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MFN 06-274
Supplement 1

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Subject: **Response to Portion of RAI Letter Number 20 Related to ESBWR Design Certification Application – Seismic Design – RAI Numbers 3.7-16S1, 3.7-24S1, 3.7-30S1, 3.7-33S1, 3.7-35S1, 3.7-38S1, 3.7-39S1, 3.7-50S1, 3.7-54S1 and 3.7-57S1 – Supplement 1**

Enclosure 1 contains supplemental responses to the subject RAIs resulting from the November 2006 NRC Seismic Audit. GE's original responses were transmitted via the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Enclosure:

1. MFN 06-274, Supplement 1 - Response to Portion of RAI Letter Number 20 Related to ESBWR Design Certification Application – Seismic Design – RAI Numbers 3.7-16S1, 3.7-24S1, 3.7-30S1, 3.7-33S1, 3.7-35S1, 3.7-38S1, 3.7-39S1, 3.7-50S1, 3.7-54S1 and 3.7-57S1

Reference:

1. MFN 06-274, Letter from David H. Hinds to U. S. Nuclear Regulatory Commission, *Response to RAI Letter Number 20 Related to ESBWR Design Certification Application – Seismic Design – RAI Numbers 3.7-16, 3.7-24, 3.7-27, 3.7-30, 3.7-32, 3.7-33, 3.7-35, 3.7-37, 3.7-38, 3.7-39, 3.7-50, 3.7-54 and 3.7-57,* August 17, 2006

cc:	AE Cubbage	USNRC (with enclosures)
	GB Stramback	GE/San Jose (with enclosures)
	eDRF	0000-0060-8447

ENCLOSURE 1

MFN 06-274

SUPPLEMENT 1

Response to Portion of RAI Letter Number 20

Related to ESBWR Design Certification Application

Seismic Design

RAI Numbers 3.7-16S1, 3.7-24S1, 3.7-30S1, 3.7-33S1, 3.7-35S1,

3.7-38S1, 3.7-39S1, 3.7-50S1, 3.7-54S1 and 3.7-57S1

Original responses previously submitted under MFN 06-274 are included to provide historical continuity during review but DCD updates previously submitted are not included in this package.

NRC RAI 3.7-16

In DCD Section 3.7.2.1.1, the applicant presents the formulation of the equations of motion in terms of undamped eigenvalues and mode shapes, with solutions obtained by integration in the time domain. The applicant is requested to address the limitations of this formulation, particularly for the case of frequency-dependent SSI stiffness and damping coefficients.

GE Response

As stated in DCD Section 3A.5, the base spring is evaluated from vibration admittance theory, based on three dimensional wave propagation theory for uniform half space soil. Though the spring values consist of frequency dependent real and imaginary parts, they are simplified and replaced with frequency-independent soil spring Kc, and damping coefficient Cc, respectively, for the time history analysis solved in the time domain.

The sites considered in the seismic analysis of the ESBWR standard plant cover a wide range of uniform soil/rock sites. For uniform sites the use of frequency-independent soil properties in the formulation is an acceptable approach in accordance with guidance of ASCE 4-98, Section 3.3.4.2.2.

The effects of frequency-dependent SSI stiffness and damping coefficients are evaluated for additional layered sites. See response to RAI 3.7-30 for details.

No DCD change was required for this RAI response.

NRC RAI 3.7-16, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

a. *NRC staff consultants (BNL) to compare the results of their confirmatory analysis at the top of the CB and the top of basemat against the GE design spectra.*

b. *Provide for the RB, a smooth plot of the transfer functions at the top of the building, top of the basemat and at the top of the four corners of the embedded walls.*

GE Response

a. GE design spectra at the top of the CB and at the top of basemat were provided to NRC/BNL at the November 2, 2006 audit by GE.

b. For the RB, the SASSI transfer functions were provided as follows:

   Figures 3.7-16 (1) through 3.7-16 (3) show the original transfer functions at the top of the RBFB building, top of basemat, and at the four corners at the top of the embedded walls, in X, Y and Z directions respectively. The soil condition is the layered site case 1 shown in the response to RAI 3.7-30 provided under MFN 06-274.

   By adding more frequency points near the spikes, all the spikes were eliminated except for the peak at 7.8 Hz in Y direction as shown in Figures 3.7-16 (4) through 3.7-16 (6).

   Adding frequencies near the peak at 7.8 Hz in Y direction actually increases the peak amplitude as shown in Figure 3.7-16 (5). A careful examination of the model did not reveal any problems associated with connectivities. The cause of the spike anomaly in the transfer function is related to differences in the calculation of the deconvolution and amplification of motion by SASSI, in which deconvolution process of the free field is performed by a methodology that is slightly different than the finite element methodology used to develop the structural response. This difference shows up in this case as a discontinuity in the transfer functions and has little impact on the response spectra.

   Figures 3.7-16 (7) through 3.7-16 (9) show FRS at the top of the RBFB and the top of basemat, for X, Y and Z direction respectively. They are calculated from the both original and refined transfer functions and compared with the design basis FRS. The differences in FRS between the original and refined transfer functions are not significant, and the both FRS are bounded by the design basis FRS.

No DCD change will be made in response to this RAI Supplement.

