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<https://doi.org/10.15760/CEEMP.16>

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PARAMETRIC STUDY OF ROCKING SHALLOW FOUNDATIONS UNDER SEISMIC
EXCITATION

BY

BENJAMIN I. HERDRICH

A research project report submitted in partial fulfillment
of the requirement for the degree of

MASTER OF SCIENCE
IN
CIVIL AND ENVIRONMENTAL ENGINEERING

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ACKNOWLEDGMENTS

I would like to sincerely thank Dr. Peter Dusicka and Reid Zimmerman for their advice and insight throughout the course of this study; their enthusiasm and willingness to review completed work, and provide recommendations on how to proceed, has been invaluable. It has been a privilege to work with them on this project.

Additionally, I would like to thank Dr. Ivan Wong for assistance in acquiring subduction ground records.

The study presented was partially supported by a generous grant from KPFF Consulting Engineers, Portland Structural Office.

ABSTRACT

Conventional design of structures relies on incorporating a certain level of inelastic deformation into select components to provide seismic energy dissipation, while ensuring the foundation remains relatively stationary. However, this inelasticity comes at the cost of severe damage to the structure, which often is no longer suitable to occupancy after a seismic event. In contrast with conventional structures, structures with rocking foundations shift the ductility demands away from the structure itself, and onto the underlying soil, which may result in less damage and greater stability. The purpose of this study is to explore the behavior and performance of a simple bridge/structure, idealized as a single degree of freedom oscillator on a rocking shallow foundation, when subjected to bidirectional seismic ground motion. Accordingly, this study explores how independent factors, such as structural, soil, and seismic characteristics affect the performance of the system during a seismic event. From this, the engineering demand parameters, such as residual displacement and instability, are related to the system characteristics through a series of nondimensional relationships and earthquake parameters. These parameters are then discussed, in order to determine what physical and dynamic characteristics of the system are captured within these parameters, and how they can be used to better understand the behavior of rocking structures.

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1.0 INTRODUCTION

In regions with high seismic activity, engineers must design structures to be able to safely withstand the forces associated with a seismic event. However, with the exception of critical infrastructure such as hospitals, power plants, and important municipal facilities, it is not economically feasible to design a structure to withstand an earthquake without suffering damage to the structure and its components. Accordingly, conventional design of structures relies on incorporating a certain level of inelastic deformation into select components to provide seismic energy dissipation, while ensuring the foundation remains relatively stationary. These components vary between structures, but may consist of shear walls, moment frames, braced frames, plastic hinging of bridge bents, or some combination thereof. By designing certain elements to behave inelastically, structures can be designed more economically, to lower force requirements, and with a lower probability of collapse.

However, this ductility comes at the cost of considerable damage to the structure, due to inelastic deformation of the components comprising the lateral force resisting system. In the process of absorbing seismic energy, steel members and rebar yield, concrete cracks, and braces buckle and elongate. Accordingly, following an earthquake, structures often have large residual displacements and reduced lateral strength, and may no longer be suitable for occupancy, which results in the replacement of the entire structure. In the case of bridges, this lateral displacement means that the bridge deck may no longer align with the approaching roadway, which can inhibit or prevent emergency vehicles from using the bridge in the aftermath of an earthquake. This has the potential to isolate communities from the surrounding region until the bridge can be repaired or replaced.

A somewhat less conventional design approach consists of designing structures with “rocking foundations”, foundations that allow movement of the footing relative to the underlying soil. In contrast with conventional design, structures with rocking foundations shift the ductility demands away from the structure itself, and onto the underlying soil, which may result in less damage and greater stability. While conventional structures often have very large spread footings which prevent significant movement of the footing, rocking foundations have smaller footings, which are more prone to uplift and settlement. Accordingly, a rocking structure may be designed to behave elastically, while the soil beneath the foundation acts to provide both inelastic deformation, as well as a certain degree of base isolation for the structure.

Due to the potential benefits of rocking foundations over conventionally designed fixed-base foundations, a number of experimental studies have been performed to compare the behaviors of the two foundation types, and to attempt to understand the behavior of rocking foundations. For instance, scale shaketable tests have indicated that rocking foundations typically have very low residual drift ratios and residual rotations (Antonellis et al. 2014).

Likewise a number of scale centrifuge tests have been conducted to characterize the behavior of rocking shallow foundations, and compare against the performance of fixed foundation bridge piers (Loli et al. 2014, Deng and Kutter 2012, Gajan and Kutter 2008). These studies have determined that rocking foundations typically experience smaller drift ratios than conventional piers, with the ductility of the rocking foundation occurring due to soil deformation, rather than yielding of the steel rebar. Accordingly, scale testing indicates that a pier on a rocking foundation typically remains linear-elastic, even after a similar conventionally designed pier has failed. Further, it has been determined that the moment required to induce rocking in the foundation does not change significantly after many cycles of seismic motion, in

contrast with strength degradation in conventional piers, due to yielding of the rebar at the plastic hinge. (Deng and Kutter 2012).

However, rocking foundations have been experimentally found to experience larger vertical settlement than a fixed-base structure (Loli et al. 2014). Some centrifuge tests have explored how the area of the footing affects the settlement and moment capacity of the foundation. As a result, it was found that the settlement of the footing was inversely proportional to the ratio of the footing area to minimum bearing area, and that the settlement was influenced by the rotation amplitude at small ratios. Moreover, the moment capacity of the footing was found to be very sensitive to changes in area for smaller ratios (Gajan and Kutter 2008).

Further, a number of analytical studies have been performed, which have utilized both OpenSees as well as finite element analyses. One study (Deng, Kutter, and Kunnath 2012) challenged the conception that rocking foundations were less stable than conventional columns, and found that rocking structures were less likely to topple, even during major seismic events. Other analytical studies (Mergos and Kawashima 2005) have explored the correlation between the moment demand on a rocking structure with the size of the foundation, as well as the yield strength of the underlying soil. For rocking foundations allowed to uplift on elastic soil, one study (Harden and Hutchinson 2006) found that the methodology of estimating the displacement of the structure as outlined in current FEMA and ATC code is unconservative for large soil strength ratios; a new equation was included which better predicted the displacement of rocking foundations. Other studies have used analytical simulations to derive a method to approximate the factor of safety against toppling for multistory frame structures, based on the approximation as a SDOF system and rigid block behavior (Gelagoti et al. 2012). Still other studies have attempted to simplify the complex nonlinear behavior of rocking foundations and soil plasticity, by simplifying the system such that it can be modeled with a series of linear springs and dashpots (Anastasopoulos and Kontoroupi 2013, Deng et al. 2014).

Relatively few studies have been able to quantify the relationship between the structural, soil, and earthquake properties with the resulting performance of the system following an earthquake. One study (Kourkoulis et. al. 2012) conducted a dimensional analysis of a SDOF system, in an attempt to determine dimensionless factors that describe the behavior of the system. The paper then performed a parametric study of the static factor of safety of the foundation, the role of $P-\delta$ effects, and the role of excitation type. Additionally, Kourkoulis et. al. proposed an equation that relates the toppling rotation and available ductility of rocking SDOF systems on inelastic soil.

However, there are still several barriers to implementation of rocking foundations in structural design, including concerns about stability as well as the inability to estimate drift and settlement (Deng and Kutter 2012). Accordingly, the purpose of this study is to explore the behavior and performance of a simple bridge/structure, idealized as a single degree of freedom oscillator on a rocking shallow foundation, when subjected to seismic ground motion. In contrast with Kourkoulis et. al., this study places less emphasis on the specific soil components, and focus more on the overall system, consisting of both structure and soil behavior. Accordingly, this study explores how independent factors, such as structural, soil, and seismic characteristics affect the performance of the system during a seismic event. From this, the engineering demand parameters, such as residual displacement and instability, are related to the system characteristics through a series of nondimensional relationships and graphical depictions. These relationships are then examined, in order to determine what physical and dynamic characteristics of the system are captured by the parameters.

2.0 PARAMETRIC MODEL

2.1 Overview

In order to determine the key nondimensional parameters that influence the behavior of the rocking system, a large number of simulations would need to be analyzed, which would consist of a varying array of structural layouts, soil properties, and ground motion records. Accordingly, a parametric analysis was conducted, which allowed for a large number of simulations to be performed in series, with the parameters incrementally changing in each simulation, with little interaction from the user. The structural analysis program OpenSees, created by the Pacific Earthquake Engineering Research Center (PEER) at University of California, Berkley, was chosen as the framework for the simulations. This program allowed the authors to simulate a wide range of combinations of system properties, the results of which were post-processed in MATLAB. The overall layout of the system is depicted in Figure 1.

This parametric study involved two different types of analysis. The first consisted of conducting a series of nonlinear dynamic time-history analyses, in which systems of various physical configurations were subjected to a number of ground records with horizontal components applied in orthogonal directions. The performance of the system during and after the earthquake, including the max lateral displacement, residual lateral displacement, and residual vertical displacement were recorded, and associated with the unique characteristics of that system. A series of nondimensional parameters were then developed, which captured trends in performance as a function of the system geometry.

Once the nondimensional parameters of interest were identified, a series of incremental dynamic analyses were conducted, to determine if those parameters had an influence on, or could be used to predict, the dynamic stability of the structure. This involved incrementally increasing the magnitude of the ground motions records associated with the 2475 year return period, while simultaneously varying the nondimensional parameter. The remaining nondimensional parameters were held constant, in order to ensure that any trends that were observed were as a result of the parameter of interest.

Fig. 1. Single degree of freedom oscillator defined in OpenSees

2.2 Ground Motions

The first step in selecting the suite of ground motion records was to generate a series of site-specific acceleration response spectra for a location in Downtown Portland, Oregon, as depicted in Figure 2. This location was chosen due to the unique combination of high population density, a large number of bridges and other simple structures, and a seismic hazard consisting of a combination of both shallow crustal and subduction type faults. The response spectra was constructed from data extracted from the 2008 interactive deaggregation application on the USGS website, for an array of 8 different return periods. Additionally, these spectra were scaled to represent NEHRP Site Class C soil conditions, which correspond to a V_{s30} of 560 meters per second.

Fig. 2. Acceleration Response Spectra for a location in Downtown Portland, Oregon. Target spectra developed by Reid Zimmerman.

After obtaining the response spectra for each return period, a suite of shallow crustal ground motion records were downloaded from the PEER NGA-West2 Ground Motion Database. A series of criteria were used to select the optimal ground motion records for the site; from the probabilistic hazard deaggregation of the site, it was determined that the shallow crustal hazard contributions to the site typically ranged in magnitude from 6.0 to 7.5 M_w , with a source-to-site distance ranging from 0 to 30 kilometers. Additionally, the shallow crustal record selection was further refined by only considering records in which the recording station was not influenced by soil-structure interaction effects, such as those in buildings, and by only considering records with two orthogonal horizontal components. Lastly, the final six shallow crustal ground motion records were selected as those with acceleration response spectra that most closely matched the 1462 year target spectra in shape and magnitude. These search criteria resulted in a suite of six shallow crustal time-history records, as tabulated in Table 1.

Table 1. Suite of ground motion records used in simulations for this study.

Event	Year	Station	Mechanism	Mw	R (km)
"Imperial Valley-06"	1979	"El Centro Differential Array"	Strike Slip	6.53	5.09
"Chi-Chi Taiwan-04"	1999	"CHY074"	Strike Slip	6.2	6.2
"Niigata Japan"	2004	"NIGH11"	Reverse	6.63	8.93
"L'Aquila Italy"	2009	"L'Aquila - V. Aterno -Colle Grilli"	Normal	6.3	6.81
"Chuetsu-oki Japan"	2007	"Sanjo Shinbori"	Reverse	6.8	23.18
"Darfield New Zealand"	2010	"Christchurch Resthaven "	Strike Slip	7.0	19.48

After selecting the ground motion suite, the shallow crustal records were spectrally matched to the target spectra through the use of RSPMatch09. Spectral matching is a process in which small wavelets are added to the acceleration time history of an earthquake, in order to manipulate the acceleration response spectra to more closely represent the target spectra. This manipulation of the acceleration time history is performed to reduce the variation in structural response between ground records. However, due to concerns about producing an unrealistic ground motion in the process of the spectral matching, a “rough” match was performed, such that the acceleration response spectrum of each record was matched to within 10-15% of the target. Additionally, the post-processed time history of each record was visually inspected and compared to the original unmatched record, to ensure that the characteristics of the ground record were preserved. This spectral matching was performed independently for both horizontal components, for all 6 records in the suite, for each of the 8 return periods, which resulted in a total of 48 ground motion records, each with two horizontal components. When these ground records were simulated in OpenSees, both horizontal records were applied in orthogonal directions simultaneously; the vertical component of the ground records were not considered in the simulations.

2.3 Structure Description

For the purpose of this study, the structure is idealized as a single degree of freedom oscillator (SDOF) on a rigid shallow footing, as depicted in Figure 3 (a), otherwise known as a cantilever column, inverted pendulum, or informally as a “lollipop structure”. The soil beneath the footing is modeled with a series of nonlinear Winkler springs, the properties of which are discussed in the following section. This structure was chosen because it can be used to approximate the behavior of a bridge experiencing motion in the transverse direction relative to the superstructure, as in Figure 3 (b). In this analogy, the superstructure of the bridge provides the tributary areas of the mass and weight of the structure, which are transmitted to the bridge bent.

Additionally, this model can also be extended to a multistory building frame, as depicted in Figure 3 (c). In a conventionally designed moment-frame type structure, plastic hinges would form at the ends of the beams and columns, while the soil under the footing remains elastic. However, by reducing the size of the spread footings, plastic deformation will occur beneath the footing prior to the formation of plastic hinges at the ends of the column (Anastasopoulos et. al. 2014). Further, by assuming that plastic hinges form at the ends of the beams, this would reduce the moment resistance of the beam connections, and would allow the columns to rocking in parallel, resulting in a series of members similar to those depicted in (a). The lumped mass and weight acting at the top of this analogous structure would consist of the mass and weight contained within the tributary of each of these respective columns.

Fig. 3. Equivalence of structures with SDOF oscillator: (a) SDOF oscillator with a spread footing on nonlinear Winkler springs, (b) an equivalent single column bridge bent, and (c) an equivalent beam-column frame system.

In order to conduct a parametric analysis of this SDOF system in OpenSees, a model was created from a series of elastic beam-column type elements, as depicted in Figure 4. The column consisted of a single elastic-beam column with variable height, diameter, and modulus of elasticity, with the top node assigned a lumped mass. The choice of elastic beam-columns over a more complex element was justified by the lack of inelastic behavior of a column attached to a rocking shallow foundation. The footing consisted of a grid of elastic beam-columns, with intermediate nodes at each element intersection. Because spread footings often have negligible flexibility relative to the superstructure, the elements comprising the footing were defined to have a stiffness of approximately 1×10^7 times the stiffness of the column. The length of each of the elements was defined as a function of the footing size, such that each of the soil springs would have an equal tributary area when the size of the footing was adjusted between simulations.

Fig. 4. OpenSees model consisting of a series of elastic beam-column elements.

This model was defined in OpenSees as a 3-dimensional, 6 degree-of-freedom system for the purpose of analysis. However, because sliding of the footing is outside the scope of this study, it was assumed that the soil along the perimeter of the footing provided a large amount of passive earth pressure, and accordingly, the system was restrained against translation in the horizontal directions. Further, the system was also restrained against rotation about the vertical axis, which would manifest as torsion of the structure about the column. As a result, the model effectively had 3 degrees of freedom, consisting of rotation about the horizontal axes (rocking), and translation in the vertical direction (settlement). The nonlinear second order P-Delta effects were considered in the analysis by applying the p-delta transformation to the elements of the structure.

Because of the elastic nature of the superstructure and footing, the Rayleigh damping applied to the model was defined as a function of the initial stiffness matrix and mass matrix of the system. Because the superstructure is assumed to not experience inelastic deformation, or any form of stiffness degradation, the stiffness matrix was constant throughout the simulation, and did not warrant a more computationally intensive method of estimating the damping.

2.4 Soil Idealization

The soil-structure interaction at the base of foundation was modeled following the guidelines of ASCE 41-13, using the 2nd method for modeling a rigid shallow footing. Accordingly, a series of 25 nonlinear Winkler springs were created in a uniform grid along the base of the footing, at each of the nodes depicted in Figure 4. These springs were defined as zero-length elements, with material properties defined by a uniaxial elastic-perfectly plastic gap material (ElasticPPGap), with zero tensile capacity.

The behavior of the material was based on a simplification of a typical compression load-displacement curve depicted in Figure 5. In this idealization, the soil is assumed to behave as a linear elastic material while the applied load is below the yield force of the soil. Once the load surpasses the yield point, the stiffness of the soil is then reduced to the post yield stiffness, which is defined as a percentage of the original elastic stiffness. Moreover, with the addition of the gap element in the material definition, removing the load after the material had entered the inelastic regime would result in permanent plastic deformation of the spring element, with only a small amount of elastic rebound. As noted above, the cohesion or tensile capacity of the soil was assumed negligible, and the spring elements provided zero resistance to uplift of the footing.

Fig. 5. Typical axial load versus vertical displacement curve for spread footing, depicting actual (black) and idealized bilinear (red) soil behavior. Schematic modified from FHWA 2010.

In order to conform to the method outlined ASCE 41-13, the springs within a distance of $B/6$ from the edge of the foundation were assigned a higher elastic stiffness, in order to match the translational and rotational stiffness obtained from an elastic approach (ASCE 2013). This increased elastic stiffness was approximately 9.4 times that of the inner springs, and the stiffness of the inner springs was a user-defined parameter. However, the post yield stiffness for both the edge and center springs was equal, as it was no longer appropriate to compare the inelastic

behavior to an elastic solution. As a result, while the end zone springs had a larger elastic stiffness, they had the same post-yield stiffness as the inner springs.

Unlike the superstructure, Rayleigh damping was neglected for the Winkler springs. Because the soil spring elements had highly variable stiffness, setting the Rayleigh damping as a function of the initial stiffness matrix would result in an artificially over-damped structure, which would yield unrealistic results (Charney 2008). The most accurate method of calculating the Rayleigh damping of the soil would be to update the stiffness matrix at each simulation increment, which would capture the variable stiffness of the system. However, this would require an eigenvalue analysis of the system to be performed at every step of the simulation, which would be impractical given the computational resources available. Accordingly, it was decided to neglect Rayleigh damping for the soil elements, which was found to provide comparable results to the damping defined as a function of the current stiffness matrix. For more insight into the decision to neglect Rayleigh damping for the soil elements, the reader is encouraged to reference the aforementioned paper.

2.5 Independent Parameters

Based on the definition of the structure and soil, a total of 9 independent parameters were identified as depicted in Figure 6, which could be varied in each of the simulations. In order to formulate the nondimensional parameters, a number of simulations were run in which each of the independent parameters were incrementally increased from a lower bound to an upper bound value, while the remaining parameters were held at a constant “base” value. The upper and lower bounds of each of these parameters were selected as the values that would push the structure outside of the period range of interest (0.5 – 5 seconds), or were otherwise restrained by some other criteria, as denoted in Table 2.

Fig. 6. Independent parameters defining the system

Height of the Structure

The height of the structure was defined as the distance from the bottom of the spread footing to the top node at which the mass of the structure was assigned. The height for the simulations ranged from 70-370 inches, corresponding to fundamental periods of the structure ranging from 0.5 to 5 seconds, respectively. The base value was selected as 240 inches, based on an example structure discussed by Kourkoulis et. al. 2012.

Width of the Footing

The width of the footing was defined as the length between edges of the square foundation. The minimum value was chosen as that which would provide a vertical factor of safety (FSV) for the base structure of 1, the max value was selected based on a Height/Width ratio 1, and the base value was chosen assuming a Height/Width ratio of 2.

Width of the Column

In the model, the geometric properties of the column were defined for a square column, with a width ranging from 21 to 100 inches. These bounds correspond to a fundamental period of 5 seconds, and a column diameter at which the superstructure acts as a rigid body, respectively. The base width of the column was chose somewhat arbitrarily assuming an aspect ratio of the column of 8.

Modulus of Elasticity of the Column

The modulus of elasticity of the column material ranged from 1.8×10^6 PSI to 29×10^6 PSI, for 1,000 PSI compressive strength concrete and steel, respectively. The base value was selected based on a concrete column with compressive strength of 6,000 PSI.

Lumped Mass

The upper and lower bounds on the lumped mass at the top of the column were selected based on fundamental periods of the base structure of 0.5 and 5 seconds, respectively. The mass used for the base condition was selected from the aforementioned example Kourkoulis et. al. 2012.

Soil Elastic Subgrade Modulus

The elastic subgrade modulus of the soil is a measurement of the elastic stiffness of the soil, per unit area, per unit displacement. For the purpose of modeling the elastic soil springs, it can be interpreted as the stiffness of the springs in force per vertical displacement, per unit of tributary area of the respective soil spring under consideration. The magnitude of the elastic subgrade modulus multiplied by the tributary area of the spring produces the elastic slope of Figure 5. The range of subgrade modulus values ranged from 18-470 lbf/in³, corresponding with values associated with loose and dense sand, respectively, and incorporating the values of silty and clayey soils within that range (Bowles 1996). The base value of 250 lbf/in³ was arbitrarily chosen in the middle of that range, and corresponds with that of a medium dense sand or clayey sand.

Soil Yield Pressure

The soil yield pressure was defined as the pressure that would cause the soil to transition from elastic to inelastic behavior. The base soil yield pressure of 31.25 psi was chosen as the allowable vertical foundation pressure of clay and silt of 1500 psf, multiplied by a factor of safety of 3 (ICC 2009). Likewise, the upper bound of the soil yield pressure corresponds with the allowable bearing pressure for crystalline bedrock of 12,000 psf, multiplied by a factor of safety of 3. The lower bound of the soil yield pressure corresponds with that which would result in a factor of safety against vertical for the base structure of 1.0. As with the elastic subgrade modulus, the yield pressure of the spring is multiplied by its respective tributary area to provide the force to cause inelastic behavior. The yield displacement, which is used to normalize the residual vertical displacement of the structure, is defined as the soil yield pressure divided by the elastic subgrade modulus. The breakpoint at which the behavior of the spring transitions from elastic to inelastic corresponds with the soil yield force and soil yield displacement in Figure 5.

Post-Yield Subgrade Modulus

The post-yield subgrade modulus, when multiplied by the tributary area of the soil spring, provided the post yield stiffness of the spring, as depicted in the second slope of Figure 5. This value is defined as a percentage of the elastic stiffness of the spring element, ranging from 0 to 70%, the latter of which resulted in numerical instability of the model.

Structure Weight

For the purpose of analysis, the weight was decoupled from the mass of the structure, such that the two parameters were independent. This was performed such that nondimensional parameters defining the gravitational load on the structure, such as the factor of safety against vertical, could be decoupled from the dynamic loads on the structure, related to the acceleration of the mass. Intuitively, this decoupling of mass and weight can be justified due to different tributary areas of the element in the example of a bridge, and different load combinations in the case of a building, such as dead and live load. The base weight of 150 kips was chosen assuming the base structure has a factor of safety against vertical of 3, which is typical for a highway bridge (Salgado 2008). The lower and upper bounds of 1 and 450 kips correspond with a very lightly loaded structure, and the base structure with a factor of safety against vertical of 1, respectively.

Table 2. Independent Parameters of the Parametric Analysis

Independent Parameter	Range (Min-Max)	Base Value	Reference
Height (in.)	70 - 370	240	Kourkoulis 2012
Width of Footing (in)	73 - 240	120	-
Column Diameter (in)	21 - 100	30	-
Column Elastic Modulus (Lbf/in ²) (10 ⁶)	1.1 -30	4.4	-
Mass (Slugs)	350 – 35,000	10,250	Kourkoulis 2012
Soil Elastic Subgrade Modulus (Lbf/in ³)	18 - 471	250	Bowles 1996, T. 9-1
Soil Yield Strength (Lbf/in ²)	12 - 250	31.25	ICC 2012
Soil Post-Yield Subgrade Modulus(Lbf/in ²)	0 – 70% of Elastic subgrade modulus	30%	-
Structure Weight (Lbf)	15,000 – 405,000	150,000	-

3.0 RESULTS OF PARAMETRIC ANALYSIS

As a result of the parametric analysis, a total of 5 nondimensional parameters were identified, which had a strong influence on the performance of the system during and after the earthquake. These relationships between the parameter and the performance are quantified through the use of demand parameters, which are discussed in the next section. Additionally, the influence of these nondimensional parameters on the stability of the system was also explored, through a series of incremental dynamic analyses (IDA), in which the maximum displacement that the structure could accommodate during an earthquake was identified as a function of the parameter.

3.1 Engineering Demand Parameters

Max Lateral Displacement / Height

The first demand parameter consists of the maximum lateral displacement measured at the lumped mass at the top of the structure during the earthquake, normalized by the total height of the structure. This parameter is effectively a measurement of total drift of the top of the structure, relative to the foundation, and can also be thought of as the max rotation of the structure in radians. This value can be related to the displacement at which the structure reaches dynamic instability, to obtain an approximate lateral or dynamic factor of safety against toppling. Further, the rotation of the structure may be a serviceability consideration, due to the potential hazard of colliding with adjacent structures, if displacement should be excessive.

Max Lateral Displacement / Spectral Displacement

The second demand parameter is similar to the first, but normalizes the maximum lateral drift by the elastic spectral displacement of the column, assuming fixed base conditions. Due to the rocking behavior of the foundation, this value is typically greater than unity, indicating that a rocking foundation will usually have larger displacements than the elastic fixed-base equivalent. By finding a relationship between this demand parameter and the nondimensional parameter, the fixed-base spectral displacement of a rocking structure, from its elastic period, could be scaled to estimate the actual displacement due to rocking behavior.

Residual Lateral Displacement / Height

By normalizing the residual lateral displacement of the top node by the height of the structure, the resulting nondimensional engineering demand parameter is equivalent to the residual rotation of the structure in radians. This parameter yields an intuitive way to approximate the residual displacement of a bridge deck relative to the approaching roadway, or of the residual story drift of a structure relative to the foundation. One of the benefits of a rocking foundation stems from the apparent ability of the structure to self-center after an earthquake (Gajan and Kutter 2008, Antonellis et al. 2014, Loli et al. 2014). However, because of the randomness of the ground motion, and the possible dependency of the residual lateral drift of the structure on the characteristics of the ground motion, the relationship between this demand parameter and any nondimensional parameters will likely have a large standard deviation.

Residual Lateral Displacement / Spectral Displacement

In addition to the height of the structure, the residual lateral displacement was also normalized by the spectral displacement of the structure. This was performed in order to account for any change in the residual lateral displacement caused by the soil stiffness or footing size, which would affect the period of the structure.

