EVALUATION OF EFFECTIVE INPUT MOTIONS TO STRUCTURES USING SEISMOGRAMS RECORDED AT STRUCTURE FOUNDATIONS AND FREE FIELD

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ABSTRACT

Reduction of the input ground motions to structures has been widely studied in the structure engineering. In this presentation, we evaluated this reduction of the input ground motions by using strong motion data recorded at the free ground surface and foundations of structures in California, United States (US). Earthquakes with magnitude greater than or equal to 4.0 were selected, and the number of the records used this study is 127 (42 for the deep foundations and 85 for the shallow foundations). The maximum distance between the basement and free-field seismometer is restricted to 1 km. Peak ground accelerations (PGA) and peak basement accelerations (PBA) were computed for each pair of records. Velocity waveforms were computed by the time domain integration after the band-pass filtering with 0.1-15 Hz, and the reduction ratio was obtained in the same way. The acceleration was reduced approximately by 20 %, and velocity reduction was about 10 %. The input loss effect is stronger in high-frequency motions. This result is consistent with the past studies for Japanese structures. We computed average spectra of input loss for structures with deep and shallow foundations and it showed that the reduction was significant at frequencies higher than 1 Hz. Structures with deep foundations have a larger reduction of PGA (about 25 %), and the reduction for structures with shallow foundations is about 20 %. We performed numerical simulations to explain the frequency dependence of input loss, and showed the input loss in the spectra can be explained by the subsurface soil amplifications.

Keywords: effective input motions, strong motion records, input loss effect, structure foundations

INTRODUCTION

A phenomenon of the reduction of input ground motions to structures has been studied since the end of 1960s (Yamahara, 1969; Yamahara, 1970). Yamahara analyzed the aftershock records of the 1968 Tokachi-oki earthquake, and found that the amplitudes and phases of the recorded short-period ground motions are different even in the records on the same building. Based on this observation, he proposed a phenomenon of the reduction of input ground motions (Yamahara, 1969). Since it is important to estimate accurate input ground motions to structures, the evaluation method has been studied in the United States (e.g. Scanlan 1976; Newmark et al., 1977; Stewart 2000; Trifunac et a., 2001; Kim and Stewart, 2003; Todorovska 2009), Japan, (e.g. Ishii and Yamahara, 1982; Harada et al., 1985; Kurimoto and Iguchi 1995; Obuchi et al., 2005; Yasui et al., 1998; Kojima et al., 2005) and many other places.

Past studies suggest that the reduction of input ground motion is caused by the rigid building base (Yamarahara 1969; Scanlan 1976). The input motion below the building base is smoothed by the horizontal extent of a builidng, and it becomes smaller than the input ground motion. Therefore, this reduction is scaled with the building base dimension, and the wavelength of the ground motions. In general, higher frequency components have larger reduction of ground motions, and reduction of the peak ground acceleration is about 30% and that of the peak ground velocity is 10% (Yasui et al. 1998).

The research on the reduction of input ground motion using the observed strong shaking is limited due to the limited number of available records at the buildings. Most of the early studies focus on a single structure which has multiple seismic stations, and make a detailed model which explains the observed ground motion records (Ishii and Yamahara, 1982; Harada et al., 1985).

In California, US, the strong motion data recorded at buildings and free surface are available on the website of the Center for Engineering Strong Motion Data (CESMD). The information on the building properties and associated subsurface soil structures is also available at the site. Kim and Stewart (2003) used these records to develop a procedure to make a transfer function of the soil-structure interaction. Stewart (2000) evaluated the conditions of which the building records provide a reasonable estimate of free-field records with these data. Extending their studies, we used the CESMD strong motion records of recent earthquakes with larger amplitudes to understand the relationship among the reduction of input motion, building type, and subsurface soil structures. In this paper, we defined the reduction of input motion as the phenomenon that the ground motions recorded at the building become smaller than those recorded at the free field due to the soil-structure interaction.

DATA

Strong Motion Records

We use strong motion data available at the CESMD website, which are recorded in California, United States. We selected earthquakes with magnitude greater than or equal to 4.0.and including at least one record with acceleration greater than or equal to 100 Gal for assuring reasonable signal to noise ratio. The list of the earthquakes of which we used the strong motion data is shown in Table 1. Among the strong motion data of these earthquakes, pair of records with the distance between the free field and building base less than 1 km are used for the analysis. The total number of pairs of data recorded at free field and building base is 127, including 42 pairs of records recorded at 26 buildings with deep foundations, and 85 pairs of records recorded at 48 buildings with shallow foundations.

Table 1. Earthquakes and number of records.

Year	Earthquake	Mag	Lon.	Lat.	Dep. (km)	No. of pair records
2010	Calexico	7.2	32.3	-115.3	32.3	18
2010	Ferndale1	6.5	40.7	-124.8	21.7	4
2010	Ferndale2	5.9	40.4	-129.9	11.2	4
2010	Ocotillo	5.7	32.7	-115.9	6.9	4
2010	WhittierNarrows	4.4	34.0	-118.1	18.9	12
2009	Inglewood	4.7	33.9	-118.3	13.9	10
2009	SanBernardino	4.5	34.1	-117.3	14.2	4
2008	ChinoHills	5.4	34.0	-117.8	14.7	19
2007	AlumRock	5.5	37.4	-121.8	10.11	10
2007	Lafayette	4.2	37.9	-122.1	16.22	5
2007	LakeElsinore	4.7	33.7	-117.5	12.6	1
2007	MammothLakes	4.6	37.5	-118.9	10.72	1
2005	Anza	5.2	33.5	-116.6	14.2	2
2004	Parkfield	6.0	35.8	-120.4	7.9	1
2003	SanSimeon	6.5	35.7	-121.1	4.7	2
2001	WestHollywood	4.2	34.1	-118.4	7.9	1
1994	Northridge	6.4	34.2	-118.5	19	7
1992	CapeMendocino1	7.1	40.4	-124.2	15	1
1992	CapeMendocino2	6.5	40.4	-124.6	19.6	1
1992	Landers	7.3	34.2	-116.4	1.1	8
1991	SieeraMadre	5.8	34.3	-118.0	9.2	1
1989	LomaPrieta	7.0	37.0	-121.9	18	5
1987	WhittierNarrows	6.1	34.1	-118.1	9.5	6

Figure 1 shows the relationship between the magnitude and epicenter distance of the records. Most of the small earthquakes (around M4.0) have only near-source records with source-station distance less than 50 km, but larger earthquakes with M>5.5 include relatively far-source records.

