6	Encino 17 Mar 2014	X-Direction	0.014	0.011	0.621	0.060	0.360	0.130		1.170	0.560	
24655	RCW	67	6	Encino 17 Mar 2014	Z-Direction	0.017	0.013	0.389	0.043	0.460	0.170		3.260	1.430	
24655	RCW	67	6	La Habra 28 Mar 2014	X-Direction	0.019	0.010	1.185	0.227	0.350	0.123		3.630	0.300	
24655	RCW	67	6	La Habra 28 Mar 2014	Z-Direction	0.030	0.010	1.427	0.247	0.440	0.170		3.790	2.420	
24655	RCW	67	6	Northridge 17 Jan 1994	X-Direction	0.275	0.153	18.849	3.461	0.400	0.130		4.210	1.550	
24655	RCW	67	6	Northridge 17 Jan 1994	Z-Direction	0.439	0.280	19.509	4.376	0.530	0.180		2.780	0.990	
24680	RCW	161	14	Borrego Springs 07 Jul 2010	X-Direction	0.006	0.004	0.467	0.068	1.090	0.260	0.092	3.090	1.200	0.433
24680	RCW	161	14	Borrego Springs 07 Jul 2010	Z-Direction	0.005	0.004	0.334	0.055	1.360	0.330	0.167	2.960	1.240	0.930
24680	RCW	161	14	Encino 17 Mar 2014	X-Direction	0.026	0.310	2.033	0.013	1.210	0.314	0.091	3.000	2.041	0.760
24680	RCW	161	14	Encino 17 Mar 2014	Z-Direction	0.004	0.070	9.819	0.823	1.430	0.380	0.110	5.940	4.560	0.910
25339	RCW	114.9	12	Calexico 04 Apr 2010	X-Direction	0.004	0.003	2.135	2.282	0.989	0.250	0.133	1.006	0.399	0.231
25339	RCW	114.9	12	Calexico 04 Apr 2010	Z-Direction	0.017	0.007	4.514	5.509	0.592	0.214	0.121	1.841	1.529	0.225
25339	RCW	114.9	12	Isla Vista 29 May 2013	X-Direction	0.002	0.002	0.138	0.021	1.021	0.263	0.131	1.807	1.014	0.517
25339	RCW	114.9	12	Isla Vista 29 May 2013	Z-Direction	0.008	0.004	0.308	0.036	0.570	0.185	0.119	1.572	1.840	0.466
25339	RCW	114.9	12	Ojai 08 May 2009	X-Direction	0.000	0.004	0.130	0.005	0.992	0.238	0.130	2.230	0.709	0.394
25339	RCW	114.9	12	Ojai 08 May 2009	Z-Direction	0.003	0.004	0.187	0.013	0.575	0.226		2.714	0.577	
25339	RCW	114.9	12	Ojai 08 May 2009	X-Direction	0.004	0.007	0.609	0.058	1.037	0.228	0.128	1.068	0.600	0.653
25339	RCW	114.9	12	Ojai 08 May 2009	Z-Direction	0.048	0.031	1.866	0.179	0.594	0.223		1.830	1.821	
25339	RCW	114.9	12	Santa Barbara 13 Aug 1978	X-Direction	0.010	0.005	0.460	0.070	0.939	0.218	0.116	2.893	0.665	0.616
25339	RCW	114.9	12	Santa Barbara 13 Aug 1978	Z-Direction	0.037	0.013	1.650	0.300	0.529	0.193		2.381	1.550	
25339	RCW	114.9	12	Westlake Village 01 May 2009	X-Direction	0.001	0.001	0.062	0.004	0.934	0.231	0.130	0.730	0.946	0.400
25339	RCW	114.9	12	Westlake Village 01 May 2009	Z-Direction	0.003	0.004	0.170	0.014	0.563	0.209		2.253	0.942	
47459	RCW	66.3	4	Loma Prieta 17 Oct 1989	X-Direction	0.703	0.359	33.287	8.953	0.380	0.130		1.510	0.500	
47459	RCW	66.3	4	Loma Prieta 17 Oct 1989	Z-Direction	1.338	0.272	54.869	18.228	0.290			1.450		
47459	RCW	66.3	4	Morgan Hill 24 Apr 1984	X-Direction	0.285	0.109	5.927	1.057	0.270	0.093		1.880	0.344	
47459	RCW	66.3	4	Morgan Hill 24 Apr 1984	Z-Direction	0.137	0.061	9.120	1.801	0.200			2.000		

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
57355	RCW	141	10	Alum Rock 30 Oct 2007	Z-Direction	0.049	0.058	3.342	0.374	0.700	0.270		3.870	2.770	
57355	RCW	141	10	Loma Prieta 17 Oct 1989	Z-Direction	0.255	0.101	21.957	12.947	0.690	0.243		2.920	1.291	
57355	RCW	141	10	Milpitas 07 Jan 2010	Z-Direction	0.010	0.007	0.294	0.047	0.650	0.240		2.700	1.710	
57355	RCW	141	10	Morgan Hill 07 Jan 2011	Z-Direction	0.005	0.012	0.385	0.038	0.640	0.240		2.520	3.400	
57355	RCW	141	10	Morgan Hill 30 March 2009	Z-Direction	0.008	0.014	0.526	0.058	0.660	0.250		1.740	2.600	
57355	RCW	141	10	Morgan Hill 24 Apr 1984	Z-Direction	0.166	0.060	10.677	2.389	0.670	0.210		1.100	1.710	
57355	RCW	141	10	Mt. Lewis 31 Mar 86	Z-Direction	0.051	0.034	7.211	1.945	0.600	0.220		1.750	2.440	
57356	RCW	96	10	Alum Rock 30 Oct 2007	Z-Direction	0.088	0.114	7.978	1.121	0.728	0.210		3.281	5.070	
57356	RCW	96	10	Loma Prieta 17 Oct 1989	X-Direction	0.222	0.093	16.549	7.258	0.758	0.216		4.639	1.184	
57356	RCW	96	10	Loma Prieta 17 Oct 1989	Z-Direction	0.335	0.118	20.531	11.609	0.438	0.100		1.987	0.070	
57356	RCW	96	10	Milpitas 07 Jan 2010	X-Direction	0.008	0.006	0.330	0.047	0.650	0.179		3.350	0.980	
57356	RCW	96	10	Milpitas 07 Jan 2010	Z-Direction	0.011	0.008	0.554	0.054	0.440	0.090		3.306	0.390	
57356	RCW	96	10	Morgan Hill 07 Jan 2011	X-Direction	0.010	0.020	0.336	0.043	0.670	0.210		1.830	0.910	
57356	RCW	96	10	Morgan Hill 07 Jan 2011	Z-Direction	0.012	0.011	0.709	0.057	0.412	0.123		3.040	0.763	
57356	RCW	96	10	Morgan Hill 30 March 2009	X-Direction	0.012	0.016	0.549	0.069	0.675	0.203		2.897	3.677	
57356	RCW	96	10	Morgan Hill 30 March 2009	Z-Direction	0.010	0.006	0.690	0.051	0.410	0.090		3.730	0.860	
57356	RCW	96	10	Morgan Hill 24 Apr 1984	X-Direction	0.148	0.054	12.103	2.835	0.630	0.220		1.990	0.880	
57356	RCW	96	10	Morgan Hill 24 Apr 1984	Z-Direction	0.122	0.058	7.474	2.179	0.428	0.133		1.996	0.711	
57356	RCW	96	10	Mt. Lewis 31 Mar 86	X-Direction	0.060	0.029	5.149	1.608	0.630	0.170		2.670	0.700	
57356	RCW	96	10	Mt. Lewis 31 Mar 86	Z-Direction	0.057	0.033	8.660	2.173	0.430	0.096		1.520	0.724	
57356	RCW	96	10	South Napa 24 Aug 2014	Z-Direction	0.017	0.011	1.192	0.465	0.402	0.094		1.739	0.736	
58224	RCW	28	2	Alamo 5 Sept 2008	X-Direction	0.021	0.010	0.342	0.026	0.277	0.055		1.367	0.330	
58224	RCW	28	2	Alamo 5 Sept 2008	Z-Direction	0.020	0.008	0.520	0.049	0.278	0.091		3.471	0.701	
58224	RCW	28	2	Alum Rock 30 Oct 2007	X-Direction	0.018	0.009	0.472	0.068	0.320			2.421		
58224	RCW	28	2	Alum Rock 30 Oct 2007	Z-Direction	0.019	0.008	0.762	0.762	0.271	0.095		3.320	0.710	
58224	RCW	28	2	Berkeley 20 Oct 2011	X-Direction	0.082	0.056	0.137	0.077	0.296	0.099		2.745	1.190	
58224	RCW	28	2	Berkeley 20 Oct 2011	Z-Direction	0.045	0.029	1.660	0.137	0.291	0.090		4.576	0.886	
58224	RCW	28	2	Berkeley 20 Oct 2011	X-Direction	0.060	0.034	0.606	0.022	0.293	0.107		3.734	0.913	
58224	RCW	28	2	Berkeley 20 Oct 2011	Z-Direction	0.023	0.021	1.231	0.091	0.293	0.104		1.289	1.475	
58224	RCW	28	2	El Cerrito 05 Mar 2012	X-Direction	0.037	0.020	0.714	0.045	0.295	0.098		2.824	0.374	
58224	RCW	28	2	El Cerrito 05 Mar 2012	Z-Direction	0.037	0.025	0.708	0.065	0.294	0.077		1.551	0.587	
58224	RCW	28	2	Lafayette 01 Mar 2007	X-Direction	0.033	0.016	0.615	0.059	0.277	0.100		2.176	0.465	
58224	RCW	28	2	Lafayette 01 Mar 2007	Z-Direction	0.032	0.019	0.622	0.067	0.273	0.110		2.498	0.922	
58224	RCW	28	2	Loma Prieta 17 Oct 1989	X-Direction	0.287	0.196	19.877	4.103	0.529	0.101		2.940	0.133	
58224	RCW	28	2	Loma Prieta 17 Oct 1989	Z-Direction	0.503	0.245	37.167	7.614	0.307	0.096		1.346	0.223	
58224	RCW	28	2	Piedmont 17 Aug 2015	X-Direction	0.041	0.024	1.150	0.114	0.511	0.091		3.727	1.357	
58224	RCW	28	2	Piedmont 17 Aug 2015	Z-Direction	0.070	0.048	2.673	0.307	0.471	0.098		3.187	1.927	
58224	RCW	28	2	Piedmont 20 Jul 2007	X-Direction	0.090	0.024	1.112	0.117	0.284	0.082		1.448	0.672	
58224	RCW	28	2	Piedmont 20 Jul 2007	Z-Direction	0.055	0.027	1.426	0.134	0.296	0.116		2.268	1.090	
58224	RCW	28	2	Piedmont Area 20 Dec 2006	X-Direction	0.019	0.007	0.374	0.031	0.293	0.085		2.055	0.855	
58224	RCW	28	2	Piedmont Area 20 Dec 2006	Z-Direction	0.015	0.009	0.327	0.033	0.305	0.102		1.986	0.541	
58224	RCW	28	2	San Leandro 23 Aug 2011	X-Direction	0.011	0.008	0.160	0.015	0.337			1.590		
58224	RCW	28	2	San Leandro 23 Aug 2011	Z-Direction	0.005	0.004	0.259	0.024	0.464			1.607		
58224	RCW	28	2	South Napa 24 Aug 2014	X-Direction	0.045	0.016	1.451	0.317	0.382	0.127		1.551	0.580	
58224	RCW	28	2	South Napa 24 Aug 2014	Z-Direction	0.042	0.015	1.139	0.417	0.311	0.079		1.033	0.290	
58334	RCW	49	3	Berkeley 20 Oct 2011	X-Direction	0.054	0.068	1.037	0.041	0.370	0.080		6.760	0.740	
58334	RCW	49	3	Berkeley 20 Oct 2011	Z-Direction	0.153	0.036	1.945	0.126	0.170			2.940		
58334	RCW	49	3	Berkeley 20 Oct 2011	X-Direction	0.053	0.039	0.734	0.028	0.330			3.010		
58334	RCW	49	3	Berkeley 20 Oct 2011	Z-Direction	0.095	0.029	1.339	0.093	0.170			2.150		
58334	RCW	49	3	El Cerrito 05 Mar 2012	X-Direction	0.041	0.020	0.688	0.056	0.300			6.220		
58334	RCW	49	3	El Cerrito 05 Mar 2012	Z-Direction	0.047	0.028	1.172	0.060	0.370			4.260		
58334	RCW	49	3	Lafayette 01 Mar 2007	X-Direction	0.011	0.006	0.245	0.025	0.450			1.910		
58334	RCW	49	3	Lafayette 01 Mar 2007	Z-Direction	0.022	0.011	0.496	0.048	0.380			1.990		
58334	RCW	49	3	Loma Prieta 17 Oct 1989	X-Direction	0.206	0.072	6.179	1.144	0.350			1.350		
58334	RCW	49	3	Loma Prieta 17 Oct 1989	Z-Direction	0.247	0.086	10.087	1.576	0.370			0.750		
58334	RCW	49	3	Piedmont 20 July 2007	X-Direction	0.216	0.092	2.519	0.191	0.344			3.868		
58334	RCW	49	3	Piedmont 20 July 2007	Z-Direction	0.080	0.068	4.110	0.320	0.408			2.578		
58334	RCW	49	3	Piedmont Area 20 Dec 2006	X-Direction	0.010	0.016	0.204	0.011	0.390			3.240		
58334	RCW	49	3	Piedmont Area 20 Dec 2006	Z-Direction	0.003	0.011	0.328	0.021	0.491			1.801		
58334	RCW	49	3	San Leandro 23 Aug 2011	X-Direction	0.016	0.007	0.215	0.012	0.321			3.780		
58334	RCW	49	3	San Leandro 23 Aug 2011	Z-Direction	0.013	0.007	0.253	0.019	0.346			1.601		
58334	RCW	49	3	San Leandro 24 Aug 2011	X-Direction	0.004	0.005	0.095	0.003	0.395			1.540		
58334	RCW	49	3	San Leandro 24 Aug 2011	Z-Direction	0.002	0.004	0.130	0.007	0.373			2.191		

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
58337	RCW		11	Berkeley 20 Oct 2011	Z-Direction	0.027	0.073	1.968	0.149	0.540	0.130	0.072	3.950	1.690	1.370
58337	RCW		11	Berkeley 20 Oct 2011	X-Direction	0.016	0.064	1.601	0.109	0.560	0.170	0.080	2.730	2.660	0.800
58337	RCW		11	Berkeley 20 Oct 2011	Z-Direction	0.015	0.084	2.032	0.095	0.530	0.140	0.082	3.830	1.020	0.665
58337	RCW		11	Berkeley 27 October 2011	Z-Direction	0.002	0.015	0.200	0.010	0.503	0.110		0.770	1.142	
58337	RCW		11	El Cerrito 05 Mar 2012	X-Direction	0.010	0.085	0.358	0.039	0.520	0.160	0.051	2.480	0.760	0.164
58337	RCW		11	El Cerrito 05 Mar 2012	Z-Direction	0.007	0.007	0.349	0.024	0.530	0.130	0.070	2.310	0.640	0.245
58337	RCW		11	Morgan Hill 07 Jan 2011	X-Direction	0.002	0.003	0.114	0.009	0.480	0.150	0.080	2.990	1.610	0.710
58337	RCW		11	Morgan Hill 07 Jan 2011	Z-Direction	0.006	0.003	0.145	0.012	0.510	0.120	0.070	1.490	1.010	0.520
58337	RCW		11	San Leandro 23 Aug 2011	X-Direction	0.006	0.005	0.187	0.014	0.510	0.160	0.070	2.670	2.690	1.160
58337	RCW		11	San Leandro 23 Aug 2011	Z-Direction	0.003	0.004	0.124	0.010	0.510	0.130	0.060	1.670	1.050	0.290
58337	RCW		11	San Leandro 24 Aug 2011	X-Direction	0.002	0.002	0.082	0.005	0.480	0.150	0.070	2.430	2.160	0.210
58337	RCW		11	San Leandro 24 Aug 2011	Z-Direction	0.001	0.002	0.063	0.005	0.500	0.130	0.070	1.700	0.740	0.390
58337	RCW		11	South Napa 24 Aug 2014	X-Direction	0.022	0.011	1.077	0.359	0.530	0.160	0.080	1.990	0.990	0.100
58337	RCW		11	South Napa 24 Aug 2014	Z-Direction	0.030	0.013	1.468	0.487	0.530	0.160	0.080	2.100	0.750	0.100
58348	RCW	40.6	3	Alamo 5 Sept 2008	X-Direction	0.050	0.022	1.018	0.072	0.310	0.060		5.090	0.310	
58348	RCW	40.6	3	Alamo 5 Sept 2008	Z-Direction	0.048	0.028	1.504	0.159	0.430	0.140		5.760	0.760	
58348	RCW	40.6	3	Alum Rock 30 Oct 2007	X-Direction	0.016	0.011	1.068	0.161	0.280	0.080		4.870	0.360	
58348	RCW	40.6	3	Alum Rock 30 Oct 2007	Z-Direction	0.024	0.011	1.386	0.232	0.410	0.140		3.040	1.240	
58348	RCW	40.6	3	Berkeley 20 Oct 2011	X-Direction	0.030	0.014	0.549	0.060	0.300	0.100		5.410	0.380	
58348	RCW	40.6	3	Berkeley 20 Oct 2011	Z-Direction	0.017	0.011	1.099	0.095	0.390	0.140		4.270	0.930	
58348	RCW	40.6	3	Concord 03 May 2015	X-Direction	0.035	0.016	0.591	0.032	0.330	0.097		3.710	0.530	
58348	RCW	40.6	3	Concord 03 May 2015	Z-Direction	0.014	0.009	0.886	0.082	0.480	0.118		2.580	0.698	
58348	RCW	40.6	3	El Cerrito 05 Mar 2012	X-Direction	0.019	0.010	0.259	0.027	0.300	0.057		3.950	0.215	
58348	RCW	40.6	3	El Cerrito 05 Mar 2012	Z-Direction	0.012	0.005	0.589	0.048	0.370	0.130		4.790	0.800	
58348	RCW	40.6	3	Lafayette 01 Mar 2007	X-Direction	0.064	0.055	1.949	0.145	0.328	0.088		2.524	0.913	
58348	RCW	40.6	3	Lafayette 01 Mar 2007	Z-Direction	0.073	0.057	2.240	0.179	0.410	0.090		2.090	0.660	
58348	RCW	40.6	3	Loma Prieta 17 Oct 1989	X-Direction	0.159	0.078	12.135	2.433	0.310			2.990		
58348	RCW	40.6	3	Loma Prieta 17 Oct 1989	Z-Direction	0.214	0.125	21.359	6.148	0.470	0.100		2.420	0.180	
58348	RCW	40.6	3	Piedmont 20 July 2007	X-Direction	0.012	0.005	0.489	0.086	0.290			2.740		
58348	RCW	40.6	3	Piedmont 20 July 2007	Z-Direction	0.014	0.005	0.443	0.069	0.370	0.140		2.350	1.050	
58348	RCW	40.6	3	San Ramon 02 Apr 2015	X-Direction	0.015	0.005	0.186	0.010	0.297			2.422		
58348	RCW	40.6	3	San Ramon 02 Apr 2015	Z-Direction	0.012	0.013	0.394	0.020	0.380	0.115		4.670	1.368	
58348	RCW	40.6	3	South Napa 24 Aug 2014	X-Direction	0.079	0.030	2.587	0.769	0.320	0.100		0.960	0.090	
58348	RCW	40.6	3	South Napa 24 Aug 2014	Z-Direction	0.109	0.036	2.971	0.596	0.450	0.114		2.870	0.228	
58364	RCW	128.5	10	Alamo 5 Sept 2008	X-Direction	0.020	0.029	0.889	0.086	0.559	0.167	0.087	2.490	1.346	1.907
58364	RCW	128.5	10	Alamo 5 Sept 2008	Z-Direction	0.009	0.021	1.443	0.099	0.771	0.199	0.106	2.750	2.141	0.418
58364	RCW	128.5	10	Alum Rock 30 Oct 2007	X-Direction	0.015	0.005	0.382	0.127	0.573	0.161	0.084	2.974	0.996	2.973
58364	RCW	128.5	10	Alum Rock 30 Oct 2007	Z-Direction	0.008	0.004	0.581	0.147	0.775	0.190	0.094	2.164	0.841	0.696
58364	RCW	128.5	10	Berkeley 20 Oct 2011	X-Direction	0.006	0.008	0.364	0.033	0.529	0.154	0.097	1.638	1.984	0.485
58364	RCW	128.5	10	Berkeley 20 Oct 2011	Z-Direction	0.003	0.008	0.172	0.019	0.736	0.192	0.090	2.010	2.259	1.110
58364	RCW	128.5	10	Berkeley 20 Oct 2011	X-Direction	0.005	0.007	0.357	0.026	0.524	0.159	0.085	2.003	2.233	1.309
58364	RCW	128.5	10	Berkeley 20 Oct 2011	Z-Direction	0.003	0.008	0.237	0.017	0.749	0.193	0.094	1.997	2.464	2.985
58364	RCW	128.5	10	Concord 03 May 2015	X-Direction	0.004	0.010	0.382	0.018	0.560	0.178	0.081	3.129	0.852	0.280
58364	RCW	128.5	10	Concord 03 May 2015	Z-Direction	0.002	0.013	0.451	0.024	0.767	0.199	0.097	2.898	1.782	3.659
58364	RCW	128.5	10	El Cerrito 05 Mar 2012	X-Direction	0.005	0.002	0.120	0.012	0.559	0.170	0.096	2.418	0.531	0.479
58364	RCW	128.5	10	El Cerrito 05 Mar 2012	Z-Direction	0.002	0.003	0.105	0.009	0.747	0.196	0.094	2.758	1.887	2.686
58364	RCW	128.5	10	LivermoreA 24 Jan 1980	X-Direction	0.079	0.029	2.395	0.189	0.481	0.166	0.098	3.225	0.506	0.203
58364	RCW	128.5	10	LivermoreA 24 Jan 1980	Z-Direction	0.071	0.030	2.324	0.254	0.715	0.171	0.109	2.391	1.793	0.423
58364	RCW	128.5	10	LivermoreB 24 Jan 1980	X-Direction	0.112	0.055	4.150	0.395	0.556	0.171		3.650	0.786	
58364	RCW	128.5	10	LivermoreB 24 Jan 1980	Z-Direction	0.104	0.045	4.434	0.588	0.722	0.182	0.098	2.524	0.876	0.373
58364	RCW	128.5	10	Loma Prieta 17 Oct 1989	X-Direction	0.219	0.098	7.297	1.260	0.628	0.191	0.100	1.584	0.764	0.140
58364	RCW	128.5	10	Loma Prieta 17 Oct 1989	Z-Direction	0.100	0.044	10.953	2.209	0.776	0.217	0.100	2.178	0.530	0.133
58364	RCW	128.5	10	San Ramon 02 Apr 2015	X-Direction	0.005	0.013	0.170	0.011	0.566	0.165	0.090	1.820	1.240	0.909
58364	RCW	128.5	10	San Ramon 02 Apr 2015	Z-Direction	0.002	0.005	0.345	0.018	0.745	0.202	0.095	2.436	1.999	0.337
58364	RCW	128.5	10	South Napa 24 Aug 2014	X-Direction	0.079	0.018	2.329	1.049	0.622	0.168	0.094	1.870	2.288	0.119
58364	RCW	128.5	10	South Napa 24 Aug 2014	Z-Direction	0.030	0.019	2.016	0.646	0.793	0.203	0.102	2.666	1.253	0.174
58394	RCW	104	9	Loma Prieta 17 Oct 1989	X-Direction	0.112	0.110	15.606	2.756	1.200	0.290	0.110	2.550	3.860	0.340
58394	RCW	104	9	Loma Prieta 17 Oct 1989	Z-Direction	0.132	0.115	13.940	3.178	1.730	0.450	0.150	4.590	0.950	0.170
58462	RCW	84.8	6	Alum Rock 30 Oct 2007	X-Direction	0.008	0.006	0.496	0.069	0.710	0.200	0.110	5.240	2.780	1.140
58462	RCW	84.8	6	Alum Rock 30 Oct 2007	Z-Direction	0.044	0.010	0.596	0.081	0.670	0.200		3.060	2.750	
58462	RCW	84.8	6	Fremont 21 Jul 2015	X-Direction	0.002	0.003	0.165	0.021	0.670			4.070		
58462	RCW	84.8	6	Fremont 21 Jul 2015	Z-Direction	0.002	0.007	0.288	0.014	0.768	0.250		4.692	3.631	
58462	RCW	84.8	6	Lafayette 01 Mar 2007	X-Direction	0.006	0.006	0.353	0.034	0.700	0.190	0.110	4.570	2.220	1.040

