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RELATIONSHIP OF SEISMIC RESPONSES AND STRENGTH INDEXES OF GROUND MOTIONS FOR LARGE-SCALE RIGID STRUCTURES

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大規模剛構造物の地震応答と地震動強度との関係

RELATIONSHIP OF SEISMIC RESPONSES AND STRENGTH INDEXES OF GROUND MOTIONS FOR LARGE-SCALE RIGID STRUCTURES

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ABSTRACT

This study focuses on seismic response of large-scale rigid structures such as a nuclear power plant (hereinafter LSR structures) as a function of seismic parameters of strong motions. Seismic parameters are represented by strength indexes of ground motions such as PGA, PGV, A0 (the measurement parameter for JMA seismic intensity), and PGA*PGV, while structure responses are represented by shear force at each floor.

The main objective of the study is to investigate the relationship of seismic responses of LSR structures and strength indexes of ground motions or ground motion parameters and to identify basic shear indexes that can indicate or predict the damage level that we have to expect in future without complex calculations.

For this purposes first an analysis model of typical LSR structures are constructed than the basic dynamic characteristic, namely, modes, natural frequencies, and transfer functions were calculated. Second, 1000 strong motion records were selected from various sites and earthquakes and used as an input motion for Nonlinear Direct Integration Time History Analysis of these LSR structures. As analysis results, the total shear forces at each floor level of LSR structures were obtained for each strong ground motion data. The computer code SAP2000, one of the most widely used static and dynamic Finite Element Analysis code, is used for Direct Integration Nonlinear Time History Analysis. Finally, shear force response of linear members were correlated with strength indexes of ground motions in order to obtain shear indexes. The relationship between seismic responses of a LSR structures and strength indexes of ground motions were investigated.

We found that the regression lines, especially with PGA for upper floors and A0 for lower floors, can be used for the easy assessment of seismic response and could be the basic indexes for the prediction of damage level of LSR structures without complex calculations.

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1. INTRODUCTION

1.1 BACKGROUND

In the long history of mankind, humans have managed to build shelters to protect themselves against natural disasters such as heavy rains and floods, tornadoes and strong winds, as well as large earthquakes. Mankind has developed buildings as one kind of shelter continuously during its struggles with natural disasters. It is well known that building materials of the present day. However human cannot escape the treat of earthquake, even today when science and technology are so highly developed. For example On January 1995, a magnitude 7.8 earthquake hit the southern region of the Hyogo prefecture of Japan and killed more than 6000 people. In the summer of 1999, two large earthquakes struck the northwestern region of Turkey and the central part of Taiwan within just two months. These two big earthquakes killed more than 15,000 people in Turkey and 2,000 people in Taiwan. There was much economic loss and disruption since many civil engineering projects and building structures had collapsed or were severely damaged. Most of the deaths and injuries were caused by collapse of commercial and residential buildings. Even very recently in December 2004, a magnitude 9.0 earthquake occurred in the Indian Ocean and the tsunami wave hit the cost of Indonesia, Sri Lanka, Thailand, Malaysia, and India, and killed more than 200,000 people and caused billions of US$ of economic lose.

It is an important issue to create safer urban areas for the people who live in, against natural hazards. Among these hazards, earthquakes are a “very special type of natural hazards in the sense that they are very rare, low probability events, whose consequences, when they do occur, are very large in terms of destruction and suffering” [1].

Earthquakes are natural disasters whose feature is that most of the human and economic losses are not due to the earthquake mechanism, but to the failures of man-made facilities: buildings and lifelines, such as dams, bridges, transportation systems, etc., which are supposedly designed and constructed for the comfort of human being.

This study is devoted to understanding of the behavior of one of the most important lifelines – Nuclear Power Plants – that is named in this study Rigid Structures, and to the prediction of damage level of these types of structures, which could give us quick information on possible condition of concerned structures immediately after a strong ground shaking.

1.2 Objectives and Scope of Study

Assessment of structural seismic response requires an understanding of anticipated ground shaking as well as an evaluation of the response of a structure to such shaking. Therefore, evaluation of seismic response of structures involves two main steps:

1. Definition of seismic parameters,
2. Assessment of structural behavior due to seismic shaking, that is, structural response. This study focuses on seismic response of LARGE-SCALE RIGID STRUCTURES (hereinafter LSR structures). Seismic parameters are represented by strength indexes of ground motions such as PGA, PGV, A_0, PGA*PGV, and structure response – by shear force. The main objective of the study is to investigate the relationship of seismic responses of LSR structures and strength indexes of ground motions or ground motion parameters. For this purpose first, we have chosen four different types of LSR Structures with different physical and dynamic properties. Second, Computer modeling of those structures was done and their dynamic characteristic such as modes, transfer functions in concerned directions were analyzed. Third, strong motion records were selected from various sites and earthquakes, and used as an input motion for Nonlinear Direct Integration Time History Analysis. Finally, Shear indexes were obtained for various earthquake cases, and the shear force response of linear members were correlated with strength indexes of ground motions.

２. PROPERTIES OF STRUCTURES

2.1 General

In this study physical properties, used for analysis model, of all four tapes of LSR Structures, were obtained from “the report of investigation of the method of evaluation of the limit characteristics of nuclear power plant facilities” [1]. We have studied three different types of LSR structure that consist of lumped masses at the each floor level, weightless frame members, springs and dampers that represent foundation of structure. We have introduced the properties of these members mentioned above in the following sections. Since we have three models, we call them here Structure A, Structure B and Structure C.

2.2 Properties of Structure A

LSR Structure A extends 80.65 m above the basement level and stands on a foundation, which stuck into ground about 13 meters. As we mentioned above, in this study the structural models are represented with a lumped mass-spring-damper system (see *Figure 2.2.1*). The lumped masses at floor levels (m1, m2,… m10) connected via massless bars (B1,B2,…B10). The lumped mass M11 represents the foundation of the structural model A. The system is joined to the ground by horizontal, vertical, and rotational spring of stiffness KH, KV, KQ, respectively and with dampers, that represents soil structure interaction.

The computer code SAP2000 Nonlinear 8.2.3, one of the most - widely used Static and Dynamic Finite Element Analysis code, is used for Direct Integration Nonlinear Time History Analysis. In the analytical model of the LSR structure, massless bars (B1,B2,…B10) which carries lumped-mass joints (M1,M2,…M11) are represented by Linear Frame Element of SAP2000 (see *Table 2.2.1* for Linear Frame Elements and *Table 2-2-2* for Lumped-Mass Joints). Springs and dampers, which stand for the rock ground, support the LSR structure at the base level and are represented by Nonlinear Nlink Elements of SAP2000 program (see *Table 2.2.3* and *Figure 2.2.2*).

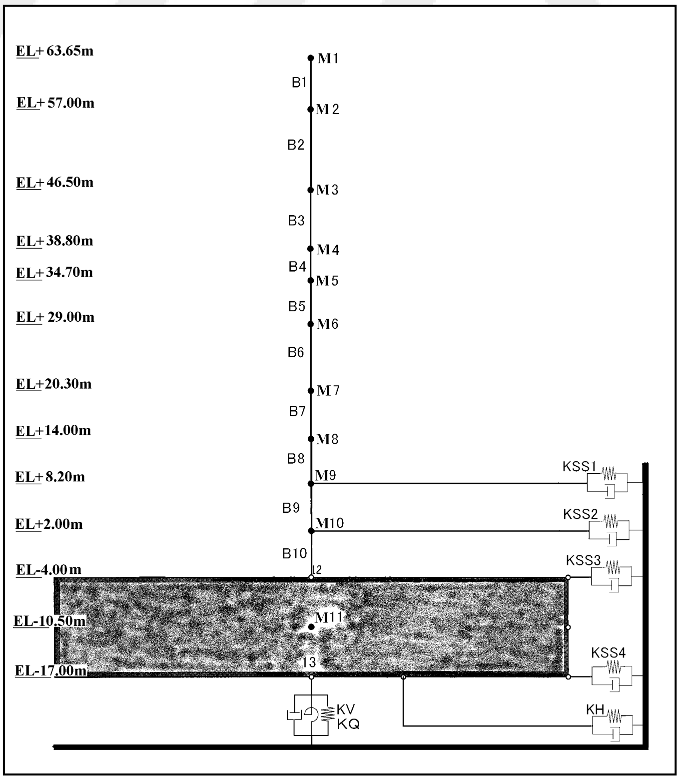


Figure 2.2.1 The Structural model A of LSR

Table 2.2.1 Properties of Linear Frame Elements

Floor Number	Frame Elements	Effective Axial Area (m^2)	Moment of Inertia ($x10^3$ m^4)		Effective Shear Area (m^2)		Shear Force Capacity (ton)	
			NS (y)	EW (x)	NS (y)	EW (x)	NS (y)	EW (x)
10	B1	52.8	18.4	20.4	25.5	27.3	3600	3700
9	B2	52.8	18.4	20.4	25.5	27.3	6200	6400
8	B3	366.0	34.7	64.4	154.0	212.0	16100	16500
7	B4	504.0	40.5	52.7	238.0	266.0	27700	28100
6	B5	299.0	38.7	45.4	156.0	143.0	36400	36700
5	B6	455.0	72.9	77.6	237.0	218.0	46100	46300
4	B7	466.0	77.6	86.3	224.0	242.0	55200	57100
3	B8	739.0	147.4	178.5	345.0	394.0	68800	71100
2	B9	918.0	208.5	218.4	454.0	464.0	80700	81000
1	B10	918.0	208.9	218.8	454.0	464.0	99200	99500

Table 2.2.2 Properties of Lumped-Mass Joints

Floor Number	Mass Joints	Location (m)	Weight (ton)	Mass ($ton.s^2/m$)	Mass Moment of Inertia ($x10^3$ $t.s^2.m$)	
					NS (y)	EW (x)
10	M1	63.65	1617	164.888	32.8	37.1
9	M2	57.00	1372	139.905	42.9	47.4
8	M3	46.50	6860	699.525	108.9	125.1
7	M4	38.80	9898	1009.315	103.8	168.0
6	M5	34.70	8477	864.413	71.4	117.5
5	M6	29.00	12446	1269.138	260.5	362.7
4	M7	20.30	16464	1678.861	565.6	508.2
3	M8	14.00	23912	2438.345	810.6	749.5
2	M9	8.20	20286	2068.596	922.1	928.6
1	M10	2.00	22491	2293.443	863.8	865.6
Foundation	M11	-10.50	158760	16189.046	6398.8	6374.2

Table 2.2.3 Properties of Springs and Dampers

NLINK Members	Stiffness (k)		Damping (c)	
	(t/m)	(t.m/rad)	(ts/m)	(tsm/rad)
KH (Horizontal) (EW)	8.707E+6		3.852E+5	
KH (Horizontal) (NS)	8.707E+6		3.851E+5	
KQ (Rotational) (EW)		1.316E+10		1.354E+8
KQ (Rotational) (NS)		1.316E+10		1.347E+8
KV (Vertical) (UD)	1.842E+7		9.747E+5	
KSS1 (Horizontal) (EW)	7.778E+4		4.053E+4	
KSS1 (Horizontal) (NS)	7.778E+4		4.052E+4	
KSS2 (Horizontal) (EW)	1.764E+5		1.035E+5	
KSS2 (Horizontal) (NS)	1.764E+5		1.034E+5	
KSS3 (Horizontal) (EW)	1.142E+6		3.354E+5	
KSS3 (Horizontal) (NS)	1.142E+6		3.353E+5	
KSS4 (Horizontal) (EW)	9.690E+5		2.591E+5	
KSS4 (Horizontal) (NS)	9.690E+5		2.590E+5	

2.3 Properties of Structure B

LSR structure B, extends 12.1 m above the basement level and stands on a 1.2 m thick foundation, which is placed on the ground level. At this point Model B is differed from Model A in a way that first model was stuck into the ground whereas model B stand on the ground level with no ambient rock soil. The model B has springs and dampers only at the bottom of the foundation slab. The structural model is represented as a lumped mass-spring-damper system shown on *Figure 2.3.1*. The lumped masses at floor levels (M1, M2, … M6) connected via massless bars (B1,B2,B3). The lumped mass M5 represents the foundation of the structural model. The system is joined to the ground by horizontal, vertical, and rotational spring of stiffness Ks, Kv, Kr, respectively and with dampers, that represents soil structure interaction. Joints M4 and M6 were constrained to the joint M5 for all degrees of freedom, so they behave as a rigid foundation.

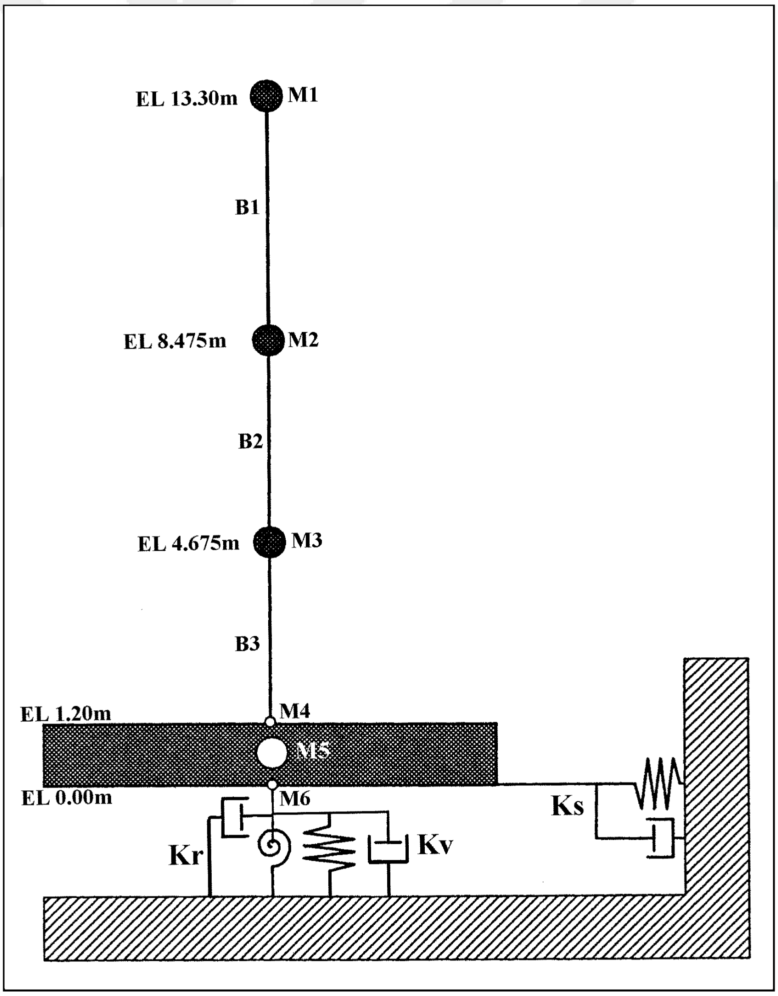


Figure 2.3.1 The Structural model B of LSR structure

In the analytical model massless bars (B1, B2 and B3), which carrie lumped-mass joints (M1,M2 and M3) are represented by Linear Frame Element of SAP2000 (see *Table 2.3.1* for Linear Frame Elements and *Table 2.3.2* for Lumped-Mass Joints). Springs and dampers, which stand for rock ground that supports the LSR structure, are represented by Nonlinear Nlink Elements of SAP2000 program (see *Table 2.3.3*).

Table 2.3.1 Properties of Linear Frame Elements

Floor Number	Frame Elements	Effective Axial Area (m^2)	Moment of Inertia (m^4)		Effective Shear Area (m^2)		Shear Force Capacity (ton)	
			NS	EW	NS	EW	NS	EW
3	B1	26.85	1302.42	2488.29	9.87	16.98	--	--
2	B2	35.84	1476.47	3334.78	13.12	22.72	--	--
1	B3	44.85	2195.58	4189.97	16.35	28.50	--	--
Foundation	--	∞	∞	∞	∞	∞	--	--

Table 2.3.2 Properties of Lumped-Mass Joints

Floor Number	Mass Joints	Location (m)	Weight (ton)	Mass ($ton.s^2/cm$)		Mass Moment of Inertia ($t.s^2.cm$)	
				NS	EW	NS	EW
3	M1	13.300	--	0.98816	0.98816	--	--
2	M2	8.475	--	1.4347	1.4347	--	--
1	M3	4.675	--	1.7804	1.7804	--	--
Foundation	M4	1.200	--	--	--	--	--
Foundation	M5	0.600	--	2.1337	2.1337	1.150E+6	1.457E+6
Foundation	M6	0.000	--	--	--	--	--

Table 2.3.3 Properties of Springs and Dampers

NLINK Members	Stiffness (k)		Damping (c)	
	(t/cm)	(t.cm/rad)	(t s/cm)	(t s.cm/rad)
KS (Horizontal) (NS)	4.453E+5		2.316E+3	
KS (Horizontal) (EW)	4.407E+5		2.274E+4	
Kr (Rotational) (NS)		8.130E+11		5.187E+8
Kr (Rotational) (EW)		9.618E+11		9.998E+8
Kv (Vertical) (UD)	5.787E+5		4.332E+3	

2.4 Properties of Structure C

The Structural Model C extends 30.1 meters above the basement level and stands on a 2.8 m thick foundation, which stuck into the ground for about 10.1 meters. Model C is differed from Model A and B, since Model A is stuck into the ground and it surrounded by ambient rock soil, and Model B stand on the ground level with no surrounding by ambient rock soil, whereas Model C, which is even stuck into the ground, but there is no surrounding by rock soil. Therefore, this model has springs and dampers only at the bottom of the foundation slab, which is similar to Model B that we have discussed previously. As other two the structural model C is represented with a lumped mass-spring-damper system (see *Figure 2.4.1*). The lumped masses at floor levels (M1, M2, … M6) connected via massless bars (B1, B2, B3). The lumped mass M5 is represent the foundation of the structural model C. The system is joined to the ground by horizontal, vertical, and rotational spring of stiffness Ks, Kv, Kr, respectively and with dampers, that represents soil structure interaction. Joints M4 and M6 were constrained to the joint M5 for all degrees of freedom, so they behave as a rigid foundation.

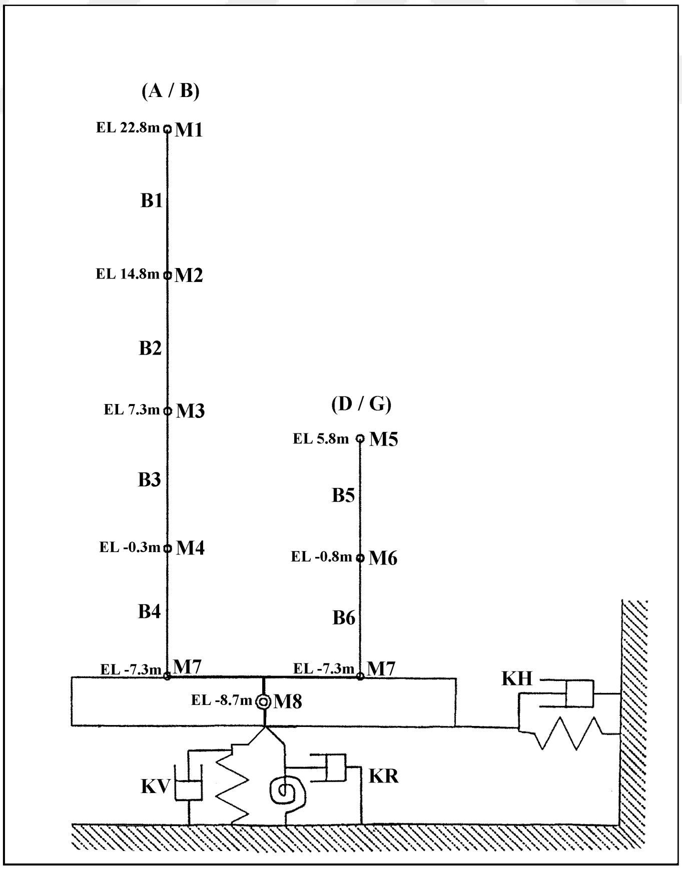


Figure 2.4.1 The Structural model C of LSR structure

In the analytical model of the LSR structure, massless bars (B1, B2 and B6), which carries lumped-mass joints (M1, M2 and M8) are represented by Linear Frame Element of SAP2000 (see *Table 2.4.1* for Linear Frame Elements and *Table 2.4.2* for Lumped-Mass Joints). Springs and dampers that support the LSR structure as a rock ground at the base level are represented by Nonlinear Nlink Elements of SAP2000 program (see *Table 2.4.3*).

Table 2.4.1 Properties of Linear Frame Elements

Floor Number	Frame Elements	Effective Axial Area (m^2)	Moment of Inertia (m^4)		Effective Shear Area (m^2)		Shear Force Capacity (ton)	
			NS	EW	NS	EW	NS	EW
4	B1	255.3	18914	9547	128.9	126.4	--	--
3	B2	562.1	128077	87505	274.9	287.2		
2	B3	813.4	172058	111229	413.8	399.6		
1	B4	1018.1	180039	125760	521.4	496.7	--	--
2	B5	171.0	1369	3594	55.2	115.8	--	--
1	B6	189.3	2028	3594	73.5	115.8		
Foundation	B7-B8	∞	∞	∞	∞	∞	--	--

Table 2.4.2 Properties of Lumped-Mass Joints

Floor Number	Mass Joints	Location (m)	Weight (ton)	Mass ($ton.s^2/cm$)		Mass Moment of Inertia ($t.s^2.cm$)	
				NS	EW	NS	EW
4	M1	22.8	--	8.706	8.706	--	--
3	M2	14.8	--	23.163	23.163	--	--
2	M3	7.3	--	28.071	28.071	--	--
1	M4	-0.3	--	38.245	38.245	--	--
2	M5	5.8	--	3.784	3.784		
1	M6	-0.8	--	3.373	3.373	--	--
Foundation	M8	-8.7		72.86	72.86	4.210E+8	4.564E+8

Table 2.4.3 Properties of Springs and Dampers

NLINK Members	Stiffness (k)		Damping (c)	
	(t/cm)	(t.cm/rad)	(t s/cm)	(t s.cm/rad)
KH (Horizontal) (NS)	1.266E+6		1.93E+4	
KH (Horizontal) (EW)	1.279E+6		1.97E+4	
KR (Rotational) (NS)		2.099E+13		9.82E+10
KR (Rotational) (EW)		1.704E+13		6.71E+10
KV (Vertical) (UD)	1.661E+6		3.95E+4	

2.5 Properties of Structure D

The Structural Model D extends 57.9 m above the basement level and stands on a foundation, which stuck into ground for about 18.5 meters deep. The height of the structure from the ground level is 63.4 m. The structural model is represented as a lumped mass-spring-damper system (see *Figure 2.5.1*). The lumped masses at floor levels (m1, m2,… m16) connected via massless bars (B1,B2,…B15). The lumped masses M9 and M10 represent the foundation of the structural model. The system is joined to the ground by horizontal, vertical, and rotational spring of stiffness Kn, Kv, Kr, respectively and dampers, that represent soil structure interaction. There was no information about vertical stiffness of the soil foundation of the structure, than adequately enough stiffness value for vertical spring (Kv) was chosen. Structure D consists of outer wall, which has joints from 1 to 8, and inner core, which has joints from 11 to 16. These two parts of the structure rigidly connected at the floor levels. The joints at each floor level were constraint for all degrees of freedom. The foundation was represented by B9 at foundation level. There are no joints at the bottom of the B8 and B15 members, so they were constraint to the joint M9 for all degrees of freedom.

In the analytical model of the LSR structure, massless bars (B1,B2,…B15) which carries lumped-mass joints (M1,M2,…M16) are represented by Linear Frame Element of SAP2000 (see *Table 2.5.1* for Linear Frame Elements and *Table 2.5.2* for Lumped-Mass Joints). Springs and dampers that support the LSR structure as a rock ground at the base level are represented by Nonlinear Nlink Elements of SAP2000 program (see *Table 2.5.3*).

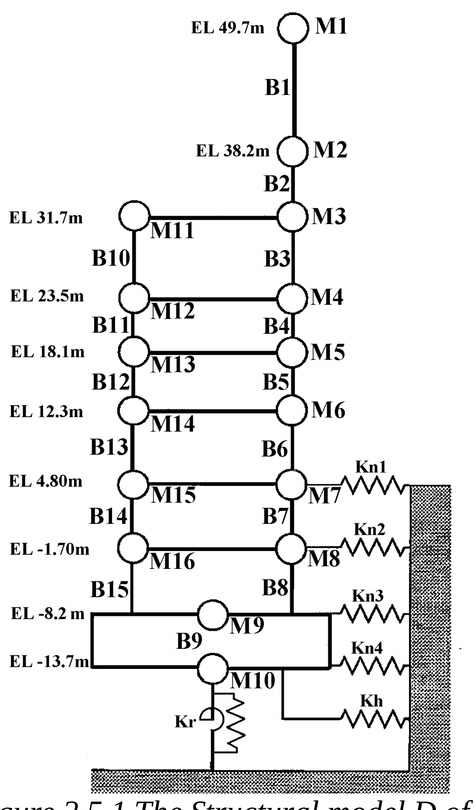


Figure 2.5.1 The Structural model D of LSR structure

Table 2.5.1 Properties of Linear Frame Elements

Floor Number	Frame Elements	Effective Axial Area (cm^2)	Moment of Inertia (cm^4)	Effective Shear Area (cm^2)	Shear Force Capacity (ton)
8	B1	4.10E+5	1.36E+12	4.10E+5	
7	B2	8.24E+5	5.05E+12	8.24E+5	
6	B3	1.17E+6	7.14E+12	1.17E+6	
5	B4	1.18E+6	7.04E+12	1.18E+6	
4	B5	1.25E+6	8.72E+12	1.25E+6	
3	B6	1.64E+6	1.03E+13	1.64E+6	
2	B7	1.81E+6	1.13E+13	1.81E+6	
1	B8	1.92E+6	1.19E+13	1.92E+6	
Foundation	B9	3.37E+7	9.01E+13	3.37E+7	
6	B10	1.14E+6	7.20E+11	1.14E+6	
5	B11	9.54E+5	2.33E+12	9.54E+5	
4	B12	9.56E+5	2.35E+12	9.56E+5	
3	B13	9.70E+5	2.34E+12	9.70E+5	
2	B14	9.95E+5	2.36E+12	9.95E+5	
1	B15	1.44E+6	2.95E+12	1.44E+6	

Table 2.5.2 Properties of Lumped-Mass Joints

Floor Number	Mass Joints	Location (m)	Weight (ton)	Mass ($ton.s^2/cm$)	Mass Moment of Inertia ($t.s^2.cm$)
8	M1	49.7	4650	4.742	8484038.89
7	M2	38.2	8300	8.464	42930052.6
6	M3	31.7	8850	9.024	50475952.5
5	M4	23.5	8450	8.617	29775713.4
4	M5	18.1	5650	5.761	20802210.7
3	M6	12.3	8400	8.566	30489514.8
2	M7	4.8	8000	8.158	30591486.4
1	M8	-1.7	8100	8.260	30489514.8
Foundation	M9	-8.20	34600	35.282	97280926.7
Foundation	M10	-13.7	22100	22.536	60265228.2
6	M11	31.7	9600	9.789	3467035.1
5	M12	23.5	16100	16.417	40074847.2
4	M13	18.1	10400	10.605	31509231.0
3	M14	12.3	20300	20.700	41502449.9
2	M15	4.8	12900	13.154	40992591.8
1	M16	-1.7	13900	14.174	38341329.6

Table 2.5.3 Properties of springs and Dampers

NLINK Members	Stiffness (k)		Damping (c)	
	(t/cm)	(t.cm/rad)	(t.s/cm)	(t.s.cm/rad)
Kn1 (Horizontal)	2.778E+4		2.381E+3	
Kn2 (Horizontal)	5.557E+4		4.763E+3	
Kn3 (Horizontal)	5.129E+4		4.396E+3	
Kn4 (Horizontal)	2.351E+4		2.015E+3	
Kh (Horizontal)	3.347E+5		6.362E+3	
Kr (Rotational)		3.086E+12		8.685E+9

3. SELECTION OF GROUND MOTIONS FOR DYNAMIC ANALYSIS

3.1 General

Total of 500 strong motion acceleration records (or more precisely 1000 strong ground motion records including NS and EW components) observed at K-NET [2], KIK-NET [3] and PEER [4] Digital Strong-motion seismograph network stations and Hyogo Ken-Nanbu earthquake records from Meteorological Agency of Japan was selected as input motions for Nonlinear Direct Integration Time History Analysis. Earthquake records are filtered by Fortran code “basecore”, which removes DC offset by using time-domain average trend as baseline, and then it removes low frequency component by time-domain low-cut filter from 20 sec to 10 sec. After that, all pairs (NS, EW components) of ground motion records are shortened by removing flat records approximately 30sec after PGA time in order to shorten analyzing time and reduce cost of analysis. All analyzed records are given in *Table3-1-1*.

Table3.1.1 All analyzed earthquakes

Occurrence time	Epicenter	Magnitude	Points
2004/10/23 17:56	Nigata	M=6.8	119
2004/10/23 18:03	Nigata (After shock 1)	M=6.2	22
2004/10/23 18:12	Nigata (After shock 2)	M=5.9	14
2004/10/23 18:34	Nigata (After shock 3)	M=6.3	59
2004/10/25 06:05	Nigata (After shock 4)	M=5.6	31
2004/10/27 10:40	Nigata (After shock 5)	M=6.0	48
2003/05/26 18:24	Miyagi Ken oki	M=7.0	44
2003/09/26 04:50	Tokachi oki	M 7.8	34
1995/01/17 05:46 1994/01/17 12:31	Damage Function data Hyogo Ken Nanbu (Kobe), Northridge	M 7.3 M 6.7	33
1995/01/17 05:46 1994/01/17 12:31	Damage Function data (Enlarged) Hyogo Ken Nanbu (Kobe), Northridge	M 7.3 M 6.7	33
Other ground motion data (PGA >300gal)			63
Total			500

3.2 Nigata Earthquake records:

Table3.2.1 Nigata Earthquake 2004_10_23_17.56_M=6.8_Kiknet data

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	FKSH010410231756	13.7	2.97	3	59.4	(EW)	1.5	(EW)	86.7	48.8	59.4	17.1	1.3	1.5	1.0
2	FKSH030410231756	44.9	4.00	4	101.2	(NS)	6.9	(EW)	694.9	101.2	79.0	53.5	4.8	6.9	3.0
3	FKSH040410231756	25.6	3.52	4	95.5	(EW)	2.9	(NS)	274.2	41.2	95.5	21.5	2.9	2.8	1.9
4	FKSH050410231756	29.2	3.63	4	67.4	(EW)	3.1	(NS)	209.8	59.8	67.4	25.8	3.1	2.4	1.4
5	FKSH060410231756	45.3	4.01	4	147.5	(EW)	4.5	(NS)	660.2	125.9	147.5	75.6	4.5	4.4	3.3
6	FKSH070410231756	23.5	3.44	3	149.2	(NS)	2.6	(EW)	392.3	149.2	101.3	89.6	2.3	2.6	2.5
7	FKSH210410231756	162.8	5.12	5+	361.8	(EW)	15.9	(EW)	5766.1	246.4	361.8	137.5	14.6	15.9	5.0
8	GNMH060410231756	33.2	3.74	4	84.0	(NS)	4.1	(NS)	345.5	84.0	75.1	17.4	4.1	2.8	2.3
9	GNMH070410231756	20.5	3.32	3	103.0	(EW)	2.4	(EW)	250.0	68.6	103.0	65.0	2.2	2.4	2.0
10	IBRH170410231756	24.4	3.47	3	50.6	(EW)	3.3	(NS)	166.1	46.3	50.6	19.7	3.3	1.9	1.7
11	NGNH070410231756	28.9	3.62	4	56.4	(NS)	3.2	(EW)	180.0	56.4	50.1	39.1	2.6	3.2	1.6
12	NGNH290410231756	61.7	4.28	4	130.3	(NS)	7.7	(EW)	1002.9	130.3	119.9	60.7	6.1	7.7	3.7
13	NIGH010410231756	527.0	6.14	6+	818.3	(NS)	61.8	(EW)	50564.1	818.3	655.2	375.5	60.9	61.8	27.6
14	NIGH040410231756	25.7	3.52	4	60.0	(EW)	2.7	(NS)	160.4	49.5	60.0	43.8	2.7	2.5	1.6
15	NIGH050410231756	43.3	3.97	4	92.6	(NS)	5.7	(NS)	526.0	92.6	88.1	17.4	5.7	4.4	2.0
16	NIGH060410231756	299.9	5.65	6-	409.4	(EW)	25.2	(EW)	10300.1	356.4	409.4	205.4	25.0	25.2	12.7
17	NIGH070410231756	35.3	3.80	4	127.6	(EW)	3.5	(EW)	449.5	115.4	127.6	49.5	3.3	3.5	1.7
18	NIGH080410231756	63.9	4.31	4	139.8	(EW)	10.9	(NS)	1527.8	125.5	139.8	59.0	10.9	10.1	4.2
19	NIGH090410231756	169.3	5.16	5+	390.1	(EW)	15.1	(NS)	5886.1	368.4	390.1	244.7	15.1	13.0	5.6
20	NIGH110410231756	302.1	5.66	6-	587.8	(EW)	58.3	(EW)	34290.5	454.5	587.8	325.2	36.7	58.3	12.7
21	NIGH120410231756	192.3	5.27	5+	409.9	(NS)	24.7	(NS)	10102.9	409.9	345.3	324.8	24.6	22.1	9.2
22	NIGH130410231756	42.4	3.95	4	84.0	(EW)	5.7	(EW)	478.6	67.0	84.0	28.1	5.6	5.7	3.4
23	NIGH150410231756	65.8	4.34	4	242.8	(NS)	9.2	(EW)	2229.8	242.8	182.7	118.5	7.0	9.2	4.3
24	NIGH170410231756	52.7	4.14	4	67.0	(NS)	6.4	(EW)	431.5	67.0	52.2	39.1	5.4	6.4	3.5
25	NIGH180410231756	72.1	4.42	4	110.4	(EW)	8.3	(NS)	913.8	96.3	110.4	44.5	8.3	5.8	3.4
26	NIGH190410231756	29.4	3.64	4	74.5	(EW)	3.2	(NS)	238.0	71.8	74.5	33.2	3.2	2.3	1.9
27	SITH060410231756	19.3	3.27	3	51.8	(EW)	2.0	(NS)	103.0	51.2	51.8	12.9	2.0	1.7	1.0
28	SITH110410231756	27.6	3.58	4	58.7	(NS)	2.4	(NS)	143.2	58.7	36.6	17.3	2.4	1.9	0.8
29	TCGH070410231756	36.9	3.83	4	160.4	(NS)	4.2	(NS)	679.8	160.4	100.5	74.3	4.2	2.7	1.9
30	TCGH080410231756	17.9	3.20	3	51.3	(NS)	2.3	(NS)	116.0	51.3	43.3	27.8	2.3	1.9	1.5
31	TCGH110410231756	18.7	3.24	3	63.2	(EW)	2.1	(EW)	131.5	41.7	63.2	22.0	1.6	2.1	1.1
32	TCGH170410231756	11.8	2.84	3	66.5	(EW)	1.5	(EW)	102.1	53.0	66.5	38.1	1.2	1.5	1.5
33	YMTH020410231756	32.4	3.72	4	57.6	(EW)	5.4	(EW)	308.5	56.7	57.6	12.7	4.8	5.4	1.6
34	YMTH060410231756	27.7	3.58	4	51.2	(EW)	3.4	(EW)	176.1	43.6	51.2	14.1	3.3	3.4	0.7
35	YMTH070410231756	25.0	3.50	3	52.5	(EW)	2.8	(EW)	147.0	46.8	52.5	14.2	2.1	2.8	1.5

Table3.2.2a Nigata Earthquake 2004_10_23_17.56_M=6.8_K-net data

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	CHB0010410231756	28.3	3.60	4	52.6	(NS)	3.2	(NS)	169.4	52.6	52.1	18.8	3.2	3.1	1.1
2	CHB0030410231756	26.1	3.53	4	57.1	(NS)	3.0	(NS)	174.0	57.1	41.1	20.5	3.0	2.2	0.9
3	FKS0210410231756	34.3	3.77	4	135.4	(NS)	6.4	(EW)	866.7	135.4	103.0	21.5	4.3	6.4	1.7
4	FKS0220410231756	82.2	4.53	5-	148.0	(EW)	7.9	(NS)	1171.1	131.6	148.0	70.7	7.9	7.6	3.2
5	FKS0230410231756	39.1	3.88	4	62.1	(EW)	4.7	(EW)	294.0	50.9	62.1	17.2	4.5	4.7	1.4
6	FKS0240410231756	42.0	3.95	4	52.6	(EW)	4.6	(EW)	239.8	40.1	52.6	31.5	4.3	4.6	2.0
7	FKS0250410231756	20.0	3.30	3	58.6	(EW)	2.4	(EW)	143.2	50.3	58.6	44.1	1.9	2.4	1.5
8	FKS0260410231756	41.7	3.94	4	132.2	(EW)	4.8	(EW)	629.5	111.4	132.2	59.7	3.7	4.8	2.3
9	FKS0270410231756	13.7	2.98	3	83.7	(EW)	2.1	(UD)	174.9	69.6	83.7	33.1	1.8	1.4	2.1
10	FKS0280410231756	100.8	4.71	5-	166.9	(EW)	12.7	(EW)	2118.2	141.3	166.9	123.1	12.2	12.7	4.2
11	FKS0290410231756	51.4	4.12	4	215.1	(NS)	3.7	(NS)	801.9	215.1	172.1	70.2	3.7	3.3	2.8
12	FKS0300410231756	40.4	3.91	4	144.5	(NS)	5.4	(EW)	786.1	144.5	97.8	50.1	4.4	5.4	2.3
13	GNM0020410231756	75.5	4.46	4	340.9	(NS)	7.9	(NS)	2678.8	340.9	279.4	194.5	7.9	6.5	3.1
14	GNM0030410231756	100.7	4.71	5-	359.1	(NS)	8.8	(NS)	3155.2	359.1	292.5	126.0	8.8	7.0	2.7
15	GNM0070410231756	29.8	3.65	4	82.2	(NS)	3.2	(EW)	266.2	82.2	52.3	38.6	3.1	3.2	1.7
16	GNM0090410231756	33.6	3.75	4	153.0	(EW)	2.9	(NS)	445.4	73.1	153.0	44.9	2.9	2.8	1.9
17	GNM0100410231756	26.8	3.56	4	67.7	(NS)	3.5	(NS)	239.1	67.7	44.8	33.0	3.5	2.6	1.7
18	GNM0110410231756	69.3	4.38	4	144.2	(EW)	6.1	(NS)	878.4	115.5	144.2	36.6	6.1	5.2	1.4
19	GNM0120410231756	16.1	3.12	3	49.8	(EW)	3.5	(NS)	176.4	26.2	49.8	19.1	3.5	3.4	1.6
20	GNM0130410231756	50.7	4.11	4	109.2	(NS)	6.6	(NS)	723.6	109.2	79.5	23.4	6.6	4.0	3.3
21	IBR0040410231756	23.3	3.43	3	59.7	(NS)	2.2	(NS)	133.4	59.7	46.3	11.8	2.2	1.5	0.8
22	IBR0150410231756	35.1	3.79	4	66.0	(NS)	3.2	(NS)	210.1	66.0	62.6	33.0	3.2	3.1	1.3
23	NIG0010410231756	20.8	3.33	3	46.2	(EW)	2.0	(EW)	93.6	29.7	46.2	17.0	1.9	2.0	0.7
24	NIG0030410231756	36.8	3.83	4	88.8	(NS)	4.2	(NS)	377.2	88.8	75.9	40.5	4.2	3.6	1.4
25	NIG0060410231756	34.4	3.77	4	66.1	(NS)	3.7	(NS)	245.7	66.1	55.0	17.4	3.7	2.5	0.7
26	NIG0080410231756	20.1	3.31	3	53.1	(EW)	2.2	(EW)	118.6	47.4	53.1	25.7	2.2	2.2	1.3
27	NIG0100410231756	50.9	4.11	4	103.7	(EW)	7.9	(EW)	822.8	68.6	103.7	33.5	7.3	7.9	2.4
28	NIG0110410231756	37.1	3.84	4	56.9	(EW)	7.5	(NS)	424.9	55.0	56.9	17.2	7.5	6.4	2.8
29	NIG0120410231756	129.1	4.92	5-	291.1	(EW)	15.9	(NS)	4635.6	236.7	291.1	62.9	15.9	14.7	3.7
30	NIG0130410231756	82.0	4.53	5-	129.2	(EW)	12.9	(NS)	1665.0	95.5	129.2	38.8	12.9	12.0	4.5
31	NIG0140410231756	115.7	4.83	5-	117.6	(NS)	14.8	(EW)	1743.2	117.6	96.3	76.2	14.5	14.8	6.6
32	NIG0150410231756	32.5	3.72	4	78.9	(EW)	5.2	(NS)	413.1	66.7	78.9	28.6	5.2	3.6	2.5
33	NIG0160410231756	55.0	4.18	4	103.1	(NS)	6.6	(NS)	681.0	103.1	85.6	36.9	6.6	5.8	2.0
34	NIG0170410231756	248.8	5.49	5+	468.4	(NS)	48.7	(NS)	22809.7	468.4	369.0	331.0	48.7	22.9	15.6
35	NIG0180410231756	128.6	4.92	5-	144.4	(EW)	31.4	(EW)	4539.4	97.9	144.4	75.6	13.5	31.4	6.7
36	NIG0190410231756	1038.4	6.73	7	1310.8	(EW)	127.8	(EW)	167527.6	1145.4	1310.8	821.0	97.1	127.8	32.5
37	NIG0200410231756	266.8	5.55	6-	521.7	(NS)	30.7	(NS)	16013.9	521.7	407.3	312.0	30.7	27.3	12.8
38	NIG0210410231756	560.8	6.20	6+	1715.4	(NS)	54.6	(NS)	93689.2	1715.4	849.2	564.7	54.6	49.7	13.3
39	NIG0220410231756	157.6	5.09	5+	342.2	(NS)	20.7	(NS)	7091.5	342.2	341.6	126.5	20.7	19.9	3.9

Table3.2.2b Nigata Earthquake 2004_10_23_17.56_M=6.8_K-net data

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
40	NIG0230410231756	142.9	5.01	5+	397.0	(NS)	26.0	(EW)	10334.0	397.0	274.6	86.5	24.9	26.0	10.1
41	NIG0240410231756	134.2	4.96	5-	240.0	(NS)	13.3	(NS)	3182.0	240.0	217.6	55.2	13.3	9.1	4.3
42	NIG0250410231756	180.2	5.21	5+	200.5	(EW)	18.3	(EW)	3667.4	189.9	200.5	38.4	16.7	18.3	2.8
43	NIG0260410231756	43.8	3.98	4	78.0	(EW)	4.1	(EW)	321.9	71.5	78.0	18.5	3.6	4.1	2.8
44	NIG0270410231756	26.6	3.55	4	60.9	(EW)	2.5	(NS)	153.8	58.1	60.9	16.0	2.5	1.8	1.0
45	NIG0280410231756	504.2	6.11	6+	870.8	(NS)	65.0	(NS)	56638.5	870.8	706.2	411.9	65.0	64.8	24.8
46	SIT0010410231756	25.0	3.49	3	45.7	(EW)	4.6	(NS)	209.3	34.9	45.7	10.3	4.6	2.8	1.4
47	SIT0040410231756	29.6	3.64	4	112.6	(EW)	3.0	(EW)	341.7	98.1	112.6	17.6	2.1	3.0	0.8
48	SIT0060410231756	17.3	3.18	3	52.1	(NS)	2.2	(NS)	114.0	52.1	32.8	10.8	2.2	2.0	0.9
49	TCG0030410231756	22.4	3.40	3	52.3	(EW)	2.3	(EW)	119.9	46.7	52.3	5.4	1.6	2.3	0.4
50	TCG0040410231756	26.2	3.54	4	48.3	(EW)	2.6	(NS)	125.9	47.1	48.3	36.3	2.6	2.2	2.2
51	TCG0050410231756	25.1	3.50	3	70.1	(EW)	3.3	(NS)	232.7	56.9	70.1	16.9	3.3	2.9	1.6
52	TCG0090410231756	49.8	4.09	4	120.2	(EW)	4.6	(NS)	549.1	86.2	120.2	61.1	4.6	4.2	1.6
53	TCG0140410231756	20.6	3.33	3	50.4	(EW)	2.6	(EW)	129.9	32.2	50.4	12.3	1.2	2.6	0.7
54	TKY0150410231756	23.3	3.43	3	46.6	(NS)	3.1	(NS)	142.7	46.6	37.7	19.6	3.1	2.7	1.3
55	YMT0140410231756	29.7	3.64	4	83.5	(EW)	3.0	(EW)	254.3	54.9	83.5	22.1	2.3	3.0	1.1
56	YMT0150410231756	34.6	3.78	4	46.5	(EW)	4.7	(NS)	217.2	42.2	46.5	15.0	4.7	3.6	2.2

Table3.2.3 Nigata Earthquake 2004_10_23_17.56_M=6.8_JMA data

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	519 沼田市西倉内町	71.0	4.40	4	190.6	(EW)	7.0	(EW)	1337.0	133.8	190.6	103.1	5.3	7.0	3.8
2	530 長岡市幸町	248.7	5.49	5+	430.3	(EW)	34.8	(NS)	14963.1	395.8	430.3	324.6	34.8	25.4	18.6
3	532 小千谷市城内	654.2	6.33	6+	897.5	(EW)	84.9	(EW)	76234.9	780.3	897.5	731.0	67.5	84.9	26.6
4	900 関城町舟生	24.5	3.48	3	37.4	(EW)	4.9	(NS)	182.9	22.1	37.4	12.7	4.9	4.5	1.3
5	905 群馬吾妻町原町	24.6	3.48	3	117.3	(NS)	2.6	(NS)	306.6	117.3	70.7	31.8	2.6	2.0	1.6
6	915 能都町宇出津	25.0	3.49	3	25.6	(NS)	3.1	(NS)	79.0	25.6	23.4	8.0	3.1	3.0	0.6
7	51B 桐生市織姫町	33.7	3.75	4	78.4	(NS)	4.1	(NS)	322.0	78.4	67.8	32.2	4.1	2.2	1.5
8	51E 久喜市下早見	105.3	4.74	5-	173.6	(EW)	11.6	(NS)	2014.0	164.8	173.6	33.6	11.6	9.5	2.1
9	8AC 山形河北町谷地	25.8	3.52	4	28.0	(NS)	4.3	(EW)	120.9	28.0	25.5	10.0	3.9	4.3	2.2
10	8AF 田島町田島	40.9	3.92	4	109.3	(EW)	5.6	(EW)	609.6	60.9	109.3	59.2	3.5	5.6	1.7
11	8B0 西会津町野沢	79.8	4.50	5-	184.2	(NS)	9.8	(NS)	1801.2	184.2	135.8	56.1	9.8	9.0	2.9
12	8B1 猪苗代町城南	27.2	3.57	4	39.8	(EW)	3.9	(EW)	155.6	39.5	39.8	14.8	3.9	3.9	1.6
13	90D 村松町大手通	32.1	3.71	4	55.4	(EW)	5.9	(NS)	328.6	44.8	55.4	32.0	5.9	5.0	3.6
14	90E 巻町巻	77.4	4.48	4	94.6	(NS)	13.4	(NS)	1269.3	94.6	92.8	35.4	13.4	12.1	6.1
15	90F 六日町伊勢町	183.2	5.23	5+	186.5	(UD)	24.9	(NS)	4641.3	136.0	111.3	186.5	24.9	18.5	8.8
16	91D 山ノ内町平穏	25.5	3.51	4	48.3	(EW)	3.4	(EW)	161.9	33.9	48.3	26.7	2.5	3.4	1.3
17	CB4 阿賀野市畑江	28.7	3.61	4	94.0	(NS)	2.6	(EW)	241.7	94.0	82.4	46.8	2.3	2.6	1.2

18	CB6 上越市中ノ俣	33.0	3.74	4	71.5	(EW)	3.8	(EW)	273.3	47.2	71.5	19.6	3.0	3.8	2.3
19	CB7 広神村米沢	98.9	4.69	5-	333.9	(NS)	16.1	(EW)	5377.7	333.9	286.6	310.7	15.7	16.1	5.4
20	D19 片品村東小川	82.1	4.53	5-	200.0	(EW)	9.3	(EW)	1868.2	162.0	200.0	101.6	5.0	9.3	2.4
21	E03 酒田市亀ヶ崎	28.4	3.61	4	48.4	(NS)	4.1	(NS)	199.3	48.4	28.4	7.9	4.1	3.3	1.5
22	E0E いわき市小名浜	30.2	3.66	4	26.9	(EW)	4.6	(EW)	123.1	15.3	26.9	6.6	2.2	4.6	1.1
23	E10 輪島市鳳至町	35.7	3.81	4	40.3	(EW)	4.7	(NS)	188.8	34.7	40.3	8.8	4.7	2.8	1.1
24	E12 佐渡市相川三町目	35.2	3.79	4	62.6	(NS)	3.0	(NS)	187.8	62.6	47.1	26.8	3.0	2.6	1.0
25	E14 新潟市幸西	53.7	4.16	4	83.1	(EW)	6.8	(EW)	564.4	58.0	83.1	21.2	6.0	6.8	2.6
26	E1A 長野市箱清水	34.8	3.78	4	40.3	(EW)	4.7	(NS)	188.1	40.2	40.3	26.1	4.7	4.0	2.1
27	E1C 上越市大手町	80.4	4.51	5-	138.9	(EW)	8.5	(EW)	1175.6	74.4	138.9	23.9	7.3	8.5	2.9
28	E4E 東京千代田区大手町	28.7	3.62	4	47.0	(EW)	4.5	(NS)	212.8	36.2	47.0	10.1	4.5	2.9	1.0

Table3.2.4 Nigata Earthquake after shock 1 2004_10_23_18.03_M=6.2_Kiknet&K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	NIGH070410231803	28.2	3.60	4	129.9	(EW)	3.5	(EW)	457.3	70.3	129.9	60.0	2.7	3.5	1.5
2	NIGH080410231803	24.4	3.48	3	66.3	(NS)	3.9	(NS)	256.5	66.3	39.2	31.6	3.9	3.2	1.9
3	NIGH180410231803	38.2	3.86	4	73.9	(NS)	4.1	(NS)	304.3	73.9	38.2	15.7	4.1	2.4	0.9
1	FKS0220410231803	35.1	3.79	4	72.4	(NS)	4.1	(NS)	298.2	72.4	55.1	34.2	4.1	3.2	1.0
2	FKS0260410231803	20.2	3.31	3	65.6	(EW)	2.1	(EW)	135.9	60.5	65.6	21.5	1.9	2.1	0.8
3	FKS0300410231803	16.3	3.13	3	56.6	(NS)	1.8	(NS)	100.3	56.6	47.3	20.0	1.8	1.7	1.2
4	GNM0020410231803	14.0	2.99	3	69.6	(EW)	1.4	(EW)	94.3	49.5	69.6	26.0	1.1	1.4	0.6
5	GNM0030410231803	20.2	3.31	3	53.9	(NS)	2.6	(NS)	138.1	53.9	36.2	22.3	2.6	1.4	0.8
6	GNM0130410231803	19.8	3.29	3	49.6	(NS)	2.1	(NS)	102.4	49.6	46.0	10.8	2.1	1.7	0.9
7	NIG0100410231803	26.0	3.53	4	62.2	(EW)	4.0	(EW)	251.5	46.1	62.2	14.5	3.4	4.0	1.5
8	NIG0120410231803	39.0	3.88	4	111.3	(NS)	6.9	(NS)	763.9	111.3	68.9	29.4	6.9	5.5	2.3
9	NIG0130410231803	37.6	3.85	4	51.8	(NS)	8.2	(EW)	422.6	51.8	49.9	24.0	7.2	8.2	2.5
10	NIG0140410231803	66.0	4.34	4	80.4	(EW)	9.7	(EW)	782.6	63.0	80.4	36.6	7.6	9.7	2.5
11	NIG0160410231803	43.9	3.98	4	110.7	(EW)	5.1	(EW)	569.8	78.0	110.7	25.6	3.7	5.1	1.5
12	NIG0180410231803	47.0	4.04	4	58.8	(NS)	7.1	(NS)	415.6	58.8	56.4	38.3	7.1	5.5	2.3
13	NIG0250410231803	42.3	3.95	4	55.1	(NS)	4.9	(NS)	268.3	55.1	52.3	14.6	4.9	3.1	0.8
14	NIG0260410231803	22.1	3.39	3	49.5	(EW)	2.5	(EW)	124.7	40.6	49.5	12.5	2.3	2.5	0.7
15	NIG0280410231803	362.5	5.82	6-	835.5	(NS)	41.3	(EW)	34478.7	835.5	508.1	435.6	31.3	41.3	16.9
16	SIT0040410231803	15.3	3.07	3	70.0	(NS)	1.3	(NS)	89.9	70.0	49.4	8.2	1.3	1.0	0.3
17	TCG0050410231803	16.3	3.12	3	56.3	(NS)	1.6	(EW)	90.9	56.3	41.9	13.6	1.1	1.6	0.6
18	TCG0090410231803	32.5	3.72	4	79.9	(EW)	3.6	(EW)	289.5	45.5	79.9	26.3	2.0	3.6	0.7
19	TCG0140410231803	23.7	3.45	3	64.0	(EW)	2.1	(EW)	132.8	41.3	64.0	8.9	1.5	2.1	0.3

Table3.2.5 Nigata Earthquake after shock 2 2004_10_23_18.12_M=5.9_Kiknet&K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	FKSH210410231812	39.0	3.88	4	112.4	(EW)	5.6	(NS)	624.6	101.7	112.4	36.6	5.6	4.1	1.3
2	NGNH290410231812	18.9	3.25	3	73.3	(NS)	2.0	(NS)	148.8	73.3	38.7	21.5	2.0	1.3	1.0
3	NIGH010410231812	117.7	4.84	5-	272.2	(EW)	15.3	(EW)	4159.4	236.6	272.2	59.4	10.8	15.3	4.1
4	NIGH050410231812	20.9	3.34	3	51.4	(EW)	2.6	(EW)	133.1	46.3	51.4	6.4	2.4	2.6	0.4
5	NIGH060410231812	114.2	4.82	5-	202.8	(NS)	9.8	(EW)	1983.6	202.8	168.4	64.5	9.6	9.8	4.3
6	NIGH070410231812	11.7	2.84	3	60.0	(EW)	1.5	(EW)	88.9	34.1	60.0	20.2	1.4	1.5	0.5
7	NIGH090410231812	70.8	4.40	4	163.9	(EW)	8.5	(EW)	1393.1	150.7	163.9	67.0	6.6	8.5	2.1
8	NIGH110410231812	91.2	4.62	5-	345.9	(EW)	14.2	(EW)	4906.6	317.8	345.9	131.8	11.5	14.2	2.1
9	NIGH120410231812	68.9	4.38	4	177.3	(NS)	8.5	(EW)	1511.0	177.3	171.5	74.9	6.3	8.5	2.3
1	FKS0290410231812	20.3	3.31	3	109.7	(EW)	1.7	(EW)	183.7	107.9	109.7	26.0	1.6	1.7	0.5
2	NIG0170410231812	126.1	4.90	5-	240.2	(NS)	14.3	(NS)	3426.9	240.2	192.5	107.0	14.3	9.8	2.7
3	NIG0200410231812	104.1	4.73	5-	276.0	(NS)	12.2	(EW)	3378.9	276.0	229.5	105.4	10.4	12.2	2.7
4	NIG0220410231812	30.1	3.66	4	77.7	(EW)	4.5	(EW)	346.4	54.8	77.7	25.1	3.7	4.5	0.8
5	NIG0250410231812	68.1	4.37	4	83.9	(NS)	7.7	(NS)	642.9	83.9	74.8	18.3	7.7	6.7	1.3