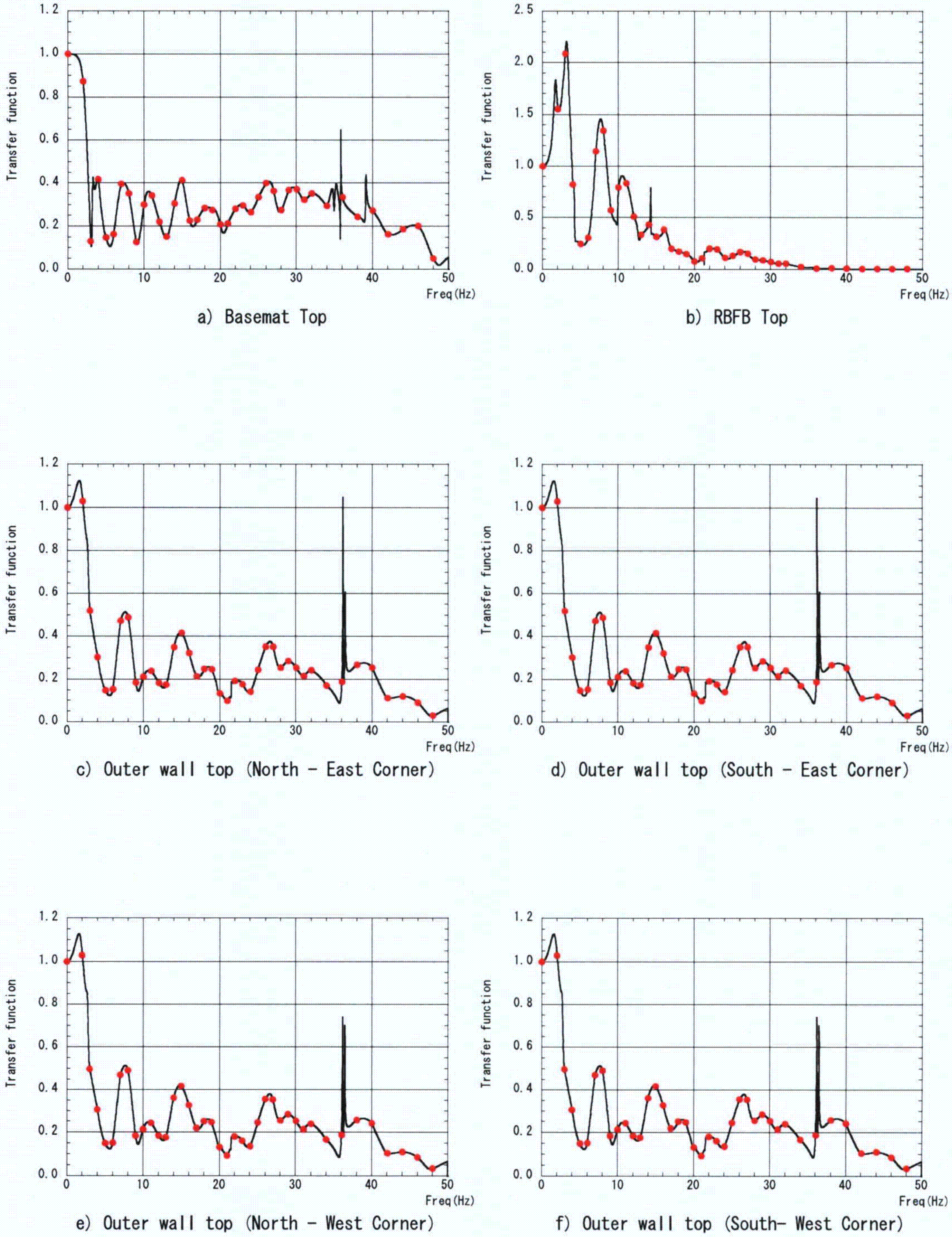
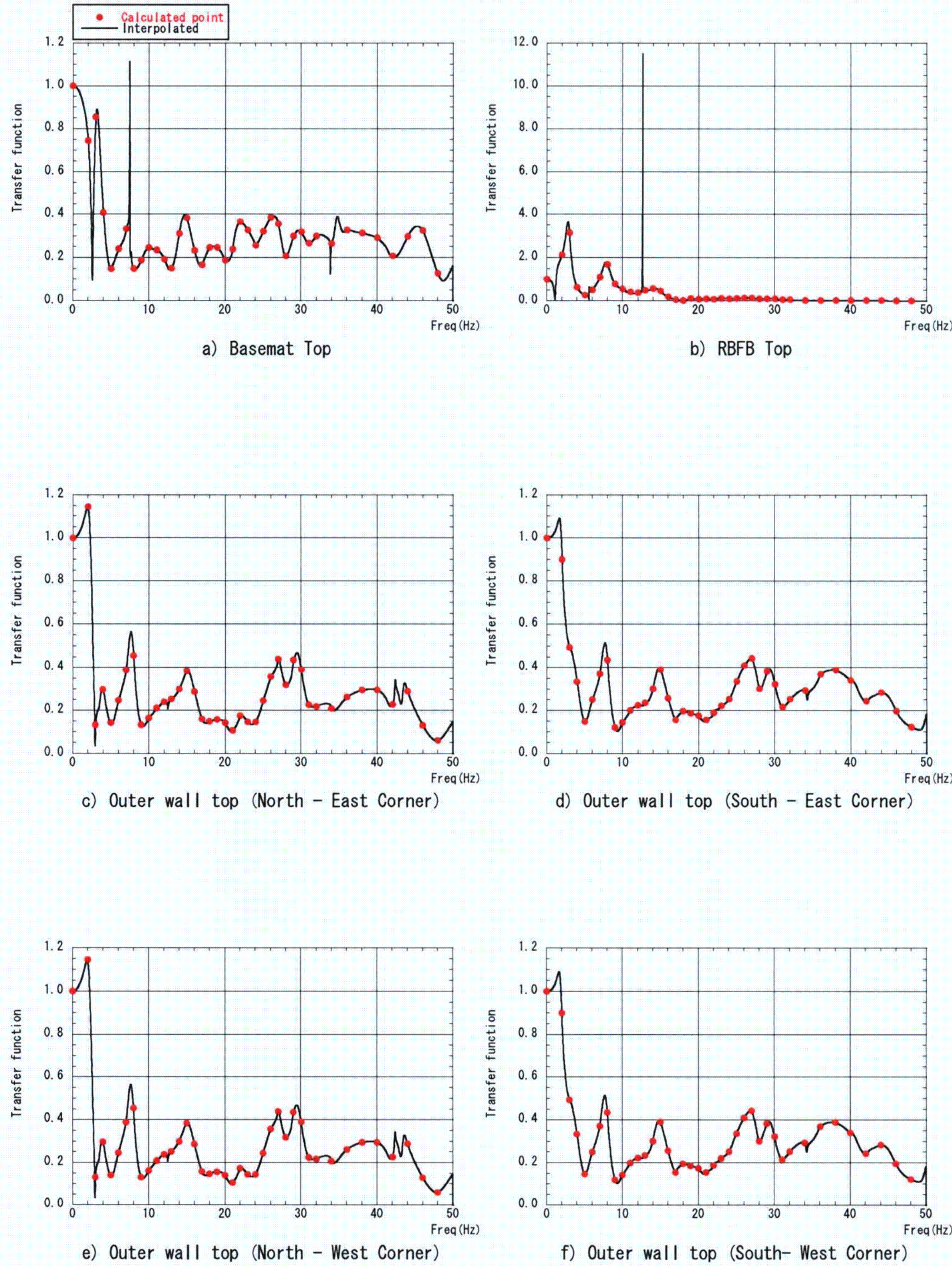


Figure 3.7-16 (1) Original Transfer Function for RBFB in X Direction



a) Basemat Top

b) RBFB Top

c) Outer wall top (North - East Corner)

d) Outer wall top (South - East Corner)

e) Outer wall top (North - West Corner)

f) Outer wall top (South- West Corner)