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
58462	RCW	84.8	6	Lafayette 01 Mar 2007	Z-Direction	0.005	0.007	0.352	0.056	0.810	0.220	0.110	4.170	1.820	0.330
58462	RCW	84.8	6	Loma Prieta 17 Oct 1989	X-Direction	0.169	0.091	10.963	2.291	0.880	0.220	0.120	3.020	1.790	0.840
58462	RCW	84.8	6	Loma Prieta 17 Oct 1989	Z-Direction	0.095	0.115	10.224	0.198	0.920	0.270	0.100	3.820	1.620	0.150
58479	RCW	78	6	Berkeley 20 Oct 2011	X-Direction	0.005	0.007	0.223	0.018	0.434	0.161		3.946	1.854	
58479	RCW	78	6	Berkeley 20 Oct 2011	Z-Direction		0.004	0.092	0.007		0.299			1.505	
58479	RCW	78	6	Loma Prieta 17 Oct 1989	X-Direction	0.363	0.094	10.465	1.739	0.754	0.221		6.898	1.448	
58479	RCW	78	6	Loma Prieta 17 Oct 1989	Z-Direction	0.150	0.066	15.094	4.226	0.348	0.129		2.394	0.920	
58480	RCW	241	18	Loma Prieta 17 Oct 1989	X-Direction	0.034	0.161	16.376	5.993	2.260	0.608	0.339	5.089	3.696	3.750
58480	RCW	241	18	Loma Prieta 17 Oct 1989	Z-Direction	0.044	0.131	15.805	2.649	3.194	0.978	0.238	6.158	6.664	2.025
58480	RCW	241	18	South Napa 24 Aug 2014	X-Direction	0.005	0.013	1.088	0.363	1.940	0.620	0.370	2.990	2.060	0.770
58480	RCW	241	18	South Napa 24 Aug 2014	Z-Direction	0.004	0.012	1.167	0.337	2.660	0.810	0.270	6.470	2.920	0.570
58483	RCW	219	24	Alamo 5 Sept 2008	X-Direction	0.000	0.003	0.095	0.006	1.637	0.527		2.847	1.777	
58483	RCW	219	24	Alamo 5 Sept 2008	Z-Direction	0.001	0.008	0.261	0.028	1.879	0.476		2.266	1.457	
58483	RCW	219	24	Berkeley 20 Oct 2011	X-Direction	0.000	0.021	0.421	0.021	1.601	0.437		1.563	1.117	
58483	RCW	219	24	Berkeley 20 Oct 2011	Z-Direction	0.000	0.024	0.603	0.032	1.879	0.499		2.266	1.252	
58483	RCW	219	24	Berkeley 20 Oct 2011	X-Direction	0.000	0.022	0.578	0.025	1.586	0.412		3.223	2.169	
58483	RCW	219	24	Berkeley 20 Oct 2011	Z-Direction	0.000	0.014	0.488	0.016	1.818	0.506		2.055	1.108	
58483	RCW	219	24	Berkeley 27 October 2011	X-Direction	0.000	0.009	0.121	0.010	1.559	0.429		2.153	1.003	
58483	RCW	219	24	Berkeley 27 October 2011	Z-Direction	0.000	0.010	0.366	0.018	1.839	0.493		2.490	1.568	
58483	RCW	219	24	El Cerrito 05 Mar 2012	X-Direction	0.000	0.008	0.224	0.014	1.756	0.517		4.736	1.514	
58483	RCW	219	24	El Cerrito 05 Mar 2012	Z-Direction	0.001	0.021	0.721	0.065	1.816	0.506		1.583	1.666	
58483	RCW	219	24	Lafayette 01 Mar 2007	X-Direction	0.000	0.006	0.170	0.012	1.384	0.438		2.996	1.061	
58483	RCW	219	24	Lafayette 01 Mar 2007	Z-Direction	0.001	0.012	0.483	0.058	1.914	0.550		3.615	0.741	
58483	RCW	219	24	Loma Prieta 17 Oct 1989	Z-Direction	0.092	0.178	30.103	6.979	2.489	0.592		4.441	2.923	
58483	RCW	219	24	Morgan Hill 07 Jan 2011	X-Direction	0.000	0.002	0.078	0.006	1.486	0.478		1.123	1.168	
58483	RCW	219	24	Morgan Hill 07 Jan 2011	Z-Direction	0.000	0.006	0.181	0.014	1.823	0.493		4.292	1.221	
58483	RCW	219	24	Piedmont 20 Jul 2007	X-Direction	0.001	0.020	0.450	0.047	1.734	0.439		2.328	1.494	
58483	RCW	219	24	Piedmont 20 Jul 2007	Z-Direction	0.004	0.035	1.735	0.206	1.926	0.498		1.593	1.491	
58483	RCW	219	24	Piedmont Area 20 Dec 2006	X-Direction	0.000	0.008	0.126	0.006	1.394	0.460		2.463	1.680	
58483	RCW	219	24	Piedmont Area 20 Dec 2006	Z-Direction	0.000	0.010	0.328	0.018	1.843	0.493		2.624	1.321	
58483	RCW	219	24	San Leandro 23 Aug 2011	X-Direction	0.000	0.010	0.241	0.016	1.419	0.537		2.551	0.947	
58483	RCW	219	24	San Leandro 23 Aug 2011	Z-Direction	0.000	0.009	0.190	0.007	1.833	0.484		2.832	2.982	
58483	RCW	219	24	South Napa 24 Aug 2014	X-Direction	0.003	0.006	0.627	0.187	1.758	0.563		1.979	1.582	
58483	RCW	219	24	South Napa 24 Aug 2014	Z-Direction	0.005	0.016	1.680	0.281	2.064	0.527		5.658	4.217	
58488	RCW	50	4	Alamo 5 Sept 2008	X-Direction	0.010	0.007	0.172	0.010	0.153	0.056		1.211	0.285	
58488	RCW	50	4	Alamo 5 Sept 2008	Z-Direction	0.015	0.005	0.297	0.015	0.182	0.057		1.270	0.620	
58488	RCW	50	4	Alum Rock 30 Oct 2007	X-Direction	0.010	0.004	0.317	0.053	0.160	0.057		0.898	0.107	
58488	RCW	50	4	Alum Rock 30 Oct 2007	Z-Direction	0.014	0.005	0.325	0.042	0.198	0.056		2.652	0.317	
58488	RCW	50	4	Lafayette 01 Mar 2007	X-Direction	0.012	0.007	0.243	0.023	0.154	0.052		1.191	0.161	
58488	RCW	50	4	Lafayette 01 Mar 2007	Z-Direction	0.016	0.005	0.453	0.051	0.182			0.464		
58488	RCW	50	4	Loma Prieta 17 Oct 1989	X-Direction	0.058	0.038	3.644	0.794	0.151			0.585		
58488	RCW	50	4	Loma Prieta 17 Oct 1989	Z-Direction	0.119	0.052	4.213	0.847	0.217			1.465		
58488	RCW	50	4	San Leandro 23 Aug 2011	X-Direction	0.015	0.007	0.141	0.008	0.151	0.052		0.706	0.229	
58488	RCW	50	4	San Leandro 23 Aug 2011	Z-Direction	0.016	0.005	0.203	0.014	0.206	0.079		3.906	1.325	
58503	RCW	47.5	3	Berkeley 20 Oct 2011	X-Direction	0.014	0.005	0.240	0.025	0.200	0.060		1.265	0.540	
58503	RCW	47.5	3	Berkeley 20 Oct 2011	Z-Direction	0.019	0.006	0.440	0.048	0.274			1.688		
58503	RCW	47.5	3	El Cerrito 05 Mar 2012	X-Direction	0.058	0.053	2.129	0.077	0.312	0.056		1.083	0.140	
58503	RCW	47.5	3	El Cerrito 05 Mar 2012	Z-Direction	0.109	0.051	1.888	0.111	0.261	0.073		2.249	0.350	
58503	RCW	47.5	3	Glenellen 02 Aug 2006	X-Direction	0.023	0.008	0.265	0.025	0.236	0.057		2.266	0.063	
58503	RCW	47.5	3	Glenellen 02 Aug 2006	Z-Direction	0.010	0.004	0.405	0.030	0.274	0.096	0.063	3.340	1.567	0.455
58503	RCW	47.5	3	Loma Prieta 17 Oct 1989	X-Direction	0.176	0.086	12.669	2.148	0.273			2.260		
58503	RCW	47.5	3	Loma Prieta 17 Oct 1989	Z-Direction	0.187	0.116	15.299	2.217	0.285	0.105		2.150	0.515	
58503	RCW	47.5	3	Piedmont Area 20 Dec 2006	X-Direction	0.011	0.005	0.136	0.008	0.294		`	1.583		
58503	RCW	47.5	3	Piedmont Area 20 Dec 2006	Z-Direction	0.020	0.006	0.309	0.019	0.269	0.082		1.454	1.087	
58503	RCW	47.5	3	South Napa 24 Aug 2014	X-Direction	0.022	0.014	1.518	0.406	0.191	0.050		2.999	0.130	
58503	RCW	47.5	3	South Napa 24 Aug 2014	Z-Direction	0.028	0.015	1.460	0.406	0.250	0.081		2.141	0.411	
68387	RCW	66.7	5	South Napa 24 Aug 2014	X-Direction	0.071	0.034	10.943	5.925	0.820	0.210		5.500	2.300	
68387	RCW	66.7	5	South Napa 24 Aug 2014	Z-Direction	0.071	0.038	11.176	5.601	0.380	0.080		4.850	0.300	
68489	RCW	124	14	South Napa 24 Aug 2014	X-Direction	0.122	0.036	12.793	6.022	1.190	0.290	0.170	3.450	1.860	1.070
68489	RCW	124	14	South Napa 24 Aug 2014	Z-Direction	0.101	0.049	10.878	6.179	1.130	0.290	0.130	3.450	1.450	2.140
89770	RCW	50	4	Bayview 11 Oct 2013	X-Direction	0.023	0.015	0.889	0.112	0.293	0.093	0.069	1.374	1.326	0.255
89770	RCW	50	4	Bayview 11 Oct 2013	Z-Direction	0.024	0.018	0.726	0.070	0.309	0.102		1.756	0.259	
89770	RCW	50	4	Crescent City 14 Jun 2005	X-Direction	0.011	0.004	0.443	0.117	0.242	0.075		1.171	0.305	

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
89770	RCW	50	4	Crescent City 14 Jun 2005	Z-Direction	0.010	0.005	0.496	0.125	0.254	0.093		1.304	0.428	
89770	RCW	50	4	Fendale 04 Feb 2010	X-Direction	0.026	0.016	0.884	0.198	0.319	0.075		3.534	0.275	
89770	RCW	50	4	Fendale 04 Feb 2010	Z-Direction	0.021	0.014	0.958	0.135	0.302	0.111		1.011	0.415	
89770	RCW	50	4	Ferndale 09 Jan 2010	X-Direction	0.922	0.285	12.462	2.414	0.371	0.128	0.095	4.369	0.682	0.608
89770	RCW	50	4	Ferndale 09 Jan 2010	Z-Direction	0.469	0.177	30.122	7.301	0.359	0.119		6.356	0.444	
89770	RCW	50	4	Ferndale 09 Mar 2014	X-Direction	0.075	0.027	2.227	1.120	0.339	0.096	0.083	4.209	0.246	0.602
89770	RCW	50	4	Ferndale 09 Mar 2014	Z-Direction	0.050	0.020	2.767	1.577	0.331	0.115		1.280	0.538	
89770	RCW	50	4	Ferndale 17 Dec 2013	X-Direction	0.012	0.006	0.300	0.030	0.277	0.083	0.063	0.988	0.418	0.583
89770	RCW	50	4	Ferndale 17 Dec 2013	Z-Direction	0.008	0.006	0.198	0.013	0.305	0.121		1.057	0.329	
89770	RCW	50	4	Ferndale 26 Feb 2007	X-Direction	0.023	0.008	0.620	0.092	0.249	0.083		0.870	0.528	
89770	RCW	50	4	Ferndale 26 Feb 2007	Z-Direction	0.015	0.007	0.787	0.115	0.279	0.093		2.393	0.270	
89770	RCW	50	4	Humboldt Hill 02 Aug 2013	X-Direction	0.013	0.011	0.402	0.024	0.295	0.088	0.062	2.909	0.314	0.346
89770	RCW	50	4	Humboldt Hill 02 Aug 2013	Z-Direction	0.008	0.010	0.419	0.030	0.346	0.101		1.413	1.031	
89770	RCW	50	4	Petrolia Offshore 26 Oct 2008	X-Direction	0.008	0.004	0.143	0.019	0.237	0.077		1.290	0.248	
89770	RCW	50	4	Petrolia Offshore 26 Oct 2008	Z-Direction	0.008	0.003	0.158	0.029	0.262	0.089		0.902	0.695	
89770	RCW	50	4	Trinidad 16 Aug 2008	X-Direction	0.020	0.013	0.470	0.056	0.245	0.080		0.947	0.350	
89770	RCW	50	4	Trinidad 16 Aug 2008	Z-Direction	0.018	0.010	0.854	0.073	0.363	0.092		1.828	1.485	
89770	RCW	50	4	Trinidad 24 Jun 2007	X-Direction	0.025	0.014	0.472	0.066	0.248	0.075		2.111	0.276	
89770	RCW	50	4	Trinidad 24 Jun 2007	Z-Direction	0.017	0.008	0.770	0.097	0.257	0.093		1.311	0.460	
89770	RCW	50	4	Willow Creek 29 Apr 2008	X-Direction	0.018	0.006	0.408	0.062	0.243	0.079		2.003	0.446	
89770	RCW	50	4	Willow Creek 29 Apr 2008	Z-Direction	0.016	0.008	0.786	0.122	0.243	0.079		2.079	0.395	
12299	SMRF	65.5	4	Borrego Springs 07 Jul 2010	X-Direction	0.068	0.032	2.556	0.358	0.690	0.182	0.105	3.047	1.939	1.402
12299	SMRF	65.5	4	Borrego Springs 07 Jul 2010	Z-Direction	0.075	0.028	1.985	0.265	0.633	0.169	0.097	2.990	2.436	1.059
12299	SMRF	65.5	4	Calexico 04 Apr 2010	Z-Direction	0.058	0.023	3.163	2.552	0.581			9.080		
12299	SMRF	65.5	4	Hector Mine 16 Oct 1999	X-Direction	0.093	0.062	7.603	2.361	0.698	0.204	0.115	3.092	1.620	0.514
12299	SMRF	65.5	4	Hector Mine 16 Oct 1999	Z-Direction	0.109	0.040	6.517	3.205	0.624	0.190	0.101	2.132	1.320	0.286
12299	SMRF	65.5	4	Palm Springs 08 Jul 1986	X-Direction	0.479	0.164	15.570	1.966	0.729	0.213	0.120	4.022	2.142	0.409
12299	SMRF	65.5	4	Palm Springs 08 Jul 1986	Z-Direction	0.236	0.188	15.511	3.198	0.631	0.192	0.095	5.016	1.224	0.772
13312	SMRF	208	13	Beaumont 14 Sept 2011	X-Direction	0.000	0.010	0.244	0.012	1.110	0.430	0.114	2.590	1.880	0.771
13312	SMRF	208	13	Beaumont 14 Sept 2011	Z-Direction	0.000	0.013	0.353	0.009	1.484	0.562	0.195	4.090	3.541	0.530
13312	SMRF	208	13	Borrego Springs 07 Jul 2010	X-Direction	0.007	0.016	1.413	0.167	1.206	0.353	0.100	5.156	1.089	0.534
13312	SMRF	208	13	Borrego Springs 07 Jul 2010	Z-Direction	0.003	0.018	1.083	0.108	1.916	0.496	0.110	4.546	1.013	0.140
13312	SMRF	208	13	Calexico 04 Apr 2010	X-Direction	0.013	0.015	2.705	3.291	1.297	0.475	0.092	4.539	4.174	0.178
13312	SMRF	208	13	Calexico 04 Apr 2010	Z-Direction	0.004	0.014	2.369	3.514	1.950	0.630	0.095	4.850	3.573	4.100
13312	SMRF	208	13	Ocotillo 14 Jun 2010	X-Direction	0.003	0.004	0.381	0.086	1.160	0.435	0.098	5.300	1.508	0.522
13312	SMRF	208	13	Ocotillo 14 Jun 2010	Z-Direction	0.001	0.005	0.331	0.114	1.820	0.620	0.173	5.020	4.039	1.437
13312	SMRF	208	13	Redlands 13 Feb 2010	X-Direction	0.001	0.014	0.398	0.031	1.150	0.251	0.090	2.580	1.233	0.800
13312	SMRF	208	13	Redlands 13 Feb 2010	Z-Direction	0.001	0.010	0.314	0.017	1.050	0.300	0.173	3.830	1.770	1.437
14323	SMRF	96	7	Whittier 01 Oct 1987	X-Direction	0.070	0.039	4.352	0.565	1.150			5.750		
14323	SMRF	96	7	Whittier 01 Oct 1987	Z-Direction	0.032	0.073	8.663	1.165	1.420			4.740		
14533	SMRF	265	15	Chino Hills 29 July 2008	X-Direction	0.003	0.013	2.130	0.578	3.548	1.181	0.665	3.189	4.047	4.066
14533	SMRF	265	15	Chino Hills 29 July 2008	Z-Direction	0.002	0.021	2.390	0.380	3.540	1.200	0.660	4.650	2.590	4.270
14533	SMRF	265	15	Inglewood 17 May 2009	X-Direction	0.001	0.059	1.544	0.076	3.230	1.120	0.590	6.380	3.230	5.320
14533	SMRF	265	15	Inglewood 17 May 2009	Z-Direction	0.000	0.043	1.557	0.133	3.320	1.150	0.610	3.840	4.990	2.940
14533	SMRF	265	15	Whittier 01 Oct 1987	X-Direction	0.011	0.055	7.126	1.182	3.340	1.180	0.650	2.660	3.960	4.570
14533	SMRF	265	15	Whittier 01 Oct 1987	Z-Direction	0.006	0.041	4.328	1.306	3.480	1.230	0.650	2.900	5.930	2.580
23481	SMRF	104.5	7	Beaumont 14 Sept 2011	X-Direction	0.001	0.030	0.705	0.030	1.147	0.402	0.240	2.532	3.120	1.393
23481	SMRF	104.5	7	Beaumont 14 Sept 2011	Z-Direction	0.001	0.021	0.463	0.022	1.261	0.453	0.284	2.632	1.538	0.513
23481	SMRF	104.5	7	Borrego Springs 07 Jul 2010	X-Direction	0.008	0.010	0.882	0.165	1.395	0.471	0.250	4.149	4.974	1.115
23481	SMRF	104.5	7	Borrego Springs 07 Jul 2010	Z-Direction	0.004	0.010	1.015	0.152	1.527	0.569	0.328	3.998	3.389	0.958
23481	SMRF	104.5	7	Calexico 04 Apr 2010	X-Direction	0.011	0.011	5.112	6.780	1.398	0.474	0.269	5.311	2.874	1.466
23481	SMRF	104.5	7	Calexico 04 Apr 2010	Z-Direction	0.011	0.014	2.402	2.841	1.628	0.529	0.334	3.418	2.108	1.505
23481	SMRF	104.5	7	Landers 28 Jun 1992	X-Direction	0.038	0.065	6.506	2.399	1.481	0.498	0.263	2.396	2.114	1.320
23481	SMRF	104.5	7	Landers 28 Jun 1992	Z-Direction	0.048	0.058	5.481	2.331	1.641	0.497	0.333	4.694	3.129	1.317
23481	SMRF	104.5	7	Redlands 13 Feb 2010	X-Direction	0.002	0.026	0.838	0.032	1.193	0.400	0.249	3.310	1.669	1.547
23481	SMRF	104.5	7	Redlands 13 Feb 2010	Z-Direction	0.001	0.020	0.816	0.059	1.420	0.440	0.320	6.110	1.180	1.370
23515	SMRF	118	9	Landers 28 Jun 1992	X-Direction	0.078	0.068	14.781	5.419	2.086	0.618	0.402	3.530	4.230	0.540
23515	SMRF	118	9	Landers 28 Jun 1992	Z-Direction	0.092	0.081	14.715	7.357	1.989	0.617	0.369	3.110	5.910	0.840
23516	SMRF	41.3	3	Beaumont 16 Jan 2010	X-Direction	0.007	0.004	3.562	0.175	0.426	0.141	0.057	4.689	3.351	0.035
23516	SMRF	41.3	3	Beaumont 16 Jan 2010	Z-Direction	0.013	0.009	0.397	0.033	0.457	0.141	0.034	3.806	1.471	0.033
23516	SMRF	41.3	3	Borrego Springs 07 Jul 2010	X-Direction	0.049	0.017	1.375	0.217	0.519	0.170	0.067	5.453	1.016	0.160
23516	SMRF	41.3	3	Borrego Springs 07 Jul 2010	Z-Direction	0.074	0.018	1.489	0.228	0.522	0.116	0.069	2.706	0.583	0.043
23516	SMRF	41.3	3	Calexico 04 Apr 2010	X-Direction	0.054	0.018	2.501	2.847	0.519	0.170	0.067	5.453	1.016	0.160

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
23516	SMRF	41.3	3	Calexico 04 Apr 2010	Z-Direction	0.099	0.022	5.851	6.986	0.519	0.168		5.601	0.616	
23516	SMRF	41.3	3	Chino Hills 29 July 2008	X-Direction	0.044	0.047	1.780	0.184	0.490	0.152	0.055	6.254	1.164	0.037
23516	SMRF	41.3	3	Chino Hills 29 July 2008	Z-Direction	0.064	0.052	2.929	0.221	0.478	0.124		4.234	0.624	
23516	SMRF	41.3	3	Inglewood 17 May 2009	X-Direction	0.019	0.008	0.466	0.029	0.443	0.141	0.042	3.001	1.678	0.020
23516	SMRF	41.3	3	Inglewood 17 May 2009	Z-Direction	0.019	0.010	0.486	0.037	0.471	0.147	0.074	4.761	0.703	0.145
23516	SMRF	41.3	3	Lake Elsinore 02 Sep 2007	X-Direction	0.027	0.031	1.083	0.076	0.479	0.159	0.035	4.783	1.479	0.030
23516	SMRF	41.3	3	Lake Elsinore 02 Sep 2007	Z-Direction	0.014	0.036	1.337	0.053	0.465	0.147	0.046	5.950	0.967	0.047
23516	SMRF	41.3	3	Landers 28 Jun 1992	X-Direction	0.201	0.081	15.070	7.640	0.557	0.175	0.097	5.222	0.863	0.346
23516	SMRF	41.3	3	Landers 28 Jun 1992	Z-Direction	0.244	0.113	23.774	12.639	0.528	0.120		5.972	0.238	
23516	SMRF	41.3	3	San Bernardino 08 Jan 2009	X-Direction	0.056	0.083	2.614	0.192	0.522	0.162	0.122	4.944	1.143	0.667
23516	SMRF	41.3	3	San Bernardino 08 Jan 2009	Z-Direction	0.120	0.102	7.304	0.467	0.578	0.160	0.055	7.618	0.882	0.213
23516	SMRF	41.3	3	Whittier 01 Oct 1987	X-Direction	0.054	0.024	1.485	0.128	0.454	0.156	0.077	1.538	1.640	0.310
23516	SMRF	41.3	3	Whittier 01 Oct 1987	Z-Direction	0.039	0.029	1.136	0.091	0.467	0.146	0.086	3.799	0.341	0.425
23634	SMRF	69	5	Big Bear 28 Jun 1992	X-Direction	0.090	0.067	5.307	1.667	0.490	0.180		3.240	1.570	
23634	SMRF	69	5	Big Bear 28 Jun 1992	Z-Direction	0.121	0.059	4.988	1.387	0.490	0.180		3.750	1.870	
23634	SMRF	69	5	Big Bear City 22 Feb 2003	X-Direction	0.020	0.023	1.521	0.111	0.470	0.180		4.560	1.380	
23634	SMRF	69	5	Big Bear City 22 Feb 2003	Z-Direction	0.048	0.012	0.662	0.075	0.470	0.180		4.070	3.270	
23634	SMRF	69	5	Chino Hills 29 July 2008	X-Direction	0.034	0.036	1.683	0.307	0.480	0.180		3.900	3.550	
23634	SMRF	69	5	Chino Hills 29 July 2008	Z-Direction	0.038	0.025	1.209	0.242	0.480	0.190		3.790	2.960	
23634	SMRF	69	5	Landers 28 Jun 1992	X-Direction	0.164	0.080	14.937	7.943	0.490	0.180		3.600	1.940	
23634	SMRF	69	5	Landers 28 Jun 1992	Z-Direction	0.181	0.078	11.171	5.887	0.490	0.180		3.240	1.990	
23634	SMRF	69	5	Northridge 17 Jan 1994	Z-Direction	0.105	0.049	4.252	0.891	0.510	0.180		1.570	2.950	
23634	SMRF	69	5	Northridge 17 Jan 1994	Z-Direction	0.122	0.057	4.244	0.650	0.496	0.180		3.076	1.950	
24104	SMRF	41	2	Calexico 04 Apr 2010	X-Direction	0.010	0.006	3.065	4.544	0.345	0.134		1.869	0.658	
24104	SMRF	41	2	Calexico 04 Apr 2010	Z-Direction	0.008	0.005	1.803	2.868	0.312	0.104		1.044	0.543	
24104	SMRF	41	2	Chatsworth 09 Aug 2007	X-Direction	0.130	0.052	3.999	0.349	0.403	0.151		1.734	2.690	
24104	SMRF	41	2	Chatsworth 09 Aug 2007	Z-Direction	0.164	0.084	6.120	0.365	0.460	0.151		3.017	0.853	
24104	SMRF	41	2	Chino Hills 29 July 2008	X-Direction	0.067	0.019	1.592	0.216	0.401	0.133		2.077	0.651	
24104	SMRF	41	2	Chino Hills 29 July 2008	Z-Direction	0.095	0.027	1.880	0.282	0.436	0.152		4.188	1.507	
24104	SMRF	41	2	Encino 17 Mar 2014	X-Direction	0.049	0.020	0.848	0.071	0.386	0.147		3.437	0.724	
24104	SMRF	41	2	Encino 17 Mar 2014	Z-Direction	0.046	0.016	1.194	0.128	0.382	0.110		1.588	0.276	
24104	SMRF	41	2	San Simeon 22 Dec 2003	X-Direction	0.009	0.009	4.325	1.838	0.361	0.109		3.932	0.585	
24104	SMRF	41	2	San Simeon 22 Dec 2003	Z-Direction	0.012	0.008	2.334	1.108	0.337	0.116		2.179	0.568	
24104	SMRF	41	2	Simi Valley 29 Oct 2003	X-Direction	0.019	0.030	1.140	0.078	0.386	0.132		3.280	0.512	
24104	SMRF	41	2	Simi Valley 29 Oct 2003	Z-Direction	0.032	0.028	0.857	0.045	0.404	0.129		3.473	0.663	
24104	SMRF	41	2	Westlake Village 01 May 2009	X-Direction	0.010	0.010	0.429	0.023	0.346	0.119		1.320	0.486	
24104	SMRF	41	2	Westlake Village 01 May 2009	Z-Direction	0.013	0.006	0.274	0.024	0.366	0.112		2.335	0.621	
24104	SMRF	41	2	W Hollywood 09 Sep 2001	X-Direction	0.012	0.004	0.260	0.021	0.359	0.133		1.896	0.589	
24104	SMRF	41	2	W Hollywood 09 Sep 2001	Z-Direction	0.016	0.008	0.312	0.028	0.361	0.125		1.086	0.524	
24198	SMRF	34	3	Chatsworth 09 Aug 2007	X-Direction	0.023	0.046	2.006	0.142	0.630	0.200		5.660	3.190	
24198	SMRF	34	3	Chatsworth 09 Aug 2007	Z-Direction	0.031	0.040	1.902	0.157	0.660	0.180		4.940	2.280	
24198	SMRF	34	3	Chino Hills 29 July 2008	X-Direction	0.062	0.043	3.484	0.497	0.660	0.200		4.640	3.730	
24198	SMRF	34	3	Chino Hills 29 July 2008	Z-Direction	0.077	0.074	5.759	0.628	0.680	0.190		4.310	2.470	
24198	SMRF	34	3	Encino 17 Mar 2014	X-Direction	0.032	0.060	2.042	0.104	0.520	0.180		5.150	3.600	
24198	SMRF	34	3	Encino 17 Mar 2014	Z-Direction	0.025	0.054	1.809	0.154	0.570	0.180		5.350	2.090	
24198	SMRF	34	3	San Simeon 22 Dec 2003	X-Direction	0.013	0.005	1.406	0.658	0.590	0.140		5.680	0.590	
24198	SMRF	34	3	San Simeon 22 Dec 2003	Z-Direction	0.013	0.007	1.894	0.785	0.620	0.150		5.400	1.320	
24288	SMRF	351.2	32	Borrego Springs 07 Jul 2010	X-Direction	0.002	0.006	0.485	0.090	2.845	1.036	0.574	2.811	2.686	2.271
24288	SMRF	351.2	32	Borrego Springs 07 Jul 2010	Z-Direction	0.001	0.005	0.656	0.179	3.191	1.125	0.630	2.734	3.056	3.199
24288	SMRF	351.2	32	Calexico 04 Apr 2010	X-Direction	0.015	0.007	2.546	2.392	2.931	1.027	0.621	2.057	1.980	1.342
24288	SMRF	351.2	32	Calexico 04 Apr 2010	Z-Direction	0.011	0.007	4.180	5.418	3.326	1.136	0.658	1.849	1.816	2.094
24288	SMRF	351.2	32	Chino Hills 29 July 2008	X-Direction	0.003	0.064	4.892	0.624	2.915	1.057	0.623	2.485	2.363	1.717
24288	SMRF	351.2	32	Chino Hills 29 July 2008	Z-Direction	0.005	0.069	6.602	1.038	2.911	1.146	0.675	2.457	2.350	2.788
24288	SMRF	351.2	32	Encino 17 Mar 2014	X-Direction	0.000	0.008	0.329	0.034	2.763	0.991	0.575	2.840	3.230	2.722
24288	SMRF	351.2	32	Encino 17 Mar 2014	Z-Direction	0.000	0.008	0.303	0.046	2.763	1.093	0.614	2.788	3.202	3.218
24288	SMRF	351.2	32	Inglewood 17 May 2009	X-Direction	0.001	0.016	0.532	0.075	2.800	0.998	0.570	2.441	3.808	3.530
24288	SMRF	351.2	32	Inglewood 17 May 2009	Z-Direction	0.000	0.009	0.529	0.116	3.090	1.097	0.618	3.010	3.346	5.279
24288	SMRF	351.2	32	La Habra 28 Mar 2014	X-Direction	0.003	0.013	1.364	0.331	2.913	1.112	0.617	1.996	2.277	2.665
24288	SMRF	351.2	32	La Habra 28 Mar 2014	Z-Direction	0.002	0.017	1.936	0.510	3.292	1.140	0.670	3.101	2.100	2.345
24288	SMRF	351.2	32	Los Angeles Airport 25 Jul 2012	X-Direction	0.000	0.007	0.187	0.008	2.519	0.947	0.535	4.860	1.889	2.038
24288	SMRF	351.2	32	Los Angeles Airport 25 Jul 2012	Z-Direction	0.001	0.008	0.193	0.009		2.150	0.588		2.520	1.750
24288	SMRF	351.2	32	Whittier Narrows 16 Mar 2010	X-Direction	0.004	0.033	1.315	0.104	2.768	1.019	0.596	2.980	2.499	2.417
24288	SMRF	351.2	32	Whittier Narrows 16 Mar 2010	Z-Direction	0.009	0.029	0.894	0.039		1.005	0.602		1.322	3.610