Table 3.2.6 Nigata Earthquake after shock 3 2004_10_23_18.34_M=6.3_Kiknet

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	FKSH010410231834	10.2	2.72	3	50.8	(EW)	0.9	(NS)	45.7	46.8	50.8	13.4	0.9	0.9	0.4
2	FKSH050410231834	22.9	3.42	3	58.2	(EW)	2.2	(NS)	130.4	48.1	58.2	25.6	2.2	2.2	1.0
3	FKSH060410231834	30.2	3.66	4	99.9	(EW)	2.6	(EW)	255.3	95.2	99.9	54.1	2.4	2.6	1.5
4	FKSH070410231834	21.9	3.38	3	176.5	(NS)	2.4	(NS)	424.3	176.5	121.9	116.0	2.4	1.8	1.5
5	FKSH100410231834	21.7	3.37	3	72.8	(EW)	1.9	(EW)	134.9	43.6	72.8	22.8	1.3	1.9	0.7
6	FKSH210410231834	108.1	4.77	5-	289.6	(EW)	9.3	(EW)	2681.2	212.0	289.6	109.5	9.1	9.3	2.8
7	GNMH060410231834	35.5	3.80	4	62.0	(NS)	3.6	(NS)	221.7	62.0	52.5	22.4	3.6	3.6	1.5
8	GNMH070410231834	33.8	3.76	4	135.2	(EW)	3.4	(NS)	464.1	97.7	135.2	90.0	3.4	3.1	1.7
9	GNMH100410231834	7.3	2.42	2	56.1	(EW)	0.9	(EW)	48.8	48.8	56.1	14.7	0.7	0.9	0.3
10	ISKH030410231834	22.9	3.42	3	50.5	(NS)	2.1	(EW)	107.7	50.5	42.4	18.3	1.9	2.1	1.1
11	NGNH290410231834	78.9	4.49	4	345.3	(NS)	11.7	(NS)	4055.7	345.3	216.1	97.6	11.7	7.7	3.4
12	NIGH010410231834	173.1	5.18	5+	321.7	(NS)	25.3	(NS)	8134.1	321.7	273.9	174.1	25.3	16.6	7.3
13	NIGH040410231834	18.2	3.22	3	61.2	(EW)	1.7	(EW)	104.2	52.3	61.2	21.6	1.4	1.7	0.9
14	NIGH050410231834	32.0	3.71	4	93.4	(EW)	3.0	(EW)	280.7	64.4	93.4	15.8	2.3	3.0	0.4
15	NIGH060410231834	136.7	4.97	5-	258.3	(NS)	13.0	(NS)	3356.0	258.3	219.2	149.6	13.0	12.7	4.8
16	NIGH070410231834	31.1	3.69	4	134.7	(EW)	3.5	(EW)	469.9	121.3	134.7	44.7	2.7	3.5	0.7
17	NIGH080410231834	31.4	3.69	4	101.7	(EW)	3.4	(EW)	345.5	75.9	101.7	37.0	2.8	3.4	2.4
18	NIGH090410231834	102.2	4.72	5-	291.7	(EW)	9.8	(EW)	2858.6	186.0	291.7	142.7	6.9	9.8	2.7
19	NIGH120410231834	208.4	5.34	5+	545.3	(NS)	25.6	(EW)	13970.0	545.3	364.1	421.1	17.7	25.6	6.7
20	NIGH130410231834	96.4	4.67	5-	234.6	(EW)	10.4	(EW)	2441.6	180.8	234.6	48.8	6.1	10.4	2.2
21	NIGH150410231834	66.5	4.35	4	211.4	(NS)	7.4	(EW)	1566.0	211.4	139.7	120.9	5.4	7.4	4.5
22	NIGH180410231834	65.7	4.33	4	135.7	(NS)	8.3	(NS)	1125.1	135.7	98.8	37.2	8.3	4.8	2.5
23	NIGH190410231834	22.0	3.39	3	69.0	(NS)	2.3	(NS)	157.9	69.0	47.9	30.5	2.3	2.2	1.3
24	TCGH070410231834	33.5	3.75	4	137.3	(NS)	2.9	(EW)	402.9	137.3	130.4	75.1	2.8	2.9	1.8
25	TCGH110410231834	20.1	3.31	3	79.0	(EW)	1.6	(EW)	124.3	41.0	79.0	23.0	1.2	1.6	0.8
26	TCGH170410231834	11.4	2.82	3	70.0	(NS)	1.5	(NS)	103.8	70.0	64.7	28.9	1.5	0.9	0.9

Table 3.2.7 Nigata Earthquake after shock 3 2004_10_23_18.34_M=6.3_K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	FKS0220410231834	45.5	4.02	4	98.9	(EW)	6.3	(NS)	620.8	90.3	98.9	46.4	6.3	3.2	1.8
2	FKS0250410231834	15.2	3.07	3	55.4	(EW)	1.5	(EW)	81.0	44.4	55.4	28.2	1.0	1.5	1.1
3	FKS0260410231834	30.2	3.66	4	92.9	(NS)	2.9	(EW)	267.8	92.9	84.4	49.9	2.7	2.9	1.3
4	FKS0290410231834	46.1	4.03	4	217.6	(NS)	3.8	(NS)	817.7	217.6	144.0	105.7	3.8	2.8	1.8
5	FKS0300410231834	24.2	3.47	3	90.6	(EW)	2.3	(NS)	209.0	90.2	90.6	38.9	2.3	2.2	1.4
6	GNM0020410231834	93.4	4.64	5-	300.5	(EW)	8.9	(EW)	2669.3	194.6	300.5	187.9	4.3	8.9	3.5
7	GNM0030410231834	75.6	4.46	4	215.7	(NS)	8.7	(NS)	1869.8	215.7	201.1	155.4	8.7	6.4	4.4
8	GNM0060410231834	14.8	3.04	3	49.4	(EW)	1.8	(NS)	87.6	33.9	49.4	22.5	1.8	1.6	0.9
9	GNM0070410231834	35.0	3.79	4	82.2	(EW)	4.7	(EW)	385.3	67.9	82.2	34.4	3.0	4.7	1.4
10	GNM0080410231834	25.8	3.52	4	45.7	(NS)	3.7	(NS)	171.1	45.7	26.8	13.6	3.7	2.8	1.2
11	GNM0090410231834	38.7	3.88	4	109.3	(EW)	3.8	(EW)	418.5	79.8	109.3	34.4	3.1	3.8	1.5
12	GNM0100410231834	27.2	3.57	4	59.4	(NS)	3.6	(NS)	216.6	59.4	52.6	23.5	3.6	2.9	1.0
13	GNM0130410231834	56.4	4.20	4	97.8	(NS)	7.0	(NS)	680.2	97.8	71.3	16.8	7.0	5.3	1.2
14	NIG0010410231834	29.4	3.64	4	66.9	(NS)	3.0	(EW)	197.9	66.9	59.7	19.3	2.6	3.0	0.9
15	NIG0020410231834	23.1	3.43	3	50.2	(EW)	2.4	(EW)	121.0	34.5	50.2	21.8	1.9	2.4	1.3
16	NIG0100410231834	29.0	3.63	4	89.5	(EW)	4.3	(EW)	389.0	54.2	89.5	18.0	2.8	4.3	0.9
17	NIG0120410231834	72.6	4.42	4	159.4	(NS)	6.6	(EW)	1046.7	159.4	113.8	30.9	6.5	6.6	1.7
18	NIG0130410231834	61.0	4.27	4	76.1	(EW)	7.8	(NS)	596.5	74.5	76.1	26.7	7.8	6.3	1.7
19	NIG0140410231834	73.9	4.44	4	77.6	(NS)	11.0	(NS)	857.5	77.6	73.1	47.8	11.0	6.5	2.1
20	NIG0160410231834	51.0	4.11	4	105.4	(EW)	4.4	(EW)	460.3	96.0	105.4	36.3	4.1	4.4	1.6
21	NIG0170410231834	177.8	5.20	5+	325.3	(EW)	21.6	(NS)	7029.0	224.9	325.3	117.0	21.6	19.4	5.6
22	NIG0180410231834	82.0	4.53	5-	149.3	(NS)	12.7	(NS)	1895.3	149.3	129.4	65.4	12.7	9.4	4.5
23	NIG0200410231834	292.0	5.63	6-	526.8	(NS)	34.8	(EW)	18347.2	526.8	524.4	329.3	26.5	34.8	10.1
24	NIG0210410231834	551.9	6.18	6+	815.5	(NS)	58.4	(NS)	47591.6	815.5	811.5	220.6	58.4	49.2	10.7
25	NIG0220410231834	224.2	5.40	5+	231.9	(NS)	28.3	(EW)	6558.8	231.9	227.6	87.7	20.6	28.3	5.6
26	NIG0230410231834	75.9	4.46	4	222.0	(EW)	10.9	(EW)	2409.9	146.1	222.0	56.3	9.2	10.9	5.5
27	NIG0250410231834	86.6	4.57	5-	115.8	(EW)	9.5	(NS)	1106.1	95.9	115.8	35.5	9.5	8.1	2.7
28	NIG0260410231834	49.8	4.10	4	91.6	(NS)	6.8	(NS)	618.2	91.6	89.1	20.1	6.8	5.5	2.3
29	NIG0270410231834	35.6	3.80	4	110.6	(NS)	3.8	(NS)	417.7	110.6	60.4	20.4	3.8	2.8	0.8
30	TCG0030410231834	29.1	3.63	4	61.2	(EW)	2.6	(EW)	159.3	58.4	61.2	3.9	1.9	2.6	0.2
31	TCG0040410231834	28.4	3.61	4	61.7	(NS)	3.5	(NS)	215.4	61.7	55.7	47.3	3.5	2.2	2.0
32	TCG0090410231834	62.8	4.30	4	166.8	(EW)	6.0	(EW)	998.7	103.4	166.8	56.4	5.1	6.0	1.5
33	YMT0140410231834	18.7	3.24	3	64.7	(EW)	1.7	(EW)	110.1	46.8	64.7	12.8	1.4	1.7	0.7

Table3.2.8 Nigata Earthquake after shock 4 2004_10_25_06.05_M=5.6_Kiknet&K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	FKSH060410250605	11.2	2.79	3	50.1	(NS)	1.2	(NS)	61.5	50.1	38.1	28.0	1.2	0.8	0.7
2	FKSH070410250605	8.3	2.54	3	55.7	(NS)	0.9	(EW)	48.1	55.7	48.7	44.5	0.7	0.9	0.5
3	FKSH210410250605	81.7	4.52	5-	332.2	(NS)	9.1	(NS)	3031.9	332.2	217.3	78.7	9.1	7.1	2.0
4	NGNH290410250605	15.2	3.07	3	55.7	(NS)	1.4	(NS)	80.1	55.7	41.2	18.4	1.4	1.1	0.6
5	NIGH010410250605	148.7	5.04	5+	354.6	(EW)	18.6	(EW)	6603.5	243.5	354.6	115.4	18.5	18.6	4.1
6	NIGH060410250605	75.6	4.46	4	109.5	(EW)	6.0	(EW)	660.2	108.6	109.5	41.9	5.8	6.0	1.6
7	NIGH070410250605	12.0	2.86	3	63.5	(EW)	1.5	(EW)	94.8	35.4	63.5	22.0	0.8	1.5	0.4
8	NIGH080410250605	14.5	3.02	3	65.2	(EW)	1.5	(NS)	96.2	60.5	65.2	20.2	1.5	1.3	0.9
9	NIGH090410250605	47.3	4.05	4	150.0	(NS)	4.3	(NS)	643.3	150.0	147.4	83.3	4.3	4.0	1.1
10	NIGH120410250605	73.4	4.43	4	247.5	(NS)	8.1	(EW)	2007.9	247.5	190.7	189.1	7.0	8.1	3.3
11	NIGH130410250605	21.0	3.34	3	57.8	(EW)	2.3	(EW)	135.2	56.2	57.8	15.3	1.5	2.3	0.5
12	NIGH150410250605	15.4	3.07	3	71.3	(NS)	1.6	(EW)	114.1	71.3	47.2	27.7	1.5	1.6	0.7
1	FKS0260410250605	11.3	2.81	3	42.9	(NS)	1.1	(EW)	48.5	42.9	35.5	22.9	0.9	1.1	0.4
2	FKS0270410250605	5.4	2.16	2	48.7	(EW)	0.8	(EW)	40.5	39.6	48.7	15.7	0.5	0.8	0.3
3	FKS0280410250605	54.2	4.17	4	96.0	(NS)	6.2	(EW)	597.7	96.0	94.9	44.2	4.7	6.2	1.7
4	FKS0300410250605	11.9	2.85	3	55.7	(EW)	1.1	(NS)	59.5	37.6	55.7	18.3	1.1	1.1	0.4
5	GNM0010410250605	27.3	3.57	4	103.4	(EW)	1.7	(EW)	178.0	96.5	103.4	72.5	1.7	1.7	0.9
6	GNM0090410250605	10.2	2.72	3	56.6	(EW)	1.1	(EW)	60.9	23.4	56.6	13.4	0.8	1.1	0.6
7	GNM0110410250605	28.8	3.62	4	47.4	(NS)	2.5	(NS)	120.3	47.4	43.3	14.4	2.5	1.6	0.6
8	NIG0030410250605	23.7	3.45	3	56.8	(NS)	3.8	(NS)	215.6	56.8	42.9	18.1	3.8	1.6	0.5
9	NIG0120410250605	40.2	3.91	4	95.7	(EW)	4.3	(EW)	407.1	65.0	95.7	20.1	3.0	4.3	0.9
10	NIG0130410250605	31.3	3.69	4	44.2	(EW)	4.3	(NS)	189.7	42.2	44.2	13.7	4.3	3.8	0.9
11	NIG0160410250605	30.3	3.66	4	56.2	(EW)	3.3	(NS)	185.8	55.2	56.2	17.5	3.3	3.0	1.2
12	NIG0170410250605	102.0	4.72	5-	244.1	(EW)	13.6	(EW)	3331.4	177.0	244.1	103.9	13.4	13.6	2.4
13	NIG0180410250605	38.0	3.86	4	52.2	(NS)	6.0	(NS)	312.9	52.2	48.9	24.0	6.0	5.2	1.6
14	NIG0190410250605	178.8	5.20	5+	285.2	(EW)	27.6	(EW)	7867.6	143.5	285.2	120.0	10.0	27.6	3.7
15	NIG0200410250605	145.0	5.02	5+	427.2	(NS)	12.2	(NS)	5220.1	427.2	209.6	124.9	12.2	10.8	3.3
16	NIG0210410250605	31.6	3.70	4	74.1	(NS)	3.5	(NS)	258.6	74.1	69.5	27.9	3.5	2.5	1.1
17	NIG0220410250605	16.5	3.14	3	61.4	(NS)	1.7	(NS)	103.5	61.4	58.4	28.6	1.7	1.6	0.6
18	NIG0240410250605	48.4	4.07	4	126.2	(EW)	5.5	(EW)	698.0	99.6	126.2	24.3	3.2	5.5	0.8
19	TCG0090410250605	23.2	3.43	3	62.8	(EW)	2.3	(EW)	147.5	53.2	62.8	29.2	2.1	2.3	0.6

Table 3.2.9 Nigata Earthquake after shock 5 2004_10_27_10.40_M=6.0_Kiknet

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	FKSH060410271040	21.0	3.35	3	77.5	(NS)	2.1	(NS)	159.5	77.5	72.6	45.3	2.1	1.6	1.2
2	FKSH070410271040	22.9	3.42	3	136.9	(NS)	2.2	(NS)	304.1	136.9	120.7	78.6	2.2	1.9	1.8
3	FKSH210410271040	142.8	5.01	5+	411.4	(NS)	18.3	(NS)	7530.5	411.4	300.0	110.4	18.3	11.5	2.5
4	GNMH070410271040	12.2	2.87	3	65.1	(NS)	1.2	(NS)	79.3	65.1	62.4	33.7	1.2	1.1	0.8
5	GNMH100410271040	7.4	2.43	2	56.3	(NS)	1.0	(NS)	57.5	56.3	45.0	16.7	1.0	0.7	0.3
6	NGNH290410271040	12.2	2.87	3	61.4	(NS)	1.3	(NS)	78.6	61.4	24.2	21.5	1.3	1.1	0.7
7	NIGH010410271040	282.9	5.60	6-	442.6	(EW)	29.2	(NS)	12915.0	399.6	442.6	171.7	29.2	25.7	6.2
8	NIGH050410271040	18.1	3.22	3	58.7	(EW)	1.8	(EW)	103.4	39.4	58.7	10.0	1.6	1.8	0.3
9	NIGH060410271040	140.4	4.99	5-	198.5	(NS)	13.5	(NS)	2681.8	198.5	184.5	79.8	13.5	9.6	3.1
10	NIGH070410271040	23.4	3.44	3	102.0	(NS)	3.1	(NS)	319.1	102.0	94.4	31.7	3.1	2.0	0.6
11	NIGH080410271040	32.9	3.73	4	182.0	(NS)	4.0	(NS)	724.4	182.0	120.9	52.5	4.0	2.9	1.3
12	NIGH090410271040	81.4	4.52	5-	287.2	(EW)	10.9	(EW)	3135.8	219.6	287.2	160.7	9.7	10.9	3.0
13	NIGH110410271040	60.3	4.26	4	194.4	(EW)	13.8	(EW)	2688.6	108.2	194.4	83.3	7.6	13.8	4.9
14	NIGH120410271040	171.3	5.17	5+	397.3	(NS)	27.4	(EW)	10905.6	397.3	336.8	264.6	19.9	27.4	7.9
15	NIGH140410271040	43.3	3.97	4	172.9	(NS)	5.1	(NS)	885.9	172.9	119.8	55.0	5.1	4.9	1.9
16	NIGH150410271040	32.7	3.73	4	214.5	(NS)	4.1	(NS)	875.2	214.5	89.1	47.4	4.1	3.9	2.8
17	NIGH180410271040	25.6	3.51	4	60.4	(EW)	3.4	(EW)	203.9	33.4	60.4	12.5	2.1	3.4	1.1
18	NIGH190410271040	18.6	3.24	3	65.6	(NS)	2.7	(NS)	177.1	65.6	53.3	28.0	2.7	1.1	0.8
19	TCGH070410271040	34.5	3.78	4	141.8	(EW)	5.6	(EW)	792.2	100.5	141.8	74.9	3.1	5.6	1.1
20	TCGH110410271040	15.0	3.05	3	55.5	(EW)	1.9	(EW)	104.9	38.4	55.5	17.9	1.2	1.9	0.5

Table 3.2.10 Nigata Earthquake after shock 5 2004_10_27_10.40_M=6.0_K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA NS	PGA EW	PGA UD	PGV NS	PGV EW	PGV UD
1	FKS0250410271040	11.2	2.80	3	56.5	(NS)	0.9	(NS)	51.5	56.5	45.2	22.8	0.9	0.8	0.6
2	FKS0260410271040	26.1	3.53	4	73.3	(EW)	2.6	(NS)	193.6	73.1	73.3	42.9	2.6	2.0	1.0
3	FKS0270410271040	8.1	2.52	3	50.9	(NS)	0.9	(EW)	45.1	50.9	44.0	21.0	0.7	0.9	0.5
4	FKS0280410271040	84.9	4.56	5-	191.5	(EW)	14.9	(EW)	2859.6	103.8	191.5	68.9	8.0	14.9	3.9
5	FKS0290410271040	56.3	4.20	4	261.1	(NS)	5.1	(NS)	1338.9	261.1	134.3	60.3	5.1	2.4	1.4
6	FKS0300410271040	16.4	3.13	3	57.2	(NS)	1.5	(EW)	88.2	57.2	56.7	25.7	1.5	1.5	0.8
7	GNM0020410271040	37.0	3.84	4	160.2	(EW)	3.1	(EW)	497.2	134.9	160.2	51.0	2.4	3.1	0.9
8	GNM0030410271040	40.7	3.92	4	100.5	(NS)	4.9	(NS)	491.4	100.5	87.4	39.2	4.9	3.8	1.5
9	GNM0070410271040	35.9	3.81	4	71.9	(NS)	4.1	(EW)	297.1	71.9	62.4	29.3	3.1	4.1	1.0
10	GNM0130410271040	26.1	3.53	4	64.1	(NS)	3.1	(EW)	201.4	64.1	49.3	19.3	2.8	3.1	0.8
11	GNM0140410271040	9.4	2.64	3	47.9	(EW)	1.4	(EW)	65.2	39.3	47.9	18.8	0.9	1.4	0.6
12	NIG0040410271040	46.4	4.03	4	88.7	(NS)	3.8	(NS)	336.9	88.7	46.4	25.1	3.8	2.1	0.9
13	NIG0120410271040	40.3	3.91	4	151.2	(NS)	4.5	(NS)	679.7	151.2	60.0	20.2	4.5	3.3	1.0
14	NIG0130410271040	36.6	3.83	4	62.0	(EW)	5.6	(EW)	347.4	48.9	62.0	24.6	4.3	5.6	1.5
15	NIG0140410271040	54.8	4.18	4	65.0	(NS)	6.6	(NS)	426.2	65.0	63.5	39.4	6.6	5.8	1.3
16	NIG0150410271040	13.1	2.93	3	59.1	(NS)	1.3	(EW)	79.7	59.1	44.5	20.4	1.2	1.3	1.0
17	NIG0160410271040	43.0	3.97	4	96.0	(EW)	4.1	(EW)	389.3	69.7	96.0	21.7	4.0	4.1	1.1
18	NIG0170410271040	175.8	5.19	5+	359.2	(EW)	19.9	(NS)	7147.3	228.4	359.2	114.4	19.9	19.7	4.9
19	NIG0180410271040	37.0	3.84	4	80.7	(NS)	5.2	(EW)	419.0	80.7	50.9	26.5	4.8	5.2	2.5
20	NIG0190410271040	239.9	5.46	5+	495.8	(EW)	44.2	(EW)	21891.5	178.3	495.8	111.1	10.5	44.2	4.5
21	NIG0200410271040	269.1	5.56	6-	530.2	(UD)	37.8	(NS)	20057.4	523.3	387.4	530.2	37.8	18.9	7.4
22	NIG0210410271040	69.9	4.39	4	226.9	(EW)	10.8	(EW)	2448.1	136.3	226.9	52.3	5.7	10.8	2.5
23	NIG0220410271040	53.3	4.15	4	130.3	(NS)	9.1	(NS)	1183.7	130.3	69.3	42.6	9.1	3.7	1.6
24	NIG0240410271040	67.4	4.36	4	153.8	(EW)	6.9	(EW)	1058.0	150.9	153.8	28.4	5.1	6.9	1.3
25	SIT0040410271040	16.3	3.13	3	92.5	(EW)	1.7	(EW)	158.6	73.3	92.5	11.4	1.6	1.7	0.3
26	TCG0040410271040	15.7	3.09	3	45.5	(EW)	1.9	(EW)	84.8	45.0	45.5	14.8	1.2	1.9	0.8
27	TCG0100410271040	15.2	3.06	3	44.7	(EW)	1.7	(EW)	76.4	41.1	44.7	22.6	1.4	1.7	0.5
28	TCG0140410271040	18.7	3.24	3	44.0	(EW)	1.6	(EW)	71.0	43.9	44.0	8.6	1.4	1.6	0.3

3.3 Miyagi earthquake records

Table3.3.1 Miyagi earthquake 2003_05_26_18.24_M=7.0_Kiknet

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	AKTH170305261824	84.4	4.55	5-	157.8	(NS)	17.9	(EW)	2819.8	157.8	150.3	110.0	11.6	17.9	6.3
2	AKTH190305261824	90.5	4.61	5-	111.4	(EW)	14.1	(EW)	1575.0	93.2	111.4	36.5	9.1	14.1	4.9
3	FKSH120305261824	95.6	4.66	5-	206.8	(EW)	9.4	(EW)	1938.6	136.3	206.8	49.8	5.2	9.4	1.6
4	FKSH200305261824	86.3	4.57	5-	117.9	(NS)	9.5	(NS)	1117.1	117.9	111.2	49.8	9.5	8.7	2.7
5	IWTH010305261824	193.1	5.27	5+	386.9	(EW)	18.0	(EW)	6971.7	243.8	386.9	77.7	14.3	18.0	5.6
6	IWTH020305261824	278.2	5.59	6-	795.6	(NS)	19.4	(NS)	15446.1	795.6	674.4	499.6	19.4	18.4	10.3
7	IWTH040305261824	392.1	5.89	6-	1280.0	(UD)	31.9	(EW)	40888.3	729.6	723.1	1280.0	31.3	31.9	17.8
8	IWTH050305261824	188.4	5.25	5+	570.6	(NS)	15.9	(EW)	9063.0	570.6	501.7	398.5	13.5	15.9	7.1
9	IWTH120305261824	113.1	4.81	5-	254.2	(NS)	13.7	(NS)	3479.9	254.2	199.3	81.8	13.7	8.7	3.0
10	IWTH140305261824	104.6	4.74	5-	458.5	(NS)	10.8	(NS)	4945.3	458.5	296.1	333.2	10.8	7.6	5.1
11	IWTH150305261824	180.8	5.21	5+	328.2	(NS)	26.0	(NS)	8543.7	328.2	268.8	131.9	26.0	18.6	8.8
12	IWTH180305261824	141.0	5.00	5-	462.1	(NS)	15.6	(EW)	7191.0	462.1	434.8	409.1	10.9	15.6	6.4
13	IWTH190305261824	146.4	5.03	5+	373.1	(EW)	13.2	(NS)	4937.8	353.6	373.1	171.7	13.2	12.4	4.9
14	IWTH200305261824	234.8	5.44	5+	317.5	(EW)	37.7	(EW)	11965.6	291.5	317.5	145.4	27.0	37.7	9.3
15	IWTH210305261824	229.1	5.42	5+	711.1	(UD)	20.4	(NS)	14523.6	550.2	586.5	711.1	20.4	19.9	12.3
16	IWTH220305261824	111.0	4.79	5-	261.4	(EW)	8.9	(EW)	2322.7	246.8	261.4	213.7	8.3	8.9	6.6
17	IWTH230305261824	139.3	4.99	5-	529.4	(EW)	15.7	(EW)	8292.9	420.0	529.4	359.6	12.3	15.7	4.6
18	IWTH240305261824	132.6	4.95	5-	268.9	(EW)	27.4	(EW)	7377.3	226.4	268.9	134.9	13.8	27.4	9.9
19	IWTH250305261824	115.2	4.82	5-	316.6	(NS)	11.7	(EW)	3712.5	316.6	287.3	204.3	9.7	11.7	6.9
20	IWTH260305261824	188.7	5.25	5+	521.2	(EW)	26.5	(EW)	13807.0	483.8	521.2	511.3	15.1	26.5	8.5
21	IWTH270305261824	233.5	5.44	5+	888.0	(NS)	17.7	(NS)	15726.5	888.0	555.9	636.4	17.7	12.3	9.9
22	MYGH010305261824	109.5	4.78	5-	196.9	(NS)	13.1	(NS)	2577.8	196.9	180.1	66.1	13.1	12.4	2.9
23	MYGH030305261824	143.0	5.01	5+	809.3	(NS)	15.3	(EW)	12345.0	809.3	650.4	459.8	11.8	15.3	5.3
24	MYGH040305261824	207.5	5.33	5+	664.8	(NS)	16.2	(EW)	10750.0	664.8	502.6	376.2	15.1	16.2	5.8
25	MYGH050305261824	251.8	5.50	6-	615.1	(NS)	30.3	(EW)	18659.6	615.1	579.0	185.2	21.1	30.3	6.8
26	MYGH070305261824	148.7	5.04	5+	305.7	(EW)	18.2	(EW)	5567.5	239.5	305.7	197.8	14.9	18.2	7.3
27	MYGH100305261824	91.8	4.63	5-	223.4	(EW)	8.0	(NS)	1786.8	221.2	223.4	91.3	8.0	8.0	2.8
28	MYGH110305261824	105.6	4.75	5-	435.4	(EW)	11.1	(EW)	4816.6	359.1	435.4	277.8	10.2	11.1	5.6
29	MYGH120305261824	98.4	4.69	5-	391.3	(EW)	11.5	(EW)	4489.9	346.5	391.3	367.3	10.8	11.5	4.6

Table3.3.2 Miyagi earthquake 2003_05_26_18.24_M=7.0_K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	AKT0160305261824	98.82	4.69	5-	121	(EW)	22.3	(EW)	2698.7	111.9	121.2	34.4	13.9	22.3	3.8
2	IWT0060305261824	224	5.4	5+	340	(EW)	21.6	(EW)	7353.8	326.1	340.2	194.8	20.7	21.6	6.8
3	IWT0070305261824	240.3	5.46	5+	1039	(EW)	23	(EW)	23930.4	593.8	1038.6	592.4	16.2	23.0	7.0
4	IWT0110305261824	172.2	5.17	5+	360	(EW)	31.1	(EW)	11204.6	207.7	360.3	183.7	19.7	31.1	10.4
5	IWT0120305261824	233.9	5.44	5+	504	(NS)	29.2	(NS)	14711.3	503.9	431.6	157.4	29.2	16.6	7.0
6	IWT0130305261824	179.1	5.21	5+	402	(EW)	18.4	(NS)	7407.6	391.2	402.2	266.3	18.4	13.6	5.5
7	IWT0140305261824	148.3	5.04	5+	259	(NS)	20.4	(NS)	5303.8	259.4	196.5	129.9	20.4	14.4	7.9
8	IWT0210305261824	160.4	5.11	5+	446	(NS)	19.1	(NS)	8516.0	446.3	279.4	128.7	19.1	11.8	10.1
9	MYG0010305261824	200.3	5.3	5+	391	(NS)	16.8	(NS)	6579.8	390.8	358.5	344.3	16.8	16.0	9.3
10	MYG0020305261824	231.2	5.43	5+	858	(EW)	21.9	(NS)	18755.5	591.5	858.1	339.4	21.9	17.2	5.8
11	MYG0030305261824	125.7	4.9	5-	549	(EW)	11.3	(NS)	6190.3	540.0	549.4	294.4	11.3	8.8	4.4
12	MYG0050305261824	109.5	4.78	5-	180	(NS)	20.1	(NS)	3609.4	180.0	176.4	112.0	20.1	17.6	9.7
13	MYG0060305261824	168.9	5.16	5+	253	(EW)	21	(EW)	5298.4	195.3	252.7	134.7	12.9	21.0	6.6
14	MYG0100305261824	205.8	5.33	5+	276	(NS)	23.4	(NS)	6464.7	276.0	236.8	116.2	23.4	15.6	4.7
15	MYG0110305261824	555.1	6.19	6+	1112	(EW)	50.2	(NS)	55824.1	1102.7	1112.5	825.4	50.2	37.7	20.2

3.4 Tokachi earthquake records

Table 3.4.1 Tokachi earthquake 2003_09_26_04.50_M=8.0_Kiknet&K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	HDKH040309260450	217.4	5.37	5+	215.7	(EW)	58.2	(EW)	12557.4	140.9	215.7	52.7	29.9	58.2	19.0
2	HDKH060309260450	236.6	5.45	5+	210	(EW)	47.9	(EW)	10052.6	189.7	210.0	119.4	36.3	47.9	25.0
3	HDKH070309260450	191.9	5.27	5+	199.2	(EW)	46	(EW)	9153.4	168.6	199.2	112.6	29.4	46.0	23.8
4	IBUH030309260450	405.5	5.92	6-	375.9	(EW)	89.6	(EW)	33662.0	256.6	375.9	93.7	78.2	89.6	19.8
5	KSRH020309260450	347.7	5.78	6-	405	(EW)	50.5	(EW)	20441.4	373.4	405.0	119.1	42.1	50.5	17.1
6	KSRH030309260450	319.7	5.71	6-	806	(NS)	31.3	(NS)	25267.7	806.0	299.7	588.2	31.3	27.9	11.3
7	KSRH070309260450	232.5	5.43	5+	500.1	(EW)	38.3	(NS)	19153.0	339.9	500.1	442.2	38.3	35.8	12.3
8	KSRH090309260450	373.9	5.85	6-	391.1	(EW)	85.5	(EW)	33436.7	368.9	391.1	242.4	44.3	85.5	17.4
9	KSRH100309260450	377.6	5.85	6-	580.6	(EW)	39.1	(EW)	22707.9	534.7	580.6	216.0	34.5	39.1	6.2
10	NMRH020309260450	238.5	5.45	5+	514	(NS)	26.7	(EW)	13747.1	514.0	455.1	392.1	20.2	26.7	9.7
11	NMRH040309260450	233.2	5.44	5+	437.9	(NS)	26.8	(NS)	11740.3	437.9	428.3	184.5	26.8	24.0	11.5
12	NMRH050309260450	233.5	5.44	5+	391.3	(NS)	38.6	(NS)	15093.6	391.3	342.6	226.3	38.6	34.8	10.5
13	TKCH050309260450	249.9	5.5	5+	406.2	(EW)	27.9	(EW)	11352.0	357.3	406.2	200.0	25.3	27.9	12.0
14	TKCH070309260450	439.3	5.99	6-	404.2	(EW)	93.9	(NS)	37972.0	366.3	404.2	148.3	93.9	77.6	16.2
15	TKCH080309260450	287.6	5.62	6-	500.7	(EW)	38.4	(EW)	19215.8	416.2	500.7	395.4	23.0	38.4	20.0
1	HKD0660309260450	404.0	5.91	6-	491.2	(EW)	51.9	(EW)	25476.2	430.1	491.2	157.4	43.3	51.9	9.9
2	HKD0670309260450	220.9	5.39	5+	334.0	(EW)	42.9	(EW)	14333.0	307.2	334.0	119.8	32.8	42.9	8.0
3	HKD0680309260450	218.3	5.38	5+	302.7	(NS)	36.7	(NS)	11102.6	302.7	298.7	166.0	36.7	27.0	10.1
4	HKD0700309260450	308.4	5.68	6-	475.3	(NS)	36.8	(NS)	17485.4	475.3	349.6	113.2	36.8	32.6	7.5
5	HKD0750309260450	242.5	5.47	5+	507.2	(EW)	28.4	(NS)	14421.9	376.0	507.2	264.1	28.4	20.1	10.5
6	HKD0760309260450	218.9	5.38	5+	216.4	(NS)	38.7	(NS)	8378.4	216.4	190.5	162.7	38.7	27.1	9.7
7	HKD0770309260450	283.9	5.61	6-	406.9	(EW)	42.6	(EW)	17340.4	311.3	406.9	163.4	37.8	42.6	10.1
8	HKD0780309260450	207.5	5.33	5+	401.5	(EW)	36.3	(NS)	14589.6	285.3	401.5	249.9	36.3	35.6	13.5
9	HKD0840309260450	318.9	5.71	6-	353.8	(EW)	49.3	(EW)	17425.9	350.9	353.8	115.6	42.0	49.3	16.7
10	HKD0850309260450	249.6	5.49	5+	277.3	(EW)	55.5	(EW)	15399.5	258.8	277.3	151.2	37.7	55.5	14.5
11	HKD0860309260450	668.7	6.35	6+	796.8	(EW)	120	(EW)	95450.3	720.0	796.8	272.5	79.6	119.8	35.7
12	HKD0900309260450	222.3	5.39	5+	468.9	(EW)	35.2	(EW)	16522.7	300.3	468.9	256.7	19.0	35.2	11.5
13	HKD0910309260450	382.1	5.86	6-	391.0	(NS)	68	(EW)	26578.0	391.0	374.7	325.5	57.6	68.0	22.8
14	HKD0920309260450	422.5	5.95	6-	609.0	(EW)	57	(NS)	34741.7	433.8	609.0	215.1	57.0	55.1	21.3
15	HKD0980309260450	422.3	5.95	6-	366.4	(NS)	74.6	(EW)	27337.4	366.4	346.7	202.0	71.6	74.6	36.1
16	HKD1000309260450	480.0	6.06	6+	970.2	(EW)	44.7	(EW)	43406.6	810.5	970.2	461.5	42.6	44.7	22.5
17	HKD1060309260450	201.8	5.31	5+	186.0	(EW)	34.6	(EW)	6426.1	140.9	186.0	66.5	28.0	34.6	23.2
18	HKD1100309260450	216.0	5.37	5+	216.0	(NS)	57.2	(NS)	12362.8	216.0	175.8	68.1	57.2	33.7	18.6
19	HKD1260309260450	245.4	5.48	5+	189.4	(NS)	46.1	(NS)	8738.7	189.4	189.0	54.7	46.1	35.0	17.1

3.5 PGA>300gal Earthquake records:

Table 3.5.1 PGA>300gal_Kiknet

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	EHMH020103241528	142.1	5.01	5+	499.2	(UD)	10.9	(EW)	5422.1	283.2	396.5	499.2	9.8	10.9	10.6
2	EHMH040103241528	190.1	5.26	5+	328.6	(EW)	21.6	(NS)	7096.0	314.0	328.6	168.5	21.6	19.8	3.4
3	EHMH050103241528	179.7	5.21	5+	506.3	(NS)	15	(NS)	7608.9	506.3	504.7	370.8	15.0	14.8	9.0
4	EHMH080103241528	226.1	5.41	5+	287.2	(EW)	21.5	(EW)	6182.6	241.2	287.2	75.3	20.2	21.5	4.6
5	HRSH010103241528	209.1	5.34	5+	615.2	(UD)	17.2	(EW)	10577.7	461.3	493.0	615.2	13.9	17.2	12.2
6	HRSH030103241528	243.8	5.47	5+	553.2	(EW)	20.9	(EW)	11563.1	375.3	553.2	488.0	11.5	20.9	12.2
7	HRSH060103241528	154.5	5.08	5+	291	(EW)	14.6	(EW)	4259.1	215.9	291.0	63.4	11.6	14.6	2.4
8	HRSH070103241528	185.5	5.24	5+	336.1	(EW)	18.2	(EW)	6108.7	284.7	336.1	265.5	15.3	18.2	8.9
9	KOCH050103241528	163.8	5.13	5+	397.2	(UD)	13.8	(NS)	5479.3	328.2	296.9	397.2	13.8	11.9	9.9
10	MIEH050010310143	134.6	4.96	5-	542.6	(NS)	15.3	(NS)	8310.7	542.6	224.2	173.7	15.3	4.8	3.2
11	SMNH010010061330	338	5.76	6-	719.6	(NS)	35.9	(NS)	25799.2	719.6	607.1	631.0	35.9	35.7	24.7
12	SMNH020010061330	155.9	5.09	5+	564.1	(NS)	21.2	(NS)	11951.7	564.1	314.7	367.2	21.2	10.4	8.1
13	TTRH020010061330	911.5	6.62	7	922.5	(NS)	128	(NS)	118191.2	922.5	756.8	776.9	128.1	85.0	56.8

Table 3.5.2 PGA>300gal_K-net

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled Seis. Int	PGA		PGV		PGA* PGV	PGA			PGV		
										NS	EW	UD	NS	EW	UD
1	AIC0109703161451	155.7	5.08	5+	524.9	(NS)	14.2	(EW)	7462.1	524.9	383.2	159.2	12.9	14.2	3.3
2	EHM0030103241528	275.5	5.58	6-	458.8	(EW)	30.4	(EW)	13961.5	325.5	458.8	117.5	21.3	30.4	4.3
3	EHM0070103241528	226.1	5.41	5+	400	(NS)	23.8	(EW)	9526.0	400.0	394.4	255.3	17.2	23.8	6.8
4	EHM0080103241528	206.3	5.33	5+	310.4	(EW)	26.6	(EW)	8250.6	211.8	310.4	113.4	15.2	26.6	2.9
5	EHM0150103241528	240.6	5.46	5+	312.5	(EW)	31.1	(EW)	9729.0	260.4	312.5	166.4	28.3	31.1	6.1
6	EHM0160103241528	195.4	5.28	5+	248.5	(NS)	21.7	(NS)	5394.0	248.5	246.6	120.1	21.7	18.0	7.3
7	HKD0670001282321	169.2	5.16	5+	354.6	(NS)	16	(NS)	5678.9	354.6	239.3	90.6	16.0	14.9	2.8
8	HKD0869905130259	234.9	5.44	5+	426.5	(EW)	32	(NS)	13634.3	397.3	426.5	121.3	32.0	22.4	4.2
9	HKD0919905130259	170.2	5.16	5+	240.8	(EW)	19.7	(NS)	4749.6	192.0	240.8	85.7	19.7	14.8	5.0
10	HRS0010010061330	154.5	5.08	5+	412	(NS)	15.8	(NS)	6525.9	412.0	402.2	247.2	15.8	8.9	4.5
11	HRS0050010061330	149.4	5.05	5+	524.1	(EW)	13.6	(EW)	7150.3	309.7	524.1	216.2	8.8	13.6	4.6
12	HRS0090103241528	315.4	5.7	6-	829.5	(EW)	29	(EW)	24080.8	414.7	829.5	217.6	19.3	29.0	8.0
13	HRS0130103241528	164.2	5.13	5+	258.5	(EW)	17.7	(EW)	4562.4	253.8	258.5	233.5	16.9	17.7	5.5
14	HRS0140103241528	294.1	5.64	6-	441.3	(EW)	36.8	(NS)	16251.4	359.3	441.3	231.9	36.8	31.8	8.0
15	HRS0170103241528	144.8	5.02	5+	651.6	(NS)	11.3	(NS)	7347.6	651.6	396.6	177.0	11.3	10.3	3.7
16	HRS0190103241528	222.2	5.39	5+	425.1	(EW)	23.2	(EW)	9881.2	311.9	425.1	203.1	19.0	23.2	4.8
17	HRS0200103241528	197	5.29	5+	390.6	(NS)	18.1	(NS)	7069.9	390.6	304.7	228.0	18.1	12.8	3.9
18	IBR0130206141142	145.8	5.03	5+	558.6	(NS)	15	(NS)	8402.8	558.6	293.4	325.0	15.0	7.7	6.2
19	KGS0029703261731	181.8	5.22	5+	727.2	(NS)	15.9	(EW)	11591.2	727.2	541.8	246.1	14.9	15.9	4.7
20	KGS0029705131438	210.2	5.35	5+	728.2	(NS)	21.2	(NS)	15464.3	728.2	443.0	189.0	21.2	17.6	4.8
21	KGS0049703261731	308	5.68	6-	292.8	(NS)	44	(NS)	12891.6	292.8	131.5	96.4	44.0	17.7	8.6
22	KGS0059703261731	259.1	5.53	6-	493.3	(EW)	36.2	(EW)	17868.6	433.7	493.3	145.8	28.8	36.2	8.1
23	KGS0059705131438	410.8	5.93	6-	902.1	(NS)	46.8	(EW)	42231.1	902.1	901.1	287.5	35.2	46.8	9.2
24	KGS0079703261731	174	5.18	5+	224.4	(EW)	28.8	(EW)	6470.2	211.1	224.4	111.0	18.1	28.8	4.1
25	KGS0079705131438	232.7	5.43	5+	317.5	(EW)	27.5	(EW)	8726.1	300.5	317.5	149.4	26.7	27.5	6.8
26	KGS0109705131438	158.5	5.1	5+	205.6	(NS)	23.2	(NS)	4773.2	205.6	190.5	114.0	23.2	21.0	5.1
27	KGS0269609091334	152.6	5.07	5+	391	(NS)	15.6	(NS)	6107.8	391.0	280.7	384.3	15.6	12.4	6.8
28	KMM0070101101909	150.4	5.05	5+	387.9	(EW)	11.9	(NS)	4626.5	254.7	387.9	182.3	11.9	11.4	4.1
29	KNG2010102251405	251.6	5.5	6-	907	(NS)	88.1	(NS)	79935.4	907.0	306.4	49.5	88.1	16.4	1.3
30	KNG2030201181646	268.7	5.56	6-	1124	(NS)	40.5	(EW)	45524.8	1124.3	835.6	241.4	21.1	40.5	5.3
31	MYG0059608110312	165.9	5.14	5+	464.1	(NS)	27	(NS)	12514.7	464.1	388.1	337.0	27.0	20.9	11.8
32	MYG0059608131113	116.1	4.83	5-	708.1	(EW)	10.3	(EW)	7292.3	324.3	708.1	292.4	8.1	10.3	5.2
33	MYG0119605231836	190.9	5.26	5+	568	(NS)	15.7	(NS)	8926.0	568.0	557.9	128.0	15.7	12.3	2.8
34	MYZ0139610192344	165.9	5.14	5+	229.6	(EW)	23.1	(NS)	5296.1	179.8	229.6	84.7	23.1	10.0	5.1
35	MYZ0179610192344	150.2	5.05	5+	216.5	(NS)	17.4	(NS)	3758.7	216.5	146.0	40.2	17.4	11.8	3.7
36	NIG0220101041318	150.1	5.05	5+	296.4	(EW)	24.4	(EW)	7225.9	270.6	296.4	163.1	13.8	24.4	4.3
37	OKY0040010061330	303.8	5.67	6-	816.1	(EW)	27.2	(EW)	22176.2	527.2	816.1	170.8	14.5	27.2	6.1
38	SMN0030010061330	110.7	4.79	5-	501.5	(NS)	19.5	(NS)	9776.5	501.5	317.2	152.4	19.5	8.4	2.9

39	SZO0029703032309	299.8	5.65	6-	587.2	(EW)	31.6	(EW)	18529.0	306.4	587.2	230.9	13.7	31.6	6.2
40	SZO0029703040030	149.4	5.05	5+	345.4	(EW)	20.6	(EW)	7104.1	166.8	345.4	128.6	9.0	20.6	3.4
41	TCG0090010181258	147.3	5.04	5+	392.3	(EW)	16	(EW)	6279.6	220.7	392.3	49.7	8.5	16.0	1.2
42	TCG0099612211029	268	5.56	6-	524.4	(NS)	21	(NS)	10994.0	524.4	422.3	183.4	21.0	17.6	5.0
43	TKY0100007150518	89.18	4.6	5-	546.3	(EW)	12.2	(EW)	6637.6	237.5	546.3	186.4	6.1	12.1	3.8
44	TTR0070010061330	358	5.81	6-	725.6	(NS)	43.1	(NS)	31301.2	725.6	573.1	404.0	43.1	26.6	11.0
45	TTR0080010061330	359.3	5.81	6-	383.5	(EW)	54.2	(EW)	20779.8	314.5	383.5	307.8	36.3	54.2	9.9
46	TTR0090010061330	249.4	5.49	5+	628.4	(NS)	39.1	(NS)	24581.4	628.4	595.3	289.3	39.1	25.7	13.2
47	WKY0059908210533	90.73	4.62	5-	580.9	(EW)	10.9	(EW)	6322.6	274.7	580.9	75.8	5.5	10.9	0.9
48	YMG0160103241528	194.6	5.28	5+	286	(EW)	22.4	(EW)	6394.2	226.8	286.0	116.4	12.4	22.4	4.1
49	YMG0170103241528	181.3	5.22	5+	236.7	(EW)	25.3	(EW)	5997.3	193.7	236.7	104.3	19.9	25.3	3.9
50	YMG0180103241528	185	5.23	5+	219.8	(EW)	24	(EW)	5265.6	157.5	219.8	110.5	18.2	24.0	5.9

Table 3.5.3 Strong motion data used for damage function by KAWASE LAB. (Hyogo ken nanbu, Northridge)

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	10AMAGASAKIBR___	314.2	5.69	6-	324	(UD)	54.1	(NS)	17513.8	265.5	293.6	324.0	54.1	46.2	24.5
2	13HIGASHIKOBE___	408.1	5.92	6-	394.9	(UD)	91.3	(EW)	36069.0	280.9	327.5	394.9	85.5	91.3	34.6
3	17PORT__________	417.9	5.94	6-	555.6	(UD)	90.2	(NS)	50113.2	340.8	284.2	555.6	90.2	51.3	62.2
4	20TAKARAZUKA____	530.5	6.15	6+	683.7	(NS)	89.1	(EW)	60934.9	683.7	601.0	418.3	66.1	89.1	35.0
5	21TAKATORI______	780.1	6.48	6+	656.2	(EW)	127	(EW)	83173.4	605.6	656.2	279.7	123.4	126.7	18.6
6	23JUTO(TKMF)____	247	5.49	5+	266.3	(EW)	34.7	(EW)	9241.5	221.7	266.3	254.9	32.6	34.7	10.9
7	24AMAGASAKI-G___	329.8	5.74	6-	473	(EW)	60.3	(EW)	28513.8	323.1	473.0	310.8	55.9	60.3	29.4
8	25KOBE__________	380.4	5.86	6-	502.8	(NS)	97.5	(NS)	49012.3	502.8	205.3	284.3	97.5	43.3	33.0
9	30OSKGAS(FUKIAI)	786.7	6.49	6+	802.8	(EW)	119	(EW)	95210.7	688.1	802.8	0.0	60.3	118.6	0.0
10	ama_____________	319.3	5.71	6-	328.8	(UD)	45.9	(EW)	15078.4	274.7	318.9	328.8	33.7	45.9	28.0
11	HRS0190103241528	222.1	5.39	5+	425.1	(EW)	23.3	(EW)	9895.4	311.8	425.1	203.1	19.0	23.3	4.8
12	KGS0059705131438	410.8	5.93	6-	902.1	(NS)	46.8	(EW)	42260.8	902.1	901.1	287.5	35.2	46.8	9.2
13	kob_____________	484.1	6.07	6+	776.3	(EW)	51.6	(EW)	40026.5	421.6	776.3	381.8	41.1	51.6	34.4
14	TTR0070010061330	357.9	5.81	6-	725.6	(NS)	43	(NS)	31216.7	725.6	573.1	404.0	43.0	26.6	11.0
15	TTR0080010061330	359.3	5.81	6-	383.6	(EW)	54.2	(EW)	20780.4	314.5	383.6	307.8	36.3	54.2	9.9
16	TTRH020010061330	911.5	6.62	7	922.5	(NS)	128	(NS)	118167.5	922.5	756.8	776.9	128.1	85.3	56.9
17	CNP____	307.1	5.67	6-	479.1	(UD)	63.2	(EW)	30253.4	348.5	412.4	479.1	33.7	63.2	14.9
18	KAT____	424.9	5.96	6-	859.8	(NS)	41.6	(NS)	35775.7	859.8	627.6	393.8	41.6	38.0	13.3
19	MUL____	465.8	6.04	6+	506.1	(EW)	65.2	(EW)	33000.8	407.3	506.1	320.0	58.1	65.2	17.0
20	RRS____	719.4	6.41	6+	835	(UD)	169	(NS)	140722.7	820.7	463.3	835.0	168.5	74.4	51.7
21	SCE____	514.4	6.12	6+	811.7	(NS)	117	(NS)	95276.5	811.7	483.4	368.9	117.4	73.7	23.6
22	SCS____	690.6	6.38	6+	879.5	(EW)	112	(NS)	98577.2	601.0	879.5	574.7	112.1	104.8	35.8
23	STC____	382.2	5.86	6-	467.1	(EW)	64.1	(EW)	29939.8	361.0	467.1	0.0	30.0	64.1	0.0
24	WPI____	457.8	6.02	6+	446.1	(NS)	91.7	(NS)	40915.2	446.1	319.0	284.5	91.7	65.9	37.6
25	169501170546KOBE	742.8	6.44	6+	820.6	(NS)	91.7	(NS)	75260.4	820.6	619.2	333.4	91.7	76.2	40.7
26	28KANDEN(SHIN-KO	548.9	6.18	6+	582.3	(EW)	79	(NS)	46000.3	506.0	582.3	495.8	79.0	77.3	27.3
27	JEN____	632.3	6.3	6+	580.6	(EW)	108	(NS)	62443.6	415.9	580.6	391.9	107.6	98.0	32.3
28	NWH____	661.6	6.34	6+	578.1	(EW)	95.9	(EW)	55415.9	571.3	578.1	537.1	74.3	95.9	31.7
29	ORR2___	390.7	5.88	6-	557	(NS)	52.8	(EW)	29415.1	557.0	504.0	212.9	52.4	52.8	11.7
30	PKC____	292.4	5.63	6-	423.9	(EW)	52.4	(EW)	22209.2	294.8	423.9	165.8	33.4	52.4	15.2
31	PUL____	756.3	6.46	6+	1553	(NS)	106	(EW)	164128.2	1553.3	1259.1	1204.2	55.8	105.7	49.0
32	SPV____	563.8	6.2	6+	920	(EW)	86.8	(NS)	79864.8	737.7	920.0	458.6	86.8	74.6	31.4
33	SYL____	569.8	6.21	6+	826.5	(EW)	129	(EW)	106669.2	592.4	826.5	524.6	77.9	129.1	20.1

Table 3.5.4 Strong motion data used for damage function by KAWASE LAB. (Enlarged Hyogo ken nanbu and Northridge)

No	STRONG MOTION MOTION NAME	A_0	Seis. Int.	Scaled	PGA		PGV		PGA* PGV	PGA			PGV		
				Seis. Int						NS	EW	UD	NS	EW	UD
1	bo10AMAGASAKIBR___	574.3	6.22	6+	573.6	(UD)	98	(NS)	56238.9	475.9	531.0	573.6	98.0	82.3	65.3
2	bo13HIGASHIKOBE___	762.1	6.46	6+	707.7	(UD)	176	(EW)	124417.0	533.2	613.6	707.7	168.5	175.8	68.5
3	bo17PORT__________	757.5	6.46	6+	990.7	(UD)	176	(NS)	174152.6	631.1	511.2	990.7	175.8	99.7	116.7
4	bo20TAKARAZUKA____	961.4	6.67	7	1232	(NS)	169	(EW)	208577.6	1232.4	1065.9	740.2	123.5	169.2	64.2
5	bo21TAKATORI______	1422	7.01	7	1178	(EW)	233	(EW)	274458.8	1104.1	1178.0	499.0	230.3	233.0	35.7
6	bo23JUTO(TKMF)____	443.3	5.99	6-	479.5	(EW)	66.5	(EW)	31861.5	401.2	479.5	454.8	60.5	66.5	20.6
7	bo24AMAGASAKI-G___	609.1	6.27	6+	855.5	(EW)	124	(EW)	106070.1	594.1	855.5	553.2	111.2	124.0	56.3
8	bo25KOBE__________	699.7	6.39	6+	915.9	(NS)	175	(NS)	159948.5	915.9	373.1	499.9	174.6	100.4	60.6
9	bo30OSKGAS(FUKIAI)	1446	7.02	7	1448	(EW)	215	(EW)	310810.5	1221.8	1448.4	0.0	117.5	214.6	0.0
10	boama_____________	590	6.24	6+	588.8	(UD)	94	(EW)	55318.2	507.6	571.7	588.8	70.4	94.0	53.4
11	boHRS0190103241528	399	5.9	6-	759.1	(EW)	41.9	(EW)	31773.3	557.7	759.1	362.6	35.1	41.9	8.5
12	boKGS0059705131438	730.7	6.43	6+	1609	(NS)	88.3	(EW)	142067.4	1609.1	1608.7	513.4	64.0	88.3	17.4
13	bokob_____________	880.1	6.59	7	1392	(EW)	95.6	(EW)	133044.5	759.8	1391.7	679.6	79.0	95.6	70.8
14	boTTR0070010061330	638.2	6.31	6+	1294	(NS)	80.6	(NS)	104320.9	1293.9	1020.2	718.2	80.6	49.3	20.2
15	boTTR0080010061330	646	6.32	6+	681.7	(EW)	98.6	(EW)	67240.1	558.4	681.7	547.4	67.5	98.6	18.4
16	boTTRH020010061330	1621	7.12	7	1644	(NS)	237	(NS)	389490.4	1643.7	1347.1	1380.9	237.0	152.7	102.8
17	boCNP__	557.6	6.19	6+	853.1	(UD)	116	(EW)	99020.3	625.7	744.8	853.1	62.6	116.1	30.4
18	boKAT__	756.2	6.46	6+	1533	(NS)	74.2	(NS)	113706.5	1533.1	1120.3	700.5	74.2	68.1	23.6
19	boMUL__	852.3	6.56	7	905.8	(EW)	119	(EW)	107828.1	724.3	905.8	569.9	109.3	119.0	30.5
20	boRRS__	1315	6.94	7	1490	(UD)	302	(NS)	450270.3	1489.1	836.7	1490.1	302.2	152.3	108.6
21	boSCE__	940.4	6.65	7	1444	(NS)	234	(NS)	337279.2	1443.7	873.4	661.7	233.6	150.3	48.7
22	boSCS__	1253	6.9	7	1592	(EW)	222	(NS)	352832.7	1099.6	1591.5	1025.0	221.7	217.3	86.2
23	boSTC__	703.3	6.39	6+	841.5	(EW)	120	(EW)	101099.0	645.2	841.5	0.0	53.9	120.1	0.0
24	boWPI__	864.4	6.57	7	846.8	(NS)	189	(NS)	160035.5	846.8	581.8	504.8	189.0	123.0	78.0
25	bo169501170546KOBE	1327	6.95	7	1473	(NS)	166	(NS)	243860.2	1473.1	1113.7	595.2	165.5	139.3	75.2
26	bo28KANDEN(SHIN-KO	990.5	6.69	7	1038	(EW)	169	(NS)	175186.8	892.5	1037.6	881.2	168.8	140.2	51.8
27	boJEN__	1165	6.83	7	1057	(EW)	207	(NS)	219189.1	754.1	1057.3	700.7	207.3	182.3	60.3
28	boNWH__	1183	6.85	7	1038	(EW)	185	(EW)	192599.9	1011.8	1038.4	945.2	135.6	185.5	61.7
29	boORR2_	711.5	6.4	6+	994.5	(NS)	94.1	(EW)	93573.4	994.5	899.2	377.9	93.4	94.1	23.7
30	boPKC__	525.9	6.14	6+	759	(EW)	93.3	(EW)	70812.3	520.0	759.0	294.2	64.8	93.3	28.9
31	boPUL__	1343	6.96	7	2767	(NS)	185	(EW)	512547.0	2767.1	2239.7	2143.1	96.3	185.2	87.8
32	boSPV__	1032	6.73	7	1650	(EW)	157	(NS)	259740.4	1330.8	1649.6	817.8	157.5	137.7	58.2
33	boSYL__	1028	6.72	7	1503	(EW)	245	(EW)	368220.6	1066.0	1503.3	929.0	146.3	244.9	41.5

4. MODELING OF STRUCTURES

4.1 General

For the modeling of each structure, general properties and parameters of the structures used in Sap2000 analysis are directly taken from the design documents [1]. Those properties and parameters are introduced previously in chapter 2. In this chapter we will describe how the analysis models are constructed.