Residual Vertical Displacement / Yield Displacement

One of the drawbacks of rocking foundations is the apparent increased vertical settlement following an earthquake, associated with the lower vertical factor of safety that stems from the smaller footing size (Loli et al. 2014). In order to quantify the settlement of the structure, the residual vertical displacement is normalized by the yield displacement, which is the amount of elastic settlement that the soil can withstand before exhibiting nonlinear behavior. From a numerical approach, the yield displacement, as depicted in Figure 5, can be approximated as the yield stress of the soil divided by the elastic subgrade modulus.

Max Dynamic Displacement / Max Static Displacement

The max dynamic displacement was obtained as a result of running a number of incremental dynamic analyses, and was defined for the purpose of this study as the maximum lateral displacement that a structure could achieve due to dynamic excitation without toppling. This value is of interest in the study of rocking structures, as there is some degree of uncertainty of when the potentially beneficial rocking behavior of the system may result in toppling of the structure. To normalize this parameter, the value was divided by the maximum static displacement, which was defined as the displacement that would result in the toppling of the structure due to a statically applied load at the mass of the structure. The max static displacement was approximated as half of the width of the footing, which is the toppling displacement for a rigid block rotating about its corner. This parameter was of interest in this study, as the variability of the stability of the structure could be studied as a function of the system parameters. Additionally, the effect of the earthquake characteristics on the stability of the system was also of interest, and this could be studied by quantifying the stability of the system when subjected to a number of different ground records.

3.2 System Parameters Not Used

As a result of the parametric analysis, all independent variables in the system are captured within the nondimensional parameters with the exception of the diameter of the column, and the modulus of elasticity of the material comprising the column. These parameters were found to have negligible influence on the dynamic behavior of the system, relative to the other independent variables.

3.3 Nondimensional Parameters

The following is a discussion of each of the nondimensional parameters that were discovered as a result of this study, the physical significance of each parameter, and the relationship between that parameter and the demand parameters. In each case, the nondimensional parameter of interest is varied by increasing each independent variable within that parameter, while holding all other nondimensional parameters constant.

Aspect Ratio

The first nondimensional parameter that was found to be of interest is the Aspect Ratio of the structure, which is the ratio of the height of the column, to the width of the footing, as denoted in Equation 1. This nondimensional parameter captures the overall proportions of the structure, and is an indicator if the structure is short and squat or tall and slender.

$$\text{Aspect Ratio} = \frac{\text{Height of Structure}}{\text{Width of Footing}} \quad \text{EQ (1)}$$

Figure 7 illustrates the variation in engineering demand parameters as a function of the Aspect Ratio, with all other nondimensional parameters held constant. As depicted in (b), (d), and (e), there is a separation in the variables between the width of the footing (red) and the height of the structure (blue) at values of Aspect Ratio below 1.25.

For aspect ratios below 1.25, there are two possible structural responses that can be observed. The first is that of a structure in which the footing is very wide, whereas the column is held at an average height. As depicted in (b) of Figure 7, as the width of the footing becomes very large, and the Aspect Ratio decreases accordingly, the maximum displacement experienced by the structure during the earthquake approaches the spectral displacement of the elastic structure. Accordingly, this indicates that the structure begins to experience fixed-base type behavior, in which flexure of the column is dominating over the rocking of the footing. This is further illustrated by part (e); as the width of the footing becomes larger, and the amount of rocking of the structure decreases, the residual vertical displacement of the structure also decreases. This indicates that the dominance of flexure in this region is shifting the force demands away from the soil, and towards the superstructure, as in the case of conventional structural design.

The second structure that can exist within this region appears to be that which results from the width of the footing held constant, and the column becoming progressively shorter. Because the diameter and modulus of elasticity of the column are constant, as the column becomes shorter, the stiffness of the superstructure is increasing cubically. Accordingly, the structure will begin rocking as a rigid body, with negligible flexure of the column. Because the superstructure will act rigidly, the system will have a relatively short period and small spectral displacement, which results in the larger values denoted in (b) of Figure 7. Likewise, the increased acceleration and reduction in energy dissipated by column flexure results in larger ductility demands placed on the soil, which results in larger vertical settlements illustrated in (e).

In contrast, for structures with Aspect Ratios above 1.25, there is general agreement between the independent parameters, and this indicates that this region is primarily dominated by a combination of rocking and flexure behavior of the system. Within this region, engineering demand parameters are not heavily dependent on the value of the Aspect Ratio; this indicates

that this nondimensional parameter plays a large role in determining what dynamic behavior will dominate within the system, but not a significant role in the performance of the system.

One should note that the aforementioned separation of variables is likely not fixed at a value of 1.25, but may also be a function of the diameter and modulus of elasticity of the column. Accordingly, one can tentatively infer that the point of divergence between flexure dominated and rigid body rocking will be a function of the overall stiffness of the column.

Fig. 7. Aspect Ratio plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Height; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Height; (d) Residual Lateral Displacement/Spectral Displacement; (e) Residual Vertical Displacement/Yield Displacement; (f) Max Dynamic Displacement / Max Static Displacement

Vertical Factor of Safety

The Vertical Factor of Safety of the structure is defined as the product of the yield stress of the soil and the area of the footing, divided by the weight of the structure, as depicted in Equation 2. This nondimensional parameter serves as an indicator of how heavily loaded the structure is, relative to the maximum bearing capacity. In order to relate this parameter to the commonly used ASD design factor of safety for spread footings, the engineer should consider the ultimate bearing capacity of the foundation, at which point the soil would yield, rather than the serviceability limit state.

$$\text{Vertical Factor of Safety} = \frac{\text{Width of Footing}^2 * \text{Yield Stress of Soil}}{\text{Weight of Structure}} \quad \text{EQ (2)}$$

As denoted in (c) and (d) of Figure 8, the residual lateral displacement of the structure tends to be proportional to the factor of safety. Although the deviation of data is quite large, it appears that structures with small values of vertical factor of safety are more prone to large lateral drifts than more lightly loaded structures. This may be due to the bearing stress of the foundation nearing the yield stress of the soil, which makes the system more prone to plastic deformation during rocking. However, one should note that while these more heavily loaded systems are more susceptible to larger residual lateral displacements, it is also possible for these structures to result in negligible lateral drift. Accordingly, while it may not be possible to estimate the exact residual lateral displacement of the structure as a function of the vertical factor of safety, it may be possible to use this parameter to estimate the upper bound of potential lateral drifts.

However, as depicted in part (e), there is a very strong correlation between the vertical factor of safety of the structure and the residual vertical settlement. This indicates that more heavily loaded structures, with foundation bearing stresses near the yield stress of the soil, will experience larger vertical settlements, and more plastic deformation. This correlation can be captured with a power function, as denoted in Equation (3), which was obtained by performing a curve-fitting of the data with MATLAB. This correlation is significant, as not only can it be used to predict the vertical settlement of a rocking structure during an earthquake, but it also illustrates the sensitivity of the vertical settlement to changes in load. Accordingly, this relationship may be useful for both determining both if an existing structure should be retrofitted to avoid vertical settlement, but also for determining the extent of the retrofit. Moreover, this observation agrees with those of Gajan and Kutter (2008), which experimentally showed that the vertical settlement is very sensitive to changes in footing size for low vertical factors of safety.

$$\frac{\text{Residual Vertical Displacement}}{\text{Yield Displacement}} = -21.05 (\text{FSV})^{-1.387} \quad \text{EQ (3)}$$
$$R^2 = 0.9648$$

Fig. 8. Vertical Factor of Safety plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Height; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Height; (d) Residual Lateral Displacement/Spectral Displacement; (e) Residual Vertical Displacement/Yield Displacement; (f) Max Dynamic Displacement / Max Static Displacement

Soil Stiffness Ratio

By comparing the elastic stiffness of the soil to the stiffness of the soil after yielding, denoted in Figure 5 as the post-yield stiffness, a nondimensional parameter can be formed, which hereafter will be referred to as the Soil Stiffness Ratio. This parameter can be thought of as a measure of the strain hardening of the soil, and is mathematically defined in Equation 4 as the post-yield stiffness normalized by the elastic soil stiffness.

$$\text{Soil Stiffness Ratio} = \frac{\text{Post-Yield Soil Stiffness}}{\text{Elastic Soil Stiffness}} \quad \text{EQ (4)}$$

As depicted in (c) and (d) of Figure 9, the residual lateral displacement of the structure tends to be inversely proportional to the Soil Stiffness Ratio. This indicates that soils with a lower degree of strain hardening tend to be more prone to residual lateral displacement. This is may be due to non-uniform yielding of the soil beneath the footing; as the structure rocks, the pressure along the loading edge will increase, and will cause the soil along the edge to

experience more yielding than the soil in the center of the footing. Accordingly, at the end of the ground motion, the soil along the edges of the foundation will have sustained more deformation than the soil in the middle, the magnitude of which will be a function of the stiffness of the soil. Consequently, systems with a lower Soil Stiffness Ratio may experience larger residual lateral displacements, due to an uneven soil profile beneath the footing after cycling.

Further, this increased deformation along the edge of the foundation also results in larger residual vertical displacements, as denoted in (e). This is most pronounced for soils with post-yield stiffness of 10% of the elastic soil stiffness or less. Accordingly, soils with marginal strain hardening, such as very soft clays, loose sands, and liquefiable soils may experience significant vertical settlement, and may require geotechnical mitigation.

Lastly, in the process of yielding, soils with a lower Soil Stiffness Ratio appear to increase the base isolation of the structure, which results in lower seismic forces and accelerations. This is depicted in (f), where this increased base isolation results in lower seismic forces and higher stability for systems with lower values of soil stiffness ratios. Conversely, when the system experiences large amounts of strain hardening of the soil, the amount of base isolation is reduced, which makes the structure more prone to toppling at lower ground motions.

Fig. 9. Soil Stiffness Ratio plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Height; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Height; (d) Residual Lateral Displacement/Spectral Displacement; (e) Residual Vertical Displacement/Yield Displacement; (f) Max Dynamic Displacement / Max Static Displacement

Static Force Ratio

The fourth nondimensional parameter, referred to as the Static Force Ratio, is denoted in Equation 5 as the product of the post-yield stiffness of the soil and the width of the footing, normalized by the weight of the structure. Intuitively, this parameter captures the ability of the system to withstand the static overturning force due to the structural weight, after the soil has yielded.

$$\text{Static Force Ratio} = \frac{(\text{Post Yield Stiffness}) * (\text{Width of Footing})}{(\text{Weight})} \quad \text{EQ (5)}$$

As a result of having a combination of soil with low post-yield stiffness and heavily loaded structures with small foundations, structures with low values of Static Force Ratio may be more susceptible to P-Delta effects. This is a result of low restoring forces at the base of the column, due to a small footing and soil with low post-yield stiffness, and large overturning forces from the self-weight of the structure. As depicted in (c) and (d) of Figure 10, this may result in a larger residual lateral drift of the structure; while the footing and soil reaction are large enough to maintain equilibrium with the weight of the structure, the lower restoring forces are not sufficient for the structure to self-center as effectively. Further, this small ratio of restoring to overturning forces also results in reduced stability of the structure, as denoted in (f); structures with a small Static Force Ratio are more susceptible to toppling, and are more likely to topple at lower ground accelerations, than structures with a large Static Force Ratio.

In addition to capturing the magnitude of P-Delta effects on the system, the Static Force Ratio also captures how prone the system is to inelastic deformation. Accordingly, systems with a small Static Force Ratio, indicating small footings, large structure weight, and soil with low post-yield stiffness, will experience larger inelastic deformations than structures with a larger Static Force Ratio. One might note that this trend is contradictory to that depicted in (e) of Figure 10. In order to decouple the contribution of the Static Force Ratio from the Vertical Factor of Safety, the yield stress is varied proportionally to the weight of the structure, and inversely proportionally to the size of the footing. Likewise, the elastic subgrade modulus of the soil is varied inversely proportionally to the post-yield stiffness, in order to maintain a constant value of Soil Stiffness Ratio. Accordingly, because the residual vertical settlement of the system is normalized by the yield displacement of the system, the trend shown in (e) is rotated 90 degrees from the “true” relationship, due to the variable yield displacement.

Fig. 10. Static Force Ratio plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Height; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Height; (d) Residual Lateral Displacement/Spectral Displacement; (e) Residual Vertical Displacement/Yield Displacement; (f) Max Dynamic Displacement / Max Static Displacement

Dynamic Force Ratio

The final nondimensional parameter is denoted in Equation 6, and is referred to as the Dynamic Force Ratio. Like the Static Force Ratio, this parameter measures the ratio of restoring to overturning forces in the system; however, the overturning forces captured by this parameter are the dynamic overturning forces due to acceleration of the mass of the structure.

$$\text{Dynamic Force Ratio} = \frac{(\text{Post Yield Stiffness}) * (\text{Width of Footing})}{(\text{SaT}) * (\text{Mass}) * (g)} \quad (\text{EQ } 6)$$

As denoted in (c) and (e) of Figure 11, there is a strong correlation between the Dynamic Force Ratio and the residual and vertical displacement, respectively. As shown in Equation 6, smaller values of the Dynamic Force Ratio indicate that large dynamic demands are placed on

the system, relative to the restoring forces due to the area of the footing and stiffness of the soil. Accordingly, in order to dissipate the seismic forces, larger ductility demands are placed on the underlying soil, which results in larger values of displacement and settlement.

Further, this parameter can also be used to relate the performance of a system across return periods, as the mass of the structure is multiplied by the spectral acceleration. Accordingly, this parameter may be used to compare the residual displacement or settlement of a structure for an event with a 10% probability of exceedance in 50 years against that with a 2% probability of exceedance in 50 year.

Fig. 11. Dynamic Force Ratio plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Height; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Height; (d) Residual Lateral Displacement/Spectral Displacement; (e) Residual Vertical Displacement/Yield Displacement; (f) Max Dynamic Displacement / Max Static Displacement

3.4 Earthquake Parameters

Numerous attempts have historically been made to numerically define the properties of ground records, in an attempt to quantify the energy, intensity, duration, and destructiveness of the earthquake. In this study, two of these parameters, the Arias Intensity and Significant Duration, were explored in order to determine the relationship between these earthquake parameters and the engineering demand parameters. In order to normalize the earthquake parameters across return periods, the engineering demand parameters were divided by the

spectral displacement of the structure. Additionally, for the Arias Intensity, the earthquake parameter was also normalized by the spectral displacement.

Arias Intensity

The Arias Intensity is a ground motion parameter that attempts to capture the intensity or destructiveness of an earthquake, by integrating the square of the acceleration time-history over the duration of the record. As depicted in Figure 12 (a), there is a moderate correlation between the Arias Intensity and the max lateral displacement of the structure. This indicates that ground records with larger accelerations will cause a rocking structure to experience larger displacements.

Fig. 12. Arias Intensity normalized by spectral displacement plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Spectral Displacement; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Spectral Displacement

Significant Duration

The significant duration, abbreviated as SD_{5-95} , is defined as the amount of time for the Arias Intensity, which is a cumulative quantity, to increase from 5% to 95% of the total value. Accordingly, it is an estimation of the amount of time it takes the ground record to impart 90% of the total energy to the system. As denoted in (c) of Figure 13, there is a strong correlation between the Significant Duration of the event with the residual vertical settlement, as one might expect. The vertical settlement of the structure is a function of the number of rocking cycles that the footing experiences during the earthquake, and the greater the number of cycles, the larger the vertical settlement. The number of cycles, in turn, will be a function of the duration of the ground excitation, as well as the dynamic properties of the system. Accordingly, longer duration earthquakes, such as subduction records, will result in larger values of inelastic deformation than shorter shallow crustal events.

Fig. 13. Significant Duration (SD5-95) plotted relative to engineering demand parameters: (a) Max Lateral Displacement/Spectral Displacement; (b) Max Lateral Displacement/Spectral Displacement; (c) Residual Lateral Displacement/ Spectral Displacement

4.0 CONCLUSIONS

This paper examined the seismic performance of a series of rocking structures subjected to bidirectional ground excitation. These structures were idealized as single degree of freedom oscillators, with a lumped mass at the top of an elastic column, attached to a rigid elastic foundation. The soil-structure interaction was modeled with a series of nonlinear Winkler springs, with the soil behavior idealized as linear-elastic, perfectly-plastic with strain hardening, a gap element, and the ability to accumulate damage. The ground accelerations consisted of a series of 6 shallow crustal records, spectrally matched to target spectra for 8 return periods, with each horizontal component applied orthogonally to the structure. A parametric study was conducted which consisted of incrementally varying each independent parameter within the system. This allowed a series of nondimensional parameters to be developed, which capture the performance of the system as a result of seismic excitation. These nondimensional parameters provide further insight into the behavior of rocking structures subject to seismic excitation, and may assist in future development of design criteria and performance prediction equations.

1. The Aspect Ratio, which relates the height of the column to the width of the footing, plays a role in determining the dynamic behavior of the system. For structures with an Aspect Ratio less than 1.25, two different behaviors can exist; structures with a base that acts fixed with flexure of the column dominating, or structures with very rigid columns which continue to rock as rigid bodies. The fixed-base condition occurs when the footing becomes relatively wide, whereas the column has a relatively low stiffness. Conversely, the rigid-rocking behavior occurs when the column is short with respect to its diameter, which results in a relatively rigid column. For structures with an Aspect Ratio above 1.25, the behavior of the system is dominated by a combination of flexure of the column and rocking of the foundation. One should note that this point of divergence in behavior is likely a function of diameter and modulus of elasticity of the column, and may vary as a function of the column stiffness.
2. The Vertical Factor of Safety of the structure is a measurement of how heavily loaded the structure is, relative to the ultimate bearing capacity of the underlying soil. While the residual lateral displacement of a structure tends to be quite random, structures with a lower Vertical Factor of Safety tend to be more prone to larger residual lateral displacements. Further, the residual vertical settlement of the structure, normalized by the plunge displacement has a very strong power-function relationship with the Vertical Factor of Safety. Accordingly, these relationships can be used to approximate the amount of inelastic deformation that will occur within the system due to the loading of the structure.
3. The Soil Stiffness Ratio is a ratio of the elastic soil stiffness to the stiffness of the soil after it has yielded, assuming bilinear elasto-plastic behavior, and captures the magnitude of strain-hardening of the soil. For systems with a low Soil Stiffness Ratio, the structure will be prone to residual lateral displacement and vertical settlement, possibly due to an uneven soil profile beneath the footing and increased soil yielding. However, because the increased amount of inelastic deformation results in a larger degree of energy dissipation, these systems tend to be more stable due to increased base isolation. Conversely, structures with higher Soil Stiffness Ratios will experience lower residual lateral and vertical settlements, as the soil is

less prone to inelastic deformation. However, the lower deformation leads to reduced base isolation, which results in a structure that is more prone to toppling.

4. The Static Force Ratio relates the ability of the system to withstand settlement and overturning due to the soil stiffness and footing size, to the magnitude of the static and P-Delta overturning forces due to the weight of the structure. It appears that smaller values of the Static Force Ratio are more prone to residual lateral displacement; this may be due to the inability of the structure to self-center if P-Delta effects are large relative the restoring forces at the base of the footing. Further, these systems are more prone to toppling due to the contribution of P-Delta to the overturning forces acting on the structure.
5. The Dynamic Force Ratio relates the ability of the system to resist dynamic overturning forces, due to acceleration of the mass of the structure during an earthquake. Larger values, indicating a higher dynamic demand on the system relative to the restoring forces, will result in greater ductility demands on the soil. These ductility requirements lead to greater inelastic behavior of the system, which results in larger residual lateral displacements and vertical settlements. Further, by approximating the acceleration of the mass as the spectral acceleration of a structure rocking on elastic soil, the performance of a system can be compared across different return periods. From this, the settlement and drift of a structure can be estimated for various levels of seismic hazard, as a function of the importance and expected lifespan of the structure.
6. The ground motion parameters of an earthquake, which attempt to quantify the intensity and duration of an earthquake, have an influence on the behavior of the system. Ground records with larger values of Arias Intensity result in larger max displacements of the structure, possibly due to larger values of acceleration within the record. Concurrently, the Significant Duration of the record has a strong correlation with the residual vertical displacement of the structure, due to the dependence of the settlement on the number of cycles of the structure.

5.0 RECOMMENDATIONS FOR FUTURE RESEARCH

In order for the use of rocking foundations as an alternative to conventional design to be accepted by the engineering community, additional research and testing must be conducted to better understand the behavior of these structures. As such, the following are potential areas in which the study presented can be expanded.

- Determine how the point of divergence with respect of the Aspect Ratio is affected by diameter and modulus of elasticity of the column, and find ways to approximate this value.
- Perform a least-squares regression fitting of the nondimensional parameters, in order to create design equations that can be used to approximate the response of the system.
- Perform similar parametric analyses with more complex soil models, such as Mohr-Coulomb soil plasticity, and test the application of these nondimensional parameters to these models.
- Introduce sliding into the model, which will add an additional 2 degrees of freedom, and develop parameters that capture the combined sliding and rocking behavior of the system.
- Perform similar parametric analyses on multi-column bridge bents, to explore how the connecting members affect the behavior of the system.
- Compare experimental results to the behavior predicted by these nondimensional parameters.

6.0 REFERENCES

- Anastasopoulos, I., Gelagoti, F., Spyridaki, A., Sideri, J., and Gazetas, G. (2014). "Seismic Rocking Isolation of an Asymmetric Frame on Spread Footings." *J. Geotech. Geoenviron. Eng.*, 140(1), 133–151.
- Anastasopoulos, I., Kontoroupi, Th., (2014), "Simplified approximate method for analysis of rocking systems accounting for soil inelasticity and foundation uplifting", *Soil Dynamics and Earthquake Engineering*, 56, 28-43.
- Antonellis G, Gavras AG, Panagiotou M, Kutter BL, Sander A, Guerrini G and Fox PJ. (2014). "Shake table test response of large-scale bridge columns supported on rocking shallow foundations." *Proceedings of the 10th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Anchorage, AK.
- ASCE (American Society of Civil Engineers). (2013). *Seismic Rehabilitation of Existing Buildings*, Reston, Virginia.
- Bowles, J., (1997) *Foundation Analysis and Design 5th ed.* Peoria: McGraw-Hill, "Special Footings and Beams on Elastic Foundations." Pg 505.
- Charney, F., (2008) "Unintended Consequences of Modeling Damping in Structures." *Journal of Structural Engineering*, 10.1061/(ASCE)0733-9445(2008)134:4(581)
- Deng, L., and Kutter, B. L. (2012). "Characterization of rocking shallow foundations using centrifuge model tests." *Earthquake Engineering and Structural Dynamics*, 41, 1043-1060.
- Deng, L., Kutter, B. L., and Kunnath, S. K. (2012). "Centrifuge modeling of bridge systems designed for rocking foundations." *Journal of Geotechnical and Geoenvironmental Engineering*, DOI: 10.1061/(ASCE)GT.1943-5606.0000605.
- Deng, L., Kutter, B., and Kunnath, S. (2014). "Seismic Design of Rocking Shallow Foundations: Displacement-Based Methodology." *J. Bridge Eng.*, 19(11), 04014043.
- Federal Highway Administration. (2010) "SELECTION OF SPREAD FOOTINGS ON SOILS TO SUPPORT HIGHWAY BRIDGE STRUCTURES." Publication No. FHWA-RC/TD-10-001
- Gajan, S., and Kutter, B.L. (2008), "Capacity, Settlement, and Energy Dissipation of Shallow Footings Subjected to Rocking" *J. Geotech. Geoenviron. Eng.* 10.1061/(ASCE) 1090-0241(2008)134:8(1129)
- Gelagoti, F., Kourkoulis, R., Anastasopoulos, I., Gazetas, G., (2012) "Rocking-isolated frame structures: Margins of safety against toppling collapse and simplified design approach" *Soil Dynamics and Earthquake Engineering*, 32(1), 87-102

Harden, C., Hutchinson, T., Moore, M., (2006). "Investigation into the Effects of Foundation Uplift on Simplified Seismic Design Procedures". *Earthquake Spectra*, 22(3), 663-692.

ICC (International Code Committee). (2009). *2009 International Building Code*, Country Club Hills, Ill.

Kourkoulis, R., Anastasopoulos, I., Gelagoti, F., Kokkali P., (2012), "Dimensional Analysis of SDOF Systems Rocking on Inelastic Soil", *Journal of Earthquake Engineering*, 16(7), 995-1022

Loli, M., Knappett, J.A., Brown, M.J., Anastasopoulos, I., Gazetas, G. (2014). "Centrifuge modeling of rocking-isolated inelastic RC bridge piers." *Earthquake Engng Struct. Dyn.*, 43(15), 2341-2359.

Mergos, P.E., Kawashima, K. (2005) "Rocking Isolation of a Typical Bridge Pier on Spread Foundation", *Journal of Earthquake Engineering*. 9(2), 395-414.

Salgado, R., (2008), *The Engineering of Foundations*. McGraw Hill, Boston

7.0 APPENDIX

7.1 Validation of OpenSees Model

In an attempt to validate the results of the OpenSees model, a comparable 2-dimensional finite element analysis (FEA) model was constructed in Abaqus, as depicted in Figure 6. This model was then used to conduct both a dynamic time-history analysis, as well as a static pushover test. The results of the two models were then compared, in an attempt to expose any fundamental flaws in the OpenSees model. The results of the FEA model, in turn, were compared against theoretical soil stress distributions and shear planes to validate the FEA model. However, because the FEA model was only intended to verify the results of the OpenSees model, the model and results are only discussed briefly.

FEA Model Definition

The superstructure of this model is depicted in Figure 6, and the dimensions are approximately those corresponding with the base values denoted in Table 2. This part was meshed with a series of CPS4R plane stress elements, designated by Abaqus as “4-node bilinear plane stress quadrilateral, reduced integration, hourglass control”. These elements were the default selection for a part generated as a 2D deformable planer shell, and were retained because this part of the assembly remained linear elastic. Further, the part was divided into these elements by applying a quad-dominated free meshing to the structure, which was found to produce the most desirable meshing pattern. The material was defined as being linear-elastic, and plasticity characteristics were not applied to the concrete for the reasons noted above; the purpose of a rocking foundation is to ensure that the concrete remains within the linear-elastic regime, and does not undergo cracking or spalling.