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
24370	SMRF	62.5	6	Borrego Springs 07 Jul 2010	X-Direction	0.010	0.006	0.576	0.088	1.176	0.397		3.696	4.201	
24370	SMRF	62.5	6	Borrego Springs 07 Jul 2010	Z-Direction	0.011	0.006	0.424	0.076	1.150	0.390		5.200	5.540	
24370	SMRF	62.5	6	Calexico 04 Apr 2010	X-Direction	0.002	0.005	1.627	1.587	1.190	0.410		4.010	2.140	
24370	SMRF	62.5	6	Calexico 04 Apr 2010	Z-Direction	0.031	0.006	2.057	2.942	1.220	0.410		3.810	5.060	
24370	SMRF	62.5	6	Chatsworth 09 Aug 2007	Z-Direction	0.119	0.010	0.291	0.025	1.090	0.370	0.080	5.880	3.240	0.110
24370	SMRF	62.5	6	Chino Hills 29 July 2008	Z-Direction	0.036	0.028	2.611	0.453	1.300	0.430	0.094	3.600	4.040	0.250
24370	SMRF	62.5	6	Northridge 17 Jan 1994	Z-Direction	0.050	0.300	24.397	4.113	1.410	0.470		3.270	4.080	
24370	SMRF	62.5	6	Sierra Madre 28 Jun 1991	X-Direction	0.082	0.124	5.839	0.782	1.320	0.460	0.100	2.810	1.080	0.110
24370	SMRF	62.5	6	Sierra Madre 28 Jun 1991	Z-Direction	0.091	0.107	7.939	0.844	1.270	0.430	0.110	3.380	4.640	0.470
24370	SMRF	62.5	6	Whittier 01 Oct 1987	X-Direction	0.001	0.226	12.507	1.270	1.280	0.450	0.090	3.000	2.200	0.310
24370	SMRF	62.5	6	Whittier 01 Oct 1987	Z-Direction	0.001	0.169	9.737	1.196	1.260	0.430	0.090	3.490	3.450	0.390
24370	SMRF	62.5	6	Whittier Narrows 16 Mar 2010	X-Direction	0.006	0.009	0.252	0.014	1.100	0.370		4.010	4.450	
24370	SMRF	62.5	6	Whittier Narrows 16 Mar 2010	Z-Direction	0.004	0.009	0.358	0.020	1.140	0.390		5.720	5.660	
24566	SMRF	168	12	Calexico 04 Apr 2010	X-Direction	0.004	0.006	1.592	2.560	2.254	0.879		5.846	6.023	
24566	SMRF	168	12	Calexico 04 Apr 2010	Z-Direction	0.004	0.006	2.062	2.575	2.158	0.832		6.130	3.751	
24566	SMRF	168	12	Chino Hills 29 July 2008	X-Direction	0.000	0.061	5.286	0.631	2.402	0.944		4.011	4.384	
24566	SMRF	168	12	Chino Hills 29 July 2008	Z-Direction	0.001	0.066	3.457	0.364	2.201	0.828		5.551	2.625	
24566	SMRF	168	12	Encino 17 Mar 2014	X-Direction	0.015	0.015	0.636	0.045	2.049	0.838		3.416	6.203	
24566	SMRF	168	12	Encino 17 Mar 2014	Z-Direction	0.011	0.009	0.267	0.016	1.612	0.683		5.327	4.879	
24566	SMRF	168	12	Northridge 17 Jan 1994	X-Direction	0.000	0.234	16.536	1.542	2.517	1.026		2.723	3.691	
24566	SMRF	168	12	Northridge 17 Jan 1994	Z-Direction	0.002	0.135	8.901	1.043	2.462	0.967		5.532	3.658	
24566	SMRF	168	12	Whittier Narrows 16 Mar 2010	X-Direction	0.021	0.107	2.624	0.146	2.092	0.760		3.020	1.835	
24566	SMRF	168	12	Whittier Narrows 16 Mar 2010	Z-Direction	0.027	0.027	0.729	0.037	1.872	0.655		1.470	3.596	
24569	SMRF	274	2	Landers 28 Jun 1992	X-Direction	0.028	0.032	7.464	6.233	3.120	1.130	0.370	1.830	3.880	0.840
24569	SMRF	274	2	Landers 28 Jun 1992	Z-Direction	0.024	0.034	12.119	7.175	3.200	1.140	0.520	2.290	3.100	4.020
24569	SMRF	274	2	Northridge 17 Jan 1994	X-Direction	0.008	0.205	16.180	2.875	3.100	1.190		2.310	3.930	
24569	SMRF	274	2	Northridge 17 Jan 1994	Z-Direction	0.012	0.134	3.162	3.162	3.090	1.175		2.480	3.036	
24609	SMRF	78.5	5	Big Bear City 22 Feb 2003	X-Direction	0.022	0.008	0.350	0.057	0.650	0.270		4.560	2.600	
24609	SMRF	78.5	5	Big Bear City 22 Feb 2003	Z-Direction	0.015	0.008	0.407	0.037	0.670	0.280		5.960	3.050	
24609	SMRF	78.5	5	Calexico 04 Apr 2010	X-Direction	0.094	0.005	1.722	1.539	0.670	0.260		4.120	1.830	
24609	SMRF	78.5	5	Calexico 04 Apr 2010	Z-Direction	0.162	0.008	1.421	1.059	0.710	0.270		3.560	2.390	
24609	SMRF	78.5	5	Landers 28 Jun 1992	X-Direction	0.085	0.051	8.552	4.907	0.690	0.270		2.580	3.190	
24609	SMRF	78.5	5	Landers 28 Jun 1992	Z-Direction	0.110	0.081	10.150	4.990	0.720	0.300		5.560	2.200	
24609	SMRF	78.5	5	Northridge 17 Jan 1994	X-Direction	0.003	0.068	7.998	2.588	0.750	0.300		5.000	2.290	
24609	SMRF	78.5	5	Northridge 17 Jan 1994	Z-Direction	0.002	0.054	9.187	2.715	0.757	0.300		4.605	3.510	
24629	SMRF	761.5	57	Big Bear 28 Jun 1992	X-Direction	0.010	0.031	3.720	0.964	5.126	1.795	1.159	1.174	1.503	1.663
24629	SMRF	761.5	57	Big Bear 28 Jun 1992	Z-Direction	0.013	0.025	4.786	1.383	6.053	1.935	1.215	1.627	1.335	1.760
24629	SMRF	761.5	57	Calexico 04 Apr 2010	X-Direction	0.002	0.008	2.923	2.254	5.259	1.883	1.189	2.626	1.758	1.672
24629	SMRF	761.5	57	Calexico 04 Apr 2010	Z-Direction	0.001	0.008	3.818	4.184	5.687	2.016	1.186	1.326	1.546	0.906
24629	SMRF	761.5	57	Chino Hills 29 July 2008	X-Direction	0.022	0.059	3.819	0.405	5.210	1.860	1.190	1.110	2.300	1.650
24629	SMRF	761.5	57	Chino Hills 29 July 2008	Z-Direction	0.022	0.055	4.857	0.951	5.717	2.042	1.219	4.828	1.723	1.132
24629	SMRF	761.5	57	Hector Mine 16 Oct 1999	X-Direction	0.002	0.017	4.859	4.646	5.308	1.908	1.221	2.086	1.400	1.338
24629	SMRF	761.5	57	Hector Mine 16 Oct 1999	Z-Direction	0.001	0.018	3.176	2.588	5.348	1.933	1.208	1.524	1.479	0.833
24629	SMRF	761.5	57	La Habra 28 Mar 2014	X-Direction	0.023	0.012	1.200	0.332	5.158	1.871	1.165	0.824	1.587	2.252
24629	SMRF	761.5	57	La Habra 28 Mar 2014	Z-Direction	0.010	0.020	1.722	0.449	5.993	2.019	1.197	1.354	2.246	2.331
24629	SMRF	761.5	57	Landers 28 Jun 1992	X-Direction	0.011	0.034	8.663	7.697	5.988	1.768	1.157	1.250	1.759	2.090
24629	SMRF	761.5	57	Landers 28 Jun 1992	Z-Direction	0.008	0.038	6.074	6.626	6.048	1.898	1.145	1.633	1.501	1.860
24629	SMRF	761.5	57	Northridge 17 Jan 1994	X-Direction	0.033	0.093	8.410	3.090	5.200	1.903	1.198	1.112	1.378	1.848
24629	SMRF	761.5	57	Northridge 17 Jan 1994	Z-Direction	0.013	0.136	9.768	2.882	6.173	2.023	1.206	1.289	1.397	1.809
54388	SMRF	26	2	Tonopah Jnctn 12 Feb 2013	X-Direction	0.013	0.007	0.383	0.044	0.280	0.144		3.200	1.220	
54388	SMRF	26	2	Tonopah Jnctn 12 Feb 2013	Z-Direction	0.015	0.006	0.383	0.044	0.276	0.133		7.925	3.157	
54388	SMRF	26	2	Qualeys Camp 18 Sep 2004	X-Direction	0.013	0.006	0.483	0.128	0.232	0.084		2.772	0.370	
54388	SMRF	26	2	Qualeys Camp 18 Sep 2004	Z-Direction	0.013	0.004	0.438	0.152	0.262	0.080		4.588	0.575	
57357	SMRF	210.6	12	Alum Rock 30 Oct 2007	X-Direction	0.154	0.090	4.088	0.346	1.984	0.685	0.405	3.999	4.389	2.351
57357	SMRF	210.6	12	Alum Rock 30 Oct 2007	Z-Direction	0.181	0.046	4.274	0.966	2.011	0.667	0.354	5.420	3.459	1.563
57357	SMRF	210.6	12	Loma Prieta 17 Oct 1989	X-Direction	0.001	0.084	22.481	9.136	2.020	0.660	0.402	5.072	1.374	1.218
57357	SMRF	210.6	12	Loma Prieta 17 Oct 1989	Z-Direction	0.001	0.098	17.599	7.089	2.120	0.719	0.451	5.918	2.407	2.048
57357	SMRF	210.6	12	Milpitas 07 Jan 2010	X-Direction	0.001	0.006	0.293	0.039	1.864	0.603	0.380	4.048	5.925	4.186
57357	SMRF	210.6	12	Milpitas 07 Jan 2010	Z-Direction	0.001	0.007	0.275	0.035	1.811	0.608	0.339	6.162	3.889	0.810
57357	SMRF	210.6	12	Morgan Hill 07 Jan 2011	X-Direction	0.057	0.007	0.446	0.042	1.749	0.598	0.379	3.469	1.902	3.012
57357	SMRF	210.6	12	Morgan Hill 07 Jan 2011	Z-Direction	0.074	0.004	0.399	0.039	1.808	0.619	0.353	4.598	3.172	2.365
57357	SMRF	210.6	12	Morgan Hill 24 Apr 1984	X-Direction	0.078	0.040	9.002	2.294	2.141	0.712	0.417	2.364	2.354	0.910
57357	SMRF	210.6	12	Morgan Hill 24 Apr 1984	Z-Direction	0.086	0.036	7.426	3.179	1.930	0.683	0.403	1.151	2.201	1.866

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
57357	SMRF	210.6	12	Mt. Lewis 31 Mar 86	X-Direction	0.034	0.028	7.306	2.268	1.866	0.715	0.424	4.019	1.315	1.629
57357	SMRF	210.6	12	Mt. Lewis 31 Mar 86	Z-Direction	0.022	0.045	7.793	2.249	1.958	0.706	0.419	1.559	0.937	0.590
57562	SMRF	49.5	3	Alum Rock 30 Oct 2007	X-Direction	0.404	0.027	1.372	0.175	0.497	0.142		3.838	1.901	
57562	SMRF	49.5	3	Alum Rock 30 Oct 2007	Z-Direction	0.293	0.028	1.282	0.174	0.658	0.221		3.613	5.478	
57562	SMRF	49.5	3	Loma Prieta 17 Oct 1989	X-Direction	0.394	0.195	15.426	3.260	0.682	0.205		5.011	1.464	
57562	SMRF	49.5	3	Loma Prieta 17 Oct 1989	Z-Direction	0.664	0.158	18.936	6.649	0.714	0.241		4.408	5.746	
58261	SMRF	52.5	4	Loma Prieta 17 Oct 1989	X-Direction	0.068	0.138	20.571	4.059	0.700	0.240		3.570	0.970	
58261	SMRF	52.5	4	Loma Prieta 17 Oct 1989	Z-Direction	0.094	0.155	22.206	5.392	0.670	0.200		3.090	0.550	
58261	SMRF	52.5	4	Morgan Hill 24 Apr 1984	X-Direction	0.051	0.023	2.887	0.418	0.560	0.190		2.770	0.760	
58261	SMRF	52.5	4	Morgan Hill 24 Apr 1984	Z-Direction	0.080	0.028	3.422	0.715	0.570	0.190		3.050	0.490	
58261	SMRF	52.5	4	South Napa 24 Aug 2014	X-Direction	0.007	0.021	1.733	0.207	0.613	0.212		3.761	1.261	
58261	SMRF	52.5	4	South Napa 24 Aug 2014	Z-Direction	0.014	0.028	2.280	0.383	0.595	0.188		3.096	0.533	
58506	SMRF	46.2	3	Alum Rock 30 Oct 2007	X-Direction	0.012	0.005	0.618	0.105	0.517	0.169	0.092	4.696	0.936	0.554
58506	SMRF	46.2	3	Alum Rock 30 Oct 2007	Z-Direction	0.005	0.005	0.357	0.089	0.535	0.196	0.093	3.553	2.323	0.303
58506	SMRF	46.2	3	Lafayette 01 Mar 2007	X-Direction	0.225	0.008	0.358	0.031	0.491	0.166	0.093	3.596	1.213	0.506
58506	SMRF	46.2	3	Lafayette 01 Mar 2007	Z-Direction	0.273	0.007	0.372	0.029	0.556	0.195	0.099	2.716	3.081	0.319
58506	SMRF	46.2	3	Loma Prieta 17 Oct 1989	X-Direction	0.020	0.083	12.921	3.215	0.640	0.220	0.140	6.440	1.330	0.300
58506	SMRF	46.2	3	Loma Prieta 17 Oct 1989	Z-Direction	0.023	0.110	20.349	4.730	0.702	0.256	0.103	2.037	1.764	0.171
58506	SMRF	46.2	3	Piedmont 20 Jul 2007	X-Direction	0.005	0.013	0.769	0.085	0.541	0.165	0.111	5.220	0.936	1.270
58506	SMRF	46.2	3	Piedmont 20 Jul 2007	Z-Direction	0.008	0.015	0.916	0.089	0.621	0.209	0.095	3.635	1.174	1.108
58506	SMRF	46.2	3	Piedmont Area 20 Dec 2006	X-Direction	0.051	0.005	0.196	0.012	0.474	0.197	0.101	2.513	0.764	0.853
58506	SMRF	46.2	3	Piedmont Area 20 Dec 2006	Z-Direction	0.044	0.006	0.360	0.024	0.549	0.200	0.096	3.560	3.640	0.390
58506	SMRF	46.2	3	South Napa 24 Aug 2014	X-Direction	0.013	0.041	2.811	1.330	0.608	0.205	0.133	4.270	3.452	0.458
58506	SMRF	46.2	3	South Napa 24 Aug 2014	Z-Direction	0.008	0.037	2.574	0.820	0.647	0.223	0.101	4.706	2.783	0.434
58532	SMRF	600	47	Loma Prieta 17 Oct 1989	X-Direction	0.001	0.011	24.404	7.707	6.230	2.190	1.030	2.120	2.870	1.340
58532	SMRF	600	47	Loma Prieta 17 Oct 1989	Z-Direction		0.107	13.974	3.364	5.260	1.750	0.400	1.260	1.790	1.140
58532	SMRF	600	47	South Napa 24 Aug 2014	X-Direction	0.002	0.158	1.103	0.411	5.590	1.940	0.650	3.040	4.400	2.750
58532	SMRF	600	47	South Napa 24 Aug 2014	Z-Direction		0.007	1.148	0.239	4.900	1.610	0.600	2.080	2.500	0.900
58755	SMRF	92.5	6	Alum Rock 30 Oct 2007	X-Direction	0.004	0.004	0.194	0.036	0.650	0.240	0.150	7.330	7.200	3.130
58755	SMRF	92.5	6	Alum Rock 30 Oct 2007	Z-Direction	0.007	0.005	0.502	0.079	0.620	0.240	0.160	1.990	1.240	1.710
58755	SMRF	92.5	6	Bolinas 18 Aug 1999	X-Direction	0.018	0.082	2.566	0.228	0.759	0.264	0.170	6.252	4.620	2.340
58755	SMRF	92.5	6	Bolinas 18 Aug 1999	Z-Direction	0.021	0.107	3.562	0.175	0.661	0.278	0.184	4.310	3.748	4.352
68669	SMRF	67.9	4	Bolinas 18 Aug 1999	X-Direction	0.033	0.010	0.683	0.072	0.504	0.200	0.156	4.293	1.338	0.595
68669	SMRF	67.9	4	Bolinas 18 Aug 1999	Z-Direction	0.052	0.012	2.338	0.213	0.427	0.149	0.126	1.887	0.778	1.487
68669	SMRF	67.9	4	Santa Rosa 25 May 2003	X-Direction	0.156	0.112	6.900	0.903	0.591	0.245	0.182	2.933	1.212	0.949
68669	SMRF	67.9	4	Santa Rosa 25 May 2003	Z-Direction	0.113	0.117	5.286	0.385	0.518	0.168	0.122	1.919	1.919	1.535
68669	SMRF	67.9	4	South Napa 24 Aug 2014	X-Direction	0.045	0.036	5.672	2.574	0.517	0.195	0.159	4.813	5.224	0.479
68669	SMRF	67.9	4	South Napa 24 Aug 2014	Z-Direction	0.055	0.026	6.475	2.845	0.497	0.149	0.129	4.350	0.983	1.067
24541	URM	82.1	7	Encino 17 Mar 2014	X-Direction	0.004	0.008	0.347	0.029	0.809	0.266		7.271	2.395	
24541	URM	82.1	7	Encino 17 Mar 2014	Z-Direction	0.001	0.008	0.217	0.016	1.281	0.356		6.163	2.810	
24541	URM	82.1	7	Landers 28 Jun 1992	X-Direction	0.100	0.034	5.374	1.231	1.178	0.335		3.610	0.496	
24541	URM	82.1	7	Landers 28 Jun 1992	Z-Direction	0.097	0.031	4.717	1.117	1.200	0.372		3.527	0.923	
24541	URM	82.1	7	Northridge 17 Jan 1994	X-Direction	0.057	0.151	9.913	0.959	1.277	0.410		7.163	0.937	
24541	URM	82.1	7	Northridge 17 Jan 1994	Z-Direction	0.020	0.098	7.157	1.224	2.165	0.535		7.190	5.100	
24541	URM	82.1	7	Sierra Madre 28 Jun 1991	X-Direction	0.021	0.187	15.331	1.381	1.939	0.403		6.508	2.241	
24541	URM	82.1	7	Sierra Madre 28 Jun 1991	Z-Direction	0.016	0.123	7.280	0.679	1.908	0.410		4.803	2.150	
12759	WOOD	24	1	Anza 11 March 2013	X-Direction	0.172	0.035	1.496	0.211	0.135	0.038		2.150	0.053	
12759	WOOD	24	1	Anza 11 March 2013	Z-Direction	0.068	0.038	1.224	0.163	0.152	0.046		2.937	0.480	
12759	WOOD	24	1	Bombay Beach 24 Mar 2009	X-Direction	0.022	0.007	0.182	0.028	0.152	0.038		2.937	0.061	
12759	WOOD	24	1	Bombay Beach 24 Mar 2009	Z-Direction	0.018	0.007	0.314	0.032	0.140	0.038		1.474	0.254	
12759	WOOD	24	1	Borrego Springs 07 Jul 2010	X-Direction	0.225	0.077	3.978	0.857	0.160	0.056		1.541	0.230	
12759	WOOD	24	1	Borrego Springs 07 Jul 2010	Z-Direction	0.179	0.055	4.904	0.713	0.153			2.659		
12759	WOOD	24	1	Idyllwild 28 Oct 2012	X-Direction	0.020	0.007	0.136	0.007	0.116			2.553		
12759	WOOD	24	1	Idyllwild 28 Oct 2012	Z-Direction	0.021	0.009	0.155	0.013	0.150	0.047		1.582	0.223	
12759	WOOD	24	1	Indio 01 Jun 2007	X-Direction	0.016	0.011	0.276	0.018	0.132	0.042		3.030	0.080	
12759	WOOD	24	1	Indio 01 Jun 2007	Z-Direction	0.010	0.007	0.260	0.019	0.140	0.048		2.100	0.480	
12759	WOOD	24	1	San Bernardino 08 Jan 2009	X-Direction	0.025	0.008	0.457	0.032	0.129	0.048		4.128	0.400	
12759	WOOD	24	1	San Bernardino 08 Jan 2009	Z-Direction	0.019	0.007	0.296	0.035	0.140	0.050		3.070	0.780	
36531	WOOD	32.2	1	Coalinga 08 Aug 2014	X-Direction	0.015	0.005	0.197	0.009	0.128	0.049		2.967	0.173	
36531	WOOD	32.2	1	New Idria 20 Oct 2012	X-Direction	0.015	0.011	1.264	0.239	0.125	0.051		3.680	0.418	
36531	WOOD	32.2	1	Parkfield 06 Aug 2012	X-Direction	0.066	0.020	1.032	0.139	0.135	0.053		0.933	0.464	
36531	WOOD	32.2	1	Parkfield 07 Apr 2010	X-Direction	0.030	0.015	0.702	0.054	0.132	0.049		0.738	0.433	
36531	WOOD	32.2	1	Parkfield 22 May 2007	X-Direction	0.053	0.012	0.498	0.045	0.141	0.052		5.328	0.679	

Building Station	Building Type	Building Height	Number of Stories	EQ	Direction	SA	PGA	PGV	PGD	T_1	T_2	T_3	ζ_1	ζ_2	ζ_3
36531	WOOD	32.2	1	Parkfield 28 Sep 2004	X-Direction	0.332	0.234	33.742	9.391	0.116			0.510		