4.2 Modeling of Linear frame members,

The frame element of Sap2000 was chosen for modeling of frame members of the LSR structures. Since only moment of inertia, effective shear area and effective axial load areas are given, frame members were modeled using “general section” member section. Since we were not aware of the size of original members, frames are created as weightless and given mass values are introduced directly to the joints as “lumped masses”. In this study, frame members are named as “Bar”, (B1, B2…) and joints are named as “Lumped Mass Joint”, (M1, M2…).

4.3 Modeling of Dampers and Springs

Dampers and springs, which introduce soil structure interaction, are modeled using Nlink elements of Sap2000 code. Different kind of Nlink elements such as linear and nonlinear springs, dampers, hook and gap elements are available in sap2000 code, but for our analysis we implemented linear spring and nonlinear damper. Figure 4.2.1 shows the typical combination of Damper-Spring.

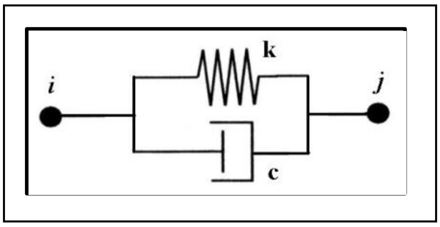


Figure 4.2.1 Typical combination of Damper-Spring.

For the spring element the stiffness values are used as it was given in design documents [1]. For the modeling of a damper element we have to introduce into the analysis model a damper element with a nonlinear characteristics, since we want to see pure damping effect of the damper. At this point it is important to understand that there are differences in damper element behavior for linear and nonlinear analysis.

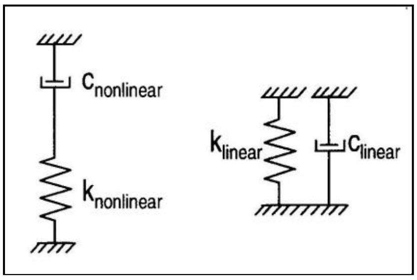


Figure 4.2.2 Behavior of damper element for nonlinear and linear analysis.

For nonlinear analysis the damper acts as a spring in series with a dashpot and uses the specified nonlinear spring stiffness and damping coefficient for the damper. In contrast, in linear analysis the damper element acts as a spring in parallel with a dashpot and uses the specified linear spring stiffness and damping coefficient for the damper. This is illustrated in *Figure 4.2.2* above. For modal analysis, which is one of linear analysis, the linear effective stiffness, k_{linear}, is set to zero, so that pure damping behavior is achieved. For nonlinear analysis the nonlinear stiffness, $k_{nonlinear}$, is set to an approximation of the stiffness of the damper.

Since we desire a pure damping behavior from the damper element for nonlinear analysis, the effect of the spring can be made negligible, by making its stiffness, $k_{nonlinear}$, sufficiently stiff. The spring stiffness should be large enough so that the characteristic time of the spring dashpot damper element, given by $\tau = c/\ k_{nonlinear}$, is approximately one to two orders of magnitude smaller than the size of the load step. It is suggested in the manual of Sap2000 that special care must be taken not to make $k_{nonlinear}$ excessively large because numerical sensitivity may result. For example, consider that we have 0.005-second time steps and damping value 3.851E+5 (ton sec/meter). Here the value of $k_{nonlinear}$, should be around (3.851E+5/(0.005/100))=7.702E+9. Using this formula we calculate nonlinear stiffness values, $k_{nonlinear}$, for all dampers.

5. DYNAMIC PROPERTIES

5.1 General

Modal analysis is used to determine the vibration modes of the structure. These modes are useful to understand the behavior of the structure. They can also be used as the basis for modal superposition in modal time-history analysis, which we need to run first to get spectral ratio-frequency graphs for Nonlinear Direct integration analysis, since only in the modal time-history analysis we can introduce constant damping ratio.

Eigenvector analysis and Ritz-vector analysis are available in the code. We use Ritz-vector because as it is stated in the manual of the code the “Ritz-vector can provide a better basis than do eigenvectors when used for time-history analyses that is based on modal superposition”[5]. Thus Ritz-vector analysis is used to obtain mode shapes.

Researches have indicated that the natural free-vibration mode shapes are not the best basis for a mode-superposition analysis of structures subjected to dynamic loads. It has been demonstrated that dynamic analyses based on a special set of load-dependent Ritz vectors yield more accurate results than the use of the same number of natural mode shapes [5].

The reason the Ritz vectors yield excellent results is that they are generated by taking into account the special distribution of the dynamic loading, where as the direct use of the natural mode shapes neglects this very important information.

In addition, the Ritz-vector algorithm automatically includes the advantages of the proven numerical techniques of static condensation, Guyan reduction, and static correction due to higher-mode truncation.

The spatial distribution of the dynamic load vector serves as a starting load vector to initiate the procedure. The first Ritz vector is the static displacement vector corresponding to the starting load vector. The remaining vectors are generated from a recurrence relationship in which the mass matrix is multiplied by the previously obtained Ritz vector and used as the load vector for the next static solution. Each static solution is called a generation cycle.

When the dynamic load is made up of several independent spatial distributions, each of these may serve as a starting load vector to generate as set of Ritz vectors. Each generation cycle creates as many Ritz vector as there are starting load vectors. If a generated Ritz vector is redundant or does not excite any mass degrees of freedom, it is discarded and the corresponding starting load vector is removed from all subsequent generation cycles.

Standard eigen-solution techniques are used to orthogonalize the set of generated Ritz vectors, resulting in a final set of Ritz-vector Modes. Each Ritz-vector mode consists of a mode shape and frequency. The full set of Ritz-vector Modes can be used as a basis to represent the dynamic displacement of the structure.

5.2 Determination of modes - Mode analysis

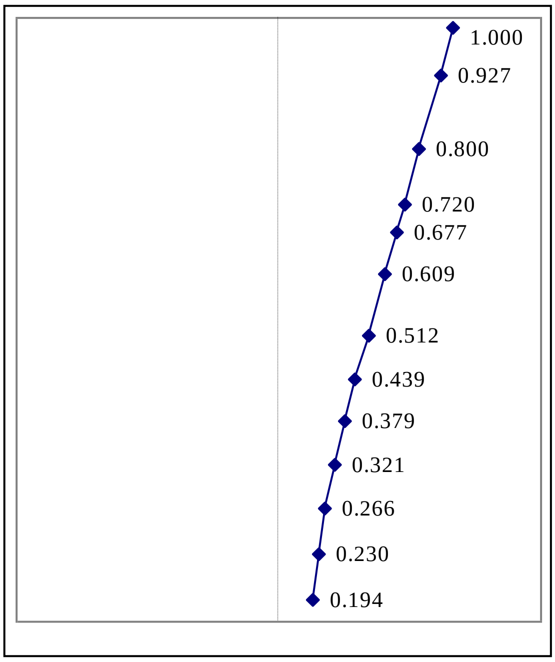
As a first step of the analyzing procedure, Mode Analysis is performed to get modal information of LSR Structures. *n*-number of modes (10, 5 and 7 modes for Structures A, B and C respectively) are requested for each model, and the modes are found by the program. Calculated Mode values and mode values given in design documents [1] were the same. Modal parameters are listed below for each structural model and mode shapes can be seen in *Figures 5-2-1* below as well.

5.2.1 Structure A

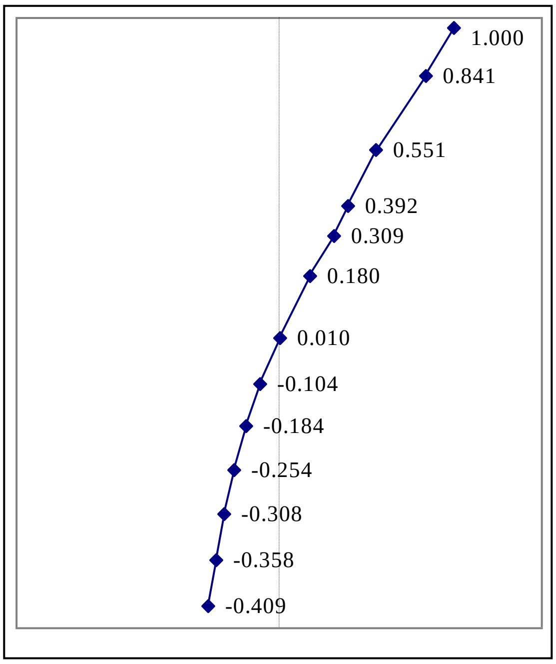
Table5.2.1-1 Modal information of NS Direction of Structure A

Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.420	2.38	14.549	14.96	223.9	0.73460000	0.735
Mode 2	0.223	4.48	-8.698	28.17	793.4	0.26250000	0.997
Mode 3	0.116	8.60	0.751	54.01	2917.3	0.00200000	0.999
Mode 4	0.093	10.71	0.435	67.27	4525.2	0.00065720	1.000
Mode 5	0.065	15.50	0.273	97.36	9479.4	0.00025950	1.000
Mode 6	0.052	19.22	0.038	120.77	14584.0	0.00000501	1.000
Mode 7	0.035	28.64	0.047	179.92	32373.0	0.00000760	1.000
Mode 8	0.022	45.22	-0.013	284.13	80727.0	0.00000055	1.000
Mode 9	0.021	47.77	0.002	300.13	90075.0	0.00000001	1.000
Mode 10	0.020	50.00	-0.001	314.16	91709.0	0.00000000	1.000

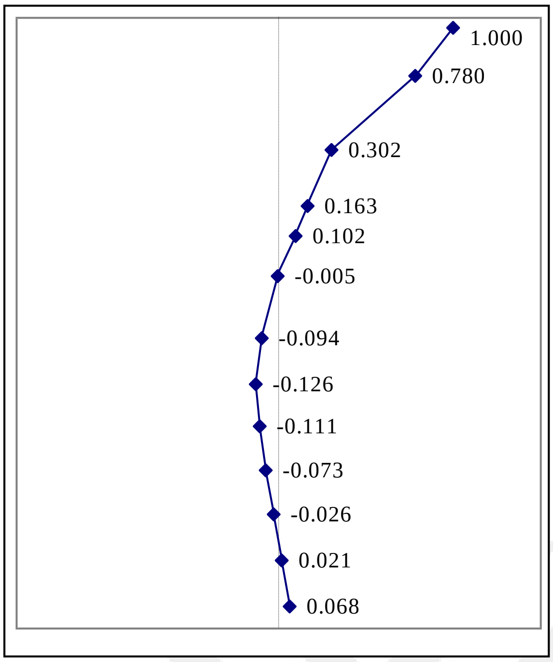
Figures 5.2.1-1 Mode Shapes of NS Direction of Structure A

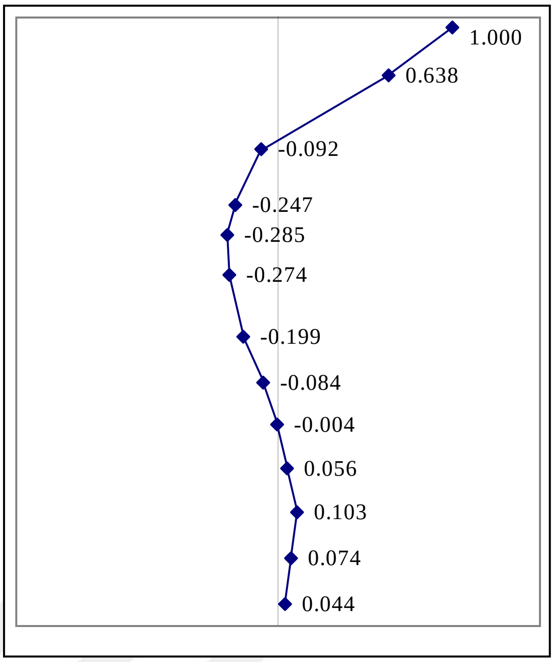


MODE 1 T=0.42 s. SWAY : 0.194
ROCKING :7.97E-6



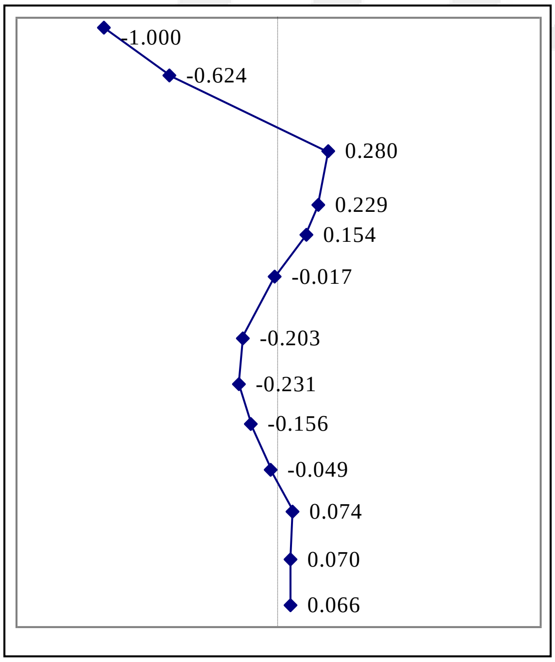
MODE 2 T=0.223 s. SWAY :-0.409
ROCKING :12.0E-6

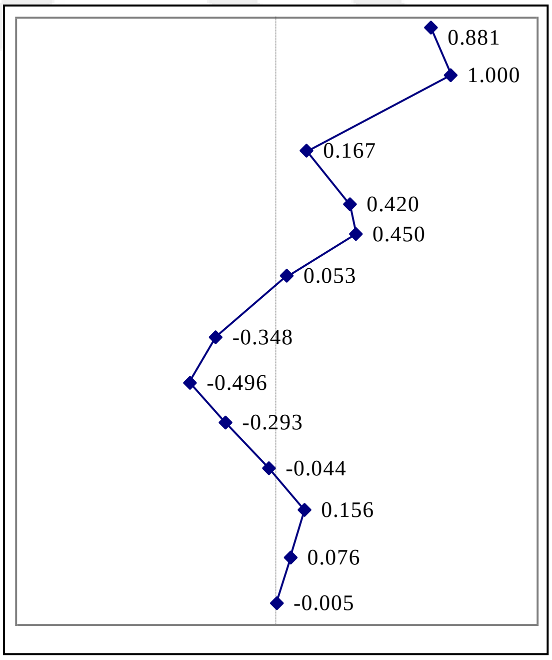




MODE 3 T=0.116s. SWAY : 0.068
ROCKING :-24.00E-6

MODE 4 T=0.093s. SWAY :-0.044
ROCKING :15.0E-6





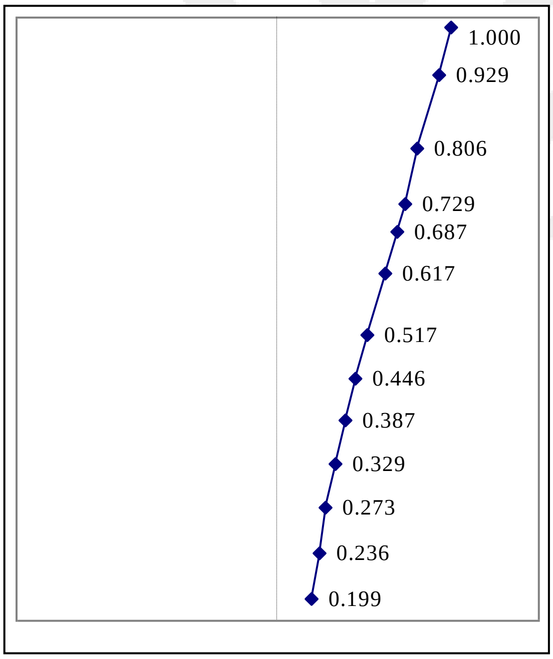
MODE 5 T=0.0650s. SWAY : 0.066
ROCKING : 2.12E-6

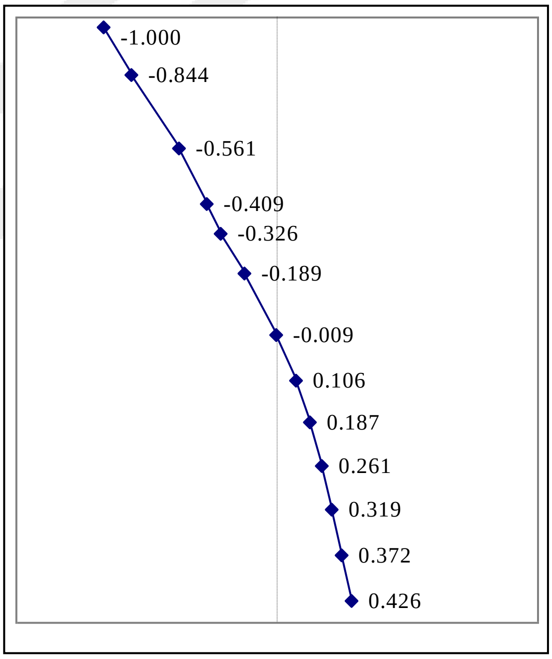
MODE 6 T=0.052s. SWAY :-0.005
ROCKING :16.0E-6

Table5.2.1-2 Modal information of EW Direction of Structure A

Mode	Period	Frequency	Modal Part. Factors	CircFreq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.418	2.40	-14.643	15.05	226.5	0.74410000	0.7441
Mode 2	0.220	4.54	8.554	28.51	812.8	0.25390000	0.9980
Mode 3	0.113	8.86	-0.570	55.66	3098.3	0.00110000	0.9991
Mode 4	0.089	11.28	-0.426	70.88	5024.3	0.00063070	0.9997
Mode 5	0.063	15.78	0.258	99.17	9833.7	0.00023020	1.0000
Mode 6	0.049	20.26	-0.056	127.27	16197.0	0.00001107	1.0000
Mode 7	0.034	29.46	-0.042	185.07	34252.0	0.00000600	1.0000
Mode 8	0.021	46.63	0.009	293.00	85851.0	0.00000031	1.0000
Mode 9	0.020	50.64	-0.005	318.20	101250.0	0.00000009	1.0000
Mode 10	0.019	52.63	-0.002	330.69	102400.0	0.000000000	1.0000

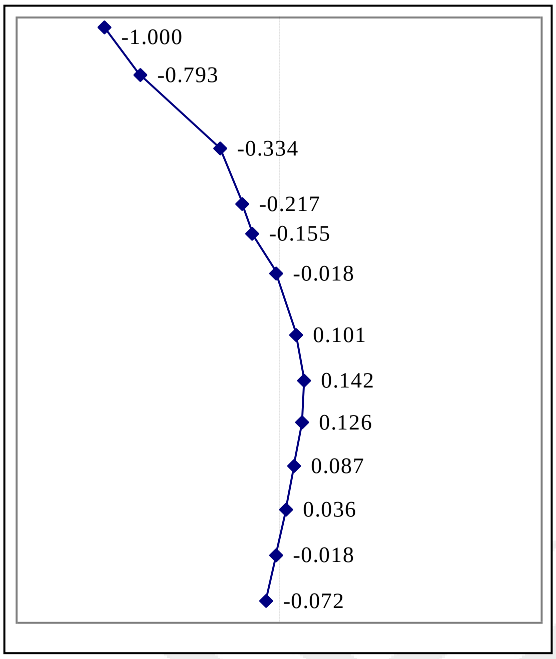
Figures 5.2.1-2 Mode Shapes of EW Direction of Structure A

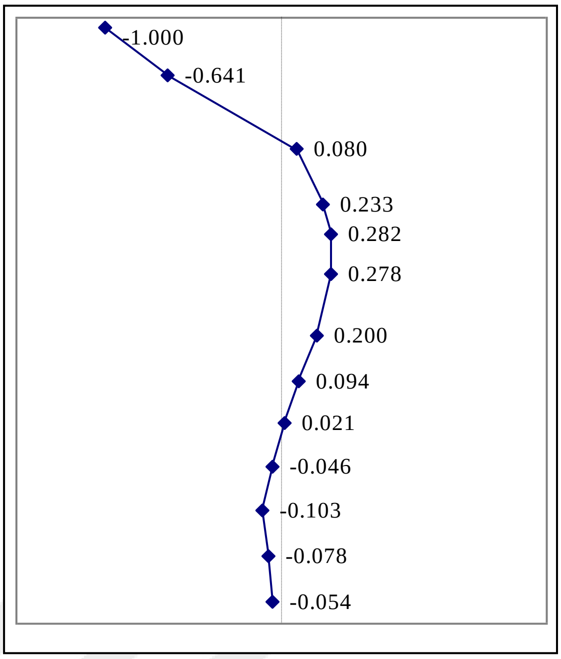




MODE 1 T=0.418 s. SWAY : 0.199
ROCKING :8.04E-6

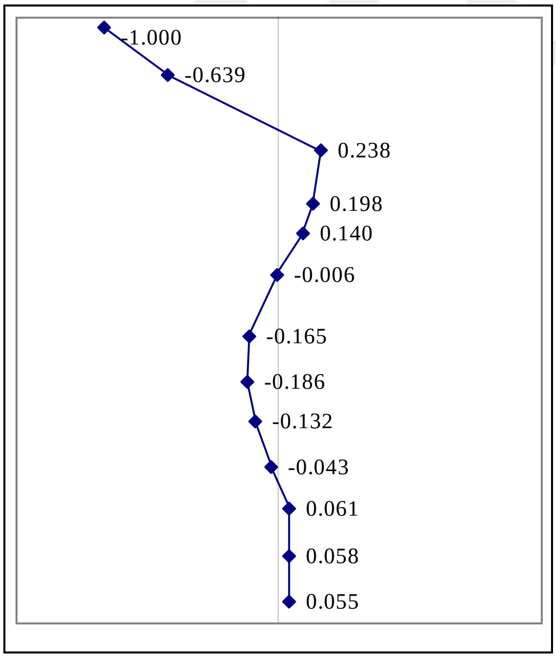
MODE 2 T=0.220 s. SWAY :-0.426
ROCKING :13.0E-6

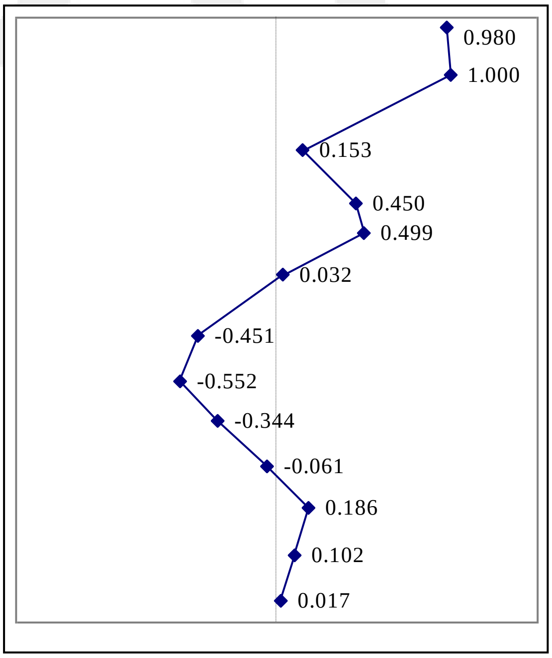




MODE 3 T=0.113s. SWAY : 0.072
ROCKING :-25.00E-6

MODE 4 T=0.089s. SWAY :-0.054
ROCKING :12.0E-6





MODE 5 T=0.063s. SWAY : 0.055
ROCKING : 1.76E-6

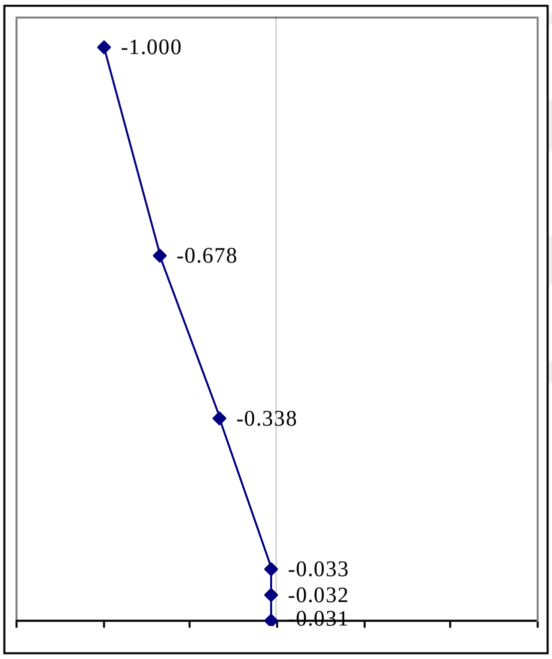
MODE 6 T=0.049s. SWAY :-0.017
ROCKING :16.0E-6

5.2.2 Structure B

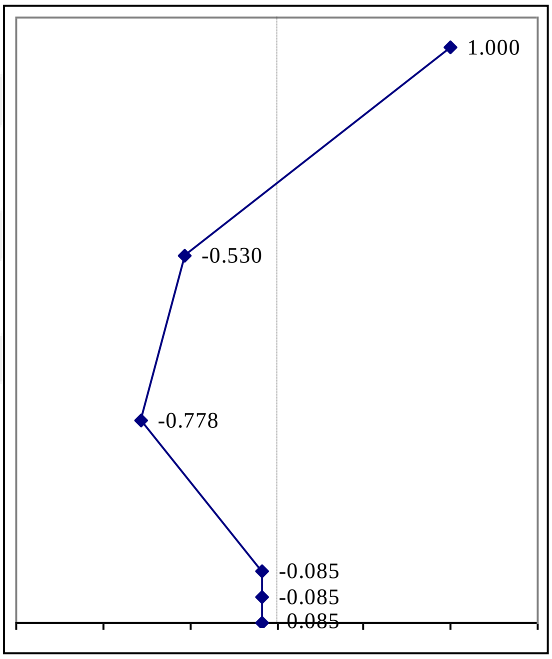
Table5.2.2-1 Modal information of NS Direction of Structure B:

Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.087	11.49	1.932	72.22	5215.8	0.58890	0.5889
Mode 2	0.037	26.72	0.849	167.89	28188.0	0.11360	0.7025
Mode 3	0.025	40.17	-0.453	252.40	63705.0	0.03240	0.7349
Mode 4	0.013	76.85	1.296	482.88	233170.0	0.26490	0.9998
Mode 5	0.007	135.25	0.039	849.79	722150.0	0.00024	1.0000

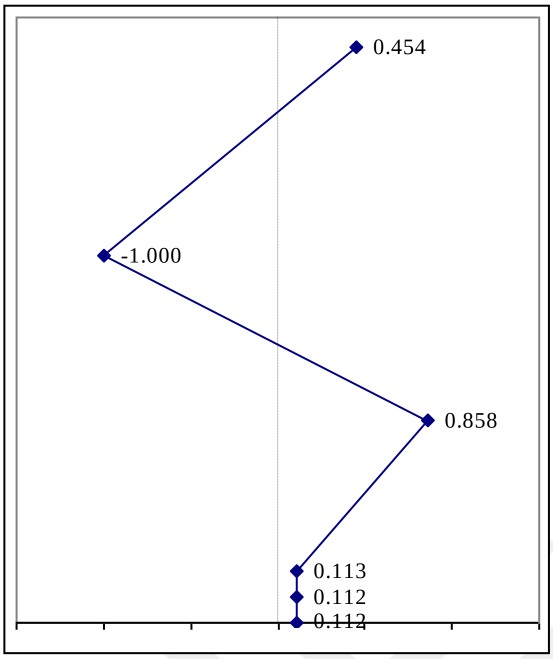
Figures 5.2.2-1 Mode Shapes of NS Direction of Structure B

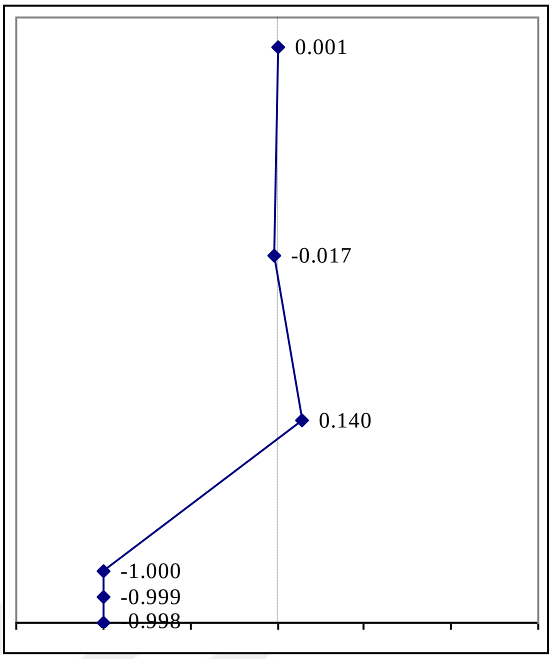


MODE 1 T=0.087 s. SWAY : -0.031
ROCKING :-12.0E-6



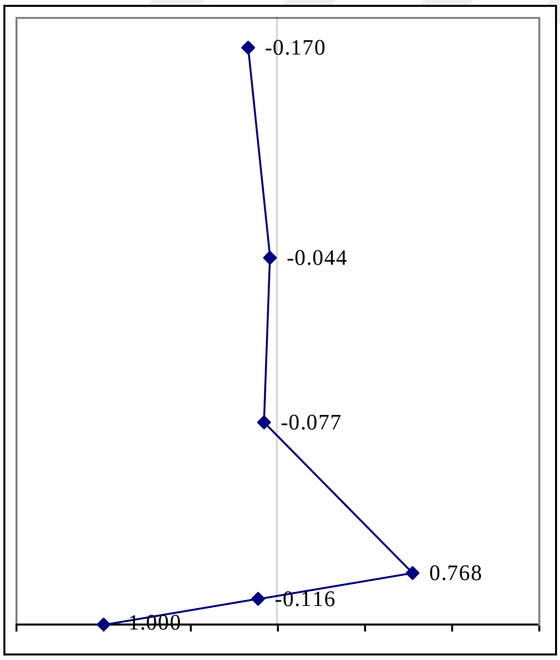
MODE 2 T=0.037 s. SWAY :-0.085
ROCKING :0.2719E-6





MODE 3 T=0.025 s. SWAY : 0.112
ROCKING :5.46E-6

MODE 4 T=0.013 s. SWAY :-0.998
ROCKING :-9.20E-6



MODE 5 T=0.007 s. SWAY : -1.000
ROCKING :932.0E-6

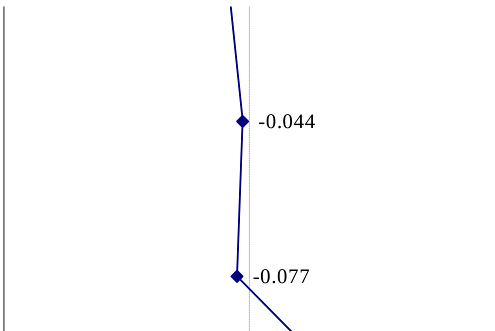
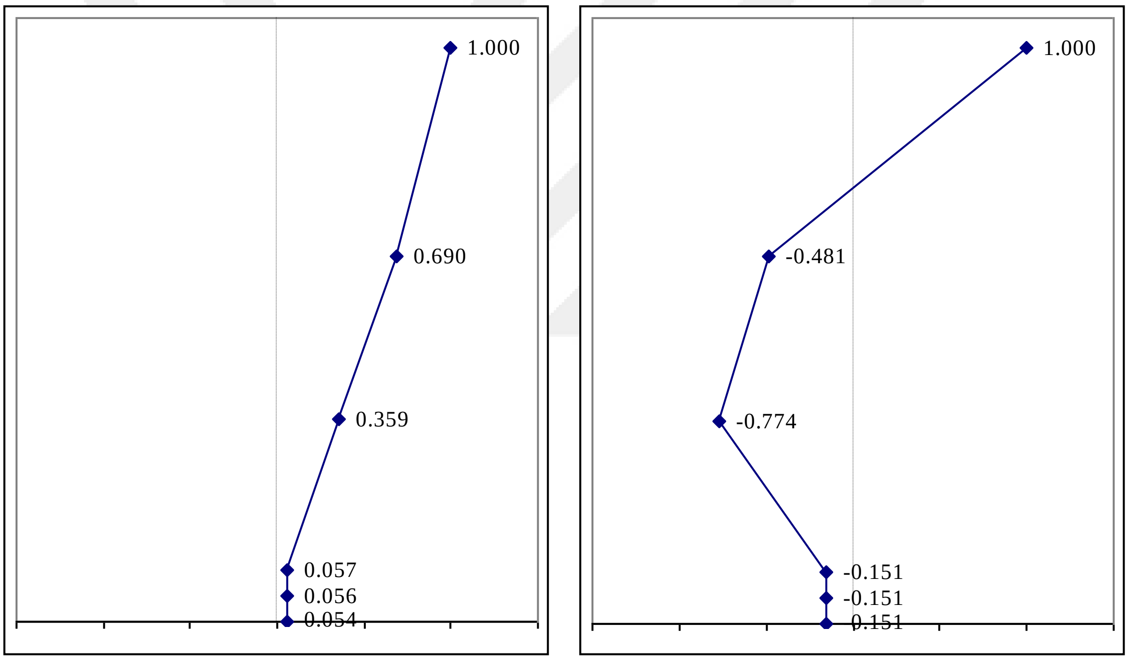


Table5.2.2-2 Modal information of EW Direction of Structure B:

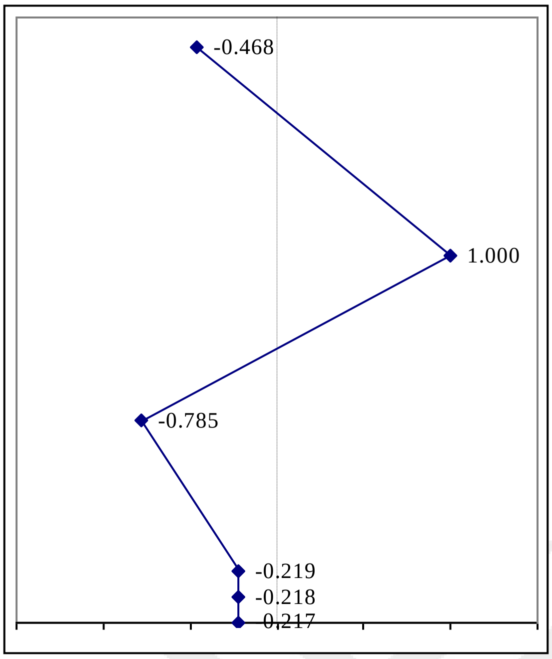
Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.067	14.90	-1.981	93.62	8764.2	0.61920	0.6192
Mode 2	0.029	34.70	0.898	218.00	47526.0	0.12720	0.7464
Mode 3	0.019	52.21	0.527	328.01	107590.0	0.04390	0.7903
Mode 4	0.012	80.24	1.152	504.14	254160.0	0.20960	0.9999
Mode 5	0.008	131.28	0.029	824.86	680400.0	0.00013	1.0000

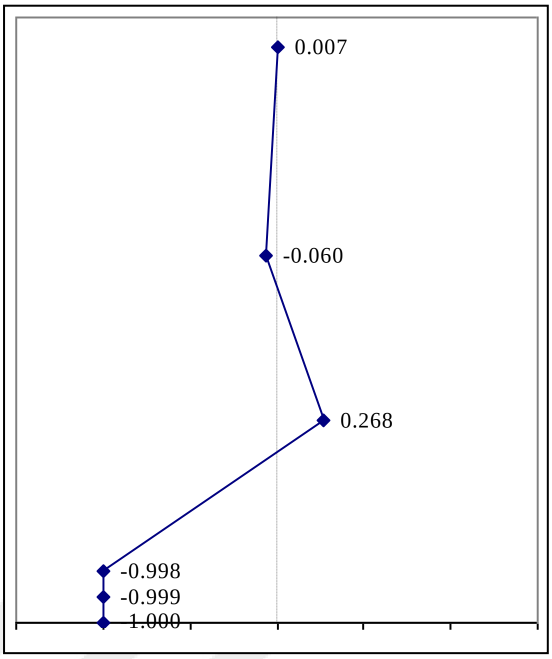
Figures 5.2.2-2 Mode Shapes of EW Direction of Structure B



MODE 1 T=0.067 s. SWAY : 0.054 ROCKING :16.0E-6

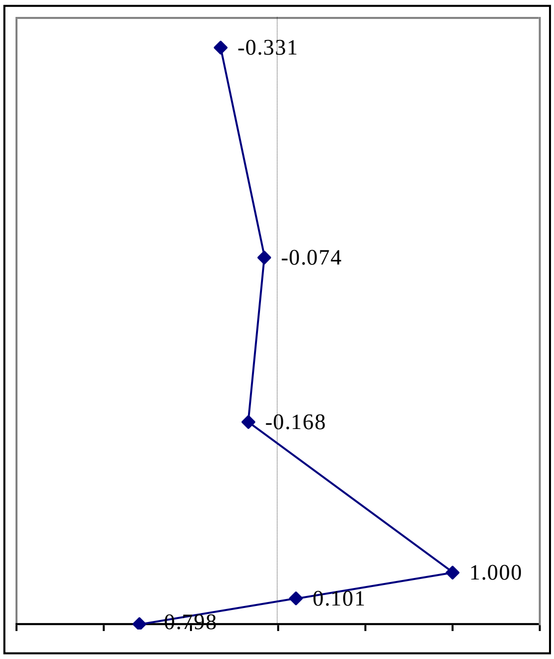
MODE 2 T=0.029 s. SWAY :-0.151 ROCKING :2.271E-6





MODE 3 T=0.019 s. SWAY : -0.217
ROCKING :-6.3E-6

MODE 4 T=0.012 s. SWAY :-1.000
ROCKING :8.86E-6



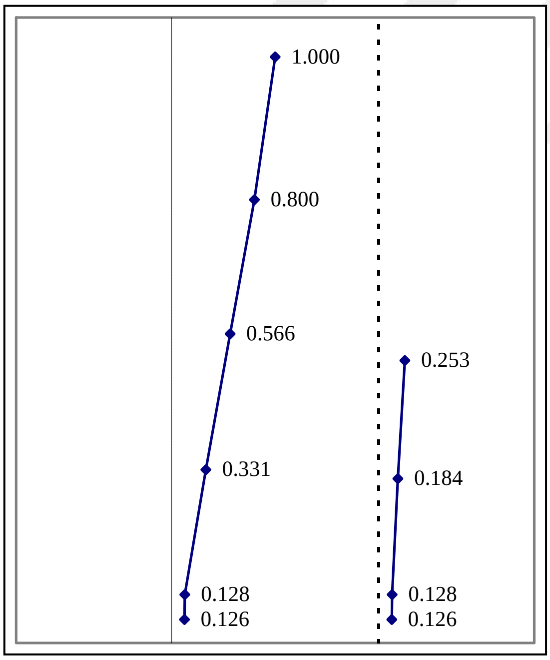
MODE 5 T=0.008 s. SWAY : -0.798
ROCKING :828.0E-6

5.2.3 Structure C

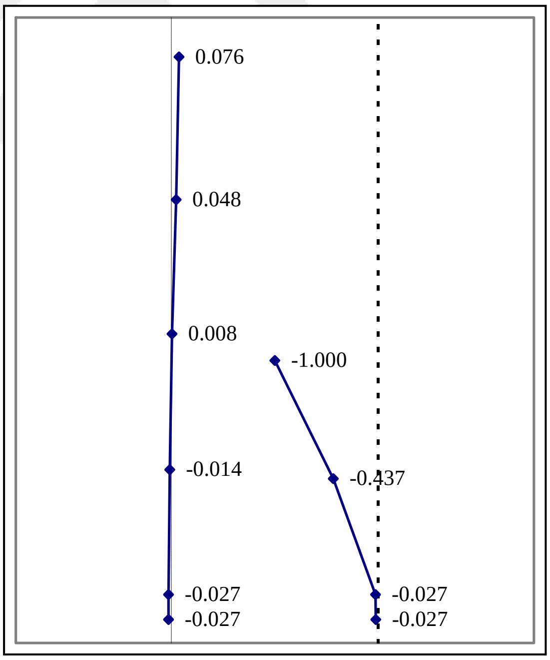
Table5.2.3-1 Modal information of NS Direction of Structure C:

Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.129	7.78	10.812	48.88	2389.5	0.64510	0.6451
Mode 2	0.082	12.23	2.739	76.85	5905.4	0.04140	0.6865
Mode 3	0.059	17.03	6.229	107.02	11454.0	0.21410	0.9006
Mode 4	0.041	24.25	-3.667	152.35	23209.0	0.07420	0.9748
Mode 5	0.032	30.92	1.988	194.27	37740.0	0.02180	0.9966
Mode 6	0.027	36.47	-0.159	229.12	52498.0	0.00014	0.9968
Mode 7	0.026	39.11	-0.766	245.70	60369.0	0.00320	1.0000

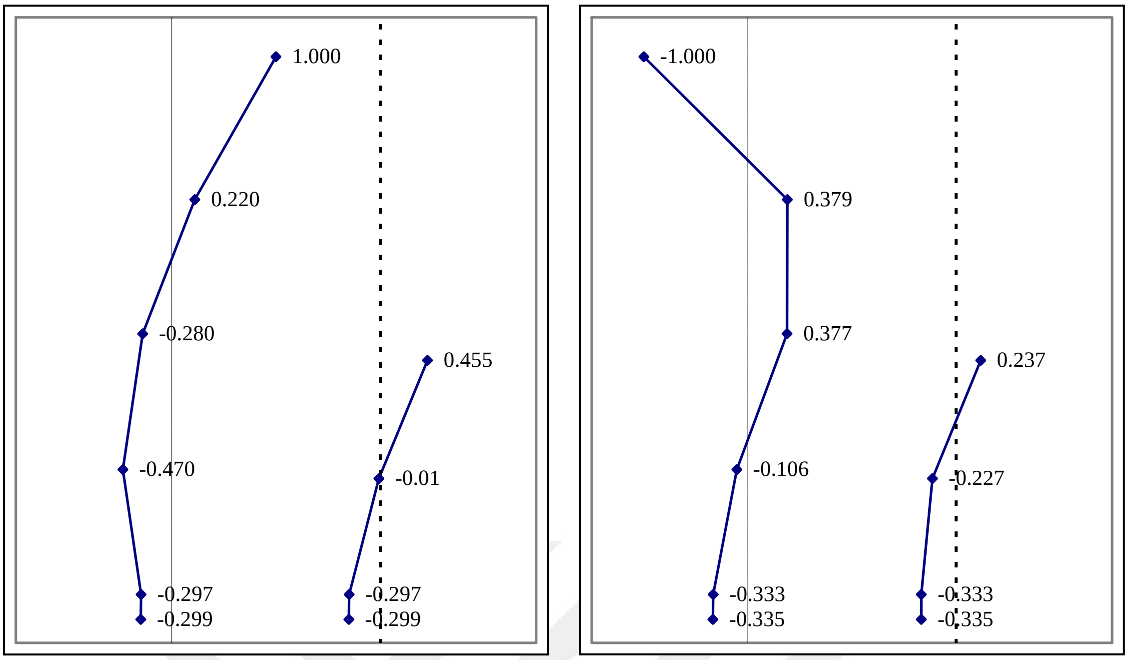
Figures 5.2.3-1 Mode Shapes of NS Direction of Structure C



MODE 1 T=0.129 s. SWAY : 0.126
ROCKING :2.11E-6

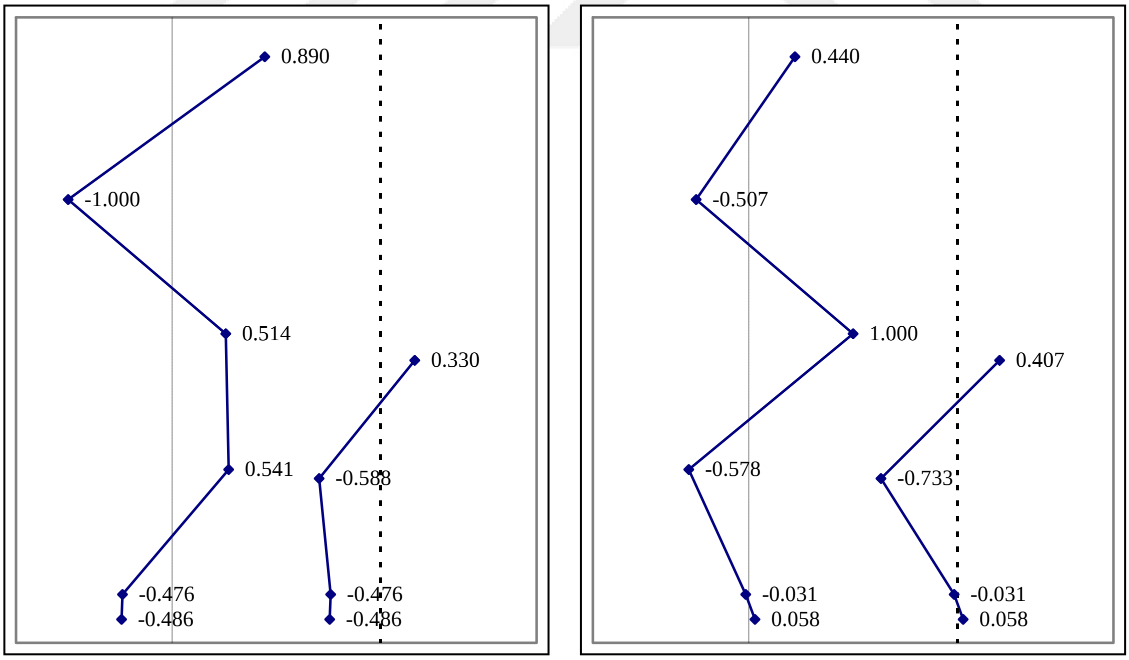


MODE 2 T=0.082 s. SWAY :-0.027
ROCKING :-0.306E-6



MODE 3 T=0.059 s. SWAY :-0.299
ROCKING :1.9E-6

MODE 4 T=0.041 s. SWAY :-0.335
ROCKING :3.09E-6



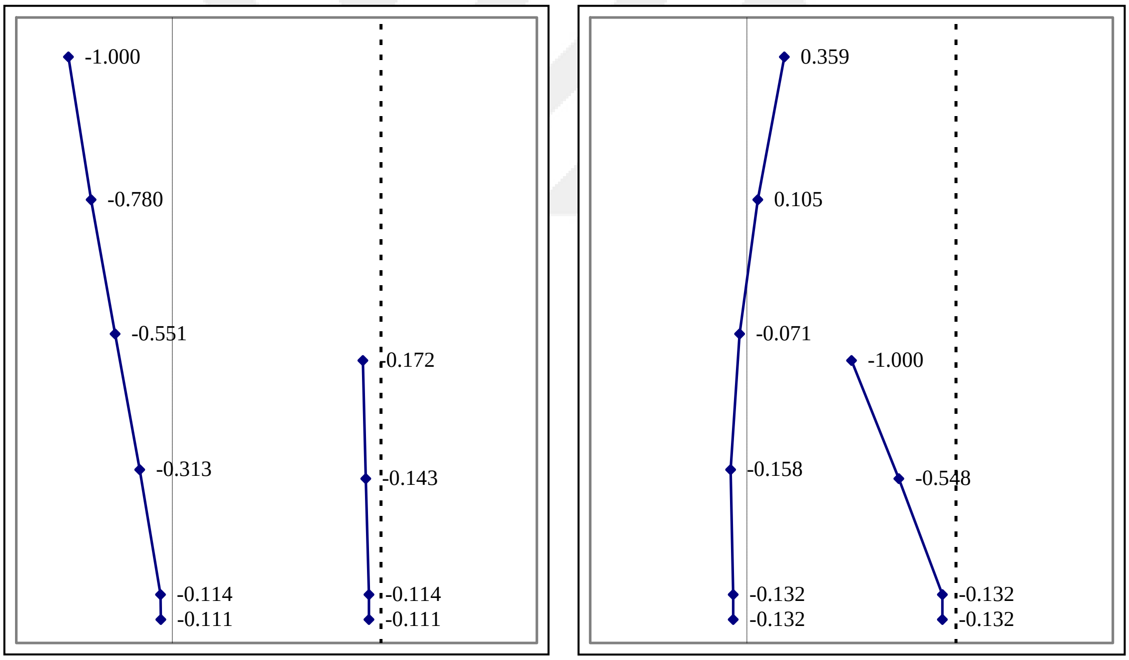
MODE 5 T=0.032 s. SWAY :-0.486
ROCKING :7.86E-6

MODE 6 T=0.027 s. SWAY :-0.058
ROCKING :-43E-6

Table5.2.3-2 Modal information of EW Direction of Structure C

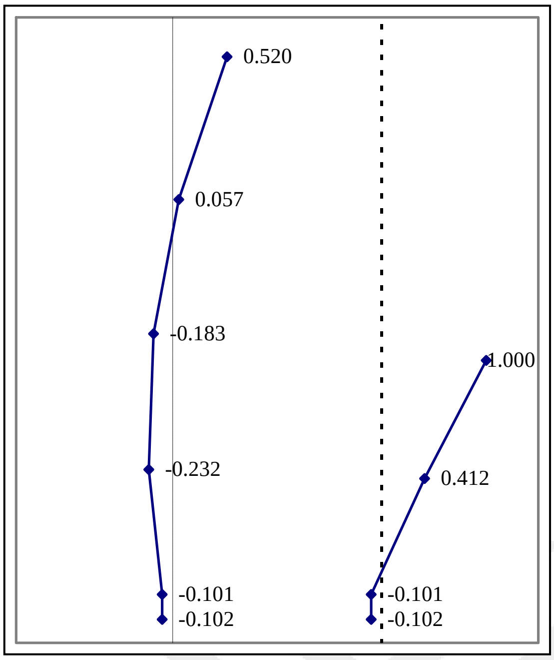
Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.133	7.52	10.591	47.27	2234.7	0.61900	0.6190
Mode 2	0.065	15.35	6.179	96.44	9301.5	0.21070	0.8297
Mode 3	0.057	17.56	3.286	110.31	12168.0	0.05960	0.8893
Mode 4	0.042	23.88	3.831	150.04	22511.0	0.08100	0.9703
Mode 5	0.033	30.07	−1.822	188.92	35692.0	0.01830	0.9886
Mode 6	0.031	32.62	−1.375	204.97	42013.0	0.01040	0.9991
Mode 7	0.022	45.33	−0.407	284.82	81124.0	0.00092	1.0000

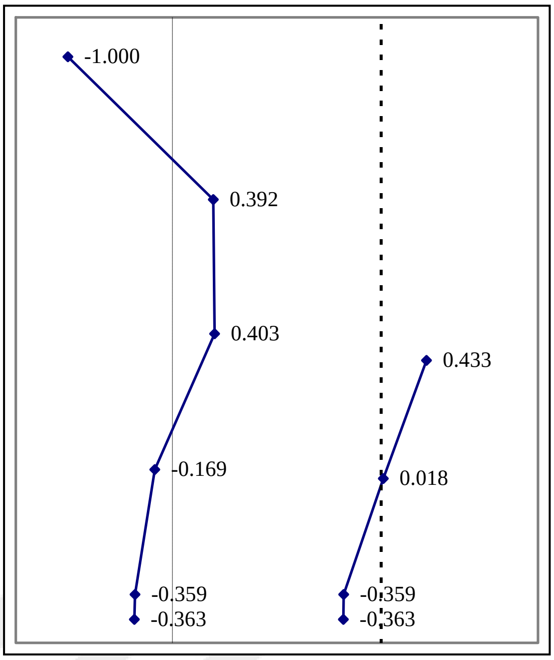
Figures 5.2.3-2 Mode Shapes of EW Direction of Structure C



MODE 1 T=0.133 s. SWAY : -0.111
ROCKING :-2.5E-6

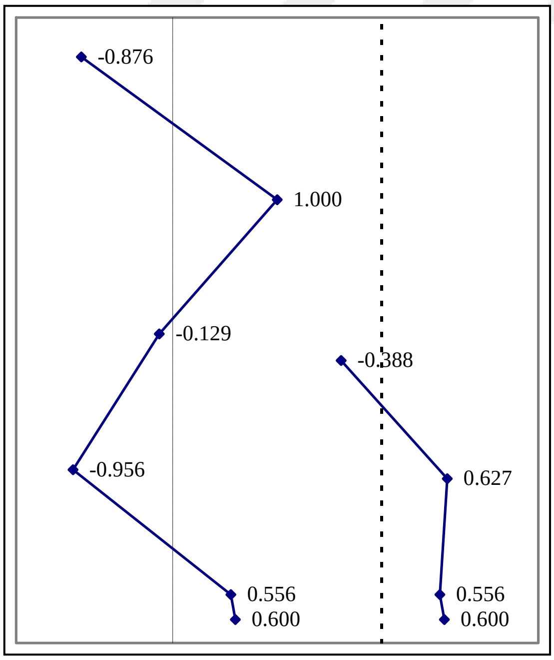
MODE 2 T=0.065 s. SWAY :-0.132
ROCKING :0.082E-6

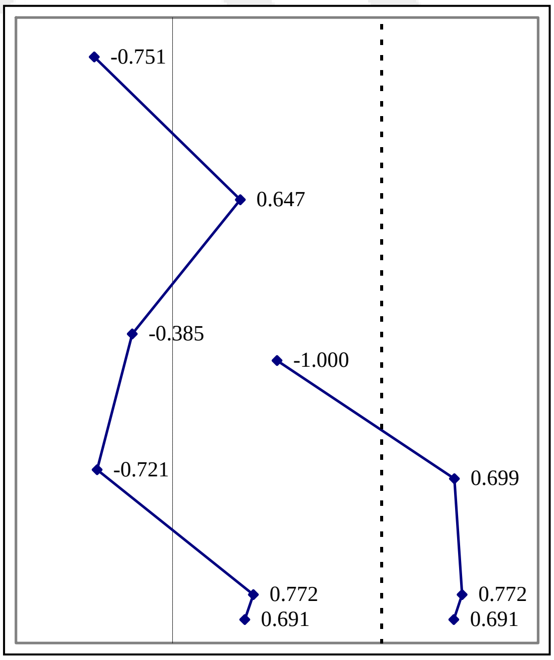




MODE 3 T=0.057 s. SWAY : -0.102
ROCKING :2.7E-6

MODE 4 T=0.042 s. SWAY :-0.363
ROCKING :5.55E-6





MODE 5 T=0.033 s. SWAY : 0.600
ROCKING :-2.7E-6

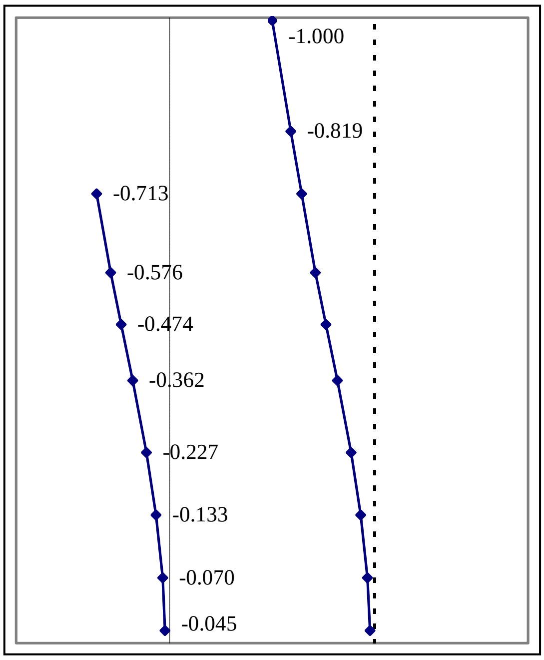
MODE 6 T=0.031 s. SWAY :0.691
ROCKING :38E-6