Figure 3.7-16 (2) Original Transfer Function for RBFB in Y Direction

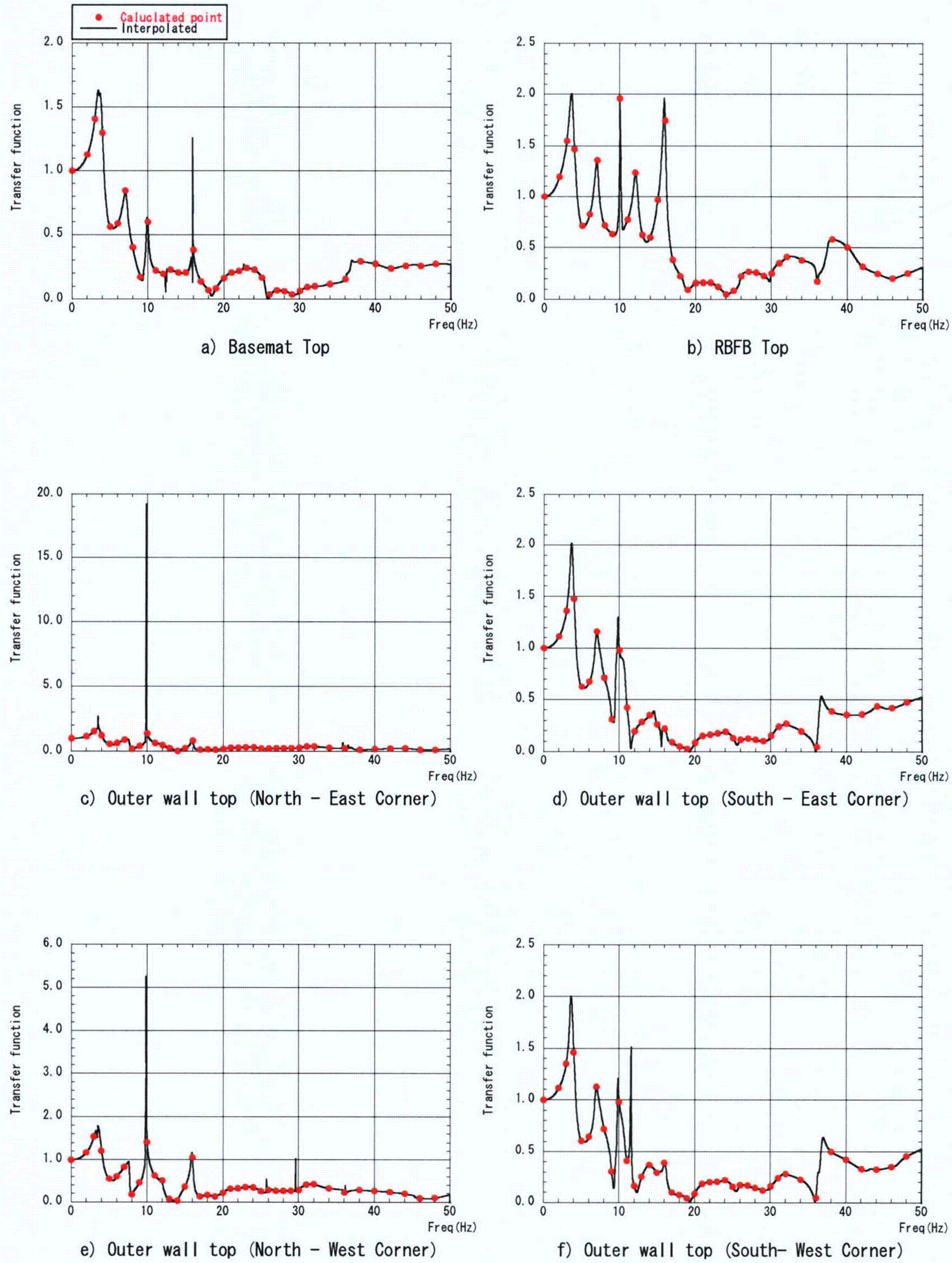
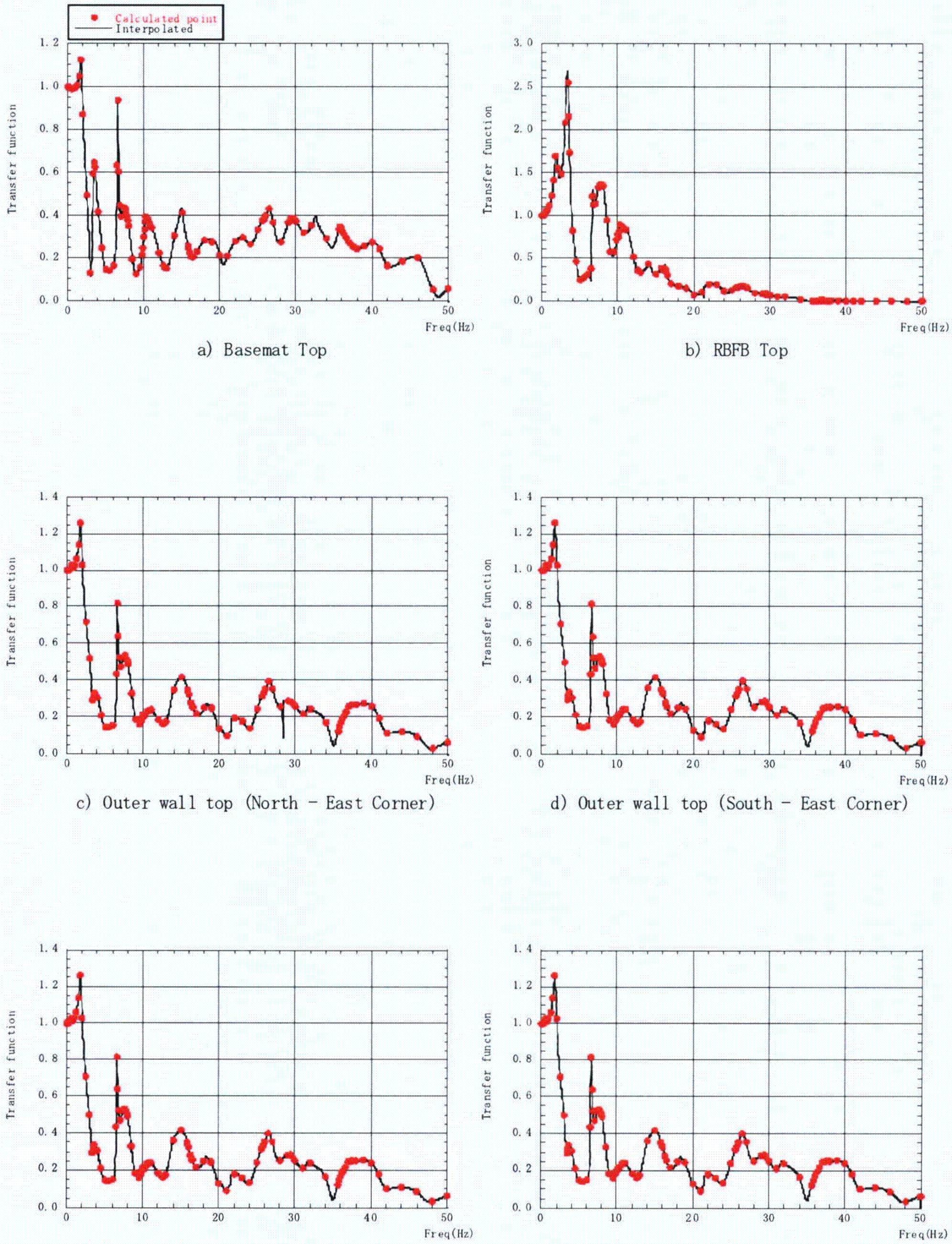


Figure 3.7-16 (3) Original Transfer Function for RBFB in Z Direction



a) Basemat Top

b) RBFB Top

c) Outer wall top (North - East Corner)

d) Outer wall top (South - East Corner)

e) Outer wall top (North - West Corner)

f) Outer wall top (South- West Corner)