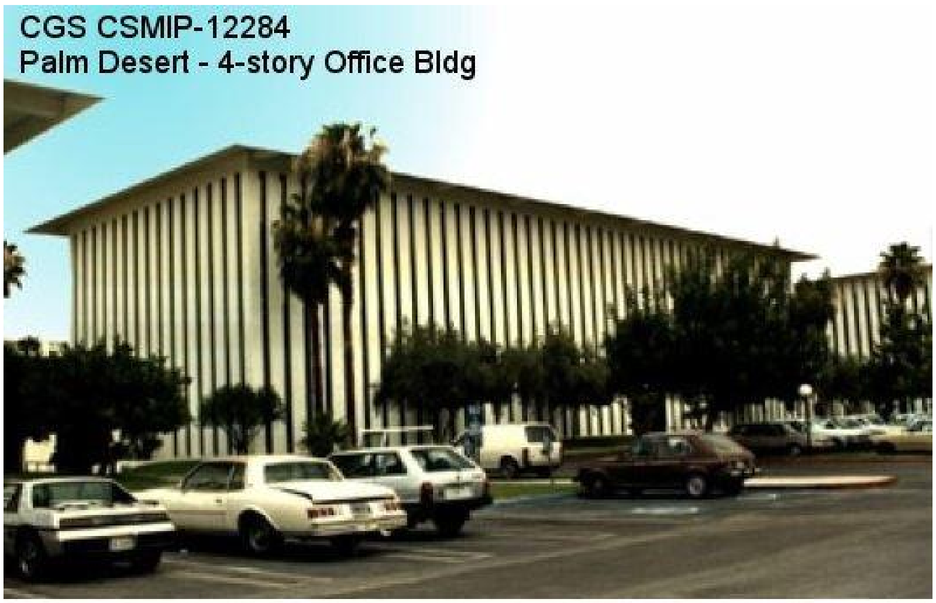
APPENDIX B: ETABS MODELS

Station 12284

Building: Palm Desert - 4-story Office Bldg

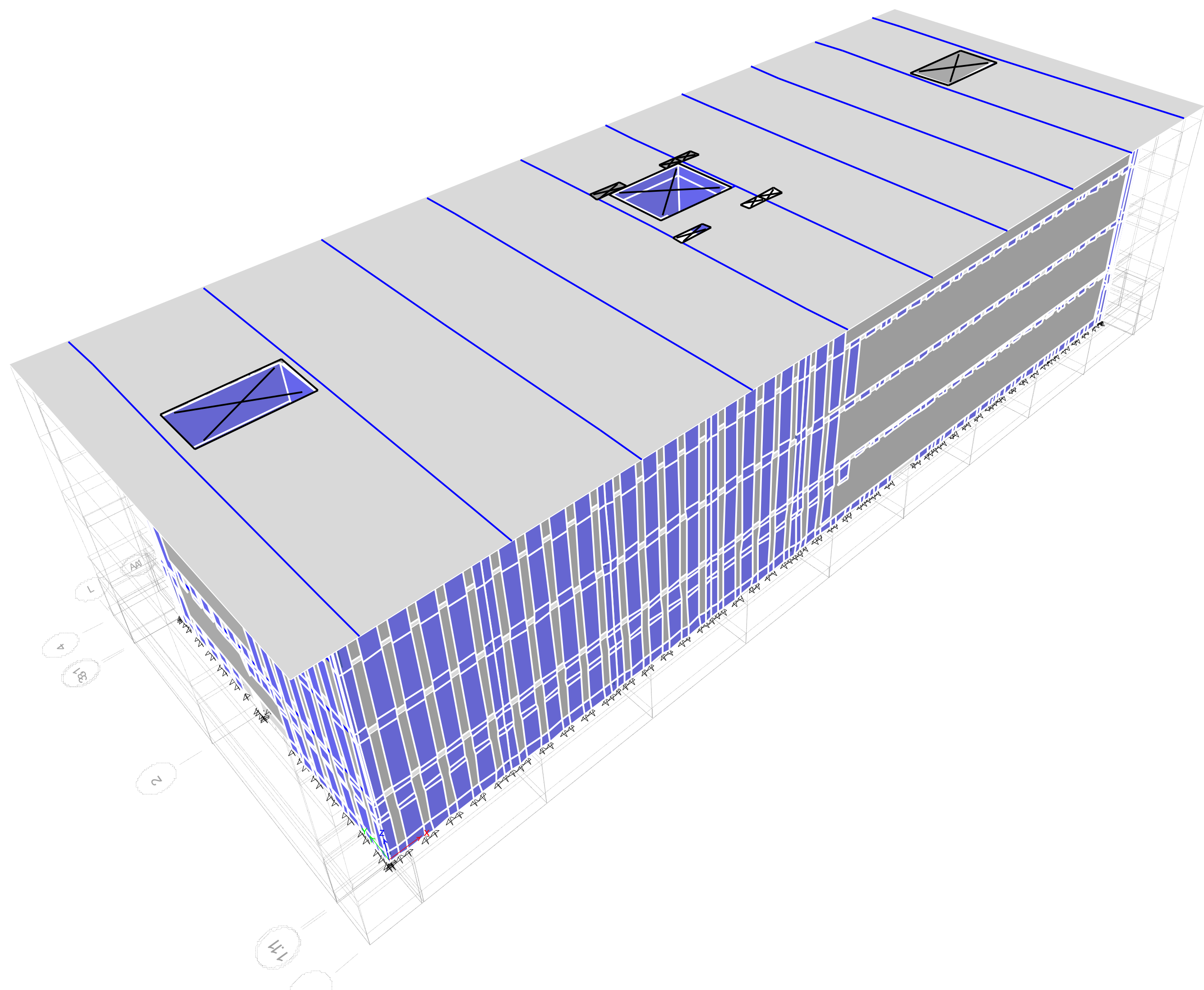
Building Type: Precast element system in conjunction with RC walls around elevator near center of plan and around stairs at each end wall.

Number of floors with Sensors: 3

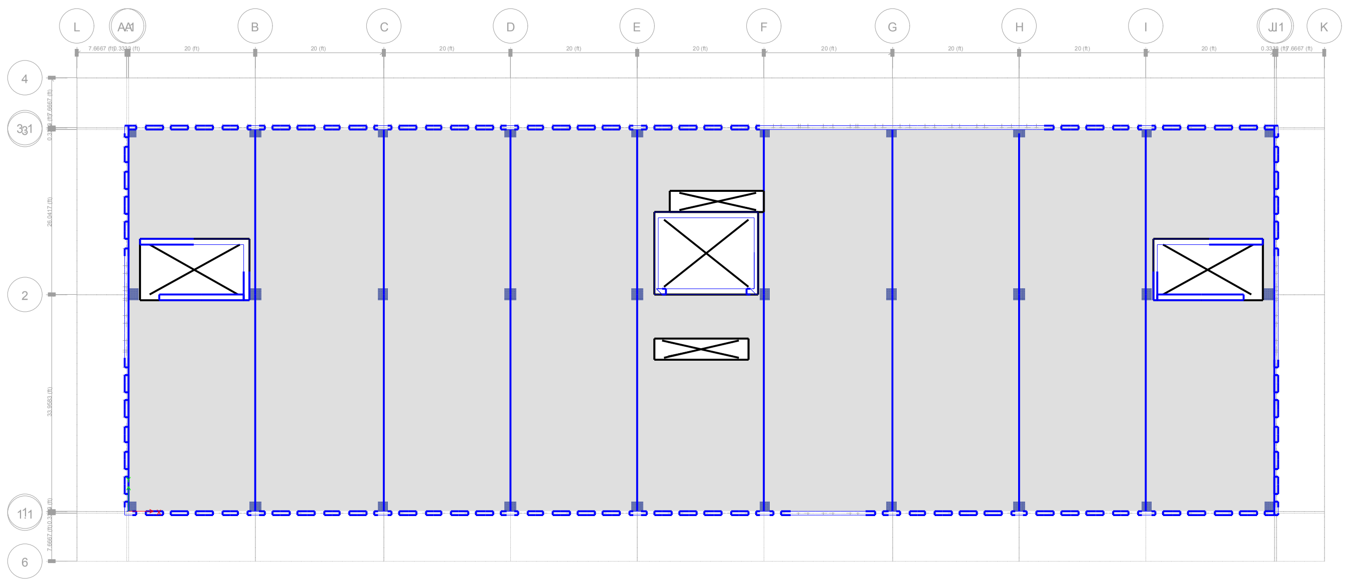


ETABS 2013 13.2.2

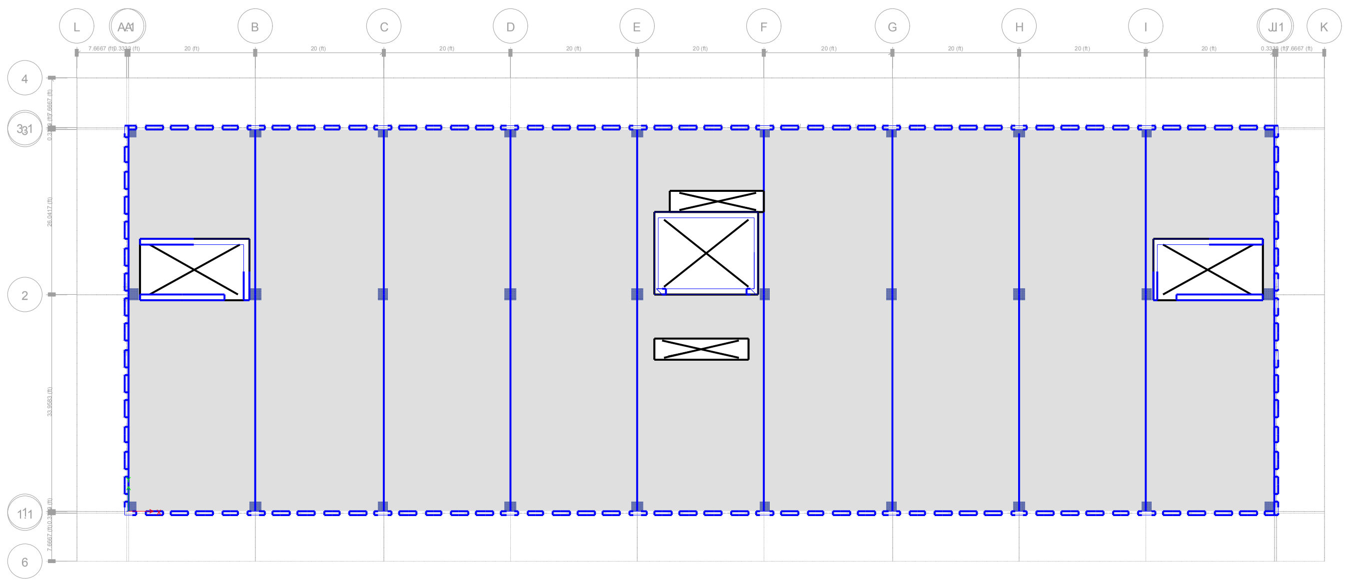
6/23/2015



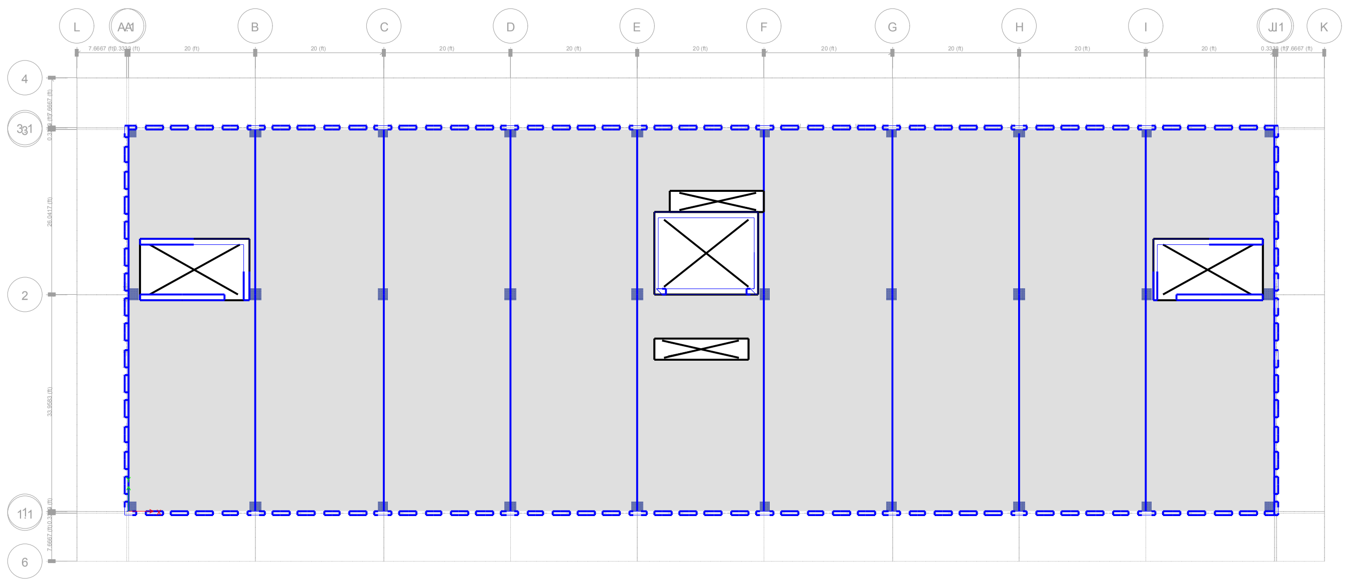
Station 12248: Palm Desert 4-Story Office Building



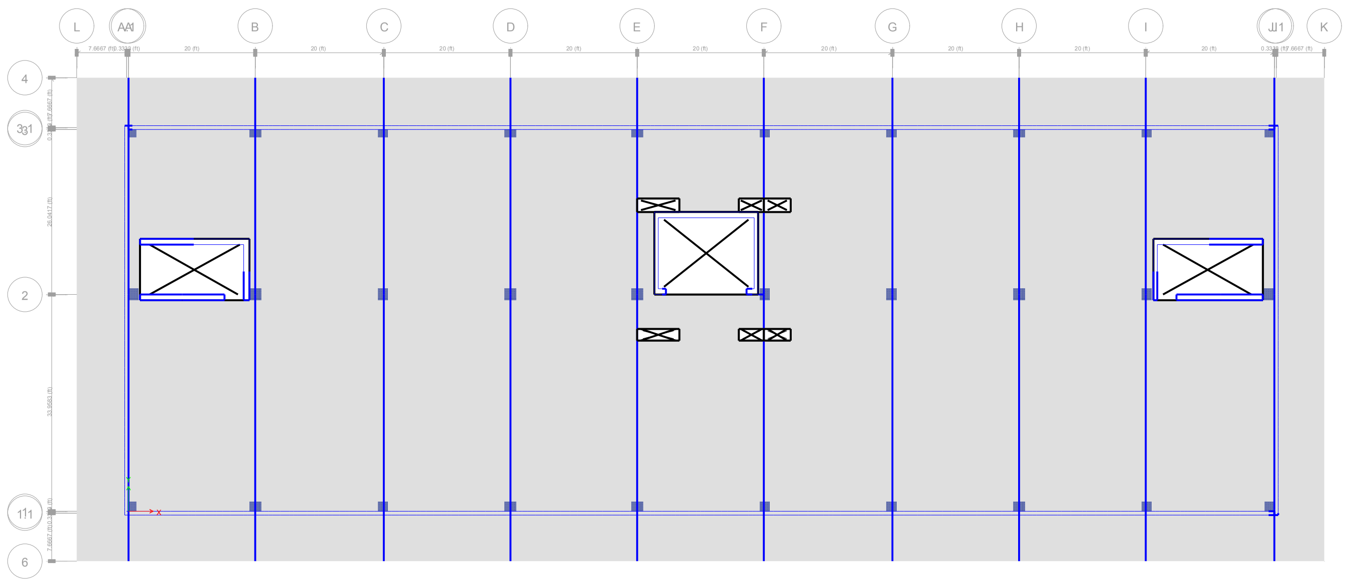
Plan View - Story 1



Plan View - Story 2



Plan View - Story 3



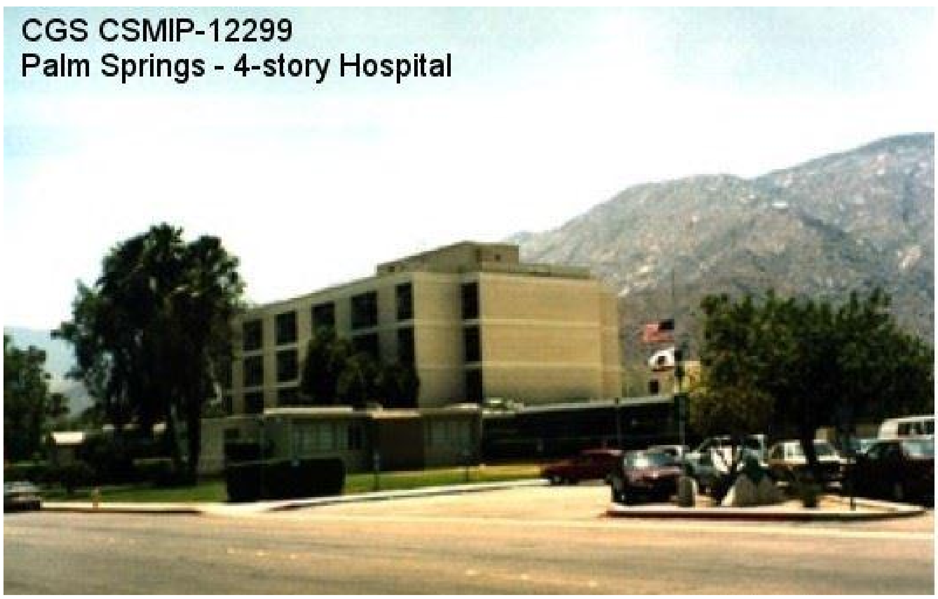
Plan View - Story 4

Station 12299

Building: Palm Springs - 4-story Hospital

Building Type: Steel moment frames

Number of floors with Sensors: 4



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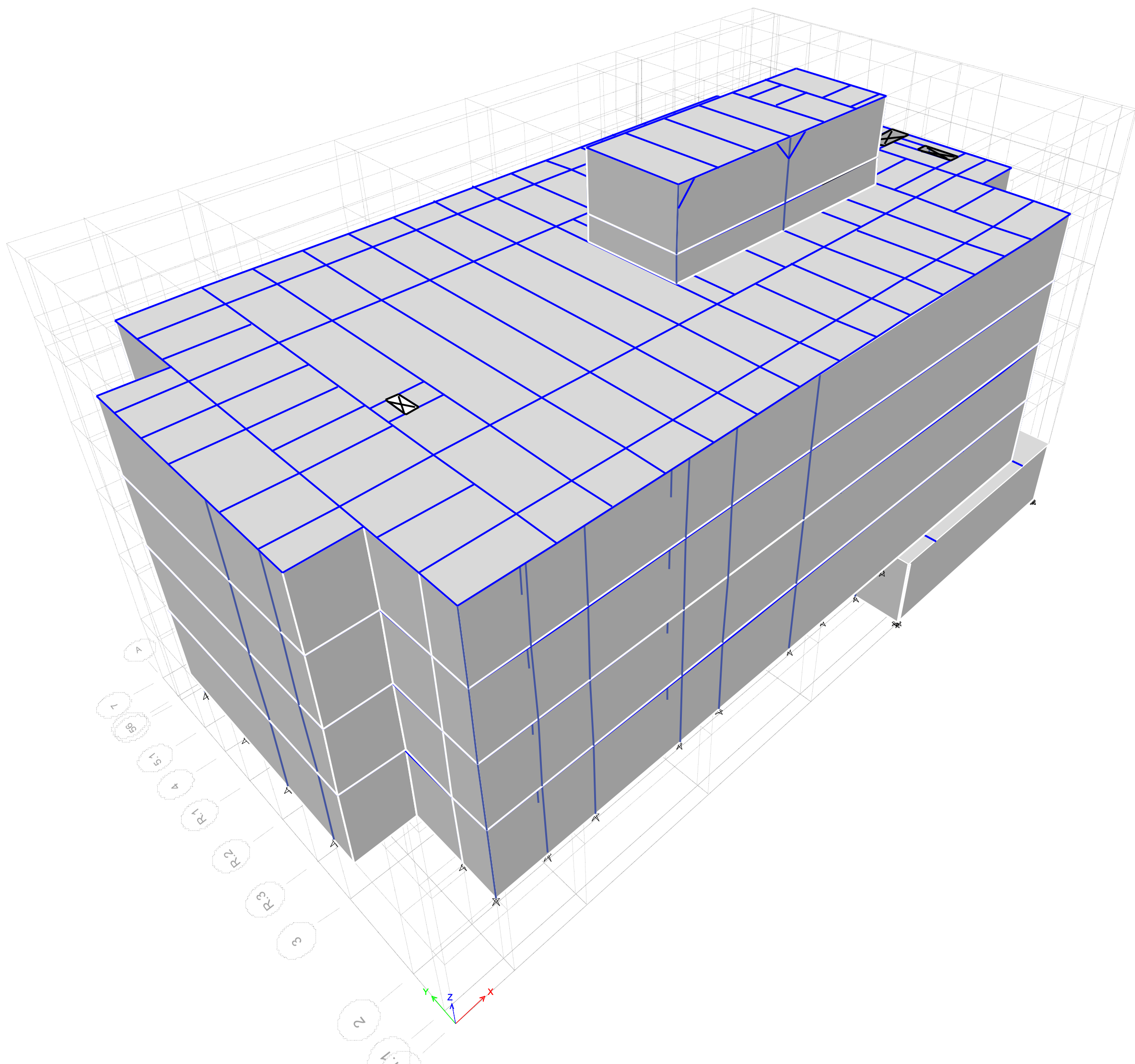
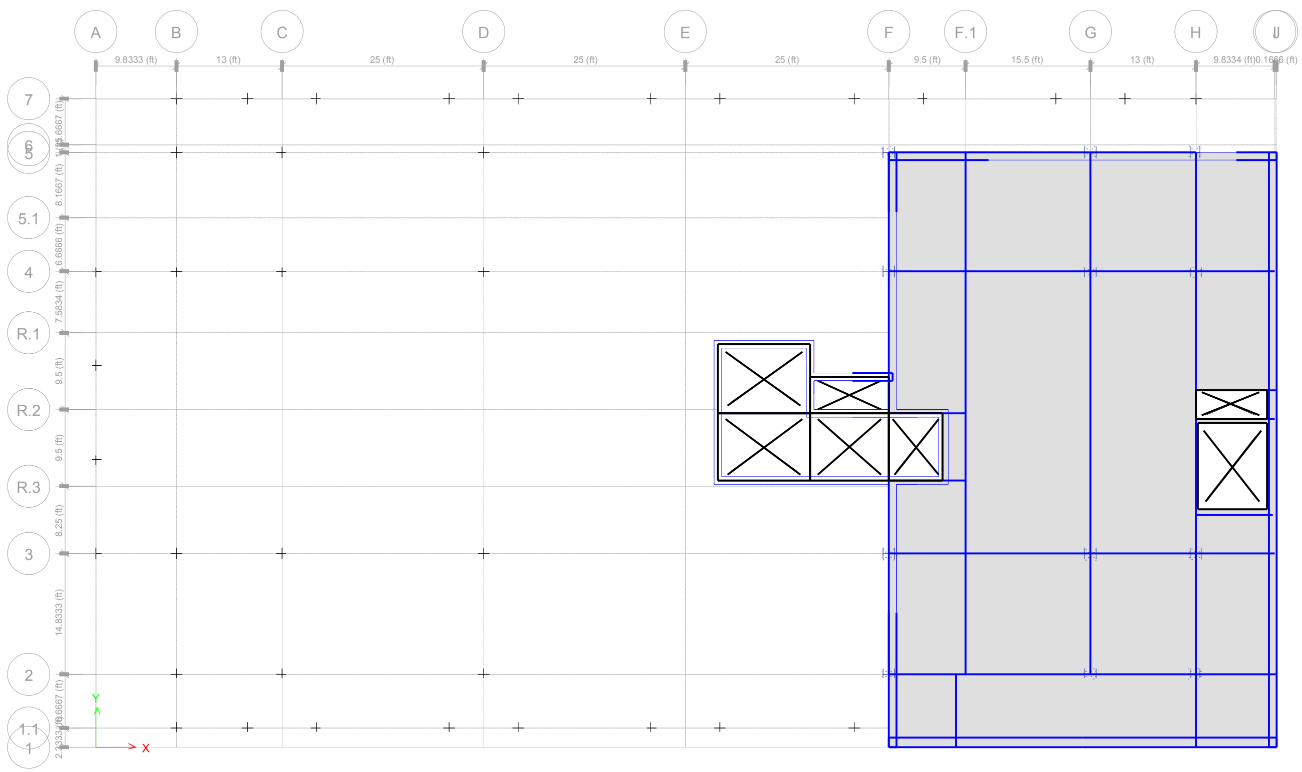
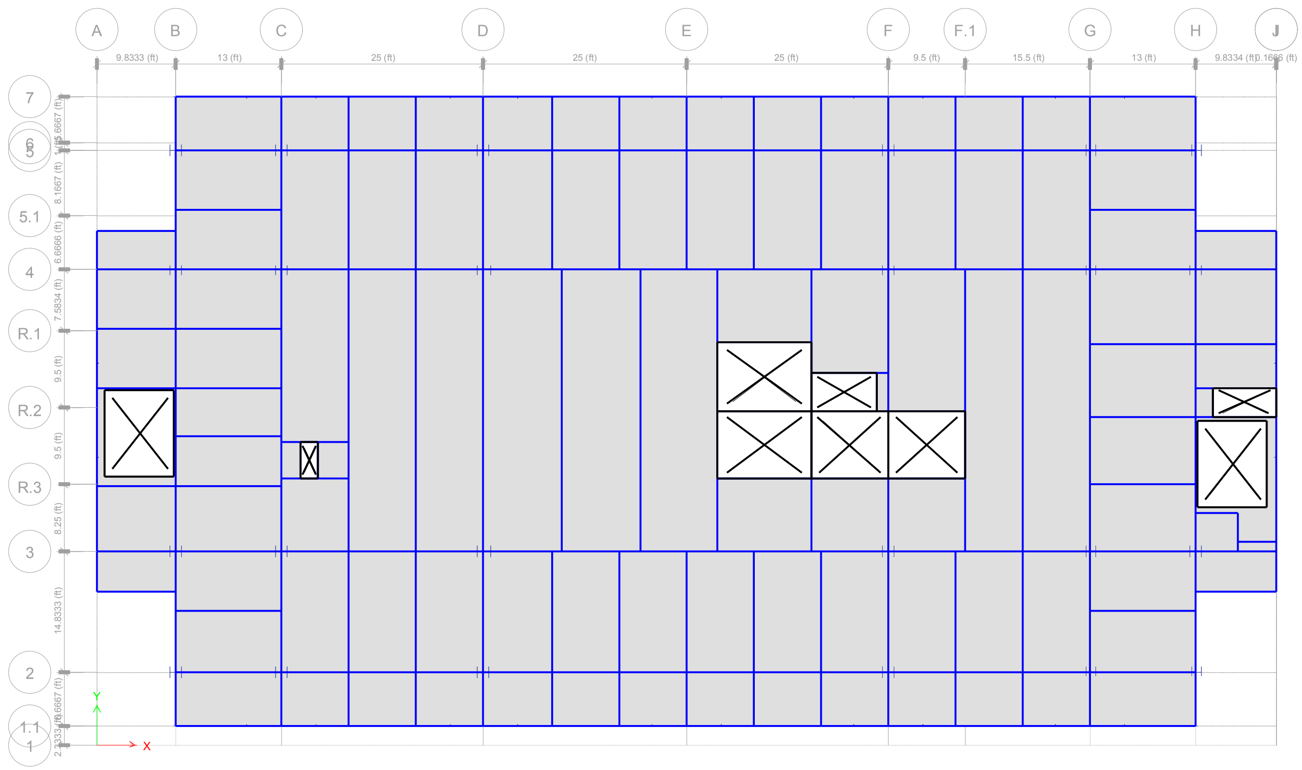