All the records are acceleration waveforms, and we applied band-pass filter between 0.1 Hz and 15 Hz to remove short-period and long-period noise. We integrated the filtered records once in the time domain to obtain the velocity waveforms. We use two horizontal components for the analysis. The direction of the free-field seismometer follows the magnetic north, and that of the building follows the site north (direction of the building edge). Therefore, all the waveforms recorded at the free field were rotated to adjust the direction of site north. Figure 2 shows an example of the waveforms recorded at the steel structure (station ID: 14724) during the 2010 Ocotillo earthquake. Two waveforms recorded at the building base and free field agree reasonably well, and the correlation is high especially for the velocity waveforms.

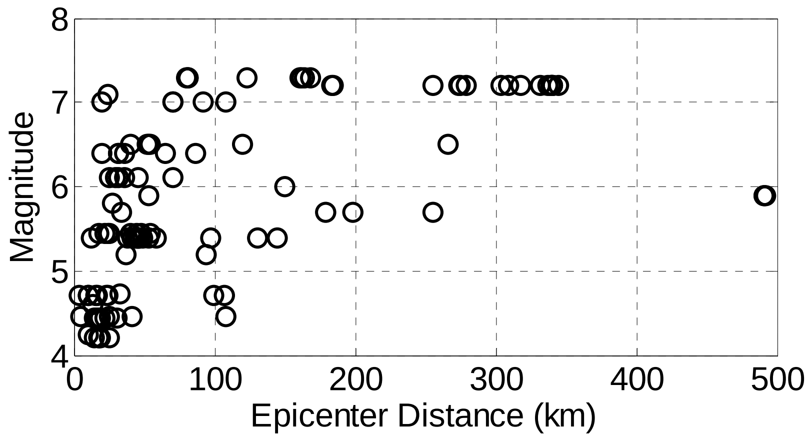
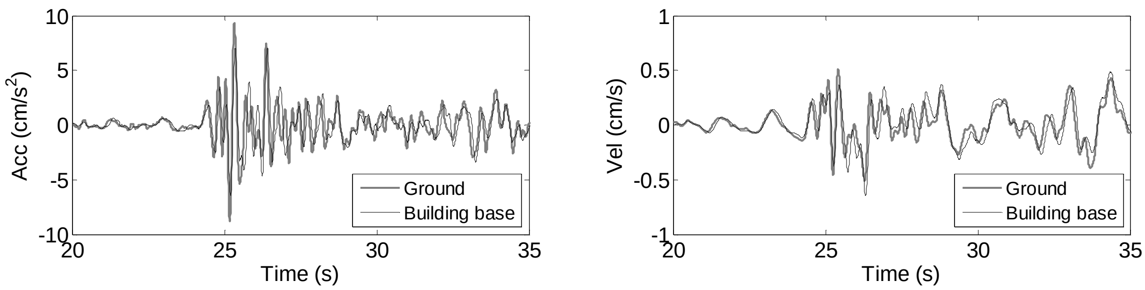


Figure 1. Relationship between the magnitude and epicenter distance of the selected earthquakes.



(a) Acceleration (b) Velocity

Figure 2. Comparison of the waveforms recorded at the building base (black) and associated free field (gray).

Building Description

We extracted the building information from CESMD website to obtain the distribution of building properties. We identified the building location (latitude and longitude), structural type (Steel or Reinforced Concrete), base type, floor number, height of the buildings, horizontal size, depth of the base from the ground surface (footing), length and diameter of the piles.

We also detected the average shear wave velocity to a depth of 30 m (VS30) and the natural frequency of two horizontal directions from seismic records. The natural frequency of a building was estimated from the peak frequency of the transfer function between the seismic records at the top floor and basement. We evaluated this natural frequency for each seismogram and used for the analysis. The VS30 was described only for a free-field station, so we used the value of the closest free field station. We selected the closest seismic station to the center of the building when there are multiple seismometers at the basement.

Classification of the Foundations

We classified type of foundations based on the definition widely used in the United States (Murthy, 2002; Kimmerling 2002). In the United States, the building foundation is divided into deep and shallow foundations. Figure 3 shows the cartoon figure of the deep and shallow foundations (Kimmerling et al., 2002; Hayashi, 2002).