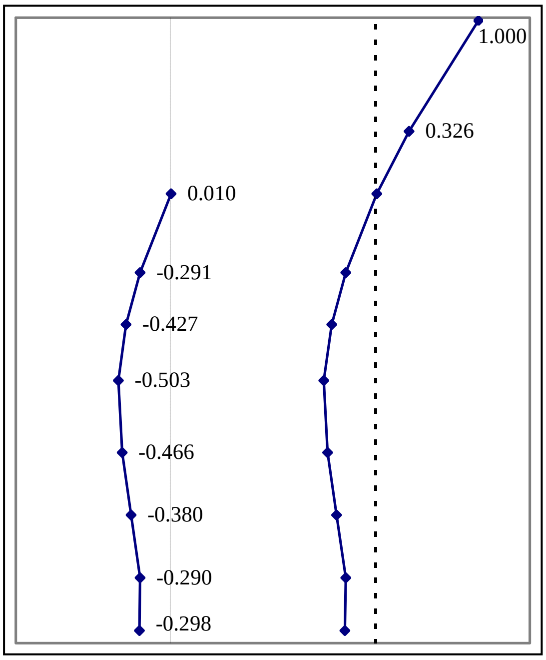
5.2.4 Structure D

Table5.2.4-1 Modal information of Structure D:

Mode	Period	Frequency	Modal Part. Factors	Circ Freq	Eigenvalue	Modal Part. Mass Ratio	Modal Part. Mass Ratio Sum
No	Sec	Cycle/sec	Ton-s^2	rad/sec	rad^2/sec^2	Unit less	Unit less
Mode 1	0.2859	3.498	10.628	21.98	483.1	0.55300000	0.5530
Mode 2	0.1199	8.340	7.759	52.40	2746.0	0.29480000	0.8478
Mode 3	0.0978	10.225	0.630	64.25	4127.7	0.00190000	0.8497
Mode 4	0.0755	13.239	2.592	83.18	6919.3	0.03290000	0.8826
Mode 5	0.0703	14.217	4.414	89.33	7979.1	0.09540000	0.9780
Mode 6	0.0569	17.562	1.921	110.35	12177.0	0.01810000	0.9961
Mode 7	0.0468	21.374	-0.374	134.29	18035.0	0.00068360	0.9968
Mode 8	0.0425	23.539	-0.720	147.90	21874.0	0.00250000	0.9993
Mode 9	0.0395	25.288	-0.003	158.89	25246.0	0.00000004	0.9993
Mode 10	0.0343	29.142	0.267	183.10	33526.0	0.00034960	0.9997
Mode 11	0.0312	32.041	0.061	201.32	40529.0	0.00001845	0.9997
Mode 12	0.0310	32.214	0.199	202.40	40967.0	0.00019340	0.9999
Mode 13	0.0288	34.737	0.036	218.26	47638.0	0.00000624	0.9999
Mode 14	0.0260	38.471	0.071	241.72	58427.0	0.00002454	0.9999
Mode 15	0.0236	42.367	-0.068	266.20	70863.0	0.00002296	0.9999
Mode 16	0.0226	44.331	0.058	278.54	77585.0	0.00001649	0.9999
Mode 17	0.0222	44.992	-0.043	282.69	79914.0	0.00000915	0.9999
Mode 18	0.0215	46.545	0.007	292.45	85527.0	0.00000027	0.9999
Mode 19	0.0195	51.210	0.026	321.76	103530.0	0.00000337	1.0000
Mode 20	0.0192	52.115	-0.006	327.45	107220.0	0.00000016	1.0000

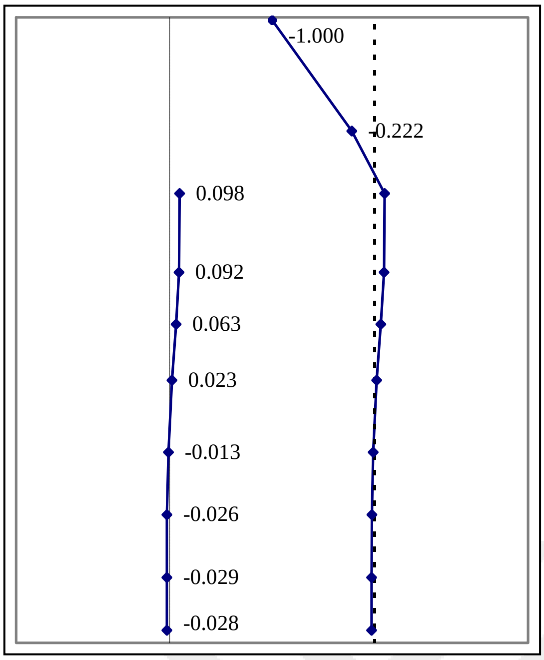
Figures 5.2.4-1: Mode Shapes of Structure D



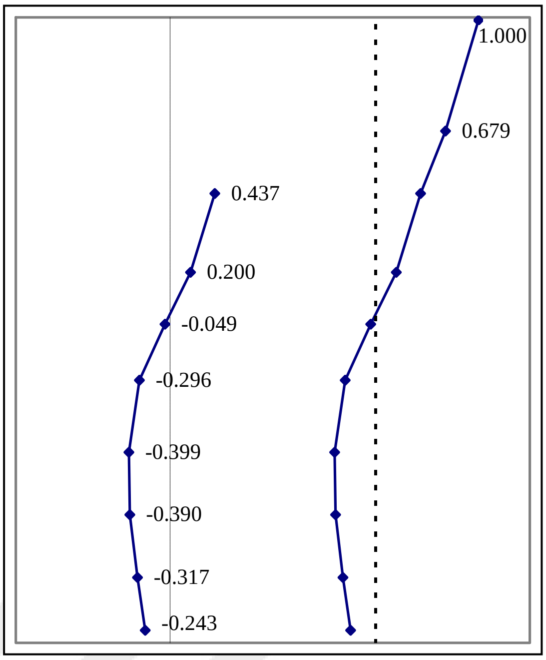


MODE 1 T=0.2859 s. SWAY : -0.045
ROCKING :-6.4E-6

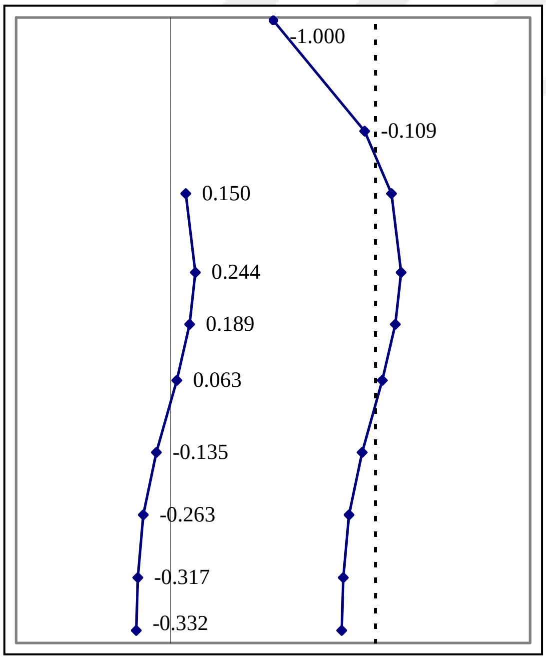
MODE 2 T=0.1199 s. SWAY :-0.298
ROCKING :5.39E-6



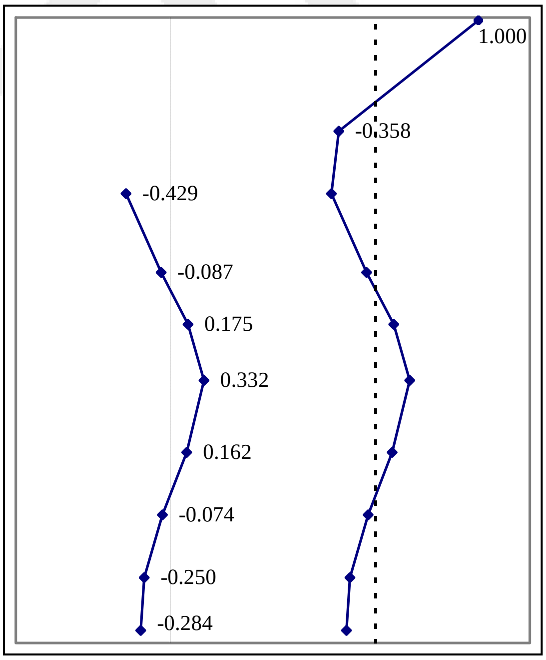
MODE 3 T=0.0978 s. SWAY : -0.028
ROCKING :0.367E-6



MODE 4 T=0.0755 s. SWAY :-0.243
ROCKING :-17E-6



MODE 5 T=0.0703 s. SWAY : -0.332
ROCKING :9.98E-6



MODE 6 T=0.0569 s. SWAY :-0.284
ROCKING :14E-6

5.3 Transfer functions of the Structures:

Before running a Nonlinear Direct Integration Time History Analysis, we need to run a Nonlinear Modal Time-History Analysis, which is based on modal superposition method, where we can use constant damping ratio for all frequencies. The NIGH010410231756.NS2 record of Nigata Earthquake was selected as a sample record to explain the analysis procedures. A Nonlinear Modal Time-History Analysis case was performed with constant modal damping for NIGH010410231756.NS2 strong ground motion record. By dividing absolute response acceleration of each level (M1,M2…Mn) to the input acceleration and using Fourier transforms, the transfer functions were calculated for each level of LSR Structure. In the *Figures 5-3-1* the mode frequencies were shown with dotted vertical lines, and the pick response frequencies were shown with thick vertical lines, and the pick values are listed on the graph.

The model Structure A had pick frequencies, which are different from mode frequencies. This may happen due to nonlinear effect of Nonlinear Nlink Elements, which represent rock ground at the base level of the LSR Structure.

Figure 5.3.1.a Structure A   NS Direction

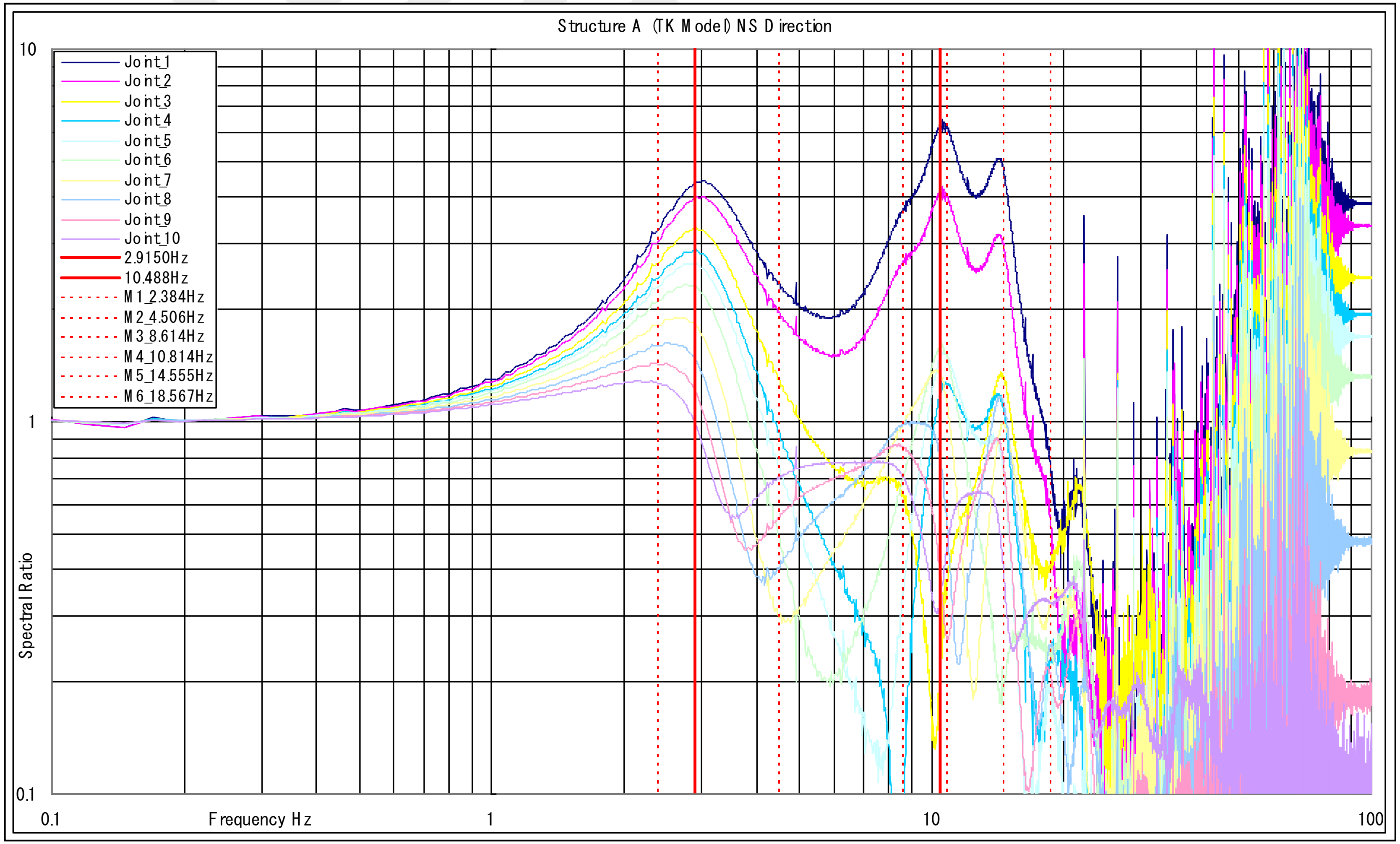


Figure 5.3.1.b Structure A　EW Direction

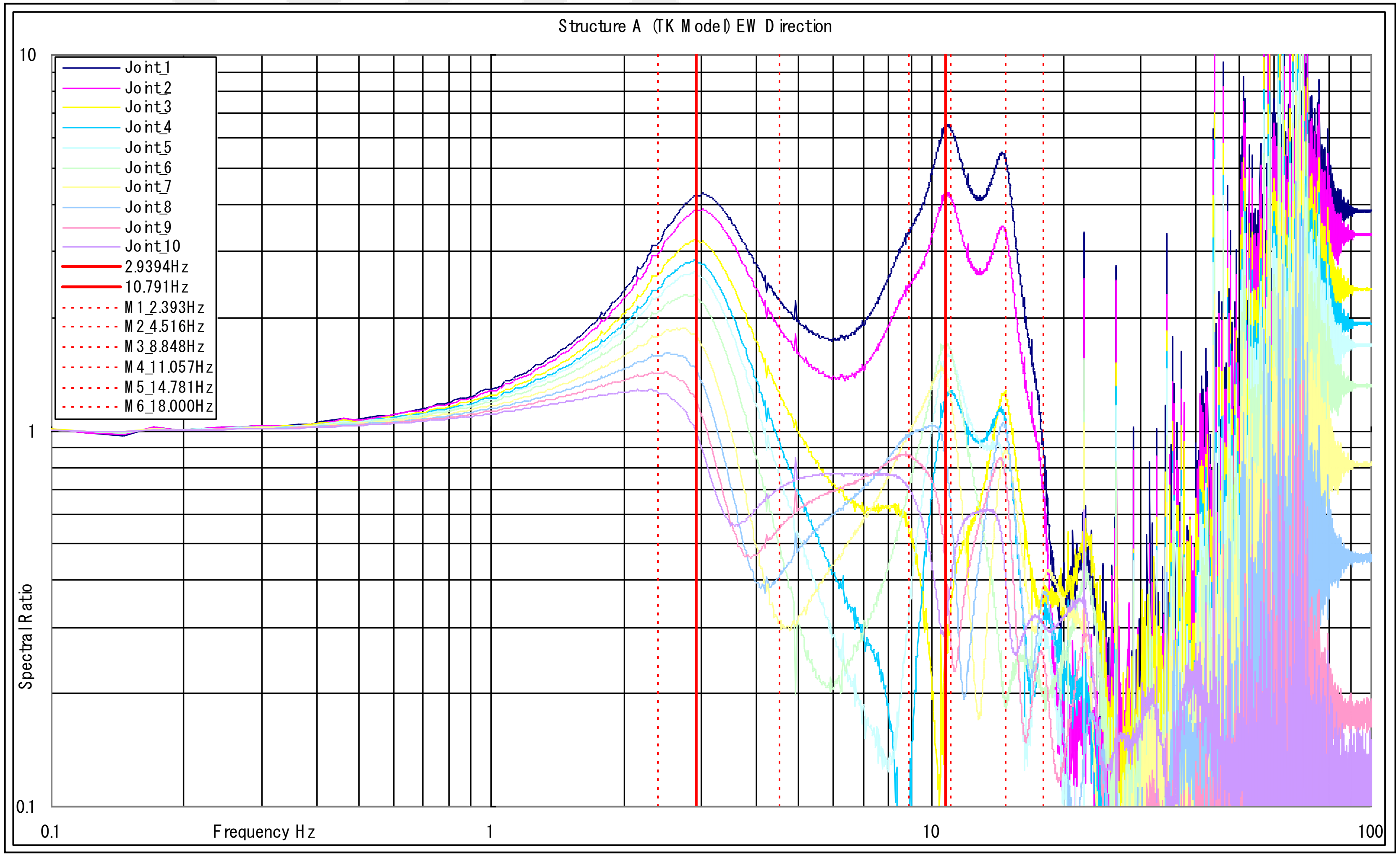


Figure 5.3.2.a Structure B   NS Direction:

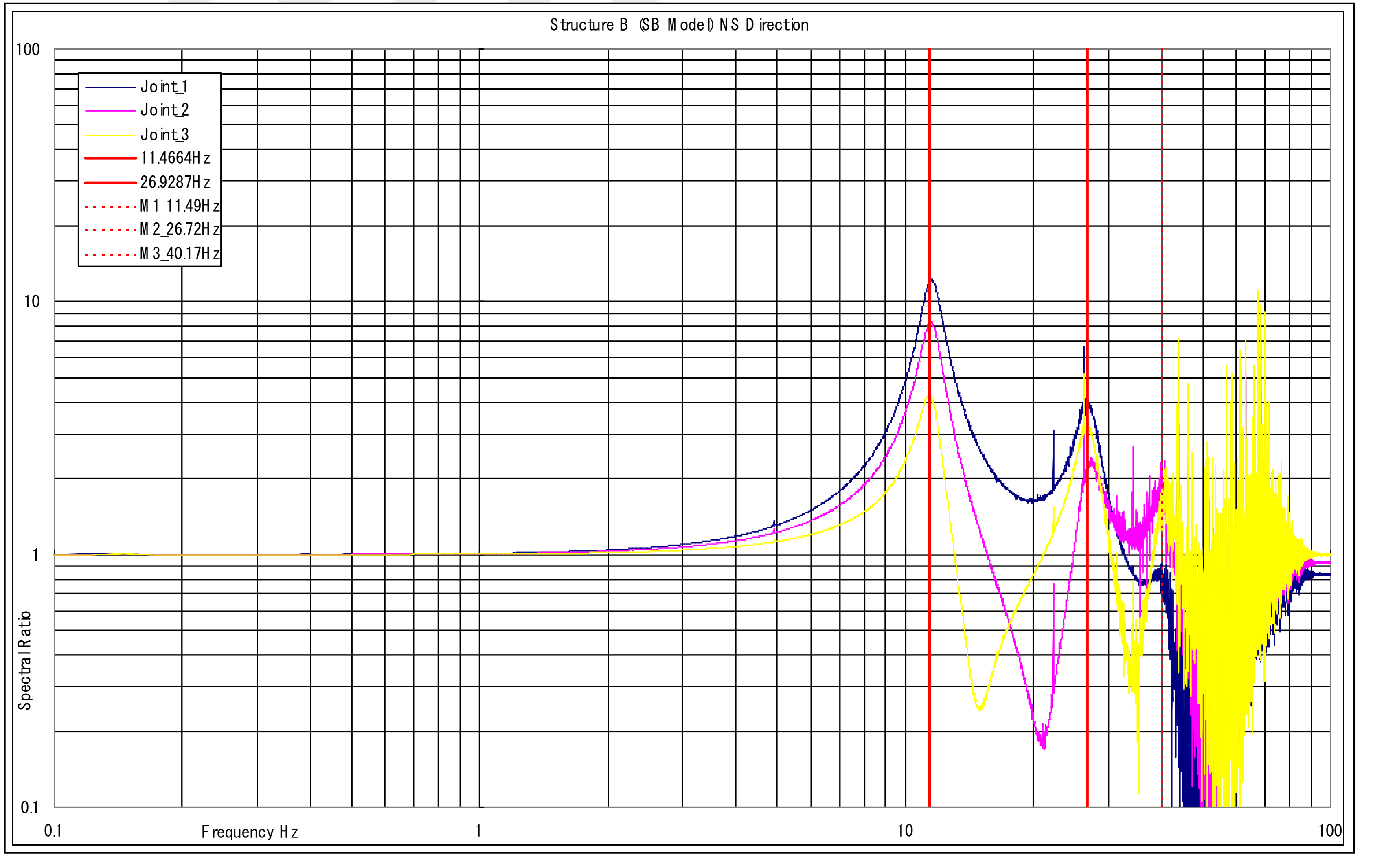


Figure 5.3.2.b Structure B   EW Direction:

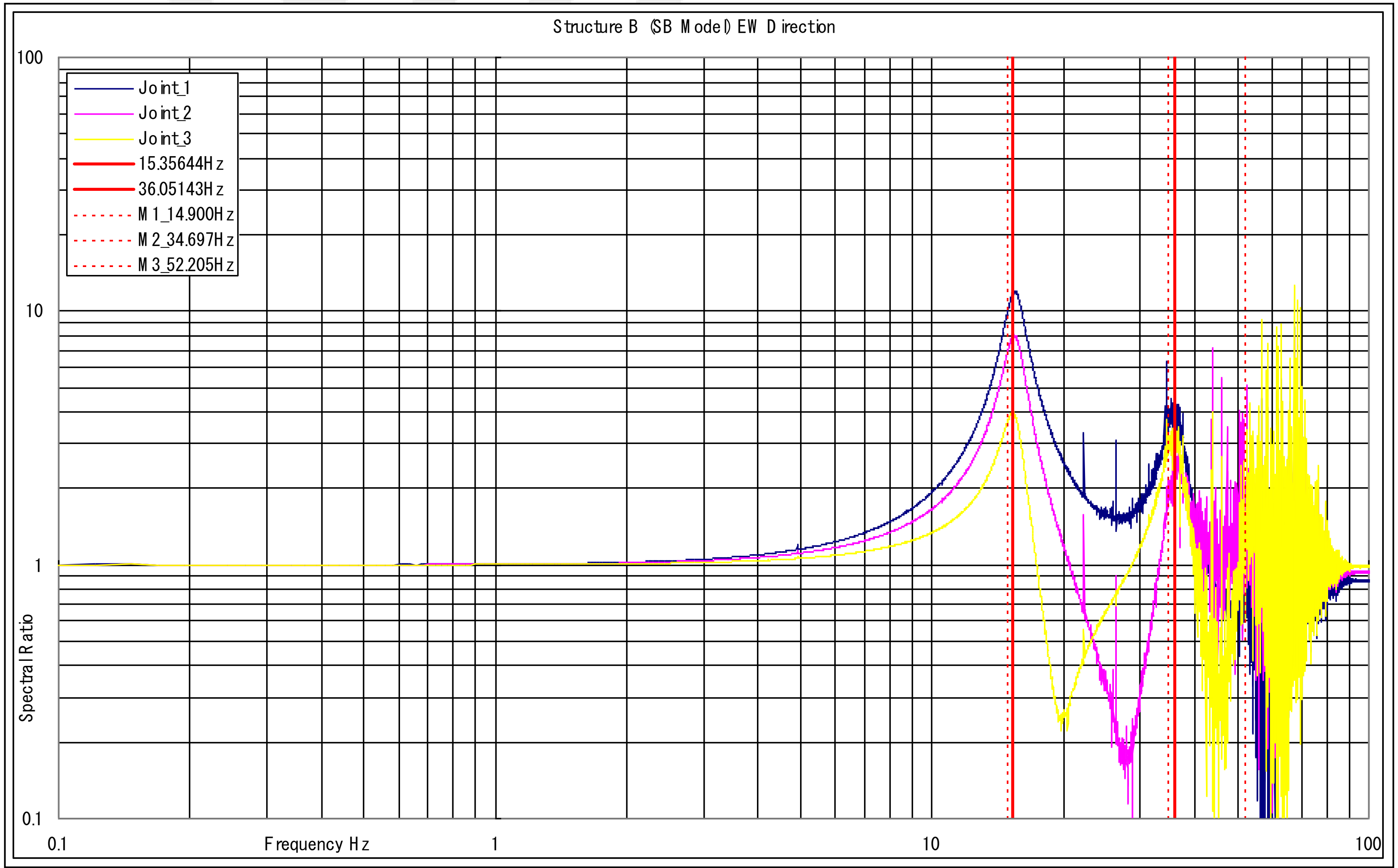


Figure 5.3.3.a Structure C   NS Direction:

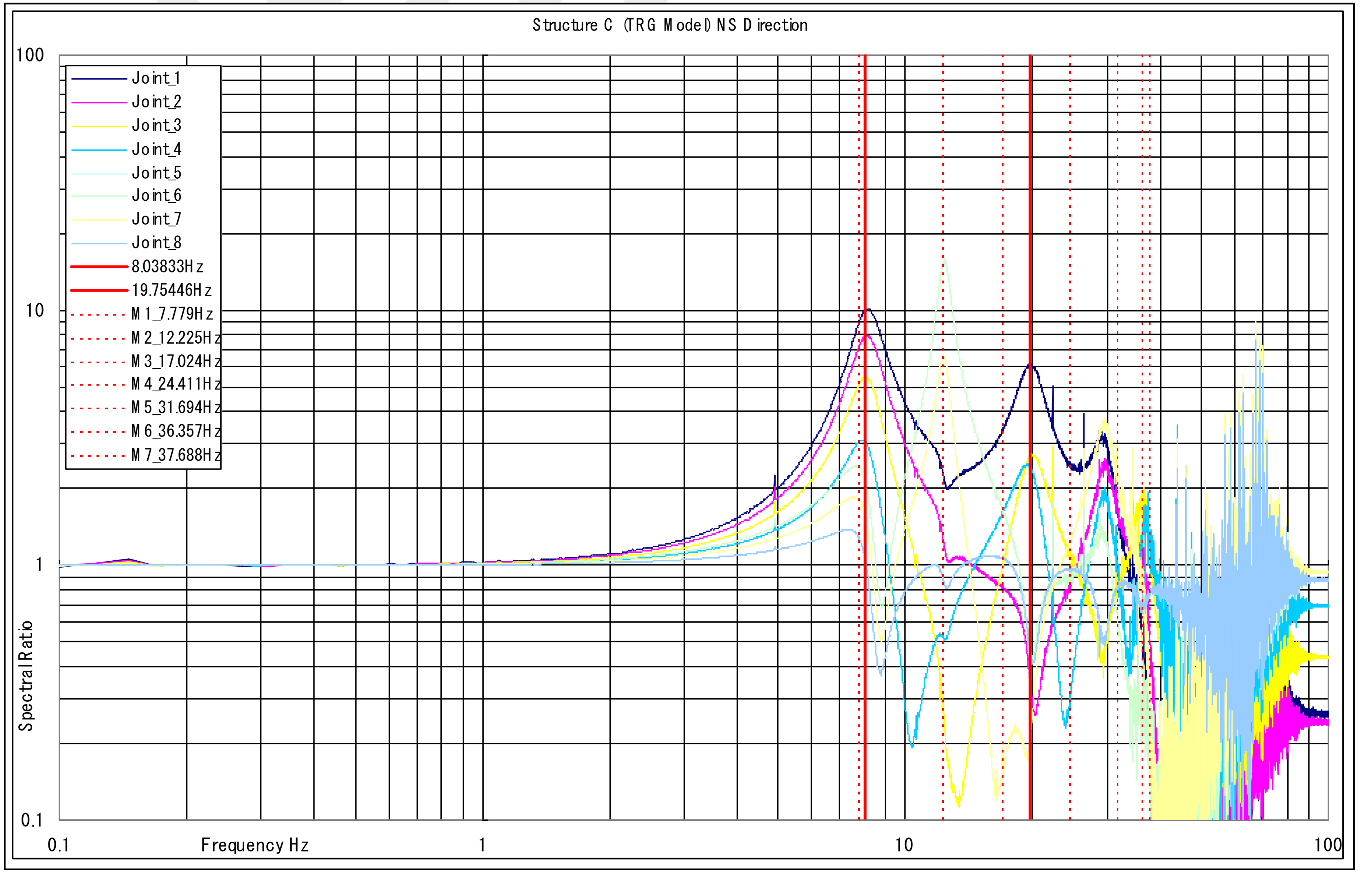


Figure 5.3.3.b Structure C   EW Direction:

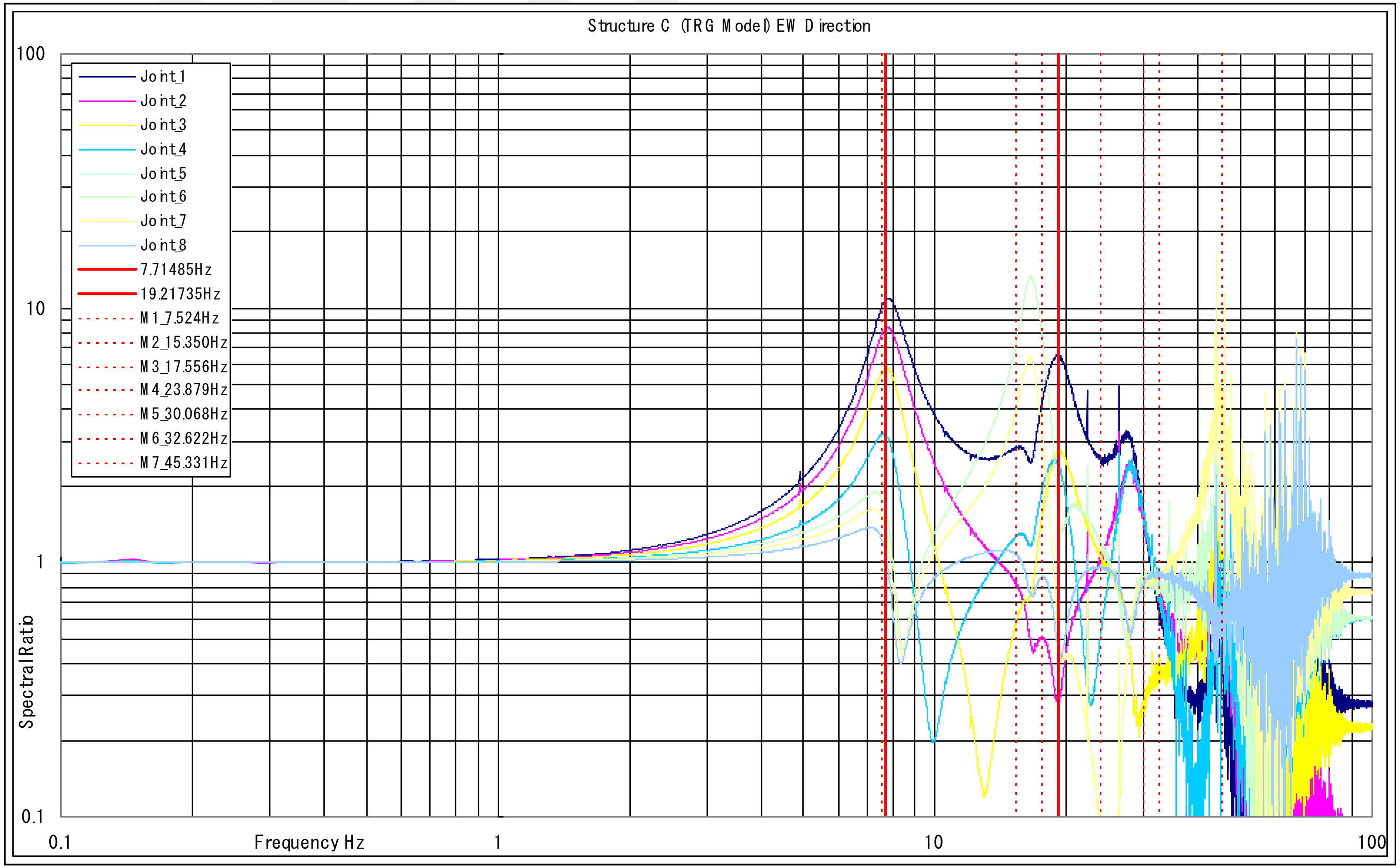
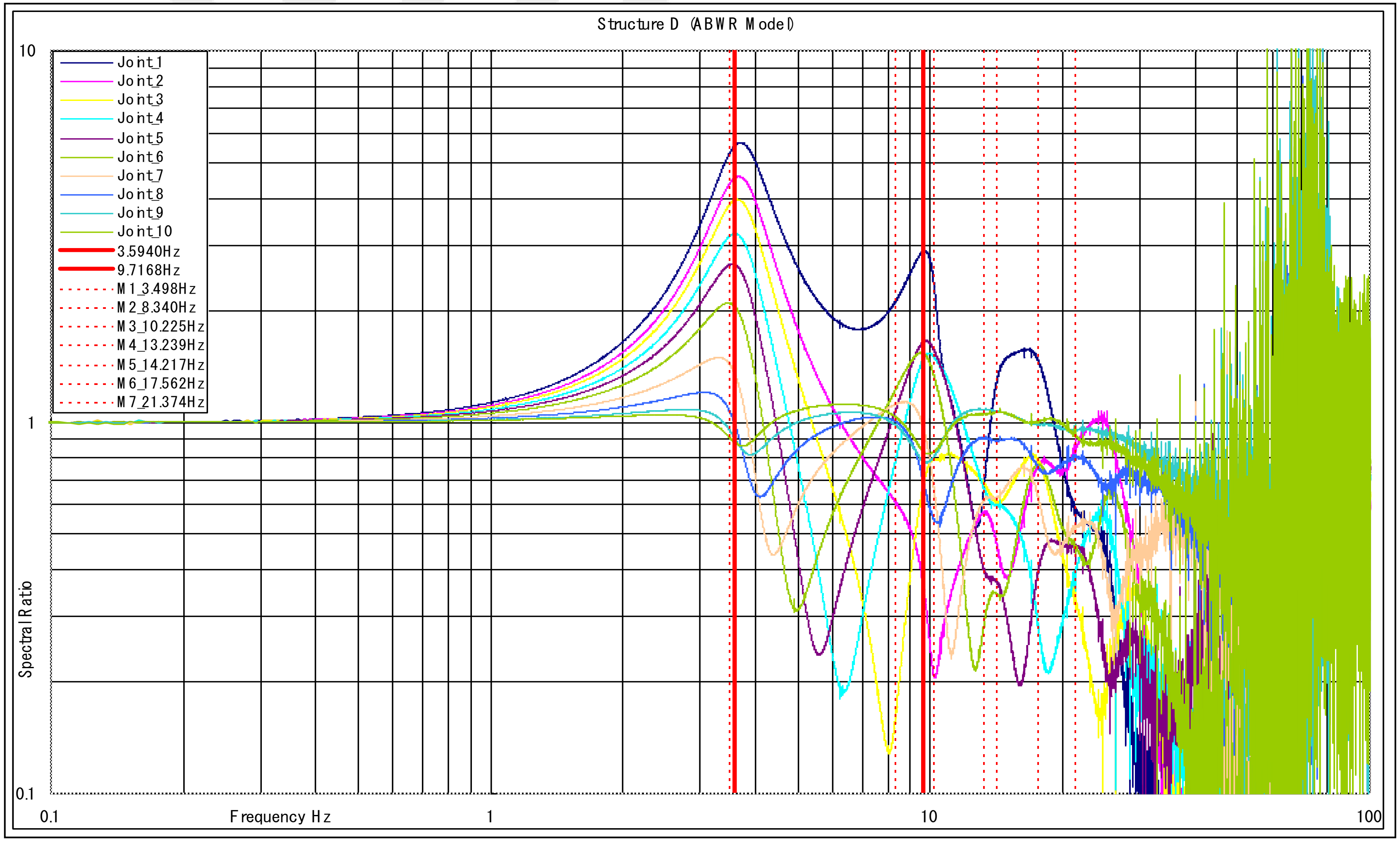


Figure 5.3.4 Structure D:



6. RESPONSE OF THE STRUCTURES – DIRECT INTEGRATION ANALYSIS

6.1 Genearal

As it was explained in the previous chapter, before running a Nonlinear Direct Integration Time History Analysis, we need to run a Nonlinear Modal Time-History Analysis, which is based on modal superposition method, where we can use constant damping ratio for all frequencies. The NIGH010410231756.NS2 record of Nigata Earthquake was selected as a sample record to explain analysis procedures. A Nonlinear Modal Time-History Analysis case was performed with constant modal damping for NIGH010410231756.NS2 strong ground motion record. By dividing absolute response acceleration of each level (M1,M2…Mn) to the input acceleration and using Fourier transforms, the transfer functions were calculated for each level of LSR Structure.

Using the following procedure the integration parameters such as Mass proportional coefficient (a_0) and stiffness proportional coefficient (a_1) is calculated. As an example the procedure that used to calculate these parameters for NS direction of Structure A is explained here. First, transfer functions are calculated (see Chapter 5 5.3.1.a Structure A NS Direction) for Structure A in NS direction. Second, average pick frequencies for top six floor is calculated. Here we got 2.91 Hz and 10.48 Hz. It is accepted that all modes has 3 (for this model) percent of constant damping. Mass and stiffness proportional coefficients are calculated by using *equation 6-1* of a_0 and a_1 [6].

Equation 6-1: Equation of Mass proportional coefficient (a_0) and stiffness proportional coefficient (a_1)

$$a_0 = \zeta \frac{2\omega_i \omega_j}{\omega_i + \omega_j} \qquad a_1 = \zeta \frac{2}{\omega_i + \omega_j}$$

Here ω_1=18.31572, ω_2=65.89982 and ξ is constant 0.03. Coefficients are calculated as a_0=0.85993833 and a_1=0.00071245755.

This time Nonlinear Direct Integration Time History Analysis is performed for NIGH010410231756.NS2 strong ground motion record, the same way as we have done in the previous case - by dividing absolute response acceleration of each level (M1, M2…M10) to the input acceleration and using Fourier transforms, the transfer functions are calculated for the each level of LSR Structure (see Chapter 5, Transfer function).

6.2. Nonlinear Direct Integration Time History Analysis

After finding out the damping coefficients, Nonlinear Direct Integration Time history Analysis is performed for 1000 strong ground motion. As we have chosen the sample NIGH010410231756.NS2 strong ground motion record waveform *(Figure6.2.1)*, and Fourier transform *(Figure6.2.2)* can be seen below. Also response acceleration (*Figure6.2.3*) and relative displacements (*Figure4-9a and 4-9b*) of each level (M1, M2…M10) of LSR Structures can be seen below.

Figure6.2.1 NIGH010410231756.NS2 earthquake records wave form.(gal)

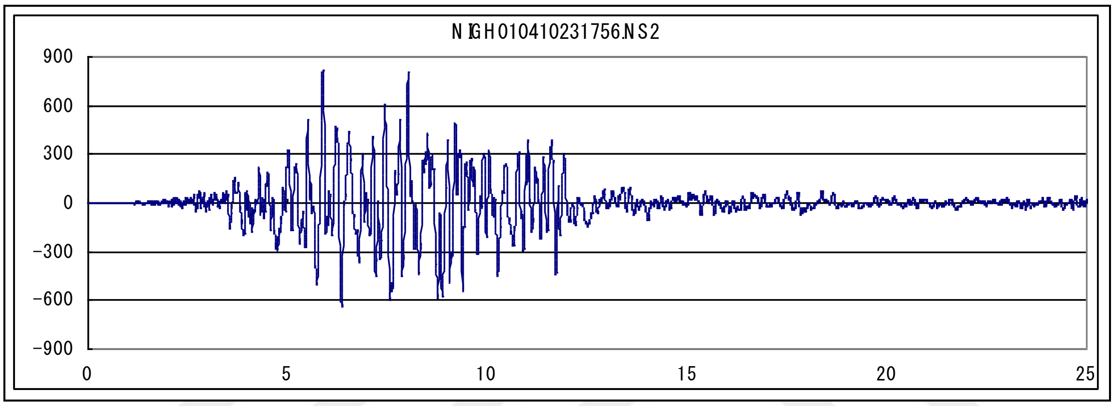


*Figure6.2.2 NIGH010410231756.NS2 earthquake record Fourier Transform. ((cm/sec/sec)*sec)-Hz*

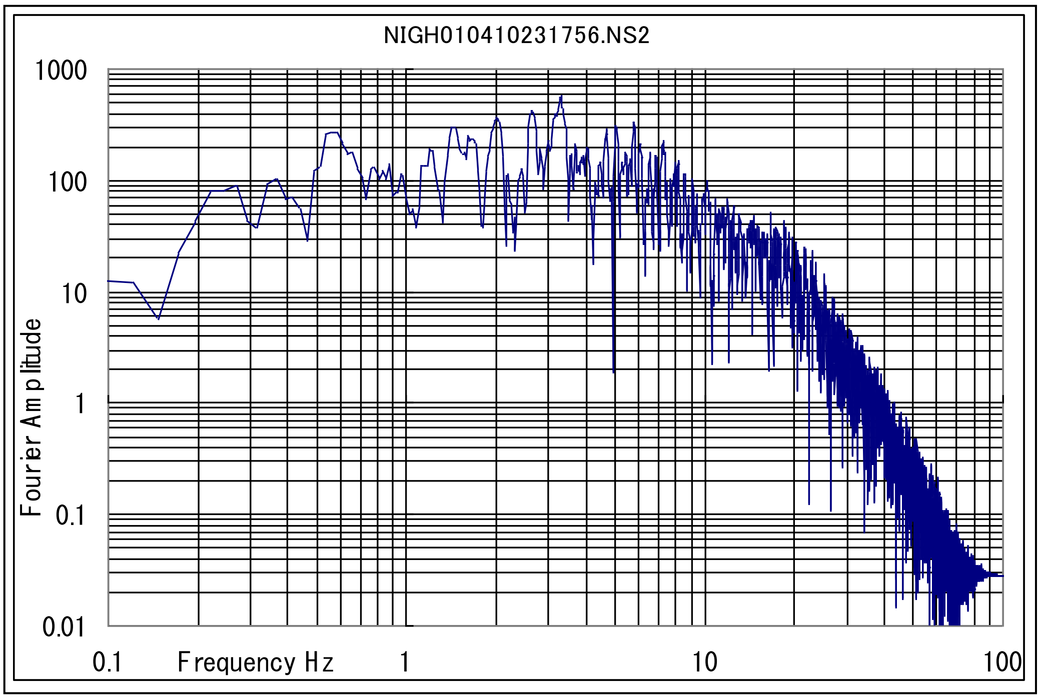


Figure6.2.3 Structure A Response acceleration for NIGH010410231756.NS2 (gal-Sec)

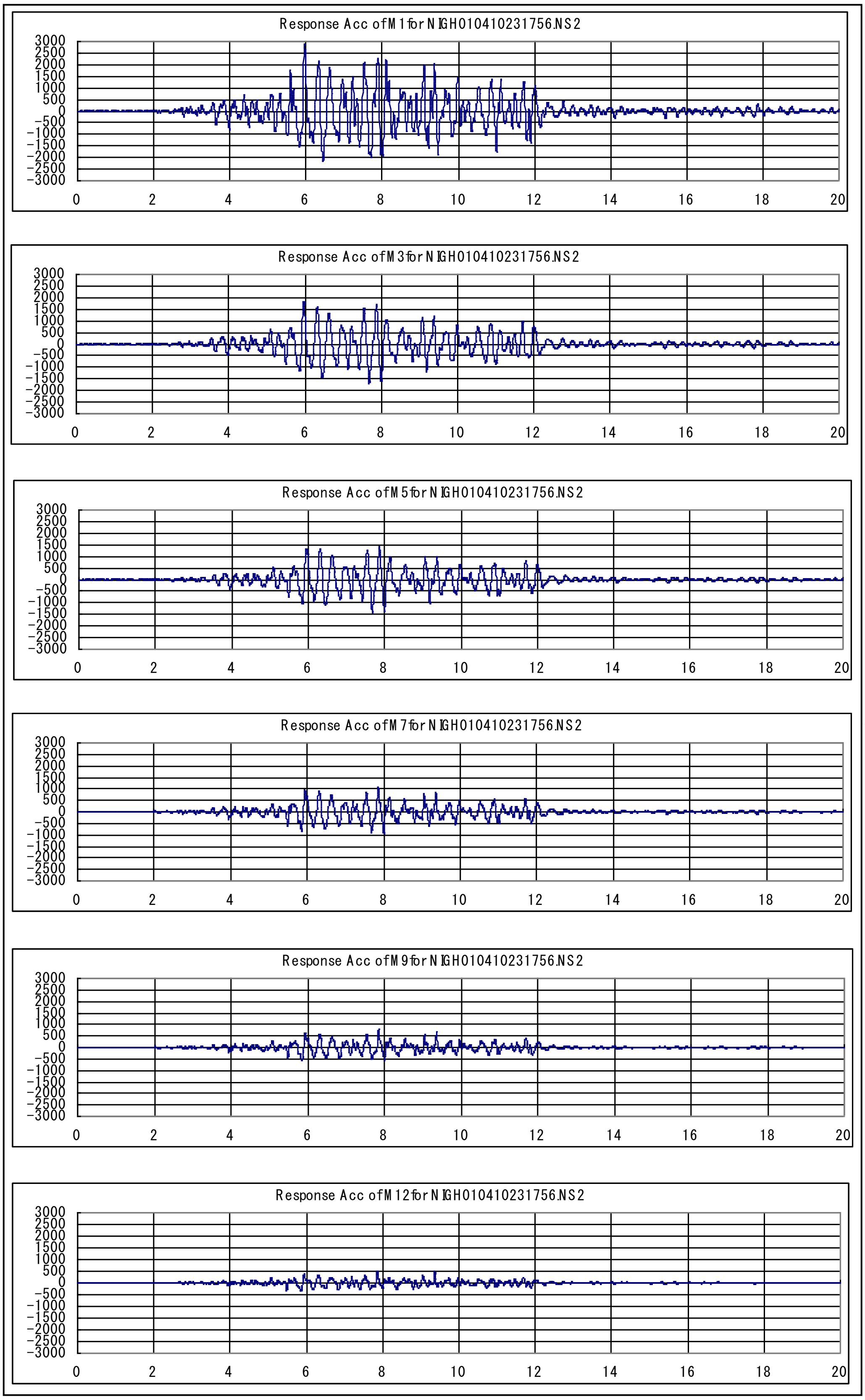
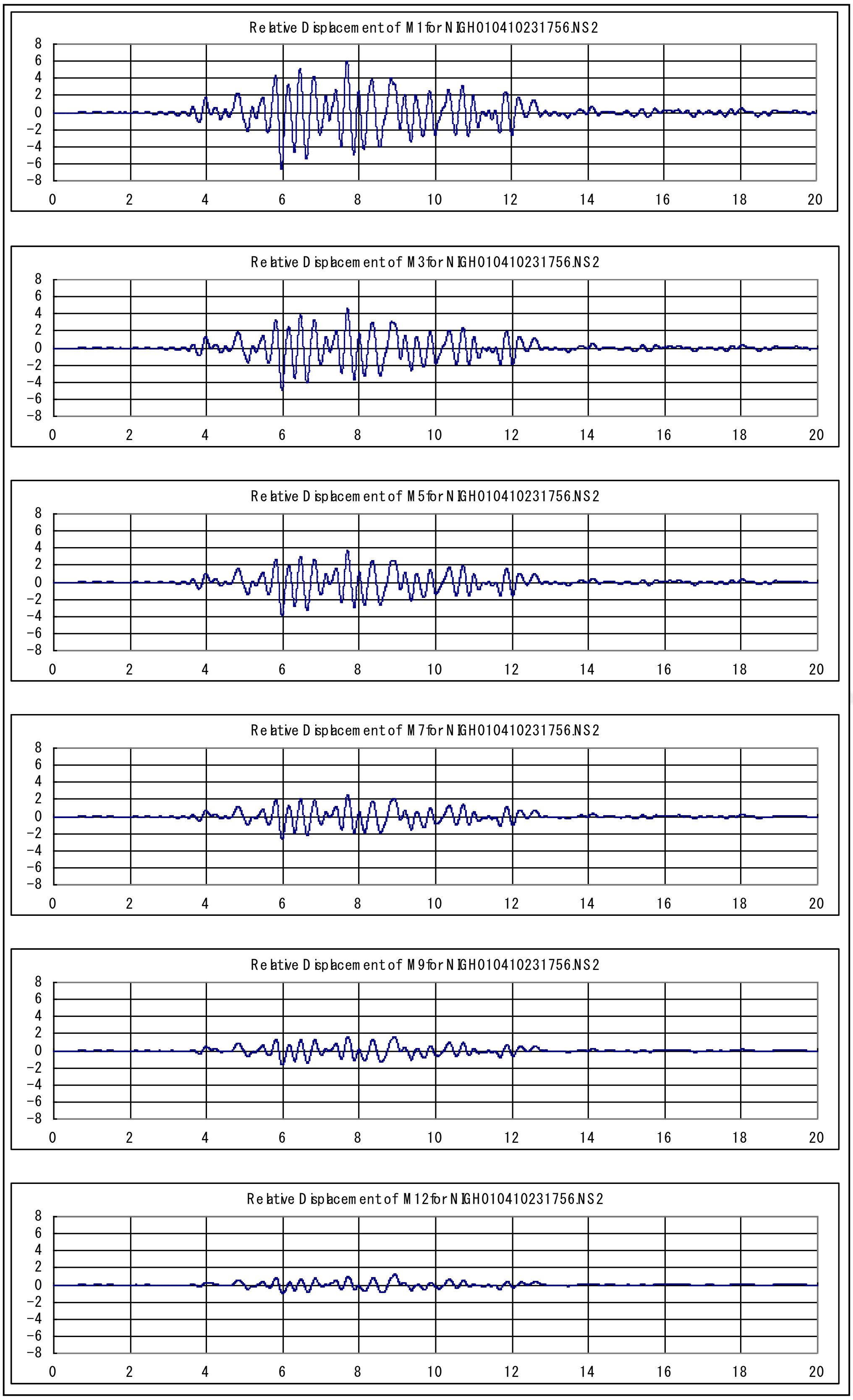


Figure6.2.4 Structure A Relative Displacement for NIGH010410231756.NS2 (cm)



7. DETERMINATION OF GROUND MOTION PARAMETERS

7.1 Seismic Indexes of Ground Motions

In this research, the correlation with the Shear responses of the LSR structure and following seismic indexes are examined. Each seismic index depends of the following method of calculating.

PGA (maximum ground motion acceleration)

PGA (maximum ground motion acceleration) is an assumed value of the maximum absolute acceleration value of the strong ground motion record. Before calculating this seismic index, the records are baseline corrected and long period vibrations filtered by using "Basefilter" subroutine that is often used for filtering data in KAWASE Laboratory.

PGV (maximum ground motion velocity)

PGV is the maximum absolute value from velocity waveform, which is obtained by integrating acceleration record using the Fourier transform.

PGA×PGV、

PGA (maximum ground motion acceleration) and PGV (maximum ground motion velocity) are multiplied.

A_0 measurement parameter of seismic intensity

The value of A_0 is an index that used to calculate seismic intensity by expression (7.1). It can be said that A_0 is a strength of the earthquake movement.

$$\mathrm{I} = 2 \cdot \log(A_0) + 0.7 \quad \text{……………………………….(7.1)}$$

Here,

I - Measurement of seismic intensity; A_0 - Maximum value of *a*, which satisfies $\int w(t \cdot a)dt \geq 0.3$ (the range of integration is assumed to be the time duration that the strong shaking continues); t - time (sec); *a* – a parameter that is related to the strong ground motion (cm/sec2); $w(t \cdot a)$ - this parameter depends on the following relations:

$$v(t) < a \text{ ------ } w(t \cdot a) = 0$$

$$v(t) \geq a \text{ ------ } w(t \cdot a) = 1$$

where

$v(t)$ is an orthogonal acceleration of three components in each time interval t of earthquake movement.

Types of Filter and its formula

Filter Type	Calculating formula
Filter for effect at cycle	$(1/f)^{1/2}$
High-cut Filter	$(1+0.694X^2+0.241X^4+0.0557X^6+0.009664X^8+0.00134X^{10}+0.000155X^{12})^{-1/2}$
Low-cut Filter	$(1-exp(-(f/0.5)^3))^{1/2}$

f - frequency of the earthquake movement (Hz);

$X = f / f_c$ ($f_c = 10\ H_z$)

$f_0 = 0.5\ H_z$

8. CONCLUSION:

RELATIONSHIP OF STRUCTURES` SEISMIC RESPONSES AND STRENGTH INDEXES OF GROUND MOTION – REGRESSION LINES

The purpose of the research is to examine the relationship between the response of LSR structures and the strength indexes of earthquakes. The strength indexes in this research are PGA, PGV, A_0 and PGAxPGV. On the other hand, the responses of the structures are represented by shear forces at each floor level.

The structures were analyzed for totally 500 earthquakes shown in *Table3-1-1*.Shear force response of linear members are plotted against ground motion strength indexes and linear regression line passing through the coordinate system 0 point is drawn. Shear elasticity limits are also shown on each figure. From the prospect of predicting building damage for a certain level earthquake, better correlation would indicate a better adequacy of a particular strength index for its use in damage estimation.

It is difficult to make a definite conclusion about an index or indexes, which are suitable for damage prediction, we intended to identify in this study. Since we have three different kinds of structures and various types of earthquake, we have to individually focus on structures and on ground motions.

Let us first discus about structure A. Structure A is highest among the concerned structures. Also it has relatively low frequency predominant mode, 3 Hz. It can be seen from *Table 8.2.1*, where includes all analyzed ground motions, shear response has a very good correlation *(R^2=0.92-0.85)* with PGA for the floors upper than 5. Therefore, the strength index PGA can be used with considerable accuracy for prediction of building damage for upper floors. On the other hand, it is clear that the strength indexes PGV does not show good correlation with shear force for upper floors, but for the lower floors PGV gives comparatively good correlation *(R^2=0.64-0.76)*. The upper floors are sensitive to the high frequency shaking, therefore can be predicted by PGA, but lower floors are more or less sensitive to the low frequency shaking, thus can be predicted by PGV. As for the A_0, from *Table 8.2.1* it can be seen that it shows considerably good correlation *(R^2=0.74-0.87)* for all floors except for the topmost floor. PGV correlation coefficient values lie between PGA and PGV correlation coefficients, except for the lowest two floors. This fact can be explained if we think that A_0 is an index intermediate between PGA and PGV [7]. It can be pointed out that index PGAxPGV does have bad linear correlation, so its correlation is made nonlinear, which improves the situation greatly.

Now let us discuss the case when only one earthquake data considered. First let us have a look on M=6.8 2004/10/23 Nigata earthquake. These sets of records consist of main shock and following five aftershocks. In total 586 (including NS, EW components) strong motion data were analyzed for this particular earthquake. From *Table 8.2.2* it is clear that PGA shows very good correlation at the top floors, but PGV and A_0 show good correlation for the lower floors.

Second, M=7.0 2003/05/26 Miyagi-oki earthquake data consists of 88 (including NS, EW components) strong motion records. From *Table 8.2.4* it is clear that PGA for top floors, PGV and A_0 for lower floors show good correlation wits shear force response.

Third, M=8.0 2003/09/26 Tokachi oki earthquake data consists of 68 (including NS, EW components) strong motion records. From *Table 8.1.3* it can be seen that PGA shows a good correlation with shear force for upper floors, as it was for the two cases before. In contrast this time we can not see good correlation with PGV for all floors. Correlation coefficients obtained are minus values. A0 shows relatively better correlation in the lower floors, but the correlation coefficient values are not the same high as it was in the previous two cases.

Now we will discus about structure B. From *Table 8.2.1 – 8.2.4* it is clear that for most cases PGA shows good correlation with shear force response. This structure has high frequency predominant vibration mode, therefore its behavior controlled by high frequency excitation, which is well represented by PGA index.