In contrast with the superstructure, which was defined as a plane stress elements, the soil block was defined as a CPE4R plain strain element, which was designated by Abaqus as a “4-node bilinear plane strain quadrilateral, reduced integration, with hourglass control”. It was determined that it was not possible to use a plane stress element in combination of Mohr-Coulomb plasticity, as this would result in an error message from Abaqus. As with the superstructure, the part was discretized into elements through the use of a quad-dominated free meshing technique. This method was chosen, as it allowed a very dense meshing at the soil-structure interaction (SSI), which would experience the largest stress gradients, and lower mesh distribution along the boundaries. The mesh was gradually transitioned from the fine mesh at the SSI to the courser meshing along the perimeter, with the rate of mesh change being proportional to the stress gradients. There are many different plasticity models in Abaqus that can be used to capture the plastic deformation of soil, including linear-plastic, cap plasticity, clay plasticity, Drucker Prager plasticity, and Mohr-Coulomb plasticity. The latter was chosen for this model, because the parameters used to define the plasticity, such as angle of internal friction and cohesion, can be directly related to a soil type.

Fig. 14. Plastic deformation of soil due to static pushover test of 5000 pounds

FEA and OpenSees Model Comparison

The first comparison between the FEA and OpenSees models involved subjecting both models to the ground motion recorded from the 1994 Northridge Earthquake, which is not part of the ground motion suite denoted in Table 1. In general, the two models show very comparable behavior throughout the duration of the earthquake, with similar residual lateral displacements. The slight discrepancy between the two models likely arises from the differences between the bilinear elastic-plastic idealization used to model the soil in OpenSees, and the Mohr-Coulomb plasticity model used to define the soil in Abaqus.

Additionally, Figure 8 depicts the comparison between the static pushover tests performed for the OpenSees and FEA models. As with the dynamic time-history analysis, the results are comparable between the two models, with the slight discrepancy likely be the result of the different soil plasticity models.

Fig. 15. Dynamic time-history analysis comparison between OpenSees and FEA models

Fig. 16. Static pushover analysis comparison between OpenSees and FEA models

7.2 OpenSees Code

In the interest of transparency, and in order to facilitate future study of the behavior of rocking shallow foundations, several key elements of code used in this project have been amended to this report. For questions, and to request access to the full database of code, please contact Ben Herdrich at bih@pdx.edu.

Alldata.tcl

The main file imported by OpenSees is called “Alldata.tcl”, and is denoted below. This code is where the user defines which ground motion records are to analyzed, sets the values of the independent parameters, and sources a number of other files to construct the model and conduct the analysis.

#Start of Code

#Note while this model is mostly compliant with ATC-40, it only applies the stiffer edge springs to the outer 1/5.5 not the outer 1/6th

wipe;

set model 5
set type "dynamic"

set metadata [open dataBIG/metadata.csv "w"]
puts \$metadata
"simulation,EQrecord,EQtype,ReturnPeriod,ScaleFactor,Variable,Period,SdT,Hc
ol,Xfoot,Mass,Weight,Icol,Ecol,Esoil,FySoil,Vmax,DynamicLoad,DSR,PYstiffne
ss,HardeningRatio,SD,MA,MV,MD,VA,ARMS,VRMS,DRMS,AI,CI,SED,CAV,
ASI,VSI,HI,SMA,SMV,EDA,A95"
close \$metadata

set simulation 0

foreach record1 {

184_1_72RSP
2734_1_72RSP
4228_1_72RSP
4481_1_72RSP
4860_1_72RSP
6959_1_72RSP
184_1_224RSP
2734_1_224RSP
4228_1_224RSP

4481_1_224RSP
 4860_1_224RSP
 6959_1_224RSP
 184_1_475RSP
 2734_1_475RSP
 4228_1_475RSP
 4481_1_475RSP
 4860_1_475RSP
 6959_1_475RSP
 184_1_975RSP
 2734_1_975RSP
 4228_1_975RSP
 4481_1_975RSP
 4860_1_975RSP
 6959_1_975RSP
 184_1_1462RSP
 2734_1_1462RSP
 4228_1_1462RSP
 4481_1_1462RSP
 4860_1_1462RSP
 6959_1_1462RSP
 184_1_2475RSP
 2734_1_2475RSP
 4228_1_2475RSP
 4481_1_2475RSP
 4860_1_2475RSP
 6959_1_2475RSP
 184_1_3712RSP
 2734_1_3712RSP
 4228_1_3712RSP
 4481_1_3712RSP
 4860_1_3712RSP
 6959_1_3712RSP
 184_1_4975RSP
 2734_1_4975RSP
 4228_1_4975RSP
 4481_1_4975RSP
 4860_1_4975RSP
 6959_1_4975RSP

} {

set dT 10000

```

source EQ_Metadata.tcl

wipe;
wipeAnalysis

for {set Hcol 70} {$Hcol <= 370} {incr Hcol 10} {

    set Variable "Height"

incr simulation 1

puts "simulation# $simulation"


model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

#set Hcol 240
set Xfoot 120.
set Bcol 30
set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]

```

```

set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV

```

```

puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icol,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}
for {set Xfoot 73} {$Xfoot <= 240} {incr Xfoot 10} {

set Variable "Xfoot"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
#set Xfoot 120.
set Bcol 30
set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12

```

```

set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]; #K/IN
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]; #K/IN
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

```

```

if {$Type == "pushover"} {source pushover.tcl}
if {$Type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set Bcol 21} {$Bcol <= 100} {incr Bcol 5} {

set Variable "ColumnDiameter"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

```

```

set Hcol 240
set Xfoot 120.
#set Bcol 30
set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

```



```

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icol,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set M 350} {$M <= 35000} {incr M 1500} {

```

```

set Variable "Mass"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
set Xfoot 120.
set Bcol 30
#set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.); #in^2

```

```

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]

```

```

puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set Ecol 1100000} {$Ecol <= 30000000} {incr Ecol 10000} {

    set Variable "Ecolumn"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
set Xfoot 120.
set Bcol 30
set M 10250
#set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 1000000000000

```

```

set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$Type == "pushover"} {source pushover.tcl}
if {$Type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters

```

```

set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set soil_subgrade_modulus 18} {$soil_subgrade_modulus <= 471} {incr
soil_subgrade_modulus 20} {

set Variable "Esoil"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
set Xfoot 120.
set Bcol 30

```

```

set M 10250
set Ecol 4400000; #PSI
#set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}

```

```

if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9;           # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set soil_yield_pressure 12} {$soil_yield_pressure <= 250} {incr
soil_yield_pressure 15} {

set Variable "Fy_soil"

```



```

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
set Xfoot 120.
set Bcol 30
set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
#set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0

```

```

set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
set Esoil_mid [expr 0.73*$soil_stiffness]
set Esoil_end [expr 6.8*$soil_stiffness]
set eta_mid [expr (6.8)/100*6.1]
set eta_end [expr (0.73)/100*6.1]
set PYstiffness [expr $eta_mid*$Esoil_mid]
set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$

```

```

SaT,$Hcol,$Xfoot,$M,$weight,$Icol,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

for {set weight 15000} {$weight <= 405000} {incr weight 20000} {

set Variable "Weight"

incr simulation 1

puts "simulation# $simulation"

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

set doRayleigh 0

set Hcol 240
set Xfoot 120.
set Bcol 30
set M 10250
set Ecol 4400000; #PSI
set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
#set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10

```

```

set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*6.1]
    set eta_end [expr (0.73)/100*6.1]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

mass 0 $M $M $M 1e-9 1e-9 1e-9; # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$type == "pushover"} {source pushover.tcl}
if {$type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]

```

```

set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

```

```

puts ""

```

```

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

```

```

wipe;
wipeAnalysis

```

```

}

```

```

for {set Etamod 0} {$Etamod <= 14} {incr Etamod 1} {

```

```

    set Variable "Eta"

```

```

    incr simulation 1

```

```

    puts "simulation# $simulation"

```

```

model basic -ndm 3 -ndf 6;
set G 386.4
set pi 3.14159265359

```

```

set doRayleigh 0

```

```

set Hcol 240
set Xfoot 120.
set Bcol 30
set M 10250
set Ecol 4400000; #PSI

```

```

set soil_subgrade_modulus 250.; #lbf/in^2/in
set soil_yield_pressure [expr 1500.*3/144]; #psi
set weight 150000

set Dcol $Bcol
set mu 0.25
set Yfoot $Xfoot
set Hfoot 12
set Afoot 100000
set Efoot 3600000
set Gfoot 10000000
set Jfoot 10000000
set Ifooty 100000000000
set Ifootz $Ifooty
set massDens 1e-10
set Acol [expr $Bcol*$Dcol]

set Gcol [expr $Ecol/(2*(1+$mu))]
set Jcol [expr 2.25*$Bcol**4]
set Icolz [expr (1/12.*$Bcol*pow($Dcol,3))]
set Icoly $Icolz

geomTransf PDelta 1 1 0 0
geomTransf PDelta 2 0 1 0

set spring_trib [expr ($Xfoot*$Xfoot)/($model**2.)]; #in^2

# soil parameters
set gap 0
    set soil_stiffness [expr $soil_subgrade_modulus*$spring_trib]; #k/in
    set soil_yield [expr $soil_yield_pressure*$spring_trib]; #kip
    set Pult [expr $soil_yield_pressure*$Xfoot*$Yfoot]; #kip
    set Esoil_mid [expr 0.73*$soil_stiffness]
    set Esoil_end [expr 6.8*$soil_stiffness]
    set eta_mid [expr (6.8)/100*$Etamod]
    set eta_end [expr 0.73/100*$Etamod]
    set PYstiffness [expr $eta_mid*$Esoil_mid]
    set HardeningRatio [expr $eta_end*$Esoil_end/$soil_stiffness]

uniaxialMaterial ElasticPPGap 10 $Esoil_mid $soil_yield $gap $eta_mid damage
uniaxialMaterial ElasticPPGap 11 $Esoil_end $soil_yield $gap $eta_end damage

if {$model == 11} {source 11_spring_geometry.tcl}
if {$model == 5} {source 5_spring_geometry.tcl}
if {$model == 3} {source 3_spring_geometry_ATC.tcl}

```

```

mass 0 $M $M $M 1e-9 1e-9 1e-9;                                # node#, Mx My Mz,
Mass=Weight/g.

#source Display.tcl
source Calc_Modes.tcl
#source Mode_Shape_Display.tcl
source EQ_Spectrum.tcl

if {$Type == "pushover"} {source pushover.tcl}
if {$Type == "dynamic"} {source dynamicBIG.tcl}

#Define Parameters
set FSV [expr $Pult/$weight]
set DynamicLoad [expr $SaT*$G*$M]
set B [expr $weight/($soil_yield_pressure*$Xfoot)]
set e [expr $Xfoot/2-$B/2]
set Vmax [expr $weight*$e/$Hcol]
set DSR [expr $DynamicLoad/$Vmax]
puts $FSV
puts $DSR

puts ""

# Record Metadata
set metadata [open dataBIG/metadata.csv "a"]
puts $metadata
"$simulation,$record1,$EQtype,$ReturnPeriod,$ScaleFactor,$Variable,$Period,$
SaT,$Hcol,$Xfoot,$M,$weight,$Icoly,$Ecol,$soil_subgrade_modulus,$soil_yield
_pressure,$Vmax,$DynamicLoad,$DSR,$PYstiffness,$HardeningRatio,$SD,$M
A,$MV,$MD,$VA,$ARMS,$VRMS,$DRMS,$AI,$CI,$SED,$CAV,$ASI,$VSI,$
HI,$SMA,$SMV,$EDA,$A95"
close $metadata

wipe;
wipeAnalysis

}

}

puts "all done"

```

#End of Code

5_spring_geometry.tcl

This file defines the geometry of the structure, including the designation and location of the nodes within the structure, the elastic-beam columns connecting the nodes, and the zero-length members which comprise the soil-springs. This generates a cantilever column on rigid rocking foundation, with a total of 25 bilinear Winkler springs, organized in a 5x5 grid. The outermost edge springs are stiffer than the inner springs, per ASCE 41-13.

#Footing Nodes

	# Node #		X			Z
	Y					
node	0	[expr 0.5	*\$Xfoot]		[expr 0.5	*\$Yfoot]
	\$Hcol					

# Node #	X		Z
Y			
# nodal coordinates:			

	# Node #		X		Y	
	Z					
node	1	[expr 0.1	*\$Xfoot]		[expr 0.1	*\$Yfoot]
	0					
node	2	[expr 0.1	*\$Xfoot]		[expr 0.3	*\$Yfoot]
	0					
node	3	[expr 0.1	*\$Xfoot]		[expr 0.5	*\$Yfoot]
	0					
node	4	[expr 0.1	*\$Xfoot]		[expr 0.7	*\$Yfoot]
	0					
node	5	[expr 0.1	*\$Xfoot]		[expr 0.9	*\$Yfoot]
	0					
node	6	[expr 0.3	*\$Xfoot]		[expr 0.1	*\$Yfoot]
	0					
node	7	[expr 0.3	*\$Xfoot]		[expr 0.3	*\$Yfoot]
	0					
node	8	[expr 0.3	*\$Xfoot]		[expr 0.5	*\$Yfoot]
	0					
node	9	[expr 0.3	*\$Xfoot]		[expr 0.7	*\$Yfoot]
	0					
node	10	[expr 0.3	*\$Xfoot]		[expr 0.9	*\$Yfoot]
	0					

node	11	[expr	0.5	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	12	[expr	0.5	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	13	[expr	0.5	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	14	[expr	0.5	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	15	[expr	0.5	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	16	[expr	0.7	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	17	[expr	0.7	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	18	[expr	0.7	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	19	[expr	0.7	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	20	[expr	0.7	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	21	[expr	0.9	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	22	[expr	0.9	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	23	[expr	0.9	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	24	[expr	0.9	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	25	[expr	0.9	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						

nodal coordinates:

	# Node #		X		Y		
	Z						
node	201	[expr	0.1	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	202	[expr	0.1	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	203	[expr	0.1	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	204	[expr	0.1	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						

node	205	[expr	0.1	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	206	[expr	0.3	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	207	[expr	0.3	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	208	[expr	0.3	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	209	[expr	0.3	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	210	[expr	0.3	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	211	[expr	0.5	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	212	[expr	0.5	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	213	[expr	0.5	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	214	[expr	0.5	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	215	[expr	0.5	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	216	[expr	0.7	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	217	[expr	0.7	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	218	[expr	0.7	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	219	[expr	0.7	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	220	[expr	0.7	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						
node	221	[expr	0.9	*\$Xfoot]	[expr	0.1	*\$Yfoot]
	0						
node	222	[expr	0.9	*\$Xfoot]	[expr	0.3	*\$Yfoot]
	0						
node	223	[expr	0.9	*\$Xfoot]	[expr	0.5	*\$Yfoot]
	0						
node	224	[expr	0.9	*\$Xfoot]	[expr	0.7	*\$Yfoot]
	0						
node	225	[expr	0.9	*\$Xfoot]	[expr	0.9	*\$Yfoot]
	0						

#fix spring ends

fix 13 1 1 0 0 0 1

fix	201	1	1	1	1	1	1
fix	202	1	1	1	1	1	1
fix	203	1	1	1	1	1	1
fix	204	1	1	1	1	1	1
fix	205	1	1	1	1	1	1
fix	206	1	1	1	1	1	1
fix	207	1	1	1	1	1	1
fix	208	1	1	1	1	1	1
fix	209	1	1	1	1	1	1
fix	210	1	1	1	1	1	1
fix	211	1	1	1	1	1	1
fix	212	1	1	1	1	1	1
fix	213	1	1	1	1	1	1
fix	214	1	1	1	1	1	1
fix	215	1	1	1	1	1	1
fix	216	1	1	1	1	1	1
fix	217	1	1	1	1	1	1
fix	218	1	1	1	1	1	1
fix	219	1	1	1	1	1	1
fix	220	1	1	1	1	1	1
fix	221	1	1	1	1	1	1
fix	222	1	1	1	1	1	1
fix	223	1	1	1	1	1	1
fix	224	1	1	1	1	1	1
fix	225	1	1	1	1	1	1

#element elasticBeamColumn \$eleTag \$iNode \$jNode \$A \$E \$G \$J \$Iy \$Iz
\$transfTag <-mass \$massDens> <-cMass>

#column

element	elasticBeamColumn	0	13	0	\$Acol	\$Ecol	\$Gcol
	\$Jcol	\$Icoly	\$Icolz	1			

#foundation

element	elasticBeamColumn	1	1	2	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	2	2	3	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	3	3	4	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	4	4	5	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	5	6	7	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	6	7	8	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	7	8	9	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	8	9	10	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	9	11	12	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	10	12	13	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	11	13	14	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	12	14	15	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	13	16	17	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	14	17	18	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	15	18	19	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	16	19	20	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	17	21	22	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	18	22	23	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	19	23	24	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	20	24	25	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 1 -mass				\$massDens
element	elasticBeamColumn	21	1	6	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens

element	elasticBeamColumn	22	2	7	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	23	3	8	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	24	4	9	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	25	5	10	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	26	6	11	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	27	7	12	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	28	8	13	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	29	9	14	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	30	10	15	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	31	11	16	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	32	12	17	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	33	13	18	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	34	14	19	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	35	15	20	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	36	16	21	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	37	17	22	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	38	18	23	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	39	19	24	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens
element	elasticBeamColumn	40	20	25	\$Afoot \$Efoot \$Gfoot
	\$Jfoot \$Ifooty\$Ifootz 2 -mass				\$massDens

```
#element zeroLength $eleTag $iNode $jNode -mat $matTag1 $matTag2 ... -dir
$dir1 $dir2 ...<-doRayleigh $rFlag> <-orient $x1 $x2 $x3 $yp1 $yp2 $yp3>
```

```
element zeroLength 1001 1 201 -mat 11 -dir 3 -doRayleigh
$doRayleigh
```

element	zeroLength	1002	2	202 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1003	3	203 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1004	4	204 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1005	5	205 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1006	6	206 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1007	7	207 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1008	8	208 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1009	9	209 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1010	10	210 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1011	11	211 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1012	12	212 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1013	13	213 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1014	14	214 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1015	15	215 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1016	16	216 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1017	17	217 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1018	18	218 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1019	19	219 -mat	10 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1020	20	220 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1021	21	221 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1022	22	222 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1023	23	223 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					
element	zeroLength	1024	24	224 -mat	11 -dir 3 -doRayleigh
\$doRayleigh					

```

element      zeroLength    1025  25    225 -mat      11 -dir 3 -doRayleigh
$doRayleigh

```

2475TargetSpectrum.tcl

This file defines the acceleration and displacement response spectrum for the 2475 year return period. The spectral pseudo-acceleration of the structure is defined by interpolating along the curve of the response spectrum based on the elastic rocking period of the structure. Similar files exist for the other return period.

#Start of Code

```

if      {$Period <0.1 } {set SaT [expr 1.2013+(0.9538-
1.2013)*(($Period-0.2)/(0.1-0.2))]}
if      {$Period >0.1 } {set SaT [expr 1.2013+(0.9538-
1.2013)*(($Period-0.2)/(0.1-0.2))]}
if      {$Period >0.2 } {set SaT [expr 0.9538+(1.2013-
0.9538)*(($Period-0.1)/(0.2-0.1))]}
if      {$Period >0.3 } {set SaT [expr 1.2013+(1.1027-
1.2013)*(($Period-0.2)/(0.3-0.2))]}
if      {$Period >0.4 } {set SaT [expr 1.1027+(0.9477-
1.1027)*(($Period-0.3)/(0.4-0.3))]}
if      {$Period >0.5 } {set SaT [expr 0.9477+(0.8411-
0.9477)*(($Period-0.4)/(0.5-0.4))]}
if      {$Period >0.6 } {set SaT [expr 0.8411+(0.7289-
0.8411)*(($Period-0.5)/(0.6-0.5))]}
if      {$Period >0.7 } {set SaT [expr 0.7289+(0.6455-
0.7289)*(($Period-0.6)/(0.7-0.6))]}
if      {$Period >0.8 } {set SaT [expr 0.6455+(0.581-
0.6455)*(($Period-0.7)/(0.8-0.7))]}
if      {$Period >0.9 } {set SaT [expr 0.581+(0.5295-
0.581)*(($Period-0.8)/(0.9-0.8))]}
if      {$Period >1   } {set SaT [expr 0.5295+(0.4873-
0.5295)*(($Period-0.9)/(1-0.9))]}
if      {$Period >1.1 } {set SaT [expr 0.4873+(0.4446-
0.4873)*(($Period-1)/(1.1-1))]}
if      {$Period >1.2 } {set SaT [expr 0.4446+(0.4088-
0.4446)*(($Period-1.1)/(1.2-1.1))]}
if      {$Period >1.3 } {set SaT [expr 0.4088+(0.3785-
0.4088)*(($Period-1.2)/(1.3-1.2))]}
if      {$Period >1.4 } {set SaT [expr 0.3785+(0.3524-
0.3785)*(($Period-1.3)/(1.4-1.3))]}
if      {$Period >1.5 } {set SaT [expr 0.3524+(0.3298-
0.3524)*(($Period-1.4)/(1.5-1.4))]}
if      {$Period >1.6 } {set SaT [expr 0.3298+(0.3099-
0.3298)*(($Period-1.5)/(1.6-1.5))]}

```

if { \$Period >1.7 }	{set	SaT	[expr 0.3099+(0.2923-
0.3099)*((\$Period-1.6)/(1.7-1.6))]	}		
if { \$Period >1.8 }	{set	SaT	[expr 0.2923+(0.2767-
0.2923)*((\$Period-1.7)/(1.8-1.7))]	}		
if { \$Period >1.9 }	{set	SaT	[expr 0.2767+(0.2627-
0.2767)*((\$Period-1.8)/(1.9-1.8))]	}		
if { \$Period >2 }	{set	SaT	[expr 0.2627+(0.2497-
0.2627)*((\$Period-1.9)/(2-1.9))]	}		
if { \$Period >2.2 }	{set	SaT	[expr 0.2497+(0.2174-
0.2497)*((\$Period-2)/(2.2-2))]	}		
if { \$Period >2.4 }	{set	SaT	[expr 0.2174+(0.1913-
0.2174)*((\$Period-2.2)/(2.4-2.2))]	}		
if { \$Period >2.6 }	{set	SaT	[expr 0.1913+(0.1701-
0.1913)*((\$Period-2.4)/(2.6-2.4))]	}		
if { \$Period >2.8 }	{set	SaT	[expr 0.1701+(0.1526-
0.1701)*((\$Period-2.6)/(2.8-2.6))]	}		
if { \$Period >3 }	{set	SaT	[expr 0.1526+(0.1379-
0.1526)*((\$Period-2.8)/(3-2.8))]	}		
if { \$Period >3.2 }	{set	SaT	[expr 0.1379+(0.1257-
0.1379)*((\$Period-3)/(3.2-3))]	}		
if { \$Period >3.4 }	{set	SaT	[expr 0.1257+(0.1152-
0.1257)*((\$Period-3.2)/(3.4-3.2))]	}		
if { \$Period >3.6 }	{set	SaT	[expr 0.1152+(0.1061-
0.1152)*((\$Period-3.4)/(3.6-3.4))]	}		
if { \$Period >3.8 }	{set	SaT	[expr 0.1061+(0.0981-
0.1061)*((\$Period-3.6)/(3.8-3.6))]	}		
if { \$Period >4 }	{set	SaT	[expr 0.0981+(0.0909-
0.0981)*((\$Period-3.8)/(4-3.8))]	}		
if { \$Period >4.2 }	{set	SaT	[expr 0.0909+(0.0819-
0.0909)*((\$Period-4)/(4.2-4))]	}		
if { \$Period >4.4 }	{set	SaT	[expr 0.0819+(0.074-
0.0819)*((\$Period-4.2)/(4.4-4.2))]	}		
if { \$Period >4.6 }	{set	SaT	[expr 0.074+(0.0672-
0.074)*((\$Period-4.4)/(4.6-4.4))]	}		
if { \$Period >4.8 }	{set	SaT	[expr 0.0672+(0.0612-
0.0672)*((\$Period-4.6)/(4.8-4.6))]	}		
if { \$Period >5 }	{set	SaT	[expr 0.0612+(0.0561-
0.0612)*((\$Period-4.8)/(5-4.8))]	}		
if { \$Period >5.2 }	{set	SaT	[expr 0.0561+(0.05402-
0.0561)*((\$Period-5)/(5.2-5))]	}		
if { \$Period >5.4 }	{set	SaT	[expr 0.05402+(0.05194-
0.05402)*((\$Period-5.2)/(5.4-5.2))]	}		
if { \$Period >5.6 }	{set	SaT	[expr 0.05194+(0.05004-
0.05194)*((\$Period-5.4)/(5.6-5.4))]	}		
if { \$Period >5.8 }	{set	SaT	[expr 0.05004+(0.04832-
0.05004)*((\$Period-5.6)/(5.8-5.6))]	}		


```

if      {$Period      >6      }      {set   SaT   [expr 0.04832+(0.0466-
0.04832)*(($Period-5.8)/(6-5.8))]    }
if      {$Period      >6.5    }      {set   SaT   [expr 0.0466+(0.0431-
0.0466)*(($Period-6)/(6.5-6))]        }
if      {$Period      >7      }      {set   SaT   [expr 0.0431+(0.04-
0.0431)*(($Period-6.5)/(7-6.5))]      }
if      {$Period      >7.5    }      {set   SaT   [expr 0.04+(0.0373-
0.04)*(($Period-7)/(7.5-7))]          }
if      {$Period      >8      }      {set   SaT   [expr 0.0373+(0.035-
0.0373)*(($Period-7.5)/(8-7.5))]      }
if      {$Period      >8.5    }      {set   SaT   [expr 0.035+(0.0329-
0.035)*(($Period-8)/(8.5-8))]          }
if      {$Period      >9      }      {set   SaT   [expr 0.0329+(0.0311-
0.0329)*(($Period-8.5)/(9-8.5))]      }
if      {$Period      >9.5    }      {set   SaT   [expr 0.0311+(0.0295-
0.0311)*(($Period-9)/(9.5-9))]        }
if      {$Period      >10     }      {set   SaT   0.028  }

```

```

if      {$Period      >0.1    }      {set   SdT   [expr
0.470315020882464+(0.0933543800294877-0.470315020882464)*(($Period-
0.2)/(0.1-0.2))]                      }
if      {$Period      >0.2    }      {set   SdT   [expr
0.971353400845716+(0.470315020882464-0.971353400845716)*(($Period-
0.3)/(0.2-0.3))]                      }
if      {$Period      >0.3    }      {set   SdT   [expr
1.48411735716411+(0.971353400845716-1.48411735716411)*(($Period-
0.4)/(0.3-0.4))]                      }
if      {$Period      >0.4    }      {set   SdT   [expr
2.05809312861192+(1.48411735716411-2.05809312861192)*(($Period-
0.5)/(0.4-0.5))]                      }
if      {$Period      >0.5    }      {set   SdT   [expr
2.56831230208195+(2.05809312861192-2.56831230208195)*(($Period-
0.6)/(0.5-0.6))]                      }
if      {$Period      >0.6    }      {set   SdT   [expr
3.0957772731628+(2.56831230208195-3.0957772731628)*(($Period-0.7)/(0.6-
0.7))] }
if      {$Period      >0.7    }      {set   SdT   [expr
3.63943097820976+(3.0957772731628-3.63943097820976)*(($Period-0.8)/(0.7-
0.8))] }
if      {$Period      >0.8    }      {set   SdT   [expr
4.19786399902989+(3.63943097820976-4.19786399902989)*(($Period-
0.9)/(0.8-0.9))]                      }
if      {$Period      >0.9    }      {set   SdT   [expr
4.76951031540882+(4.19786399902989-4.76951031540882)*(($Period-1)/(0.9-
1))] }