Figure 3.7-16 (4) Refined Transfer Function for RBFB in X Direction

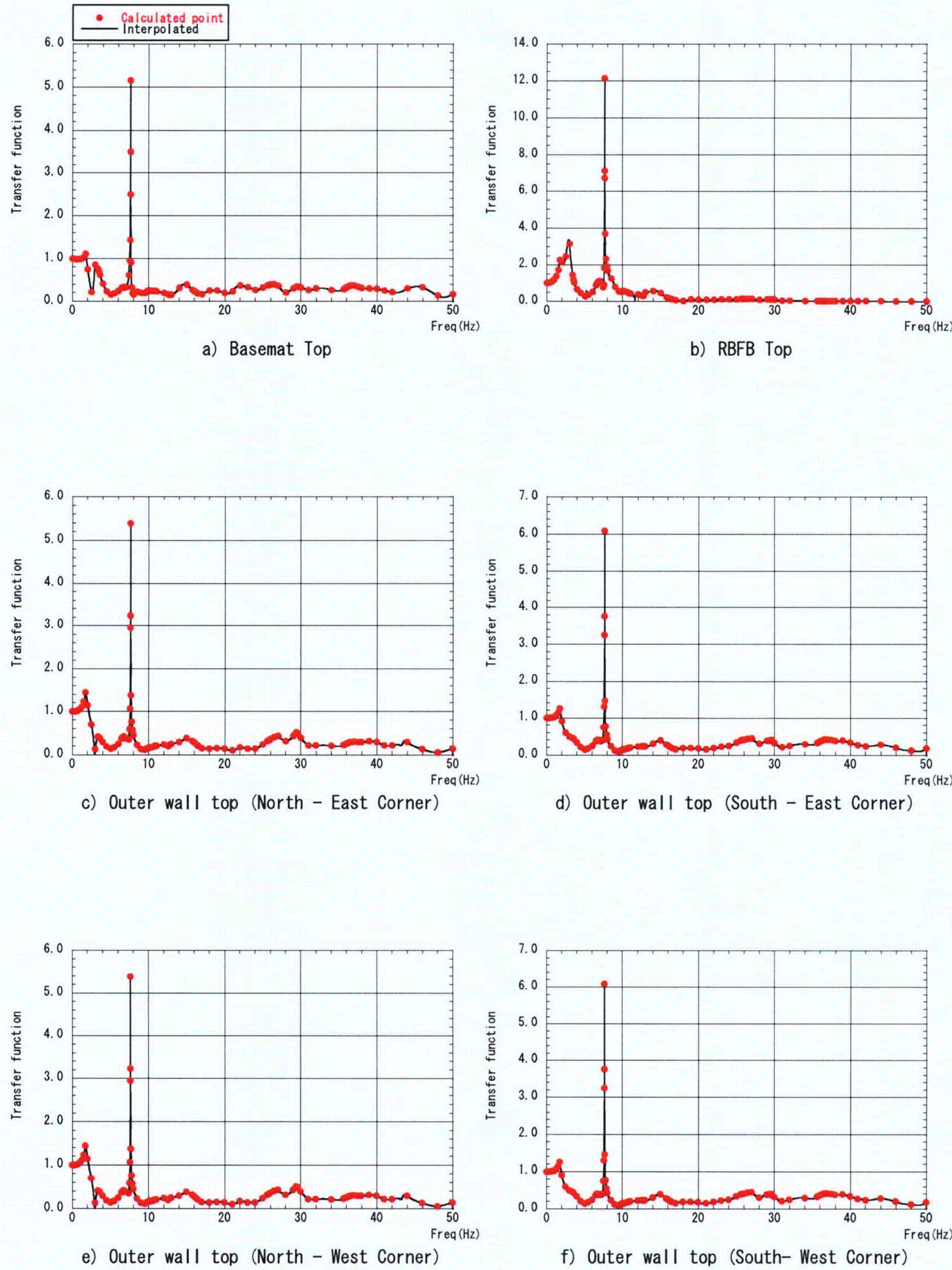
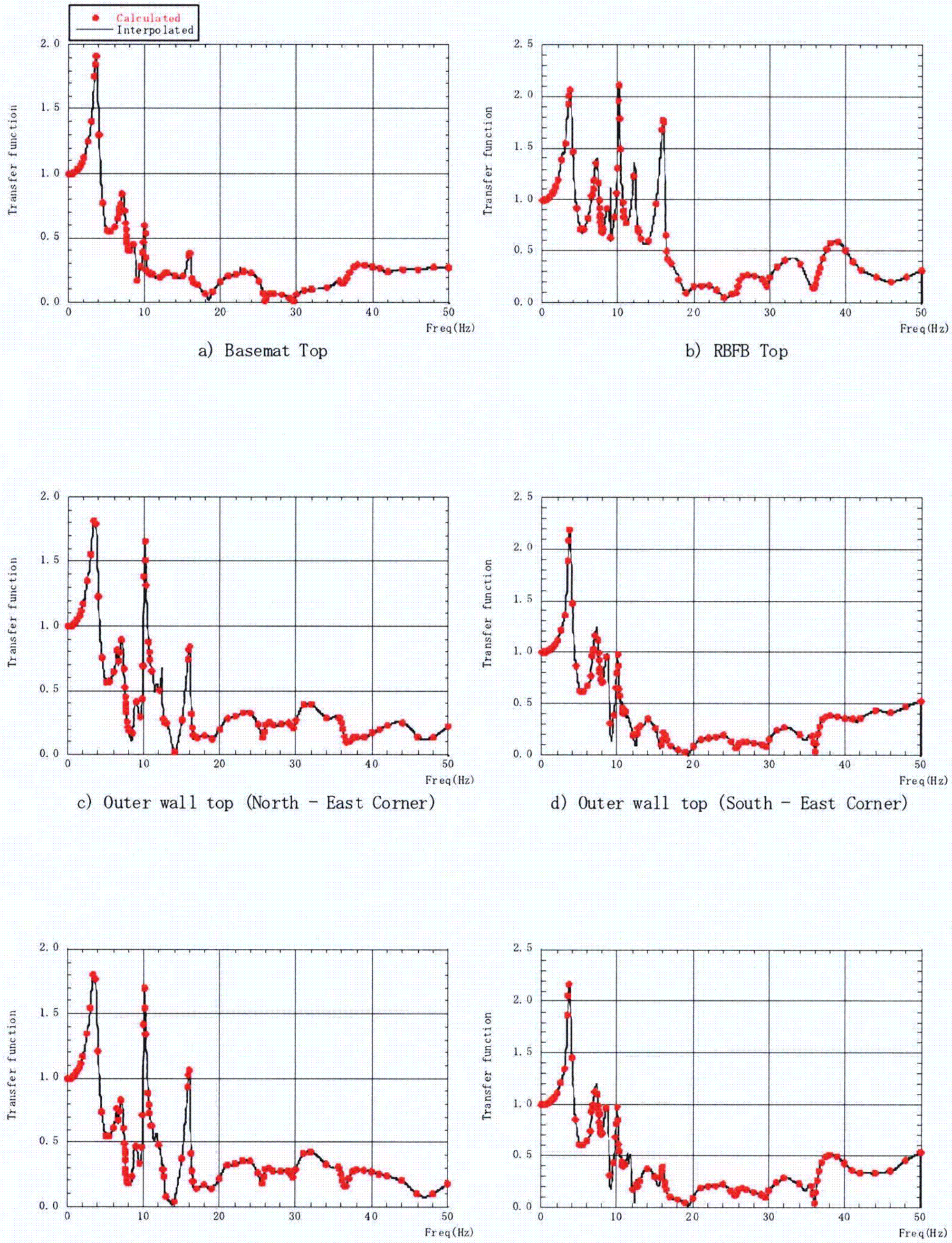


Figure 3.7-16 (5) Refined Transfer Function for RBFB in Y Direction



a) Basemat Top

b) RBFB Top

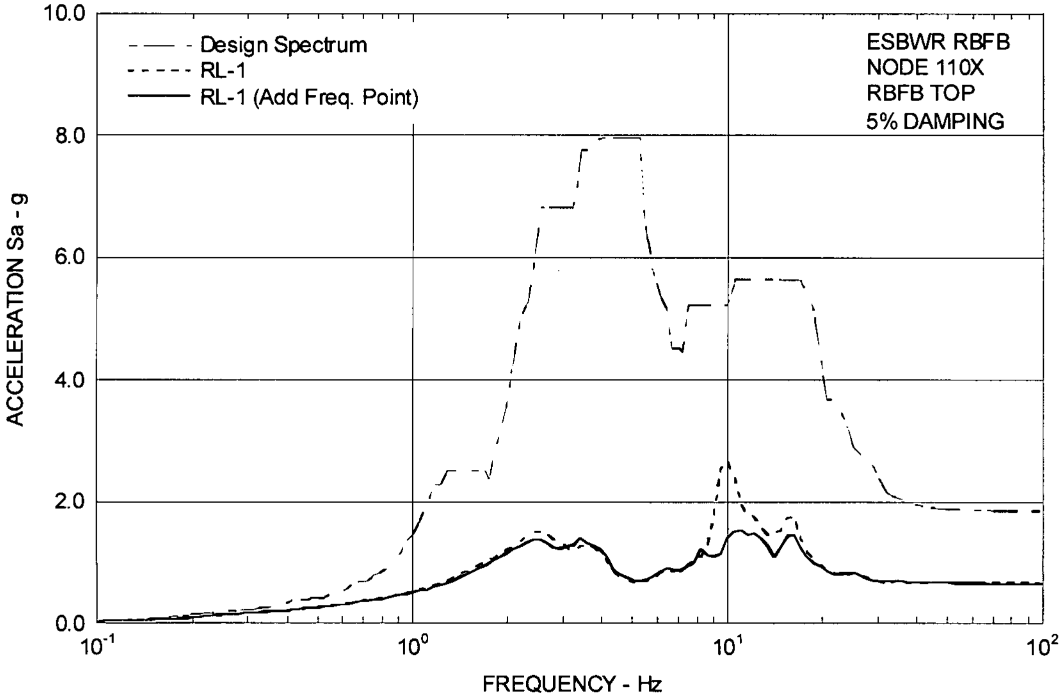
c) Outer wall top (North - East Corner)

d) Outer wall top (South - East Corner)

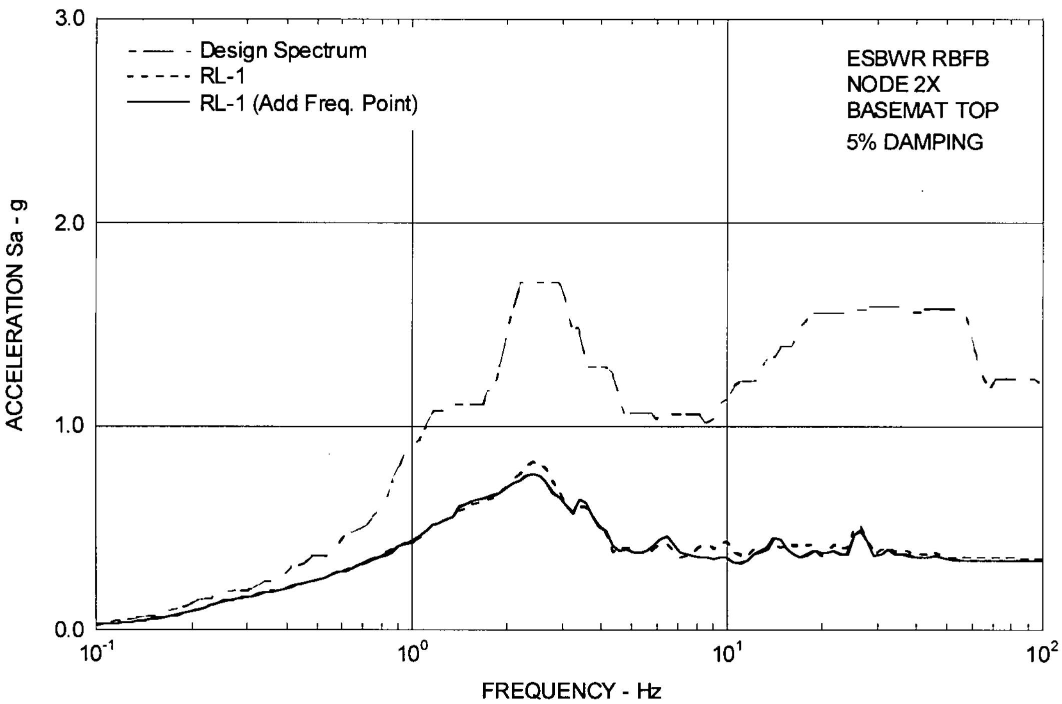
e) Outer wall top (North - West Corner)

f) Outer wall top (South- West Corner)