For structure C, as we can see from *Table 8.3.1 – 8.3.4,* it is clear that PGA shows very good correlation for all floors. This structure has high frequency predominant vibration mode, same as structure B, and can be explained the same way. For these structures PGA is the best index in prediction of building damage.

At last, for structure D, which has relatively low frequency predominant vibration mode, , as we can see from *Table 8.4.1-8.4.4,* PGA is the best correlated index for all cases except for Miyagi Oki earthquake. In case of Miyagi earthquake PGA shows good correlation for only topmost floor (0.73), where A_0 is well correlated in all floors (0.7-0.79).

In general, it is difficult to predict and explain the expected building damage using only one particular strength index. PGA can be used to predict the damage for structures, which have higher predominant vibration frequency such as structure B, and Structure C. PGV can be use to find damage index for the lower floors of structures, which have relatively lower predominant vibration frequency, such as structure A, and Structure D. It could be said that PGA index in most cases are good index for damage prediction, but PGV can be considered the second good index after PGA for low frequency LSR structures.

Therefore, it is necessary to use a proper strength index according to the frequency characteristics, which rules the shear force response of floors. The regression values and regression coefficients calculated for each individual earthquake are summarized in *Tables 8.1.1-8.3.4* and *Figures 8.1.1-8.3.16* below.

Using shear indexes which represent well correlated strength index of ground motion PGA, PGV A0 and PGA*PGV, we can predict damage level of a building immediately after an earthquake, without any complex calculations.

Table 8.1.1 Structure A Shear indexes and Regression line coefficients R^2

For all selected ground motions (n=1000)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL10 (Bar1)	4.576	0.920	4.408	0.920	33.830	0.214	32.735	0.224	5.404	0.497	5.219	0.504	$43.099x^{0.401}$	0.823	$41.218x^{0.401}$	0.822
FL9 (Bar2)	7.764	0.933	7.487	0.932	58.362	0.263	56.542	0.274	9.273	0.541	8.966	0.548	$68.809x^{0.408}$	0.845	$65.953x^{0.408}$	0.844
FL8 (Bar3)	17.693	0.909	17.230	0.907	145.785	0.518	142.554	0.529	22.506	0.733	21.978	0.740	$93.066x^{0.463}$	0.929	$89.987x^{0.463}$	0.931
FL7 (Bar4)	30.301	0.859	29.735	0.858	259.365	0.596	255.266	0.602	39.551	0.772	38.895	0.776	$115.044x^{0.494}$	0.918	$110.844x^{0.496}$	0.919
FL6 (Bar5)	40.807	0.849	40.175	0.847	352.869	0.617	348.178	0.622	53.636	0.783	52.886	0.787	$148.308x^{0.498}$	0.920	$143.685x^{0.499}$	0.919
FL5 (Bar6)	54.717	0.847	54.037	0.846	477.544	0.641	472.125	0.644	72.371	0.800	71.519	0.802	$193.710x^{0.500}$	0.925	$192.018x^{0.500}$	0.925
FL4 (Bar7)	70.279	0.845	69.597	0.847	619.996	0.670	613.893	0.671	93.598	0.819	92.676	0.821	$241.030x^{0.503}$	0.930	$242.443x^{0.502}$	0.931
FL3 (Bar8)	90.518	0.848	89.908	0.851	805.816	0.697	799.573	0.696	121.163	0.837	120.269	0.838	$311.559x^{0.503}$	0.940	$315.111x^{0.501}$	0.940
FL2 (Bar9)	98.315	0.846	97.941	0.851	884.343	0.724	879.206	0.723	132.374	0.853	131.694	0.854	$336.697x^{0.503}$	0.946	$341.173x^{0.502}$	0.946
FL1 (Bar10)	98.327	0.834	98.058	0.838	900.280	0.764	896.291	0.763	133.757	0.872	133.216	0.872	$317.672x^{0.508}$	0.949	$322.206x^{0.507}$	0.950
Average		**0.869**		**0.870**		**0.570**		**0.575**		**0.751**		**0.754**		**0.913**		**0.913**

Table 8.1.2 Structure A Shear indexes and Regression line coefficients R^2

For 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL10 (Bar1)	4.982	0.936	4.777	0.932	68.245	0.648	65.544	0.648	7.869	0.713	7.548	0.710	$32.892x^{0.446}$	0.780	$31.789x^{0.445}$	0.773
FL9 (Bar2)	8.393	0.941	8.059	0.938	115.991	0.681	111.502	0.681	13.371	0.747	12.842	0.744	$52.726x^{0.452}$	0.807	$51.034x^{0.451}$	0.800
FL8 (Bar3)	18.754	0.925	18.190	0.925	271.562	0.821	263.795	0.825	31.182	0.873	30.273	0.875	$68.155x^{0.517}$	0.914	$66.289x^{0.517}$	0.916
FL7 (Bar4)	31.624	0.893	30.933	0.892	466.337	0.844	456.809	0.847	53.369	0.885	52.272	0.887	$81.984x^{0.554}$	0.880	$78.834x^{0.557}$	0.880
FL6 (Bar5)	42.153	0.889	41.397	0.887	624.158	0.851	613.615	0.852	71.317	0.887	70.095	0.888	$107.089x^{0.556}$	0.882	$103.616x^{0.558}$	0.879
FL5 (Bar6)	55.666	0.887	54.881	0.887	827.762	0.861	816.124	0.860	94.475	0.894	93.131	0.893	$141.868x^{0.556}$	0.888	$141.144x^{0.555}$	0.888
FL4 (Bar7)	70.125	0.882	69.408	0.885	1050.031	0.874	1037.563	0.872	119.671	0.904	118.253	0.902	$179.924x^{0.556}$	0.892	$182.211x^{0.553}$	0.893
FL3 (Bar8)	88.356	0.876	87.927	0.880	1334.224	0.891	1325.293	0.890	151.843	0.917	150.820	0.916	$242.053x^{0.548}$	0.903	$245.081x^{0.546}$	0.904
FL2 (Bar9)	94.440	0.874	94.246	0.878	1432.964	0.902	1427.419	0.902	162.925	0.926	162.275	0.925	$269.520x^{0.543}$	0.910	$273.037x^{0.542}$	0.910
FL1 (Bar10)	92.269	0.870	92.053	0.874	1407.219	0.913	1401.497	0.912	159.820	0.933	159.167	0.932	$261.749x^{0.544}$	0.912	$265.445x^{0.542}$	0.912
Average		**0.897**		**0.898**		**0.829**		**0.829**		**0.868**		**0.867**		**0.877**		**0.876**

Table 8.1.3 Structure A ***Shear indexes and Regression line coefficients*** R^2

For 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL10 (Bar1)	4.460	0.891	4.286	0.890	32.268	-0.460	31.068	-0.461	5.440	0.342	5.235	0.346	$7.458x^{0.552}$	0.423	$7.379x^{0.549}$	0.426
FL9 (Bar2)	7.784	0.891	7.487	0.890	56.500	-0.438	54.453	-0.439	9.515	0.360	9.163	0.364	$12.975x^{0.553}$	0.440	$12.925x^{0.549}$	0.443
FL8 (Bar3)	20.507	0.862	19.959	0.863	151.158	-0.336	147.351	-0.335	25.345	0.433	24.684	0.435	$34.873x^{0.552}$	0.502	$34.450x^{0.550}$	0.506
FL7 (Bar4)	36.412	0.832	35.793	0.835	271.754	-0.285	267.252	-0.282	45.382	0.471	44.604	0.472	$62.068x^{0.552}$	0.534	$60.808x^{0.553}$	0.538
FL6 (Bar5)	49.033	0.817	48.368	0.819	368.579	-0.262	363.624	-0.259	61.404	0.493	60.551	0.492	$83.366x^{0.553}$	0.551	$81.732x^{0.554}$	0.554
FL5 (Bar6)	65.039	0.793	64.338	0.797	494.820	-0.222	489.151	-0.226	82.062	0.528	81.121	0.525	$109.118x^{0.555}$	0.578	$108.450x^{0.555}$	0.580
FL4 (Bar7)	81.973	0.756	81.198	0.760	634.696	-0.158	628.176	-0.161	104.486	0.577	103.430	0.574	$135.323x^{0.558}$	0.613	$133.555x^{0.559}$	0.615
FL3 (Bar8)	103.138	0.699	102.259	0.703	815.393	-0.079	807.947	-0.084	132.991	0.627	131.807	0.627	$176.891x^{0.556}$	0.652	$175.404x^{0.556}$	0.653
FL2 (Bar9)	110.318	0.650	109.631	0.656	885.748	-0.019	879.293	-0.024	143.431	0.663	142.446	0.662	$200.749x^{0.552}$	0.684	$198.663x^{0.552}$	0.685
FL1 (Bar10)	108.566	0.577	107.954	0.584	887.693	0.065	881.888	0.061	142.524	0.699	141.634	0.699	$214.166x^{0.545}$	0.712	$211.657x^{0.545}$	0.714
Average		**0.777**		**0.780**		**-0.219**		**-0.221**		**0.519**		**0.52**		**0.569**		**0.571**

Table 8.1.4 Structure A *Shear indexes and Regression line coefficients* R^2

For 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL10 (Bar1)	4.576	0.920	4.408	0.920	33.830	0.214	32.735	0.224	5.404	0.497	5.219	0.504	$43.099x^{0.401}$	0.823	$41.218x^{0.401}$	0.822
FL9 (Bar2)	7.764	0.933	7.487	0.932	58.362	0.263	56.542	0.274	9.273	0.541	8.966	0.548	$68.809x^{0.408}$	0.845	$65.953x^{0.408}$	0.844
FL8 (Bar3)	17.693	0.909	17.230	0.907	145.785	0.518	142.554	0.529	22.506	0.733	21.978	0.740	$93.066x^{0.463}$	0.929	$89.987x^{0.463}$	0.931
FL7 (Bar4)	30.301	0.859	29.753	0.858	259.365	0.596	255.266	0.602	39.551	0.772	38.895	0.776	$115.044x^{0.494}$	0.918	$110.844x^{0.496}$	0.919
FL6 (Bar5)	40.807	0.849	40.175	0.847	352.869	0.617	348.178	0.622	53.636	0.783	52.886	0.787	$148.308x^{0.498}$	0.920	$143.685x^{0.499}$	0.919
FL5 (Bar6)	54.717	0.847	54.037	0.846	477.544	0.641	472.125	0.644	72.371	0.800	71.519	0.802	$193.710x^{0.500}$	0.925	$192.018x^{0.500}$	0.925
FL4 (Bar7)	70.279	0.845	69.597	0.847	619.996	0.670	613.893	0.671	93.598	0.819	92.676	0.821	$241.030x^{0.503}$	0.930	$242.443x^{0.502}$	0.931
FL3 (Bar8)	90.518	0.848	89.908	0.851	805.816	0.697	799.573	0.696	121.163	0.837	120.269	0.838	$311.559x^{0.503}$	0.940	$315.111x^{0.501}$	0.940
FL2 (Bar9)	98.315	0.846	97.941	0.851	884.343	0.724	879.206	0.723	132.374	0.853	131.694	0.854	$336.697x^{0.503}$	0.946	$341.173x^{0.502}$	0.946
FL1 (Bar10)	98.327	0.834	98.058	0.838	900.280	0.764	896.291	0.763	133.757	0.872	133.216	0.872	$317.672x^{0.508}$	0.949	$322.206x^{0.507}$	0.950
Average		**0.869**		**0.870**		**0.570**		**0.575**		**0.751**		**0.754**		**0.913**		**0.913**

Table 8.2.1 Structure B *Shear indexes and Regression line coefficients* R^2

For all selected ground motions (n=1000)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL3 (Bar1)	1.988	0.644	1.645	0.748	13.088	-0.110	11.168	0.022	2.166	0.136	1.831	0.267	$27.582x^{0.353}$	0.604	$17.484x^{0.379}$	0.684
FL2 (Bar2)	4.257	0.705	3.614	0.798	28.764	-0.057	25.089	0.068	4.715	0.198	4.078	0.323	$55.513x^{0.361}$	0.648	$37.374x^{0.384}$	0.725
FL1 (Bar3)	6.368	0.778	5.564	0.865	44.541	0.028	39.969	0.148	7.216	0.291	6.415	0.409	$75.664x^{0.373}$	0.703	$54.632x^{0.392}$	0.775
Average		**0.709**		**0.804**		**-0.046**		**0.079**		**0.208**		**0.333**		**0.652**		**0.728**

Table 8.2.2 Structure B *Shear indexes and Regression line coefficients* R^2

For 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL3 (Bar1)	2.173	0.689	1.807	0.841	27.763	0.263	23.621	0.472	3.192	0.308	2.705	0.509	$23.279x^{0.378}$	0.480	$15.288x^{0.398}$	0.559
FL2 (Bar2)	4.555	0.722	3.918	0.874	58.786	0.306	51.378	0.499	6.762	0.354	5.898	0.544	$47.913x^{0.382}$	0.519	$33.209x^{0.401}$	0.604
FL1 (Bar3)	6.644	0.768	5.941	0.914	87.111	0.376	78.522	0.546	10.011	0.425	9.032	0.598	$66.715x^{0.391}$	0.575	$49.321x^{0.406}$	0.664
Average		**0.726**		**0.876**		**0.315**		**0.506**		**0.362**		**0.55**		**0.525**		**0.609**

Table 8.2.3 Structure B Shear indexes and Regression line coefficients R^2

For 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL3 (Bar1)	1.415	0.852	1.176	0.934	10.118	-0.670	8.523	-0.683	1.707	0.171	1.431	0.248	$3.725x^{0.506}$	0.363	$2.848x^{0.517}$	0.462
FL2 (Bar2)	3.208	0.895	2.764	0.957	23.152	-0.645	20.189	-0.645	3.890	0.223	3.377	0.288	$8.240x^{0.510}$	0.408	$6.375x^{0.523}$	0.500
FL1 (Bar3)	5.134	0.936	4.595	0.975	37.412	-0.603	33.826	-0.601	6.255	0.276	5.634	0.329	$12.442x^{0.517}$	0.465	$10.037x^{0.529}$	0.542
Average		**0.894**		**0.955**		**-0.639**		**-0.643**		**0.223**		**0.288**		**0.412**		**0.501**

Table 8.2.4 Structure B Shear indexes and Regression line coefficients R^2

For 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL3 (Bar1)	3.289	0.668	2.582	0.655	65.851	-0.152	51.277	-0.081	6.792	0.089	5.317	0.142	$2.031x^{0.713}$	0.473	$1.150x^{0.747}$	0.521
FL2 (Bar2)	6.612	0.692	5.418	0.689	134.224	-0.149	108.740	-0.067	13.814	0.112	11.254	0.171	$5.157x^{0.691}$	0.493	$3.019x^{0.724}$	0.545
FL1 (Bar3)	9.161	0.728	7.778	0.745	188.876	-0.136	158.601	-0.046	19.380	0.145	16.372	0.218	$9.041x^{0.668}$	0.526	$5.786x^{0.696}$	0.581
Average		**0.696**		**0.696**		**-0.146**		**-0.065**		**0.115**		**0.177**		**0.497**		**0.549**

Table 8.3.1 Structure C Shear indexes and Regression line coefficients R^2

For all selected ground motions (n=1000)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL4 (Bar1)	23.683	0.699	24.954	0.710	155.450	-0.061	164.190	-0.056	25.841	0.192	27.285	0.202	$239.150x^{0.386}$	0.640	$245.850x^{0.388}$	0.647
FL3 (Bar2)	73.202	0.750	75.507	0.755	492.708	-0.017	511.842	-0.006	81.227	0.248	84.196	0.260	$682.013x^{0.397}$	0.677	$679.922x^{0.401}$	0.685
FL2 (Bar3)	118.399	0.796	121.782	0.794	818.400	0.038	846.109	0.047	133.641	0.308	137.981	0.317	$1009.783x^{0.408}$	0.712	$999.694x^{0.412}$	0.717
FL1 (Bar4)	163.330	0.849	166.441	0.847	1165.100	0.117	1192.083	0.124	188.140	0.390	192.427	0.398	$1249.506x^{0.421}$	0.751	$1229.871x^{0.425}$	0.756
FL2 (Bar5)	7.569	0.710	5.953	0.785	51.026	-0.027	41.409	0.058	8.383	0.222	6.747	0.320	$80.627x^{0.380}$	0.621	$53.611x^{0.400}$	0.696
FL1 (Bar6)	11.947	0.782	10.110	0.854	83.422	0.051	72.370	0.135	13.532	0.308	11.671	0.405	$116.796x^{0.391}$	0.675	$85.264x^{0.408}$	0.735
Average		**0.764**		**0.791**		**0.017**		**0.050**		**0.278**		**0.317**		**0.679**		**0.706**

Table 8.3.2 Structure C Shear indexes and Regression line coefficients R^2

For 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL4 (Bar1)	25.047	0.806	26.642	0.826	333.500	0.463	355.650	0.491	38.286	0.509	40.716	0.531	$179.380x^{0.430}$	0.542	$183.770x^{0.433}$	0.555
FL3 (Bar2)	76.771	0.828	79.653	0.842	1024.719	0.488	1068.742	0.517	117.832	0.540	122.557	0.562	$513.873x^{0.440}$	0.577	$509.622x^{0.445}$	0.590
FL2 (Bar3)	122.539	0.851	126.457	0.860	1645.650	0.523	1712.223	0.556	189.267	0.576	196.246	0.601	$765.543x^{0.451}$	0.610	$753.597x^{0.456}$	0.620
FL1 (Bar4)	166.191	0.881	170.113	0.885	2259.406	0.582	2331.051	0.611	259.557	0.634	266.833	0.653	$962.866x^{0.461}$	0.645	$942.621x^{0.466}$	0.653
FL2 (Bar5)	8.247	0.799	6.483	0.862	107.745	0.409	84.760	0.485	12.373	0.455	9.752	0.534	$65.598x^{0.411}$	0.477	$45.479x^{0.424}$	0.548
FL1 (Bar6)	12.767	0.853	10.727	0.901	168.897	0.481	141.487	0.533	19.409	0.531	16.285	0.585	$96.687x^{0.420}$	0.528	$73.894x^{0.429}$	0.586
Average		**0.836**		**0.863**		**0.491**		**0.532**		**0.541**		**0.578**		**0.563**		**0.592**

Table 8.3.3 Structure C Shear indexes and Regression line coefficients R^2

For 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL4 (Bar1)	18.304	0.515	19.765	0.463	126.47	-0.779	135.190	-0.771	21.568	-0.134	23.116	-0.175	$105.780x^{0.421}$	0.175	$136.810x^{0.401}$	0.147
FL3 (Bar2)	60.301	0.568	63.939	0.515	419.265	-0.783	440.530	-0.776	71.318	-0.101	75.121	-0.144	$307.051x^{0.435}$	0.203	$386.230x^{0.416}$	0.175
FL2 (Bar3)	102.557	0.635	107.852	0.580	717.391	-0.779	747.956	-0.782	121.767	-0.056	127.254	-0.104	$447.955x^{0.452}$	0.238	$556.825x^{0.434}$	0.207
FL1 (Bar4)	148.980	0.727	155.309	0.674	1050.806	-0.762	1087.288	-0.767	177.753	0.012	184.289	-0.036	$531.689x^{0.474}$	0.291	$631.650x^{0.460}$	0.260
FL2 (Bar5)	5.651	0.835	4.750	0.923	39.819	-0.691	34.203	-0.685	6.754	0.120	5.765	0.236	$15.234x^{0.502}$	0.339	$11.263x^{0.519}$	0.437
FL1 (Bar6)	9.643	0.893	8.577	0.944	68.793	-0.666	62.213	-0.655	11.614	0.188	10.445	0.270	$25.378x^{0.506}$	0.390	$20.081x^{0.521}$	0.468
Average		**0.696**		**0.683**		**-0.743**		**-0.739**		**0.005**		**0.008**		**0.273**		**0.282**

Table 8.3.4 Structure C Shear indexes and Regression line coefficients R^2

For 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)																
	PGA				PGV				A_0				PGA*PGV			
Floor No	NS		EW		NS		EW		NS		EW		NS		EW	
(Member No)	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL4 (Bar1)	34.901	0.741	37.062	0.751	738.070	-0.085	783.060	-0.047	75.596	0.227	80.508	0.271	$31.020x^{0.682}$	0.541	$27.770x^{0.701}$	0.562
FL3 (Bar2)	103.216	0.751	107.534	0.754	2220.756	-0.040	2319.236	0.014	227.036	0.292	237.982	0.351	$107.893x^{0.667}$	0.569	$94.698x^{0.685}$	0.588
FL2 (Bar3)	160.479	0.762	165.621	0.750	3486.057	-0.010	3617.569	0.048	355.793	0.332	370.615	0.395	$190.359x^{0.654}$	0.596	$168.197x^{0.671}$	0.608
FL1 (Bar4)	208.877	0.771	213.443	0.752	4586.474	0.026	4718.488	0.083	467.101	0.376	482.164	0.439	$285.473x^{0.640}$	0.633	$255.932x^{0.654}$	0.644
FL2 (Bar5)	12.163	0.705	9.082	0.683	248.970	-0.063	182.167	-0.110	25.704	0.199	18.867	0.141	$5.489x^{0.750}$	0.535	$4.947x^{0.728}$	0.542
FL1 (Bar6)	17.837	0.742	14.284	0.739	370.064	-0.050	291.954	-0.091	38.145	0.239	30.118	0.186	$11.073x^{0.718}$	0.564	$10.319x^{0.701}$	0.579
Average		**0.745**		**0.738**		**-0.037**		**-0.017**		**0.278**		**0.297**		**0.573**		**0.587**

Table 8.4.1 Structure D Shear indexes and Regression line coefficients R^2

Floor No (Member No)	For all selected ground motions (n=1000)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL8 (Bar1)	11.209	0.875	86.208	0.307	13.675	0.572	$82.995x^{0.462}$	0.861
FL7 (Bar2)	25.856	0.853	205.972	0.393	32.315	0.632	$146.025x^{0.454}$	0.870
FL6 (Bar3)	40.119	0.836	326.322	0.440	50.839	0.661	$191.607x^{0.471}$	0.866
FL5 (Bar4)	58.644	0.833	484.891	0.482	75.076	0.689	$261.534x^{0.477}$	0.872
FL4 (Bar5)	69.988	0.839	582.695	0.504	89.959	0.706	$314.094x^{0.477}$	0.882
FL3 (Bar6)	93..033	0.852	782.784	0.540	120.326	0.736	$420.781x^{0.476}$	0.895
FL2 (Bar7)	77.185	0.860	659.340	0.587	100.631	0.768	$338.219x^{0.479}$	0.905
FL1 (Bar8)	50.091	0.863	435.052	0.639	65.963	0.802	$201.996x^{0.487}$	0.915
Foundation	81.382	0.858	728.664	0.720	109.291	0.857	$296.523x^{0.497}$	0.931
Average		**0.852**		**0.512**		**0.714**		**0.889**

Floor No (Member No)	For all selected ground motions (n=1000)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL6 (Bar10)	14.447	0.860	117.651	0.454	18.292	0.677	$81.195x^{0.454}$	0.891
FL5 (Bar11)	28.116	0.872	231.535	0.489	35.823	0.704	$155.604x^{0.457}$	0.900
FL4 (Bar12)	35.384	0.880	292.540	0.504	45.170	0.717	$195.761x^{0.457}$	0.904
FL3 (Bar13)	40.670	0.891	339.179	0.534	52.154	0.740	$223.296x^{0.458}$	0.910
FL2 (Bar14)	33.749	0.887	287.195	0.592	43.799	0.777	$196.186x^{0.467}$	0.918
FL1 (Bar15)	33.993	0.875	294.580	0.641	44.674	0.807	$145.082x^{0.481}$	0.922
Foundation	81.382	0.858	728.664	0.720	109.291	0.857	$296.523x^{0.497}$	0.931
Average		**0.862**		**0.522**		**0.723**		**0.896**

Table 8.4.2 Structure D Shear indexes and Regression line coefficients R^2

Floor No (Member No)	For 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL8 (Bar1)	12.051	0.875	165.880	0.637	19.196	0.704	$63.665x^{0.470}$	0.832
FL7 (Bar2)	27.207	0.851	380.656	0.666	44.019	0.729	$109.572x^{0.502}$	0.819
FL6 (Bar3)	41.787	0.837	589.395	0.677	68.121	0.738	$142.292x^{0.522}$	0.797
FL5 (Bar4)	60.280	0.832	856.275	0.691	98.863	0.750	$198.787x^{0.524}$	0.798
FL4 (Bar5)	71.439	0.835	1018.537	0.702	117.497	0.759	$242.075x^{0.521}$	0.812
FL3 (Bar6)	93.805	0.844	1350.350	0.733	155.371	0.785	$331.040x^{0.517}$	0.827
FL2 (Bar7)	75.966	0.843	1105.698	0.759	126.792	0.804	$274.385x^{0.515}$	0.833
FL1 (Bar8)	47.657	0.838	700.658	0.782	80.165	0.821	$168.799x^{0.518}$	0.840
Foundation	74.142	0.834	1114.549	0.837	127.134	0.869	$257.040x^{0.522}$	0.857
Average		**0.843**		**0.720**		**0.773**		**0.824**

Floor No (Member No)	For 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL6 (Bar10)	14.894	0.854	209.584	0.682	24.201	0.743	$64.665x^{0.493}$	0.838
FL5 (Bar11)	28.879	0.862	409.398	0.707	47.187	0.764	$125.062x^{0.493}$	0.844
FL4 (Bar12)	36.098	0.865	513.856	0.719	59.152	0.774	$158.721x^{0.492}$	0.846
FL3 (Bar13)	40.801	0.865	586.219	0.742	67.319	0.792	$184.108x^{0.490}$	0.848
FL2 (Bar14)	32.944	0.858	478.884	0.767	54.862	0.811	$142.912x^{0.495}$	0.851
FL1 (Bar15)	32.115	0.844	472.713	0.787	54.019	0.826	$123.356x^{0.509}$	0.850
Foundation	74.142	0.834	1114.549	0.837	127.134	0.869	$257.040x^{0.522}$	0.857
Average		**0.855**		**0.749**		**0.797**		**0.848**

Table 8.4.3 Structure D Shear indexes and Regression line coefficients R^2

Floor No (Member No)	For 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL8 (Bar1)	13.892	0.766	93.441	-0.461	16.259	0.169	$33.083x^{0.507}$	0.270
FL7 (Bar2)	33.619	0.774	228.599	-0.433	39.599	0.199	$75.975x^{0.513}$	0.300
FL6 (Bar3)	53.335	0.778	365.596	-0.407	63.101	0.222	$113.806x^{0.520}$	0.325
FL5 (Bar4)	77.863	0.783	539.546	-0.378	92.717	0.253	$155.273x^{0.528}$	0.357
FL4 (Bar5)	92.217	0.787	643.728	-0.361	110.280	0.272	$178.615x^{0.532}$	0.378
FL3 (Bar6)	120.002	0.794	850.131	-0.329	144.709	0.309	$221.106x^{0.538}$	0.420
FL2 (Bar7)	94.989	0.801	698.597	-0.295	118.042	0.351	$173.254x^{0.543}$	0.467
FL1 (Bar8)	61.079	0.812	449.120	-0.255	75.225	0.409	$106.685x^{0.548}$	0.530
Foundation	93.654	0.793	722.267	-0.181	118.590	0.544	$189.161x^{0.538}$	0.645
Average		**0.788**		**-0.344**		**0.303**		**0.410**

Floor No (Member No)	For 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL6 (Bar10)	18.420	0.777	127.941	-0.376	12.977	0.257	$36.708x^{0.502}$	0.359
FL5 (Bar11)	35.447	0.787	249.905	-0.344	42.630	0.292	$65.667x^{0.537}$	0.403
FL4 (Bar12)	44.117	0.791	313.256	-0.327	53.256	0.310	$79.148x^{0.541}$	0.425
FL3 (Bar13)	49.664	0.805	357.329	-0.301	60.374	0.345	$86.934x^{0.545}$	0.466
FL2 (Bar14)	40.351	0.810	295.204	-0.271	49.530	0.389	$71.729x^{0.546}$	0.513
FL1 (Bar15)	40.632	0.815	300.593	-0.249	50.229	0.427	$72.546x^{0.546}$	0.546
Foundation	93.654	0.793	722.267	-0.181	118.590	0.544	$189.161x^{0.538}$	0.645
Average		**0.797**		**-0.293**		**0.366**		**0.480**

Table 8.4.4 Structure D Shear indexes and Regression line coefficients R^2

Floor No (Member No)	For 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL8 (Bar1)	11.324	0.727	266.130	0.392	27.067	0.778	$37.388x^{0.545}$	0.732
FL7 (Bar2)	23.478	0.563	570.347	0.461	57.811	0.791	$103.165x^{0.512}$	0.662
FL6 (Bar3)	34.064	0.470	842.919	0.476	85.206	0.771	$182.261x^{0.490}$	0.585
FL5 (Bar4)	47.436	0.424	1186.276	0.487	119.304	0.753	$289.820x^{0.475}$	0.564
FL4 (Bar5)	55.689	0.422	1392.605	0.487	139.590	0.742	$366.109x^{0.468}$	0.583
FL3 (Bar6)	72.332	0.425	1806.894	0.489	180.266	0.733	$488.663x^{0.467}$	0.607
FL2 (Bar7)	58.594	0.411	1469.150	0.499	145.956	0.723	$418.945x^{0.461}$	0.622
FL1 (Bar8)	36.074	0.368	914.755	0.521	90.375	0.703	$288.188x^{0.449}$	0.617
Foundation	55.392	0.363	1415.292	0.588	138.908	0.747	$443.132x^{0.451}$	0.670
Average		**0.464**		**0.489**		**0.749**		**0.6270**

Floor No (Member No)	For 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)							
	PGA		PGV		A_0		PGA*PGV	
	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2	Shear Index	R^2
FL6 (Bar10)	12.789	0.576	319.293	0.441	31.158	0.749	$58.694x^{0.509}$	0.677
FL5 (Bar11)	24.215	0.581	584.581	0.425	58.551	0.711	$119.710x^{0.501}$	0.689
FL4 (Bar12)	30.228	0.585	729.238	0.419	72.923	0.703	$154.164x^{0.498}$	0.690
FL3 (Bar13)	34.315	0.585	827.818	0.408	82.524	0.687	$184.004x^{0.494}$	0.700
FL2 (Bar14)	27.154	0.523	663.647	0.443	65.893	0.687	$161.604x^{0.483}$	0.697
FL1 (Bar15)	25.125	0.433	628.896	0.514	62.237	0.716	$179.487x^{0.462}$	0.665
Foundation	55.392	0.363	1415.292	0.588	138.908	0.747	$443.132x^{0.451}$	0.670
Average		**0.521**		**0.463**		**0.714**		**0.684**

Figure 8.1.1 Structure A Shear Force and PGA Correlation Graphs for all selected ground motions (n=1000)

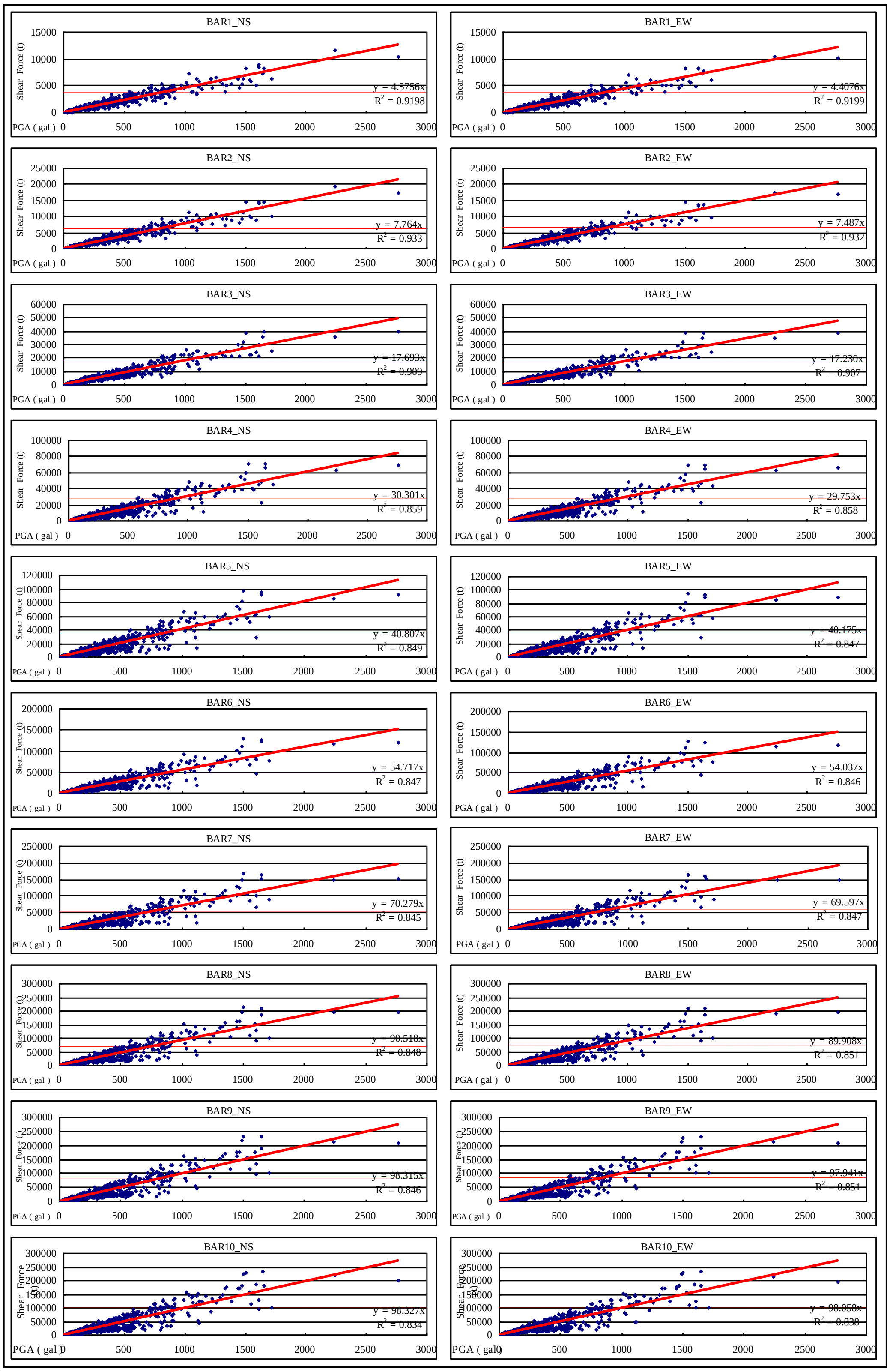


Figure 8.1.2 Structure A Shear Force and A_0 Correlation Graphs for all selected ground motions (n=1000)

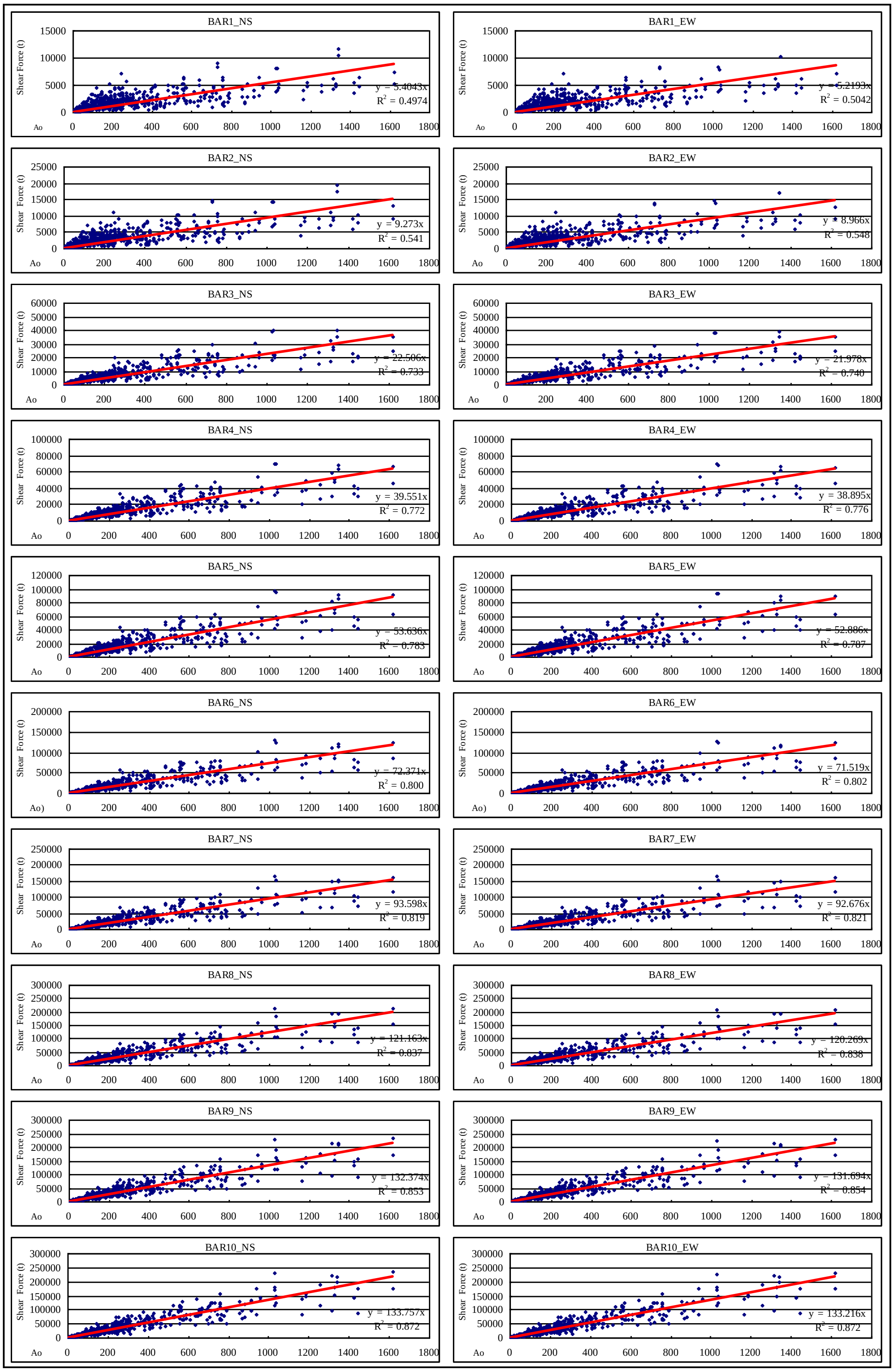


Figure 8.1.3 Structure A Shear Force and PGV Correlation Graphs for all selected ground motions (n=1000)

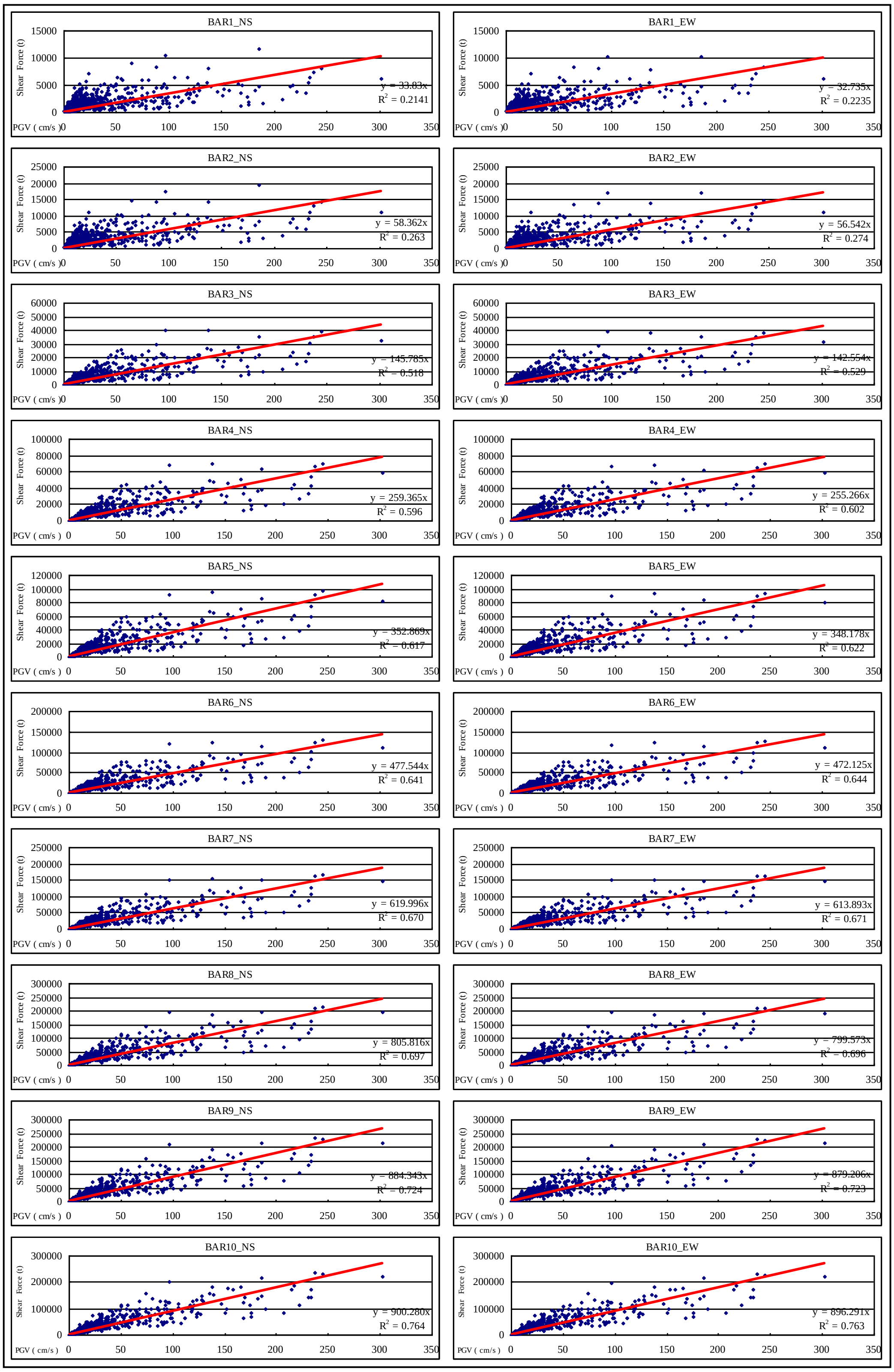


*Figure 8.1.4 Structure A Shear Force and PGA*PGV Correlation Graphs for all selected ground motions (n=1000)*

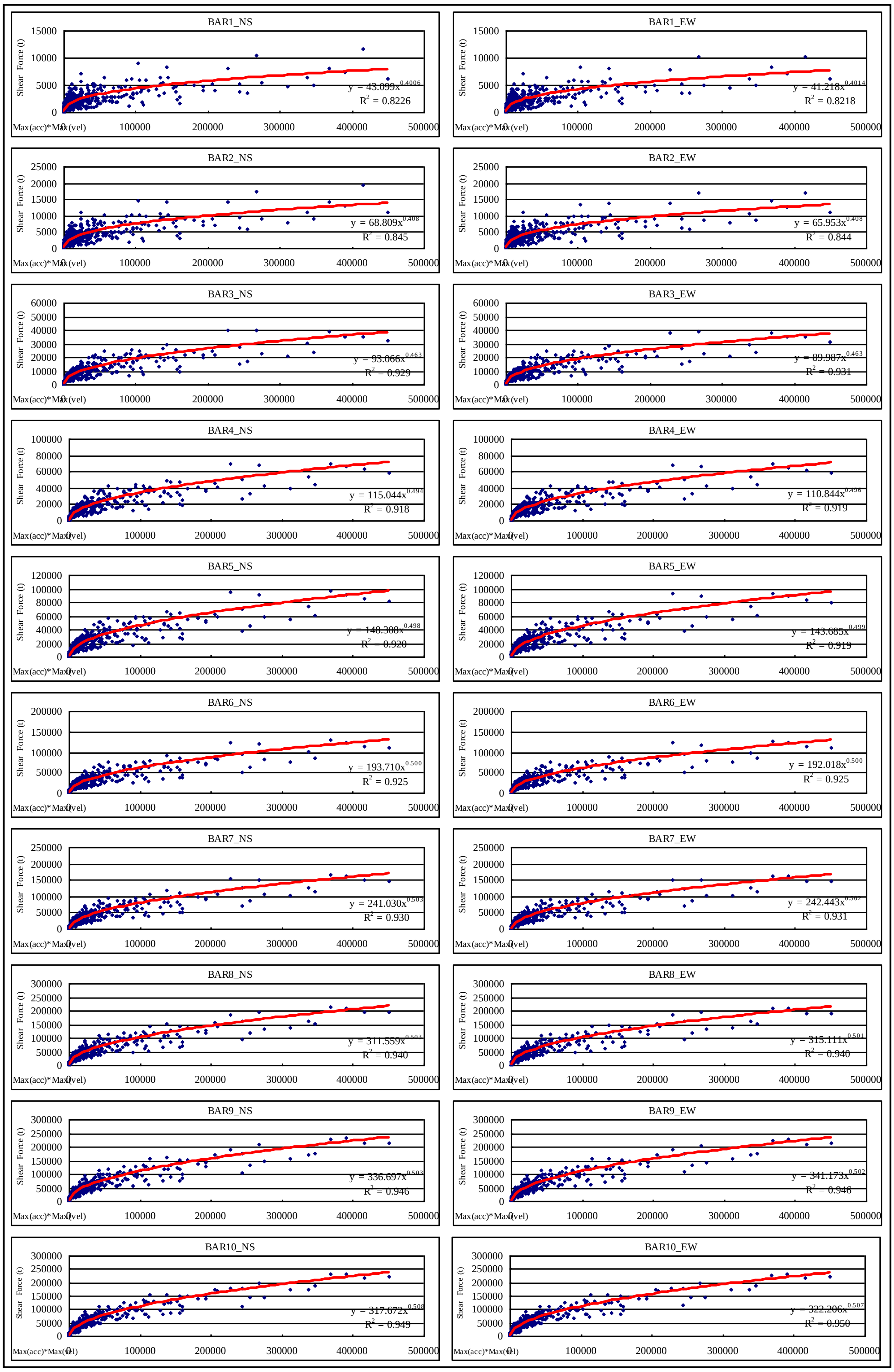


Figure 8.1.5 Structure A Shear Force and PGA Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

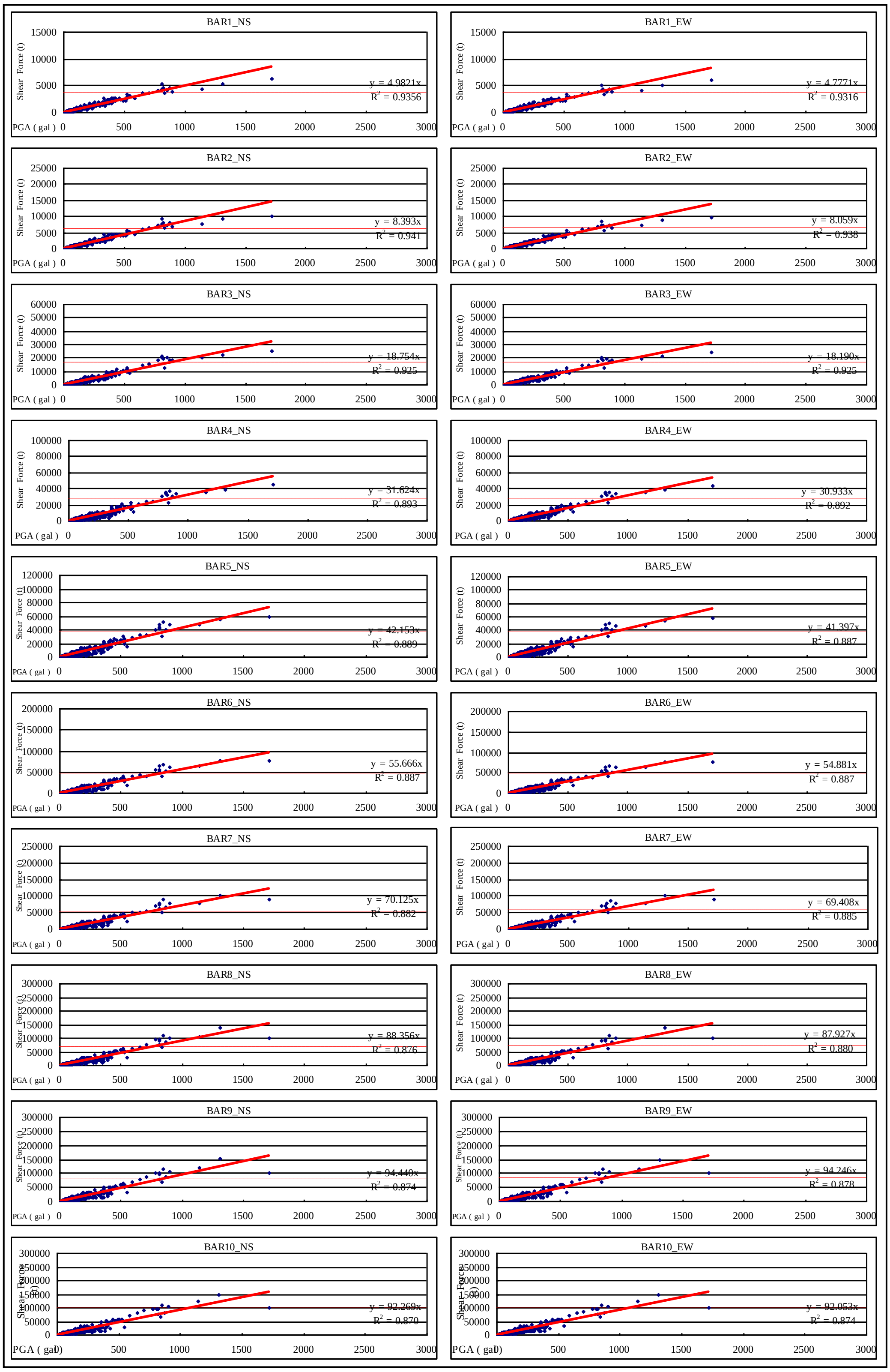


Figure 8.1.6 Structure A Shear Force and A_0 Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

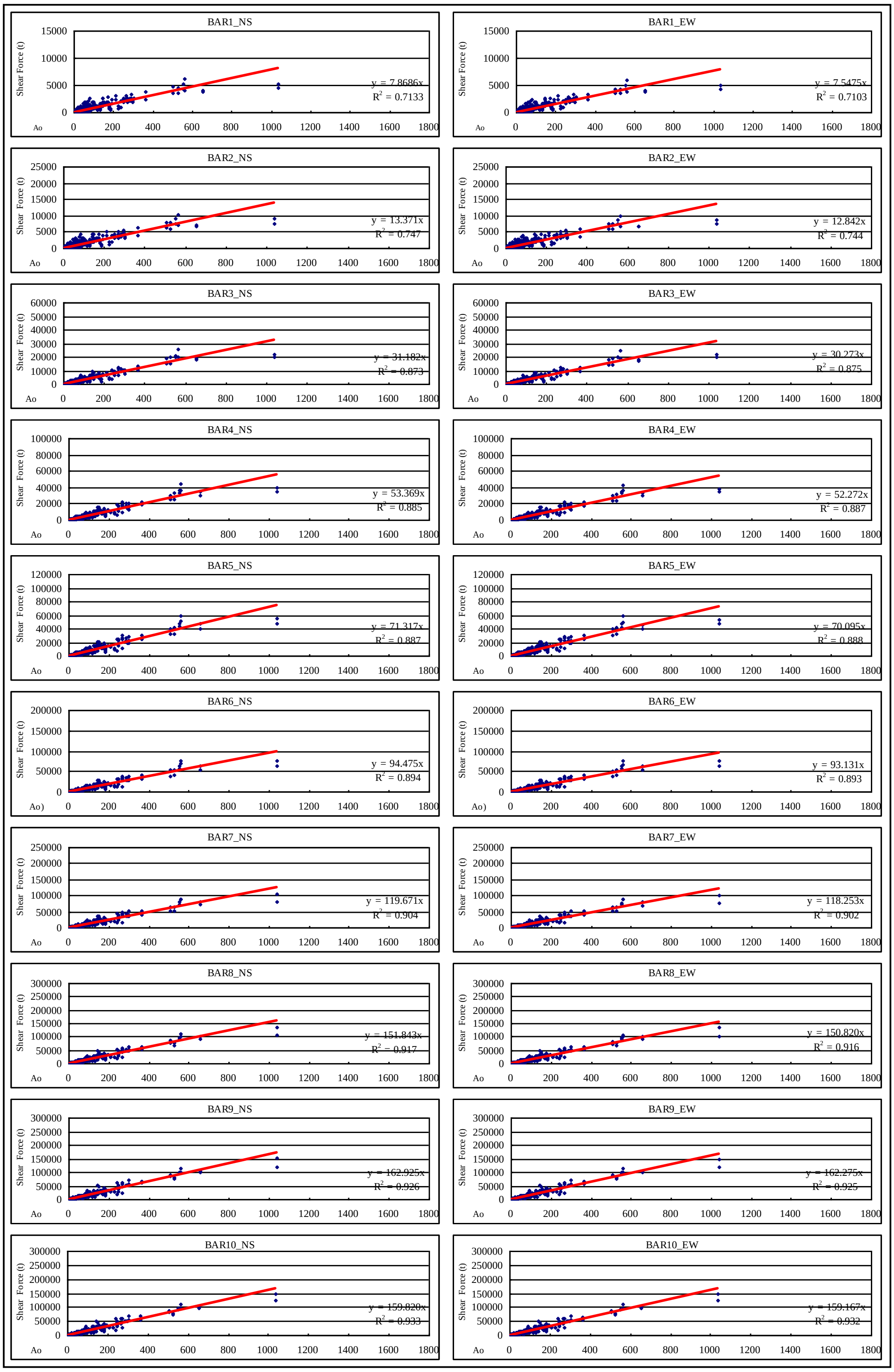


Figure 8.1.7 Structure A Shear Force and PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

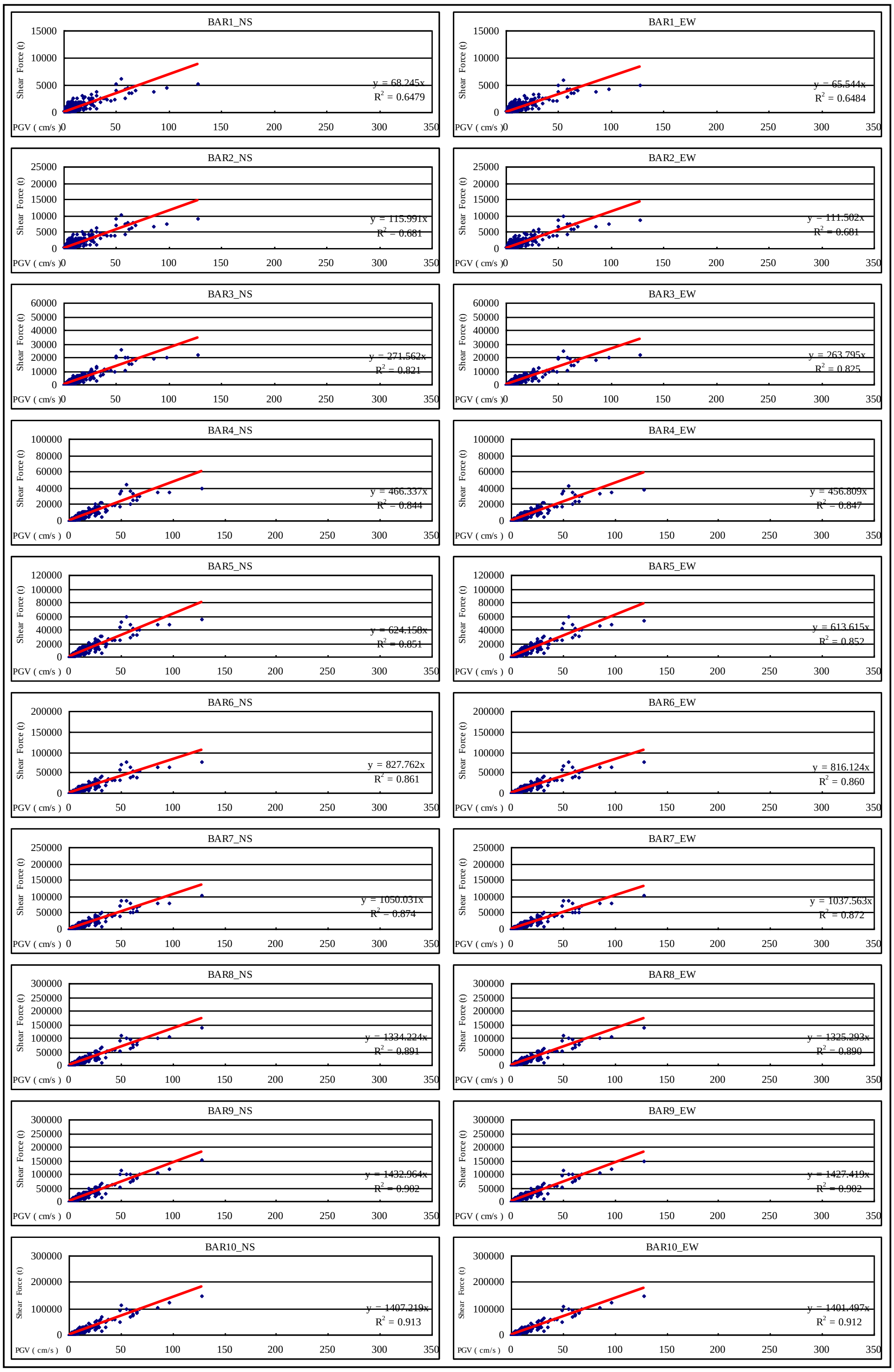


*Figure 8.1.8 Structure A Shear Force and PGA*PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)*