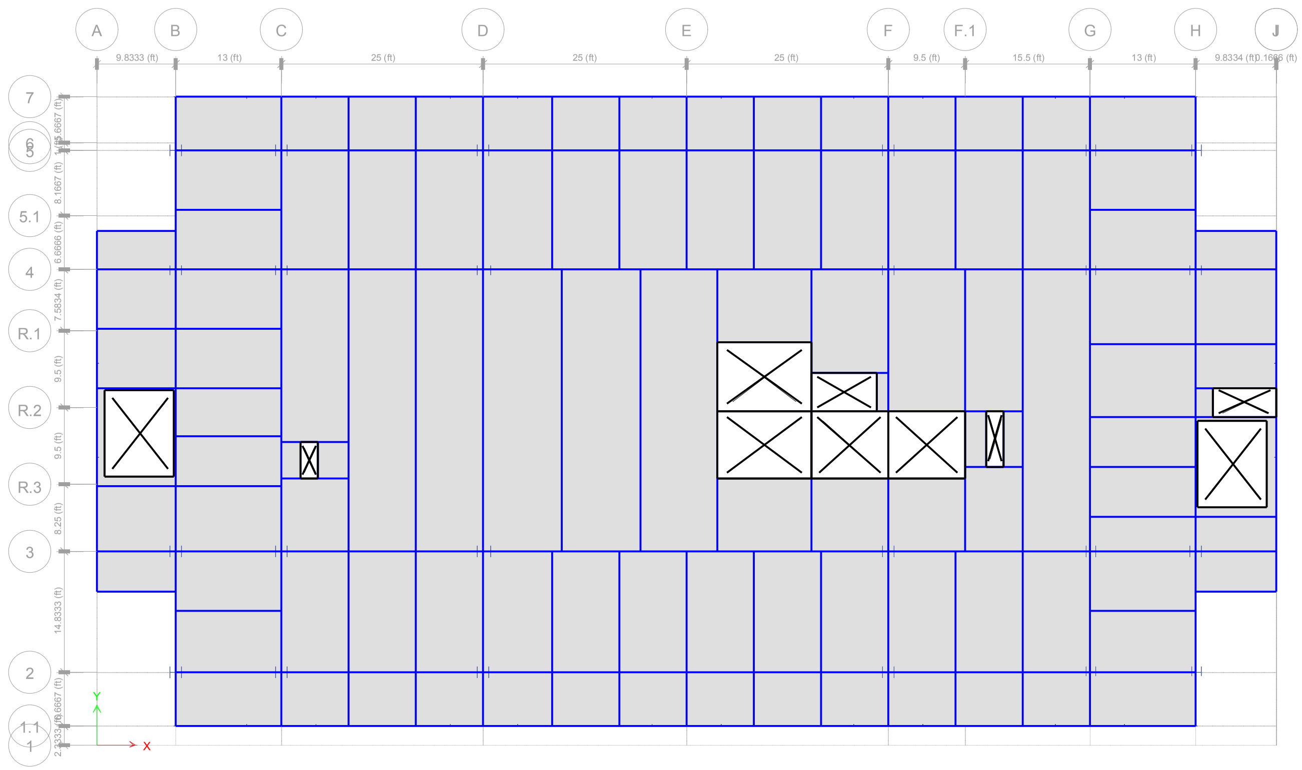
Station 12299: Palm Springs 4-Story Hospital



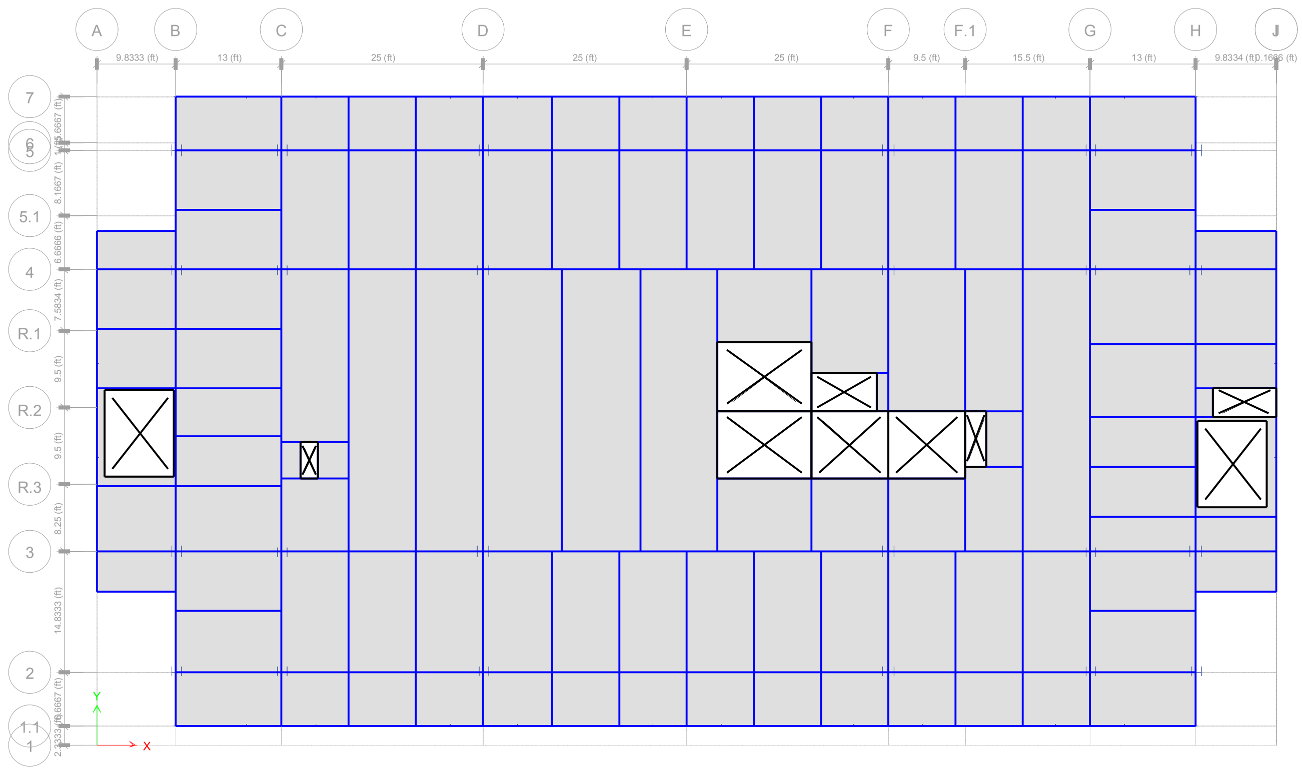
Plan View - Story 1



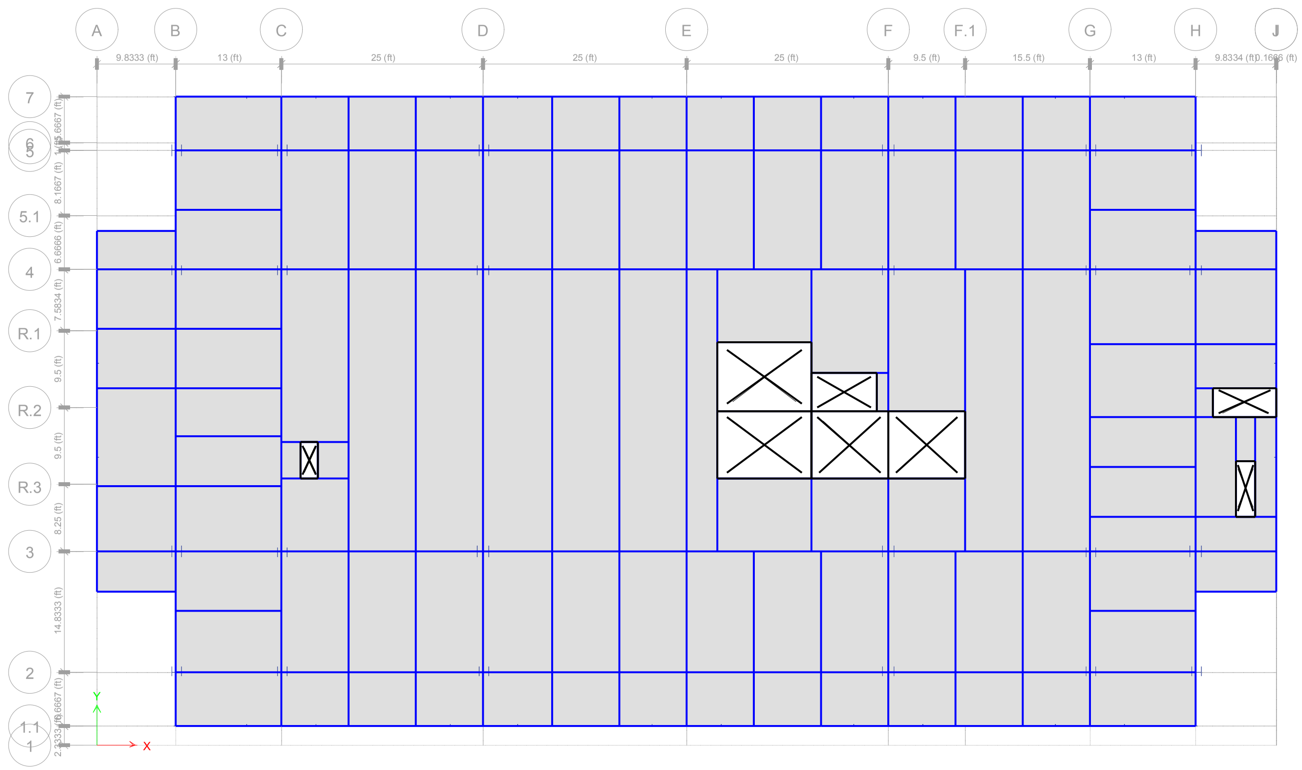
Plan View - Story 2



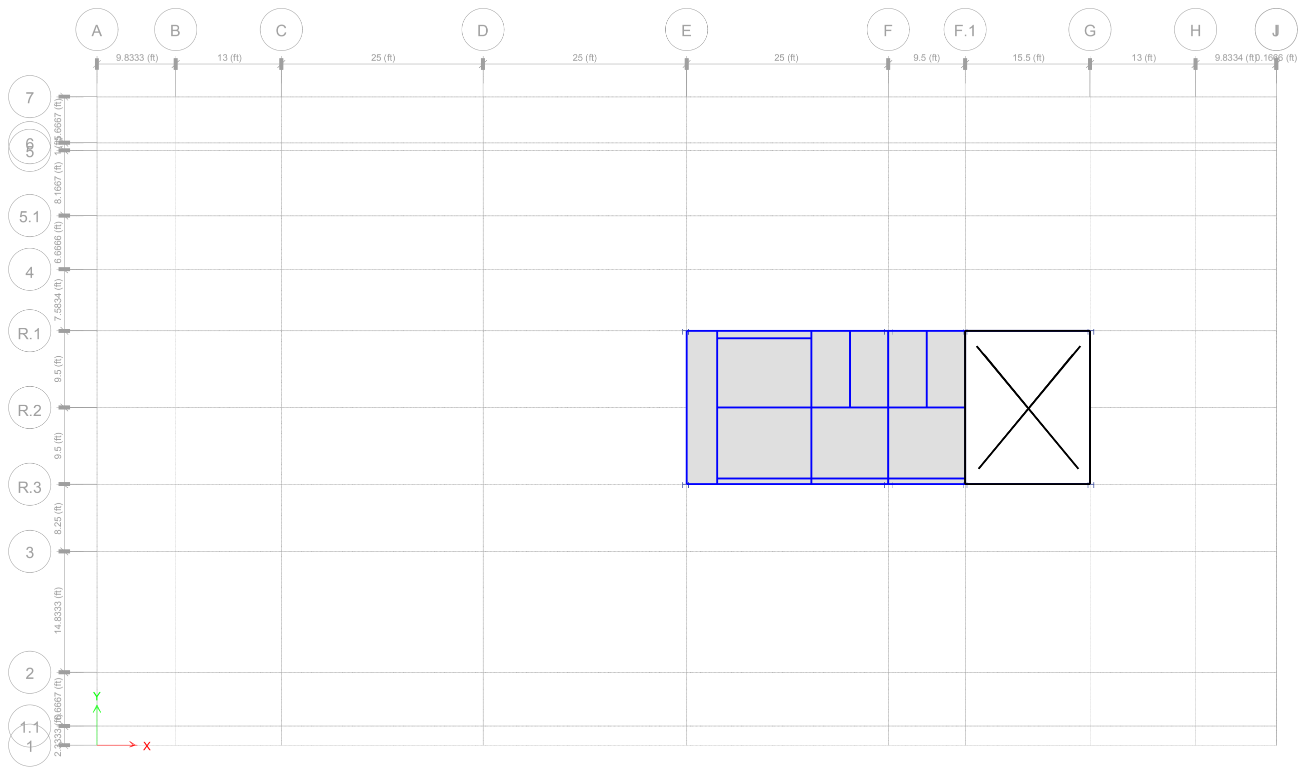
Plan View - Story 3



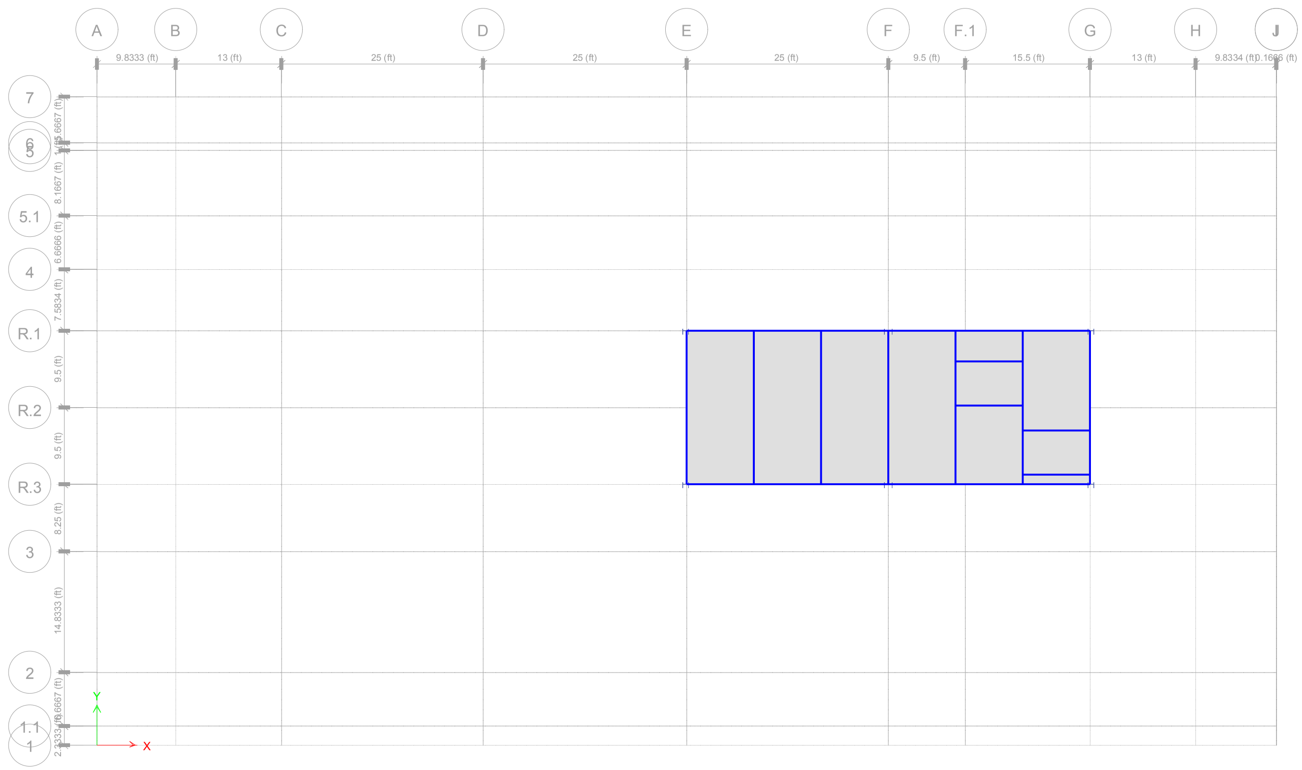
Plan View - Story 4



Plan View - Roof



Plan View - Mechanical Room



Plan View - Penthouse

Station 23287

Building: San Bernardino - 6-story Hotel

Building Type: San Bernardino - 6-story Hotel

Number of floors with Sensors: 3

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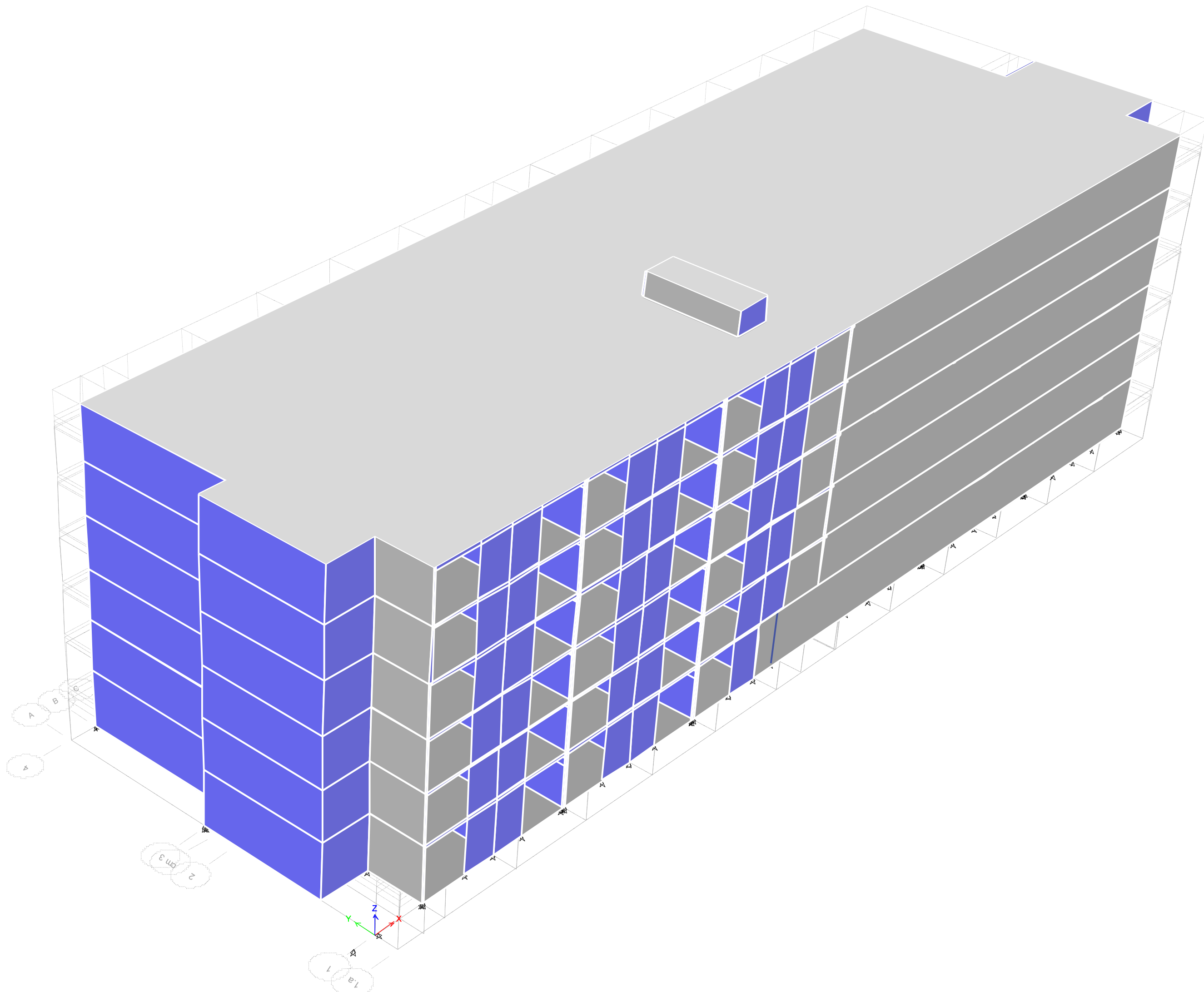
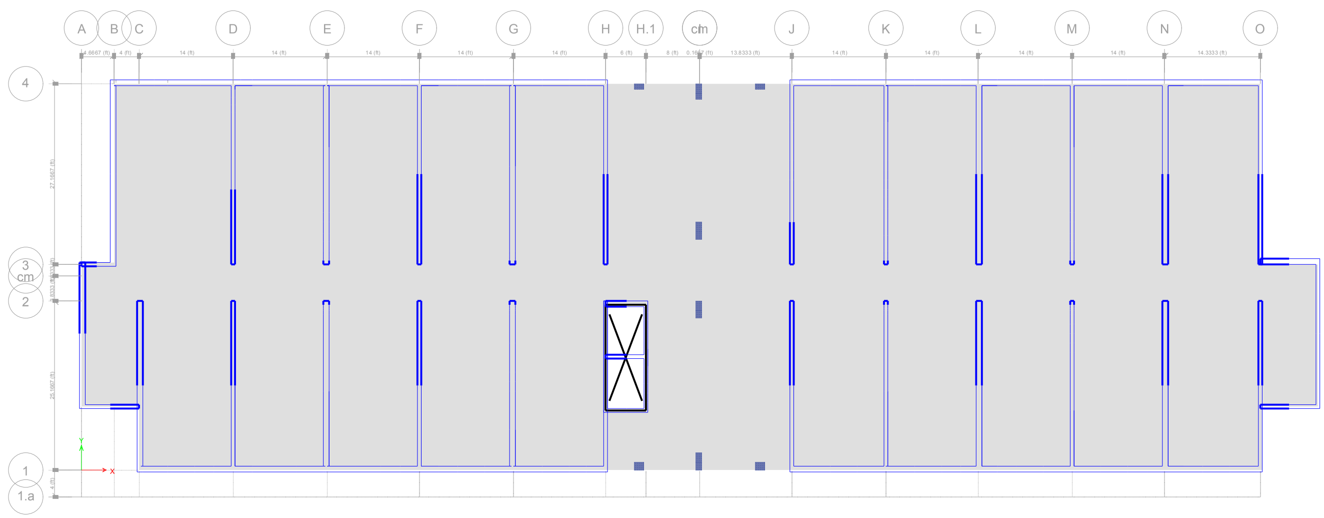
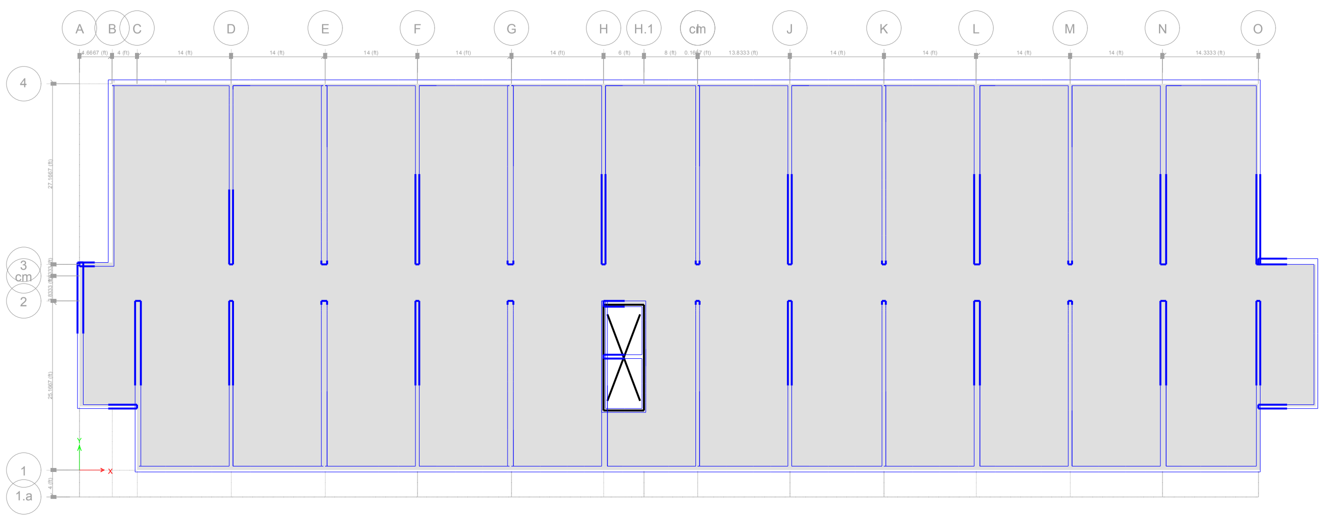


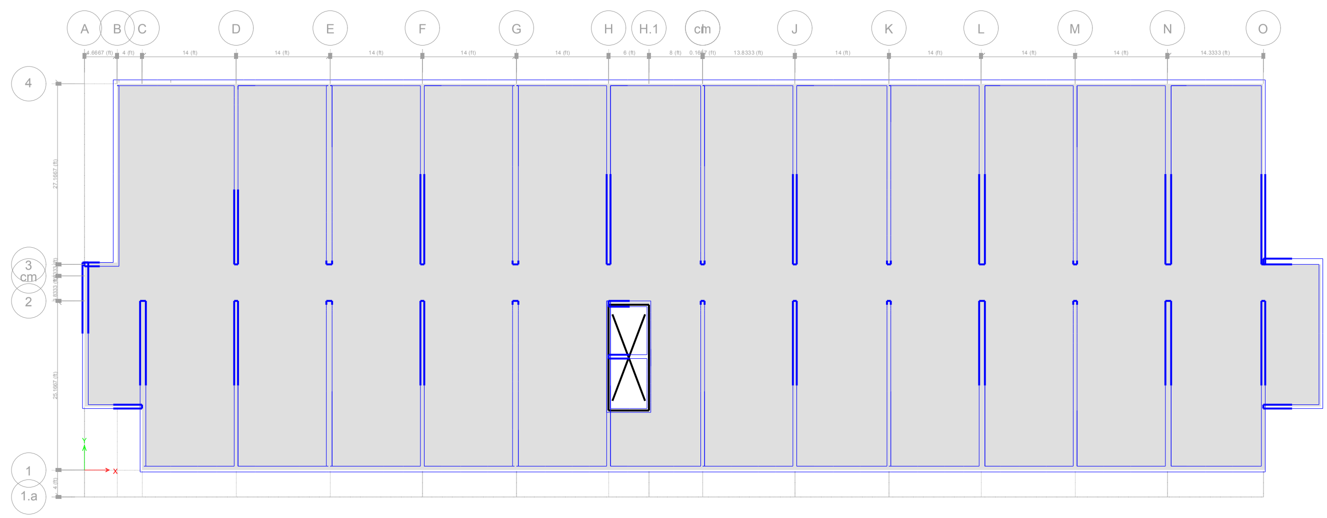
Station 23287: San Bernardino 6-Story Hotel