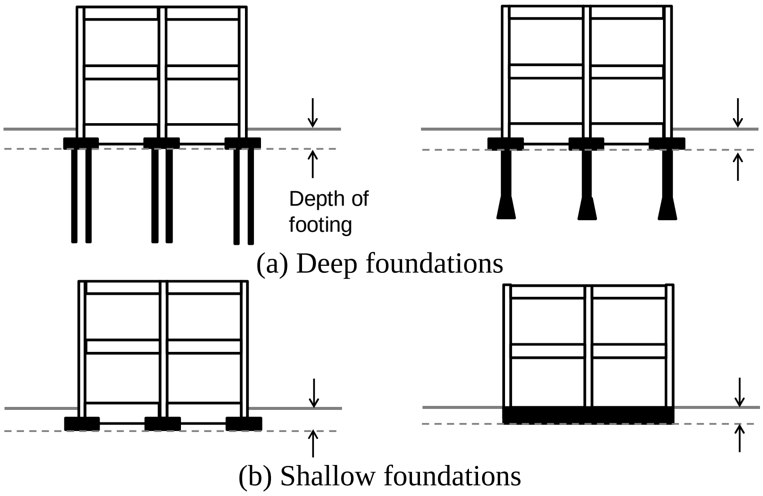


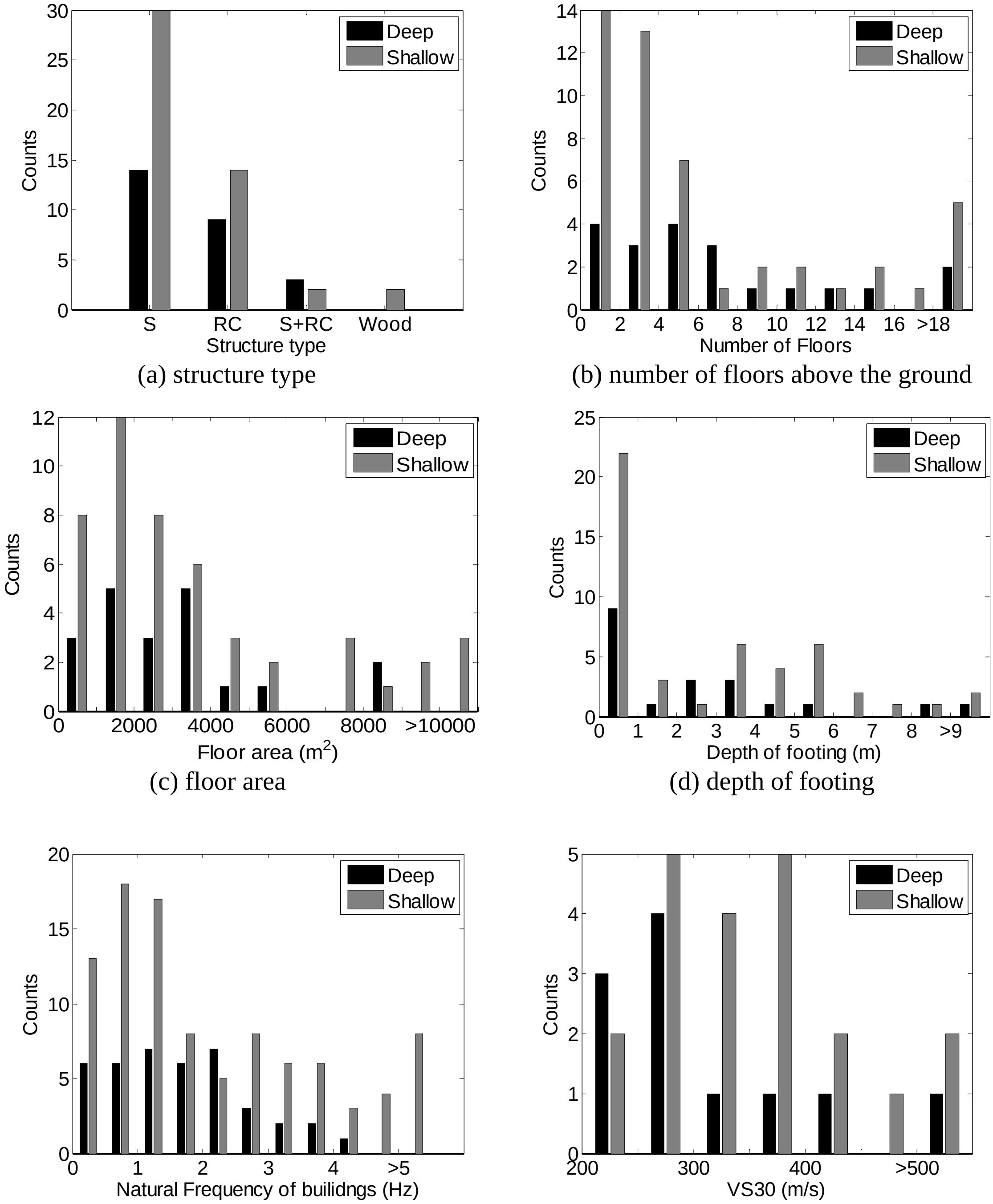
Figure 3. Cartoon figures of the deep and shallow foundations.

The deep foundation indicates mostly pile foundations, which supports the structure weight by deep piles. It is often used at the soft soil. Depending on the support system, it is classified into end bearing pile and friction pile. For the end bearing piles, the bottom end of the pile reaches the layer of strong soil or bedrock. The load of the building is supported by the end of the pile on the strong layer. On the other hand, a friction pile transfers the load of the building to the soil across the full height of the pile by friction. It is mainly used for the soil structure of which the strong layer is too deep for the pile to reach. In the United States, caisson is also classified to the deep foundation (Murthy, 2002; Kimmerling et al., 2002). Caisson is a prefabricated hollow box or cylinder which are constructed above ground level, then sunk to the required level by excavating or dredging material in the caisson. It is then filled with concrete to form a foundation. This foundation is used for the large scale low-rise buildings, such as hospitals, and high-rise steel structures (CESMD website). In Japan, it is often used in the construction of bridge piers or foundations under water.

Shallow foundations are those founded near to the ground surface, and transfer the loading directly to the soil. It includes mat-slab foundations, raft-slab foundations, and spread footing foundations (Murthy, 2002; Kimmerling et al., 2002). Shallows foundations are used when surface soils are sufficiently strong and stiff to support the weight of structures.

Distribution of the Building Types

We used seismic data recorded at 74 buildings, with 26 deep foundations and 48 shallow foundations. Figure 4 shows the distribution of the (a) structure type, (b) number of floors above the ground (c) floor area (d) depth of footing (e) natural frequency and (f) VS30 around the building. Most of the buildings are either steel or reinforced concrete structures for both deep and shallow foundations. There are many low-rise buildings with shallow foundations, and relatively high and medium-rise buildings with deep foundations. The depth of footing (described in Figure 3) for structures with deep foundations is shallower than that of shallow foundations, with the average depth of 3.62 m and 4.71 m, respectively. The VS30 for the shallow foundations is in general larger than that for the deep foundations, which indicates the deep foundations are used at the places with bad soil conditions.



(a) structure type

(b) number of floors above the ground

(c) floor area

(d) depth of footing

(e) natural frequency

(f) VS30 around the building

Figure 4. Distributions of the building properties.

EFFECT OF REDUCTION OF INPUT MOTION

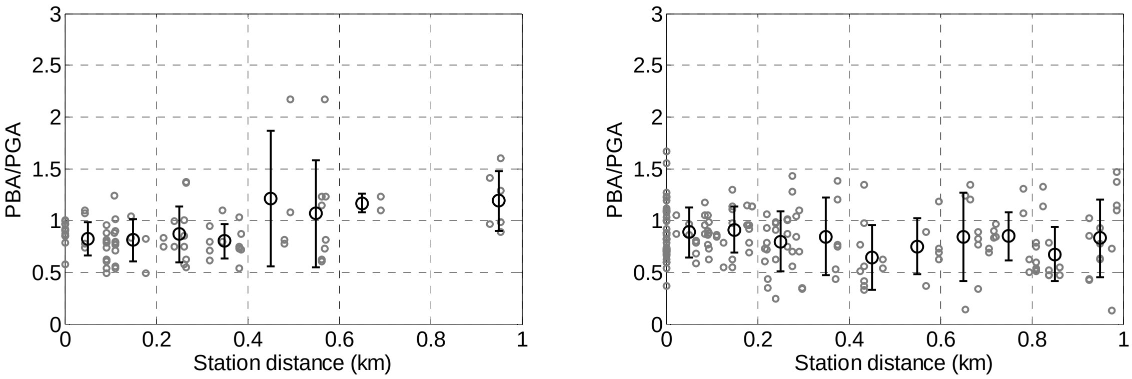
Effect of Building-Station Distance

To evaluate the reduction of input ground motion, we computed the peak ground acceleration and velocity at the building base and free surface. First, we computed the peak value of the free-field records and its recording time, and then computed maximum value of the building base records within ± 3 seconds from the peak time of the corresponding free-field records. Here we defined the peak value of the free-field records as PGA (peak ground acceleration) or PGV (peak ground velocity), and the corresponding peak value of the building base records as PBA (peak building-base acceleration) or PBV (peak building-base velocity).