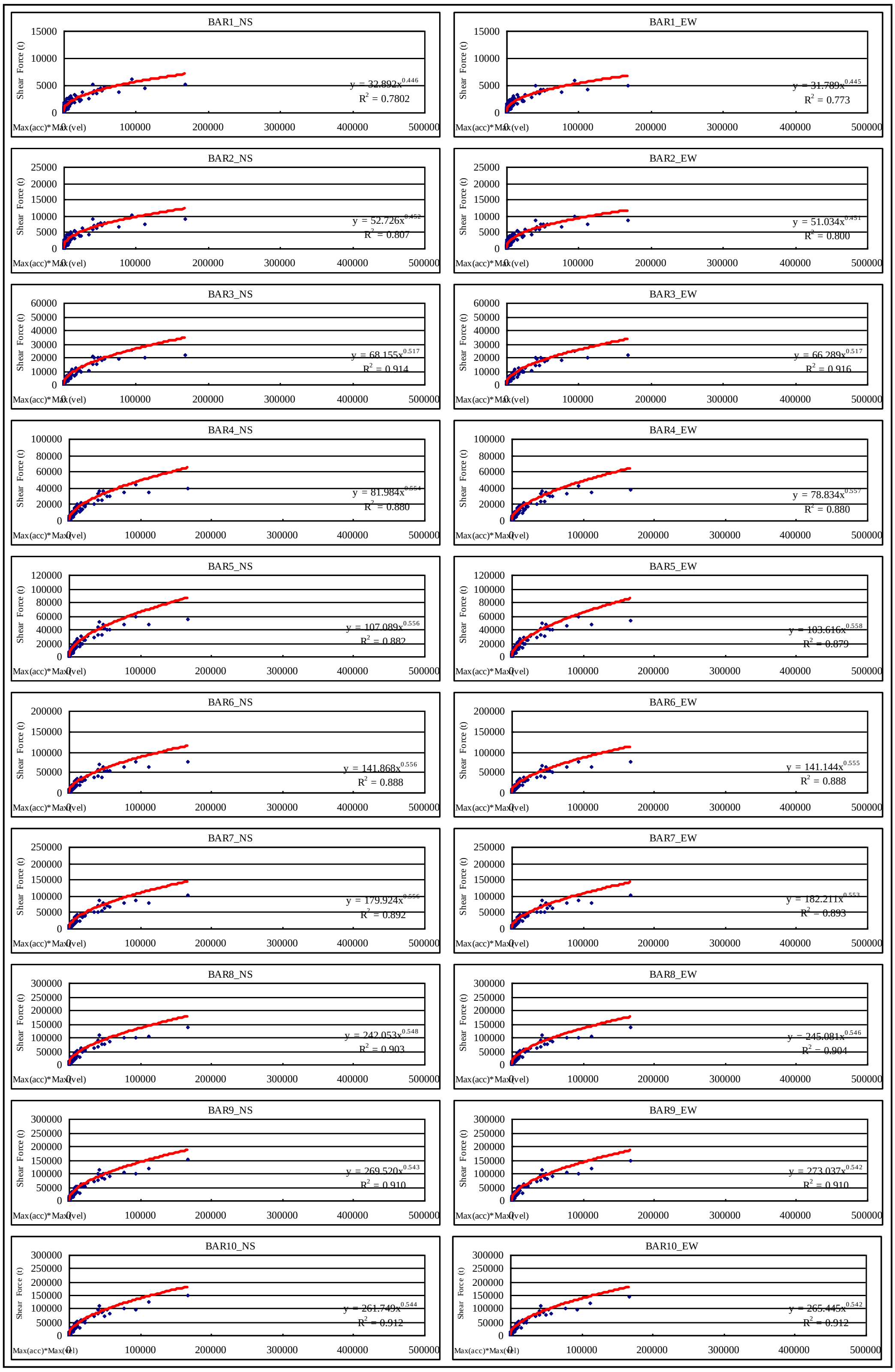


Figure 8.1.9 Structure A Shear Force and PGA Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

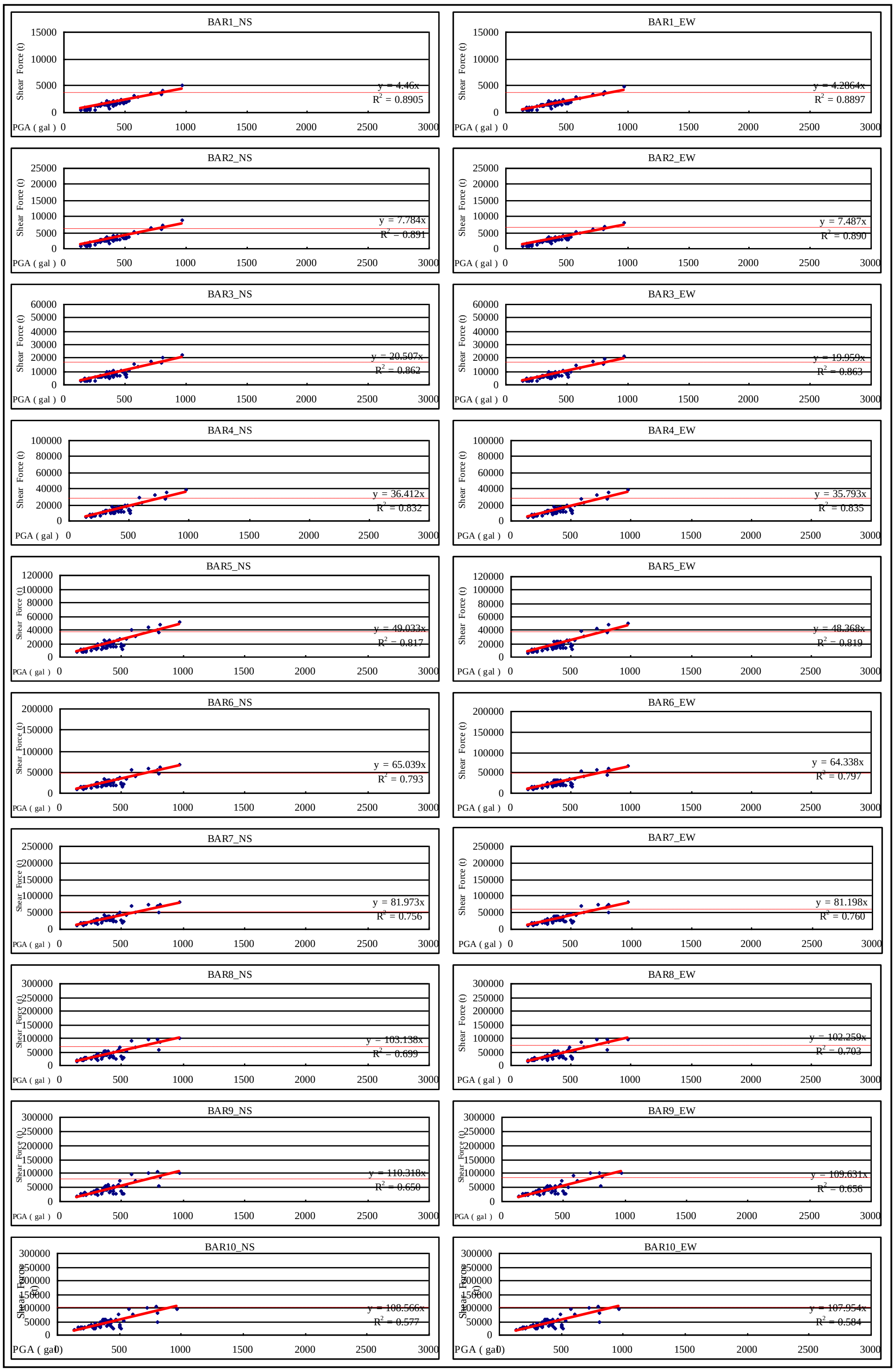


Figure 8.1.10 Structure A Shear Force and A_0 Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

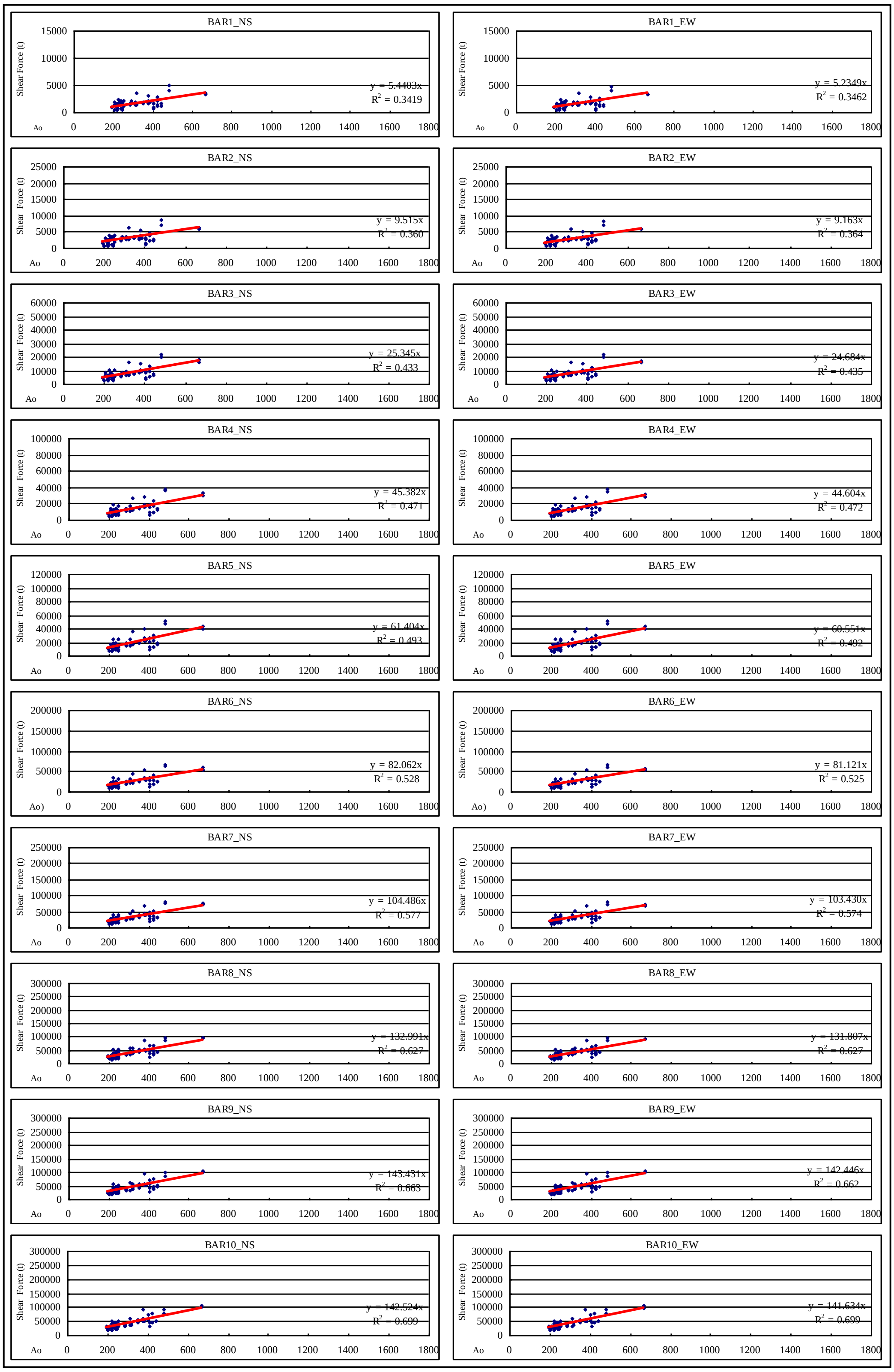


Figure 8.1.11 Structure A Shear Force and PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

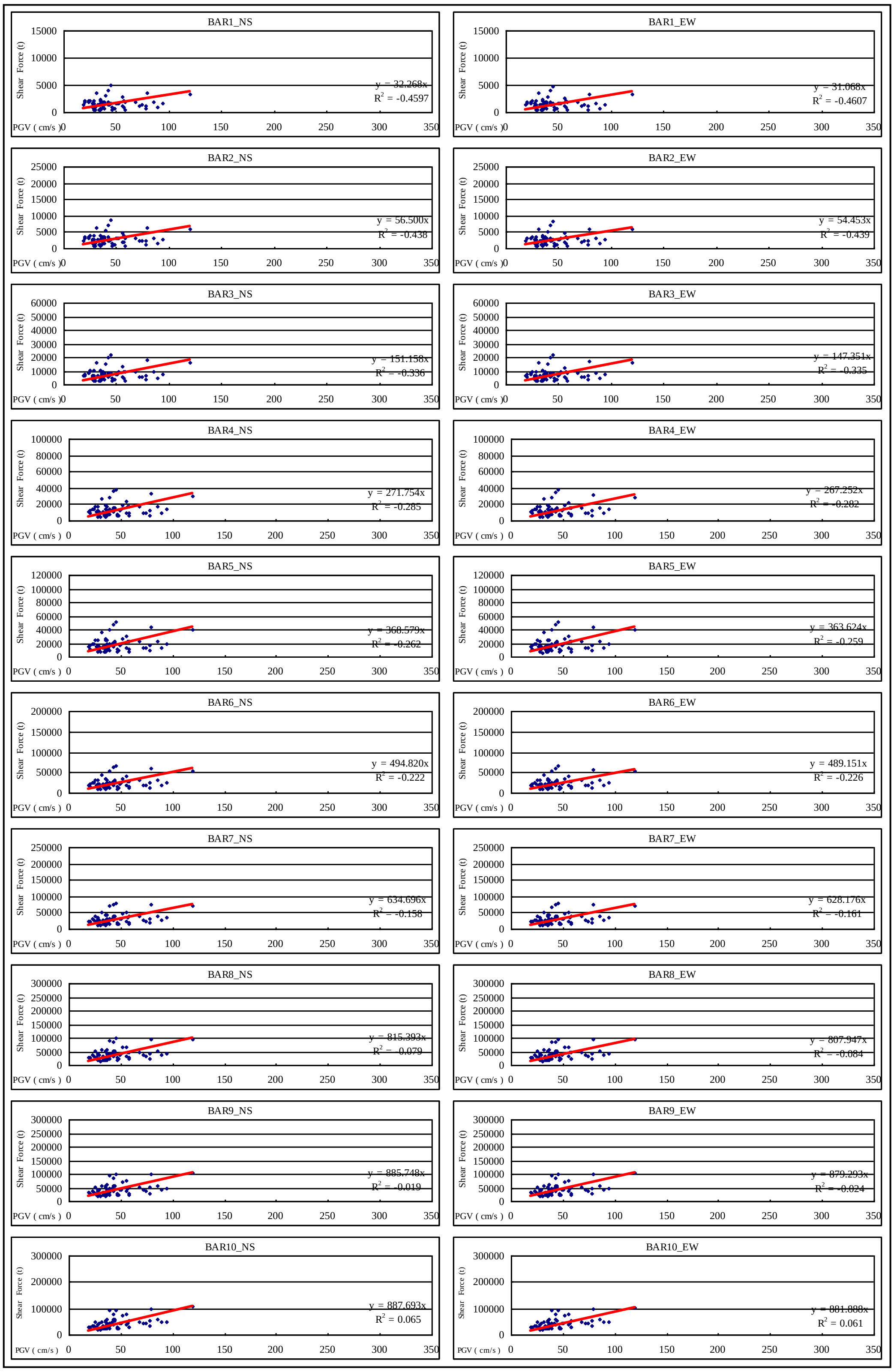


*Figure 8.1.12 Structure A Shear Force and PGA*PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)*

Figure 8.1.13 Structure A Shear Force and PGA Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

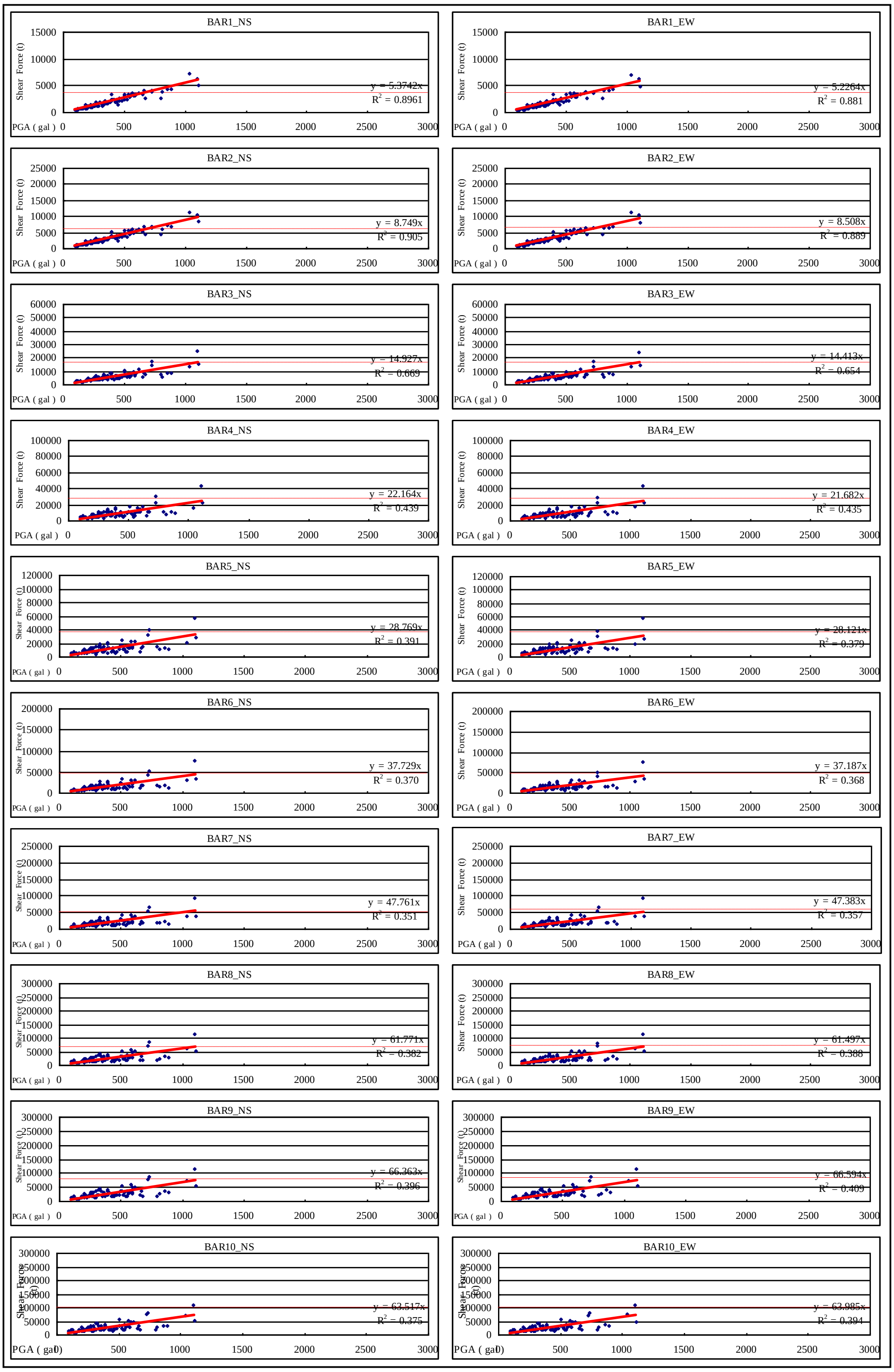


Figure 8.1.14 Structure A Shear Force and A_0 Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

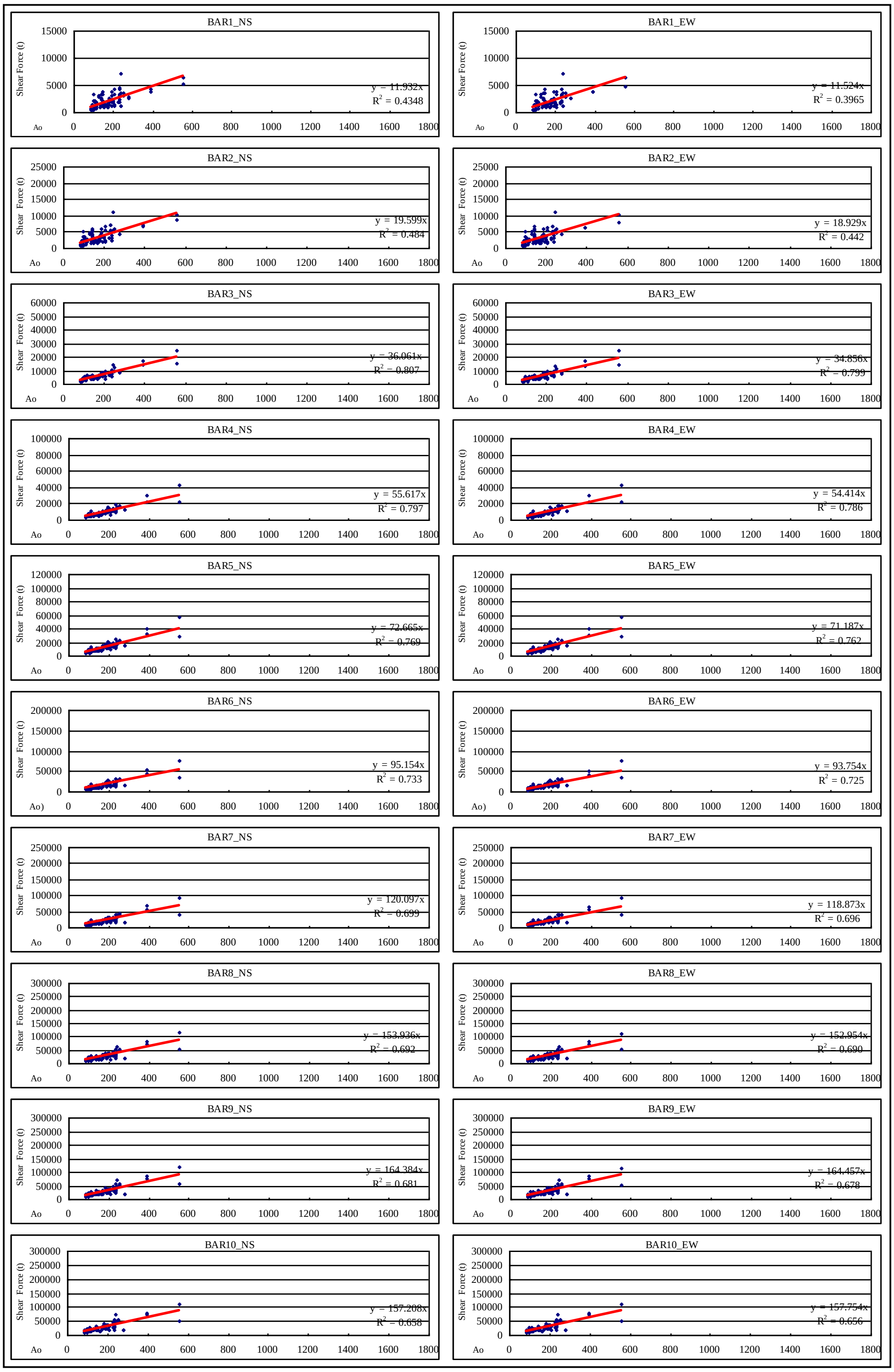


Figure 8.1.15 Structure A Shear Force and PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

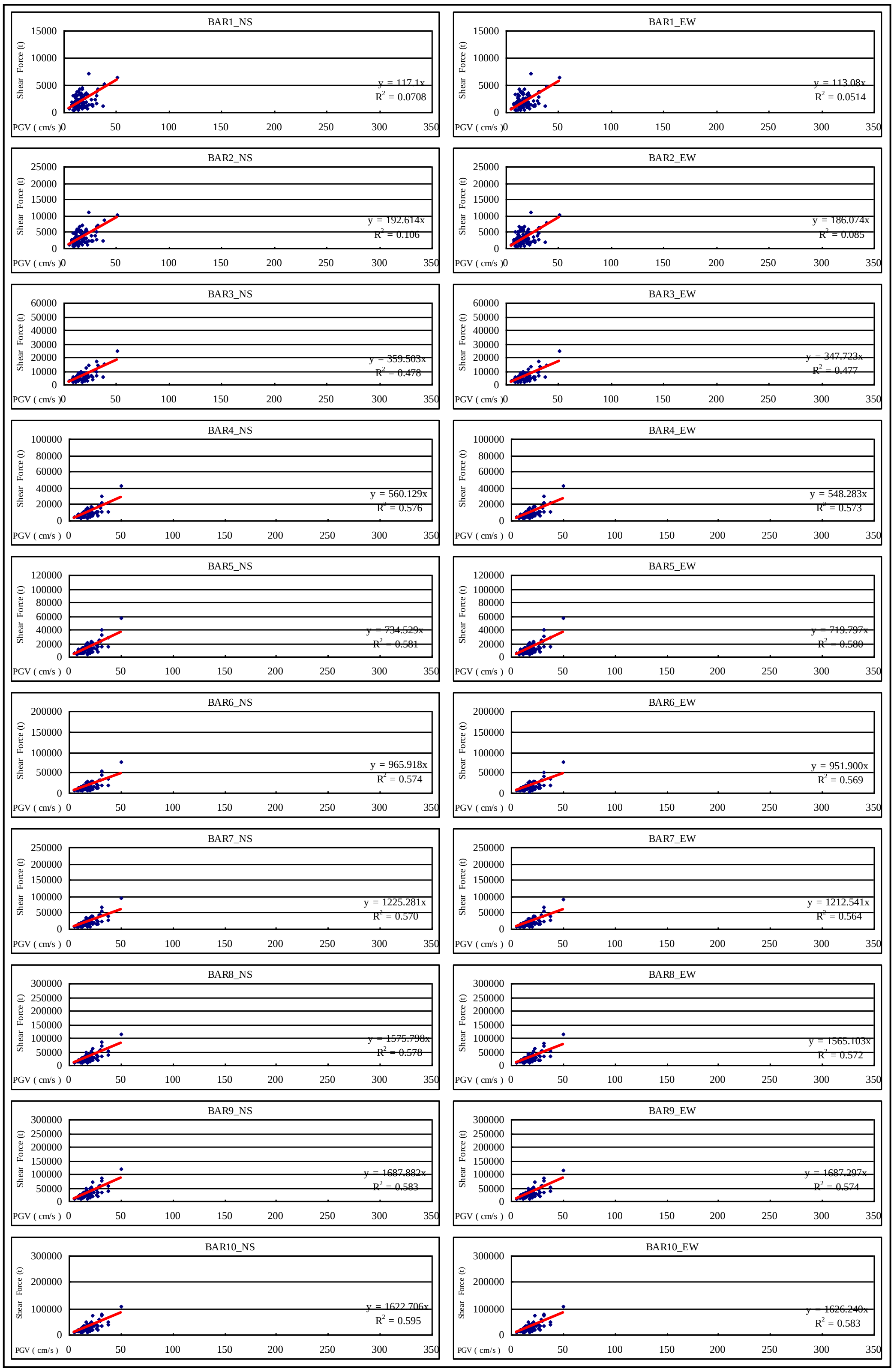


*Figure 8.1.16 Structure A Shear Force and PGA*PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)*

Figure 8.2.1 Structure B Shear Force and PGA Correlation Graphs for all selected ground motions (n=1000)

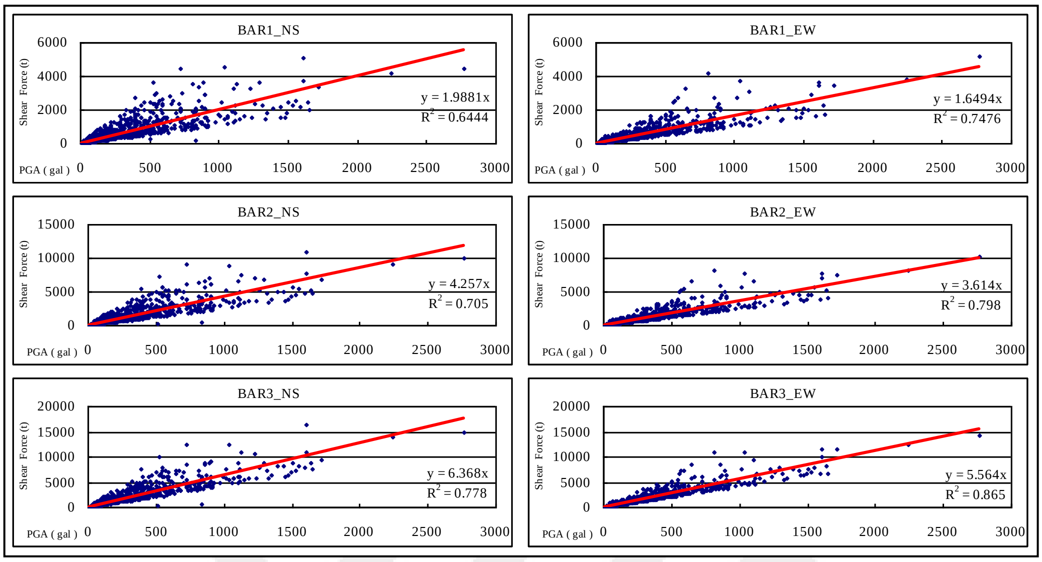


Figure 8.2.2 Structure B Shear Force and A_0 Correlation Graphs for all selected ground motions (n=1000)

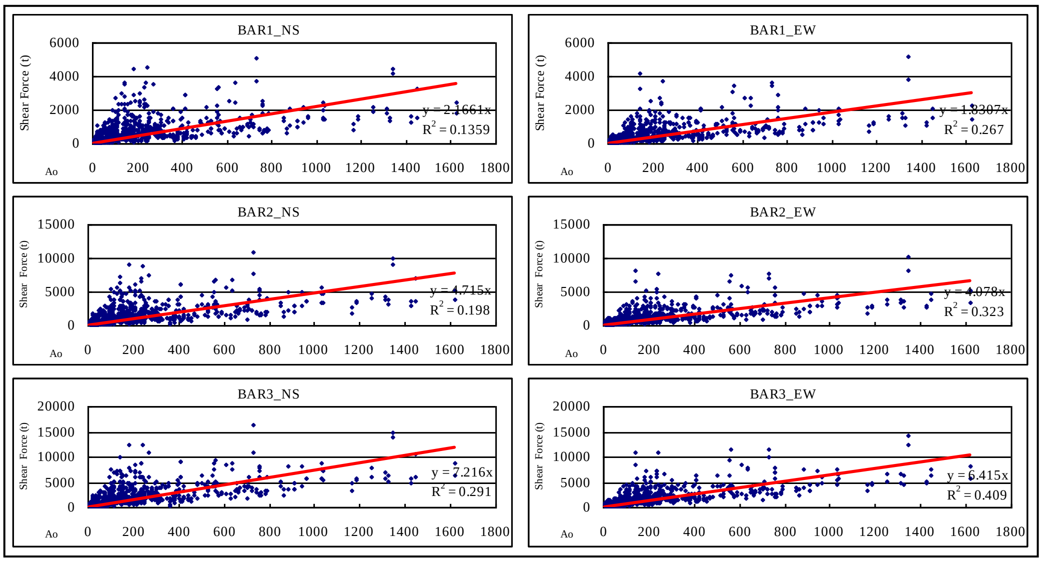


Figure 8.2.3 Structure B Shear Force and PGV Correlation Graphs for all selected ground motions (n=1000)

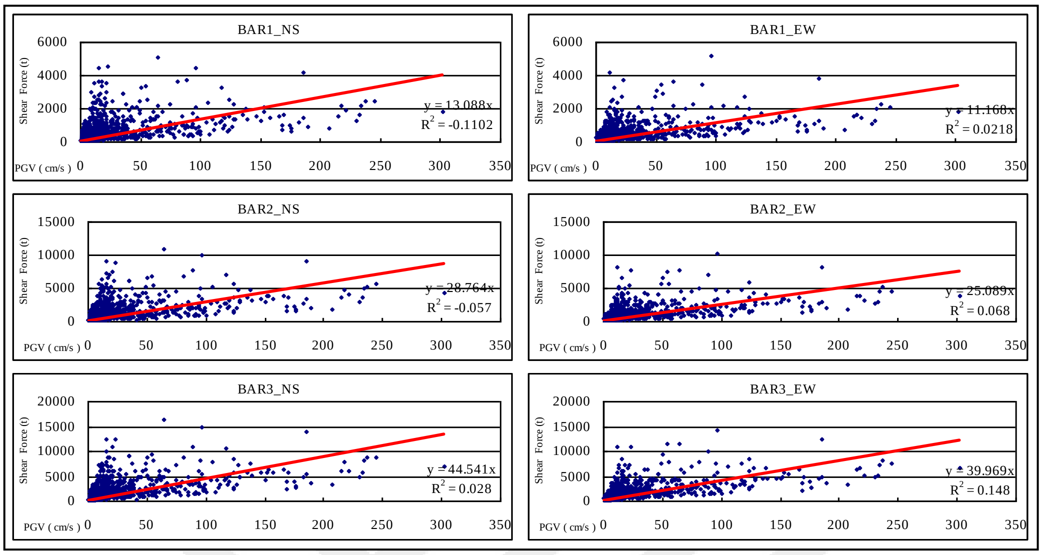


*Figure 8.2.4 Structure B Shear Force and PGA*PGV Correlation Graphs for all selected ground motions (n=1000)*

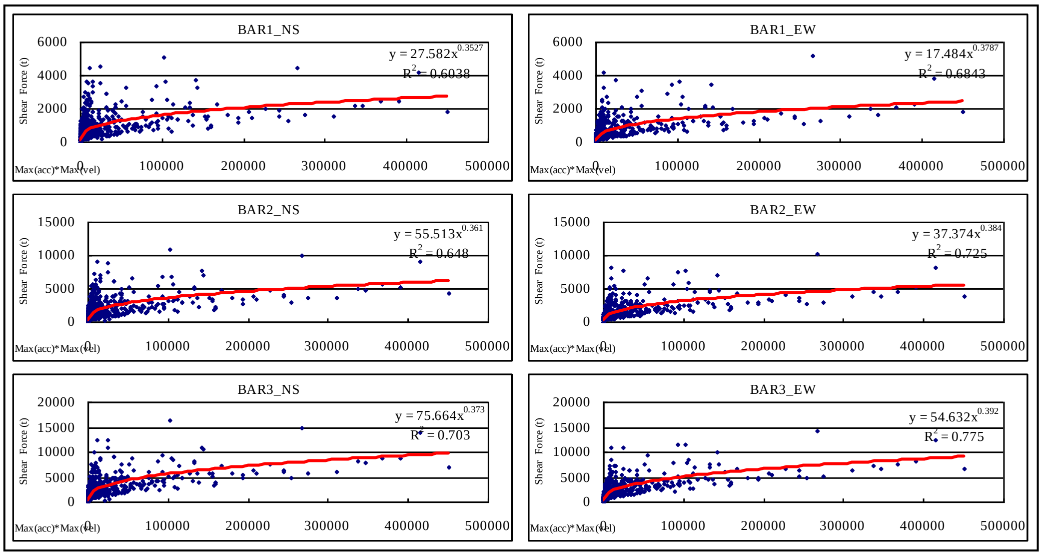


Figure 8.2.5 Structure B Shear Force and PGA Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

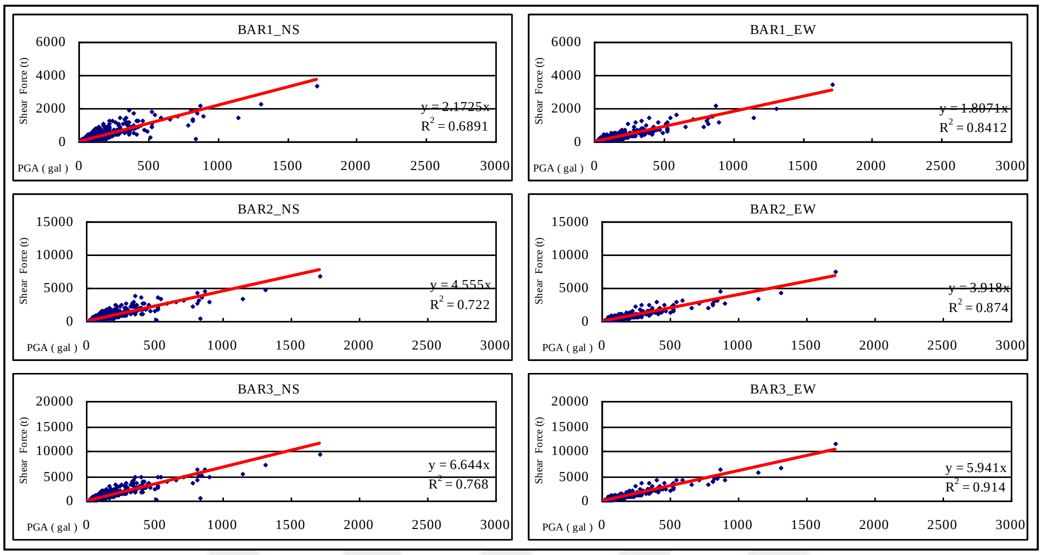


Figure 8.2.6 Structure B Shear Force and A₀ Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

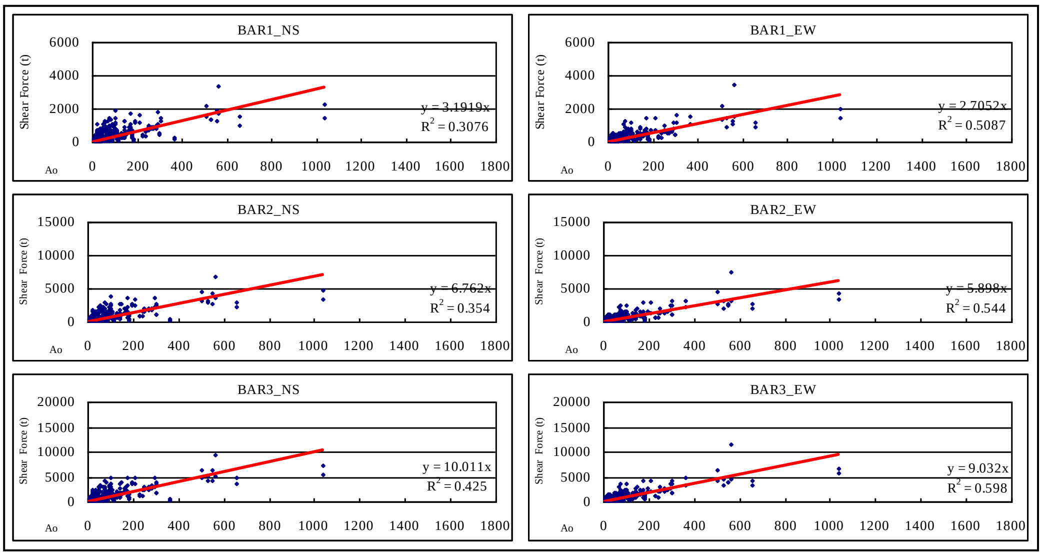


Figure 8.2.7 Structure B Shear Force and PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

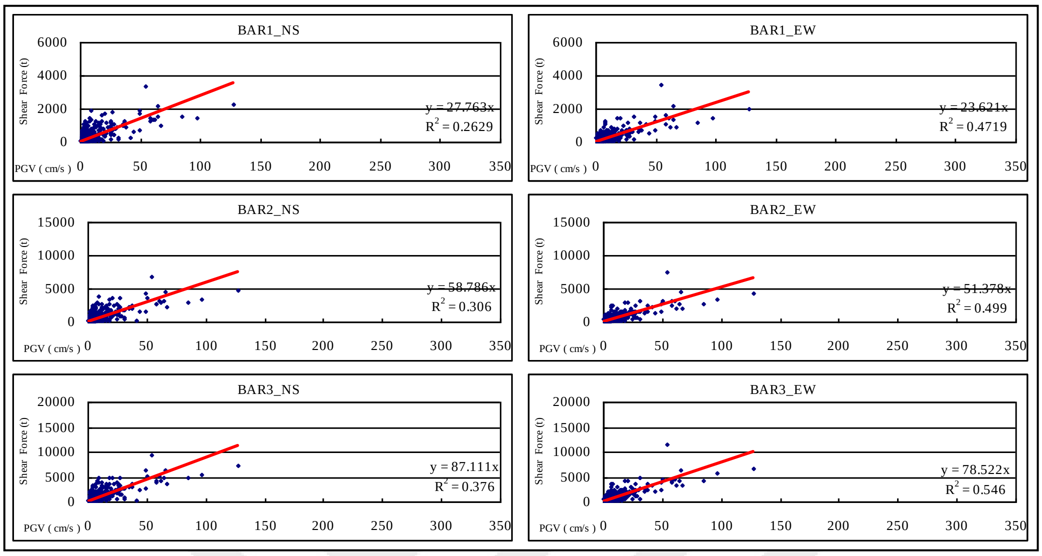


*Figure 8.2.8 Structure B Shear Force and PGA*PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)*

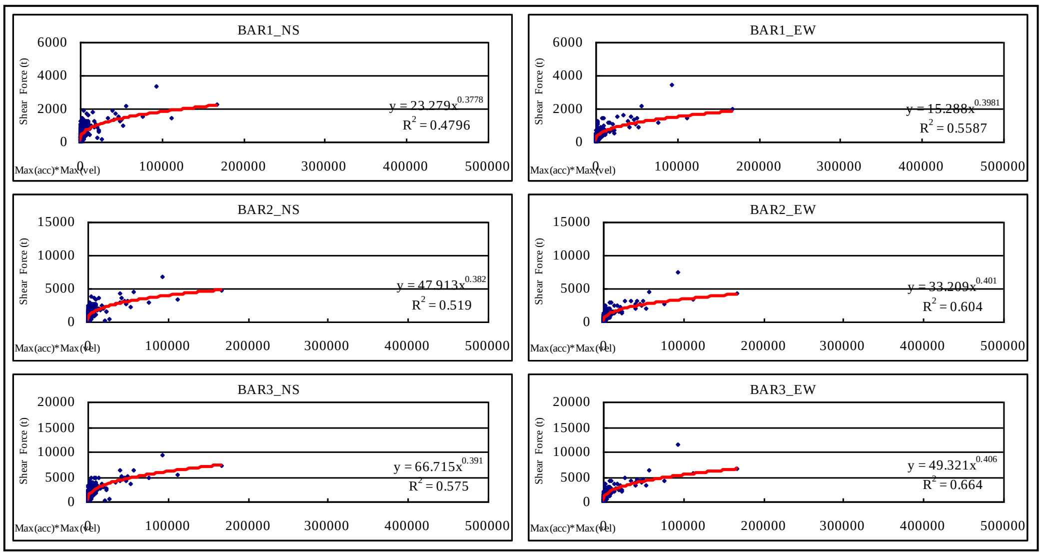


Figure 8.2.9 Structure B Shear Force and PGA Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

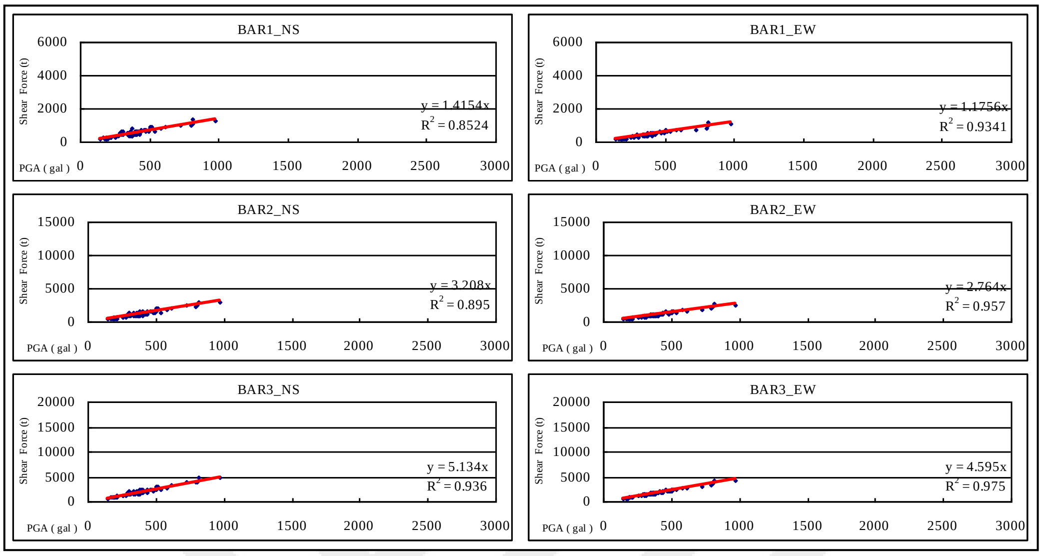


Figure 8.2.10 Structure B Shear Force and A_0 Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

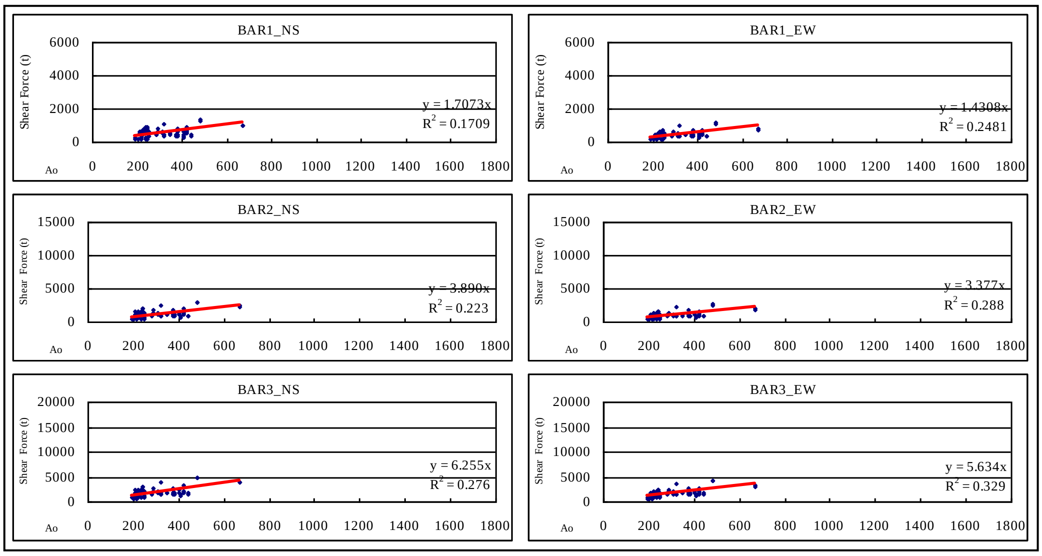


Figure 8.2.11 Structure B Shear Force and PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

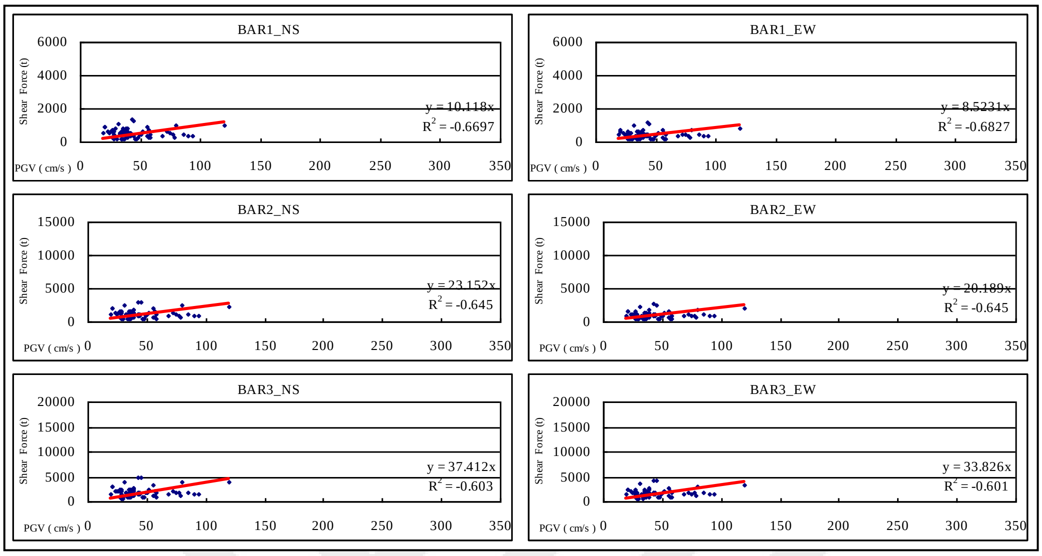


*Figure 8.2.12 Structure B Shear Force and PGA*PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)*

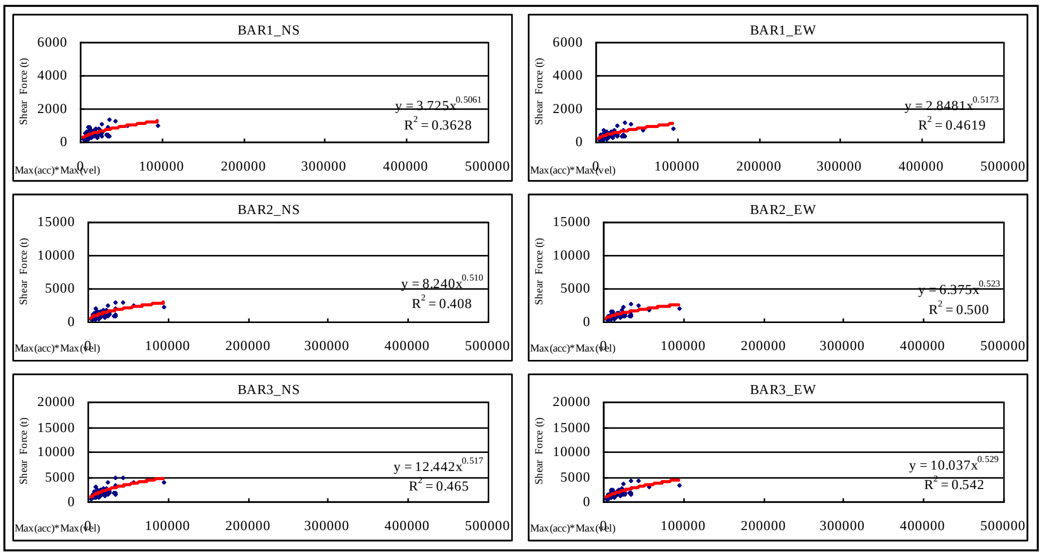


Figure 8.2.13 Structure B Shear Force and PGA Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

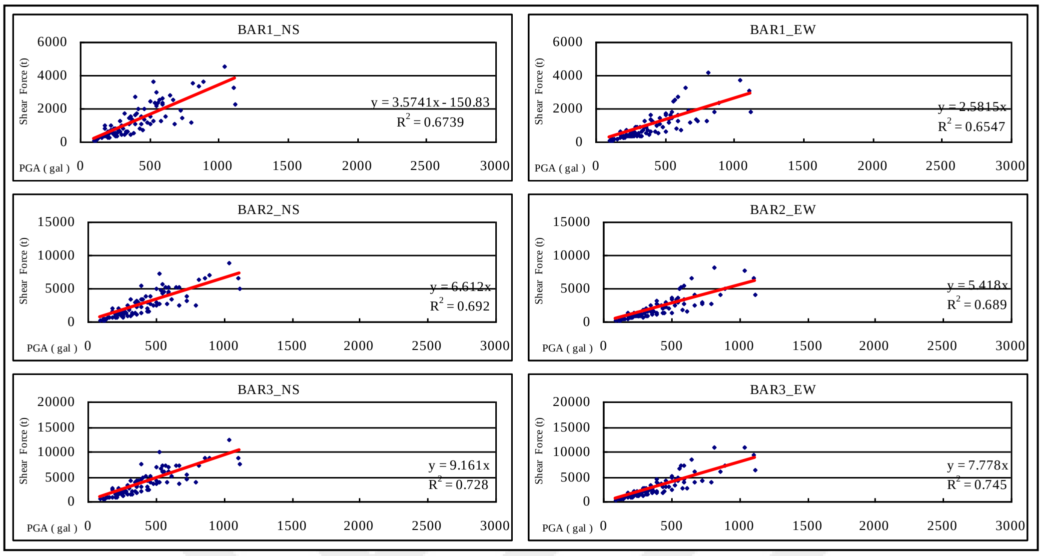


Figure 8.2.14 Structure B Shear Force and A_0 Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

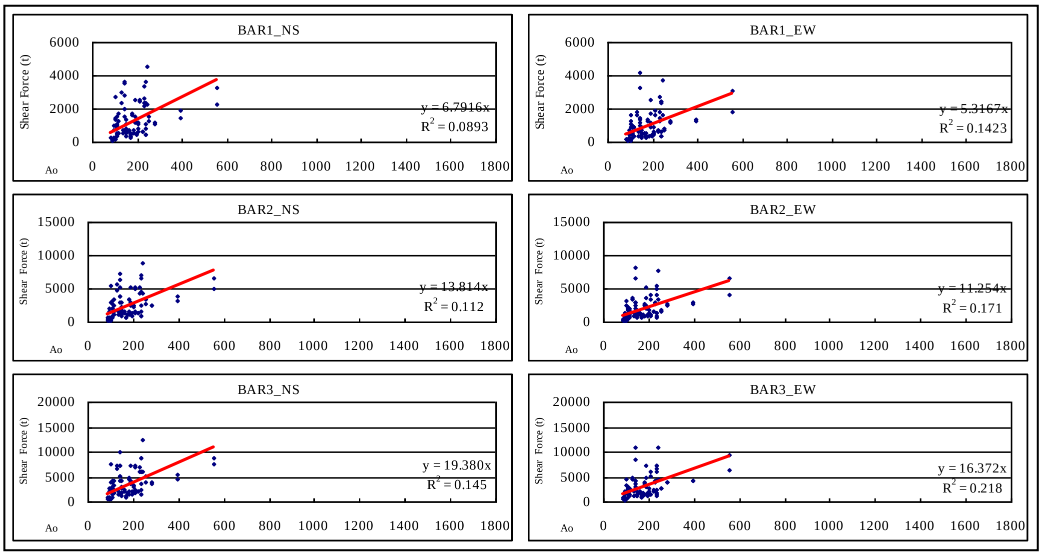


Figure 8.2.15 Structure B Shear Force and PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

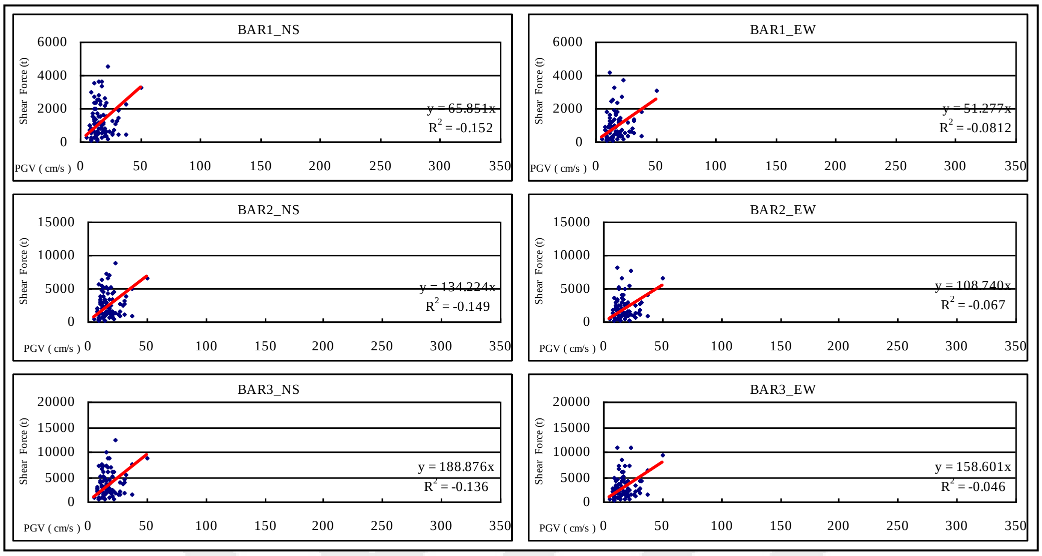


*Figure 8.2.16 Structure B Shear Force and PGA*PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)*