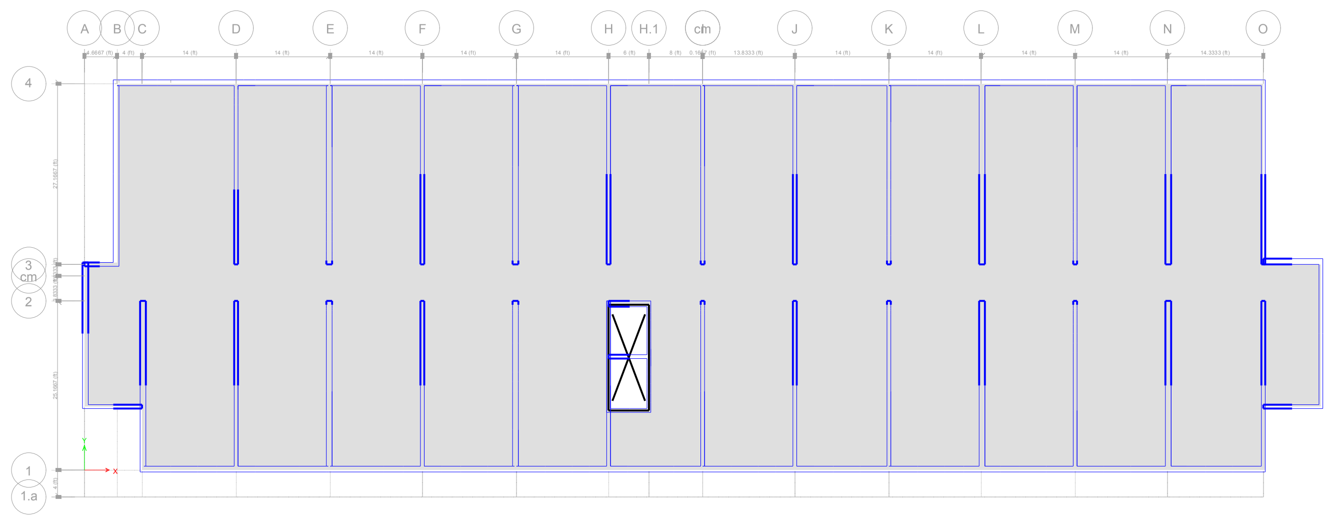
Plan View - Story 1



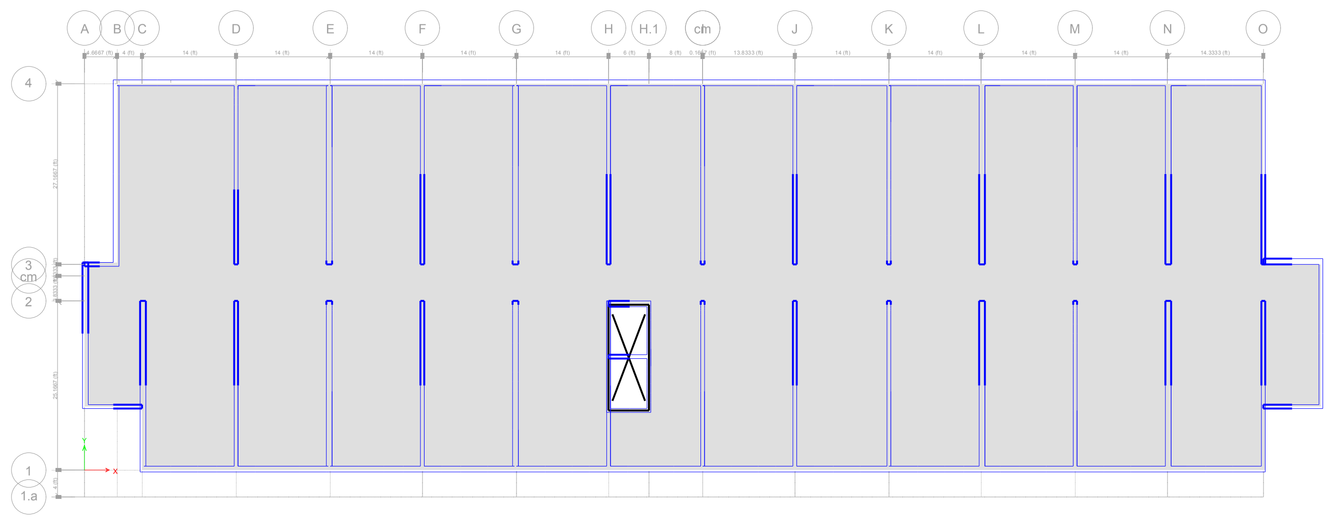
Plan View - Story 2



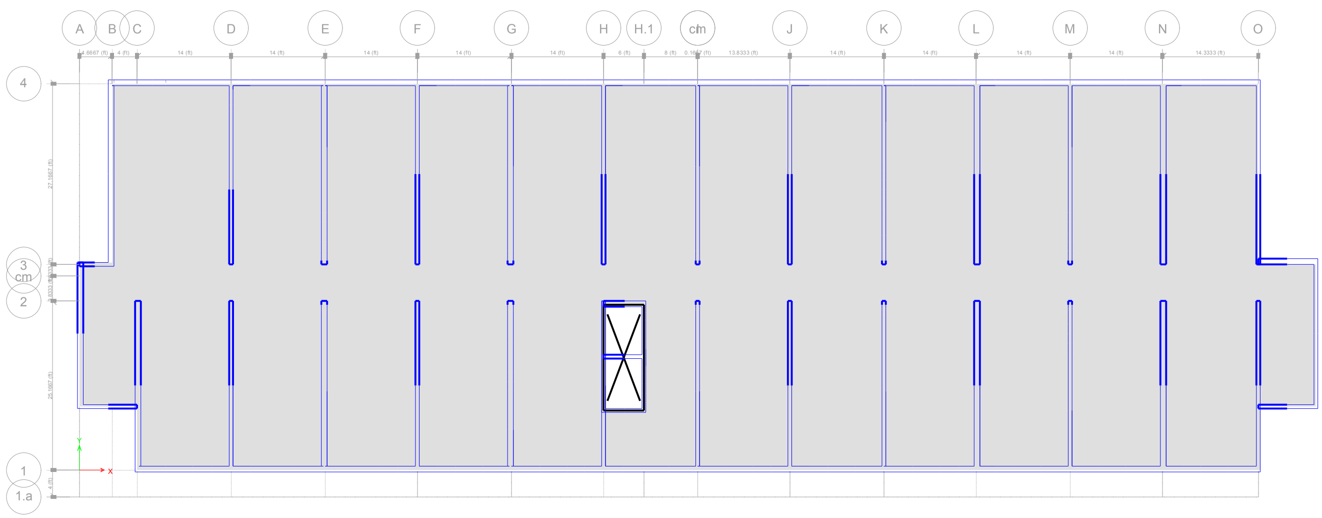
Plan View - Story 3



Plan View - Story 4



Plan View - Story 5



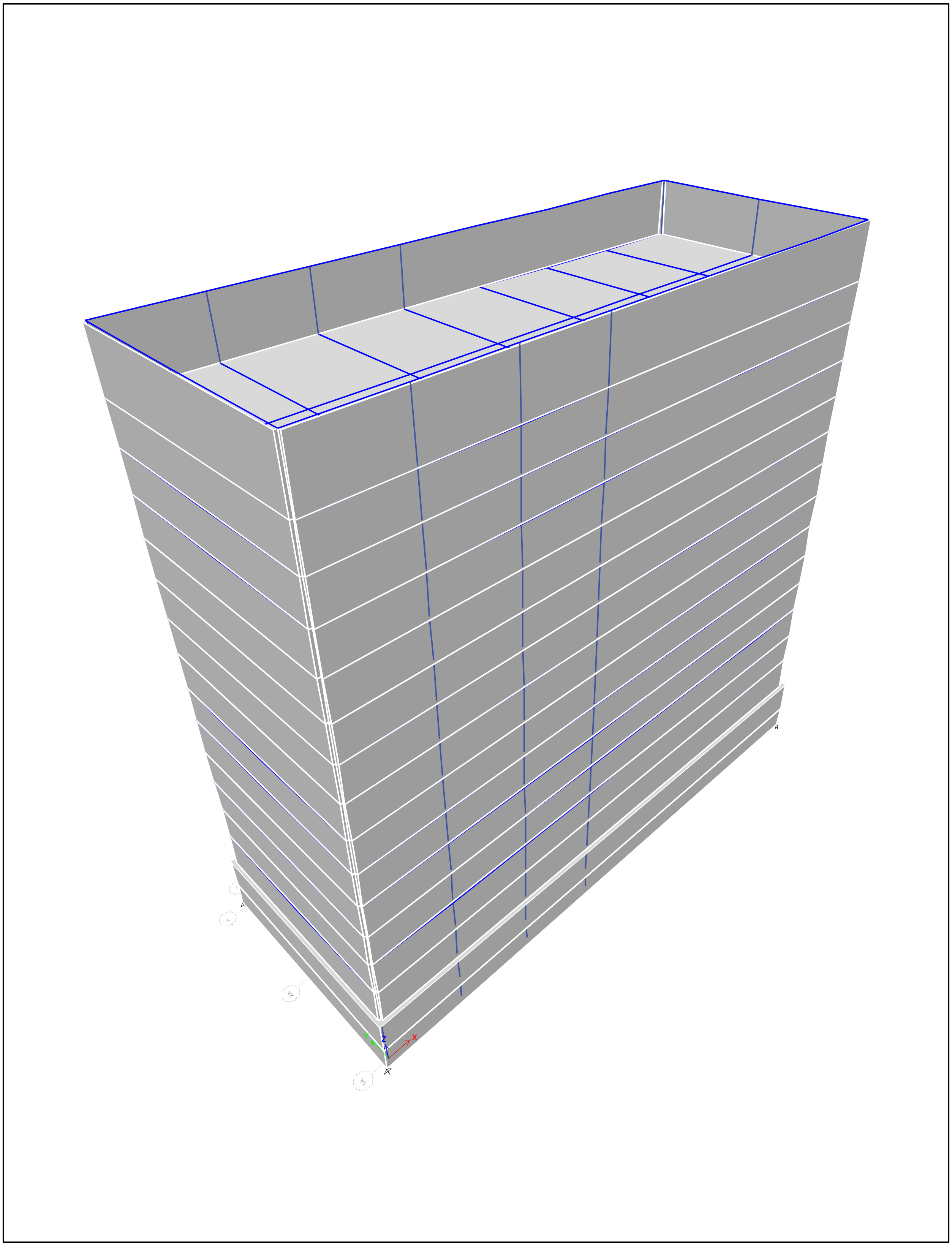
Plan View - Story 6

Station 24322

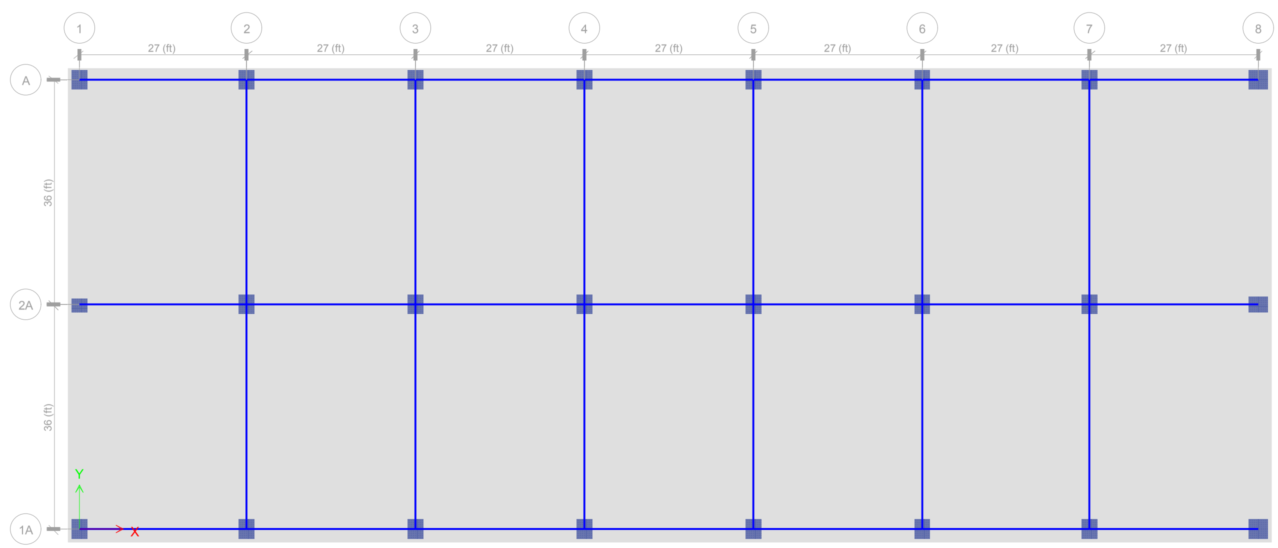
Building: Sherman Oaks - 13-story Commercial Bldg

Building Type: Moment resisting concrete frames in both directions for the upper stories; concrete shear walls in the basements.

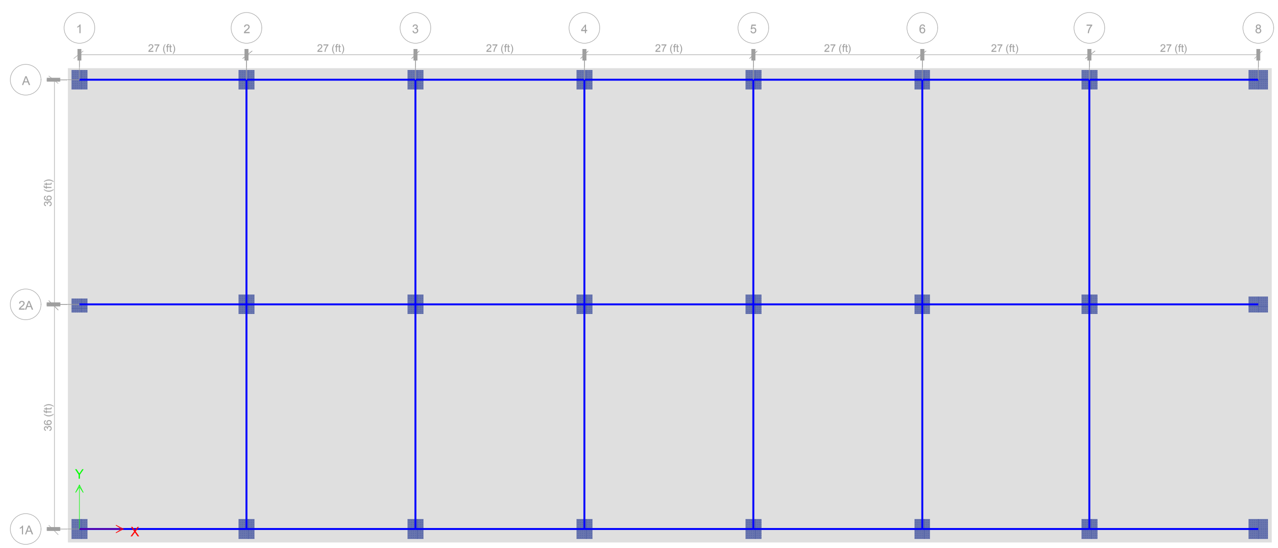
Number of floors with Sensors: 5



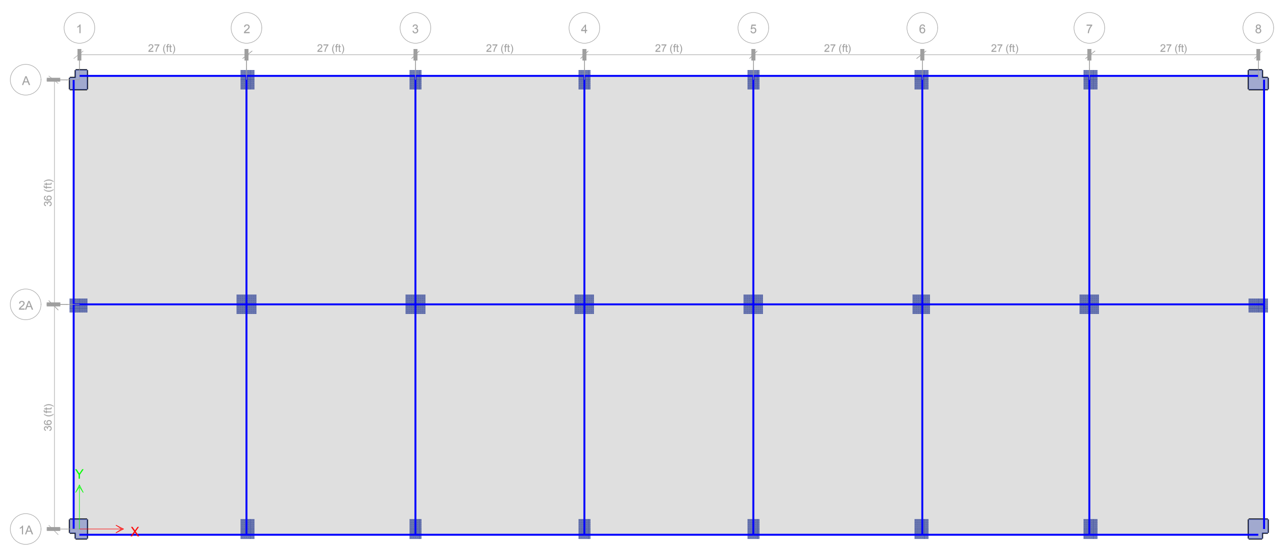
Station 24322: Sherman Oaks 13-Story Commercial Building