The distance between the free-field station and building-base station is very important to discuss the effect of the reduction of input ground motions. When the distance between stations is large, the assumption of homogeneous layered soil structure is not valid any more, and input motions to the stations cannot be assumed as identical. To study the reduction of input motions, the distance between stations should be as short as possible. In this study, we use the pair of records at the stations whose distance is less than 1 km. Here, we evaluate the effect of distance between stations on the strong motion records.

Figure 5 shows the effect of station distances on the ratio of the peak acceleration between the records at the free field and building base (PBA/PGA). For the shallow foundations in Figure 5(b), the ratio of acceleration is almost constant, and the median of the ratio is less than 1 for all the bins with 0.1 km. This suggests that the ratio of accelerations for the shallow foundations is not so sensitive to the distance between the stations. Therefore, we think this distance threshold is reasonable for the shallow foundations.

On the other hand, the acceleration ratio of the deep foundations in Figure 5(a) shows the distance dependency. The PBA/PGA ratio exceeds one for the station distance greater than 0.5 km and increases as a function of station distance. This is counter intuitive to the characteristic of the reduction of input ground motion. The similar characteristic was also observed in the velocity waveforms. This suggests that the assumption of the plane wave incidence cannot be hold any more for this distance range. Therefore, we use the station pairs with distance less than 0.5 km for deep foundations. This excludes 6 pairs of records, 19 % of the total records of deep foundations. We also checked the difference of the records with the distance less than 0.5 km for shallow foundations, but the overall characteristics do not change. Therefore, we keep all the records with the station distance less than 1 km for shallow foundations to maximize the sample numbers.

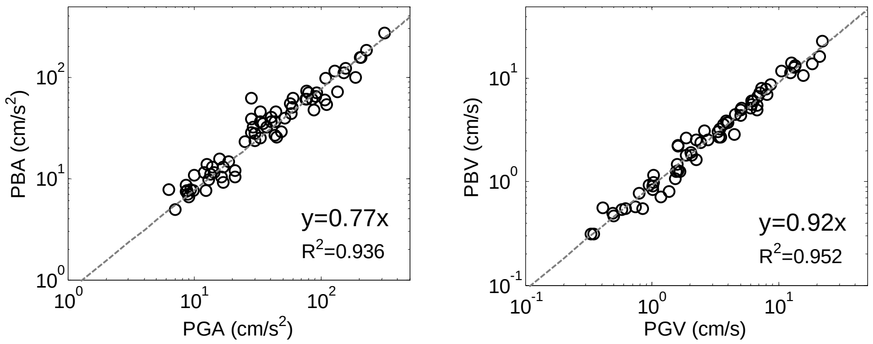


(a) Deep foundations (b) Shallow foundations

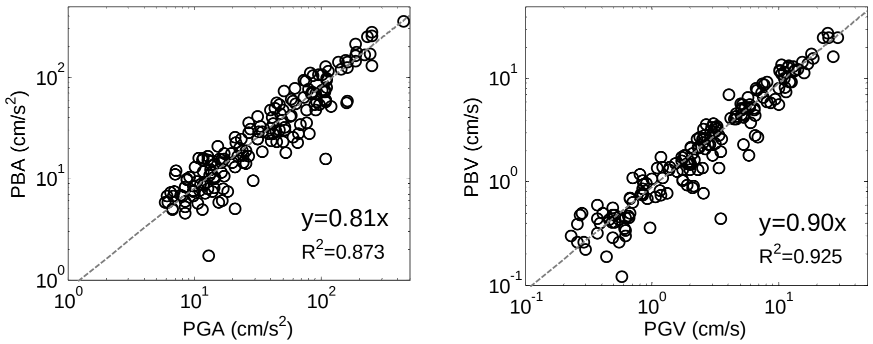
Figure 5. Relationship between the station distances and the ratio of the peak acceleration (PBA/PGA). The black circles show the median of the data with the increment of 0.1 km, and the error bar shows the standard distribution.

Peak Ground Acceleration and Peak Ground Velocity

The ratios of the accelerations and velocities recorded at the building base and free field are shown in Figure 6. The data was classified into the deep and shallow foundations. The broken line in the figure shows the regression line through the origin obtained from the least square fitting. The slope is less than 1 for all 4 cases, which clearly shows the effect of reduction of input ground motion. The reductions of the peak acceleration and velocity for the deep foundations are 23% and 8% respectively (Figure 6(a)), and those for the shallow foundations are 19% and 10% (Figure 6(b)). For both cases, the reductions of accelerations are 2-3 times larger than those of velocities. These results are consistent with the result of Yasui et al. (1998), in which they showed the reductions of peak accelerations and velocities are 30 % and 10 %, respectively. The deep foundations have better correlations between building base and free field records.



(a) deep foundations



(b) shallow foundations

Figure 6. Relationship of the ground motion measures recorded at the free field and building base.

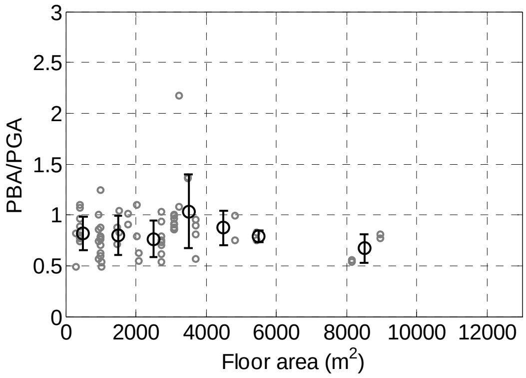
EFFECT OF SOIL AND BUIDING PROPERTIES ON REDUCTION OF INPUT MOTION

To evaluate effect of the building and ground motion properties on the reduction of input ground motions, we discuss the relationship between ratio of accelerations and various building properties.