```

```

if    {$Period    >1    }    {set    SdT    [expr
5.26541019154365+(4.76951031540882-5.26541019154365)*(($Period-1.1)/(1-
1.1))] }
if    {$Period    >1.1  }    {set    SdT    [expr
5.76170157273208+(5.26541019154365-5.76170157273208)*(($Period-
1.2)/(1.1-1.2))] }
if    {$Period    >1.2  }    {set    SdT    [expr
6.26080200268004+(5.76170157273208-6.26080200268004)*(($Period-
1.3)/(1.2-1.3))] }
if    {$Period    >1.3  }    {set    SdT    [expr
6.76035266343964+(6.26080200268004-6.76035266343964)*(($Period-
1.4)/(1.3-1.4))] }
if    {$Period    >1.4  }    {set    SdT    [expr
7.26290812548557+(6.76035266343964-7.26290812548557)*(($Period-
1.5)/(1.4-1.5))] }
if    {$Period    >1.5  }    {set    SdT    [expr
7.76495463096182+(7.26290812548557-7.76495463096182)*(($Period-
1.6)/(1.5-1.6))] }
if    {$Period    >1.6  }    {set    SdT    [expr
8.26806798770912+(7.76495463096182-8.26806798770912)*(($Period-
1.7)/(1.6-1.7))] }
if    {$Period    >1.7  }    {set    SdT    [expr
8.77468531468609+(8.26806798770912-8.77468531468609)*(($Period-
1.8)/(1.7-1.8))] }
if    {$Period    >1.8  }    {set    SdT    [expr
9.28206607651757+(8.77468531468609-9.28206607651757)*(($Period-
1.9)/(1.8-1.9))] }
if    {$Period    >1.9  }    {set    SdT    [expr
9.77588118824201+(9.28206607651757-9.77588118824201)*(($Period-2)/(1.9-
2))] }
if    {$Period    >2    }    {set    SdT    [expr
10.2986970368114+(9.77588118824201-10.2986970368114)*(($Period-2.2)/(2-
2.2))] }
if    {$Period    >2.2  }    {set    SdT    [expr
10.7848680123644+(10.2986970368114-10.7848680123644)*(($Period-
2.4)/(2.2-2.4))] }
if    {$Period    >2.4  }    {set    SdT    [expr
11.2545566251612+(10.7848680123644-11.2545566251612)*(($Period-
2.6)/(2.4-2.6))] }
if    {$Period    >2.6  }    {set    SdT    [expr
11.7097595509749+(11.2545566251612-11.7097595509749)*(($Period-
2.8)/(2.6-2.8))] }
if    {$Period    >2.8  }    {set    SdT    [expr
12.1474230503876+(11.7097595509749-12.1474230503876)*(($Period-3)/(2.8-
3))] }

```

```

if      {$Period      >3      }      {set      SdT      [expr
12.5983194206118+(12.1474230503876-12.5983194206118)*(($Period-3.2)/(3-
3.2))] }
if      {$Period      >3.2    }      {set      SdT      [expr
13.0342994482941+(12.5983194206118-13.0342994482941)*(($Period-
3.4)/(3.2-3.4))] }
if      {$Period      >3.4    }      {set      SdT      [expr
13.4585343243685+(13.0342994482941-13.4585343243685)*(($Period-
3.6)/(3.4-3.6))] }
if      {$Period      >3.6    }      {set      SdT      [expr
13.864799118483+(13.4585343243685-13.864799118483)*(($Period-3.8)/(3.6-
3.8))] }
if      {$Period      >3.8    }      {set      SdT      [expr
14.2351237486776+(13.864799118483-14.2351237486776)*(($Period-4)/(3.8-
4))] }
if      {$Period      >4      }      {set      SdT      [expr
14.1403403752025+(14.2351237486776-14.1403403752025)*(($Period-4.2)/(4-
4.2))] }
if      {$Period      >4.2    }      {set      SdT      [expr
14.0221449995225+(14.1403403752025-14.0221449995225)*(($Period-
4.4)/(4.2-4.4))] }
if      {$Period      >4.4    }      {set      SdT      [expr
13.9175348492021+(14.0221449995225-13.9175348492021)*(($Period-
4.6)/(4.4-4.6))] }
if      {$Period      >4.6    }      {set      SdT      [expr
13.8010229452526+(13.9175348492021-13.8010229452526)*(($Period-
4.8)/(4.6-4.8))] }
if      {$Period      >4.8    }      {set      SdT      [expr
13.7271459416394+(13.8010229452526-13.7271459416394)*(($Period-5)/(4.8-
5))] }
if      {$Period      >5      }      {set      SdT      [expr
14.2643887514337+(13.7271459416394-14.2643887514337)*(($Period-5.2)/(5-
5.2))] }
if      {$Period      >5.2    }      {set      SdT      [expr
14.8016315612281+(14.2643887514337-14.8016315612281)*(($Period-
5.4)/(5.2-5.4))] }
if      {$Period      >5.4    }      {set      SdT      [expr
15.3401467624466+(14.8016315612281-15.3401467624466)*(($Period-
5.6)/(5.4-5.6))] }
if      {$Period      >5.6    }      {set      SdT      [expr
15.8799343550894+(15.3401467624466-15.8799343550894)*(($Period-
5.8)/(5.6-5.8))] }
if      {$Period      >5.8    }      {set      SdT      [expr
16.4197219477321+(15.8799343550894-16.4197219477321)*(($Period-6)/(5.8-
6))] }

```

```

if    {$Period    >6    }    {set    SdT    [expr
17.823022874208+(16.4197219477321-17.823022874208)*(($Period-6.5)/(6-
6.5))] }
if    {$Period    >6.5  }    {set    SdT    [expr
19.1837476261057+(17.823022874208-19.1837476261057)*(($Period-7)/(6.5-
7))] }
if    {$Period    >7    }    {set    SdT    [expr
20.5356635142974+(19.1837476261057-20.5356635142974)*(($Period-7.5)/(7-
7.5))] }
if    {$Period    >7.5  }    {set    SdT    [expr
21.9242830012636+(20.5356635142974-21.9242830012636)*(($Period-8)/(7.5-
8))] }
if    {$Period    >8    }    {set    SdT    [expr
23.2654325004815+(21.9242830012636-23.2654325004815)*(($Period-8.5)/(8-
8.5))] }
if    {$Period    >8.5  }    {set    SdT    [expr
24.6560095127157+(23.2654325004815-24.6560095127157)*(($Period-9)/(8.5-
9))] }
if    {$Period    >9    }    {set    SdT    [expr
26.0583316765577+(24.6560095127157-26.0583316765577)*(($Period-9.5)/(9-
9.5))] }
if    {$Period    >9.5  }    {set    SdT    [expr
27.4053537515795+(26.0583316765577-27.4053537515795)*(($Period-10)/(9.5-
10))] }
if    {$Period    >10   }    {set    SdT    27.40535375 }

```

#End of Code

Calc_Modes.tcl

This file performs an eigenvalue analysis of the system, and calculates the first two periods and eigenvectors of the system.

#Start of Code

```

set numModes 2

# record eigenvectors
#-----
for { set k 1 } { $k <= $numModes } { incr k } {
    recorder Node -file [format "modes/mode%i.out" $k] -nodeRange 1 6 -dof 1 2
    3 "eigen $k"
}

# perform eigen analysis

```

```

#-----
set lambda [eigen $numModes];

# calculate frequencies and periods of the structure
#-----
set omega {}
set f {}
set T {}
set pi 3.141593

foreach lam $lambda {
    lappend omega [expr sqrt($lam)]
    lappend f [expr sqrt($lam)/(2*$pi)]
    set Period [expr (2*$pi)/sqrt($lam)]
    lappend T [expr (2*$pi)/sqrt($lam)]
}

puts "periods are $T"

# write the output file consisting of periods
#-----
set period "modes/Periods.txt"
set Periods [open $period "w"]
foreach t $T {
    puts $Periods " $t"
}
close $Periods
#End of Code

```

Damping_MDOF.tcl

This file performs an eigenvalue analysis of the system, and calculates the Rayleigh damping matrix of the system based on the mass and initial stiffness matrix. Originally written by Silvia Mazzoni.

```

#Start of Code
# -----
--
# define damping for Multi-DOF system
# apply Rayleigh DAMPING from $xDamp -- from $omegaI & $omegaJ (modes
1&3 recomm. for mdof)
# D=$alphaM*M + $betaKcurr*Kcurrent + $betaKcomm*KlastCommit +
$beatKinit*$Kinitial
#      Silvia Mazzoni, 2006 (opensees-support @berkeley_NO_SPAM_.edu)

```

```

# apply Rayleigh DAMPING from $xDamp -- from $omegaI & $omegaJ (modes
1&3 recomm. for mdof)
set xDamp 0.05
set MpropSwitch 1; # where M/K proportionality lies.
set KcurrSwitch 0 ;
set KcommSwitch 0;
set KinitSwitch 1;

set nEigenI 1; # mode 1
set nEigenJ 3; # mode 3
set lambdaN [eigen [expr $nEigenJ]]; # eigenvalue analysis for nEigenJ
modes
set lambdaI [lindex $lambdaN [expr $nEigenI-1]]; # eigenvalue mode i
set lambdaJ [lindex $lambdaN [expr $nEigenJ-1]]; # eigenvalue mode j

set omegaI [expr pow($lambdaI,0.5)];
set omegaJ [expr pow($lambdaJ,0.5)];
set alphaM [expr
$MpropSwitch*$xDamp*(2*$omegaI*$omegaJ)/($omegaI+$omegaJ)]; # M-
prop. damping; D = alphaM*M
set betaKcurr [expr $KcurrSwitch*2.*$xDamp/($omegaI+$omegaJ)]; # K-
proportional damping; +beatKcurr*KCurrent
set betaKcomm [expr $KcommSwitch*2.*$xDamp/($omegaI+$omegaJ)]; # K-
prop. damping parameter; +betaKcomm*KlastCommitt
set betaKinit [expr $KinitSwitch*2.*$xDamp/($omegaI+$omegaJ)]; # initial-
stiffness proportional damping +beatKinit*Kini

# define damping
rayleigh $alphaM $betaKcurr $betaKinit $betaKcomm; # RAYLEIGH damping

```

#End of Code

dynamic.tcl

This file defines the node displacement recorders, performs the gravity analysis, and performs the dynamic time-history analysis.

```

# Define RECORDERS -----
recorder Node -file Data/DFree_node0_$simulation.txt -time -dT 0.1 -node 0 -dof
1 2 3 disp; # displacements of free nodes

# define GRAVITY -----
timeSeries Linear 1
pattern Plain 1 1 {

```

```

load 0 0. 0. -$weight 0. 0. 0.;                                # node#, FX FY MZ --
superstructure-weight
}
constraints Plain;                                              # how it handles boundary
conditions
numberer Plain;                                                # renumber dof's to
minimize band-width (optimization), if you want to
system BandGeneral;                                           # how to store and solve the
system of equations in the analysis
algorithm Linear;      # use Linear algorithm for linear analysis
integrator LoadControl 0.1;    # determine the next time step for an
analysis, # apply gravity in 10 steps
analysis Static;                # define type of analysis
static or transient
analyze 10;                      # perform gravity analysis
loadConst -time 0.0;             # hold gravity constant and restart
time

#
# create load pattern
timeSeries Path 2 -dt $dT -filePath GMR/$record1.acc -factor $G; # define
acceleration vector from file (dt=0.005 is associated with the input file gm)
pattern UniformExcitation 2 1 -accel 2;    # define where and how
(pattern tag, dof) acceleration is applied

timeSeries Path 3 -dt $dT -filePath GMR/$record2.acc -factor $G; # define
acceleration vector from file (dt=0.005 is associated with the input file gm)
pattern UniformExcitation 3 2 -accel 3;    # define where and how
(pattern tag, dof) acceleration is applied

#recorder Node -file Data/AFree_node0_A_$simulation.txt -timeSeries 2 3 -time
-dT 0.005 -node 0 -dof 1 2 accel;          # displacements of
free nodes
#recorder Node -file Data/AFree_node0_R_$simulation.txt -time -dT 0.005 -node
0 -dof 1 2 3 4 5 6 accel;

# #####
#source Damping_SDOF.tcl
source Damping_MDOF.tcl

# #####

# create the analysis

```

```

wipeAnalysis;                                # clear previously-define analysis
parameters
constraints Plain;                            # how it handles boundary
conditions
numberer Plain;                              # renumber dof's to
minimize band-width (optimization), if you want to
system BandGeneral;                          # how to store and solve the
system of equations in the analysis
algorithm Linear;                            # use Linear algorithm for
linear analysis
integrator Newmark 0.5 0.25 ;                # determine the next time step for an
analysis
analysis Transient;                          # define type of analysis:
time-dependent
analyze 50000 0.005;

#End of Code

```

EQ_Spectrum.tcl

This file identifies which target spectrum OpenSees should refer to in order to calculate the pseudo acceleration, based on the ground record file name.

```

#Start of Code
if { $record1 == "184_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "2734_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "4228_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "4481_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "4860_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "6959_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S1_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S2_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S3_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S4_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S5_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "S6_1_72RSP" } {source 72TargetSpectrum.tcl}
if { $record1 == "184_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "2734_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "4228_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "4481_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "4860_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "6959_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "S1_1_224RSP" } {source 224TargetSpectrum.tcl}
if { $record1 == "S2_1_224RSP" } {source 224TargetSpectrum.tcl}

```


[illegible]

```

if { $record1 == "S1_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "S2_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "S3_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "S4_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "S5_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "S6_1_2475RSP" } {source 2475TargetSpectrum.tcl}
if { $record1 == "184_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "2734_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "4228_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "4481_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "4860_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "6959_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S1_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S2_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S3_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S4_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S5_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "S6_1_3712RSP" } {source 3712TargetSpectrum.tcl}
if { $record1 == "184_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "2734_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "4228_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "4481_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "4860_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "6959_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S1_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S2_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S3_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S4_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S5_1_4975RSP" } {source 4975TargetSpectrum.tcl}
if { $record1 == "S6_1_4975RSP" } {source 4975TargetSpectrum.tcl}

```

#End of Code

EQ_Metadata.tcl

This file defines the earthquake parameters, based on the name of the record that OpenSees is analyzing.

```

if { $record1 == "184_1_72RSP" } {set dT 0.005}
if { $record1 == "2734_1_72RSP" } {set dT 0.005}
if { $record1 == "4228_1_72RSP" } {set dT 0.005}
if { $record1 == "4481_1_72RSP" } {set dT 0.005}
if { $record1 == "4860_1_72RSP" } {set dT 0.01}
if { $record1 == "6959_1_72RSP" } {set dT 0.005}

```

```

if {$record1 == "S1_1_72RSP"} {set dT 0.005}
if {$record1 == "S2_1_72RSP"} {set dT 0.01}
if {$record1 == "S3_1_72RSP"} {set dT 0.005}
if {$record1 == "S4_1_72RSP"} {set dT 0.01}
if {$record1 == "S5_1_72RSP"} {set dT 0.01}
if {$record1 == "S6_1_72RSP"} {set dT 0.01}
if {$record1 == "184_1_224RSP"} {set dT 0.005}
if {$record1 == "2734_1_224RSP"} {set dT 0.005}
if {$record1 == "4228_1_224RSP"} {set dT 0.005}
if {$record1 == "4481_1_224RSP"} {set dT 0.005}
if {$record1 == "4860_1_224RSP"} {set dT 0.01}
if {$record1 == "6959_1_224RSP"} {set dT 0.005}
if {$record1 == "S1_1_224RSP"} {set dT 0.005}
if {$record1 == "S2_1_224RSP"} {set dT 0.01}
if {$record1 == "S3_1_224RSP"} {set dT 0.005}
if {$record1 == "S4_1_224RSP"} {set dT 0.01}
if {$record1 == "S5_1_224RSP"} {set dT 0.01}
if {$record1 == "S6_1_224RSP"} {set dT 0.01}
if {$record1 == "184_1_475RSP"} {set dT 0.005}
if {$record1 == "2734_1_475RSP"} {set dT 0.005}
if {$record1 == "4228_1_475RSP"} {set dT 0.005}
if {$record1 == "4481_1_475RSP"} {set dT 0.005}
if {$record1 == "4860_1_475RSP"} {set dT 0.01}
if {$record1 == "6959_1_475RSP"} {set dT 0.005}
if {$record1 == "S1_1_475RSP"} {set dT 0.005}
if {$record1 == "S2_1_475RSP"} {set dT 0.01}
if {$record1 == "S3_1_475RSP"} {set dT 0.005}
if {$record1 == "S4_1_475RSP"} {set dT 0.01}
if {$record1 == "S5_1_475RSP"} {set dT 0.01}
if {$record1 == "S6_1_475RSP"} {set dT 0.01}
if {$record1 == "184_1_975RSP"} {set dT 0.005}
if {$record1 == "2734_1_975RSP"} {set dT 0.005}
if {$record1 == "4228_1_975RSP"} {set dT 0.005}
if {$record1 == "4481_1_975RSP"} {set dT 0.005}
if {$record1 == "4860_1_975RSP"} {set dT 0.01}
if {$record1 == "6959_1_975RSP"} {set dT 0.005}
if {$record1 == "S1_1_975RSP"} {set dT 0.005}
if {$record1 == "S2_1_975RSP"} {set dT 0.01}
if {$record1 == "S3_1_975RSP"} {set dT 0.005}
if {$record1 == "S4_1_975RSP"} {set dT 0.01}
if {$record1 == "S5_1_975RSP"} {set dT 0.01}
if {$record1 == "S6_1_975RSP"} {set dT 0.01}
if {$record1 == "184_1_1462RSP"} {set dT 0.005}
if {$record1 == "2734_1_1462RSP"} {set dT 0.005}
if {$record1 == "4228_1_1462RSP"} {set dT 0.005}
if {$record1 == "4481_1_1462RSP"} {set dT 0.005}

```

```

if {$record1 == "4860_1_1462RSP"} {set dT 0.01}
if {$record1 == "6959_1_1462RSP"} {set dT 0.005}
if {$record1 == "S1_1_1462RSP"} {set dT 0.005}
if {$record1 == "S2_1_1462RSP"} {set dT 0.01}
if {$record1 == "S3_1_1462RSP"} {set dT 0.005}
if {$record1 == "S4_1_1462RSP"} {set dT 0.01}
if {$record1 == "S5_1_1462RSP"} {set dT 0.01}
if {$record1 == "S6_1_1462RSP"} {set dT 0.01}
if {$record1 == "184_1_2475RSP"} {set dT 0.005}
if {$record1 == "2734_1_2475RSP"} {set dT 0.005}
if {$record1 == "4228_1_2475RSP"} {set dT 0.005}
if {$record1 == "4481_1_2475RSP"} {set dT 0.005}
if {$record1 == "4860_1_2475RSP"} {set dT 0.01}
if {$record1 == "6959_1_2475RSP"} {set dT 0.005}
if {$record1 == "S1_1_2475RSP"} {set dT 0.005}
if {$record1 == "S2_1_2475RSP"} {set dT 0.01}
if {$record1 == "S3_1_2475RSP"} {set dT 0.005}
if {$record1 == "S4_1_2475RSP"} {set dT 0.01}
if {$record1 == "S5_1_2475RSP"} {set dT 0.01}
if {$record1 == "S6_1_2475RSP"} {set dT 0.01}
if {$record1 == "184_1_3712RSP"} {set dT 0.005}
if {$record1 == "2734_1_3712RSP"} {set dT 0.005}
if {$record1 == "4228_1_3712RSP"} {set dT 0.005}
if {$record1 == "4481_1_3712RSP"} {set dT 0.005}
if {$record1 == "4860_1_3712RSP"} {set dT 0.01}
if {$record1 == "6959_1_3712RSP"} {set dT 0.005}
if {$record1 == "S1_1_3712RSP"} {set dT 0.005}
if {$record1 == "S2_1_3712RSP"} {set dT 0.01}
if {$record1 == "S3_1_3712RSP"} {set dT 0.005}
if {$record1 == "S4_1_3712RSP"} {set dT 0.01}
if {$record1 == "S5_1_3712RSP"} {set dT 0.01}
if {$record1 == "S6_1_3712RSP"} {set dT 0.01}
if {$record1 == "184_1_4975RSP"} {set dT 0.005}
if {$record1 == "2734_1_4975RSP"} {set dT 0.005}
if {$record1 == "4228_1_4975RSP"} {set dT 0.005}
if {$record1 == "4481_1_4975RSP"} {set dT 0.005}
if {$record1 == "4860_1_4975RSP"} {set dT 0.01}
if {$record1 == "6959_1_4975RSP"} {set dT 0.005}
if {$record1 == "S1_1_4975RSP"} {set dT 0.005}
if {$record1 == "S2_1_4975RSP"} {set dT 0.01}
if {$record1 == "S3_1_4975RSP"} {set dT 0.005}
if {$record1 == "S4_1_4975RSP"} {set dT 0.01}
if {$record1 == "S5_1_4975RSP"} {set dT 0.01}
if {$record1 == "S6_1_4975RSP"} {set dT 0.01}

```

```

if {$record1 == "184_1_72RSP"} {set record2 184_2_72RSP}
if {$record1 == "2734_1_72RSP"} {set record2 2734_2_72RSP}
if {$record1 == "4228_1_72RSP"} {set record2 4228_2_72RSP}
if {$record1 == "4481_1_72RSP"} {set record2 4481_2_72RSP}
if {$record1 == "4860_1_72RSP"} {set record2 4860_2_72RSP}
if {$record1 == "6959_1_72RSP"} {set record2 6959_2_72RSP}
if {$record1 == "S1_1_72RSP"} {set record2 S1_2_72RSP}
if {$record1 == "S2_1_72RSP"} {set record2 S2_2_72RSP}
if {$record1 == "S3_1_72RSP"} {set record2 S3_2_72RSP}
if {$record1 == "S4_1_72RSP"} {set record2 S4_2_72RSP}
if {$record1 == "S5_1_72RSP"} {set record2 S5_2_72RSP}
if {$record1 == "S6_1_72RSP"} {set record2 S6_2_72RSP}
if {$record1 == "184_1_224RSP"} {set record2 184_2_224RSP}
if {$record1 == "2734_1_224RSP"} {set record2 2734_2_224RSP}
if {$record1 == "4228_1_224RSP"} {set record2 4228_2_224RSP}
if {$record1 == "4481_1_224RSP"} {set record2 4481_2_224RSP}
if {$record1 == "4860_1_224RSP"} {set record2 4860_2_224RSP}
if {$record1 == "6959_1_224RSP"} {set record2 6959_2_224RSP}
if {$record1 == "S1_1_224RSP"} {set record2 S1_2_224RSP}
if {$record1 == "S2_1_224RSP"} {set record2 S2_2_224RSP}
if {$record1 == "S3_1_224RSP"} {set record2 S3_2_224RSP}
if {$record1 == "S4_1_224RSP"} {set record2 S4_2_224RSP}
if {$record1 == "S5_1_224RSP"} {set record2 S5_2_224RSP}
if {$record1 == "S6_1_224RSP"} {set record2 S6_2_224RSP}
if {$record1 == "184_1_475RSP"} {set record2 184_2_475RSP}
if {$record1 == "2734_1_475RSP"} {set record2 2734_2_475RSP}
if {$record1 == "4228_1_475RSP"} {set record2 4228_2_475RSP}
if {$record1 == "4481_1_475RSP"} {set record2 4481_2_475RSP}
if {$record1 == "4860_1_475RSP"} {set record2 4860_2_475RSP}
if {$record1 == "6959_1_475RSP"} {set record2 6959_2_475RSP}
if {$record1 == "S1_1_475RSP"} {set record2 S1_2_475RSP}
if {$record1 == "S2_1_475RSP"} {set record2 S2_2_475RSP}
if {$record1 == "S3_1_475RSP"} {set record2 S3_2_475RSP}
if {$record1 == "S4_1_475RSP"} {set record2 S4_2_475RSP}
if {$record1 == "S5_1_475RSP"} {set record2 S5_2_475RSP}
if {$record1 == "S6_1_475RSP"} {set record2 S6_2_475RSP}
if {$record1 == "184_1_975RSP"} {set record2 184_2_975RSP}
if {$record1 == "2734_1_975RSP"} {set record2 2734_2_975RSP}
if {$record1 == "4228_1_975RSP"} {set record2 4228_2_975RSP}
if {$record1 == "4481_1_975RSP"} {set record2 4481_2_975RSP}
if {$record1 == "4860_1_975RSP"} {set record2 4860_2_975RSP}
if {$record1 == "6959_1_975RSP"} {set record2 6959_2_975RSP}
if {$record1 == "S1_1_975RSP"} {set record2 S1_2_975RSP}
if {$record1 == "S2_1_975RSP"} {set record2 S2_2_975RSP}
if {$record1 == "S3_1_975RSP"} {set record2 S3_2_975RSP}
if {$record1 == "S4_1_975RSP"} {set record2 S4_2_975RSP}