Figure 3.7-16 (6) Refined Transfer Function for RBFB in Z Direction

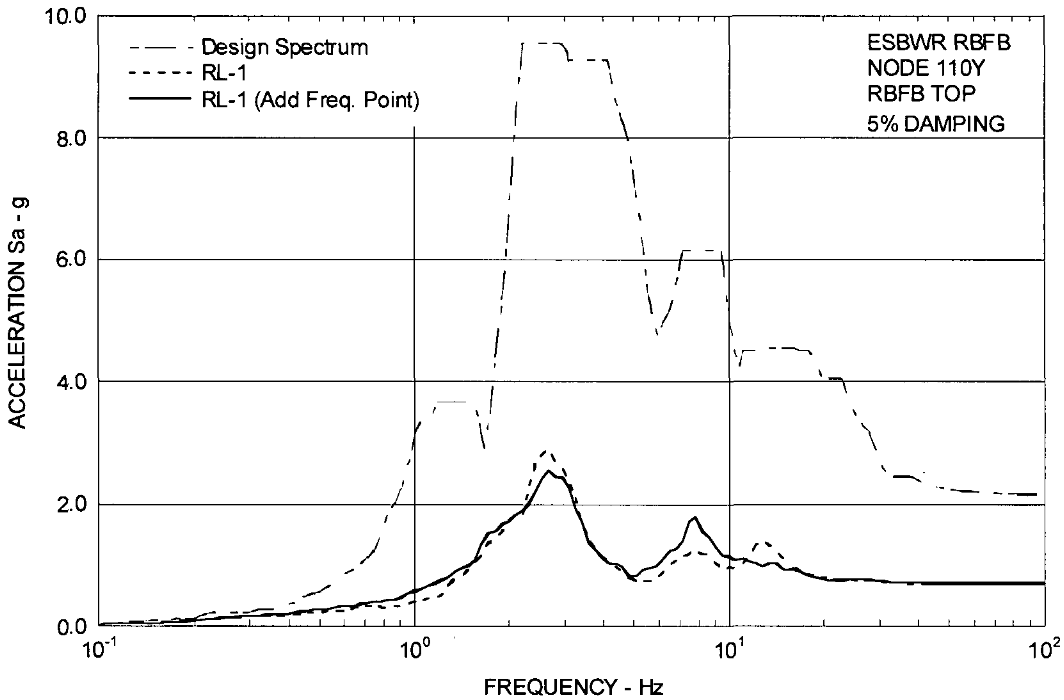


(a) Top of RBFB

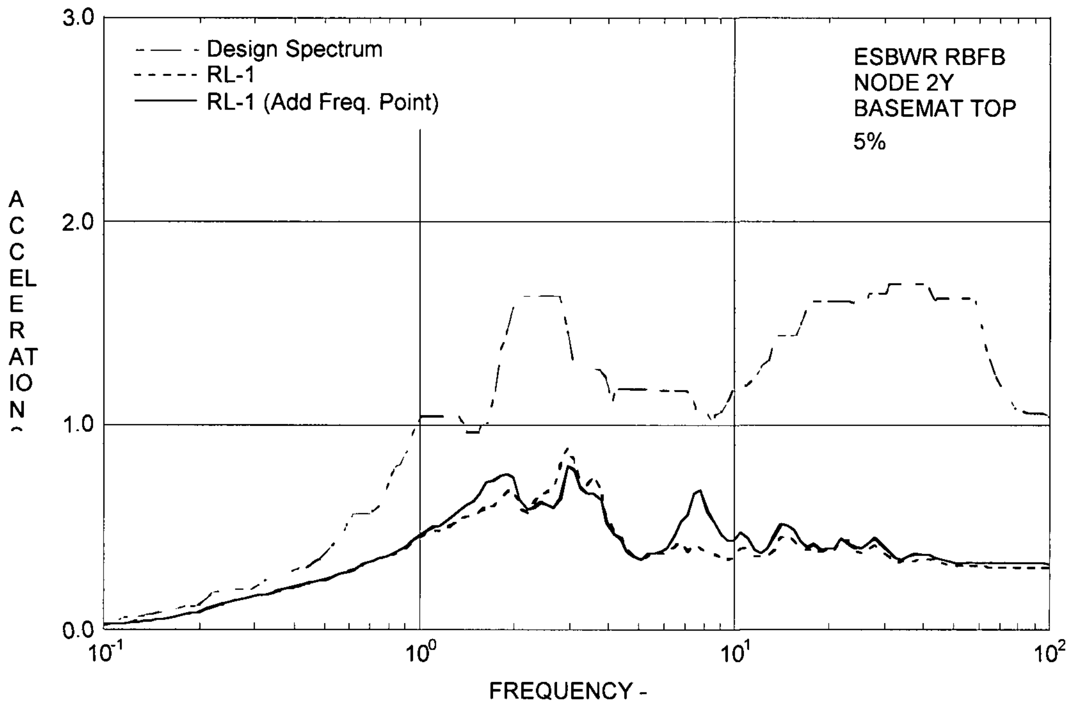


(b) Top of Basemat

Figure 3.7-16 (7) FRS in X Direction

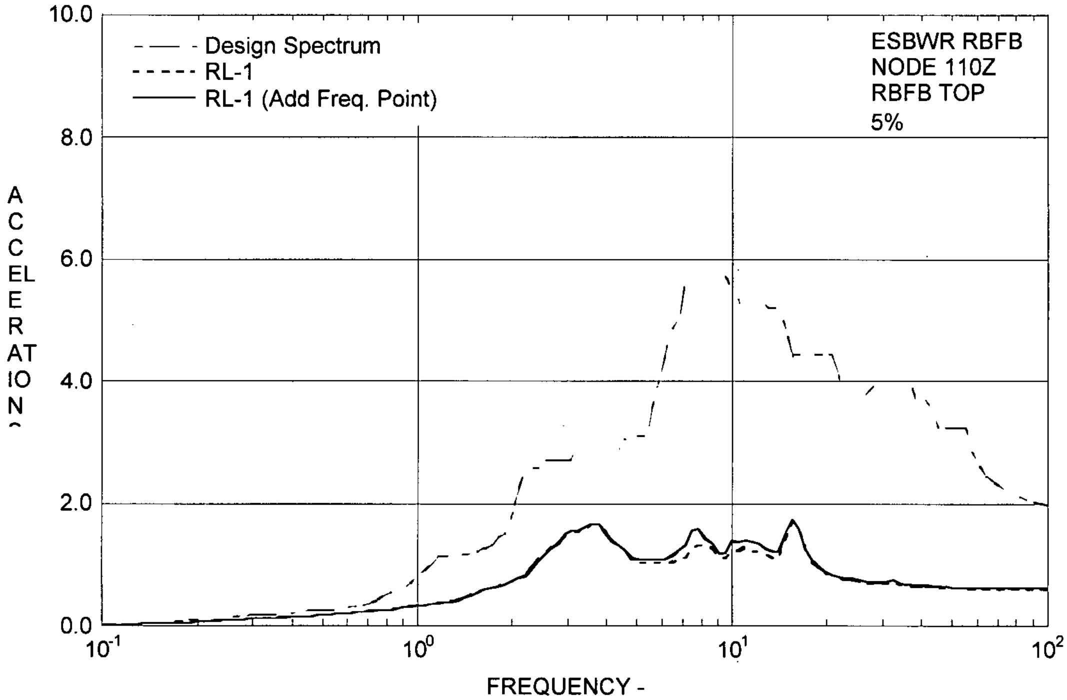


(a) Top of RBFB

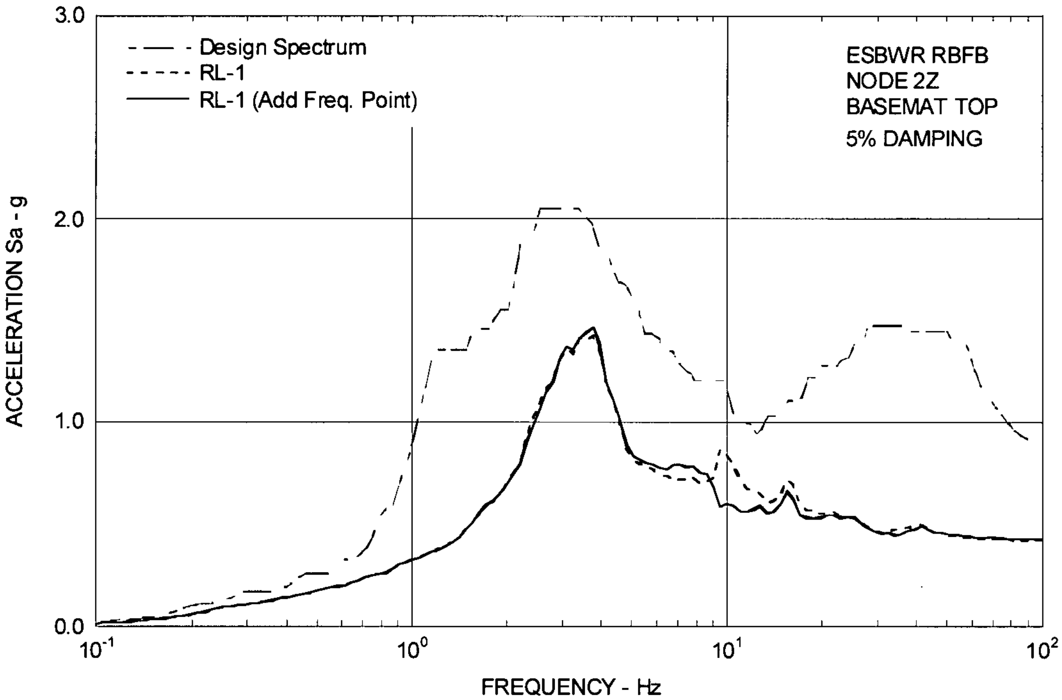


(b) Top of Basemat

Figure 3.7-16 (8) FRS in Y Direction


10.0
8.0
6.0
4.0
2.0
0.0
ACCELERATION
Design Spectrum
RL-1
RL-1 (Add Freq. Point)
ESBWR RBFB
NODE 110Z
RBFB TOP
5%
10^{-1}
10^{0}
10^{1}
10^{2}
FREQUENCY -

(a)



Top of RBFB

(b) Top of Basemat

Figure 3.7-16 (9) FRS in Z Direction

NRC RAI 3.7-24

The last two sentences in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) state that the number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency. The staff generally agrees with this criteria, but it is not clear how the criteria has been implemented in the development of the seismic structural models. The applicant is requested to include in the DCD specific information on how these criteria were satisfied for each seismic structural model.

GE Response

Since the SSI analyses were performed by the direct integration method in the time domain, the cutoff frequency was not applied. However, as mentioned in the response to RAI 3.7-17, the highest structural frequency of interest is 33 Hz for generic site and 50 Hz for North Anna site. Therefore, the number of dynamic degrees of freedom was checked if it is no less than twice the number of modes below 50Hz. According to the check results, the original RB/FB model in DCD has enough dynamic degrees of freedom. However, it was found that the original CB model in DCD does not have enough dynamic degrees of freedom.

Therefore, the CB model was modified to increase the number of masses. It is confirmed that for the revised model the number of dynamic degrees of freedom is no less than twice the number of modes below 50 Hz. Details can be found in SER-ESB-024, *Revised Control Building Stick Model, Rev. 1*, provided to the NRC by MFN 06-251.

The original RB/FB model in DCD was also revised to add vertical shear springs to consider the vertical coupling of walls through the floor slabs/pool girders in response to NRC's Audit comment on RAI 3.7-36. It is confirmed that the number of dynamic degrees of freedom is no less than twice the number of modes below 50 Hz. Details can be found in SER-ESB-023, *Revised Reactor and Fuel Building Stick Model, Rev. 1*, provided to the NRC by MFN 06-278.

DCD Section 3.7.2.3 will be revised confirming that the number of degrees of freedom is no less than the number of modes below 50Hz.

A markup of DCD Tier 2 Section 3.7.2.3 (p. 3.7-11) was provided in MFN 06-274.

NRC RAI 3.7-24, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Even with the number of DOF considered no less than twice the number of modes below 50Hz, assess whether critical modes are captured.

GE Response

The last paragraph of the response to RAI 3.7-24 provided under MFN 06-274 is corrected as follows:

"DCD Section 3.7.2.3 (Page 3.7-11) will be revised in the next update as noted in the attached markup confirming that the number of degrees of freedom is no less than twice the number of modes below 50Hz."