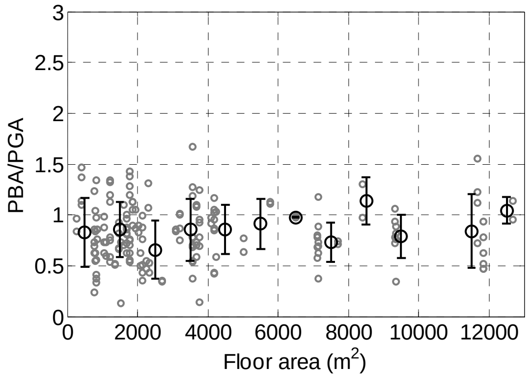
Effect of Building Floor Plan

We evaluated the relationship between the floor area and acceleration reduction ratio in order to study the effect of the building floor plan on the reduction of input ground motion. The past studies suggest that the reduction of input ground motion is larger for the building with larger floor area and wider foundation width (e.g., Yamahara, 1970; Kojima et al., 2005). However, as shown in Figure 7, the positive correlation between the floor area and acceleration reduction ratio was not clear in our dataset. Deep foundations in Figure 7(a) shows larger reductions for the building with floor area greater than 5000 m^2, but the tendency is not clear fot the structures with shallow foundations. We also compared the foundation width instead of the floor area, but there was no clear correlation with the acceleration reduction ratio.

According to Yamahara (1969, 1970), the reduction of input ground motion is caused by the rigid building base. The input motion below the building base is cancelled and averaged by the rigid base, and it becomes smaller than the input ground motion. This reduction can be evaluated the ratio between the wave length and width of building base. The reduction is smaller if the ratio between the wave length and width of building base is large. We approximated the wave length of the ground motion by the product of equivalent period of ground motion ($2\pi*$PGV /PGA) and VS30. The relationship between the area and the length ratio between the ground motion and building is shown in Figure 8. In our dataset, the length ratio becomes smaller as the width of the building base becomes larger, which suggests there should be larger reduction as the area increases. It is not clear why the dependency to the floor area is not visible in our dataset. One possible interpretation is that the rigid base assumption is somewhat invalid due to the particular velocity structure or building base property.



(a) Deep foundations



(b) Shallow foundations

Figure 7. Relationship of the floor area and acceleration reduction ratio.

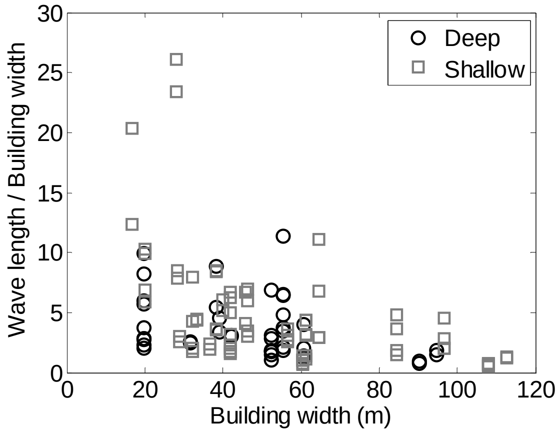
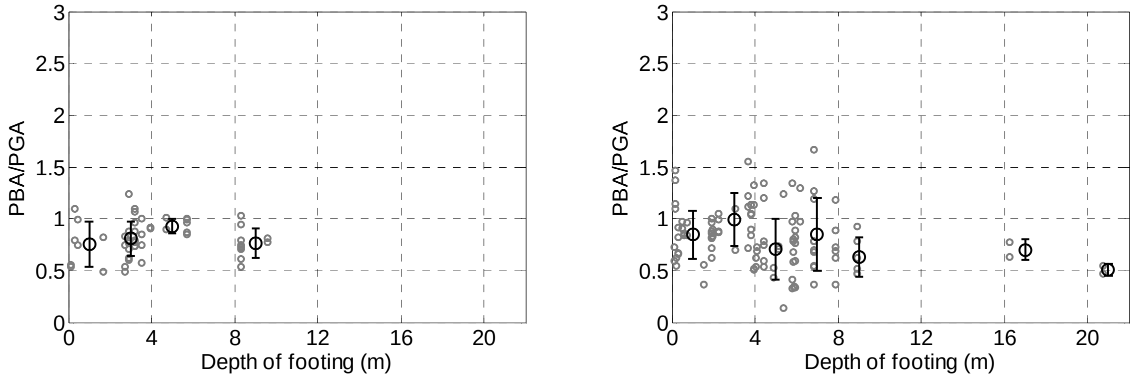


Figure 8. Relationship between the building width and the ratio between the wave length and building width.

Effect of Subsurface Soil Structures

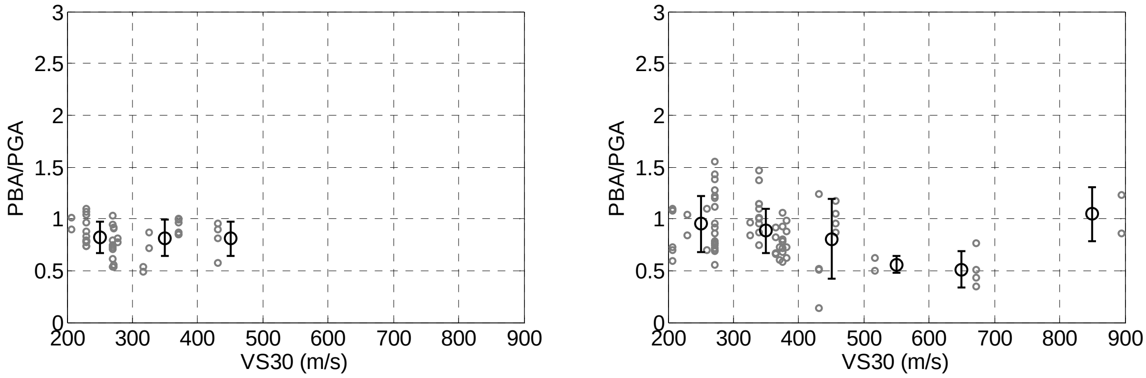
We compared the depth of footing and the acceleration reduction ratio and showed in Figure 9. The dependency to the depth of footing becomes significant if the depth of footing is deeper than 8 m, and the reduction of acceleration increases as the depth of footing increases. The dataset of deep foundations does not show the clear dependency due to the limited range of dataset. In general, the stiffness of the soil increases as the depth becomes deeper, therefore, the input ground motion is amplified as propagating to the ground surface (Kojima et al., 2005). Therefore, buildings with deeper footing have larger difference between building base and free field accelerations. Assuming the building base is a rigid body, a ground motion at the level of footing is almost identical to the level of seismic station in the building. This is why we have larger reduction of input ground motions for buildings with deeper footing.