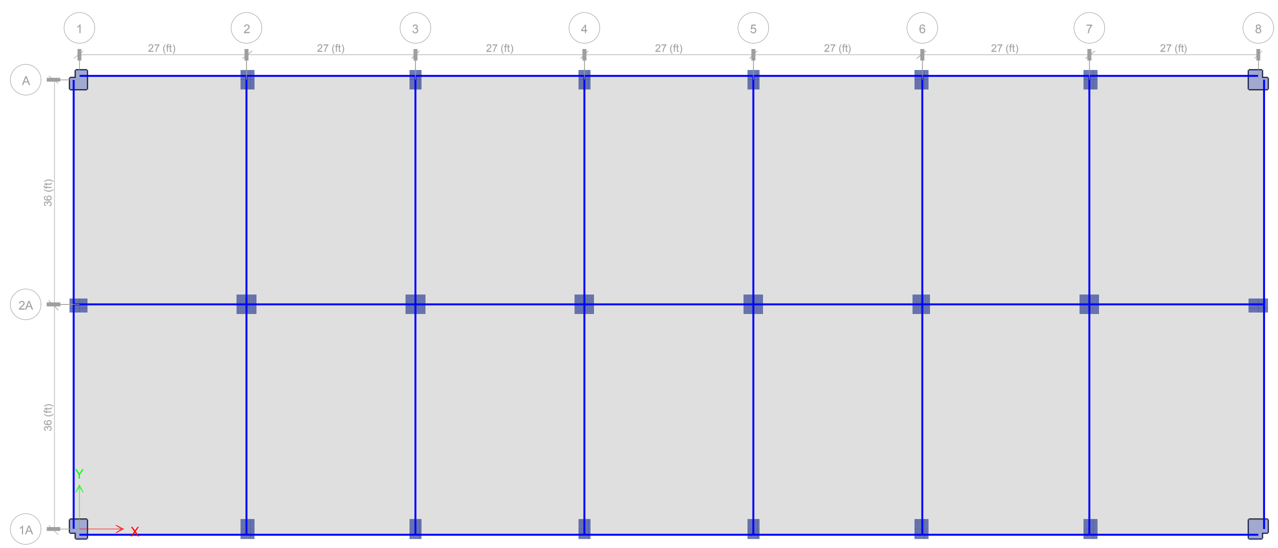
Plan View - Basement 1



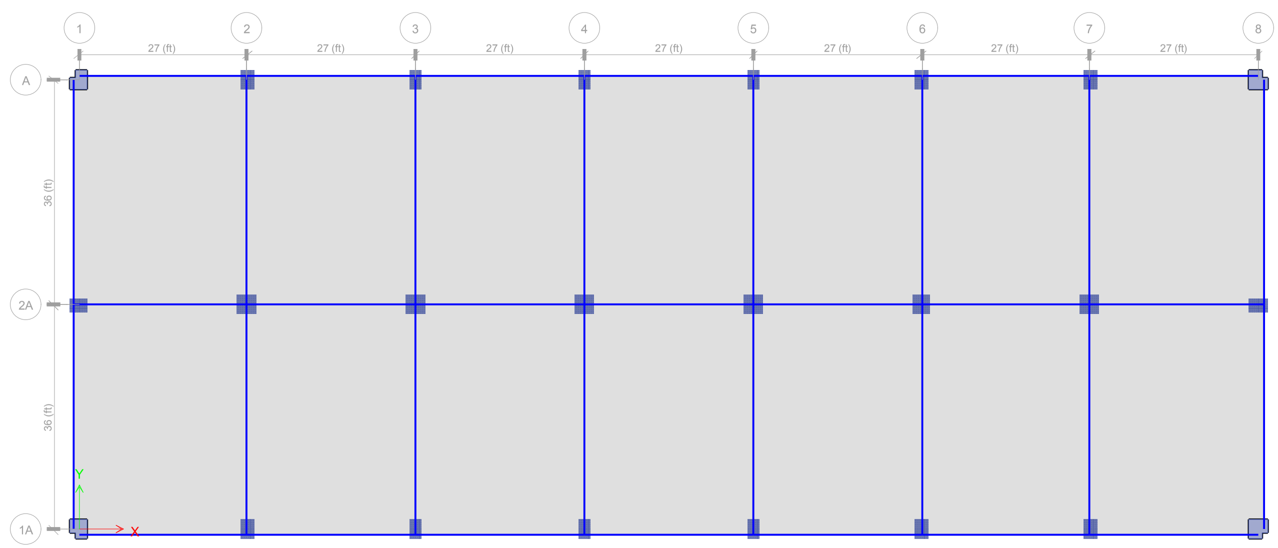
Plan View - Story 1



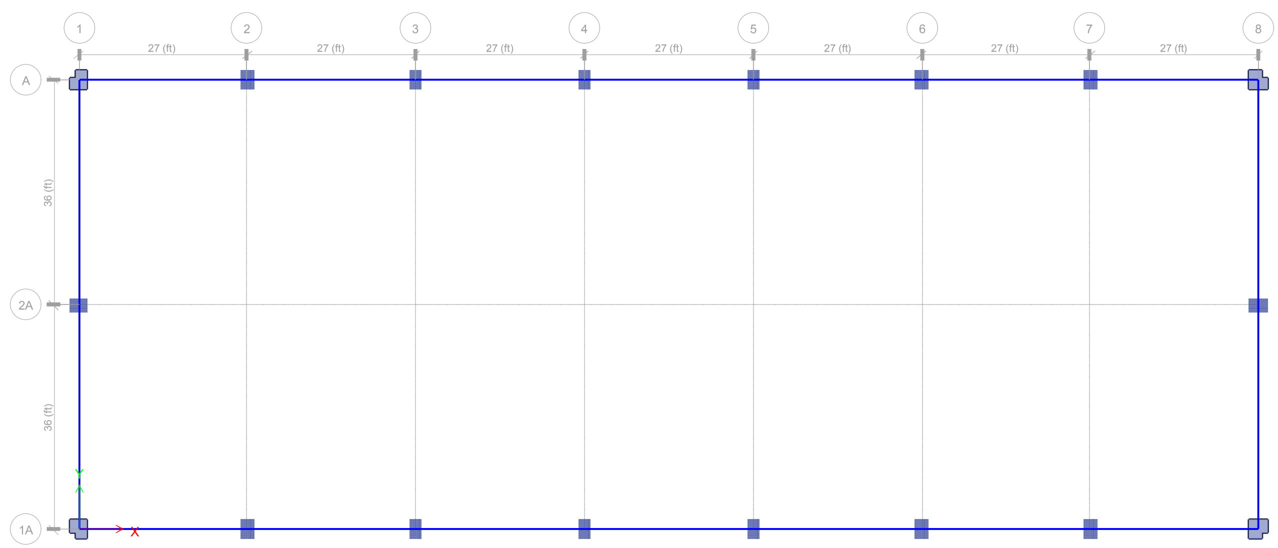
Plan View - Story 2



Plan View - Story 3



Plan View - Roof



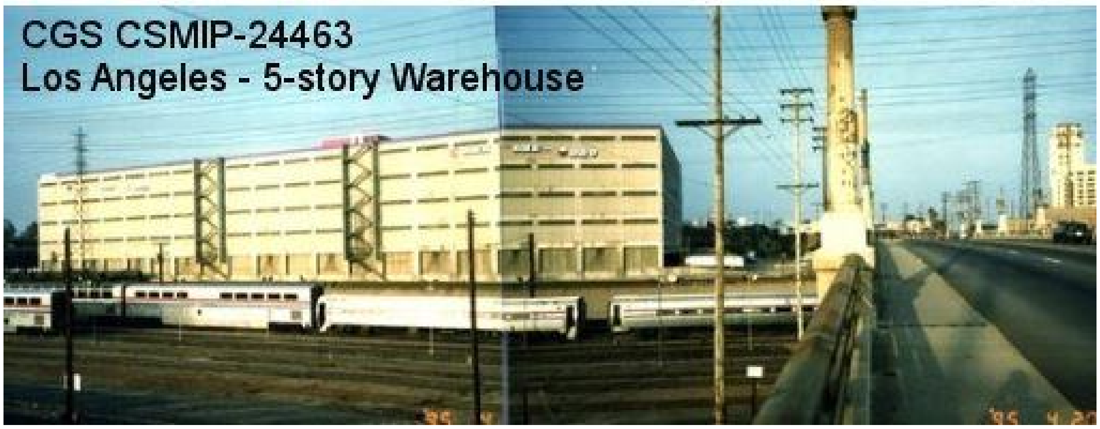
Plan View - Roof 2

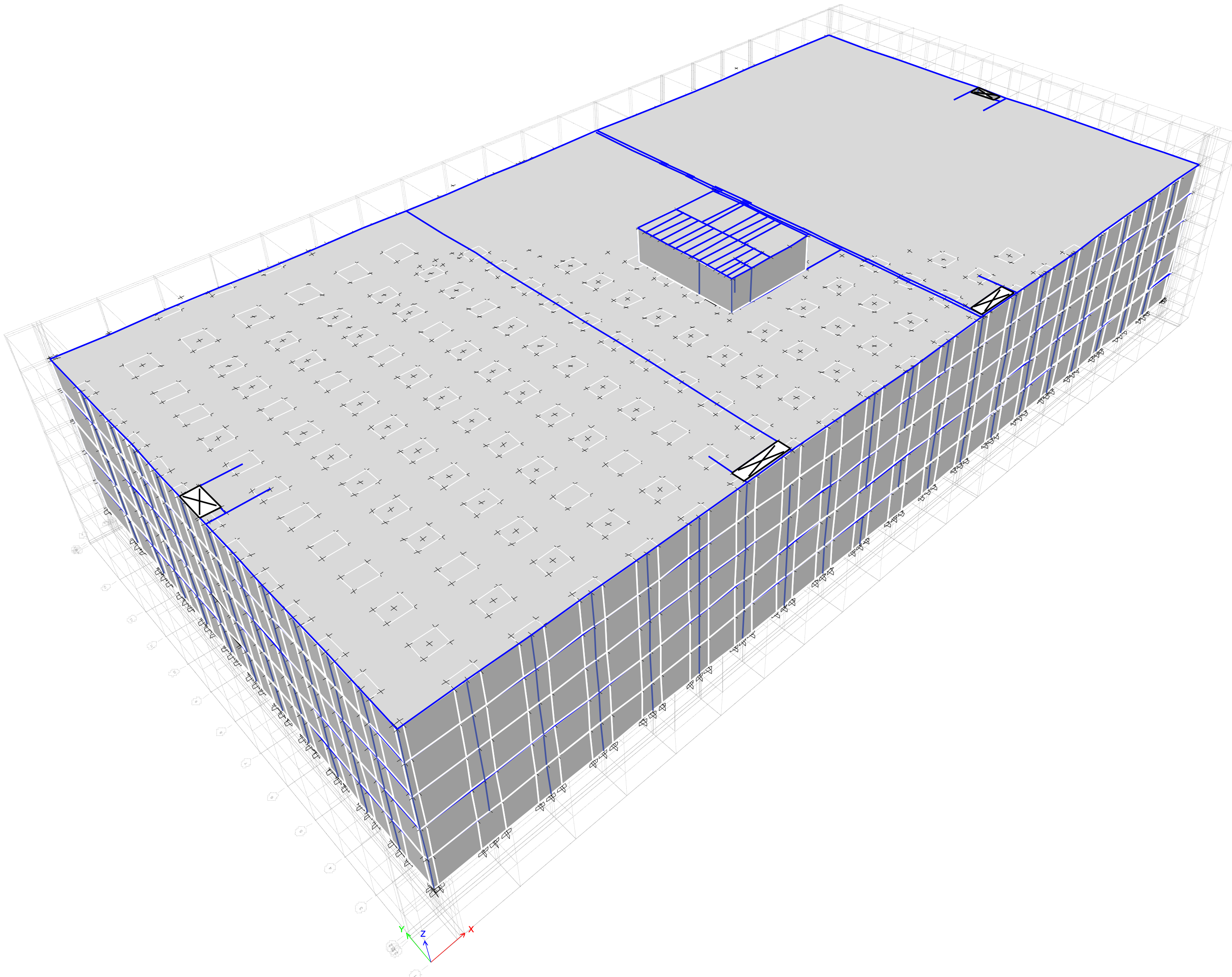
Station 24463

Building: Los Angeles - 5 Story Warehouse

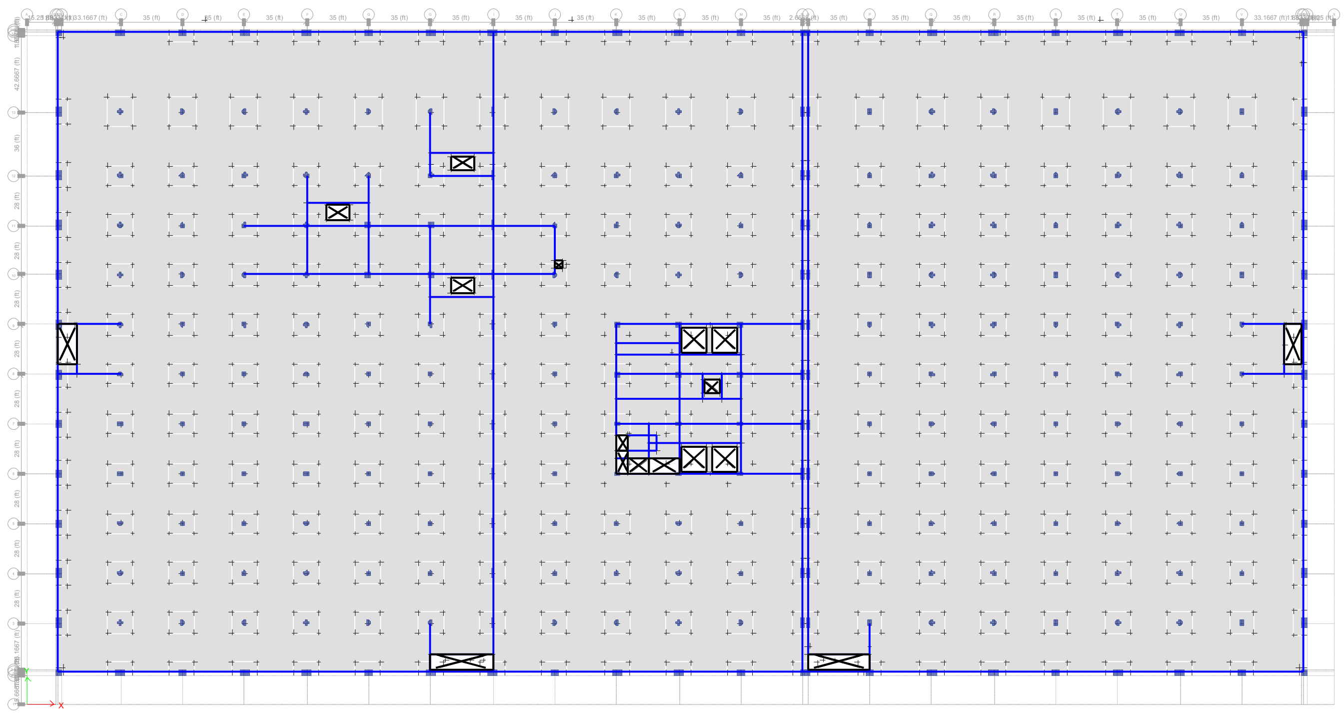
Building Type: Ductile reinforced concrete perimeter frame and basement shear walls

Number of floors with Sensors: 4

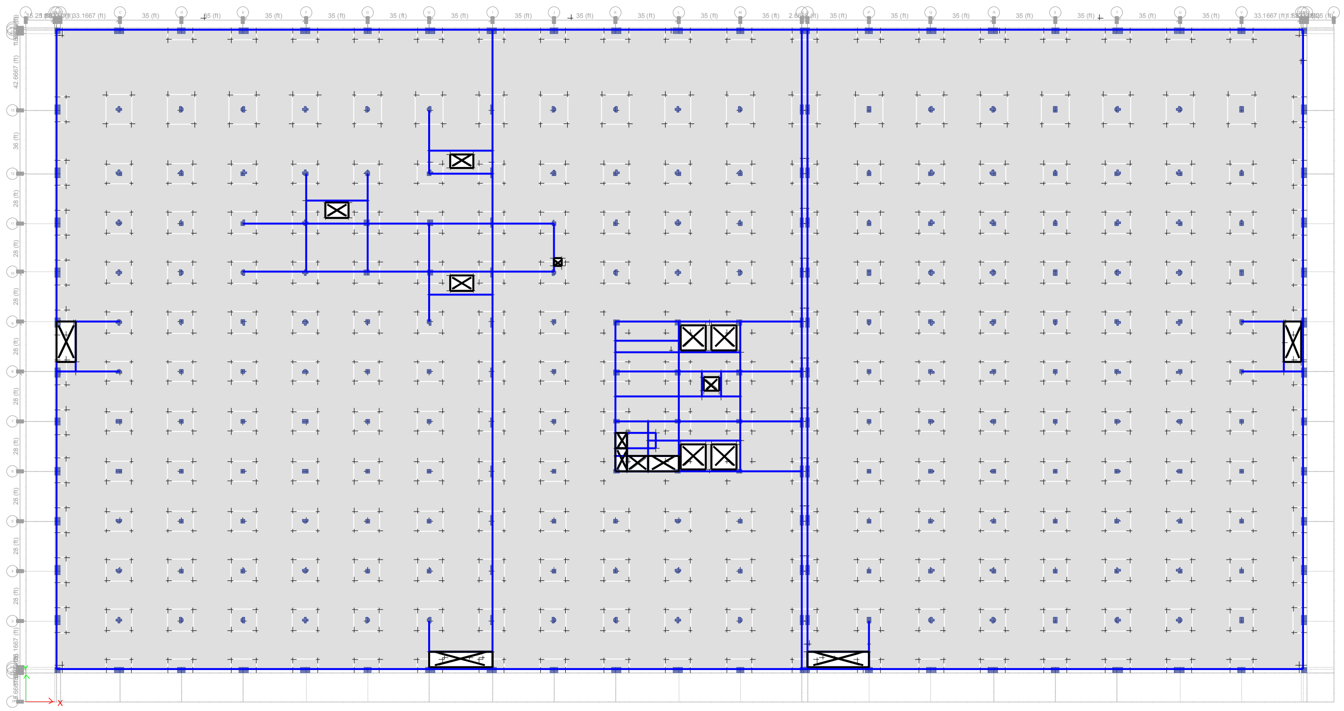




Station 24463: Los Angeles 5-Story Warehouse

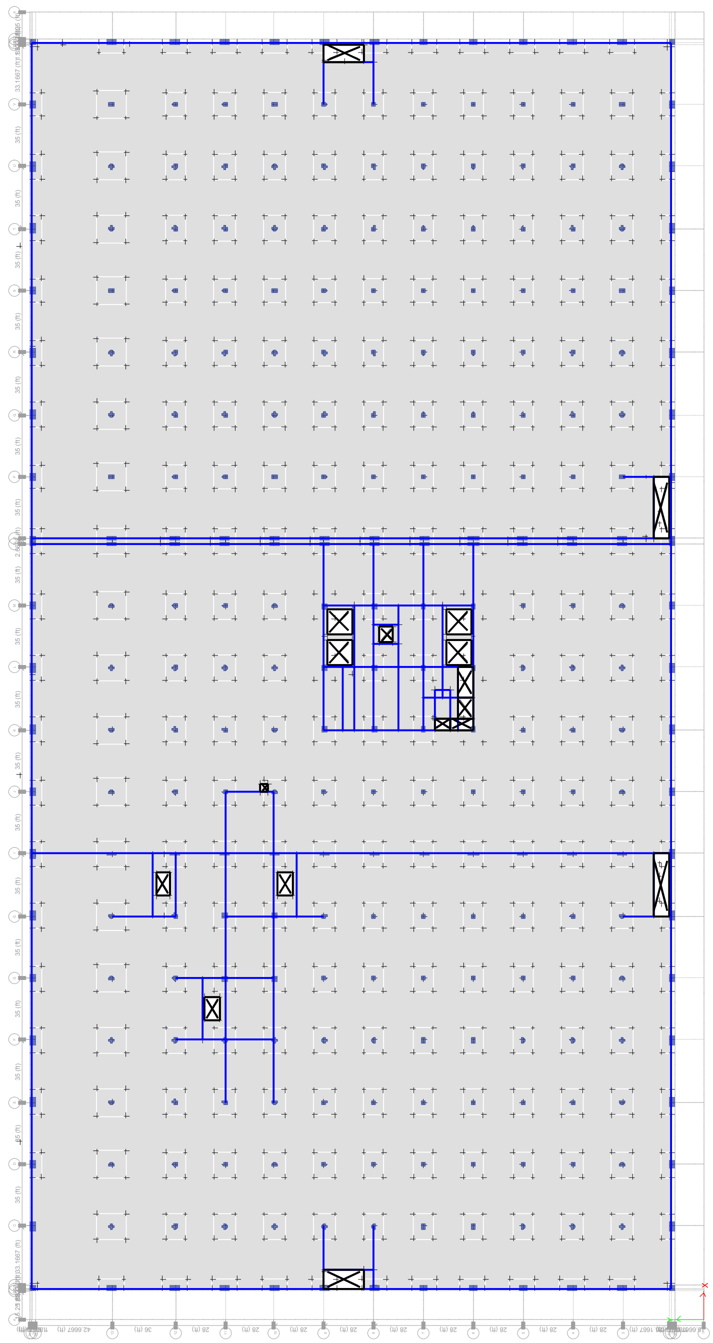


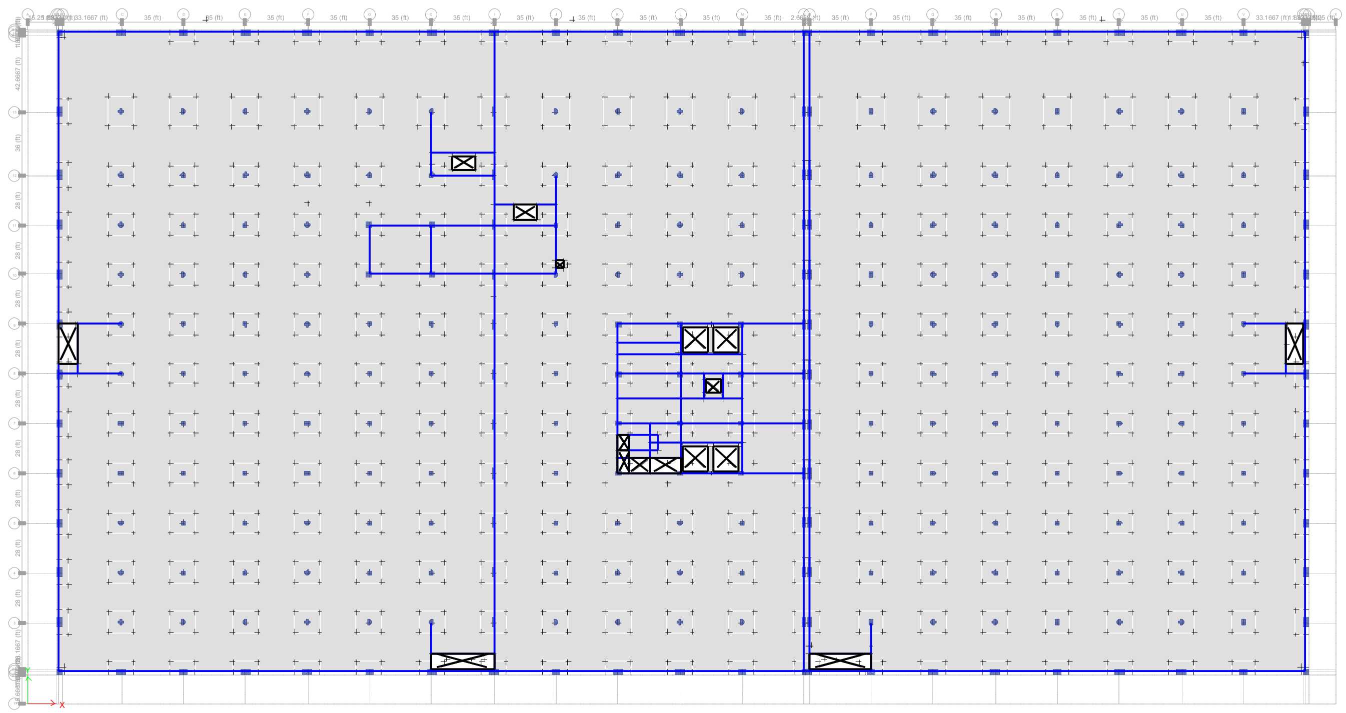
Plan View - Story 2



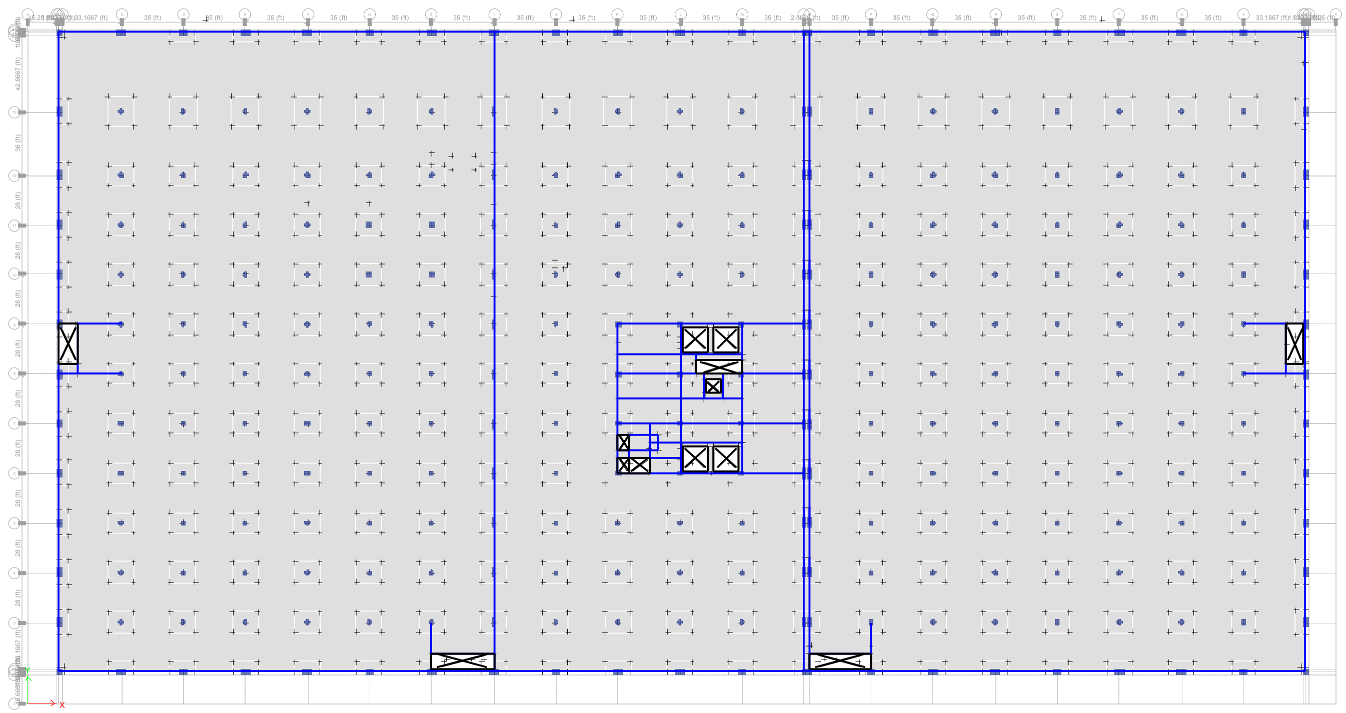
Plan View - Story 3

Plan View - Story 4

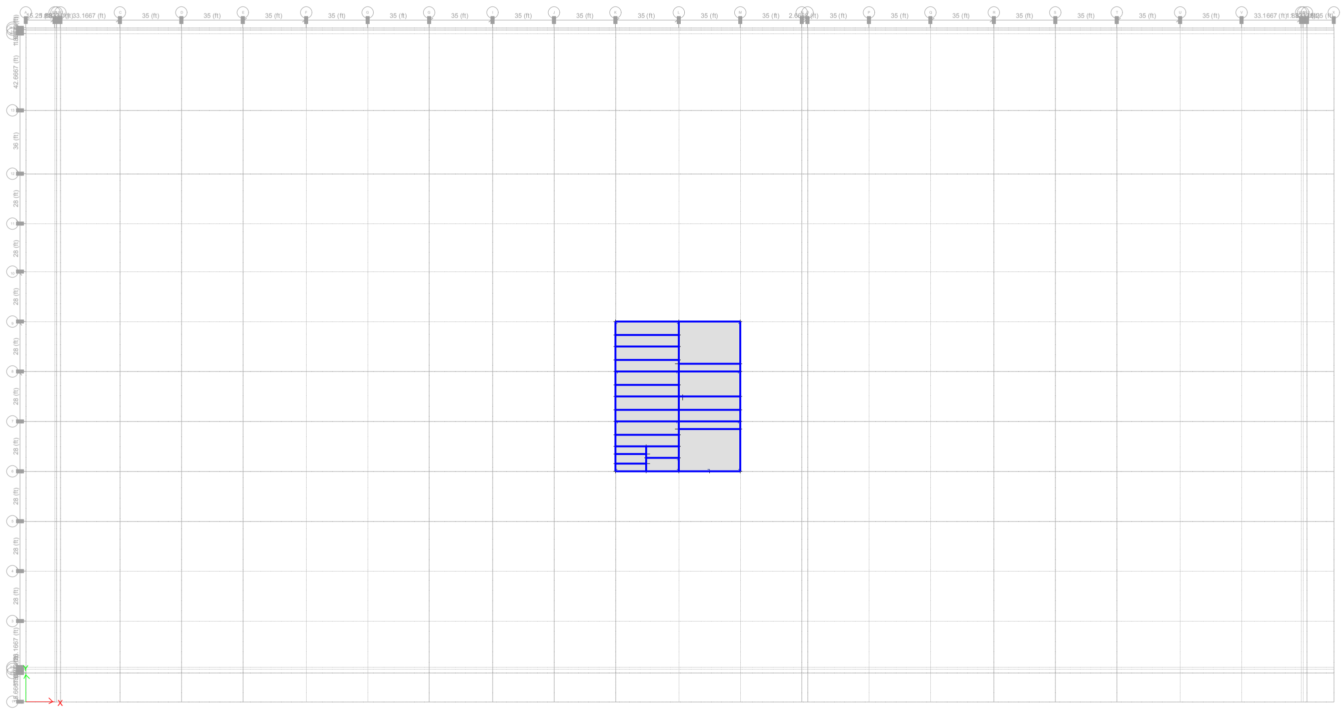




Plan View - Story 5



Plan View - Roof



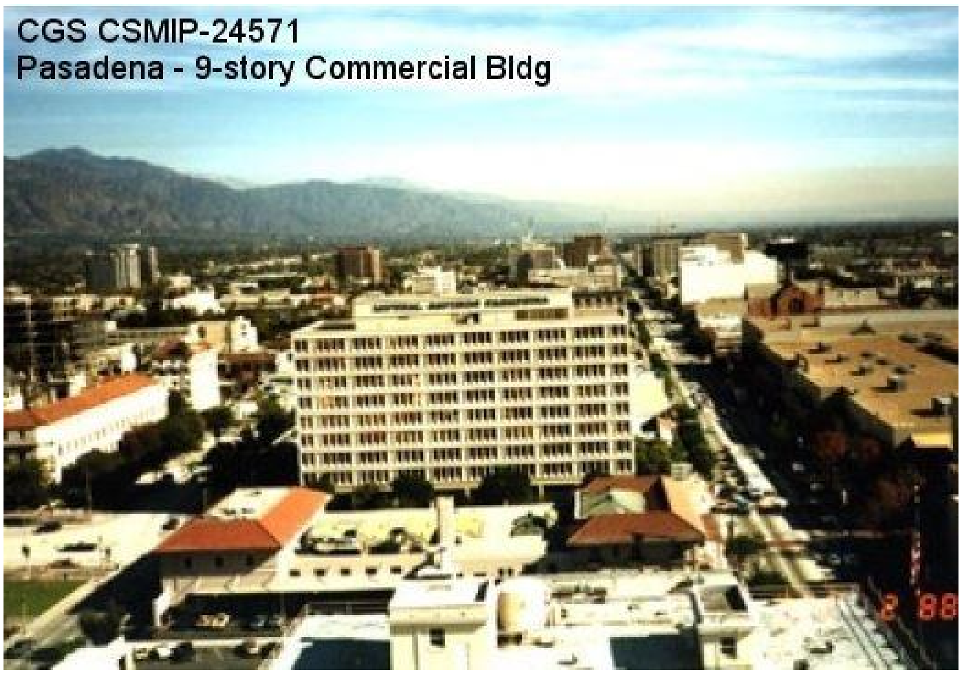
Plan View - Penthouse

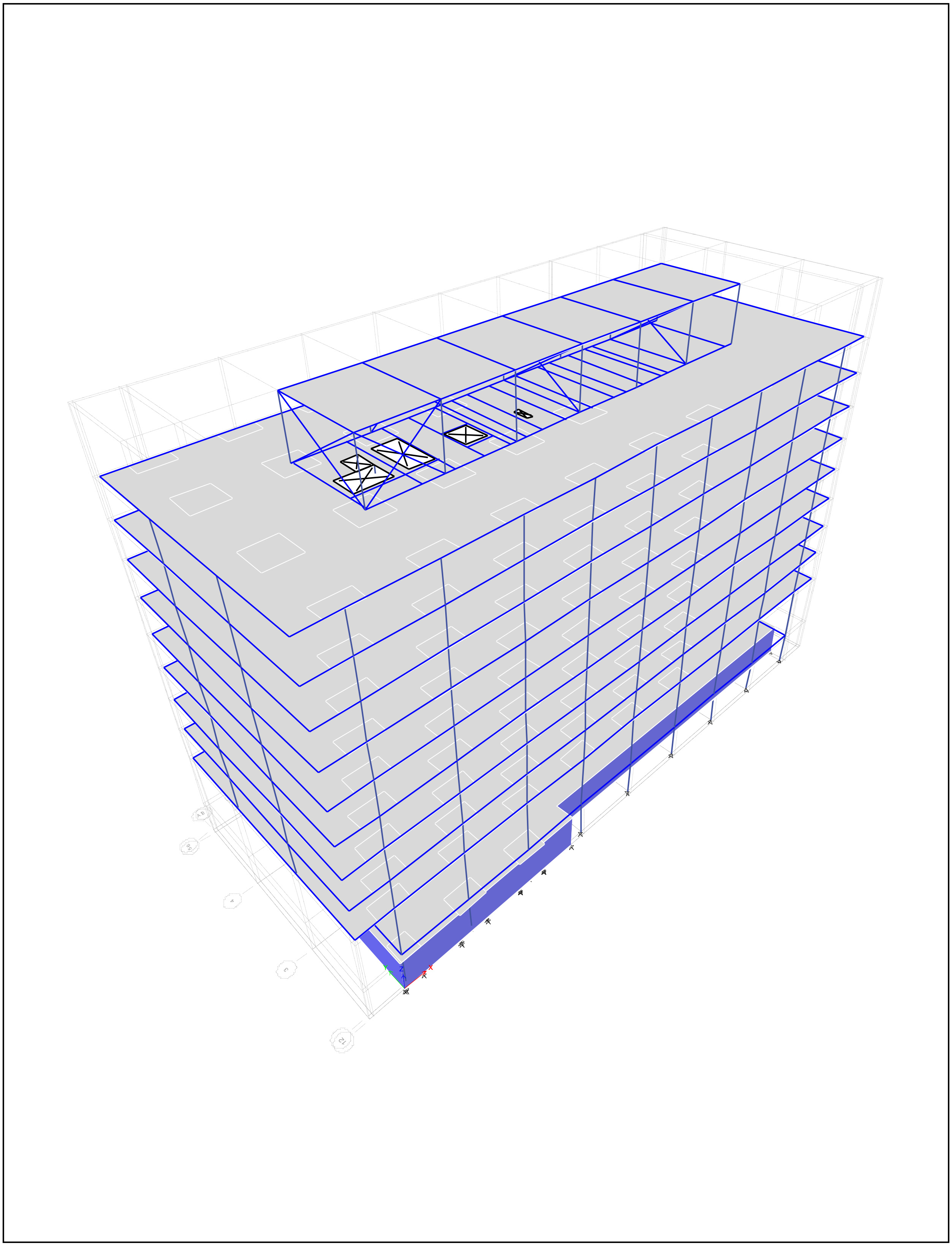
Station 24571

Building: Pasadena - 9-story Commercial Bldg

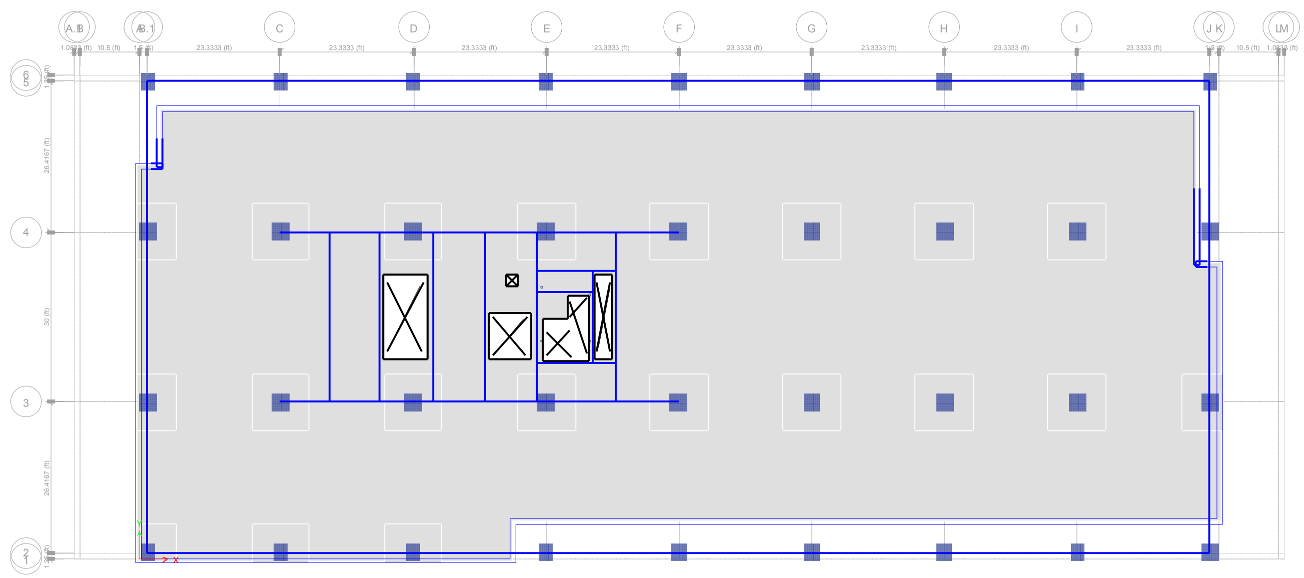
Building Type: Reinforced concrete slab-column system providing moment resistance; beam-column system at the core of each floor