```

```

if {$record1 == "S5_1_975RSP"} {set record2 S5_2_975RSP}
if {$record1 == "S6_1_975RSP"} {set record2 S6_2_975RSP}
if {$record1 == "184_1_1462RSP"} {set record2 184_2_1462RSP}
if {$record1 == "2734_1_1462RSP"} {set record2 2734_2_1462RSP}
if {$record1 == "4228_1_1462RSP"} {set record2 4228_2_1462RSP}
if {$record1 == "4481_1_1462RSP"} {set record2 4481_2_1462RSP}
if {$record1 == "4860_1_1462RSP"} {set record2 4860_2_1462RSP}
if {$record1 == "6959_1_1462RSP"} {set record2 6959_2_1462RSP}
if {$record1 == "S1_1_1462RSP"} {set record2 S1_2_1462RSP}
if {$record1 == "S2_1_1462RSP"} {set record2 S2_2_1462RSP}
if {$record1 == "S3_1_1462RSP"} {set record2 S3_2_1462RSP}
if {$record1 == "S4_1_1462RSP"} {set record2 S4_2_1462RSP}
if {$record1 == "S5_1_1462RSP"} {set record2 S5_2_1462RSP}
if {$record1 == "S6_1_1462RSP"} {set record2 S6_2_1462RSP}
if {$record1 == "184_1_2475RSP"} {set record2 184_2_2475RSP}
if {$record1 == "2734_1_2475RSP"} {set record2 2734_2_2475RSP}
if {$record1 == "4228_1_2475RSP"} {set record2 4228_2_2475RSP}
if {$record1 == "4481_1_2475RSP"} {set record2 4481_2_2475RSP}
if {$record1 == "4860_1_2475RSP"} {set record2 4860_2_2475RSP}
if {$record1 == "6959_1_2475RSP"} {set record2 6959_2_2475RSP}
if {$record1 == "S1_1_2475RSP"} {set record2 S1_2_2475RSP}
if {$record1 == "S2_1_2475RSP"} {set record2 S2_2_2475RSP}
if {$record1 == "S3_1_2475RSP"} {set record2 S3_2_2475RSP}
if {$record1 == "S4_1_2475RSP"} {set record2 S4_2_2475RSP}
if {$record1 == "S5_1_2475RSP"} {set record2 S5_2_2475RSP}
if {$record1 == "S6_1_2475RSP"} {set record2 S6_2_2475RSP}
if {$record1 == "184_1_3712RSP"} {set record2 184_2_3712RSP}
if {$record1 == "2734_1_3712RSP"} {set record2 2734_2_3712RSP}
if {$record1 == "4228_1_3712RSP"} {set record2 4228_2_3712RSP}
if {$record1 == "4481_1_3712RSP"} {set record2 4481_2_3712RSP}
if {$record1 == "4860_1_3712RSP"} {set record2 4860_2_3712RSP}
if {$record1 == "6959_1_3712RSP"} {set record2 6959_2_3712RSP}
if {$record1 == "S1_1_3712RSP"} {set record2 S1_2_3712RSP}
if {$record1 == "S2_1_3712RSP"} {set record2 S2_2_3712RSP}
if {$record1 == "S3_1_3712RSP"} {set record2 S3_2_3712RSP}
if {$record1 == "S4_1_3712RSP"} {set record2 S4_2_3712RSP}
if {$record1 == "S5_1_3712RSP"} {set record2 S5_2_3712RSP}
if {$record1 == "S6_1_3712RSP"} {set record2 S6_2_3712RSP}
if {$record1 == "184_1_4975RSP"} {set record2 184_2_4975RSP}
if {$record1 == "2734_1_4975RSP"} {set record2 2734_2_4975RSP}
if {$record1 == "4228_1_4975RSP"} {set record2 4228_2_4975RSP}
if {$record1 == "4481_1_4975RSP"} {set record2 4481_2_4975RSP}
if {$record1 == "4860_1_4975RSP"} {set record2 4860_2_4975RSP}
if {$record1 == "6959_1_4975RSP"} {set record2 6959_2_4975RSP}
if {$record1 == "S1_1_4975RSP"} {set record2 S1_2_4975RSP}
if {$record1 == "S2_1_4975RSP"} {set record2 S2_2_4975RSP}

```

```

if {$record1 == "S3_1_4975RSP"} {set record2 S3_2_4975RSP}
if {$record1 == "S4_1_4975RSP"} {set record2 S4_2_4975RSP}
if {$record1 == "S5_1_4975RSP"} {set record2 S5_2_4975RSP}
if {$record1 == "S6_1_4975RSP"} {set record2 S6_2_4975RSP}

```

```

if {$record1 == "184_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_72RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_72RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_72RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_72RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_72RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_72RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_72RSP"} {set EQtype Subduction}
if {$record1 == "184_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_224RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_224RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_224RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_224RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_224RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_224RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_224RSP"} {set EQtype Subduction}
if {$record1 == "184_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_475RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_475RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_475RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_475RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_475RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_475RSP"} {set EQtype Subduction}
if {$record1 == "184_1_975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_975RSP"} {set EQtype ShallowCrustral}

```

```

if {$record1 == "4228_1_975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_975RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_975RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_975RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_975RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_975RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_975RSP"} {set EQtype Subduction}
if {$record1 == "184_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_1462RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_1462RSP"} {set EQtype Subduction}
if {$record1 == "184_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_2475RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_2475RSP"} {set EQtype Subduction}
if {$record1 == "184_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_3712RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_3712RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_3712RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_3712RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_3712RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_3712RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_3712RSP"} {set EQtype Subduction}

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if {$record1 == "184_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "2734_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4228_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4481_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "4860_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "6959_1_4975RSP"} {set EQtype ShallowCrustral}
if {$record1 == "S1_1_4975RSP"} {set EQtype Subduction}
if {$record1 == "S2_1_4975RSP"} {set EQtype Subduction}
if {$record1 == "S3_1_4975RSP"} {set EQtype Subduction}
if {$record1 == "S4_1_4975RSP"} {set EQtype Subduction}
if {$record1 == "S5_1_4975RSP"} {set EQtype Subduction}
if {$record1 == "S6_1_4975RSP"} {set EQtype Subduction}

```

```

if {$record1 == "184_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "2734_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "4228_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "4481_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "4860_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "6959_1_72RSP"} {set ReturnPeriod R72 }
if {$record1 == "184_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "2734_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "4228_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "4481_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "4860_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "6959_1_224RSP"} {set ReturnPeriod R224 }
if {$record1 == "184_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "2734_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "4228_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "4481_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "4860_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "6959_1_475RSP"} {set ReturnPeriod R475 }
if {$record1 == "184_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "2734_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "4228_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "4481_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "4860_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "6959_1_975RSP"} {set ReturnPeriod R975 }
if {$record1 == "184_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "2734_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "4228_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "4481_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "4860_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "6959_1_1462RSP"} {set ReturnPeriod R1462 }
if {$record1 == "184_1_2475RSP"} {set ReturnPeriod R2475 }
if {$record1 == "2734_1_2475RSP"} {set ReturnPeriod R2475 }

```

```

if {$record1 == "4228_1_2475RSP"} {set ReturnPeriod R2475 }
if {$record1 == "4481_1_2475RSP"} {set ReturnPeriod R2475 }
if {$record1 == "4860_1_2475RSP"} {set ReturnPeriod R2475 }
if {$record1 == "6959_1_2475RSP"} {set ReturnPeriod R2475 }
if {$record1 == "184_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "2734_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "4228_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "4481_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "4860_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "6959_1_3712RSP"} {set ReturnPeriod R3712 }
if {$record1 == "184_1_4975RSP"} {set ReturnPeriod R4975 }
if {$record1 == "2734_1_4975RSP"} {set ReturnPeriod R4975 }
if {$record1 == "4228_1_4975RSP"} {set ReturnPeriod R4975 }
if {$record1 == "4481_1_4975RSP"} {set ReturnPeriod R4975 }
if {$record1 == "4860_1_4975RSP"} {set ReturnPeriod R4975 }
if {$record1 == "6959_1_4975RSP"} {set ReturnPeriod R4975 }

if {$record1 == "184_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "2734_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "4228_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "4481_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "4860_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "6959_1_72RSP"} {set ScaleFactor 1 }
if {$record1 == "184_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "2734_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "4228_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "4481_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "4860_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "6959_1_224RSP"} {set ScaleFactor 3.026411277 }
if {$record1 == "184_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "2734_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "4228_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "4481_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "4860_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "6959_1_475RSP"} {set ScaleFactor 5.655623402 }
if {$record1 == "184_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "2734_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "4228_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "4481_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "4860_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "6959_1_975RSP"} {set ScaleFactor 9.256669355 }
if {$record1 == "184_1_1462RSP"} {set ScaleFactor 11.77178308 }
if {$record1 == "2734_1_1462RSP"} {set ScaleFactor 11.77178308 }
if {$record1 == "4228_1_1462RSP"} {set ScaleFactor 11.77178308 }
if {$record1 == "4481_1_1462RSP"} {set ScaleFactor 11.77178308 }

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if {$record1 == "4860_1_1462RSP"} {set ScaleFactor 11.77178308 }
if {$record1 == "6959_1_1462RSP"} {set ScaleFactor 11.77178308 }
if {$record1 == "184_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "2734_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "4228_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "4481_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "4860_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "6959_1_2475RSP"} {set ScaleFactor 15.54381897 }
if {$record1 == "184_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "2734_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "4228_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "4481_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "4860_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "6959_1_3712RSP"} {set ScaleFactor 18.62805752 }
if {$record1 == "184_1_4975RSP"} {set ScaleFactor 21.15640971 }
if {$record1 == "2734_1_4975RSP"} {set ScaleFactor 21.15640971 }
if {$record1 == "4228_1_4975RSP"} {set ScaleFactor 21.15640971 }
if {$record1 == "4481_1_4975RSP"} {set ScaleFactor 21.15640971 }
if {$record1 == "4860_1_4975RSP"} {set ScaleFactor 21.15640971 }
if {$record1 == "6959_1_4975RSP"} {set ScaleFactor 21.15640971 }

```

```

if {$record1 == "S1_1_2475RSP"} {set SD 36.1325 }
if {$record1 == "S2_1_2475RSP"} {set SD 50.255 }
if {$record1 == "S3_1_2475RSP"} {set SD 47.74 }
if {$record1 == "S4_1_2475RSP"} {set SD 89.76 }
if {$record1 == "S5_1_2475RSP"} {set SD 76.925 }
if {$record1 == "S6_1_2475RSP"} {set SD 78.92 }

```

```

if {$record1 == "184_1_72RSP"} {set SD 6.82 }
if {$record1 == "2734_1_72RSP"} {set SD 5.1325 }
if {$record1 == "4228_1_72RSP"} {set SD 4.1175 }
if {$record1 == "4481_1_72RSP"} {set SD 5.4025 }
if {$record1 == "4860_1_72RSP"} {set SD 8.58 }
if {$record1 == "6959_1_72RSP"} {set SD 6.945 }
if {$record1 == "184_1_224RSP"} {set SD 5.49 }
if {$record1 == "2734_1_224RSP"} {set SD 6.1925 }
if {$record1 == "4228_1_224RSP"} {set SD 5.7525 }
if {$record1 == "4481_1_224RSP"} {set SD 5.685 }
if {$record1 == "4860_1_224RSP"} {set SD 17.96 }
if {$record1 == "6959_1_224RSP"} {set SD 21.3775 }
if {$record1 == "184_1_475RSP"} {set SD 7.44 }
if {$record1 == "2734_1_475RSP"} {set SD 8.1475 }
if {$record1 == "4228_1_475RSP"} {set SD 7.1 }
if {$record1 == "4481_1_475RSP"} {set SD 5.9225 }

```

```

if {$record1 == "4860_1_475RSP"} {set SD 20.58 }
if {$record1 == "6959_1_475RSP"} {set SD 32.0825 }
if {$record1 == "184_1_975RSP"} {set SD 9.345 }
if {$record1 == "2734_1_975RSP"} {set SD 9.71 }
if {$record1 == "4228_1_975RSP"} {set SD 9.1775 }
if {$record1 == "4481_1_975RSP"} {set SD 7.9075 }
if {$record1 == "4860_1_975RSP"} {set SD 22.25 }
if {$record1 == "6959_1_975RSP"} {set SD 46.3 }
if {$record1 == "184_1_1462RSP"} {set SD 10.67 }
if {$record1 == "2734_1_1462RSP"} {set SD 11.87 }
if {$record1 == "4228_1_1462RSP"} {set SD 12.1375 }
if {$record1 == "4481_1_1462RSP"} {set SD 8.2725 }
if {$record1 == "4860_1_1462RSP"} {set SD 22.935 }
if {$record1 == "6959_1_1462RSP"} {set SD 53.8075 }
if {$record1 == "184_1_2475RSP"} {set SD 10.73 }
if {$record1 == "2734_1_2475RSP"} {set SD 10.955 }
if {$record1 == "4228_1_2475RSP"} {set SD 12.6175 }
if {$record1 == "4481_1_2475RSP"} {set SD 8.22 }
if {$record1 == "4860_1_2475RSP"} {set SD 23.09 }
if {$record1 == "6959_1_2475RSP"} {set SD 51.675 }
if {$record1 == "184_1_3712RSP"} {set SD 14.48 }
if {$record1 == "2734_1_3712RSP"} {set SD 16.825 }
if {$record1 == "4228_1_3712RSP"} {set SD 19.4225 }
if {$record1 == "4481_1_3712RSP"} {set SD 9.3925 }
if {$record1 == "4860_1_3712RSP"} {set SD 24.465 }
if {$record1 == "6959_1_3712RSP"} {set SD 72.935 }
if {$record1 == "184_1_4975RSP"} {set SD 14.655 }
if {$record1 == "2734_1_4975RSP"} {set SD 17.315 }
if {$record1 == "4228_1_4975RSP"} {set SD 19.735 }
if {$record1 == "4481_1_4975RSP"} {set SD 9.585 }
if {$record1 == "4860_1_4975RSP"} {set SD 26.175 }
if {$record1 == "6959_1_4975RSP"} {set SD 76.8725 }

```

```

if {$record1 == "184_1_72RSP"} {set MA 0.04678 }
if {$record1 == "2734_1_72RSP"} {set MA 0.04967 }
if {$record1 == "4228_1_72RSP"} {set MA 0.058625 }
if {$record1 == "4481_1_72RSP"} {set MA 0.052755 }
if {$record1 == "4860_1_72RSP"} {set MA 0.05373 }
if {$record1 == "6959_1_72RSP"} {set MA 0.052985 }
if {$record1 == "184_1_224RSP"} {set MA 0.13479 }
if {$record1 == "2734_1_224RSP"} {set MA 0.13826 }
if {$record1 == "4228_1_224RSP"} {set MA 0.166695 }
if {$record1 == "4481_1_224RSP"} {set MA 0.15965 }
if {$record1 == "4860_1_224RSP"} {set MA 0.15044 }