We also evaluated the effect of VS30 on the reduction of input ground motions in Figure 10, and observed larger reduction of input ground motions for the sites with larger VS30. Although we do not have detail velocity structures for each site, in general, smaller VS30 suggests the thick sedimental deposit around the ground surface, and the variance of the velocity between the ground surface and the depth of 30 m would be small. On the other hand, the larger VS30 suggests the thin sedimental layer and existence of the hard rock layer near the ground surface. Therefore, the variance of the shear wave structure near the surface becomes large and the amplification between the surface and the depth of foundation is significant, resulting in the larger reduction of input ground motion.



(a) Deep foundations (b) Shallow foundations

Figure 9. Relationship of the depth of footing and acceleration reduction ratio.

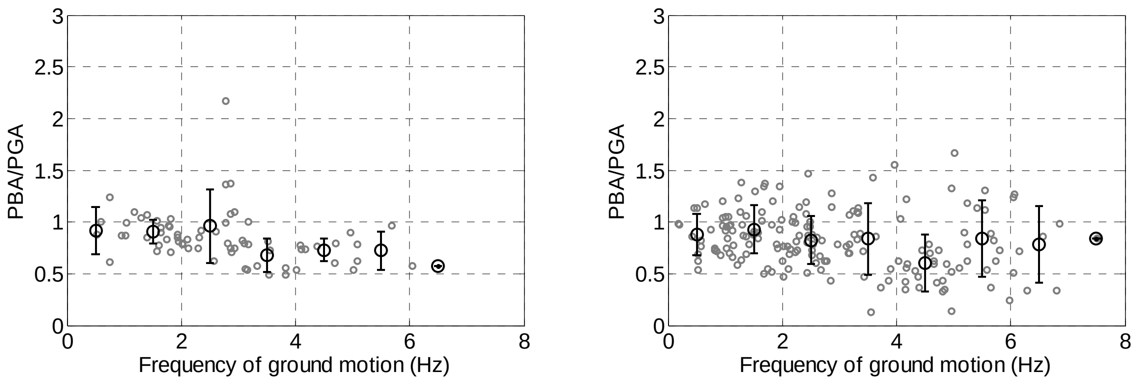


(a) Deep foundations (b) Shallow foundations

Figure 10. Relationship of the VS30 and acceleration reduction ratio.

Effect of Predominant Periods of Ground Motions

Figure 11 shows the relationship between the equivalent frequency of the strong motions and reduction ratio of accelerations. The equivalent frequency of the strong motion was obtained from the equation of PGA/PGV/2π for the computation convenience (Kojima et al., 2005). The acceleration reduction ratio increases as the frequency of the ground motion increases. This is consistent with the result of previous section that the reduction of acceleration is larger than that of velocity. Note that some samples between 1-3 Hz exceed one in Figure 11, which suggests that there is no reduction of input ground motions. We think this is the effect of upper structures and discuss in the next section.



(a) Deep foundations (b) Shallow foundations

Figure 11. Relationship of the frequency of the strong motion and acceleration reduction ratio.

EFFECT OF REDUCTION OF INPUT MOTION IN FREQUENCY DOMAIN

Effect of Foundation Types

In order to evaluate the frequency dependence of the reduction of input ground motions, we compared the Fourier amplitude spectrum of the acceleration records at the free field and building base, and computed the ratio in the frequency domain. We call this spectrum as acceleration reduction spectrum. Figure 12 shows the average reduction spectrum for deep and shallow foundations. Same as Figure 11, the reduction of input ground motion becomes larger as the frequency becomes higher. The reduction is significant especially for the frequency higher than 1.5 Hz. However, the reduction spectrum becomes constant for the frequency range higher than 6 Hz and frequency dependency is less significant. The reduction spectrum of deep foundations is larger than that of shallow foundations for the frequency of 2.0-3.5 Hz, and smaller for the frequency higher than 3.5 Hz.

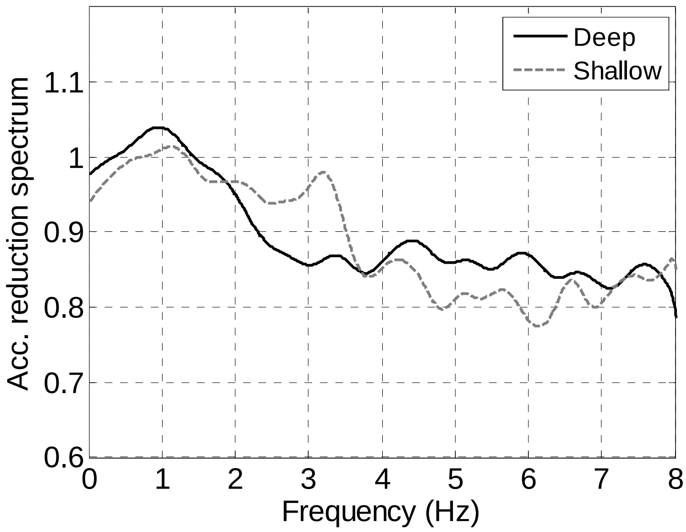
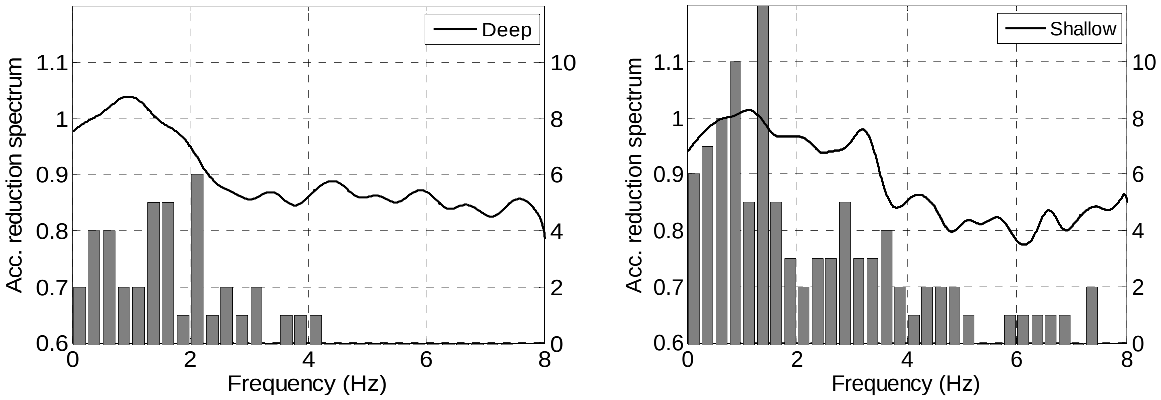


Figure 12. Average reduction spectrum for deep and shallow foundations.