Number of floors with Sensors: 5

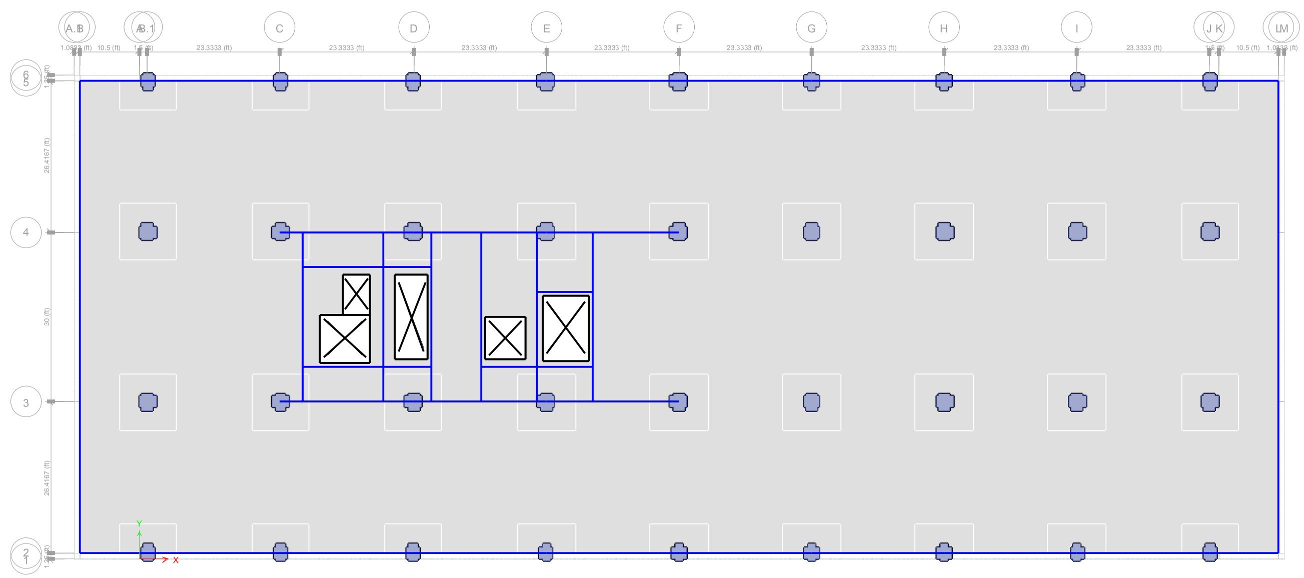




Station 24571: Pasadena 9-Story Commercial Building

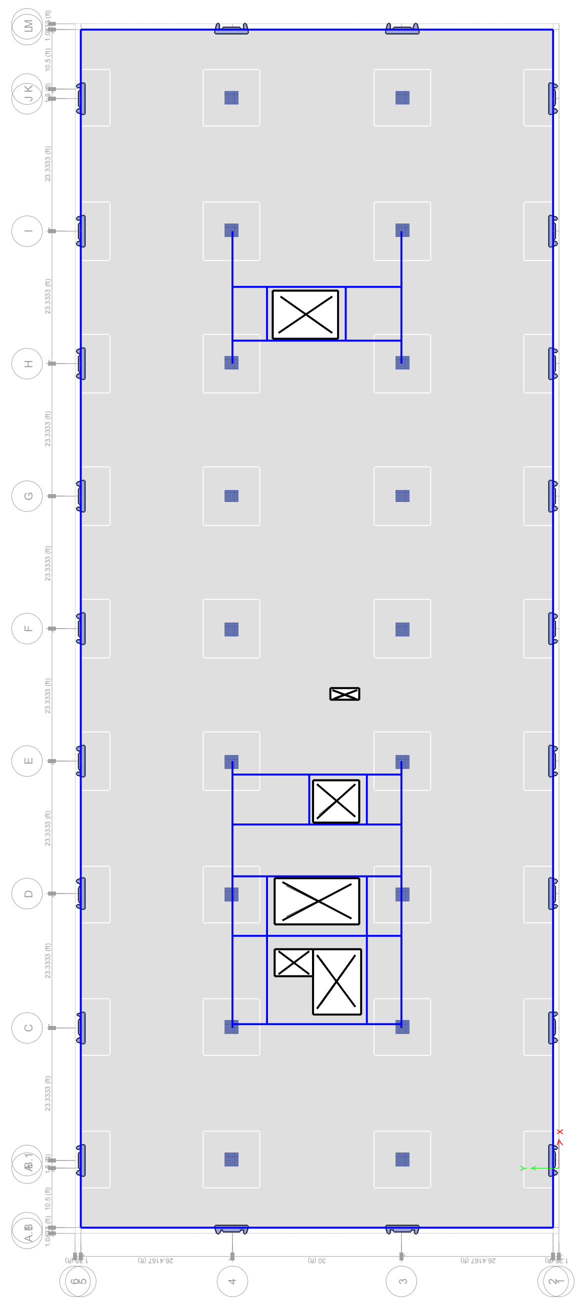


Plan View - Story 1



Plan View - Story 2

6/23/2015



Plan View - Story 3

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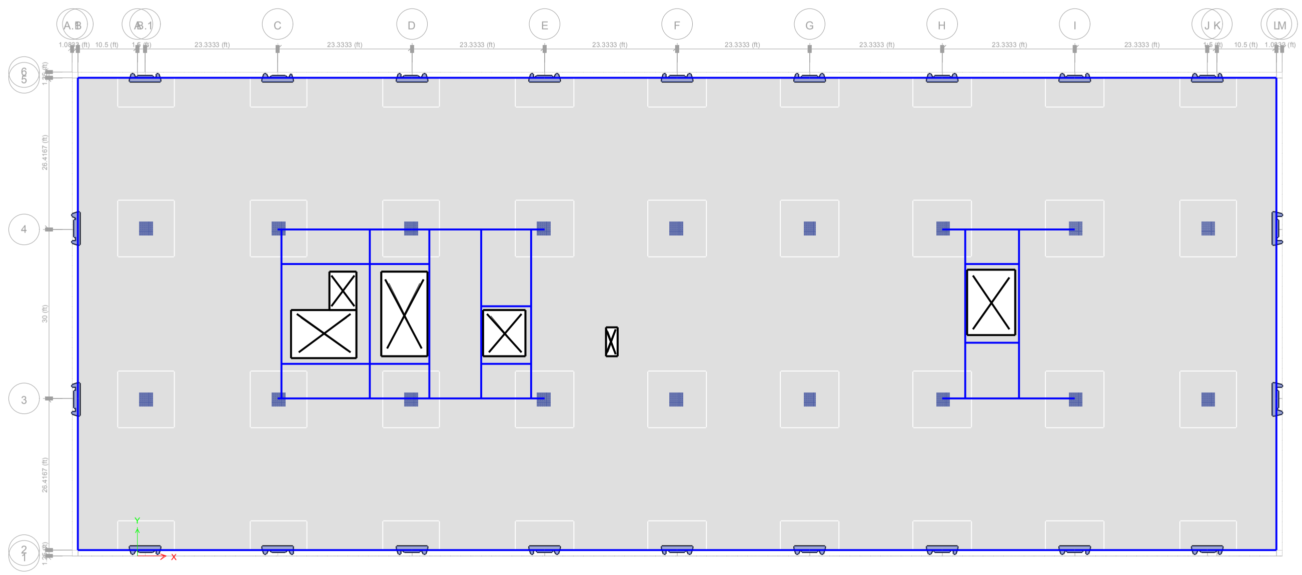
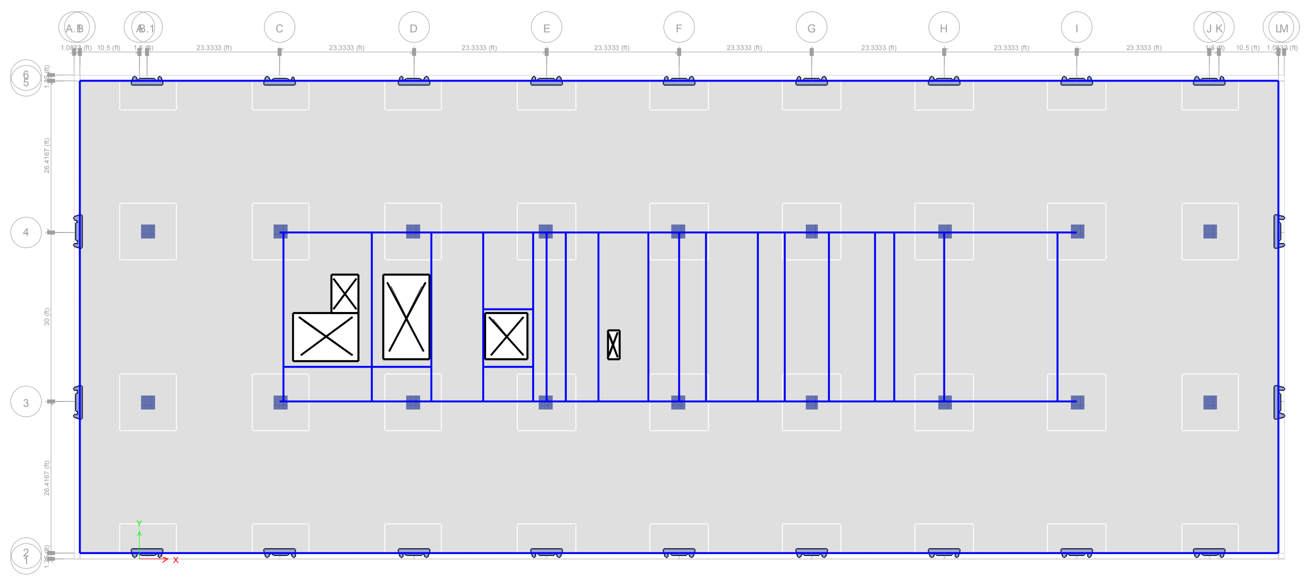
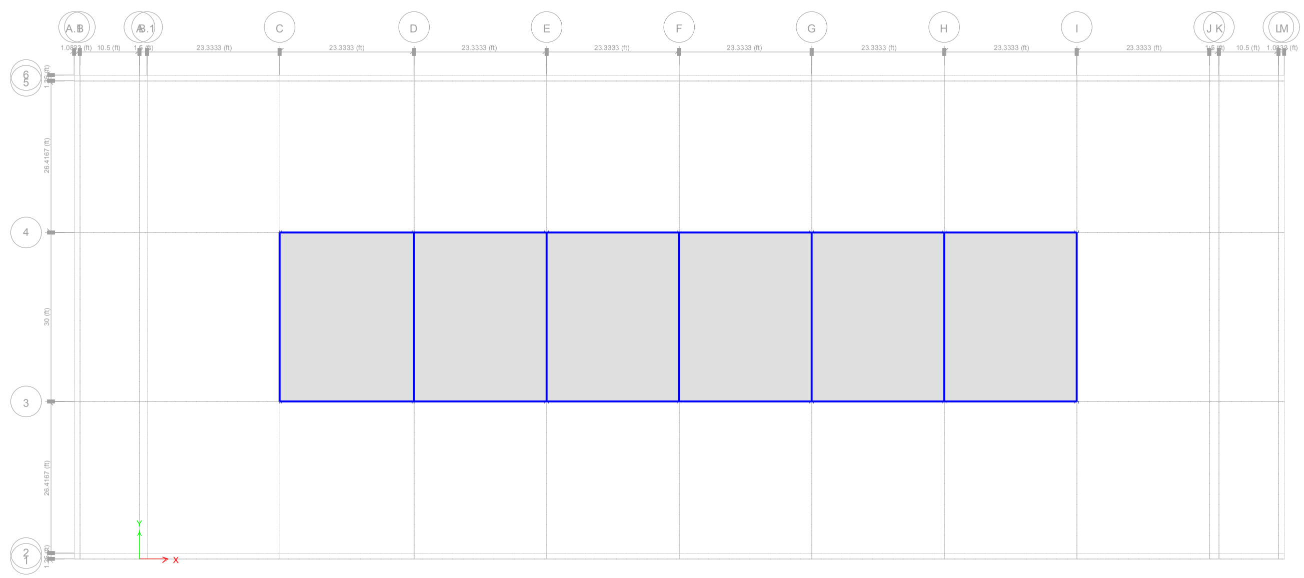


Plan View - Story 4



Plan View - Roof



Plan View - Penthouse

Station 54388

Building: Bishop - 2-story Office Bldg

Building Type: Transverse direction: steel columns and trusses connected to provide moment resistant frames. Longitudinal direction: steel rod x-bracing in exterior walls

Number of floors with Sensors: 3

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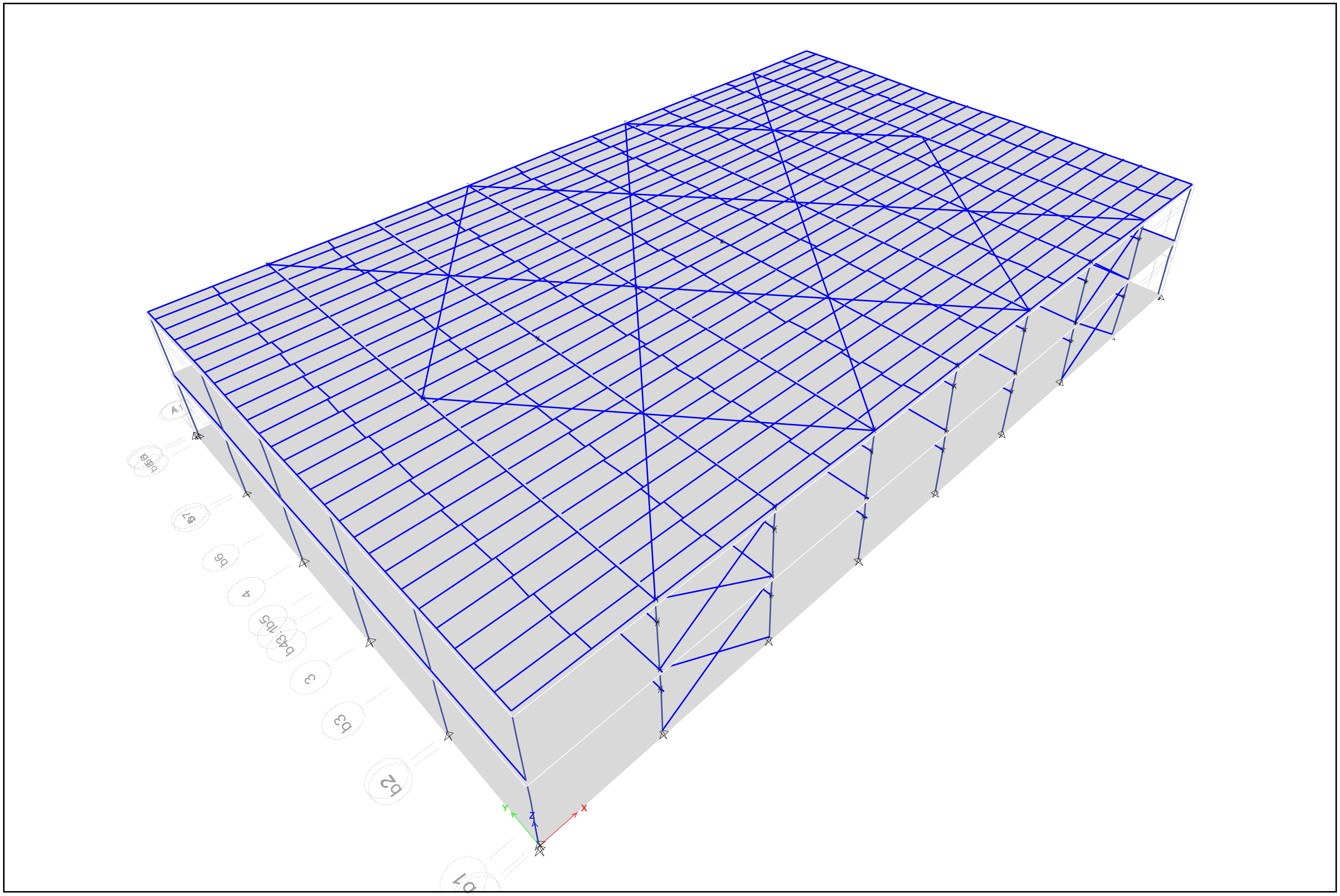
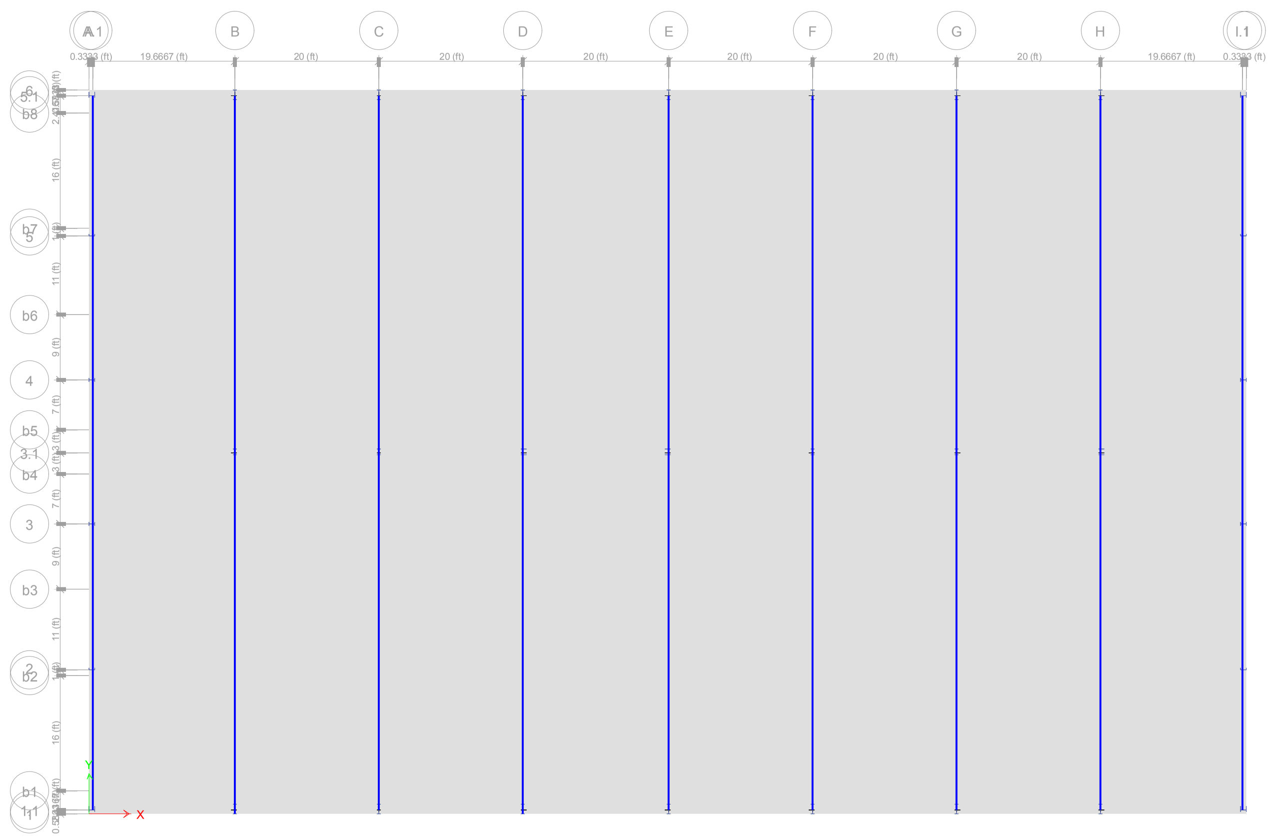
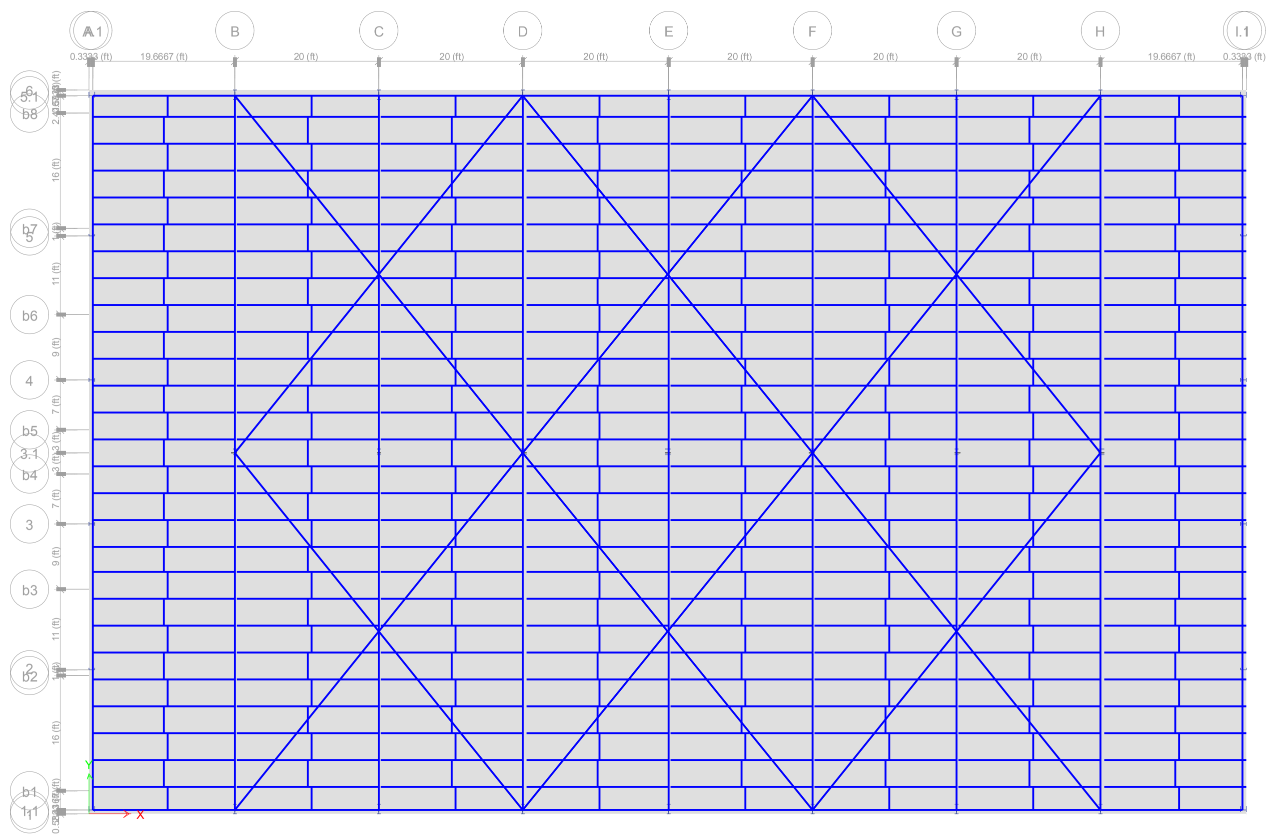


Station 54388: Bishop 2-Story Office Building



Plan View - Story 2



Plan View - Roof