```

```

if {$record1 == "6959_1_224RSP"} {set MA 0.13717 }
if {$record1 == "184_1_475RSP"} {set MA 0.206655 }
if {$record1 == "2734_1_475RSP"} {set MA 0.20723 }
if {$record1 == "4228_1_475RSP"} {set MA 0.237225 }
if {$record1 == "4481_1_475RSP"} {set MA 0.22221 }
if {$record1 == "4860_1_475RSP"} {set MA 0.245795 }
if {$record1 == "6959_1_475RSP"} {set MA 0.1895 }
if {$record1 == "184_1_975RSP"} {set MA 0.344265 }
if {$record1 == "2734_1_975RSP"} {set MA 0.310745 }
if {$record1 == "4228_1_975RSP"} {set MA 0.318515 }
if {$record1 == "4481_1_975RSP"} {set MA 0.329745 }
if {$record1 == "4860_1_975RSP"} {set MA 0.325585 }
if {$record1 == "6959_1_975RSP"} {set MA 0.297375 }
if {$record1 == "184_1_1462RSP"} {set MA 0.39996 }
if {$record1 == "2734_1_1462RSP"} {set MA 0.409765 }
if {$record1 == "4228_1_1462RSP"} {set MA 0.455515 }
if {$record1 == "4481_1_1462RSP"} {set MA 0.405225 }
if {$record1 == "4860_1_1462RSP"} {set MA 0.39078 }
if {$record1 == "6959_1_1462RSP"} {set MA 0.38644 }
if {$record1 == "184_1_2475RSP"} {set MA 0.501095 }
if {$record1 == "2734_1_2475RSP"} {set MA 0.41412 }
if {$record1 == "4228_1_2475RSP"} {set MA 0.54717 }
if {$record1 == "4481_1_2475RSP"} {set MA 0.547895 }
if {$record1 == "4860_1_2475RSP"} {set MA 0.492515 }
if {$record1 == "6959_1_2475RSP"} {set MA 0.437595 }
if {$record1 == "184_1_3712RSP"} {set MA 0.657015 }
if {$record1 == "2734_1_3712RSP"} {set MA 0.62632 }
if {$record1 == "4228_1_3712RSP"} {set MA 0.657625 }
if {$record1 == "4481_1_3712RSP"} {set MA 0.644035 }
if {$record1 == "4860_1_3712RSP"} {set MA 0.612445 }
if {$record1 == "6959_1_3712RSP"} {set MA 0.5319 }
if {$record1 == "184_1_4975RSP"} {set MA 0.78423 }
if {$record1 == "2734_1_4975RSP"} {set MA 0.73801 }
if {$record1 == "4228_1_4975RSP"} {set MA 0.646245 }
if {$record1 == "4481_1_4975RSP"} {set MA 0.743555 }
if {$record1 == "4860_1_4975RSP"} {set MA 0.68292 }
if {$record1 == "6959_1_4975RSP"} {set MA 0.60646 }

if {$record1 == "S1_1_2475RSP"} {set MA 0.551835 }
if {$record1 == "S2_1_2475RSP"} {set MA 0.486915 }
if {$record1 == "S3_1_2475RSP"} {set MA 1.1576 }
if {$record1 == "S4_1_2475RSP"} {set MA 0.48942 }
if {$record1 == "S5_1_2475RSP"} {set MA 0.48836 }
if {$record1 == "S6_1_2475RSP"} {set MA 0.50992 }

if {$record1 == "184_1_72RSP"} {set MA1 0.04946 }

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```

if {$record1 == "2734_1_72RSP"} {set    MA1  0.04561    }
if {$record1 == "4228_1_72RSP"} {set    MA1  0.05263    }
if {$record1 == "4481_1_72RSP"} {set MA1      0.04768    }
if {$record1 == "4860_1_72RSP"} {set    MA1  0.05706    }
if {$record1 == "6959_1_72RSP"} {set    MA1  0.04915    }

if {$record1 == "184_1_72RSP"} {set    MA2  0.0441    }
if {$record1 == "2734_1_72RSP"} {set    MA2  0.05373    }
if {$record1 == "4228_1_72RSP"} {set    MA2  0.06462    }
if {$record1 == "4481_1_72RSP"} {set    MA2  0.05783    }
if {$record1 == "4860_1_72RSP"} {set    MA2  0.0504    }
if {$record1 == "6959_1_72RSP"} {set    MA2  0.05682    }

if {$record1 == "184_1_224RSP"} {set    MA1  0.1413    }
if {$record1 == "2734_1_224RSP"} {set    MA1  0.11842    }
if {$record1 == "4228_1_224RSP"} {set    MA1  0.17906    }
if {$record1 == "4481_1_224RSP"} {set    MA1  0.13346    }
if {$record1 == "4860_1_224RSP"} {set    MA1  0.15892    }
if {$record1 == "6959_1_224RSP"} {set    MA1  0.14154    }

if {$record1 == "184_1_224RSP"} {set    MA2  0.12828    }
if {$record1 == "2734_1_224RSP"} {set    MA2  0.1581    }
if {$record1 == "4228_1_224RSP"} {set    MA2  0.15433    }
if {$record1 == "4481_1_224RSP"} {set    MA2  0.18584    }
if {$record1 == "4860_1_224RSP"} {set    MA2  0.14196    }
if {$record1 == "6959_1_224RSP"} {set    MA2  0.1328    }

if {$record1 == "184_1_475RSP"} {set    MA1  0.19461    }
if {$record1 == "2734_1_475RSP"} {set    MA1  0.20438    }
if {$record1 == "4228_1_475RSP"} {set    MA1  0.244    }
if {$record1 == "4481_1_475RSP"} {set    MA1  0.2037    }
if {$record1 == "4860_1_475RSP"} {set    MA1  0.26942    }
if {$record1 == "6959_1_475RSP"} {set    MA1  0.18456    }

if {$record1 == "184_1_475RSP"} {set    MA2  0.2187    }
if {$record1 == "2734_1_475RSP"} {set    MA2  0.21008    }
if {$record1 == "4228_1_475RSP"} {set    MA2  0.23045    }
if {$record1 == "4481_1_475RSP"} {set    MA2  0.24072    }
if {$record1 == "4860_1_475RSP"} {set    MA2  0.22217    }
if {$record1 == "6959_1_475RSP"} {set    MA2  0.19444    }

if {$record1 == "184_1_975RSP"} {set    MA1  0.29201    }
if {$record1 == "2734_1_975RSP"} {set    MA1  0.31005    }
if {$record1 == "4228_1_975RSP"} {set    MA1  0.33397    }
if {$record1 == "4481_1_975RSP"} {set    MA1  0.34208    }
if {$record1 == "4860_1_975RSP"} {set    MA1  0.31365    }

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if {$record1 == "6959_1_975RSP"} {set    MA1  0.31672    }

if {$record1 == "184_1_975RSP"} {set    MA2  0.39652    }
if {$record1 == "2734_1_975RSP"} {set    MA2  0.31144    }
if {$record1 == "4228_1_975RSP"} {set    MA2  0.30306    }
if {$record1 == "4481_1_975RSP"} {set    MA2  0.31741    }
if {$record1 == "4860_1_975RSP"} {set    MA2  0.33752    }
if {$record1 == "6959_1_975RSP"} {set    MA2  0.27803    }

if {$record1 == "184_1_1462RSP"} {set    MA1  0.38673    }
if {$record1 == "2734_1_1462RSP"} {set    MA1  0.44786    }
if {$record1 == "4228_1_1462RSP"} {set    MA1  0.44576    }
if {$record1 == "4481_1_1462RSP"} {set    MA1  0.4013    }
if {$record1 == "4860_1_1462RSP"} {set    MA1  0.40023    }
if {$record1 == "6959_1_1462RSP"} {set    MA1  0.34145    }

if {$record1 == "184_1_1462RSP"} {set    MA2  0.41319    }
if {$record1 == "2734_1_1462RSP"} {set    MA2  0.37167    }
if {$record1 == "4228_1_1462RSP"} {set    MA2  0.46527    }
if {$record1 == "4481_1_1462RSP"} {set    MA2  0.40915    }
if {$record1 == "4860_1_1462RSP"} {set    MA2  0.38133    }
if {$record1 == "6959_1_1462RSP"} {set    MA2  0.43143    }

if {$record1 == "184_1_2475RSP"} {set    MA1  0.44223    }
if {$record1 == "2734_1_2475RSP"} {set    MA1  0.39033    }
if {$record1 == "4228_1_2475RSP"} {set    MA1  0.48025    }
if {$record1 == "4481_1_2475RSP"} {set    MA1  0.55121    }
if {$record1 == "4860_1_2475RSP"} {set    MA1  0.50081    }
if {$record1 == "6959_1_2475RSP"} {set    MA1  0.44303    }

if {$record1 == "184_1_2475RSP"} {set    MA2  0.55996    }
if {$record1 == "2734_1_2475RSP"} {set    MA2  0.43791    }
if {$record1 == "4228_1_2475RSP"} {set    MA2  0.61409    }
if {$record1 == "4481_1_2475RSP"} {set    MA2  0.54458    }
if {$record1 == "4860_1_2475RSP"} {set    MA2  0.48422    }
if {$record1 == "6959_1_2475RSP"} {set    MA2  0.43216    }

if {$record1 == "184_1_3712RSP"} {set    MA1  0.54849    }
if {$record1 == "2734_1_3712RSP"} {set    MA1  0.60325    }
if {$record1 == "4228_1_3712RSP"} {set    MA1  0.64111    }
if {$record1 == "4481_1_3712RSP"} {set    MA1  0.61696    }
if {$record1 == "4860_1_3712RSP"} {set    MA1  0.67738    }
if {$record1 == "6959_1_3712RSP"} {set    MA1  0.51579    }

if {$record1 == "184_1_3712RSP"} {set    MA2  0.76554    }
if {$record1 == "2734_1_3712RSP"} {set    MA2  0.64939    }

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if {$record1 == "4228_1_3712RSP"} {set MA2 0.67414 }
if {$record1 == "4481_1_3712RSP"} {set MA2 0.67111 }
if {$record1 == "4860_1_3712RSP"} {set MA2 0.54751 }
if {$record1 == "6959_1_3712RSP"} {set MA2 0.54801 }

if {$record1 == "184_1_4975RSP"} {set MA1 0.64948 }
if {$record1 == "2734_1_4975RSP"} {set MA1 0.71591 }
if {$record1 == "4228_1_4975RSP"} {set MA1 0.6299 }
if {$record1 == "4481_1_4975RSP"} {set MA1 0.75369 }
if {$record1 == "4860_1_4975RSP"} {set MA1 0.6328 }
if {$record1 == "6959_1_4975RSP"} {set MA1 0.61949 }

if {$record1 == "184_1_4975RSP"} {set MA2 0.91898 }
if {$record1 == "2734_1_4975RSP"} {set MA2 0.76011 }
if {$record1 == "4228_1_4975RSP"} {set MA2 0.66259 }
if {$record1 == "4481_1_4975RSP"} {set MA2 0.73342 }
if {$record1 == "4860_1_4975RSP"} {set MA2 0.73304 }
if {$record1 == "6959_1_4975RSP"} {set MA2 0.59343 }

if {$record1 == "184_1_72RSP"} {set MV 1.411524384 }
if {$record1 == "2734_1_72RSP"} {set MV 1.255482961 }
if {$record1 == "4228_1_72RSP"} {set MV 1.3480775 }
if {$record1 == "4481_1_72RSP"} {set MV 1.408193674 }
if {$record1 == "4860_1_72RSP"} {set MV 1.424175966 }
if {$record1 == "6959_1_72RSP"} {set MV 1.284496757 }
if {$record1 == "184_1_224RSP"} {set MV 3.584842487 }
if {$record1 == "2734_1_224RSP"} {set MV 4.925492817 }
if {$record1 == "4228_1_224RSP"} {set MV 5.350345409 }
if {$record1 == "4481_1_224RSP"} {set MV 4.541925681 }
if {$record1 == "4860_1_224RSP"} {set MV 3.569064919 }
if {$record1 == "6959_1_224RSP"} {set MV 3.665118121 }
if {$record1 == "184_1_475RSP"} {set MV 8.072939399 }
if {$record1 == "2734_1_475RSP"} {set MV 8.645175928 }
if {$record1 == "4228_1_475RSP"} {set MV 8.644353093 }
if {$record1 == "4481_1_475RSP"} {set MV 8.579599121 }
if {$record1 == "4860_1_475RSP"} {set MV 5.500388797 }
if {$record1 == "6959_1_475RSP"} {set MV 6.998182913 }
if {$record1 == "184_1_975RSP"} {set MV 14.18163758 }
if {$record1 == "2734_1_975RSP"} {set MV 12.45668586 }
if {$record1 == "4228_1_975RSP"} {set MV 12.17677626 }
if {$record1 == "4481_1_975RSP"} {set MV 10.09630466 }
if {$record1 == "4860_1_975RSP"} {set MV 10.25756263 }
if {$record1 == "6959_1_975RSP"} {set MV 11.42378963 }
if {$record1 == "184_1_1462RSP"} {set MV 17.64249772 }

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if {$record1 == "2734_1_1462RSP"} {set MV 16.52423727 }
if {$record1 == "4228_1_1462RSP"} {set MV 13.70940701 }
if {$record1 == "4481_1_1462RSP"} {set MV 16.09376656 }
if {$record1 == "4860_1_1462RSP"} {set MV 13.51471793 }
if {$record1 == "6959_1_1462RSP"} {set MV 13.36506037 }
if {$record1 == "184_1_2475RSP"} {set MV 20.43634174 }
if {$record1 == "2734_1_2475RSP"} {set MV 22.69945714 }
if {$record1 == "4228_1_2475RSP"} {set MV 21.95140359 }
if {$record1 == "4481_1_2475RSP"} {set MV 17.17886164 }
if {$record1 == "4860_1_2475RSP"} {set MV 15.66749862 }
if {$record1 == "6959_1_2475RSP"} {set MV 17.35472788 }
if {$record1 == "184_1_3712RSP"} {set MV 23.24541216 }
if {$record1 == "2734_1_3712RSP"} {set MV 22.00036621 }
if {$record1 == "4228_1_3712RSP"} {set MV 23.04533134 }
if {$record1 == "4481_1_3712RSP"} {set MV 20.23282392 }
if {$record1 == "4860_1_3712RSP"} {set MV 19.33402225 }
if {$record1 == "6959_1_3712RSP"} {set MV 21.56342503 }
if {$record1 == "184_1_4975RSP"} {set MV 24.27856035 }
if {$record1 == "2734_1_4975RSP"} {set MV 26.60345531 }
if {$record1 == "4228_1_4975RSP"} {set MV 31.84309003 }
if {$record1 == "4481_1_4975RSP"} {set MV 28.9994822 }
if {$record1 == "4860_1_4975RSP"} {set MV 22.93971121 }
if {$record1 == "6959_1_4975RSP"} {set MV 25.0318836 }

if {$record1 == "184_1_72RSP"} {set MD 0.769400022 }
if {$record1 == "2734_1_72RSP"} {set MD 0.650842871 }
if {$record1 == "4228_1_72RSP"} {set MD 0.589039688 }
if {$record1 == "4481_1_72RSP"} {set MD 0.743063393 }
if {$record1 == "4860_1_72RSP"} {set MD 0.667610597 }
if {$record1 == "6959_1_72RSP"} {set MD 0.748024026 }
if {$record1 == "184_1_224RSP"} {set MD 2.321707947 }
if {$record1 == "2734_1_224RSP"} {set MD 2.209186232 }
if {$record1 == "4228_1_224RSP"} {set MD 2.014961718 }
if {$record1 == "4481_1_224RSP"} {set MD 1.738863144 }
if {$record1 == "4860_1_224RSP"} {set MD 2.132711782 }
if {$record1 == "6959_1_224RSP"} {set MD 2.288068165 }
if {$record1 == "184_1_475RSP"} {set MD 4.76982541 }
if {$record1 == "2734_1_475RSP"} {set MD 3.897080845 }
if {$record1 == "4228_1_475RSP"} {set MD 4.576764282 }
if {$record1 == "4481_1_475RSP"} {set MD 3.316328562 }
if {$record1 == "4860_1_475RSP"} {set MD 3.353263622 }
if {$record1 == "6959_1_475RSP"} {set MD 4.402569307 }
if {$record1 == "184_1_975RSP"} {set MD 8.971309963 }
if {$record1 == "2734_1_975RSP"} {set MD 6.329450268 }
if {$record1 == "4228_1_975RSP"} {set MD 7.550665495 }
if {$record1 == "4481_1_975RSP"} {set MD 5.969698106 }

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if {$record1 == "4860_1_975RSP"} {set MD 7.85628377 }
if {$record1 == "6959_1_975RSP"} {set MD 8.16130362 }
if {$record1 == "184_1_1462RSP"} {set MD 10.33483235 }
if {$record1 == "2734_1_1462RSP"} {set MD 9.239615226 }
if {$record1 == "4228_1_1462RSP"} {set MD 10.83211215 }
if {$record1 == "4481_1_1462RSP"} {set MD 8.526679801 }
if {$record1 == "4860_1_1462RSP"} {set MD 6.392342035 }
if {$record1 == "6959_1_1462RSP"} {set MD 11.09159064 }
if {$record1 == "184_1_2475RSP"} {set MD 13.72525347 }
if {$record1 == "2734_1_2475RSP"} {set MD 13.55355456 }
if {$record1 == "4228_1_2475RSP"} {set MD 11.68756143 }
if {$record1 == "4481_1_2475RSP"} {set MD 9.604113454 }
if {$record1 == "4860_1_2475RSP"} {set MD 9.978826255 }
if {$record1 == "6959_1_2475RSP"} {set MD 15.14036251 }
if {$record1 == "184_1_3712RSP"} {set MD 15.74916795 }
if {$record1 == "2734_1_3712RSP"} {set MD 13.79788147 }
if {$record1 == "4228_1_3712RSP"} {set MD 19.84785521 }
if {$record1 == "4481_1_3712RSP"} {set MD 12.19206958 }
if {$record1 == "4860_1_3712RSP"} {set MD 14.41989558 }
if {$record1 == "6959_1_3712RSP"} {set MD 17.84590727 }
if {$record1 == "184_1_4975RSP"} {set MD 21.42490921 }
if {$record1 == "2734_1_4975RSP"} {set MD 20.53501896 }
if {$record1 == "4228_1_4975RSP"} {set MD 22.63483899 }
if {$record1 == "4481_1_4975RSP"} {set MD 19.26760883 }
if {$record1 == "4860_1_4975RSP"} {set MD 18.72287822 }
if {$record1 == "6959_1_4975RSP"} {set MD 21.56341716 }

if {$record1 == "184_1_72RSP"} {set VA 0.077985 }
if {$record1 == "2734_1_72RSP"} {set VA 0.066085 }
if {$record1 == "4228_1_72RSP"} {set VA 0.05979 }
if {$record1 == "4481_1_72RSP"} {set VA 0.069205 }
if {$record1 == "4860_1_72RSP"} {set VA 0.06907 }
if {$record1 == "6959_1_72RSP"} {set VA 0.063785 }
if {$record1 == "184_1_224RSP"} {set VA 0.06921 }
if {$record1 == "2734_1_224RSP"} {set VA 0.09718 }
if {$record1 == "4228_1_224RSP"} {set VA 0.082665 }
if {$record1 == "4481_1_224RSP"} {set VA 0.07244 }
if {$record1 == "4860_1_224RSP"} {set VA 0.06104 }
if {$record1 == "6959_1_224RSP"} {set VA 0.069365 }
if {$record1 == "184_1_475RSP"} {set VA 0.101385 }
if {$record1 == "2734_1_475RSP"} {set VA 0.10805 }
if {$record1 == "4228_1_475RSP"} {set VA 0.09434 }
if {$record1 == "4481_1_475RSP"} {set VA 0.10041 }
if {$record1 == "4860_1_475RSP"} {set VA 0.057955 }
if {$record1 == "6959_1_475RSP"} {set VA 0.09588 }
if {$record1 == "184_1_975RSP"} {set VA 0.1093 }

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if {$record1 == "2734_1_975RSP"} {set VA 0.10378 }
if {$record1 == "4228_1_975RSP"} {set VA 0.099685 }
if {$record1 == "4481_1_975RSP"} {set VA 0.07964 }
if {$record1 == "4860_1_975RSP"} {set VA 0.082065 }
if {$record1 == "6959_1_975RSP"} {set VA 0.100185 }
if {$record1 == "184_1_1462RSP"} {set VA 0.11376 }
if {$record1 == "2734_1_1462RSP"} {set VA 0.10469 }
if {$record1 == "4228_1_1462RSP"} {set VA 0.077775 }
if {$record1 == "4481_1_1462RSP"} {set VA 0.102625 }
if {$record1 == "4860_1_1462RSP"} {set VA 0.08921 }
if {$record1 == "6959_1_1462RSP"} {set VA 0.09059 }
if {$record1 == "184_1_2475RSP"} {set VA 0.10715 }
if {$record1 == "2734_1_2475RSP"} {set VA 0.1434 }
if {$record1 == "4228_1_2475RSP"} {set VA 0.105855 }
if {$record1 == "4481_1_2475RSP"} {set VA 0.08125 }
if {$record1 == "4860_1_2475RSP"} {set VA 0.08212 }
if {$record1 == "6959_1_2475RSP"} {set VA 0.10268 }
if {$record1 == "184_1_3712RSP"} {set VA 0.09318 }
if {$record1 == "2734_1_3712RSP"} {set VA 0.09084 }
if {$record1 == "4228_1_3712RSP"} {set VA 0.0909 }
if {$record1 == "4481_1_3712RSP"} {set VA 0.08103 }
if {$record1 == "4860_1_3712RSP"} {set VA 0.081675 }
if {$record1 == "6959_1_3712RSP"} {set VA 0.10479 }
if {$record1 == "184_1_4975RSP"} {set VA 0.082615 }
if {$record1 == "2734_1_4975RSP"} {set VA 0.093515 }
if {$record1 == "4228_1_4975RSP"} {set VA 0.12706 }
if {$record1 == "4481_1_4975RSP"} {set VA 0.10093 }
if {$record1 == "4860_1_4975RSP"} {set VA 0.088315 }
if {$record1 == "6959_1_4975RSP"} {set VA 0.10694 }

if {$record1 == "184_1_72RSP"} {set ARMS 0.004945 }
if {$record1 == "2734_1_72RSP"} {set ARMS 0.00275 }
if {$record1 == "4228_1_72RSP"} {set ARMS 0.00235 }
if {$record1 == "4481_1_72RSP"} {set ARMS 0.004305 }
if {$record1 == "4860_1_72RSP"} {set ARMS 0.004275 }
if {$record1 == "6959_1_72RSP"} {set ARMS 0.00292 }
if {$record1 == "184_1_224RSP"} {set ARMS 0.01271 }
if {$record1 == "2734_1_224RSP"} {set ARMS 0.007915 }
if {$record1 == "4228_1_224RSP"} {set ARMS 0.00674 }
if {$record1 == "4481_1_224RSP"} {set ARMS 0.012775 }
if {$record1 == "4860_1_224RSP"} {set ARMS 0.013855 }
if {$record1 == "6959_1_224RSP"} {set ARMS 0.00923 }
if {$record1 == "184_1_475RSP"} {set ARMS 0.025525 }
if {$record1 == "2734_1_475RSP"} {set ARMS 0.014655 }
if {$record1 == "4228_1_475RSP"} {set ARMS 0.01128 }
if {$record1 == "4481_1_475RSP"} {set ARMS 0.019205 }

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if {$record1 == "4860_1_475RSP"} {set ARMS 0.027985 }
if {$record1 == "6959_1_475RSP"} {set ARMS 0.01817 }
if {$record1 == "184_1_975RSP"} {set ARMS 0.03466 }
if {$record1 == "2734_1_975RSP"} {set ARMS 0.02359 }
if {$record1 == "4228_1_975RSP"} {set ARMS 0.02127 }
if {$record1 == "4481_1_975RSP"} {set ARMS 0.03469 }
if {$record1 == "4860_1_975RSP"} {set ARMS 0.045595 }
if {$record1 == "6959_1_975RSP"} {set ARMS 0.03184 }
if {$record1 == "184_1_1462RSP"} {set ARMS 0.04624 }
if {$record1 == "2734_1_1462RSP"} {set ARMS 0.02987 }
if {$record1 == "4228_1_1462RSP"} {set ARMS 0.026135 }
if {$record1 == "4481_1_1462RSP"} {set ARMS 0.0433 }
if {$record1 == "4860_1_1462RSP"} {set ARMS 0.05966 }
if {$record1 == "6959_1_1462RSP"} {set ARMS 0.042165 }
if {$record1 == "184_1_2475RSP"} {set ARMS 0.056685 }
if {$record1 == "2734_1_2475RSP"} {set ARMS 0.03778 }
if {$record1 == "4228_1_2475RSP"} {set ARMS 0.03058 }
if {$record1 == "4481_1_2475RSP"} {set ARMS 0.051565 }
if {$record1 == "4860_1_2475RSP"} {set ARMS 0.07471 }
if {$record1 == "6959_1_2475RSP"} {set ARMS 0.05246 }
if {$record1 == "184_1_3712RSP"} {set ARMS 0.078055 }
if {$record1 == "2734_1_3712RSP"} {set ARMS 0.04851 }
if {$record1 == "4228_1_3712RSP"} {set ARMS 0.042585 }
if {$record1 == "4481_1_3712RSP"} {set ARMS 0.069205 }
if {$record1 == "4860_1_3712RSP"} {set ARMS 0.098535 }
if {$record1 == "6959_1_3712RSP"} {set ARMS 0.072415 }
if {$record1 == "184_1_4975RSP"} {set ARMS 0.09091 }
if {$record1 == "2734_1_4975RSP"} {set ARMS 0.05888 }
if {$record1 == "4228_1_4975RSP"} {set ARMS 0.051655 }
if {$record1 == "4481_1_4975RSP"} {set ARMS 0.082215 }
if {$record1 == "4860_1_4975RSP"} {set ARMS 0.112885 }
if {$record1 == "6959_1_4975RSP"} {set ARMS 0.084725 }

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if {$record1 == "184_1_72RSP"} {set VRMS 0.194683176 }
if {$record1 == "2734_1_72RSP"} {set VRMS 0.124360303 }
if {$record1 == "4228_1_72RSP"} {set VRMS 0.10032092 }
if {$record1 == "4481_1_72RSP"} {set VRMS 0.204004047 }
if {$record1 == "4860_1_72RSP"} {set VRMS 0.205210741 }
if {$record1 == "6959_1_72RSP"} {set VRMS 0.133746135 }
if {$record1 == "184_1_224RSP"} {set VRMS 0.609742455 }
if {$record1 == "2734_1_224RSP"} {set VRMS 0.380496268 }
if {$record1 == "4228_1_224RSP"} {set VRMS 0.334116322 }
if {$record1 == "4481_1_224RSP"} {set VRMS 0.574108578 }
if {$record1 == "4860_1_224RSP"} {set VRMS 0.712907865 }
if {$record1 == "6959_1_224RSP"} {set VRMS 0.463836865 }

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if {$record1 == "184_1_475RSP"} {set VRMS 1.242179805 }
if {$record1 == "2734_1_475RSP"} {set VRMS 0.730524017 }
if {$record1 == "4228_1_475RSP"} {set VRMS 0.595551503 }
if {$record1 == "4481_1_475RSP"} {set VRMS 0.990949354 }
if {$record1 == "4860_1_475RSP"} {set VRMS 1.390735003 }
if {$record1 == "6959_1_475RSP"} {set VRMS 0.9949966 }
if {$record1 == "184_1_975RSP"} {set VRMS 2.04475701 }
if {$record1 == "2734_1_975RSP"} {set VRMS 1.212398292 }
if {$record1 == "4228_1_975RSP"} {set VRMS 1.139721088 }
if {$record1 == "4481_1_975RSP"} {set VRMS 1.625477256 }
if {$record1 == "4860_1_975RSP"} {set VRMS 2.390538692 }
if {$record1 == "6959_1_975RSP"} {set VRMS 1.778006866 }
if {$record1 == "184_1_1462RSP"} {set VRMS 2.647670721 }
if {$record1 == "2734_1_1462RSP"} {set VRMS 1.652691837 }
if {$record1 == "4228_1_1462RSP"} {set VRMS 1.532845316 }
if {$record1 == "4481_1_1462RSP"} {set VRMS 2.456221799 }
if {$record1 == "4860_1_1462RSP"} {set VRMS 2.957125613 }
if {$record1 == "6959_1_1462RSP"} {set VRMS 2.369450098 }
if {$record1 == "184_1_2475RSP"} {set VRMS 3.455277456 }
if {$record1 == "2734_1_2475RSP"} {set VRMS 2.202759064 }
if {$record1 == "4228_1_2475RSP"} {set VRMS 1.807538378 }
if {$record1 == "4481_1_2475RSP"} {set VRMS 2.897674793 }
if {$record1 == "4860_1_2475RSP"} {set VRMS 3.881445009 }
if {$record1 == "6959_1_2475RSP"} {set VRMS 3.057840234 }
if {$record1 == "184_1_3712RSP"} {set VRMS 4.402254346 }
if {$record1 == "2734_1_3712RSP"} {set VRMS 2.729887301 }
if {$record1 == "4228_1_3712RSP"} {set VRMS 2.588001398 }
if {$record1 == "4481_1_3712RSP"} {set VRMS 3.80620678 }
if {$record1 == "4860_1_3712RSP"} {set VRMS 4.749524218 }
if {$record1 == "6959_1_3712RSP"} {set VRMS 3.893708796 }
if {$record1 == "184_1_4975RSP"} {set VRMS 5.335532409 }
if {$record1 == "2734_1_4975RSP"} {set VRMS 3.354984095 }
if {$record1 == "4228_1_4975RSP"} {set VRMS 2.93240119 }
if {$record1 == "4481_1_4975RSP"} {set VRMS 4.933500696 }
if {$record1 == "4860_1_4975RSP"} {set VRMS 5.584329787 }
if {$record1 == "6959_1_4975RSP"} {set VRMS 4.729108853 }

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if {$record1 == "184_1_72RSP"} {set DRMS 0.174480409 }
if {$record1 == "2734_1_72RSP"} {set DRMS 0.112090612 }
if {$record1 == "4228_1_72RSP"} {set DRMS 0.090509891 }
if {$record1 == "4481_1_72RSP"} {set DRMS 0.202045385 }
if {$record1 == "4860_1_72RSP"} {set DRMS 0.17683671 }
if {$record1 == "6959_1_72RSP"} {set DRMS 0.126289438 }
if {$record1 == "184_1_224RSP"} {set DRMS 0.623455061 }
if {$record1 == "2734_1_224RSP"} {set DRMS 0.356864366 }

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if {$record1 == "4228_1_224RSP"} {set DRMS 0.307405678 }
if {$record1 == "4481_1_224RSP"} {set DRMS 0.462132139 }
if {$record1 == "4860_1_224RSP"} {set DRMS 0.612023953 }
if {$record1 == "6959_1_224RSP"} {set DRMS 0.381486426 }
if {$record1 == "184_1_475RSP"} {set DRMS 1.314599135 }
if {$record1 == "2734_1_475RSP"} {set DRMS 0.615234584 }
if {$record1 == "4228_1_475RSP"} {set DRMS 0.541395962 }
if {$record1 == "4481_1_475RSP"} {set DRMS 0.871953227 }
if {$record1 == "4860_1_475RSP"} {set DRMS 1.04018757 }
if {$record1 == "6959_1_475RSP"} {set DRMS 1.013311571 }
if {$record1 == "184_1_975RSP"} {set DRMS 2.550298621 }
if {$record1 == "2734_1_975RSP"} {set DRMS 1.02811276 }
if {$record1 == "4228_1_975RSP"} {set DRMS 1.224089244 }
if {$record1 == "4481_1_975RSP"} {set DRMS 1.40149682 }
if {$record1 == "4860_1_975RSP"} {set DRMS 2.062008988 }
if {$record1 == "6959_1_975RSP"} {set DRMS 1.628892612 }
if {$record1 == "184_1_1462RSP"} {set DRMS 3.054222122 }
if {$record1 == "2734_1_1462RSP"} {set DRMS 1.649325694 }
if {$record1 == "4228_1_1462RSP"} {set DRMS 1.993176273 }
if {$record1 == "4481_1_1462RSP"} {set DRMS 2.437085962 }
if {$record1 == "4860_1_1462RSP"} {set DRMS 2.024349518 }
if {$record1 == "6959_1_1462RSP"} {set DRMS 2.472550548 }
if {$record1 == "184_1_2475RSP"} {set DRMS 4.238236541 }
if {$record1 == "2734_1_2475RSP"} {set DRMS 2.454143058 }
if {$record1 == "4228_1_2475RSP"} {set DRMS 1.676967441 }
if {$record1 == "4481_1_2475RSP"} {set DRMS 2.912172832 }
if {$record1 == "4860_1_2475RSP"} {set DRMS 2.99335201 }
if {$record1 == "6959_1_2475RSP"} {set DRMS 3.316663208 }
if {$record1 == "184_1_3712RSP"} {set DRMS 5.289317817 }
if {$record1 == "2734_1_3712RSP"} {set DRMS 3.032161086 }
if {$record1 == "4228_1_3712RSP"} {set DRMS 2.837485784 }
if {$record1 == "4481_1_3712RSP"} {set DRMS 3.698376013 }
if {$record1 == "4860_1_3712RSP"} {set DRMS 3.603791316 }
if {$record1 == "6959_1_3712RSP"} {set DRMS 4.138643967 }
if {$record1 == "184_1_4975RSP"} {set DRMS 7.203354284 }
if {$record1 == "2734_1_4975RSP"} {set DRMS 3.854775704 }
if {$record1 == "4228_1_4975RSP"} {set DRMS 3.122505623 }
if {$record1 == "4481_1_4975RSP"} {set DRMS 6.800198554 }
if {$record1 == "4860_1_4975RSP"} {set DRMS 4.876931767 }
if {$record1 == "6959_1_4975RSP"} {set DRMS 5.450258849 }

if {$record1 == "S1_1_2475RSP"} {set AI 568.0527553 }
if {$record1 == "S2_1_2475RSP"} {set AI 522.9681097 }
if {$record1 == "S3_1_2475RSP"} {set AI 3011.074013 }

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if {\$record1 == "S4_1_2475RSP"} {set	AI	833.3436999	}
if {\$record1 == "S5_1_2475RSP"} {set	AI	515.7775585	}
if {\$record1 == "S6_1_2475RSP"} {set	AI	1308.393503	}
if {\$record1 == "184_1_72RSP"} {set	AI	0.847244552	}
if {\$record1 == "2734_1_72RSP"} {set	AI	0.604724736	}
if {\$record1 == "4228_1_72RSP"} {set	AI	0.626181441	}
if {\$record1 == "4481_1_72RSP"} {set	AI	0.640157826	}
if {\$record1 == "4860_1_72RSP"} {set	AI	0.6692917	}
if {\$record1 == "6959_1_72RSP"} {set	AI	0.795866572	}
if {\$record1 == "184_1_224RSP"} {set	AI	5.209057931	}
if {\$record1 == "2734_1_224RSP"} {set	AI	4.964766461	}
if {\$record1 == "4228_1_224RSP"} {set	AI	5.009254674	}
if {\$record1 == "4481_1_224RSP"} {set	AI	5.893900821	}
if {\$record1 == "4860_1_224RSP"} {set	AI	6.987799049	}
if {\$record1 == "6959_1_224RSP"} {set	AI	7.752760092	}
if {\$record1 == "184_1_475RSP"} {set	AI	21.52068091	}
if {\$record1 == "2734_1_475RSP"} {set	AI	17.05493047	}
if {\$record1 == "4228_1_475RSP"} {set	AI	14.20118877	}
if {\$record1 == "4481_1_475RSP"} {set	AI	14.27756677	}
if {\$record1 == "4860_1_475RSP"} {set	AI	28.50572405	}
if {\$record1 == "6959_1_475RSP"} {set	AI	30.07068553	}
if {\$record1 == "184_1_975RSP"} {set	AI	40.08545472	}
if {\$record1 == "2734_1_975RSP"} {set	AI	44.18073252	}
if {\$record1 == "4228_1_975RSP"} {set	AI	50.01656244	}
if {\$record1 == "4481_1_975RSP"} {set	AI	46.78034022	}
if {\$record1 == "4860_1_975RSP"} {set	AI	75.73448972	}
if {\$record1 == "6959_1_975RSP"} {set	AI	92.40103415	}
if {\$record1 == "184_1_1462RSP"} {set	AI	68.72562766	}
if {\$record1 == "2734_1_1462RSP"} {set	AI	70.87917213	}
if {\$record1 == "4228_1_1462RSP"} {set	AI	76.33252153	}
if {\$record1 == "4481_1_1462RSP"} {set	AI	70.22799068	}
if {\$record1 == "4860_1_1462RSP"} {set	AI	129.543377	}
if {\$record1 == "6959_1_1462RSP"} {set	AI	165.7912313	}
if {\$record1 == "184_1_2475RSP"} {set	AI	107.2156091	}
if {\$record1 == "2734_1_2475RSP"} {set	AI	113.403014	}
if {\$record1 == "4228_1_2475RSP"} {set	AI	104.2321429	}
if {\$record1 == "4481_1_2475RSP"} {set	AI	102.4217089	}
if {\$record1 == "4860_1_2475RSP"} {set	AI	203.2069995	}
if {\$record1 == "6959_1_2475RSP"} {set	AI	254.095216	}
if {\$record1 == "184_1_3712RSP"} {set	AI	195.631208	}
if {\$record1 == "2734_1_3712RSP"} {set	AI	186.5630929	}
if {\$record1 == "4228_1_3712RSP"} {set	AI	199.3910526	}
if {\$record1 == "4481_1_3712RSP"} {set	AI	182.3937993	}
if {\$record1 == "4860_1_3712RSP"} {set	AI	353.378931	}
if {\$record1 == "6959_1_3712RSP"} {set	AI	484.5829388	}

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if {$record1 == "184_1_4975RSP"} {set AI 274.9281012 }
if {$record1 == "2734_1_4975RSP"} {set AI 273.5430611 }
if {$record1 == "4228_1_4975RSP"} {set AI 291.7999607 }
if {$record1 == "4481_1_4975RSP"} {set AI 255.8196263 }
if {$record1 == "4860_1_4975RSP"} {set AI 463.8159985 }
if {$record1 == "6959_1_4975RSP"} {set AI 663.5013425 }

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if {$record1 == "184_1_72RSP"} {set CI 0.00263 }
if {$record1 == "2734_1_72RSP"} {set CI 0.001655 }
if {$record1 == "4228_1_72RSP"} {set CI 0.00156 }
if {$record1 == "4481_1_72RSP"} {set CI 0.00213 }
if {$record1 == "4860_1_72RSP"} {set CI 0.00217 }
if {$record1 == "6959_1_72RSP"} {set CI 0.00195 }
if {$record1 == "184_1_224RSP"} {set CI 0.010445 }
if {$record1 == "2734_1_224RSP"} {set CI 0.008045 }
if {$record1 == "4228_1_224RSP"} {set CI 0.007465 }
if {$record1 == "4481_1_224RSP"} {set CI 0.011135 }
if {$record1 == "4860_1_224RSP"} {set CI 0.01263 }
if {$record1 == "6959_1_224RSP"} {set CI 0.01086 }
if {$record1 == "184_1_475RSP"} {set CI 0.03009 }
if {$record1 == "2734_1_475RSP"} {set CI 0.020295 }
if {$record1 == "4228_1_475RSP"} {set CI 0.016235 }
if {$record1 == "4481_1_475RSP"} {set CI 0.021245 }
if {$record1 == "4860_1_475RSP"} {set CI 0.03626 }
if {$record1 == "6959_1_475RSP"} {set CI 0.030005 }
if {$record1 == "184_1_975RSP"} {set CI 0.047825 }
if {$record1 == "2734_1_975RSP"} {set CI 0.041445 }
if {$record1 == "4228_1_975RSP"} {set CI 0.04187 }
if {$record1 == "4481_1_975RSP"} {set CI 0.051715 }
if {$record1 == "4860_1_975RSP"} {set CI 0.075435 }
if {$record1 == "6959_1_975RSP"} {set CI 0.069625 }
if {$record1 == "184_1_1462RSP"} {set CI 0.072325 }
if {$record1 == "2734_1_1462RSP"} {set CI 0.059075 }
if {$record1 == "4228_1_1462RSP"} {set CI 0.05732 }
if {$record1 == "4481_1_1462RSP"} {set CI 0.070785 }
if {$record1 == "4860_1_1462RSP"} {set CI 0.112865 }
if {$record1 == "6959_1_1462RSP"} {set CI 0.10732 }
if {$record1 == "184_1_2475RSP"} {set CI 0.100035 }
if {$record1 == "2734_1_2475RSP"} {set CI 0.084035 }
if {$record1 == "4228_1_2475RSP"} {set CI 0.07247 }
if {$record1 == "4481_1_2475RSP"} {set CI 0.0933 }
if {$record1 == "4860_1_2475RSP"} {set CI 0.158185 }
if {$record1 == "6959_1_2475RSP"} {set CI 0.148185 }
if {$record1 == "184_1_3712RSP"} {set CI 0.15863 }
if {$record1 == "2734_1_3712RSP"} {set CI 0.122135 }

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if {$record1 == "4228_1_3712RSP"} {set CI 0.118275 }
if {$record1 == "4481_1_3712RSP"} {set CI 0.144235 }
if {$record1 == "4860_1_3712RSP"} {set CI 0.239565 }
if {$record1 == "6959_1_3712RSP"} {set CI 0.24042 }
if {$record1 == "184_1_4975RSP"} {set CI 0.202875 }
if {$record1 == "2734_1_4975RSP"} {set CI 0.16293 }
if {$record1 == "4228_1_4975RSP"} {set CI 0.1576 }
if {$record1 == "4481_1_4975RSP"} {set CI 0.186185 }
if {$record1 == "4860_1_4975RSP"} {set CI 0.293775 }
if {$record1 == "6959_1_4975RSP"} {set CI 0.304275 }

if {$record1 == "S1_1_2475RSP"} {set CI 0.33964 }
if {$record1 == "S2_1_2475RSP"} {set CI 0.255295 }
if {$record1 == "S3_1_2475RSP"} {set CI 0.86477 }
if {$record1 == "S4_1_2475RSP"} {set CI 0.312955 }
if {$record1 == "S5_1_2475RSP"} {set CI 0.23492 }
if {$record1 == "S6_1_2475RSP"} {set CI 0.50681 }

if {$record1 == "184_1_72RSP"} {set SED 2.16478703 }
if {$record1 == "2734_1_72RSP"} {set SED 2.025734701 }
if {$record1 == "4228_1_72RSP"} {set SED 1.879512059 }
if {$record1 == "4481_1_72RSP"} {set SED 2.35517856 }
if {$record1 == "4860_1_72RSP"} {set SED 2.526397328 }
if {$record1 == "6959_1_72RSP"} {set SED 2.68487507 }
if {$record1 == "184_1_224RSP"} {set SED 19.73770228 }
if {$record1 == "2734_1_224RSP"} {set SED 18.84261966 }
if {$record1 == "4228_1_224RSP"} {set SED 20.29724022 }
if {$record1 == "4481_1_224RSP"} {set SED 19.60670686 }
if {$record1 == "4860_1_224RSP"} {set SED 30.50509719 }
if {$record1 == "6959_1_224RSP"} {set SED 32.33182001 }
if {$record1 == "184_1_475RSP"} {set SED 84.56634013 }
if {$record1 == "2734_1_475RSP"} {set SED 69.89807877 }
if {$record1 == "4228_1_475RSP"} {set SED 64.99041711 }
if {$record1 == "4481_1_475RSP"} {set SED 62.46554963 }
if {$record1 == "4860_1_475RSP"} {set SED 116.050844 }
if {$record1 == "6959_1_475RSP"} {set SED 148.499528 }
if {$record1 == "184_1_975RSP"} {set SED 229.8640903 }
if {$record1 == "2734_1_975RSP"} {set SED 192.4029473 }
if {$record1 == "4228_1_975RSP"} {set SED 236.4090768 }
if {$record1 == "4481_1_975RSP"} {set SED 170.2430265 }
if {$record1 == "4860_1_975RSP"} {set SED 344.5115808 }
if {$record1 == "6959_1_975RSP"} {set SED 474.3491979 }
if {$record1 == "184_1_1462RSP"} {set SED 372.1504371 }
if {$record1 == "2734_1_1462RSP"} {set SED 358.2996636 }
if {$record1 == "4228_1_1462RSP"} {set SED 431.0585514 }

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if {$record1 == "4481_1_1462RSP"} {set SED 372.1086645 }
if {$record1 == "4860_1_1462RSP"} {set SED 524.5911642 }
if {$record1 == "6959_1_1462RSP"} {set SED 861.3743986 }
if {$record1 == "184_1_2475RSP"} {set SED 660.8060202 }
if {$record1 == "2734_1_2475RSP"} {set SED 636.6121946 }
if {$record1 == "4228_1_2475RSP"} {set SED 599.0649188 }
if {$record1 == "4481_1_2475RSP"} {set SED 538.67965 }
if {$record1 == "4860_1_2475RSP"} {set SED 904.7313535 }
if {$record1 == "6959_1_2475RSP"} {set SED 1420.940308 }
if {$record1 == "184_1_3712RSP"} {set SED 1033.753814 }
if {$record1 == "2734_1_3712RSP"} {set SED 974.9046957 }
if {$record1 == "4228_1_3712RSP"} {set SED 1211.467575 }
if {$record1 == "4481_1_3712RSP"} {set SED 909.0694091 }
if {$record1 == "4860_1_3712RSP"} {set SED 1354.365395 }
if {$record1 == "6959_1_3712RSP"} {set SED 2304.374743 }
if {$record1 == "184_1_4975RSP"} {set SED 1555.285369 }
if {$record1 == "2734_1_4975RSP"} {set SED 1469.433953 }
if {$record1 == "4228_1_4975RSP"} {set SED 1558.927001 }
if {$record1 == "4481_1_4975RSP"} {set SED 1519.521723 }
if {$record1 == "4860_1_4975RSP"} {set SED 1872.713216 }
if {$record1 == "6959_1_4975RSP"} {set SED 3396.756755 }

if {$record1 == "184_1_72RSP"} {set CAV 37.50776829 }
if {$record1 == "2734_1_72RSP"} {set CAV 28.58204102 }
if {$record1 == "4228_1_72RSP"} {set CAV 28.68088557 }
if {$record1 == "4481_1_72RSP"} {set CAV 30.32023094 }
if {$record1 == "4860_1_72RSP"} {set CAV 38.59605234 }
if {$record1 == "6959_1_72RSP"} {set CAV 50.11897391 }
if {$record1 == "184_1_224RSP"} {set CAV 94.85956697 }
if {$record1 == "2734_1_224RSP"} {set CAV 98.2200806 }
if {$record1 == "4228_1_224RSP"} {set CAV 105.3966002 }
if {$record1 == "4481_1_224RSP"} {set CAV 99.73004992 }
if {$record1 == "4860_1_224RSP"} {set CAV 157.912912 }
if {$record1 == "6959_1_224RSP"} {set CAV 221.7444819 }
if {$record1 == "184_1_475RSP"} {set CAV 222.337 }
if {$record1 == "2734_1_475RSP"} {set CAV 208.5976599 }
if {$record1 == "4228_1_475RSP"} {set CAV 199.8326886 }
if {$record1 == "4481_1_475RSP"} {set CAV 156.8107107 }
if {$record1 == "4860_1_475RSP"} {set CAV 340.6489025 }
if {$record1 == "6959_1_475RSP"} {set CAV 509.735982 }
if {$record1 == "184_1_975RSP"} {set CAV 318.5269791 }
if {$record1 == "2734_1_975RSP"} {set CAV 375.9148093 }
if {$record1 == "4228_1_975RSP"} {set CAV 427.237528 }
if {$record1 == "4481_1_975RSP"} {set CAV 318.1451659 }
if {$record1 == "4860_1_975RSP"} {set CAV 585.0484892 }
if {$record1 == "6959_1_975RSP"} {set CAV 978.0688333 }

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if {$record1 == "184_1_1462RSP"} {set CAV 436.3920467 }
if {$record1 == "2734_1_1462RSP"} {set CAV 503.4298821 }
if {$record1 == "4228_1_1462RSP"} {set CAV 577.9941802 }
if {$record1 == "4481_1_1462RSP"} {set CAV 407.5590134 }
if {$record1 == "4860_1_1462RSP"} {set CAV 787.2871456 }
if {$record1 == "6959_1_1462RSP"} {set CAV 1370.688484 }
if {$record1 == "184_1_2475RSP"} {set CAV 540.1189826 }
if {$record1 == "2734_1_2475RSP"} {set CAV 629.9424268 }
if {$record1 == "4228_1_2475RSP"} {set CAV 655.9203424 }
if {$record1 == "4481_1_2475RSP"} {set CAV 486.6416742 }
if {$record1 == "4860_1_2475RSP"} {set CAV 978.2800893 }
if {$record1 == "6959_1_2475RSP"} {set CAV 1681.188433 }
if {$record1 == "184_1_3712RSP"} {set CAV 815.2863202 }
if {$record1 == "2734_1_3712RSP"} {set CAV 898.1962094 }
if {$record1 == "4228_1_3712RSP"} {set CAV 1060.414236 }
if {$record1 == "4481_1_3712RSP"} {set CAV 678.3021557 }
if {$record1 == "4860_1_3712RSP"} {set CAV 1352.643162 }
if {$record1 == "6959_1_3712RSP"} {set CAV 2509.129304 }
if {$record1 == "184_1_4975RSP"} {set CAV 967.4679004 }
if {$record1 == "2734_1_4975RSP"} {set CAV 1128.208462 }
if {$record1 == "4228_1_4975RSP"} {set CAV 1309.141951 }
if {$record1 == "4481_1_4975RSP"} {set CAV 823.0681137 }
if {$record1 == "4860_1_4975RSP"} {set CAV 1568.774796 }
if {$record1 == "6959_1_4975RSP"} {set CAV 2993.71842 }

if {$record1 == "S1_1_2475RSP"} {set CAV 2032.790033 }
if {$record1 == "S2_1_2475RSP"} {set CAV 2653.493305 }
if {$record1 == "S3_1_2475RSP"} {set CAV 6420.07703 }
if {$record1 == "S4_1_2475RSP"} {set CAV 4274.030268 }
if {$record1 == "S5_1_2475RSP"} {set CAV 3063.291793 }
if {$record1 == "S6_1_2475RSP"} {set CAV 4828.412486 }

if {$record1 == "184_1_72RSP"} {set ASI 0.0409 }
if {$record1 == "2734_1_72RSP"} {set ASI 0.04099 }
if {$record1 == "4228_1_72RSP"} {set ASI 0.04135 }
if {$record1 == "4481_1_72RSP"} {set ASI 0.041215 }
if {$record1 == "4860_1_72RSP"} {set ASI 0.041395 }
if {$record1 == "6959_1_72RSP"} {set ASI 0.041185 }
if {$record1 == "184_1_224RSP"} {set ASI 0.110205 }
if {$record1 == "2734_1_224RSP"} {set ASI 0.109335 }
if {$record1 == "4228_1_224RSP"} {set ASI 0.10935 }
if {$record1 == "4481_1_224RSP"} {set ASI 0.10923 }
if {$record1 == "4860_1_224RSP"} {set ASI 0.110015 }
if {$record1 == "6959_1_224RSP"} {set ASI 0.109755 }
if {$record1 == "184_1_475RSP"} {set ASI 0.183875 }
if {$record1 == "2734_1_475RSP"} {set ASI 0.18219 }

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if {$record1 == "4228_1_475RSP"} {set ASI 0.18154 }
if {$record1 == "4481_1_475RSP"} {set ASI 0.181505 }
if {$record1 == "4860_1_475RSP"} {set ASI 0.182525 }
if {$record1 == "6959_1_475RSP"} {set ASI 0.182985 }
if {$record1 == "184_1_975RSP"} {set ASI 0.26952 }
if {$record1 == "2734_1_975RSP"} {set ASI 0.26856 }
if {$record1 == "4228_1_975RSP"} {set ASI 0.2711 }
if {$record1 == "4481_1_975RSP"} {set ASI 0.270925 }
if {$record1 == "4860_1_975RSP"} {set ASI 0.27108 }
if {$record1 == "6959_1_975RSP"} {set ASI 0.26946 }
if {$record1 == "184_1_1462RSP"} {set ASI 0.330365 }
if {$record1 == "2734_1_1462RSP"} {set ASI 0.33166 }
if {$record1 == "4228_1_1462RSP"} {set ASI 0.33271 }
if {$record1 == "4481_1_1462RSP"} {set ASI 0.33067 }
if {$record1 == "4860_1_1462RSP"} {set ASI 0.331705 }
if {$record1 == "6959_1_1462RSP"} {set ASI 0.32987 }
if {$record1 == "184_1_2475RSP"} {set ASI 0.41853 }
if {$record1 == "2734_1_2475RSP"} {set ASI 0.41877 }
if {$record1 == "4228_1_2475RSP"} {set ASI 0.419085 }
if {$record1 == "4481_1_2475RSP"} {set ASI 0.419665 }
if {$record1 == "4860_1_2475RSP"} {set ASI 0.41703 }
if {$record1 == "6959_1_2475RSP"} {set ASI 0.4181 }
if {$record1 == "184_1_3712RSP"} {set ASI 0.49341 }
if {$record1 == "2734_1_3712RSP"} {set ASI 0.492095 }
if {$record1 == "4228_1_3712RSP"} {set ASI 0.49167 }
if {$record1 == "4481_1_3712RSP"} {set ASI 0.492795 }
if {$record1 == "4860_1_3712RSP"} {set ASI 0.492915 }
if {$record1 == "6959_1_3712RSP"} {set ASI 0.491915 }
if {$record1 == "184_1_4975RSP"} {set ASI 0.554385 }
if {$record1 == "2734_1_4975RSP"} {set ASI 0.552955 }
if {$record1 == "4228_1_4975RSP"} {set ASI 0.553175 }
if {$record1 == "4481_1_4975RSP"} {set ASI 0.55698 }
if {$record1 == "4860_1_4975RSP"} {set ASI 0.55352 }
if {$record1 == "6959_1_4975RSP"} {set ASI 0.553585 }

if {$record1 == "184_1_72RSP"} {set VSI 5.364514708 }
if {$record1 == "2734_1_72RSP"} {set VSI 5.12707954 }
if {$record1 == "4228_1_72RSP"} {set VSI 5.814404715 }
if {$record1 == "4481_1_72RSP"} {set VSI 4.996825533 }
if {$record1 == "4860_1_72RSP"} {set VSI 5.451004912 }
if {$record1 == "6959_1_72RSP"} {set VSI 5.536735273 }
if {$record1 == "184_1_224RSP"} {set VSI 15.97249288 }
if {$record1 == "2734_1_224RSP"} {set VSI 15.31885079 }
if {$record1 == "4228_1_224RSP"} {set VSI 15.91007355 }
if {$record1 == "4481_1_224RSP"} {set VSI 16.09782168 }
if {$record1 == "4860_1_224RSP"} {set VSI 15.13811054 }

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if {$record1 == "6959_1_224RSP"} {set VSI 15.84663651 }
if {$record1 == "184_1_475RSP"} {set VSI 28.57761976 }
if {$record1 == "2734_1_475RSP"} {set VSI 28.19228491 }
if {$record1 == "4228_1_475RSP"} {set VSI 30.47761095 }
if {$record1 == "4481_1_475RSP"} {set VSI 28.79319862 }
if {$record1 == "4860_1_475RSP"} {set VSI 27.93449737 }
if {$record1 == "6959_1_475RSP"} {set VSI 27.47266444 }
if {$record1 == "184_1_975RSP"} {set VSI 44.87324667 }
if {$record1 == "2734_1_975RSP"} {set VSI 43.39485808 }
if {$record1 == "4228_1_975RSP"} {set VSI 46.36206441 }
if {$record1 == "4481_1_975RSP"} {set VSI 47.0382439 }
if {$record1 == "4860_1_975RSP"} {set VSI 43.15357645 }
if {$record1 == "6959_1_975RSP"} {set VSI 43.59481685 }
if {$record1 == "184_1_1462RSP"} {set VSI 54.91567532 }
if {$record1 == "2734_1_1462RSP"} {set VSI 54.49592903 }
if {$record1 == "4228_1_1462RSP"} {set VSI 55.83278015 }
if {$record1 == "4481_1_1462RSP"} {set VSI 57.09657808 }
if {$record1 == "4860_1_1462RSP"} {set VSI 55.33503382 }
if {$record1 == "6959_1_1462RSP"} {set VSI 54.3620451 }
if {$record1 == "184_1_2475RSP"} {set VSI 73.29828564 }
if {$record1 == "2734_1_2475RSP"} {set VSI 70.5082487 }
if {$record1 == "4228_1_2475RSP"} {set VSI 74.98827278 }
if {$record1 == "4481_1_2475RSP"} {set VSI 76.54432874 }
if {$record1 == "4860_1_2475RSP"} {set VSI 70.79831579 }
if {$record1 == "6959_1_2475RSP"} {set VSI 70.7481012 }
if {$record1 == "184_1_3712RSP"} {set VSI 85.8898141 }
if {$record1 == "2734_1_3712RSP"} {set VSI 84.36388808 }
if {$record1 == "4228_1_3712RSP"} {set VSI 88.71366602 }
if {$record1 == "4481_1_3712RSP"} {set VSI 90.6135824 }
if {$record1 == "4860_1_3712RSP"} {set VSI 84.98998093 }
if {$record1 == "6959_1_3712RSP"} {set VSI 85.3328886 }
if {$record1 == "184_1_4975RSP"} {set VSI 98.06851162 }
if {$record1 == "2734_1_4975RSP"} {set VSI 96.8995917 }
if {$record1 == "4228_1_4975RSP"} {set VSI 103.0298627 }
if {$record1 == "4481_1_4975RSP"} {set VSI 100.6118988 }
if {$record1 == "4860_1_4975RSP"} {set VSI 98.47751774 }
if {$record1 == "6959_1_4975RSP"} {set VSI 97.18986154 }

if {$record1 == "S1_1_2475RSP"} {set VSI 73.55007283 }
if {$record1 == "S2_1_2475RSP"} {set VSI 72.46319291 }
if {$record1 == "S3_1_2475RSP"} {set VSI 153.4581614 }
if {$record1 == "S4_1_2475RSP"} {set VSI 72.7901122 }
if {$record1 == "S5_1_2475RSP"} {set VSI 73.39205315 }
if {$record1 == "S6_1_2475RSP"} {set VSI 74.22604724 }

if {$record1 == "184_1_72RSP"} {set HI 4.741388387 }

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```

if {$record1 == "2734_1_72RSP"} {set HI 4.768352969 }
if {$record1 == "4228_1_72RSP"} {set HI 4.776721083 }
if {$record1 == "4481_1_72RSP"} {set HI 4.748016343 }
if {$record1 == "4860_1_72RSP"} {set HI 4.783288016 }
if {$record1 == "6959_1_72RSP"} {set HI 4.837490801 }
if {$record1 == "184_1_224RSP"} {set HI 14.23569863 }
if {$record1 == "2734_1_224RSP"} {set HI 14.03730679 }
if {$record1 == "4228_1_224RSP"} {set HI 14.05198003 }
if {$record1 == "4481_1_224RSP"} {set HI 14.22465729 }
if {$record1 == "4860_1_224RSP"} {set HI 14.24396045 }
if {$record1 == "6959_1_224RSP"} {set HI 14.17942892 }
if {$record1 == "184_1_475RSP"} {set HI 25.73943713 }
if {$record1 == "2734_1_475RSP"} {set HI 25.44374602 }
if {$record1 == "4228_1_475RSP"} {set HI 25.4476161 }
if {$record1 == "4481_1_475RSP"} {set HI 25.42830507 }
if {$record1 == "4860_1_475RSP"} {set HI 25.67061229 }
if {$record1 == "6959_1_475RSP"} {set HI 25.49194487 }
if {$record1 == "184_1_975RSP"} {set HI 40.6529255 }
if {$record1 == "2734_1_975RSP"} {set HI 41.09782534 }
if {$record1 == "4228_1_975RSP"} {set HI 41.0228194 }
if {$record1 == "4481_1_975RSP"} {set HI 40.74314405 }
if {$record1 == "4860_1_975RSP"} {set HI 40.57199238 }
if {$record1 == "6959_1_975RSP"} {set HI 40.38072062 }
if {$record1 == "184_1_1462RSP"} {set HI 51.04140552 }
if {$record1 == "2734_1_1462RSP"} {set HI 51.20199222 }
if {$record1 == "4228_1_1462RSP"} {set HI 51.18764969 }
if {$record1 == "4481_1_1462RSP"} {set HI 51.19774221 }
if {$record1 == "4860_1_1462RSP"} {set HI 51.5096597 }
if {$record1 == "6959_1_1462RSP"} {set HI 50.84300186 }
if {$record1 == "184_1_2475RSP"} {set HI 66.59390998 }
if {$record1 == "2734_1_2475RSP"} {set HI 67.38697143 }
if {$record1 == "4228_1_2475RSP"} {set HI 66.80178607 }
if {$record1 == "4481_1_2475RSP"} {set HI 66.26356531 }
if {$record1 == "4860_1_2475RSP"} {set HI 66.60285289 }
if {$record1 == "6959_1_2475RSP"} {set HI 66.95553812 }
if {$record1 == "184_1_3712RSP"} {set HI 79.03161748 }
if {$record1 == "2734_1_3712RSP"} {set HI 79.4146984 }
if {$record1 == "4228_1_3712RSP"} {set HI 79.27003493 }
if {$record1 == "4481_1_3712RSP"} {set HI 79.71467494 }
if {$record1 == "4860_1_3712RSP"} {set HI 78.83762131 }
if {$record1 == "6959_1_3712RSP"} {set HI 79.20065497 }
if {$record1 == "184_1_4975RSP"} {set HI 89.97867851 }
if {$record1 == "2734_1_4975RSP"} {set HI 90.45564333 }
if {$record1 == "4228_1_4975RSP"} {set HI 90.1392908 }
if {$record1 == "4481_1_4975RSP"} {set HI 90.16250735 }
if {$record1 == "4860_1_4975RSP"} {set HI 90.17090696 }

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if {$record1 == "6959_1_4975RSP"} {set HI 89.98686159 }

if {$record1 == "S1_1_2475RSP"} {set HI 66.88113189 }
if {$record1 == "S2_1_2475RSP"} {set HI 66.88469094 }
if {$record1 == "S3_1_2475RSP"} {set HI 139.4789213 }
if {$record1 == "S4_1_2475RSP"} {set HI 66.90983268 }
if {$record1 == "S5_1_2475RSP"} {set HI 66.81965354 }
if {$record1 == "S6_1_2475RSP"} {set HI 66.64914764 }


if {$record1 == "184_1_72RSP"} {set SMA 0.039095 }
if {$record1 == "2734_1_72RSP"} {set SMA 0.03809 }
if {$record1 == "4228_1_72RSP"} {set SMA 0.040535 }
if {$record1 == "4481_1_72RSP"} {set SMA 0.03827 }
if {$record1 == "4860_1_72RSP"} {set SMA 0.02519 }
if {$record1 == "6959_1_72RSP"} {set SMA 0.037245 }
if {$record1 == "184_1_224RSP"} {set SMA 0.113385 }
if {$record1 == "2734_1_224RSP"} {set SMA 0.10683 }
if {$record1 == "4228_1_224RSP"} {set SMA 0.103625 }
if {$record1 == "4481_1_224RSP"} {set SMA 0.108375 }
if {$record1 == "4860_1_224RSP"} {set SMA 0.107545 }
if {$record1 == "6959_1_224RSP"} {set SMA 0.09555 }
if {$record1 == "184_1_475RSP"} {set SMA 0.173065 }
if {$record1 == "2734_1_475RSP"} {set SMA 0.15793 }
if {$record1 == "4228_1_475RSP"} {set SMA 0.18169 }
if {$record1 == "4481_1_475RSP"} {set SMA 0.16349 }
if {$record1 == "4860_1_475RSP"} {set SMA 0.1878 }
if {$record1 == "6959_1_475RSP"} {set SMA 0.16572 }
if {$record1 == "184_1_975RSP"} {set SMA 0.237725 }
if {$record1 == "2734_1_975RSP"} {set SMA 0.256795 }
if {$record1 == "4228_1_975RSP"} {set SMA 0.28427 }
if {$record1 == "4481_1_975RSP"} {set SMA 0.28228 }
if {$record1 == "4860_1_975RSP"} {set SMA 0.247195 }
if {$record1 == "6959_1_975RSP"} {set SMA 0.270645 }
if {$record1 == "184_1_1462RSP"} {set SMA 0.343965 }
if {$record1 == "2734_1_1462RSP"} {set SMA 0.33258 }
if {$record1 == "4228_1_1462RSP"} {set SMA 0.323665 }
if {$record1 == "4481_1_1462RSP"} {set SMA 0.360815 }
if {$record1 == "4860_1_1462RSP"} {set SMA 0.33808 }
if {$record1 == "6959_1_1462RSP"} {set SMA 0.29585 }
if {$record1 == "184_1_2475RSP"} {set SMA 0.394905 }
if {$record1 == "2734_1_2475RSP"} {set SMA 0.382765 }
if {$record1 == "4228_1_2475RSP"} {set SMA 0.432645 }
if {$record1 == "4481_1_2475RSP"} {set SMA 0.470965 }
if {$record1 == "4860_1_2475RSP"} {set SMA 0.38087 }
if {$record1 == "6959_1_2475RSP"} {set SMA 0.395025 }

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if {$record1 == "184_1_3712RSP"} {set SMA 0.48646 }
if {$record1 == "2734_1_3712RSP"} {set SMA 0.52818 }
if {$record1 == "4228_1_3712RSP"} {set SMA 0.51892 }
if {$record1 == "4481_1_3712RSP"} {set SMA 0.535385 }
if {$record1 == "4860_1_3712RSP"} {set SMA 0.486875 }
if {$record1 == "6959_1_3712RSP"} {set SMA 0.48089 }
if {$record1 == "184_1_4975RSP"} {set SMA 0.587555 }
if {$record1 == "2734_1_4975RSP"} {set SMA 0.58372 }
if {$record1 == "4228_1_4975RSP"} {set SMA 0.568615 }
if {$record1 == "4481_1_4975RSP"} {set SMA 0.6353 }
if {$record1 == "4860_1_4975RSP"} {set SMA 0.596515 }
if {$record1 == "6959_1_4975RSP"} {set SMA 0.554175 }

if {$record1 == "184_1_72RSP"} {set SMV 0.928396171 }
if {$record1 == "2734_1_72RSP"} {set SMV 1.062646243 }
if {$record1 == "4228_1_72RSP"} {set SMV 0.885114651 }
if {$record1 == "4481_1_72RSP"} {set SMV 0.819173671 }
if {$record1 == "4860_1_72RSP"} {set SMV 0.892122529 }
if {$record1 == "6959_1_72RSP"} {set SMV 0.895008357 }
if {$record1 == "184_1_224RSP"} {set SMV 2.598792742 }
if {$record1 == "2734_1_224RSP"} {set SMV 2.903141331 }
if {$record1 == "4228_1_224RSP"} {set SMV 2.397324129 }
if {$record1 == "4481_1_224RSP"} {set SMV 2.689253421 }
if {$record1 == "4860_1_224RSP"} {set SMV 2.437213915 }
if {$record1 == "6959_1_224RSP"} {set SMV 2.953499626 }
if {$record1 == "184_1_475RSP"} {set SMV 4.818260476 }
if {$record1 == "2734_1_475RSP"} {set SMV 5.50778447 }
if {$record1 == "4228_1_475RSP"} {set SMV 4.996555848 }
if {$record1 == "4481_1_475RSP"} {set SMV 4.546419778 }
if {$record1 == "4860_1_475RSP"} {set SMV 4.688240721 }
if {$record1 == "6959_1_475RSP"} {set SMV 5.255953626 }
if {$record1 == "184_1_975RSP"} {set SMV 8.256793829 }
if {$record1 == "2734_1_975RSP"} {set SMV 9.293036514 }
if {$record1 == "4228_1_975RSP"} {set SMV 8.940829631 }
if {$record1 == "4481_1_975RSP"} {set SMV 7.442941027 }
if {$record1 == "4860_1_975RSP"} {set SMV 7.893185365 }
if {$record1 == "6959_1_975RSP"} {set SMV 8.174563469 }
if {$record1 == "184_1_1462RSP"} {set SMV 8.628061746 }
if {$record1 == "2734_1_1462RSP"} {set SMV 11.87897295 }
if {$record1 == "4228_1_1462RSP"} {set SMV 10.08522592 }
if {$record1 == "4481_1_1462RSP"} {set SMV 12.30910114 }
if {$record1 == "4860_1_1462RSP"} {set SMV 9.690026886 }
if {$record1 == "6959_1_1462RSP"} {set SMV 11.65703189 }
if {$record1 == "184_1_2475RSP"} {set SMV 15.21488026 }
if {$record1 == "2734_1_2475RSP"} {set SMV 15.12112037 }
if {$record1 == "4228_1_2475RSP"} {set SMV 13.56270024 }

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if {$record1 == "4481_1_2475RSP"} {set SMV 11.64055156 }
if {$record1 == "4860_1_2475RSP"} {set SMV 12.64735132 }
if {$record1 == "6959_1_2475RSP"} {set SMV 15.14839007 }
if {$record1 == "184_1_3712RSP"} {set SMV 15.4451422 }
if {$record1 == "2734_1_3712RSP"} {set SMV 17.87325571 }
if {$record1 == "4228_1_3712RSP"} {set SMV 17.53263545 }
if {$record1 == "4481_1_3712RSP"} {set SMV 18.17186218 }
if {$record1 == "4860_1_3712RSP"} {set SMV 16.04316024 }
if {$record1 == "6959_1_3712RSP"} {set SMV 18.45857296 }
if {$record1 == "184_1_4975RSP"} {set SMV 21.21704689 }
if {$record1 == "2734_1_4975RSP"} {set SMV 20.69360369 }
if {$record1 == "4228_1_4975RSP"} {set SMV 18.04161998 }
if {$record1 == "4481_1_4975RSP"} {set SMV 16.42158367 }
if {$record1 == "4860_1_4975RSP"} {set SMV 18.79143141 }
if {$record1 == "6959_1_4975RSP"} {set SMV 21.8973819 }

if {$record1 == "184_1_72RSP"} {set EDA 0.045945 }
if {$record1 == "2734_1_72RSP"} {set EDA 0.04718 }
if {$record1 == "4228_1_72RSP"} {set EDA 0.05324 }
if {$record1 == "4481_1_72RSP"} {set EDA 0.052715 }
if {$record1 == "4860_1_72RSP"} {set EDA 0.04879 }
if {$record1 == "6959_1_72RSP"} {set EDA 0.04894 }
if {$record1 == "184_1_224RSP"} {set EDA 0.126065 }
if {$record1 == "2734_1_224RSP"} {set EDA 0.117065 }
if {$record1 == "4228_1_224RSP"} {set EDA 0.142 }
if {$record1 == "4481_1_224RSP"} {set EDA 0.13686 }
if {$record1 == "4860_1_224RSP"} {set EDA 0.121385 }
if {$record1 == "6959_1_224RSP"} {set EDA 0.1266 }
if {$record1 == "184_1_475RSP"} {set EDA 0.194795 }
if {$record1 == "2734_1_475RSP"} {set EDA 0.19046 }
if {$record1 == "4228_1_475RSP"} {set EDA 0.19868 }
if {$record1 == "4481_1_475RSP"} {set EDA 0.21132 }
if {$record1 == "4860_1_475RSP"} {set EDA 0.230795 }
if {$record1 == "6959_1_475RSP"} {set EDA 0.16119 }
if {$record1 == "184_1_975RSP"} {set EDA 0.33337 }
if {$record1 == "2734_1_975RSP"} {set EDA 0.256605 }
if {$record1 == "4228_1_975RSP"} {set EDA 0.28299 }
if {$record1 == "4481_1_975RSP"} {set EDA 0.27949 }
if {$record1 == "4860_1_975RSP"} {set EDA 0.27746 }
if {$record1 == "6959_1_975RSP"} {set EDA 0.281645 }
if {$record1 == "184_1_1462RSP"} {set EDA 0.395825 }
if {$record1 == "2734_1_1462RSP"} {set EDA 0.366295 }
if {$record1 == "4228_1_1462RSP"} {set EDA 0.410735 }
if {$record1 == "4481_1_1462RSP"} {set EDA 0.39465 }
if {$record1 == "4860_1_1462RSP"} {set EDA 0.33975 }
if {$record1 == "6959_1_1462RSP"} {set EDA 0.334025 }