Effect of Natural Frequency of Buildings

We evaluated the effect of natural frequencies of the upper structures to the acceleration reduction spectrum. We added histogram of natural frequencies of buildings on Figure 12, which is shown in Figure 13. Structures with deep foundations have a frequency between 0.5-1.5 Hz in Figure 13(a). On the other hand, structures with shallow foundations have a frequency in two ranges: 0.5-1.5 Hz and 2.5-3.5 Hz in Figure 13(b). For both spectra, the reduction spectrum tends to exceed one around the natural frequency of upper structures. That is, the reduction of input motion is less significant at around the frequency close to the natural frequency of the structures, and it is more effective for the higher frequency range.

We normalized the horizontal axis of Figure 12 by the natural frequency of each structure and showed as Figure 14. The reduction spectrum exceeds one at around one in the normalized frequency, which corresponds to the phenomenon that the input ground motion amplifies at around the natural frequency of the structures. This is consistent with the average acceleration ratio becomes one between 1-3 Hz in the section of the ‘Effect of Predominant Periods of Ground Motions’. By using normalized frequency, the dependency to the natural frequency of buildings is reduced, and the spectra of deep and shallow foundations are generalized.



(a) Deep foundations (b) Shallow foundations

Figure 13. Acceleration reduction spectrum in Figure 11 and histogram of natural frequency of structures.

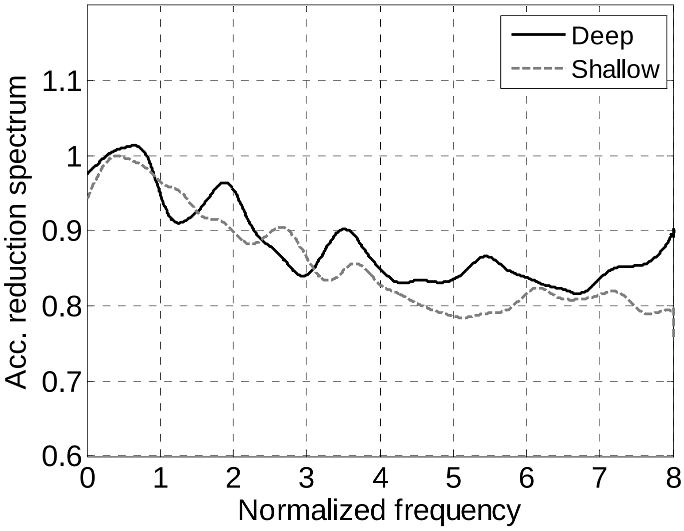


Figure 14. Average reduction spectrum for deep and shallow foundations normalized by the natural frequency of each structure.

CONCLUSIONS

In this paper, we used the strong motion records obtained in the buildings in California, United States, and evaluated the reduction of input ground motions for the buildings with deep and shallow foundations. Our conclusions are as follows:

1) Reduction ratio of maximum acceleration is about 24 % for the deep foundations and about 19 % for the shallow foundations. For the maximum velocity, the reduction ratio was about 10 % for both foundations. This result is consistent with the research of Japanese structures. The R2 coefficient of determination for deep foundations is smaller than that for shallow foundations.
2) The relationship between the floor size and reduction of input ground motion was not clear in the dataset of this study. The reduction of input ground motion has a correlation between the foundation depth and subsurface soil amplification such as VS30.
3) We proposed acceleration reduction spectra which describe the frequency dependent input loss for deep and shallow foundations. The reduction of input ground motions becomes larger at the higher frequency range regardless the foundation types. The reduction is significant especially for the frequency higher than 1.5 Hz, but it becomes constant for the frequency range higher than 6 Hz.

4) Reduction spectrum of input ground motion is affected by the natural frequency of the upper structures so it is more generalized if we normalize the frequency axis by the natural frequency of the structures.

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APPENDIX

Table A1. List of stations used in this study. Shaded records are not used in the analysis.