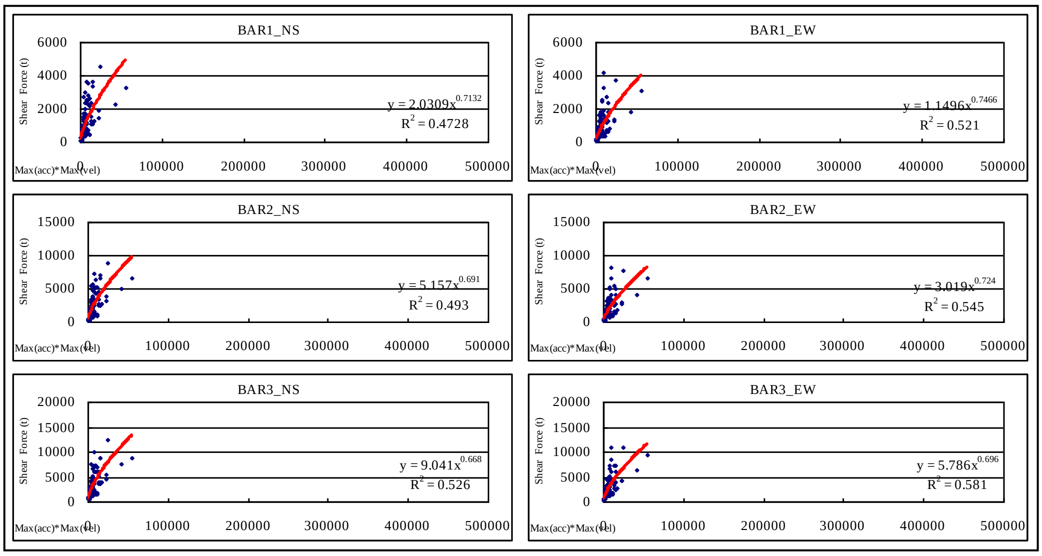


Figure 8.3.1 Structure C Shear Force and PGA Correlation Graphs for all selected ground motions (n=1000)

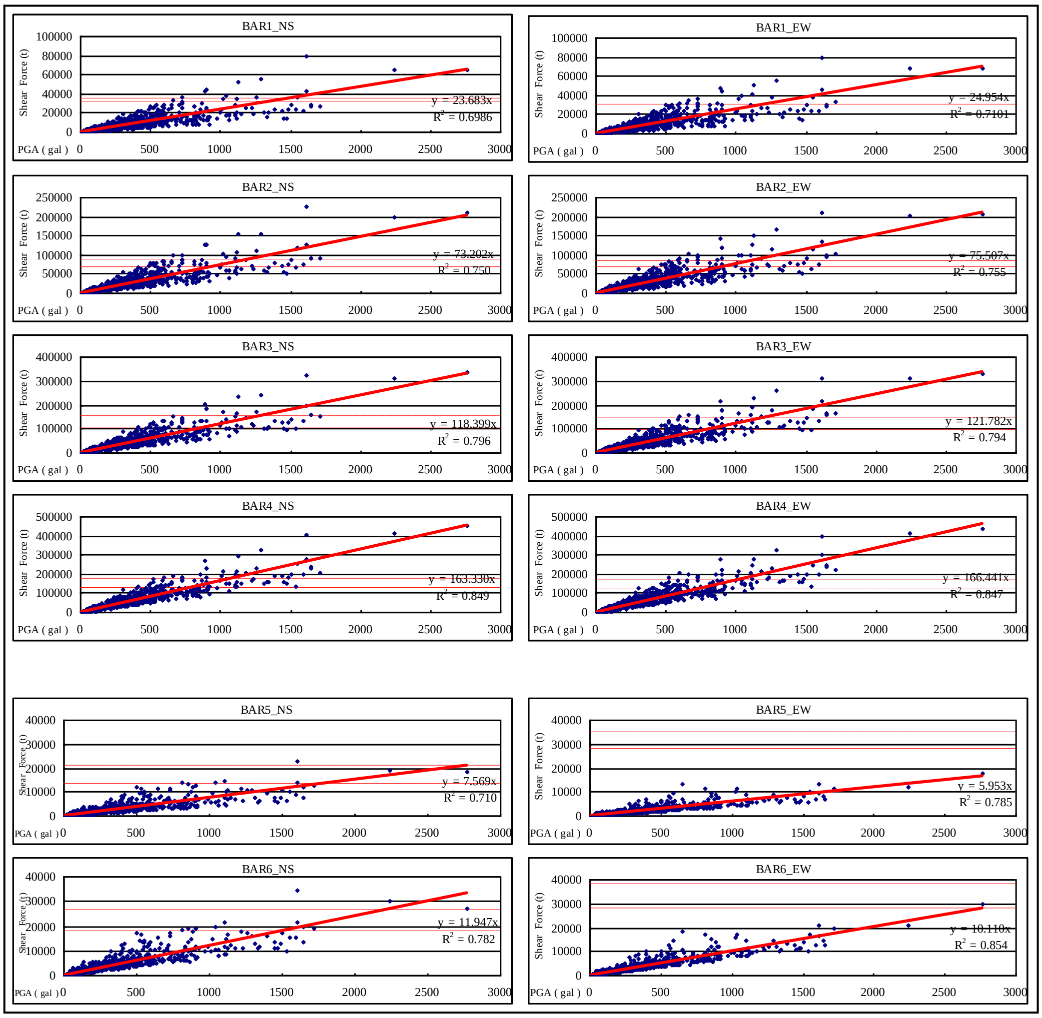


Figure 8.3.2 Structure C Shear Force and A_0 Correlation Graphs for all selected ground motions (n=1000)

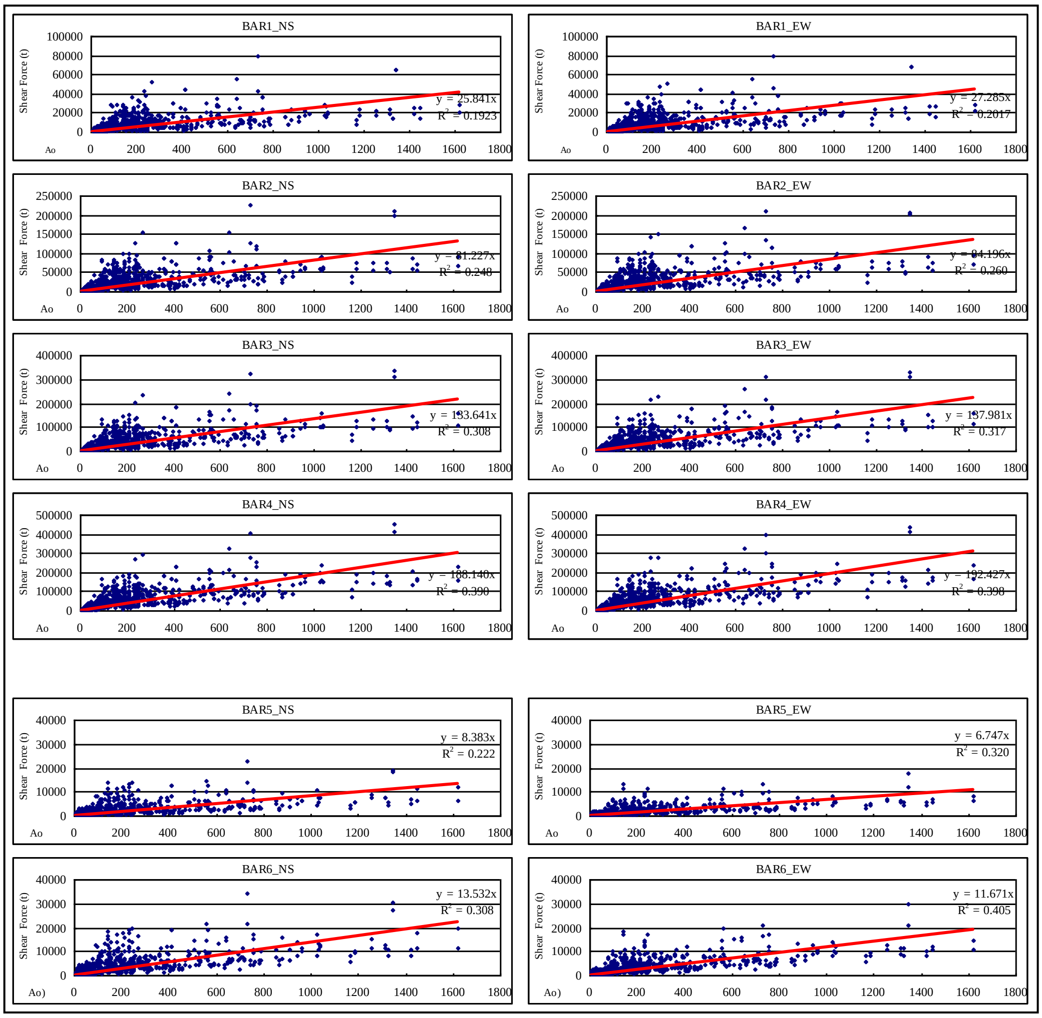


Figure 8.3.3 Structure C Shear Force and PGV Correlation Graphs for all selected ground motions (n=1000)

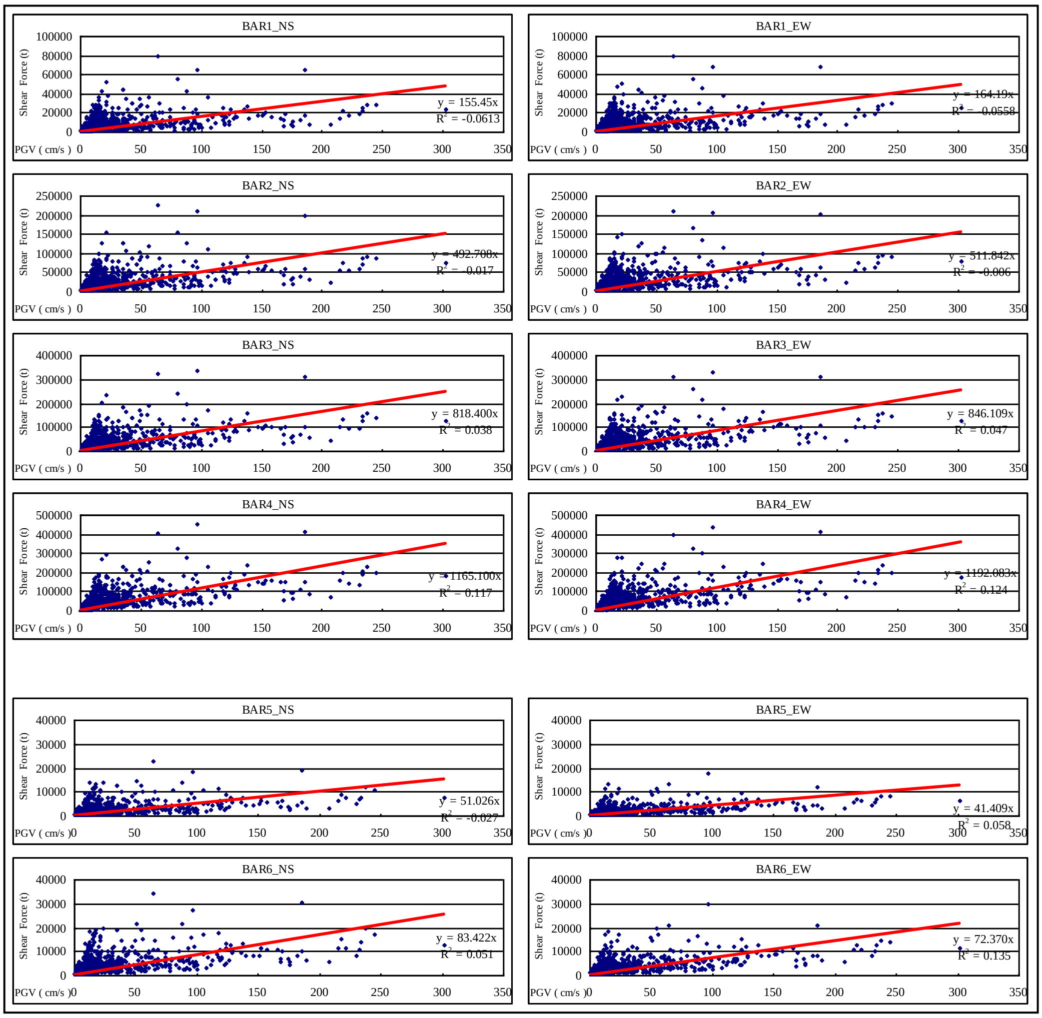


*Figure 8.3.4 Structure C Shear Force and PGA*PGV Correlation Graphs for all selected ground motions (n=1000)*

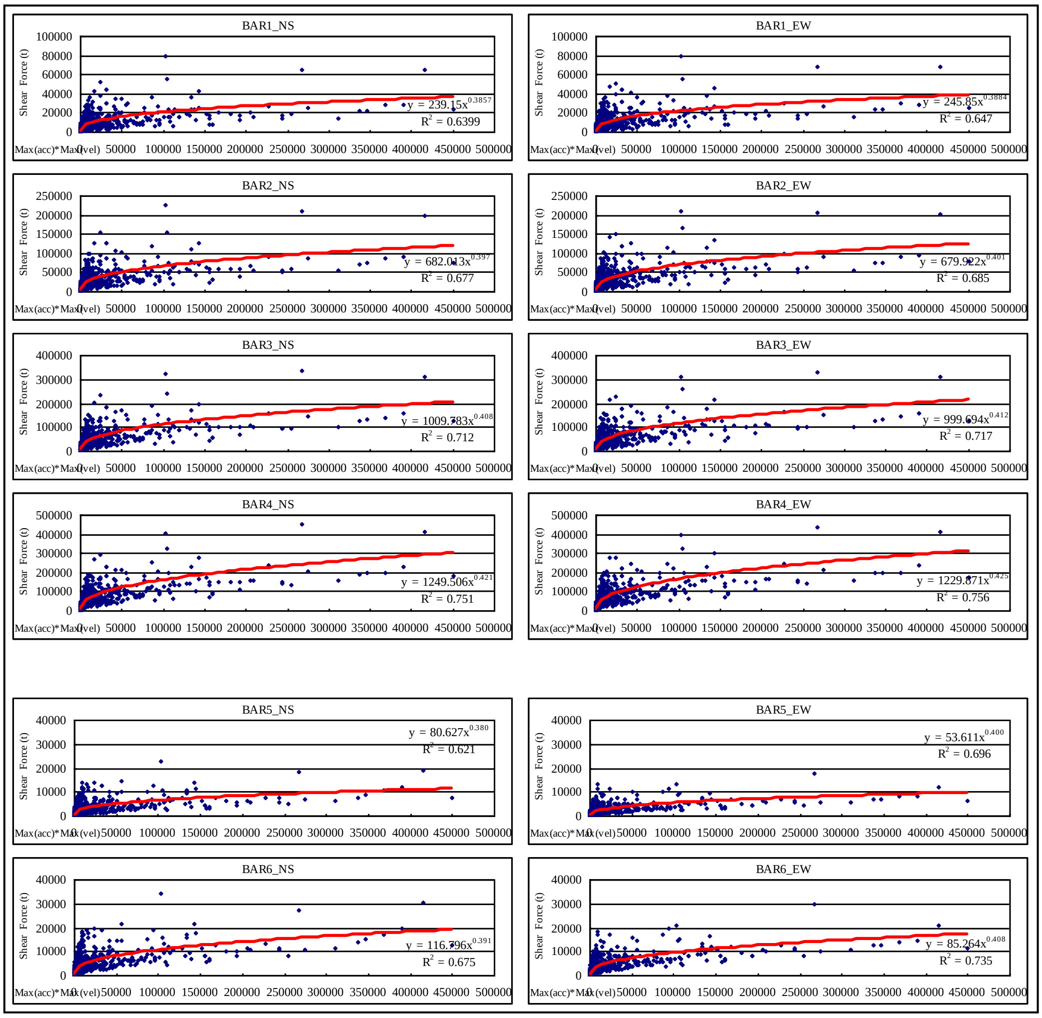


Figure 8.3.5 Structure C Shear Force and PGA Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

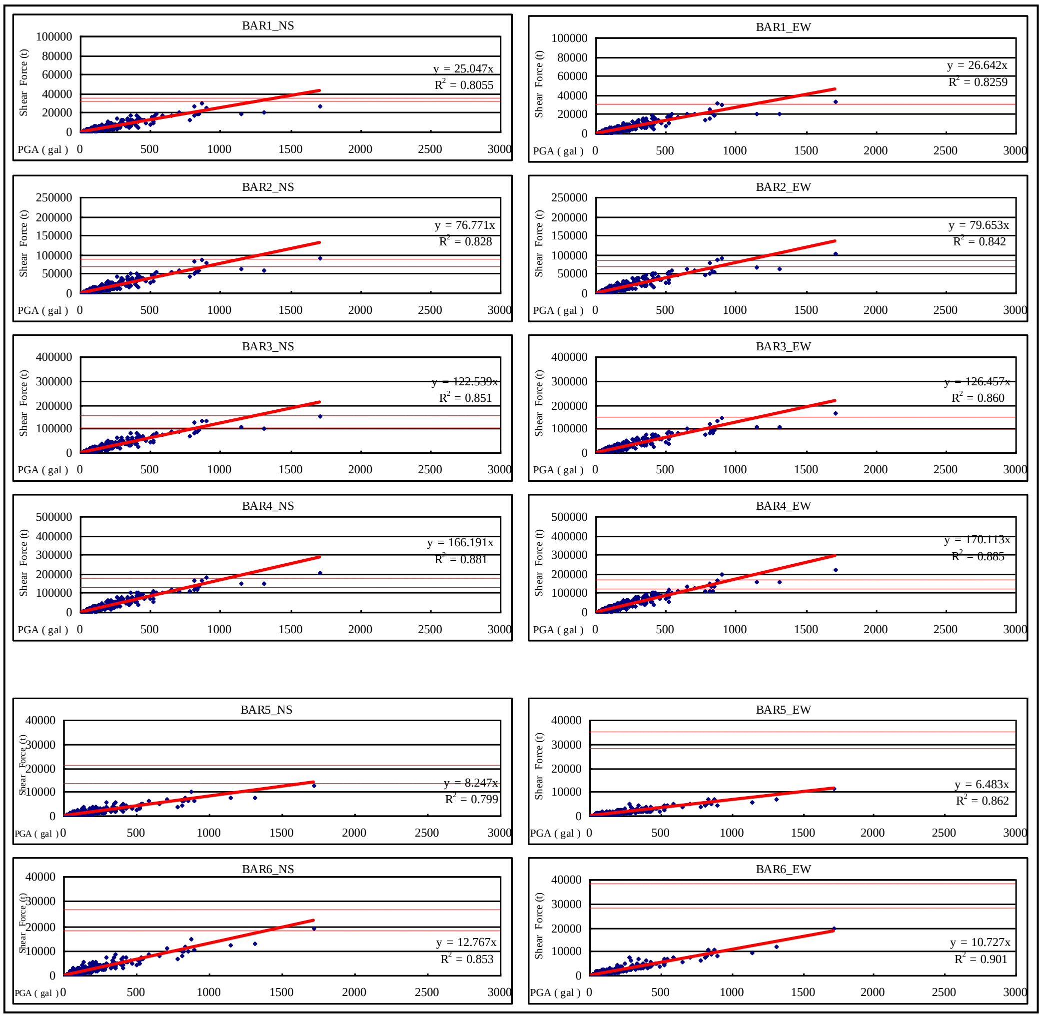


Figure 8.3.6 Structure C Shear Force and A_0 Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

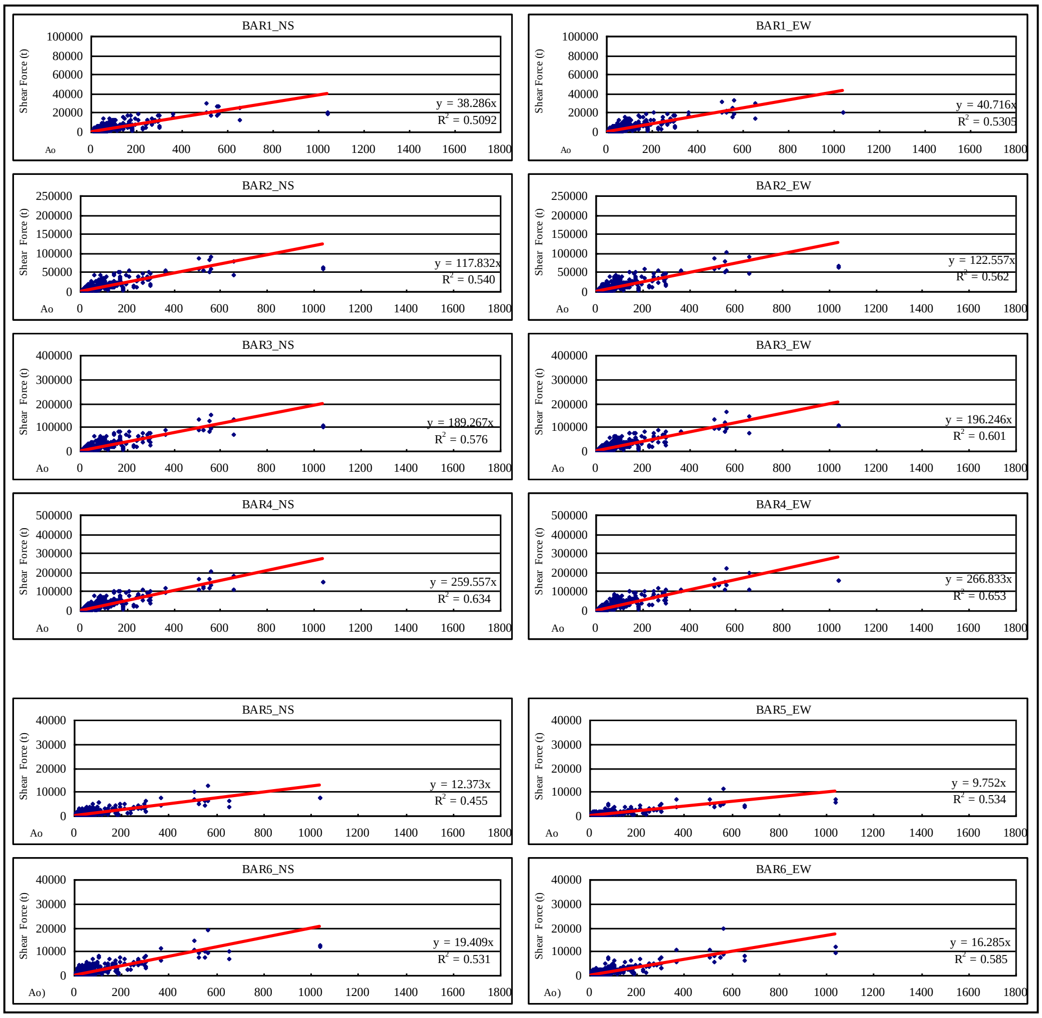


Figure 8.3.7 Structure C Shear Force and PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

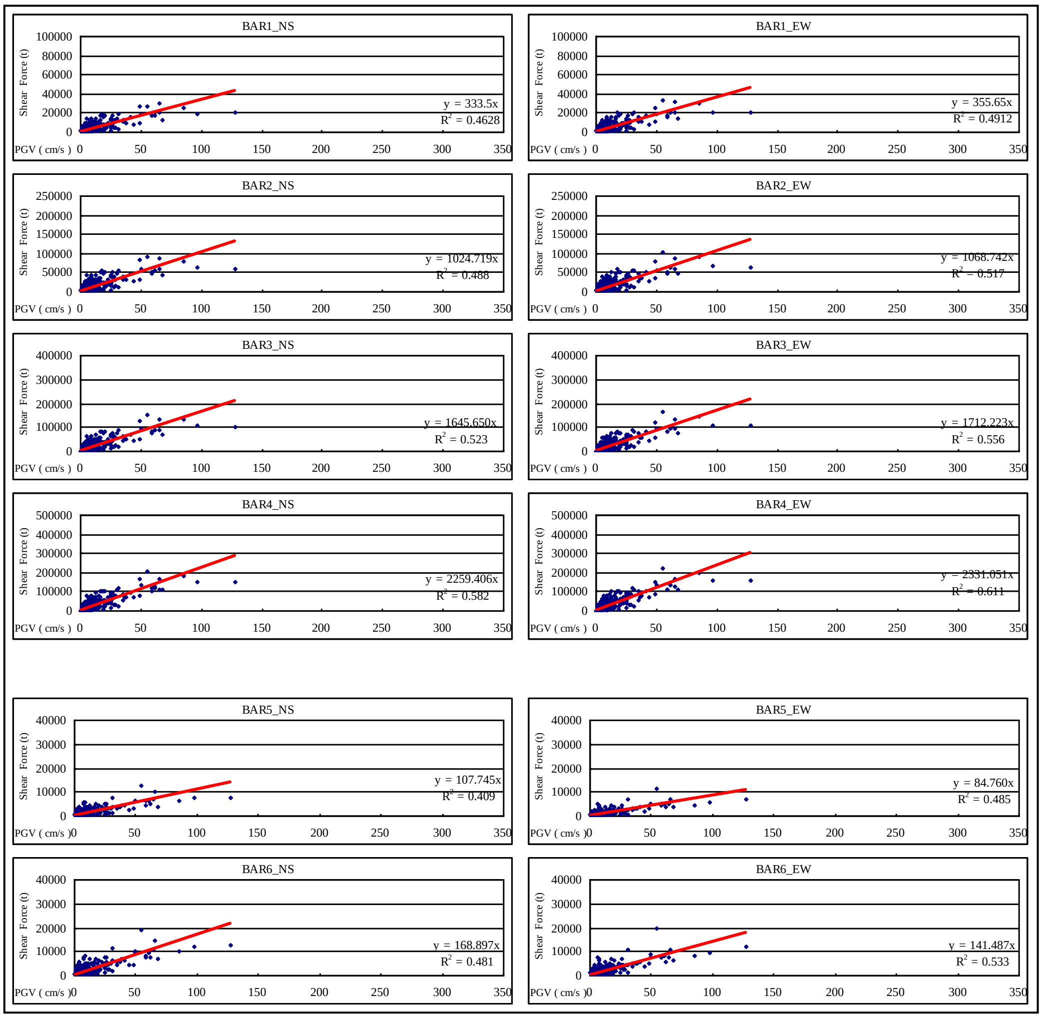


*Figure 8.3.8 Structure C Shear Force and PGA*PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)*

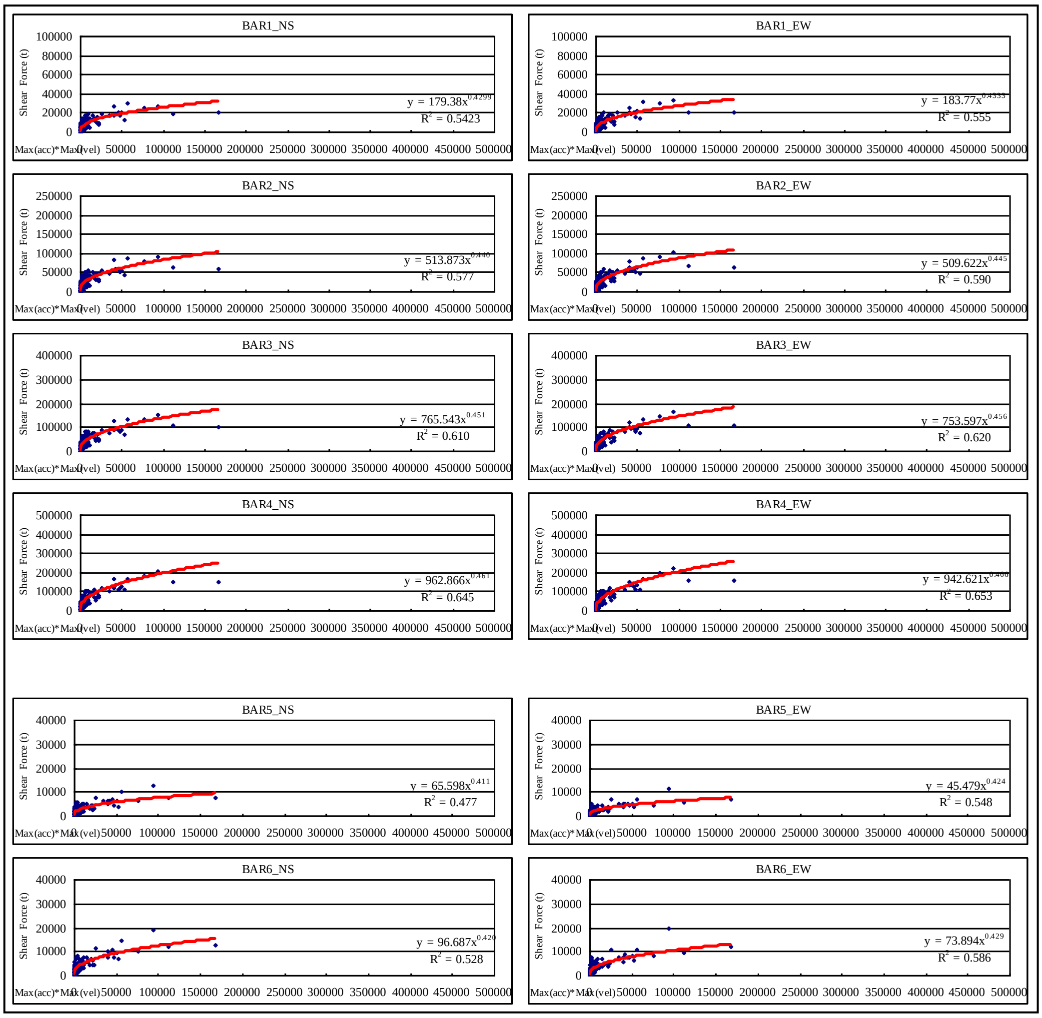


Figure 8.3.9 Structure C Shear Force and PGA Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

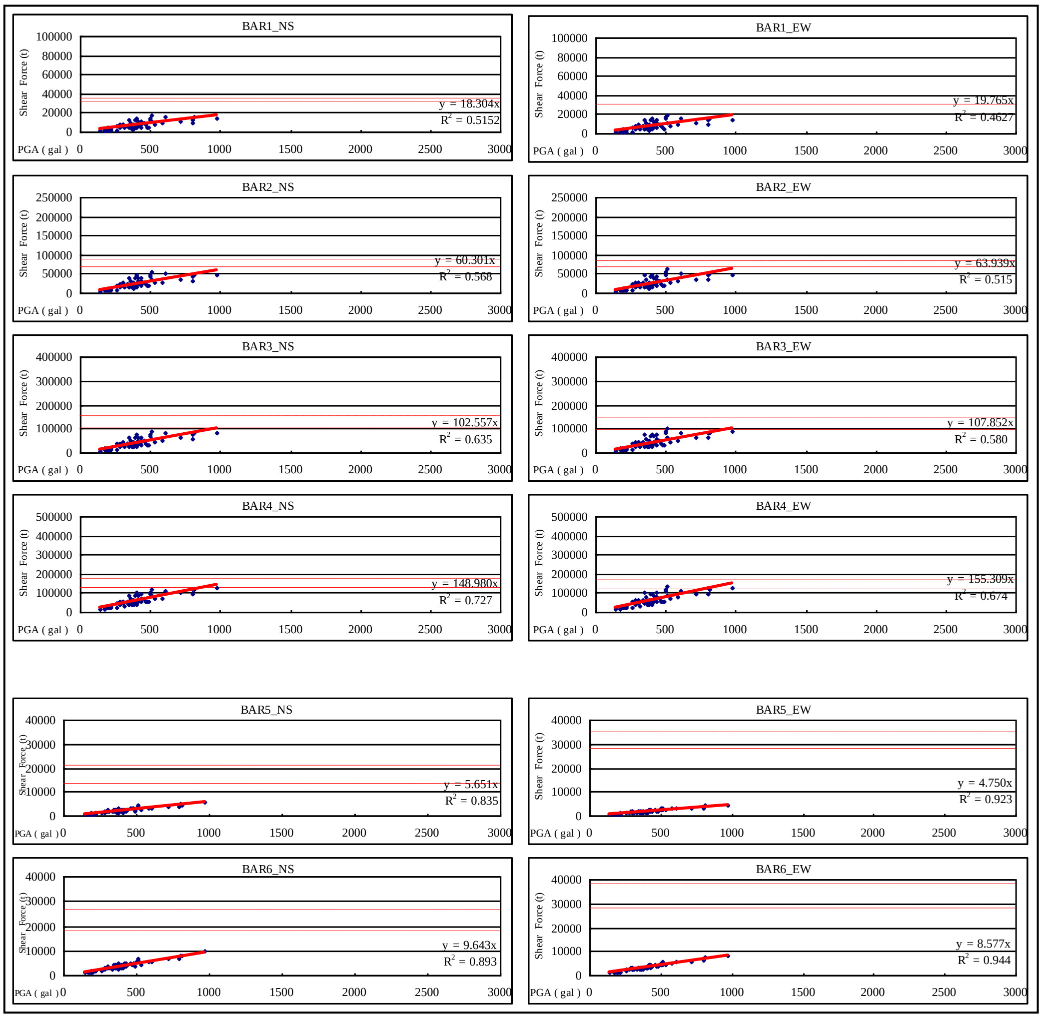


Figure 8.3.10 Structure C Shear Force and A_0 Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

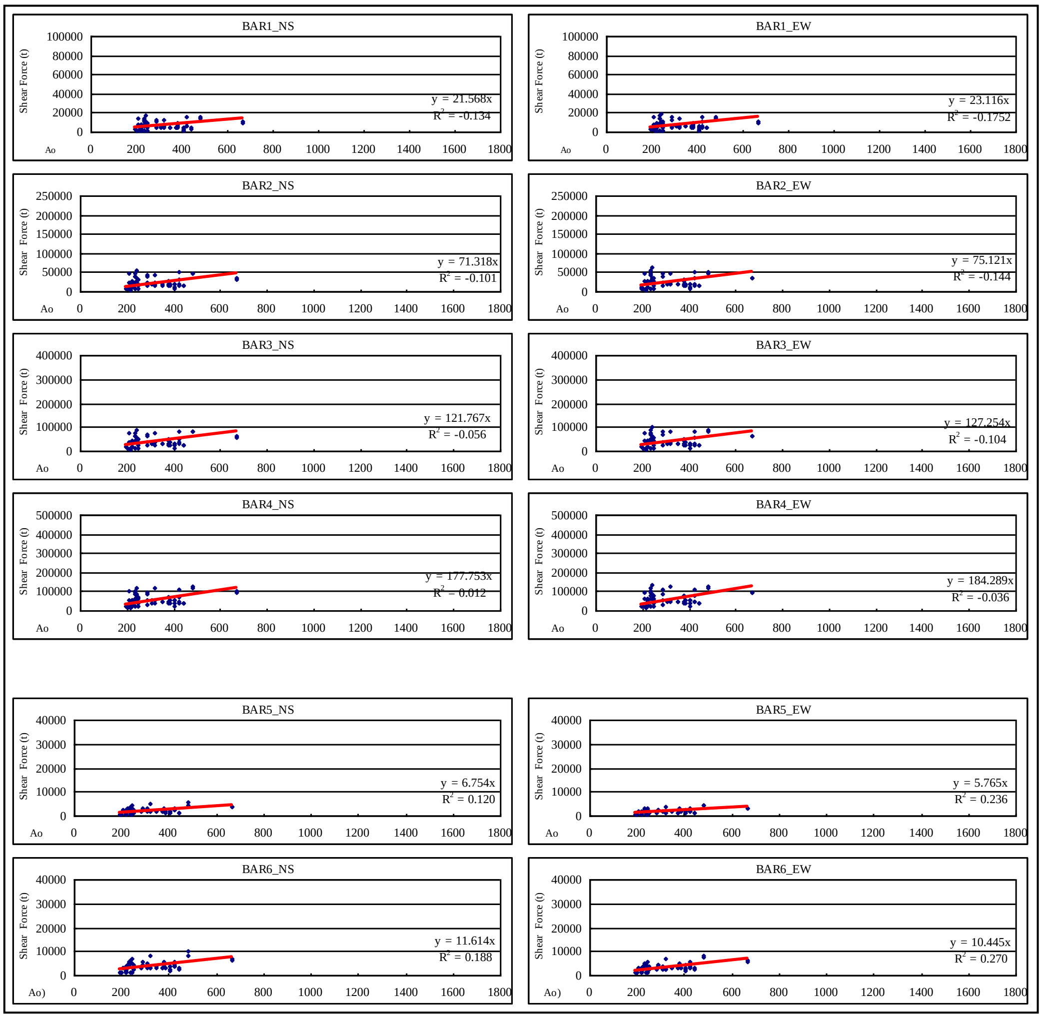


Figure 8.3.11 Structure C Shear Force and PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

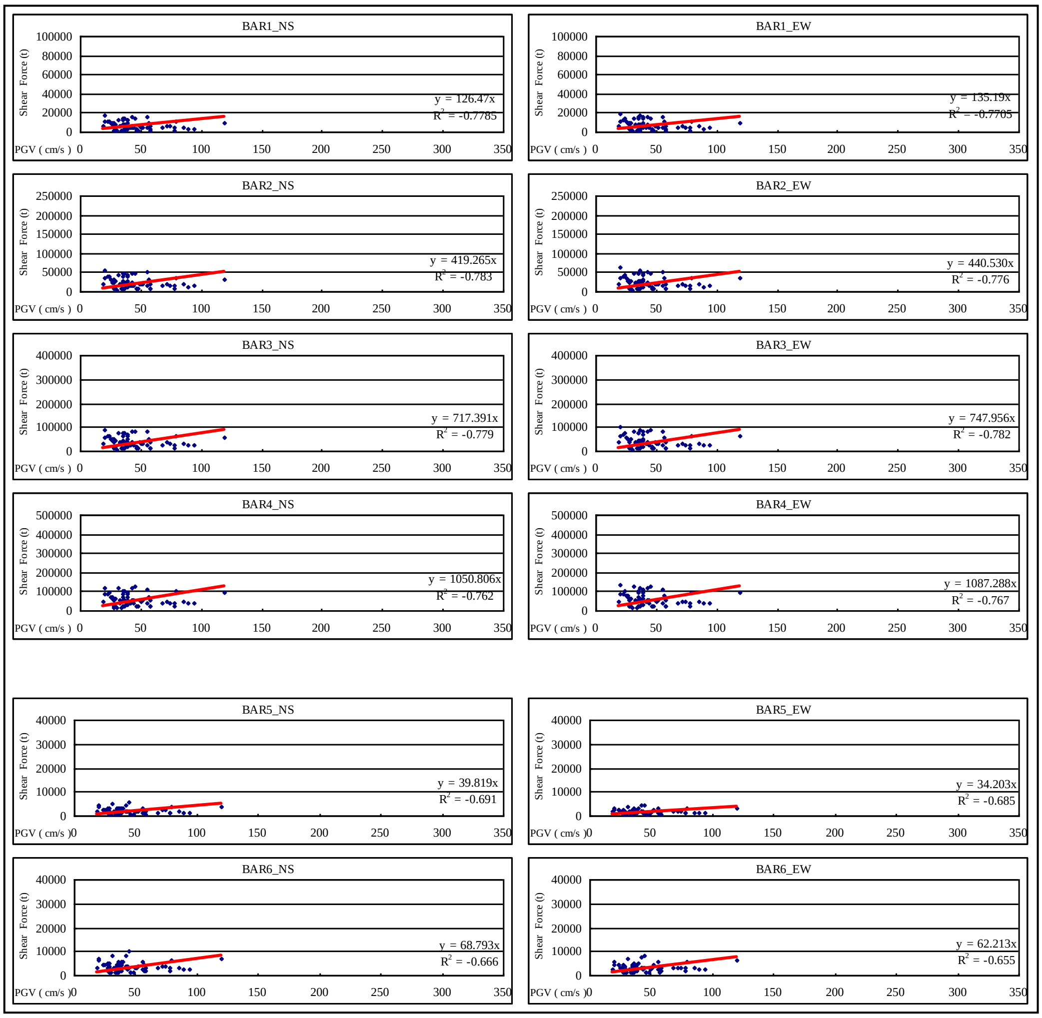


*Figure 8.3.12 Structure C Shear Force and PGA*PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)*

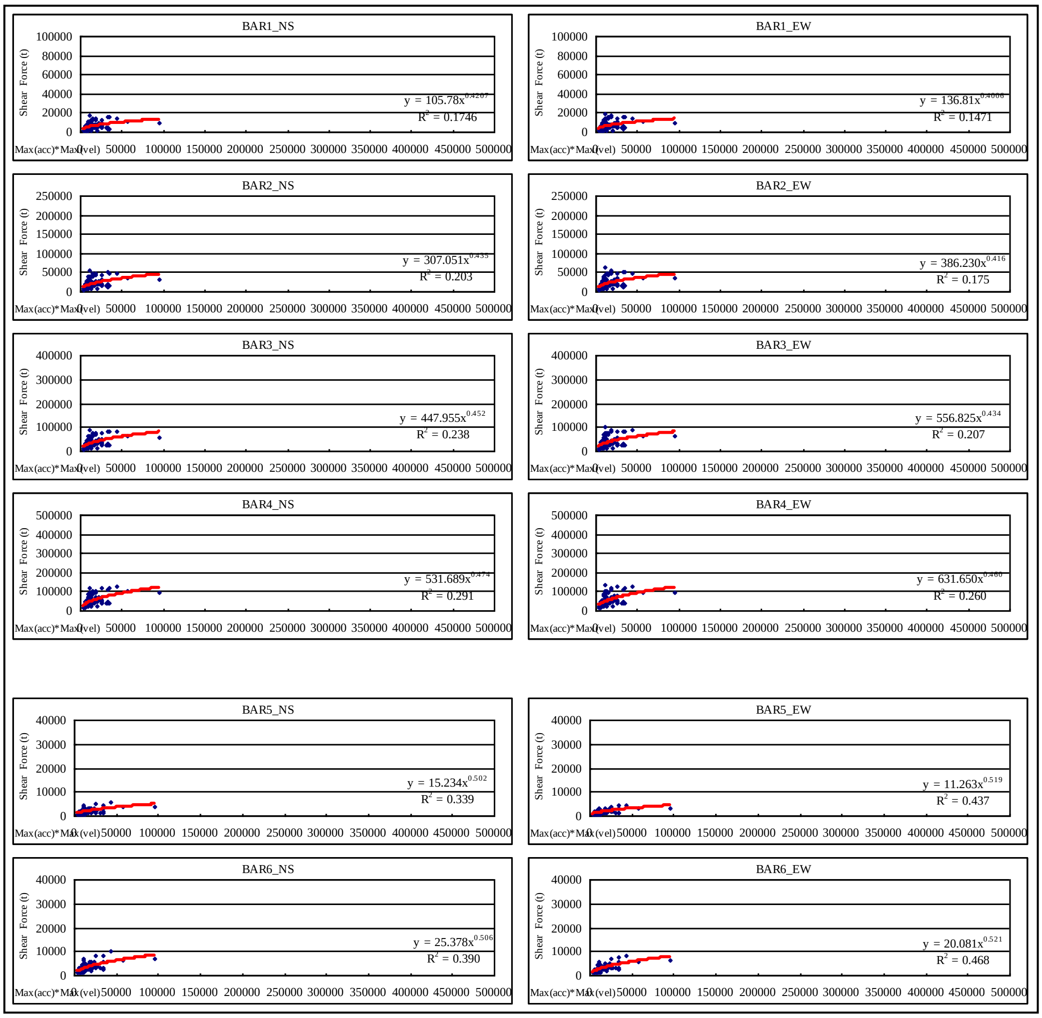


Figure 8.3.13 Structure C Shear Force and PGA Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

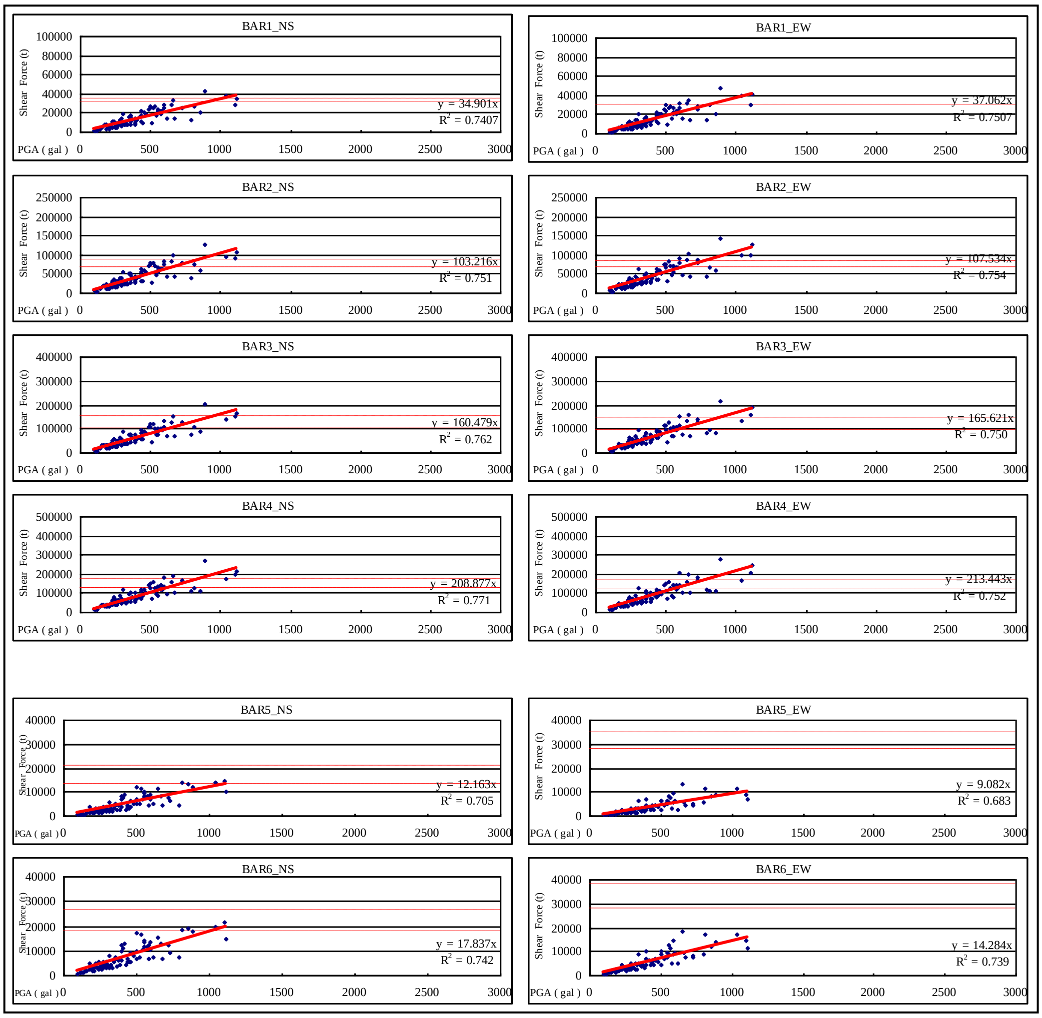


Figure 8.3.14 Structure C Shear Force and A_0 Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

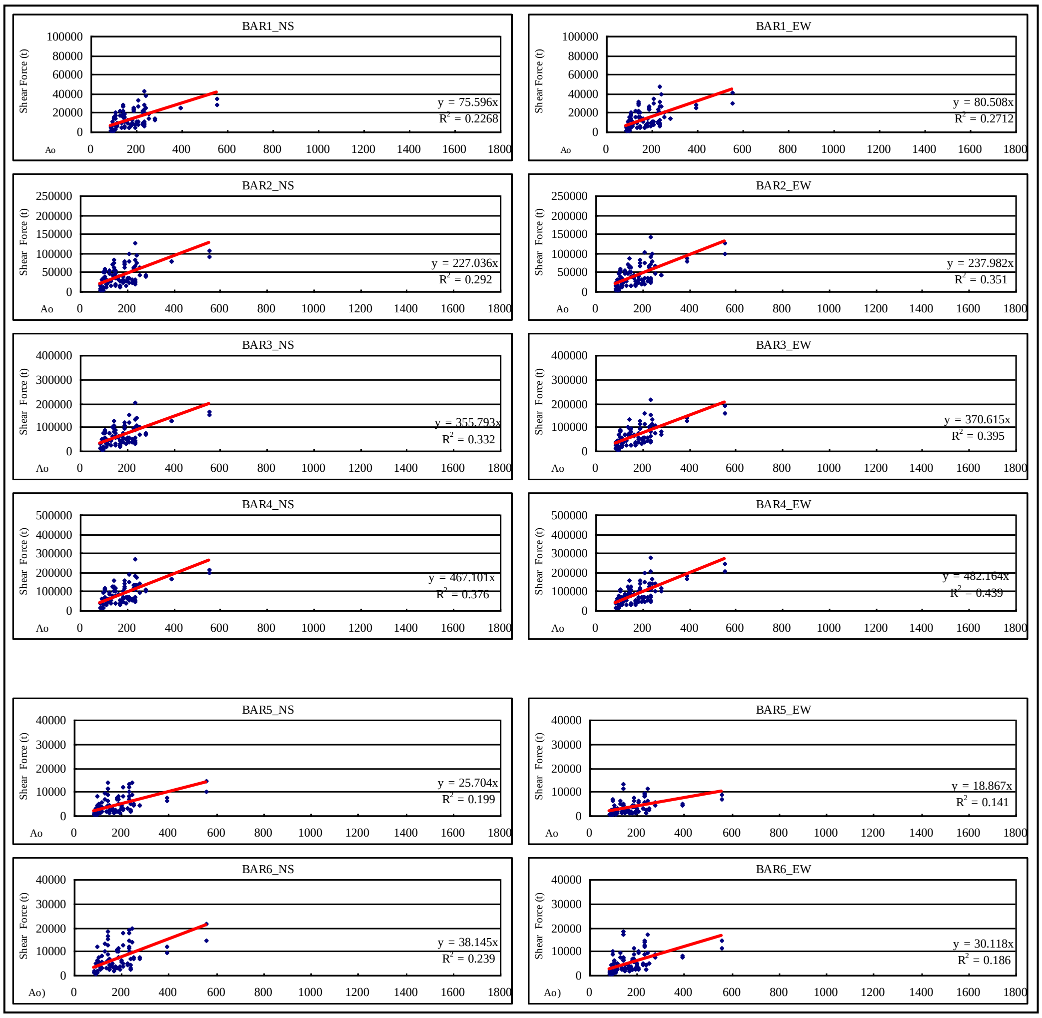


Figure 8.3.15 Structure C Shear Force and PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

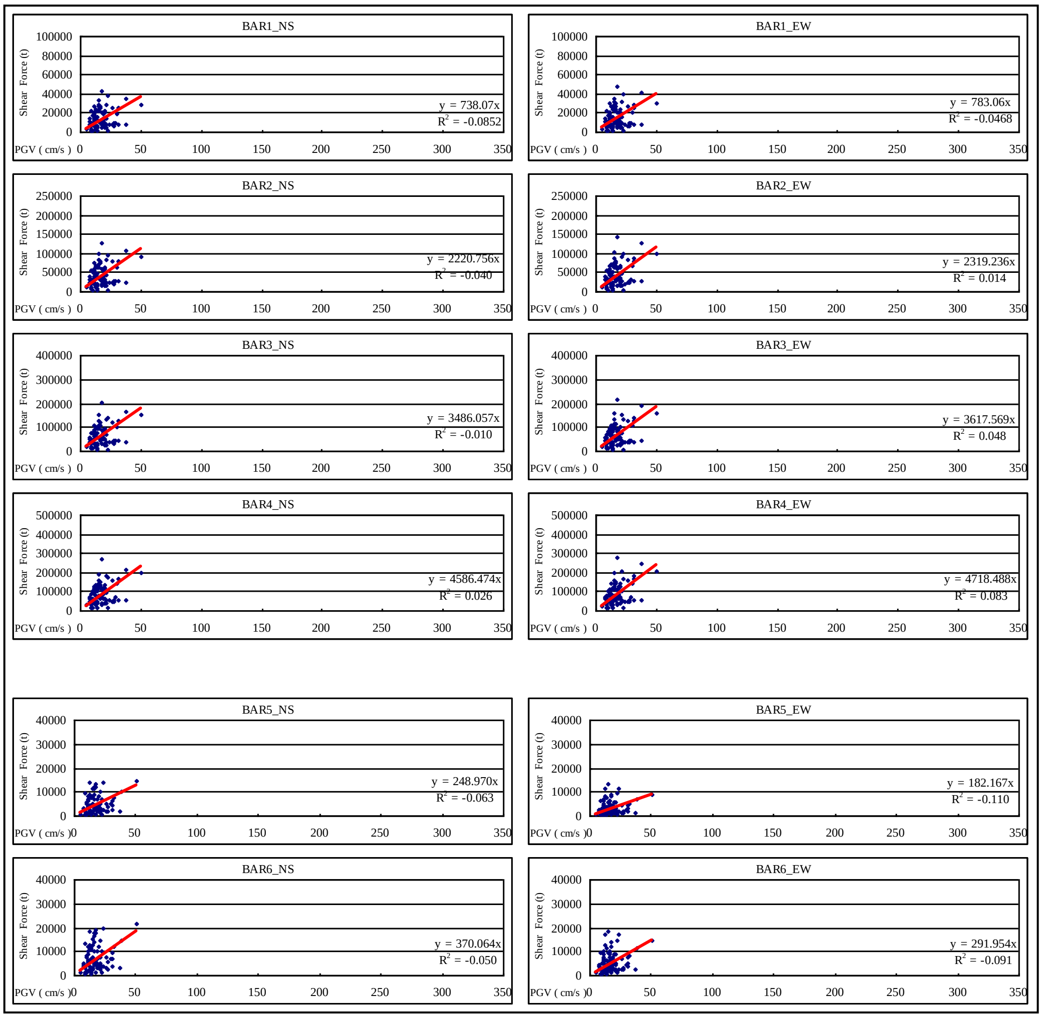


*Figure 8.3.16 Structure C Shear Force and PGA*PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)*