```

```

if {$record1 == "184_1_2475RSP"} {set EDA 0.47972 }
if {$record1 == "2734_1_2475RSP"} {set EDA 0.405085 }
if {$record1 == "4228_1_2475RSP"} {set EDA 0.511855 }
if {$record1 == "4481_1_2475RSP"} {set EDA 0.511645 }
if {$record1 == "4860_1_2475RSP"} {set EDA 0.44419 }
if {$record1 == "6959_1_2475RSP"} {set EDA 0.416105 }
if {$record1 == "184_1_3712RSP"} {set EDA 0.591455 }
if {$record1 == "2734_1_3712RSP"} {set EDA 0.56745 }
if {$record1 == "4228_1_3712RSP"} {set EDA 0.576805 }
if {$record1 == "4481_1_3712RSP"} {set EDA 0.561925 }
if {$record1 == "4860_1_3712RSP"} {set EDA 0.528305 }
if {$record1 == "6959_1_3712RSP"} {set EDA 0.49197 }
if {$record1 == "184_1_4975RSP"} {set EDA 0.703565 }
if {$record1 == "2734_1_4975RSP"} {set EDA 0.67552 }
if {$record1 == "4228_1_4975RSP"} {set EDA 0.60758 }
if {$record1 == "4481_1_4975RSP"} {set EDA 0.62251 }
if {$record1 == "4860_1_4975RSP"} {set EDA 0.592445 }
if {$record1 == "6959_1_4975RSP"} {set EDA 0.59059 }

if {$record1 == "184_1_72RSP"} {set A95 0.04619 }
if {$record1 == "2734_1_72RSP"} {set A95 0.0493 }
if {$record1 == "4228_1_72RSP"} {set A95 0.05819 }
if {$record1 == "4481_1_72RSP"} {set A95 0.052235 }
if {$record1 == "4860_1_72RSP"} {set A95 0.053325 }
if {$record1 == "6959_1_72RSP"} {set A95 0.05244 }
if {$record1 == "184_1_224RSP"} {set A95 0.133095 }
if {$record1 == "2734_1_224RSP"} {set A95 0.13662 }
if {$record1 == "4228_1_224RSP"} {set A95 0.165825 }
if {$record1 == "4481_1_224RSP"} {set A95 0.15811 }
if {$record1 == "4860_1_224RSP"} {set A95 0.148545 }
if {$record1 == "6959_1_224RSP"} {set A95 0.135085 }
if {$record1 == "184_1_475RSP"} {set A95 0.203005 }
if {$record1 == "2734_1_475RSP"} {set A95 0.20409 }
if {$record1 == "4228_1_475RSP"} {set A95 0.234855 }
if {$record1 == "4481_1_475RSP"} {set A95 0.219505 }
if {$record1 == "4860_1_475RSP"} {set A95 0.241455 }
if {$record1 == "6959_1_475RSP"} {set A95 0.182735 }
if {$record1 == "184_1_975RSP"} {set A95 0.339445 }
if {$record1 == "2734_1_975RSP"} {set A95 0.306045 }
if {$record1 == "4228_1_975RSP"} {set A95 0.312115 }
if {$record1 == "4481_1_975RSP"} {set A95 0.323925 }
if {$record1 == "4860_1_975RSP"} {set A95 0.3157 }
if {$record1 == "6959_1_975RSP"} {set A95 0.289985 }
if {$record1 == "184_1_1462RSP"} {set A95 0.395975 }
if {$record1 == "2734_1_1462RSP"} {set A95 0.40272 }
if {$record1 == "4228_1_1462RSP"} {set A95 0.44983 }