No	ID_BG	ID_FF	base	type	#floor	#basement	ht.(m)	Vs30 (m/s)	B-Gdist. (km)	area (m^2)	foot. dep.(m)	Fq_BG EW(Hz)	Fq_BG NS(Hz)	#data
1	12493	12543	Deep	RC	4	1	20	207	0.11	1773	4.72	1.42	1.75	1
2	13698	13726	Deep	S	2	0	13	-	0.22	5437	2.74	2.17	2.02	1
3	14323	14305	Deep	S	7	0	32	230	0.14	1533	-	0.86	0.70	1
4	14578	14578	Deep	S	8	1	35	371	0.14	3083	5.70	0.89	1.03	3
5	14724	14787	Deep	S+RC	5	1	27	270	0.38	2735	8.29	1.51	1.71	4
6	23511	23525	Deep	RC	2	1	9	230	0.09	395	3.20	4.25	2.05	5
7	23515	23522	Deep	S	9	0	36	326	0.39	1461	-	0.46	0.54	1
8	23634	23898	Deep	S	5	0	21	-	0.35	2035	0.30	2.14	2.14	1
9	24053	24611	Deep	S	3	0	15	376	0.95	2569	2.07	1.35	1.37	2
10	24266	24303	Deep	RC	14	1	45	895	0.09	1008	2.74	0.56	1.69	1
11	24288	24289	Deep	S	32	0	105	-	0.11	1006	2.98	0.51	0.28	4
12	24332	24389	Deep	S+RC	3	2	22	278	0.56	4903	6.86	2.24	2.58	2
13	24566	24691	Deep	S	12	0	51	461	0.09	5699	-	1.09	1.33	2
14	24601	24611	Deep	RC	17	0	45	376	0.69	1659	0.08	0.97	0.83	1
15	24643	24389	Deep	S	19	4	86	278	0.48	8952	9.60	0.24	0.22	1
16	24655	24852	Deep	RC	6	0	20	-	0.57	5669	-	2.17	2.54	1
17	24713	24980	Deep	S+RC	8	1	45	-	0.93	5443	-	1.02	1.11	1
18	48733	48906	Deep	RC	5	1	24	271	0.00	3077	3.96	1.38	1.31	1
19	57301	57311	Deep	S	2	0	10	-	0.24	4823	0.44	2.82	2.62	1
20	57594	57600	Deep	S	5	0	28	271	0.11	8159	0.13	1.80	1.49	1
21	57783	57311	Deep	S	3	0	20	-	0.49	3232	-	2.19	2.60	1
22	57784	57311	Deep	S	2	0	10	-	0.27	3478	-	3.52	3.86	1
23	58354	58219	Deep	RC	13	0	61	517	0.57	1165	0.46	0.78	0.74	1
24	58615	58619	Deep	S	16	0	68	-	0.27	2090	-	0.53	0.50	1
25	58641	58665	Deep	RC	8	0	28	-	0.18	284	1.69	2.42	1.54	1
26	89770	89781	Deep	RC	4	1	15	-	0.26	935	3.33	3.22	3.21	2
27	1699	1711	Shallow	S	1	0	4	-	0.15	803	0.19	0.00	0.00	1
28	3603	3145	Shallow	S	19	4	81	-	0.95	5061	16.25	0.41	0.35	1
29	3743	3746	Shallow	S	11	1	48	-	0.15	8408	6.17	1.50	1.74	1
30	12759	12904	Shallow	W	1	0	7	207	0.00	3665	-	7.44	8.10	3
31	13208	13220	Shallow	S	2	0	10	-	0.00	2146	2.26	1.43	1.43	2
32	13213	13213	Shallow	S	3	1	18	-	0.00	3569	6.86	3.12	2.41	5
33	13589	13610	Shallow	RC	11	0	45	371	0.22	1102	-	1.36	1.19	1
34	14127	14127	Shallow	S	2	0	11	-	0.00	1705	1.92	5.00	4.51	4
35	14533	14560	Shallow	S	15	1	81	381	0.09	1044	-	0.80	0.82	2
36	14766	14767	Shallow	S	4	0	18	-	0.14	5780	-	1.25	1.34	2
37	23497	23107	Shallow	S	4	1	23	-	0.00	4231	5.92	1.46	1.45	1
38	23516	23542	Shallow	S	3	0	12	271	0.28	1766	-	1.84	1.91	4
39	23544	23525	Shallow	RC	6	1	22	250	0.28	795	3.81	1.75	1.71	1
40	23622	23522	Shallow	RC	1	0	5	326	0.72	279	0.73	0.00	4.34	1
41	23788	23788	Shallow	S	6	0	37	271	0.00	11668	3.66	1.08	1.00	2
42	24008	24289	Shallow	S	2	0	34	-	0.57	7161	7.87	1.94	2.27	5
43	24104	24126	Shallow	S	2	1	9	-	0.09	1849	3.81	2.72	2.89	2
44	24222	24289	Shallow	RC	32	1	139	-	0.84	11851	8.92	0.52	0.52	3
45	24319	24691	Shallow	S	6	1	63	461	0.65	3761	5.35	2.59	2.15	1
46	24454	5296	Shallow	RC	3	1	12	-	0.30	2692	5.91	2.77	2.49	1
47	24463	24034	Shallow	RC	5	1	36	-	0.08	9365	5.94	0.80	0.71	2
48	24464	24865	Shallow	RC	20	1	54	-	0.47	1766	4.03	0.46	0.46	1
49	24514	24763	Shallow	S	6	0	29	339	0.18	12682	-	3.48	3.83	1
50	24517	24526	Shallow	S	3	0	13	271	0.09	839	-	5.25	4.80	1
51	24567	24289	Shallow	S	13	1	46	-	0.67	1215	4.42	0.75	0.62	5
52	24569	24611	Shallow	S+RC	15	2	85	376	0.22	9664	-	0.62	0.51	2
53	24571	24691	Shallow	RC	9	1	41	461	0.81	1548	3.96	2.06	0.98	1
54	24579	24838	Shallow	RC	9	1	39	-	0.82	1228	3.96	0.99	1.27	1
55	24580	24592	Shallow	S	2	0	10	365	0.00	1467	0.29	1.25	1.22	2
56	24602	24289	Shallow	S	52	5	218	-	0.86	2261	20.73	0.55	0.52	1
57	24605	24605	Shallow	S	7	1	36	376	0.07	7122	5.85	0.82	0.76	2
58	24652	24852	Shallow	S	5	1	26	-	0.43	812	1.52	1.26	1.27	3
59	25949	25969	Shallow	S	4	1	16	-	0.00	7702	5.12	1.73	1.68	1
60	47796	47762	Shallow	S	3	0	20	271	0.18	3756	-	3.19	2.95	2
61	54331	54332	Shallow	S	1	0	5	-	0.11	3079	0.59	6.53	5.76	1
62	57200	57203	Shallow	S	2	0	9	-	0.24	4105	0.51	2.63	3.31	1
63	57562	57563	Shallow	S	3	0	15	672	0.22	2157	-	1.42	1.40	2
64	58224	1821	Shallow	S	2	0	9	-	0.78	2517	-	3.72	4.19	1
65	58334	58790	Shallow	RC	3	0	17	-	0.24	780	-	6.24	6.43	2
66	58483	1821	Shallow	RC	24	0	67	-	0.98	1529	-	0.49	0.65	1
67	58488	58219	Shallow	RC	4	0	15	517	0.79	2090	-	4.54	6.98	1
68	58508	58505	Shallow	RC	3	1	11	260	0.29	1594	3.05	3.48	3.94	1
69	58661	58330	Shallow	S	2	1	9	-	0.71	763	4.08	3.52	3.06	1
70	58675	1821	Shallow	S+RC	18	1	93	-	0.72	2023	1.94	0.82	0.78	1
71	58769	1754	Shallow	S	4	1	17	-	0.37	2341	4.88	2.98	2.94	1
72	89473	89486	Shallow	S	1	0	7	457	0.08	4166	-	0.00	3.73	4
73	89494	89509	Shallow	RC	5	0	14	339	0.26	3211	-	3.67	4.46	2
74	89687	89509	Shallow	W	2	0	8	339	0.99	401	0.18	0.00	0.00	2