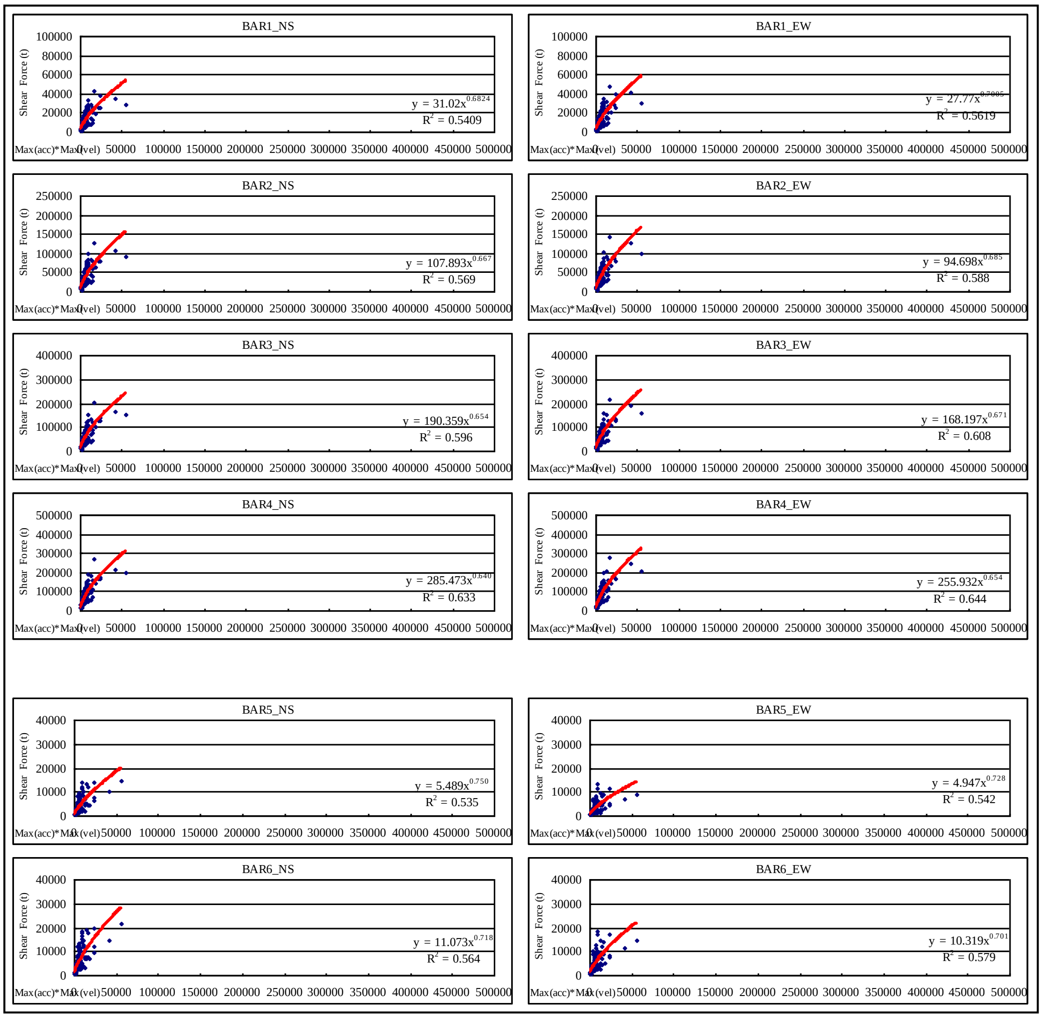


Figure 8.4.1 Structure D Shear Force and PGA Correlation Graphs for all selected ground motions (n=1000)

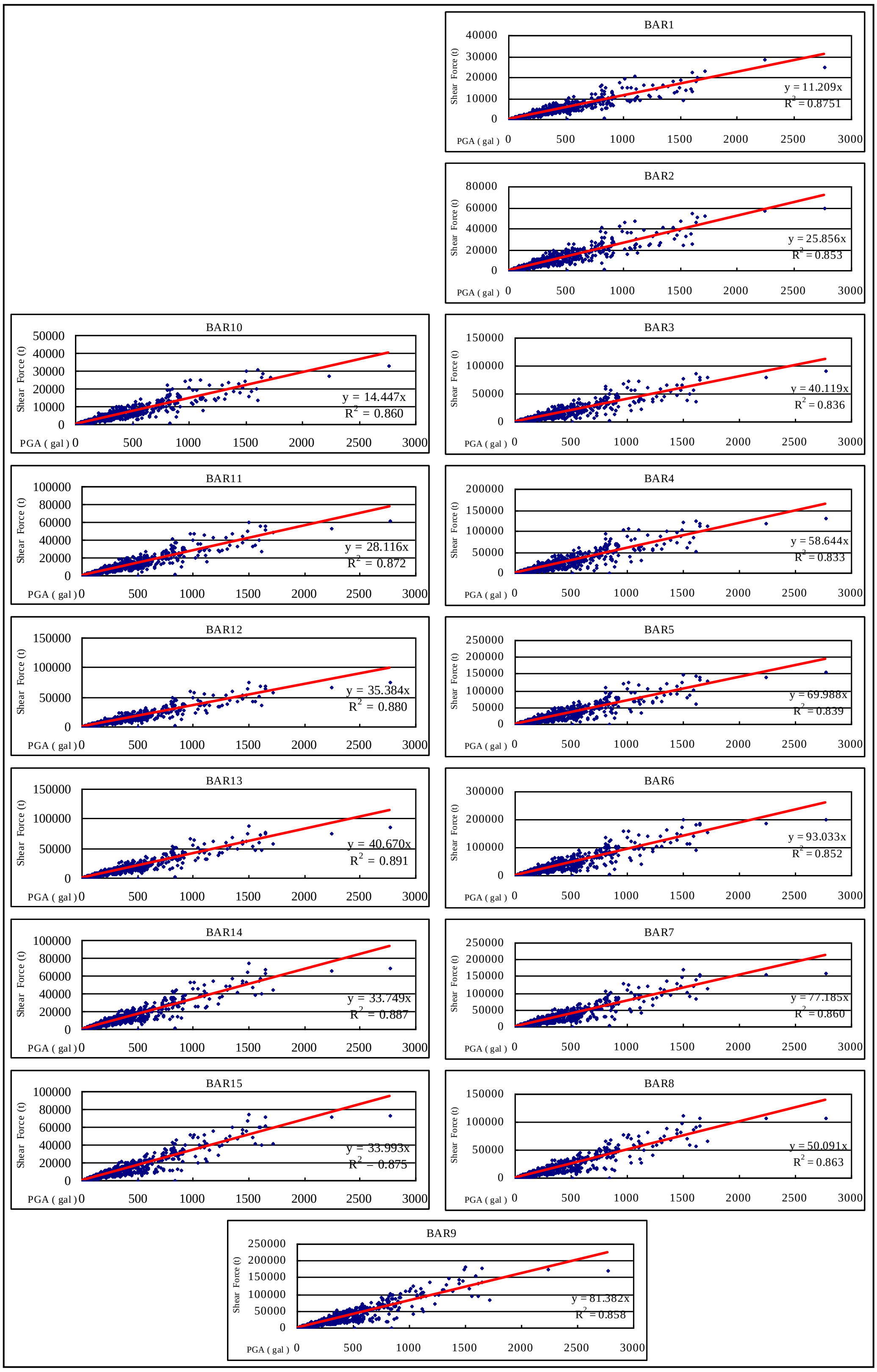


Figure 8.4.2 Structure D Shear Force and A_0 Correlation Graphs for all selected ground motions (n=1000)

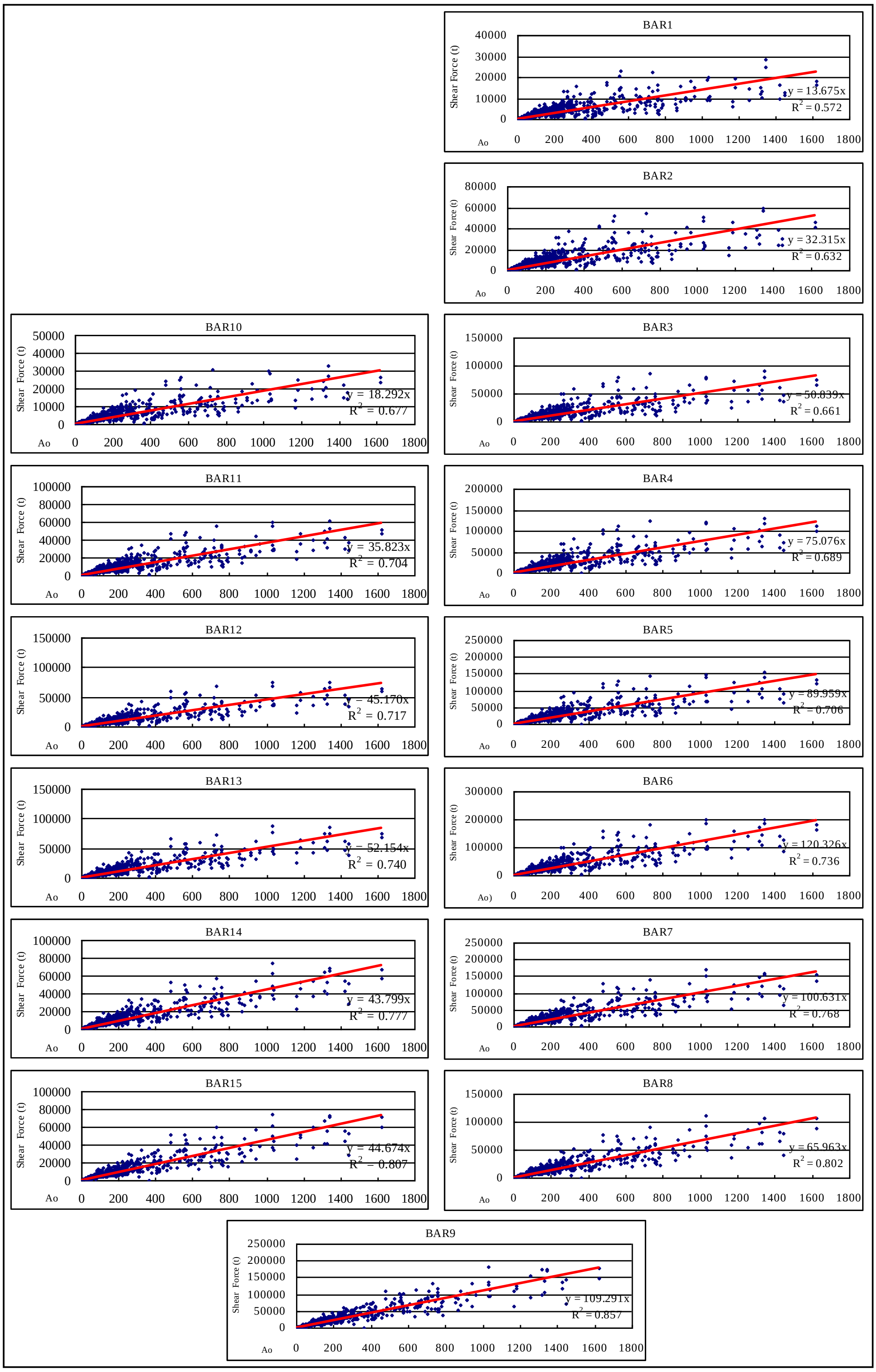


Figure 8.4. 3 Structure D Shear Force and PGV Correlation Graphs for all selected ground motions (n=1000)

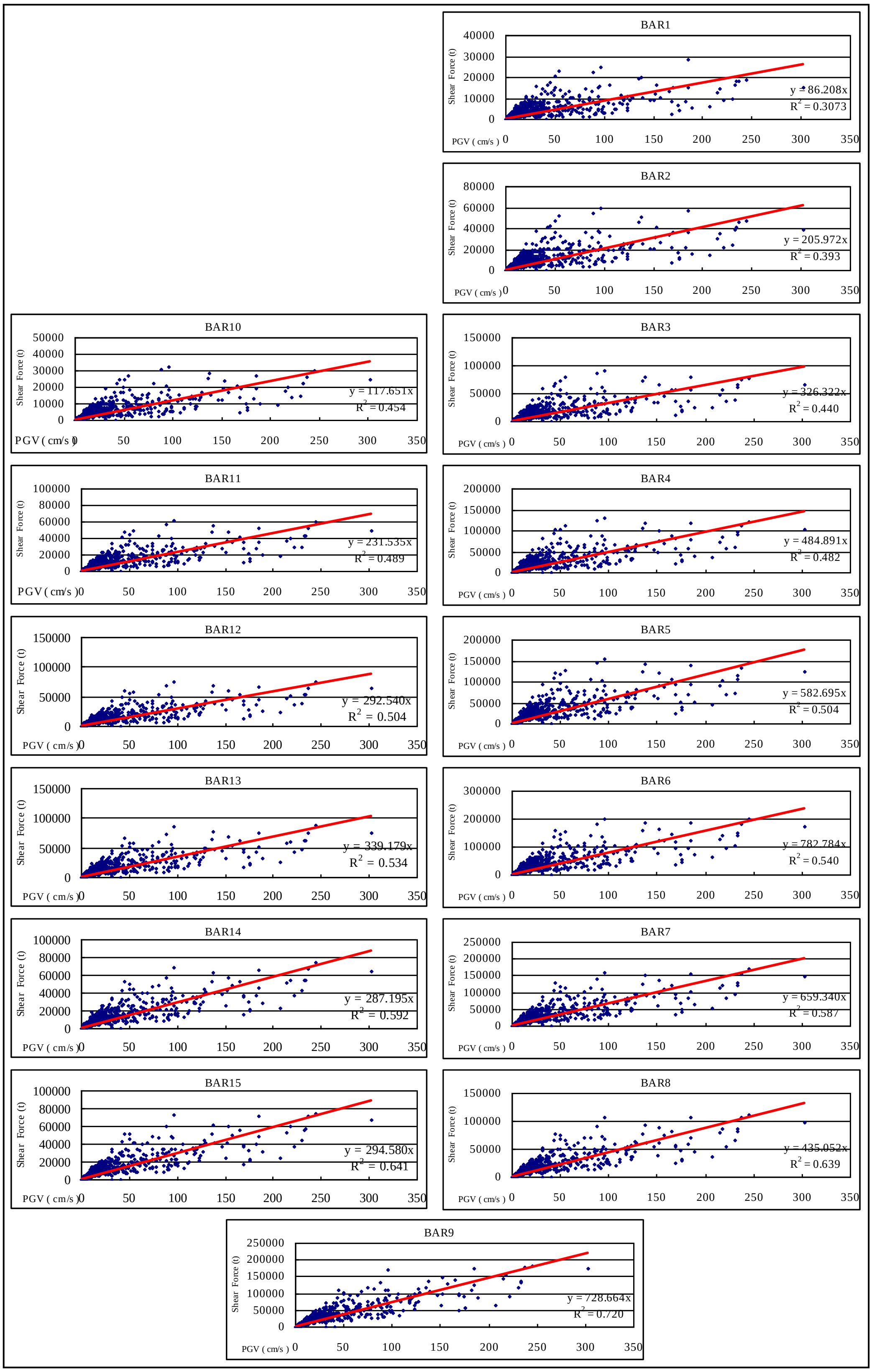


*Figure 8.4.4 Structure D Shear Force and PGA*PGV Correlation Graphs for all selected ground motions (n=1000)*

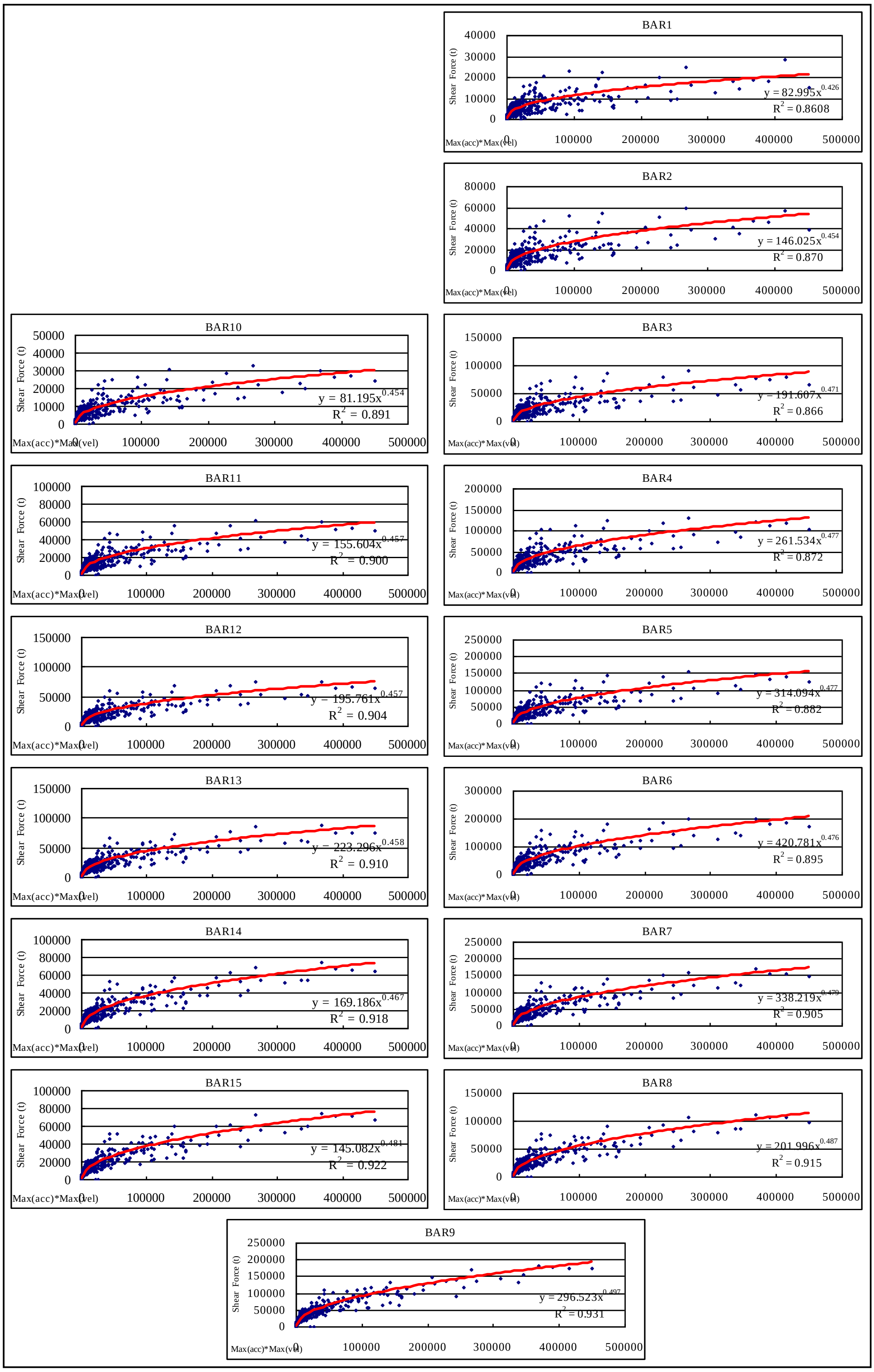


Figure 8.4.5 Structure D Shear Force and PGA Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)

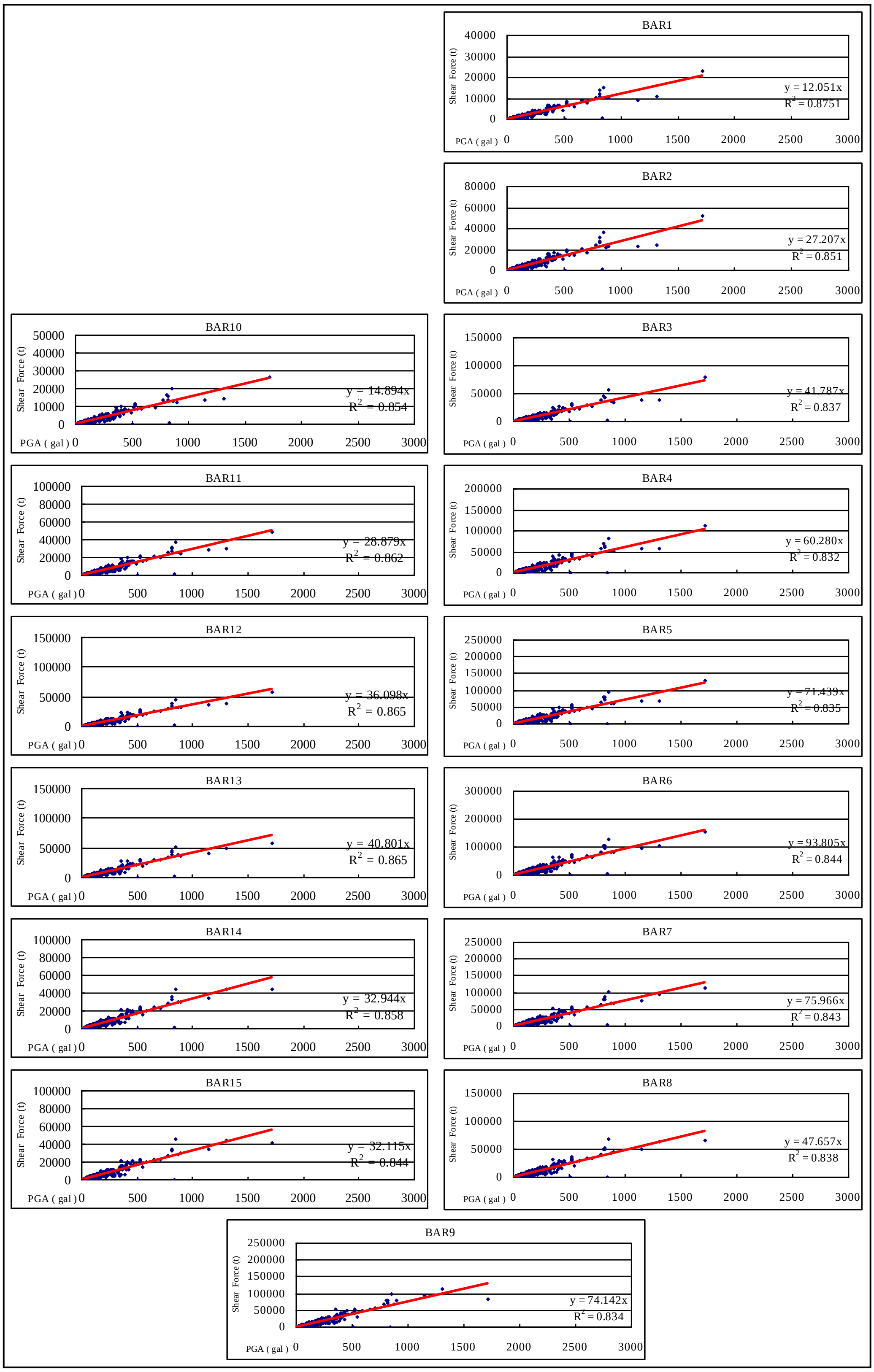
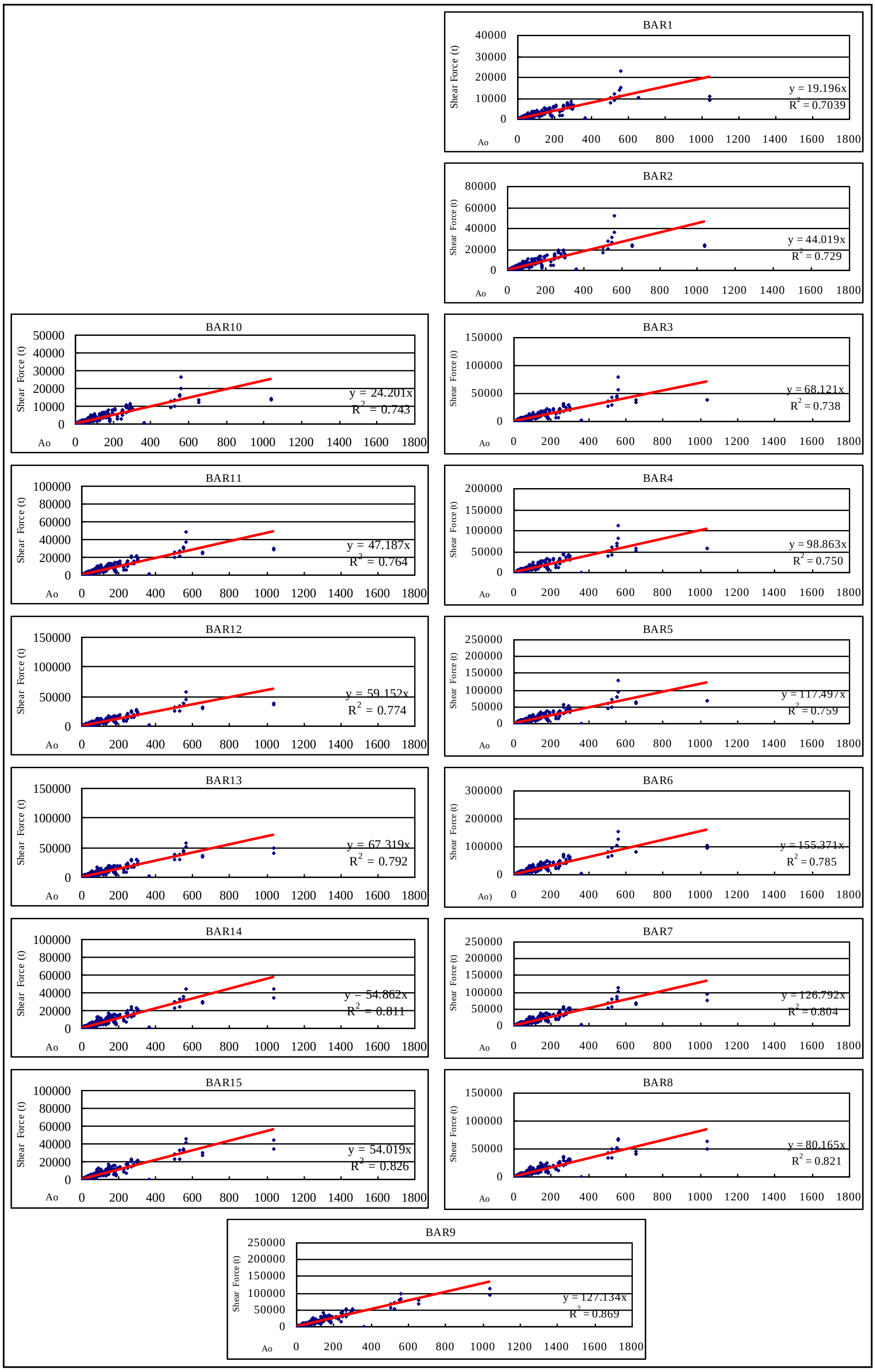


Figure 8.4.6 Structure D Shear Force and A_0 Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)



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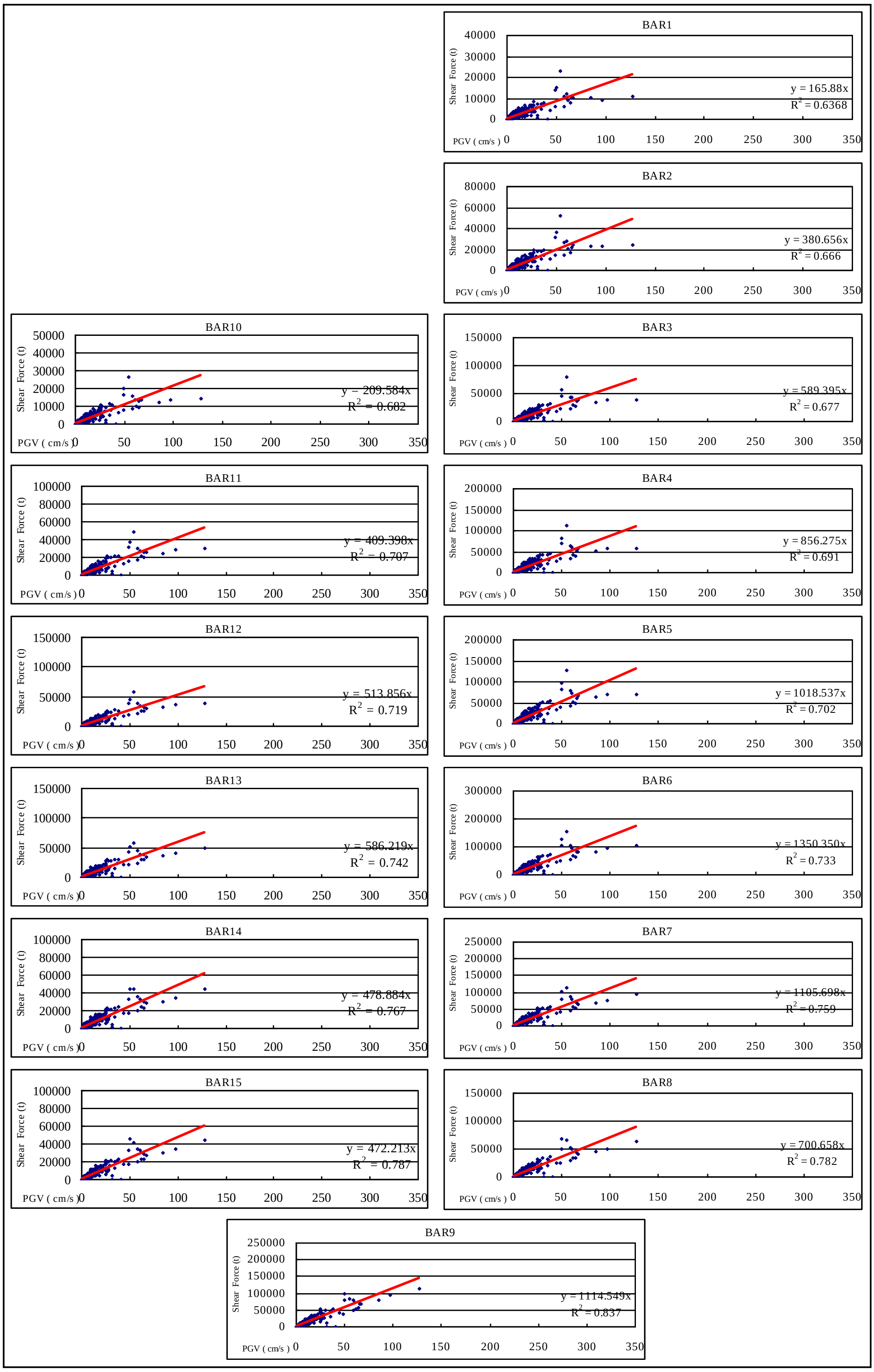

*Figure 8.4.8 Structure D Shear Force and PGA*PGV Correlation Graphs for 2004.10.23 17:56 Mw=6.8 Nigata Earthquake and aftershocks ground motions (n=586)*

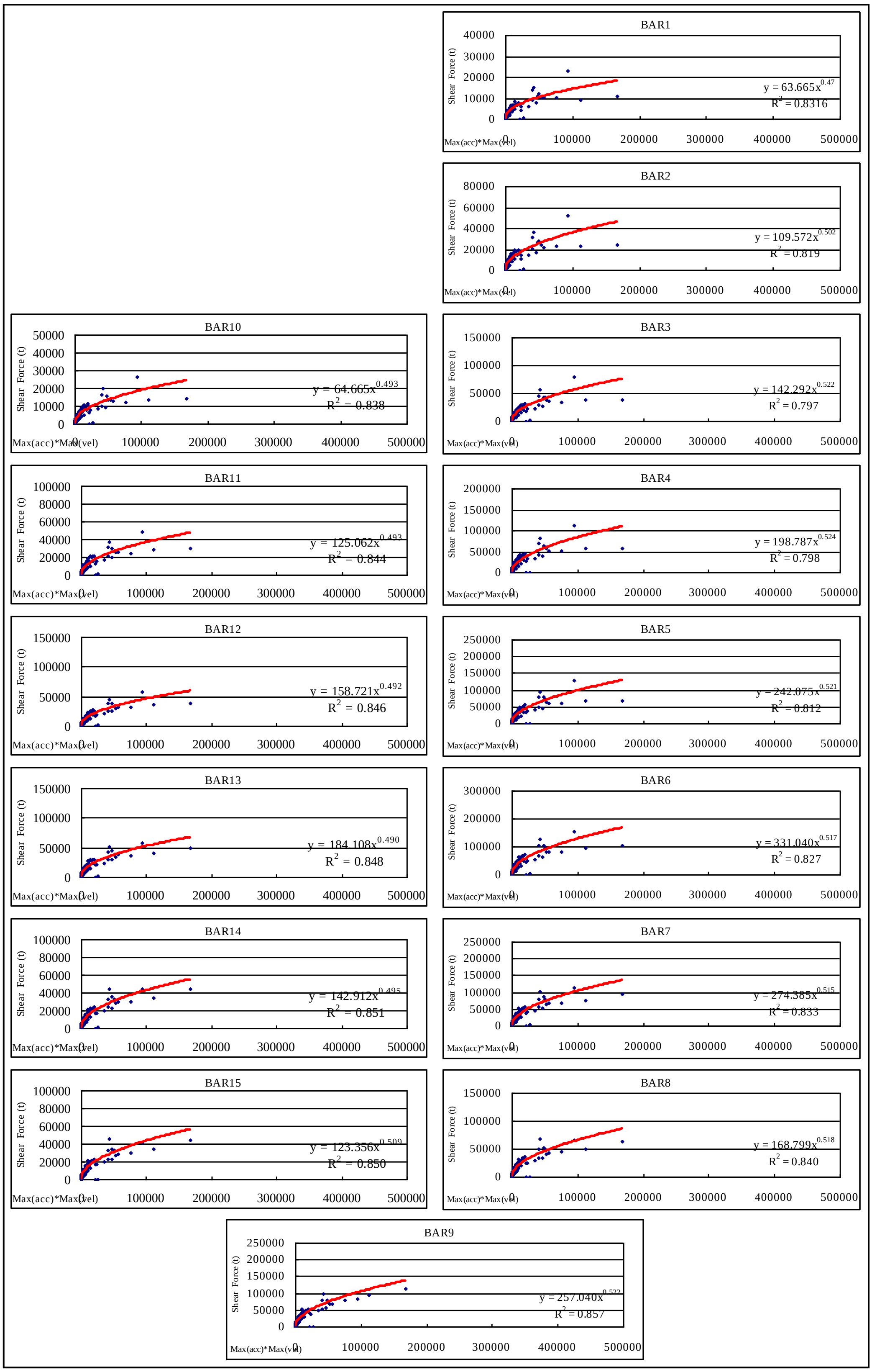

Figure 8.4.9 Structure D Shear Force and PGA Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

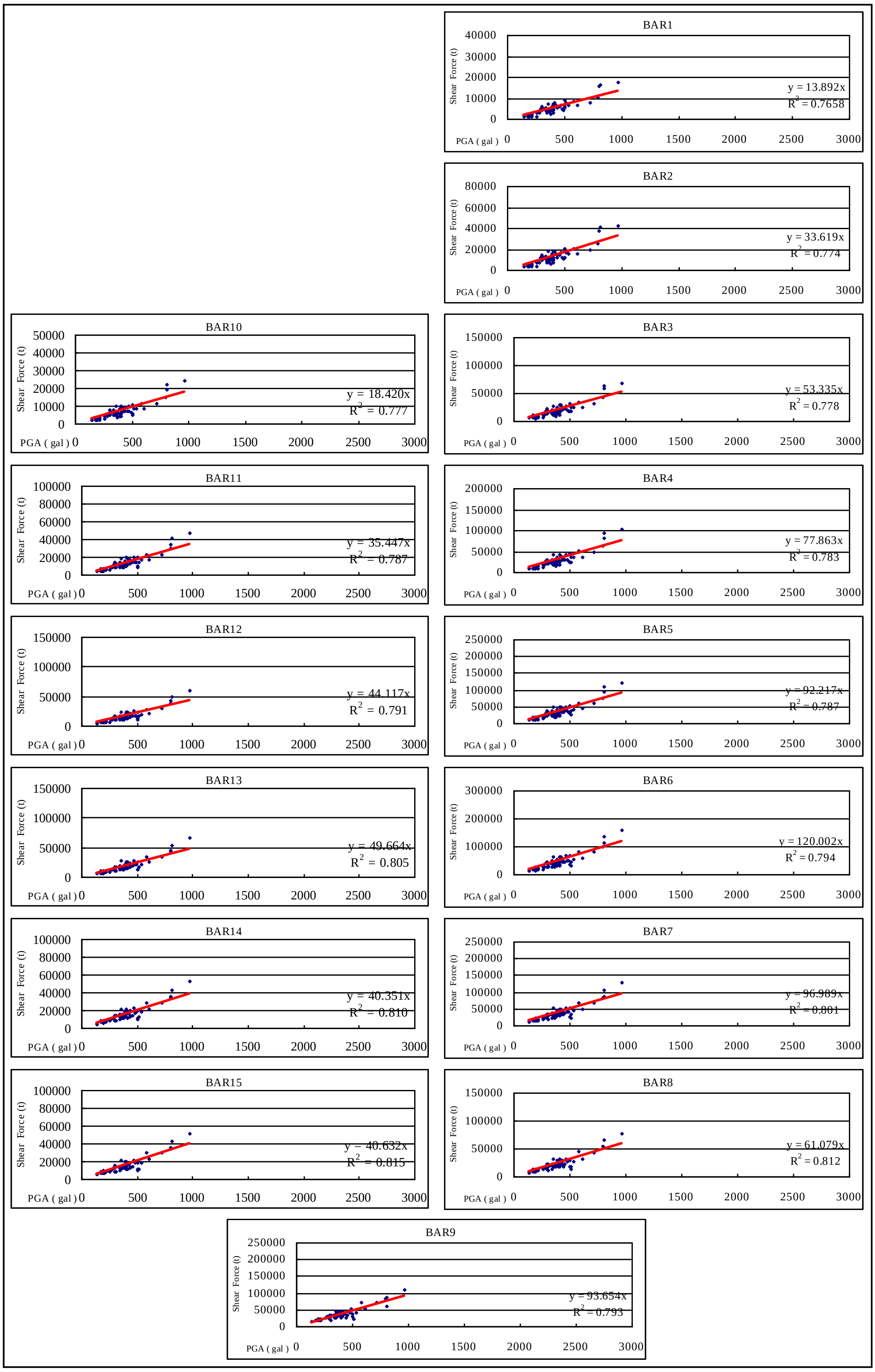

Figure 8.4.10 Structure D Shear Force and A₀ Correlation Graphs for2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

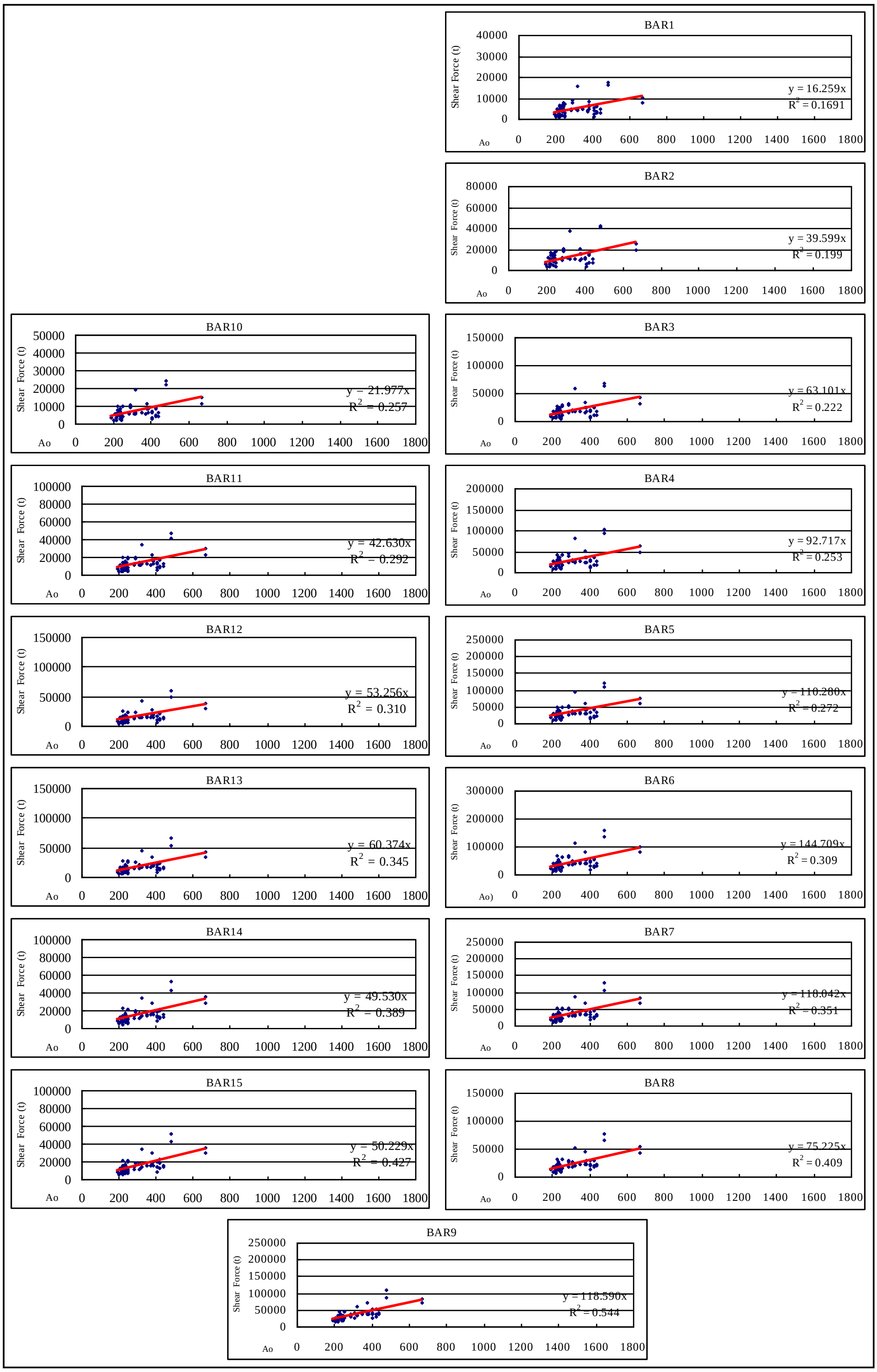

Figure 8.4.11 Structure D Shear Force and PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)

*Figure 8.4.12 Structure D Shear Force and PGA*PGV Correlation Graphs for 2003.09.26 04:50 Mw=8.00 Tokachi Oki Earthquake ground motions (n=34)*

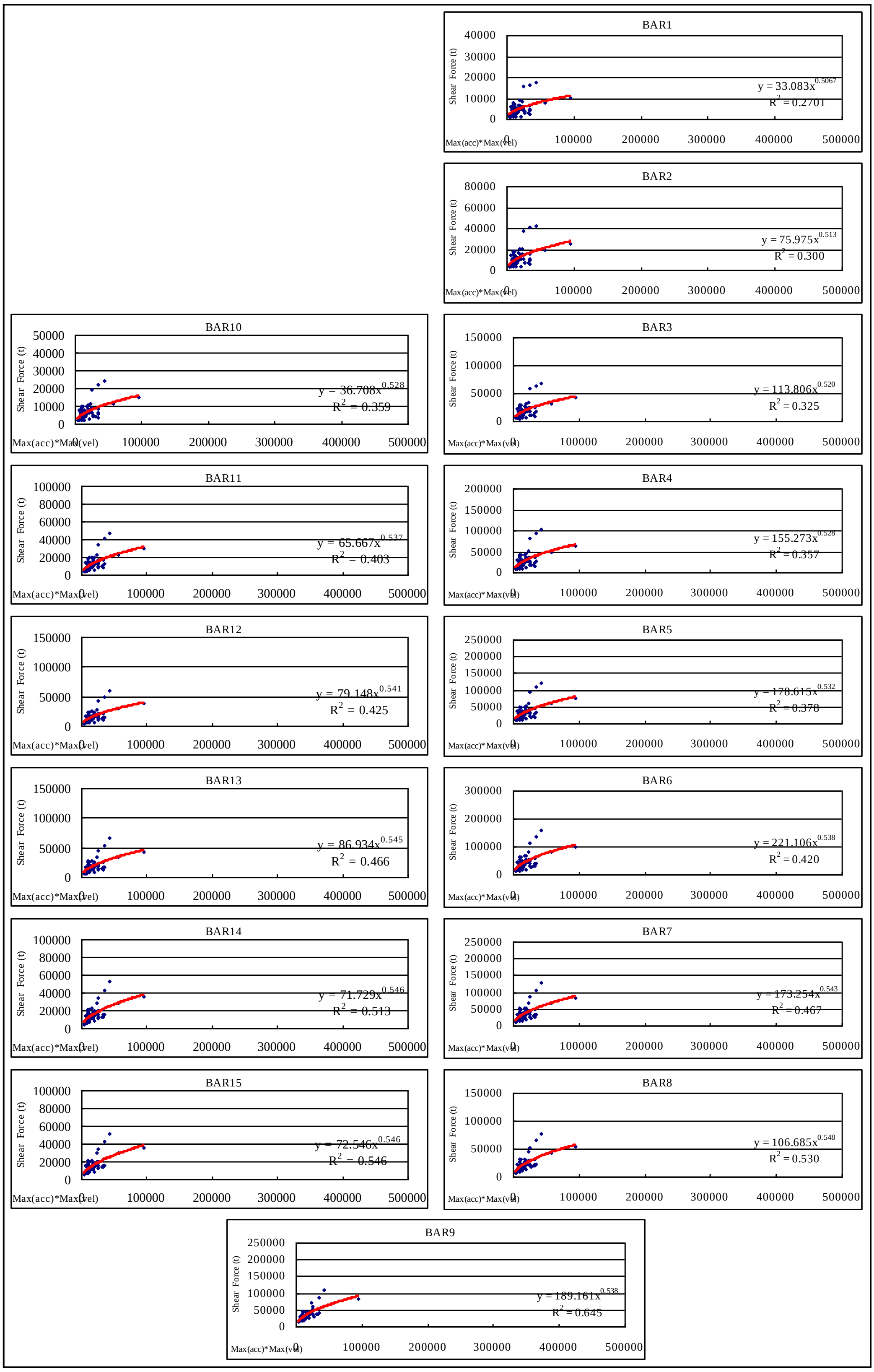

Figure 8.4.13 Structure D Shear Force and PGA Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

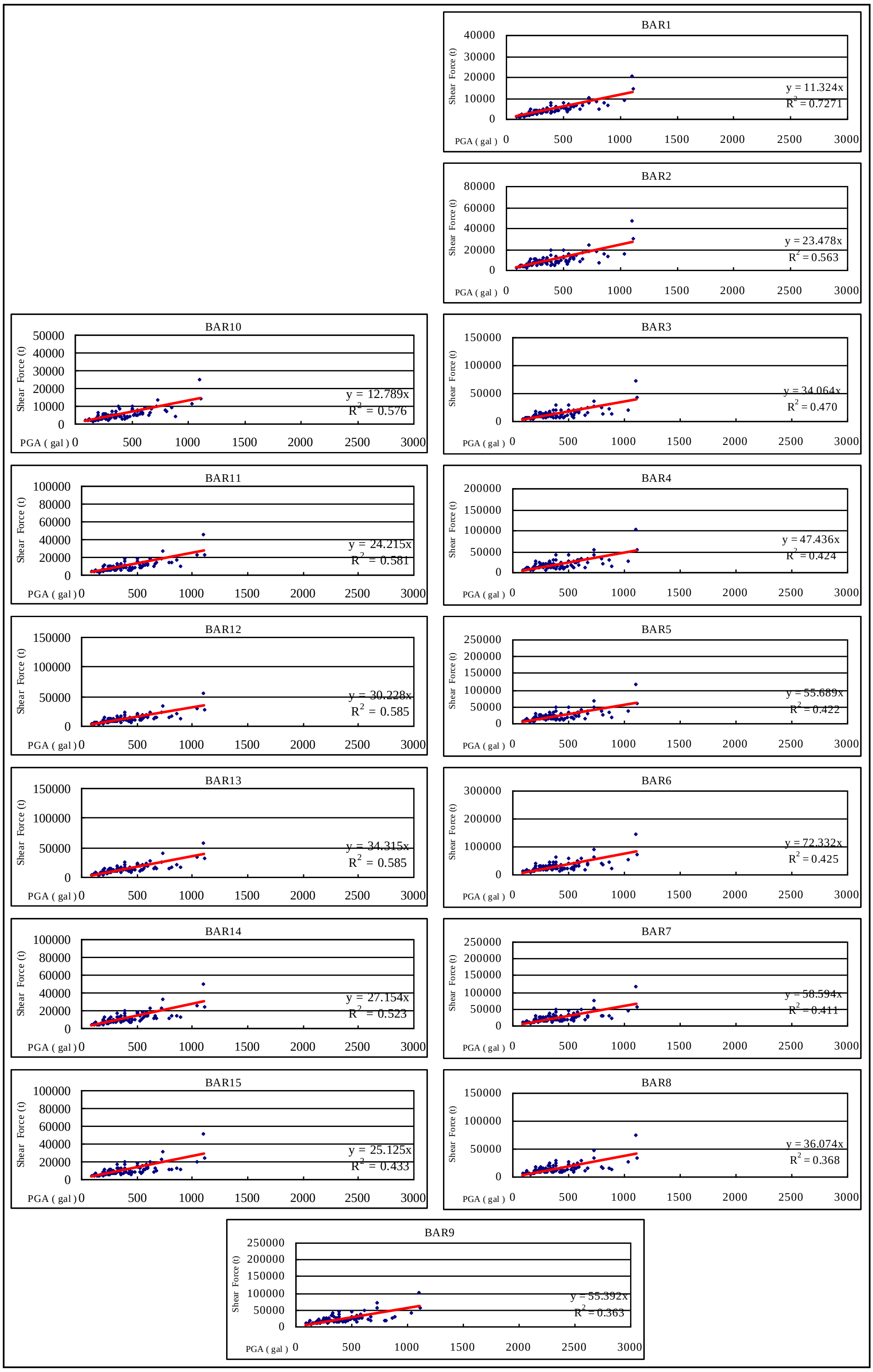

Figure 8.4.14 Structure D Shear Force and A_0 Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

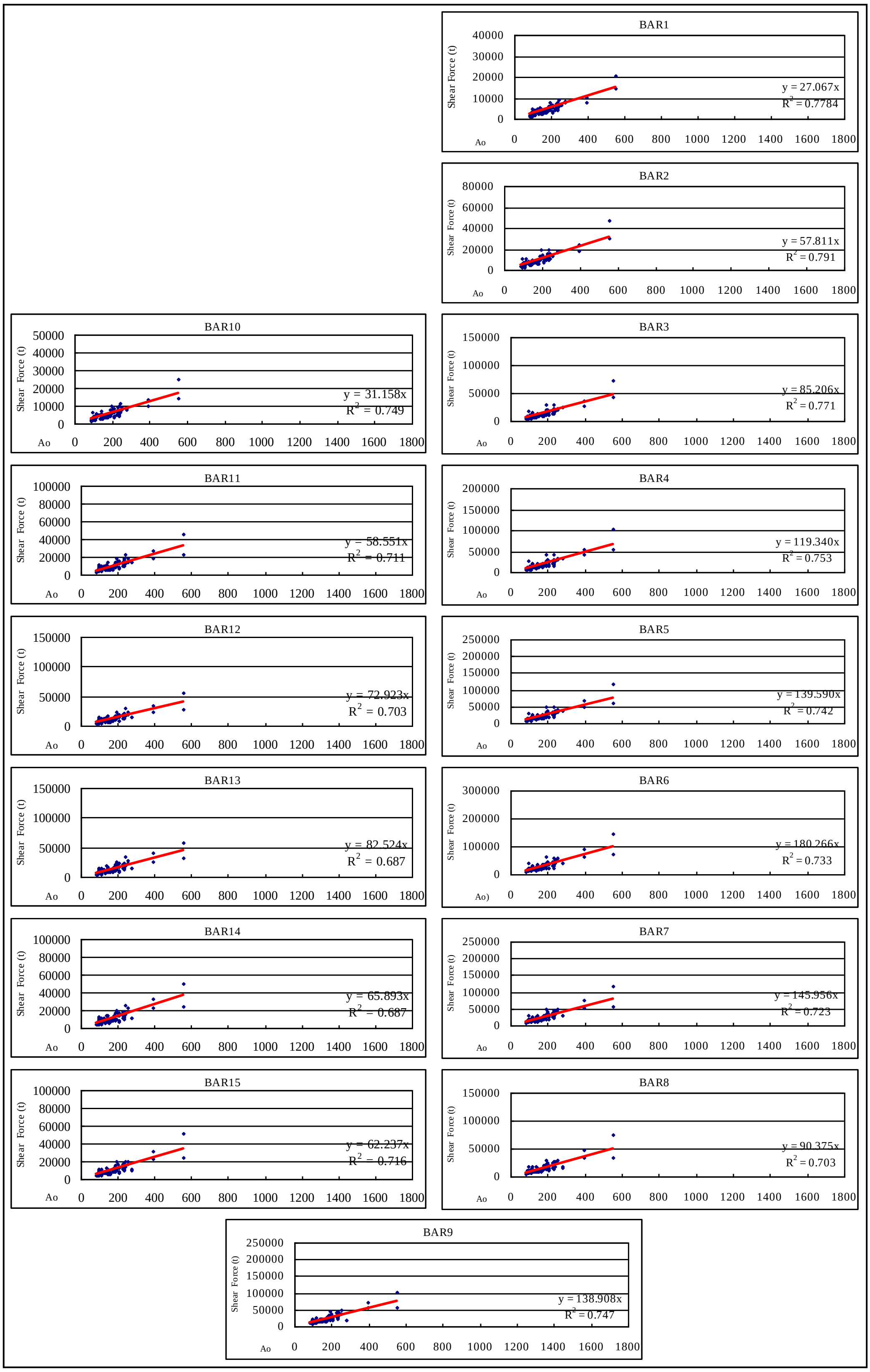

Figure 8.4.15 Structure D Shear Force and PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)

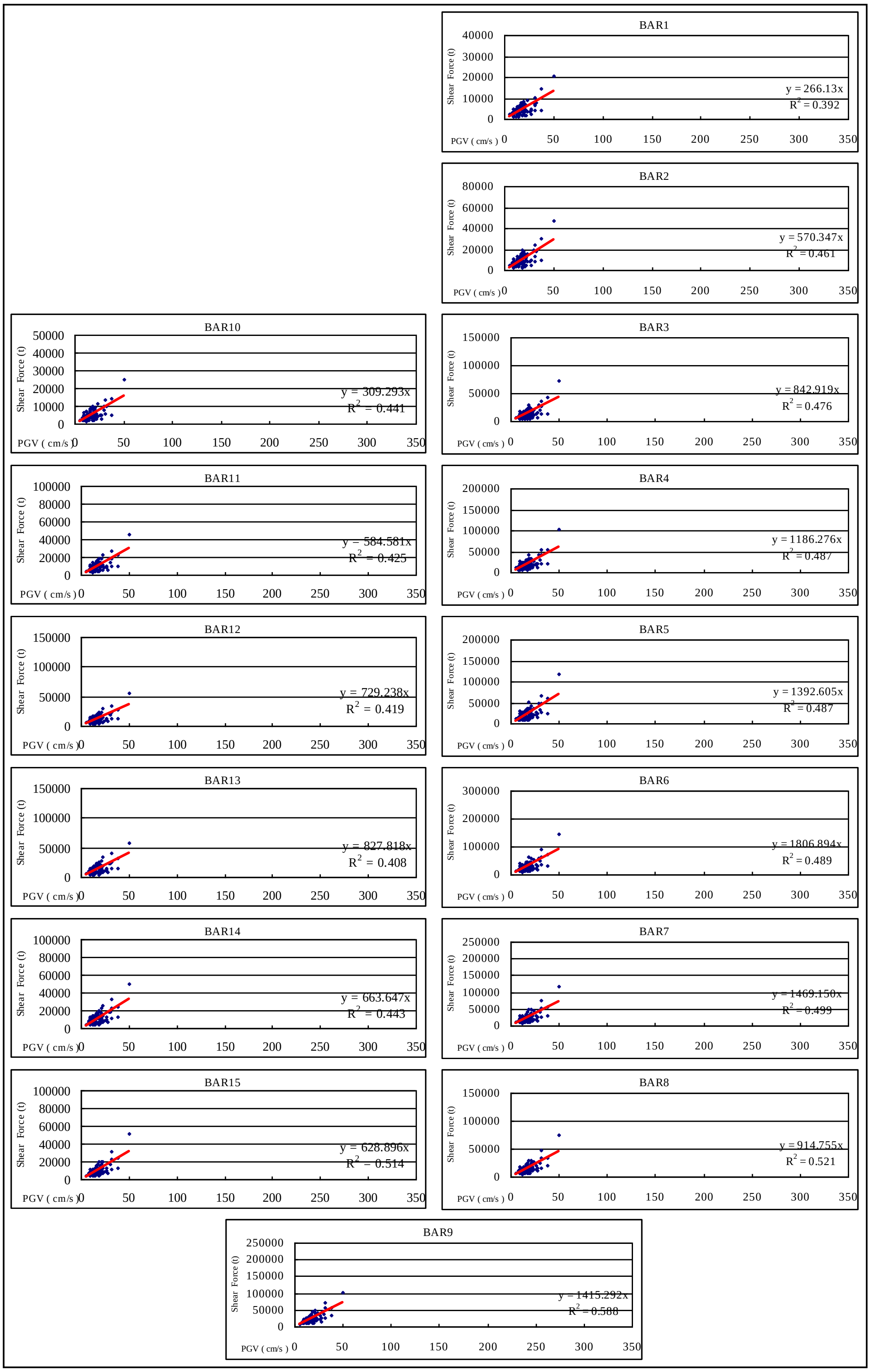

*Figure 8.4.16 Structure D Shear Force and PGA*PGV Correlation Graphs for 2003.05.26 18:24 Mw=7.0 Miyagi Oki Earthquake ground motions (n=44)*

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