```

```

if {$record1 == "4481_1_1462RSP"} {set A95 0.400125 }
if {$record1 == "4860_1_1462RSP"} {set A95 0.376875 }
if {$record1 == "6959_1_1462RSP"} {set A95 0.372555 }
if {$record1 == "184_1_2475RSP"} {set A95 0.494795 }
if {$record1 == "2734_1_2475RSP"} {set A95 0.40569 }
if {$record1 == "4228_1_2475RSP"} {set A95 0.54029 }
if {$record1 == "4481_1_2475RSP"} {set A95 0.541005 }
if {$record1 == "4860_1_2475RSP"} {set A95 0.47624 }
if {$record1 == "6959_1_2475RSP"} {set A95 0.42425 }
if {$record1 == "184_1_3712RSP"} {set A95 0.64736 }
if {$record1 == "2734_1_3712RSP"} {set A95 0.61537 }
if {$record1 == "4228_1_3712RSP"} {set A95 0.646015 }
if {$record1 == "4481_1_3712RSP"} {set A95 0.63109 }
if {$record1 == "4860_1_3712RSP"} {set A95 0.59079 }
if {$record1 == "6959_1_3712RSP"} {set A95 0.50887 }
if {$record1 == "184_1_4975RSP"} {set A95 0.774365 }
if {$record1 == "2734_1_4975RSP"} {set A95 0.72304 }
if {$record1 == "4228_1_4975RSP"} {set A95 0.634745 }
if {$record1 == "4481_1_4975RSP"} {set A95 0.730425 }
if {$record1 == "4860_1_4975RSP"} {set A95 0.660085 }
if {$record1 == "6959_1_4975RSP"} {set A95 0.58795 }

```

#End of Code

7.3 MATLAB Code

Dynamic.m

The first MATLAB script that was developed was used to import and process the results and metadata from the OpenSees simulations, and organize the results into a series of matrices. The first block of code imports the comma delineated text file, and sorts metadata related to each simulation into cell arrays, including ground record data, structure and soil properties, and ground motion parameters. The second block of data opens each structural displacement time-history, and sorts the max recorded displacement, residual lateral displacement, and residual vertical displacement into a series of cell arrays. Additionally, this part of the code also determines which structures have toppled, and removes toppled structures from the data. The final block of code converts the cell arrays to Nx1 matrices, which are easier to plot.

```

% Start of Code
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Import and sort metadata
T = readtable('metadata.csv');
C = table2cell(T);
EQrecord=C(1:end,2);

```

```

EQType=C(1:end,3);
ReturnPeriod=C(1:end,4);
ScaleFactor=C(1:end,5);
    ScaleFactor=cell2mat(ScaleFactor);
Variable=C(1:end,6);
Period=C(1:end,7);
    Period=cell2mat(Period);
SaT=C(1:end,8);
    SaT=cell2mat(SaT);
Height=C(1:end,9);
    Height=cell2mat(Height);
Xfoot=C(1:end,10);
    Xfoot=cell2mat(Xfoot);
Mass=C(1:end,11);
    Mass=cell2mat(Mass);
Weight=C(1:end,12);
    Weight=cell2mat(Weight);
Icol=C(1:end,13);
    Icol=cell2mat(Icol);
Ecol=C(1:end,14);
    Ecol=cell2mat(Ecol);
Esoil=C(1:end,15);
    Esoil=cell2mat(Esoil);
Fysoil=C(1:end,16);
    Fysoil=cell2mat(Fysoil);
Vmax=C(1:end,17);
    Vmax=cell2mat(Vmax);
DynamicLoad=C(1:end,18);
    DynamicLoad=cell2mat(DynamicLoad);
DSR=C(1:end,19);
    DSR=cell2mat(DSR);
PostYieldStiffness=C(1:end,20);
    PostYieldStiffness=cell2mat(PostYieldStiffness);
HardeningRatio=C(1:end,21);
    HardeningRatio=cell2mat(HardeningRatio);
SD=C(1:end,22);
    SD=cell2mat(SD);
MA=C(1:end,23);
    MA=cell2mat(MA);
MV=C(1:end,24);
    MV=cell2mat(MV);
MD=C(1:end,25);
    MD=cell2mat(MD);
VA=C(1:end,26);
    VA=cell2mat(VA);
ARMS=C(1:end,27);
    ARMS=cell2mat(ARMS);
VRMS=C(1:end,28);
    VRMS=cell2mat(VRMS);
DRMS=C(1:end,29);
    DRMS=cell2mat(DRMS);
AI=C(1:end,30);
    AI=cell2mat(AI);
CI=C(1:end,31);
    CI=cell2mat(CI);
SED=C(1:end,32);
    SED=cell2mat(SED);

```

```

CAV=C(1:end,33);
    CAV=cell2mat(CAV);
ASI=C(1:end,34);
    ASI=cell2mat(ASI);
VSI=C(1:end,35);
    VSI=cell2mat(VSI);
HI=C(1:end,36);
    HI=cell2mat(HI);
SMA=C(1:end,37);
    SMA=cell2mat(SMA);
SMV=C(1:end,38);
    SMV=cell2mat(SMV);
EDA=C(1:end,39);
    EDA=cell2mat(EDA);
A95=C(1:end,40);
    A95=cell2mat(A95);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Seperate shallow crustal and suduction records
shallow1=strfind(EQType,'ShallowCrustal');
    ix=cellfun('isempty',shallow1);
    shallow1(ix)={0};
    shallow1=cell2mat(shallow1);

subduction1=strfind(EQType,'Subduction');
    ix=cellfun('isempty',subduction1);
    subduction1(ix)={0};
    subduction1=cell2mat(subduction1);

% Import and analyze time-history files
%Open all .txt files
N = 20;
files=dir('*.txt');
for i=1:length(files);
file = ['DFree_node0_' num2str(i) '.txt'];
fileID = fopen(file);
ix=sprintf('d%d',i);
D.(ix) = textscan(fileID,'%f %f %f %f %f %f %f',...
'Delimiter',' ');
fclose(fileID);

%Define what data is in which column
Lat_disp1.(ix) = D.(ix){2};
Lat_disp2.(ix) = D.(ix){3};
Vert_disp.(ix) = D.(ix){4};

%Average residual values for each file, 1:i
ALD1.(ix) = mean(Lat_disp1.(ix)(end-N+1:end));
ALD2.(ix) = mean(Lat_disp2.(ix)(end-N+1:end));
ALD.(ix) = sqrt((ALD1.(ix))^2+ (ALD2.(ix))^2);
AVD.(ix) = mean(Vert_disp.(ix)(end-N+1:end));

```

```

MLD1.(ix) = max(abs(Lat_disp1.(ix)));
MLD2.(ix) = max(abs(Lat_disp2.(ix)));
MLD.(ix) = sqrt((MLD1.(ix))^2+ (MLD2.(ix))^2);

if (abs(ALD.(ix)) > Height);
    Topple.(ix)=1;
else
    Topple.(ix)=0;
end

if (Topple.(ix) == 1);
    ALD.(ix)=nan;
    MLD.(ix)=nan;
    AVD.(ix)=nan;
end

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Convert structure to cell array
AVD = struct2cell(AVD); %Average Vertical Displacement
ALD = struct2cell(ALD); %Average Lateral Displacement
MLD = struct2cell(MLD); %Max Lateral Displacement

AVD=cell2mat(AVD);
ALD=cell2mat(ALD);
MLD=cell2mat(MLD);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Topple = struct2cell(Topple);
Topple=cell2mat(Topple);

errordlg('Time-History Analysis Done')

%End of Code

```

Plotdata.m

The second MATLAB script is used to sort the data generated from the first script, and generate figures relating the engineering demand parameters against a user defined parameter. The first block of code generates various parameters used in the script. The second block generates a series of “switch” matrices that consist of a number of 1’s and 0’s, based on what value is within the Variable and Return Period matrices. This allows the user to multiply the main matrix by these “switch” vectors, and retain or omit data, based on if the values are multiplied by a 1 or 0. As such, the user can “turn on” or “turn off” data, such as certain variables or return periods, to remove them from the graphical figures. The second block of data allows the user to define what nondimensional parameter they want plotted on the x-axis, what

variables should be plotted, what return periods are displayed, what the “groups” are for the group scatter-plot, and if the axis is linear or log. The final portion of the code truncates simulations with periods in excess of 5 seconds, defines the engineering demand parameters, and generates the scatter plots.

```
%Start of Code

%Calculate misc parameters
PlungeDisplacement=Fysoil./Esoil;
g=386.4;
SdT=SaT.*g.*((Period./(2*pi())).^2);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Truncate useless data
V1=strfind(Variable,'Height');
ix=cellfun('isempty',V1);
V1(ix)={0};
V1=cell2mat(V1);
V2=strfind(Variable,'Xfoot');
ix=cellfun('isempty',V2);
V2(ix)={0};
V2=cell2mat(V2);
V3=strfind(Variable,'ColumnDiameter');
ix=cellfun('isempty',V3);
V3(ix)={0};
V3=cell2mat(V3);
V4=strfind(Variable,'Mass');
ix=cellfun('isempty',V4);
V4(ix)={0};
V4=cell2mat(V4);
V5=strfind(Variable,'Ecolumn');
ix=cellfun('isempty',V5);
V5(ix)={0};
V5=cell2mat(V5);
V6=strfind(Variable,'Esoil');
ix=cellfun('isempty',V6);
V6(ix)={0};
V6=cell2mat(V6);
V7=strfind(Variable,'Fy_soil');
ix=cellfun('isempty',V7);
V7(ix)={0};
V7=cell2mat(V7);
V8=strfind(Variable,'Weight');
ix=cellfun('isempty',V8);
V8(ix)={0};
V8=cell2mat(V8);
V9=strfind(Variable,'Eta');
ix=cellfun('isempty',V9);
V9(ix)={0};
V9=cell2mat(V9);
V10=strfind(Variable,'Earthquake');
ix=cellfun('isempty',V10);
V10(ix)={0};
V10=cell2mat(V10);
```

```

R1=strfind(ReturnPeriod,'R72');
    ix=cellfun('isempty',R1);
    R1(ix)={0};
    R1=cell2mat(R1);
R2=strfind(ReturnPeriod,'R224');
    ix=cellfun('isempty',R2);
    R2(ix)={0};
    R2=cell2mat(R2);
R3=strfind(ReturnPeriod,'R475');
    ix=cellfun('isempty',R3);
    R3(ix)={0};
    R3=cell2mat(R3);
R4=strfind(ReturnPeriod,'R975');
    ix=cellfun('isempty',R4);
    R4(ix)={0};
    R4=cell2mat(R4);
R5=strfind(ReturnPeriod,'R1462');
    ix=cellfun('isempty',R5);
    R5(ix)={0};
    R5=cell2mat(R5);
R6=strfind(ReturnPeriod,'R2475');
    ix=cellfun('isempty',R6);
    R6(ix)={0};
    R6=cell2mat(R6);
R7=strfind(ReturnPeriod,'R3712');
    ix=cellfun('isempty',R7);
    R7(ix)={0};
    R7=cell2mat(R7);
R8=strfind(ReturnPeriod,'R4975');
    ix=cellfun('isempty',R8);
    R8(ix)={0};
    R8=cell2mat(R8);

Rx=R1+R2+R3+R4+R5+R6+R7+R8;

Vx=V1+V2+V3+V4+V5+V6+V7+V8+V9+V10;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Height=C(1:end,9);      [ INCHES]      V1
%Xfoot=C(1:end,10);      [ INCHES]      V2
%Icol=C(1:end,13);        [ IN^4]        V3
%Mass=C(1:end,11);        [ SLUGS]      V4
%Ecol=C(1:end,14);        [ PSI]         V5
%Esoil=C(1:end,15);        [ PSI/IN]     V6
%Fysoil=C(1:end,16);      [ PSI]         V7
%Weight=C(1:end,12);      [ LBF]         V8
%PostYieldStiffness      [ LBF/IN]      V9
PYS=PostYieldStiffness;

%-----%
Parameter=(PYS.*25). *Xfoot./ (Mass.*SaT.*g);

```



```

Group=Variable;    %Select Group (EQType,EQrecord, Variable, AI,
SD, ect.)
scale='log';        %Select linear or log-log plot
%Vx=V1+V2;        %Define which variables will be plotted
xubound=max(Parameter);
xlbound=min(Parameter);

%xubound=500; %Define upper limit of x-axis
%xlbound=0;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Px(Period<5)=1;
Px(Period>5)=nan;

Pxx=rot90(Px,3);

%Convert structure to cell array
AVDx=AVD.*Vx.*Rx.*Pxx;
    AVDx(AVDx == 0) = nan;
ALDx=ALD.*Vx.*Rx.*Pxx;
    ALDx(ALDx == 0) = nan;
MLDx=MLD.*Vx.*Rx.*Pxx;
    MLDx(MLDx == 0) = nan;

TopleftHist=Parameter.*Topleft;
    TopleftHistSub=TopleftHist.*subduction1;
    TopleftHistShallow=TopleftHist.*shallow1;
    TopleftHist=horzcat(TopleftHistSub,TopleftHistShallow);
TopleftHist(TopleftHist == 0) = nan;

[countsTH,centersTH] = hist(TopleftHist);
xbins=centersTH;
[counts,centers] = hist(Parameter,xbins);
counts=rot90(counts,3);
counts=counts;
counts=horzcat(counts,count);
PercentTopleft=countsTH./counts.*100;

%Nondimensional Parameters
EDP1=MLDx./Height;
EDP2=MLDx./SdT;
EDP3=ALDx./Height;
EDP4=ALDx./SdT;
EDP5=AVDx./PlungeDisplacement;

figure(1)
gscatter(Parameter,EDP1,Group)
    set(gca,'xscale',scale)
    set(gca,'yscale',scale)
    title('Max Lateral Displacement/Height vs. Parameter')
ylabel('Max Lateral Displacement/Height')

```

```

xlabel('Parameter')
xlim([xlbound xubound])
%ylim([0 0.16])
hLeg = legend('figure (1)');
set(hLeg, 'visible', 'off');

figure(2)
gscatter(Parameter,EDP2,Group)
    set(gca, 'xscale', scale)
    set(gca, 'yscale', scale)
    title('Max Lateral Displacement/Spectral Displacement vs.
Parameter')
ylabel('Max Lateral Displacement/Spectral Displacement')
xlabel('Parameter')
xlim([xlbound xubound])
%ylim([0 5.5])
hLeg = legend('figure (2)');
set(hLeg, 'visible', 'off');

%Generate Figures
figure(3)
gscatter(Parameter,EDP3,Group)
%lsline
    set(gca, 'xscale', scale)
    set(gca, 'yscale', scale)
    title('Residual Lateral Displacement/Height vs. Parameter')
ylabel('(Residual Lateral Displacement) / (Height)')
xlabel('Parameter')
xlim([xlbound xubound])
%ylim([0 0.09])
hLeg = legend('figure (3)');
set(hLeg, 'visible', 'off');

figure(4)
gscatter(Parameter,(abs(EDP4)),Group)
    set(gca, 'xscale', scale)
    set(gca, 'yscale', scale)
    title('Lateral Displacement/Spectral Displacement vs.
Parameter')
ylabel('(Residual Lateral Displacement) / (Spectral
Displacement)')
xlabel('Parameter')
xlim([xlbound xubound])
%ylim([0 1.6])
hLeg = legend('figure (4)');
set(hLeg, 'visible', 'off');

figure(5)
gscatter(Parameter,abs(EDP5),Group)
    set(gca, 'xscale', scale)
    set(gca, 'yscale', scale)
    title('Vertical Displacement/Plunge vs. Parameter')
ylabel('Residual Vertical Displacement / Plunge Displacement')
xlabel('Parameter')

```

```

xlim([xlbound xubound])
%ylim([0 120])
hLeg = legend('figure (5)');
set(hLeg, 'visible', 'off');

figure(100)
bar(centers, PercentTopple)
title('Percent Toppled')
ylabel('Percent of Failures (for each GR type)')
xlabel('Parameter')
legend('Subduction', 'Shallow Crustal')
hLeg = legend;
set(hLeg, 'FontSize', 6);

%End of Code

```