Mode shapes for all six components (3 translations and 3 rotations) associated with the fixed base model for modes up to 50 Hz are submitted in Attachment SER-ESB-054, *Mode Shapes of RBFB Seismic Stick Model, Rev. 0*

Details of the analysis model were included in the Report SER-ESB-023, *Revised Reactor/Fuel Building Complex Stick Model, Rev. 1* issued under MFN 06-278.

As shown in Appendix B of the Report SER-ESB-023, the analysis model is subject to the following conditions:

- Fixed base case.
- Floor oscillators are eliminated and their weights are added to the nodes that they are attached to.
- RPV is eliminated and its weight (21413kN) is added to the pedestal top.

In the NRC audit, the mode shape of mode No. 3, which contains torsional mode, was discussed. The issue was why the Y direction translation of the RBFB node 107 at EL 22.5m is larger than the other adjacent floor nodes.

The RBFB seismic stick model is a 3-D model considering the building eccentricity as shown in Figures 1 through 4 in Attachment SER-ESB-054. The RBFB node 107 at EL 22.5m is located south of the other adjacent floor nodes, because of the FB roof weight. Therefore, if a torsional mode is predominant in mode No. 3, Y direction translation of this floor becomes larger than those of the other floors.

It should be noted that the good comparison of the stick and NASTRAN finite element models provided in RAI 3.7-59 response further demonstrates that the number of degrees of freedom in the stick model is sufficient to capture critical modes.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-30

The last part of the second paragraph on page 3A-4 of DCD Section 3A.3.1 states that three subsurface conditions (soft, medium, rock and hard rock sites) are considered to be uniform half-space, as provided in Table 3A.3-1 for SSI analyses. According to the staff's review experience, there are a number of sites composed of layered materials that should be considered for siting of nuclear plants. Such sites may have significant variation of shear wave velocity with depth, leading to potentially significant impedance mismatches between layers. Such profiles can have effective impedance functions that are significantly different from those associated with a uniform half-space. (See for example, "Handbook of Impedance Functions" by Sieffert and Cevaer). These sites are typically characterized by impedance functions that are highly frequency-dependent, particularly those associated with radiation damping. The approach of using a frequency-independent assumption for both stiffness and damping in SSI may lead to significantly different computed responses. The behavior (or response) of a massive structure (such as RB/FB or CB) may be significantly influenced by these variations due to site conditions. For the design of a standard plant such as ESBWR, the DCD should address the limitations on site layering that will be required, to ensure the applicability of the ESBWR design, which is based on the assumption of uniformity. The staff requests the applicant to include this information in the DCD, and also identify it as a COL interface item.

GE Response

In order to enhance the applicability of the ESBWR design, four cases of layered sites shown in Table 3.7-30 (1) were evaluated for seismic analyses of the RB/FB and the CB using SASSI computer code. These cases cover a wide range of variation of shear wave velocity with depth so that the effect of impedance mismatches between layers can be captured. Details are contained in Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0.* Since the results of layered sites are considered in the site-envelope design loads, there is no limitation on site layering for COL application of the ESBWR standard plant design.

It should be noted that the input ground motion used in the layer site analysis, also in other additional analyses performed to address other related RAIs, corresponds to the single envelope ground spectrum described in response to RAI 3.7-5.

DCD Section 3.7.1 will be revised to clarify the definition of design ground motion, and DCD Section 3A will be revised to include the results of site layering evaluation.

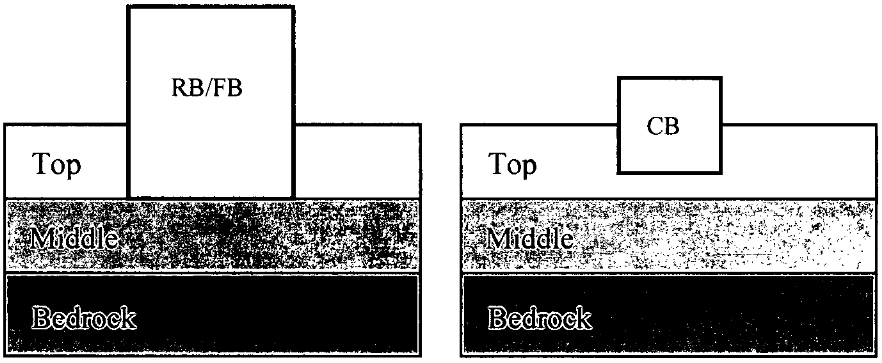
Markups of DCD Tier 2 Sections 3.7.1, 3A and 3A.3.1 and a new DCD Tier 2 Table 3A.3-3 were provided in MFN 06-274.

Table 3.7-30 (1) Layered Site Cases

Layer	Shear Wave Velocity (m/s) / Depth (m)			
	CASE 1	CASE 2	CASE 3	CASE 4
Top	300/20	300/20	300/20	300/20
Middle	300/20	800/20	300/40	800/40
Bedrock	1700	1700	1700	1700

Note: 1) The 20 m depth of the middle layer corresponds to the embedded depth of the RB/FB and the 40 m depth corresponds to about one-half the largest plan dimension of the RB/FB foundation.

2) Properties of the three layers of soils are the same as the generic site properties for soft, medium, and hard soils in DCD Table 3A.3-1.



NRC RAI 3.7-30, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Effect of the layered site condition used by BNL in the confirmatory analysis shows that the closer the hard layer is to the bottom of foundation, the higher the building response is, and frequencies shift toward the higher end. Resolution depends on results of RAI 3.7-16a.

GE Response

Please see the response to RAI 3.7-16, Supplement 1, a.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-33

DCD Section 3A.5 indicates that the use of lateral pressures computed from the equivalent static pressure analysis listed in ASCE 4-98 is conservative. Based on reviews of a number of facilities, it is known that actual pressures computed from detailed SSI evaluations of embedded foundations are directly influenced by the characteristics of the foundation response spectrum used to define the ground motions as well as the relative stiffness (shear wave velocity) of the soils above the basemat level. The staff requests the applicant clearly indicate in the DCD either (1) the technical basis for the statement that these static pressures are conservative for any site, or (2) any limitations that need to be incorporated into the acceptable site profile characteristics to limit the actual dynamic pressures anticipated.

GE Response

In order to confirm that the ASCE 4-98 approach is conservative, an additional evaluation was performed for the layered sites with deep embedment using SASSI computer code, as described in the response to RAI 3.7-30. This evaluation shows that the lateral pressures calculated by the ASCE 4-98 approach is generally bounding. An envelope of these two sets of values will be used for exterior wall design. Details are contained in Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0.*

DCD Section 3A will be revised to include this information.

A markup of DCD Tier 2 Section 3A was provided in MFN 06-274.

NRC RAI 3.7-33, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Provide clarification of the responses submitted to document the explanations given at the audit that embedded walls are designed for the worst soil pressures resulting from either SASSI analysis or ASCE 4-98 methodology.

GE Response

In the third sentence of the original response to RAI 3.7-33, GE stated that, "An envelope of these two sets of values will be used for exterior wall design." This means that the embedded walls are designed for the worst soil pressures resulting from either SASSI analysis or ASCE 4-98 methodology.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-35

As stated in DCD Appendix 3A, Section 3A.7, the elastic half-space theory was used for modeling the soil foundation for both the generic site condition and the North Anna site condition. The staff identified the following issues in need of clarification: (1) what soil damping (material damping and energy loss due to wave propagation) was assigned for the SSI analyses, and (2) how the embedment effects (especially at relatively soft soil sites) were considered in the analysis. The applicant is requested to address these clarifications, and also describe how the elastic half-space theory was applied to the North Anna site, in the DCD.

GE Response

(1) Please see the responses to RAIs 3.7-16 and 3.7-32.

(2) In order to evaluate the embedment effects, additional evaluation is performed for the layered sites with deep embedment using SASSI computer code, as described in the response to RAI 3.7-30. This evaluation shows that the effect of embedment works to reduce basemat reaction shear forces. Details are contained in Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0.*

The foundation properties considered in the SSI analysis for North Anna site shown in DCD Table 3A.3-2 are applied as uniform half-space soil. As stated in DCD Section 3A.3.2, they are determined based on the North Anna ESP site-specific conditions. See response to RAI 3.7-7 for further details.

DCD Section 3A will be revised to provide the requested clarifications.

A markup of DCD Tier 2 Section 3A was provided in MFN 06-274.

NRC RAI 3.7-35, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

The acceptability of the responses submitted is depended on the resolution of RAI 3.7-16a.

GE Response

Please see the response to RAI 3.7-16, Supplement 1, a.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-38

It is stated in DCD Appendix 3A that the shear wave velocities and material damping ratios are strain compatible. The staff requests the applicant provide the following information in the DCD: (1) the theory (methods or formula) for calculating all soil springs, (2) the method (or formula) for calculating damping ratios, and (3) a clear description how the strain dependency of these values is accounted for in the soil-springs used in the SSI analyses.

GE Response

(1) and (2): See the response to RAI 3.7-37.

(3): As stated in DCD Section 3A.3, the shear wave velocities and the material damping ratios shown in DCD Tables 3A.3-1 and 3A.3-2 are considered to be compatible with the strain level expected during SSE. These strain compatible values were used directly in computing soil spring and damper properties.

A markup of DCD Tier 2 Section 3A.3 was provided in MFN 06-274.

NRC RAI 3.7-38, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Confirm that using the envelop of soil sites that include a fixed base condition envelops the concerns about radiation damping described before.

GE Response

As shown on Table 6-1 of Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0* submitted under MFN 06-274, it is confirmed that the design basis envelope forces and FRS include the results of fixed basis analysis in which radiation damping is zero.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-39

For the SSI analyses that were performed, the staff requests the applicant to describe in detail in the DCD how it considered the effect of structure-to-structure interaction through the soil between the RB/FB and CB. The staff considers this a potentially significant effect, especially for the response of the CB.

GE Response

In order to address the effect of structure-to-structure interaction through the soil between the RB/FB and CB, an additional evaluation is performed for the layered sites using SASSI computer code.

This evaluation shows that the effect of structure-to-structure interaction is the largest in the Y-direction (East-West) response of the CB. However, the Floor Response Spectra (FRS) with and without structure-to-structure interaction effect are bounded by the broadened envelope responses of uniform site cases in the whole frequency range. Details are contained in Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0.*

DCD Section 3A will be revised to include this information.

A markup of DCD Tier 2 Section 3A was provided in MFN 06-274.

NRC RAI 3.7-39, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Provide clarification that the description given regarding the structure-to-structure interaction agrees with the material in report SER-ESB-033.

GE Response

In the original response to RAI 3.7-39, GE stated that, "both FRSs without and with structure-structure interaction effect are bounded by the broadened envelope responses of uniform site cases in the whole frequency range." The basis of this statement is that the design FRS is determined by enveloping the results of all cases considered as stated in Section 8 of Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0* submitted under MFN 06-274.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-50

DCD Section 3.7.2.3, "Procedures Used for Analytical Modeling," does not address the method used to develop stiffness values (uncracked concrete sections versus cracked concrete sections) for concrete structural elements for the seismic analysis models. The staff requests the applicant include in the DCD a detailed description of the method applied to determine the stiffness values for both cracked concrete sections and uncracked concrete sections in the seismic analysis models.

GE Response

In order to address the effect of the cracked concrete stiffness, an additional evaluation is performed using SASSI computer code, assuming that the cracked concrete stiffness is 50% of the uncracked value in accordance with ASCE 43-05, Section 3.4.1.

This evaluation shows that the Floor Response Spectra (FRS) peaks move to lower frequencies when concrete cracking is considered. However, both FRSs of uncracked and cracked cases are bounded by the broadened envelope response of uniform site cases in the whole frequency range. Details are contained in Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0.*

DCD Section 3A will be revised to include this information.

A markup of DCD Tier 2 Section 3A was provided in MFN 06-274.

NRC RAI 3.7-50, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Clearly indicate that the design basis spectrum for ESBWR envelops all cases of modeling, using cracked and un-cracked concrete properties as well as all soil conditions listed.

GE Response

In the original response to RAI 3.7-50, GE stated that, "both FRSs of uncracked and cracked cases are bounded by the broadened envelope response of uniform site cases in the whole frequency range." The basis of this statement is that the design FRS is determined by enveloping the results of all cases considered as stated in Section 8 of Attachment SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev.0,* submitted under MFN 06-274.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-54

In DCD Section 3.7.5, the applicant indicated that the COL applicant needs to confirm that the site-specific shear wave velocity is no less than 1,000 fps in order to confirm the design adequacy of the plant. However, in following the guidance of the SRP for an individual site evaluation, the COL applicant needs to perform site-specific response calculations, reducing the low-strain shear-wave velocity profile from the Best Estimate (BE) to a Lower Bound (LB) value, defined as the BE divided by the square root of 2. DCD Section 3.7.5 needs to indicate that 1,000 fps is a LB velocity and not a BE velocity, or, as an alternative, the minimum acceptable BE velocity can be specified. In addition, since all design analyses were performed for assumed uniform velocity profiles, the site acceptance criteria needs to include information on what degree of variation from the uniform velocity profile is acceptable for the design.

GE Response

Please see response to RAI 3.7-31 for clarification of the minimum shear wave velocity definition. To enhance site suitability for ESBWR Standard Plant design, additional SSI analyses are performed for generic layered sites using the SASSI computer code. See response to RAI 3.7-16 for details.

No DCD change was required for this RAI response.

NRC RAI 3.7-54, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

Acceptability of the response to this RAI depends on the results of RAI 3.7-16a.

GE Response

Please see the response to RAI 3.7-16, Supplement 1, a.

No DCD change will be made in response to this RAI Supplement.

NRC RAI 3.7-57

DCD Tier 2, Section 3.7.2.3 indicates that the mathematical model of the structural system is constructed either as a stick model or a finite element model. These models are used in the soil-structure interaction (SSI) response analyses to determine seismic response of the soil structure system as indicated in DCD Section 3.7.2.4 and described in Appendix 3A to DCD Section 3.7. The free-field ground motions used as input to the plant analysis and design are described in DCD Section 3.7.1 and are ground motions that envelope either the RG 1.60 low frequency response spectrum or the high frequency ground motion developed for the North Anna early site permit site.

DCD Figure 3.7-30 presents a plot of the North Anna design ground response spectrum and indicates a response spectrum that possesses its primary spectral accelerations in the frequency ranges from about 10 Hz to 50 Hz with a peak spectral acceleration at a frequency of about 20 Hz for the horizontal response spectrum and about 30 to 50 Hz for the vertical response spectrum. Appendix 3A to DCD Section 3.7 presents descriptions of the stick models developed for use in SSI analyses for the primary structures and internals of the plant. DCD tables 3A.7-5 through 3A.7-14 present the results of eigenvalue analyses that are carried to frequencies as high as 27 Hz. These indicate participation factors of 0.28 at frequencies as high as about 25 Hz. The staff requests that the applicant demonstrate that the stick structural models developed based on the process described in the DCD can transmit frequencies up to 50 Hz and be able to capture the responses resulting from the high frequency components of North Anna input ground motions.

GE Response

Please see the response to RAI 3.7-24.

No DCD change was required for this RAI response.

<u>NRC RAI 3.7-57, Supplement 1</u>

<u>NRC Assessment Following the November 2, 2006 Audit</u>

Provide mode shape plots including rotation and torsional components as discussed in RAI 3.7-24.

<u>GE Response</u>

The mode shape plots including rotation and torsional components are provided in Attachment SER-ESB-054, as discussed in RAI 3.7-24, Supplement 1.

No DCD change will be made in response to this RAI Supplement.

ATTACHMENT SER-ESB-054, REV. 0

Mode Shapes of RBFB Seismic Stick Model

Shimizu Engineering Report

Project	General Electric Company ESBWR Project	Shimizu Document No.	SER-ESB-054
Title	Mode Shapes of RBFB Seismic Stick Model	Rev.	0
		Issued Date	11/30/06
		Revised Date	

NOTE:

This document provides mode shapes of Reactor/Fuel Building Complex (RBFB) stick model in response to NRC's Audit comment on RAI 3.7-24.

Mode shapes for all six components (3 translations and 3 rotations) associated with the fixed base model for modes up to 50 Hz are contained.

Details of the analysis model are included in the following report.

· SER-ESB-023, Revised Reactor/Fuel Building Complex Stick Model, Rev. 1

As shown in Appendix B of the report SER-ESB-023, the analysis model conditions are as follows.

- Fixed base case
- Foor oscillators are eliminated and their weights are added to the nodes which they are attached to.
- RPV is eliminated and its weight (21413kN) is added to the pedestal top.

Please note that the RBFB seismic stick model is a 3-D model considering the building eccentricity as shown in Figures 1 through 4. However, in the mode shape figures, each stick is shown in a straight line as zero displacement. Therefore, if a torsional mode is predominant, translation of the node that is located far from the tortional center become larger. For example, in mode No. 3, in which torsional mode is predominant, Y direction translation of the RBFB node 107 at EL 22.5m is larger than the other adjacent floor nodes. This is because the RBFB node 107 at EL 22.5m is located south of the other adjacent floor nodes, because of the FB roof weight.

0	11/30/06	Issue for use	Y.O.	N.M.	S.O
Rev.	Date	Note	Approve	Review	Prepare

Shimizu Corporation	Prepared by	S. Oguri	11/30/06
	Reviewed by	N. Miura	11/30/06
	Approved by	Y. Orito	11/30/06

Table 1 Eigenvalue Analysis Results

FIX	X			Y			Z		
	NODE= 38	DOF= 76		NODE= 38	DOF= 76		NODE= 38	DOF= 38	
1	2-th	4.41 Hz	110 X	1-th	3.95 Hz	110 Y	17-th	17.22 Hz	110 Z
2	5-th	8.73 Hz	110 X	3-th	6.09 Hz	107 Y	20-th	20.94 Hz	110 Z
3	6-th	11.05 Hz	707 X	4-th	8.07 Hz	110 Y	28-th	27.60 Hz	110 Z
4	8-th	13.08 Hz	707 X	7-th	11.89 Hz	707 Y	37-th	32.60 Hz	203 Z
5	11-th	14.18 Hz	707 X	9-th	13.58 Hz	110 Y	38-th	35.06 Hz	701 Z
6	12-th	14.58 Hz	707 X	10-th	14.04 Hz	707 Y	48-th	42.71 Hz	108 Z
7	16-th	16.50 Hz	707 X	13-th	15.03 Hz	707 Y	56-th	52.21 Hz	102 Z
8	22-th	22.35 Hz	707 X	14-th	16.01 Hz	707 Y	60-th	54.89 Hz	209 Z
9	24-th	24.81 Hz	707 X	15-th	16.07 Hz	707 Y	63-th	57.28 Hz	707 Z
10	25-th	25.76 Hz	707 X	18-th	18.44 Hz	707 Y	66-th	59.97 Hz	109 Z
11	32-th	30.10 Hz	702 X	19-th	20.46 Hz	107 Y	68-th	60.87 Hz	209 Z
12	34-th	31.81 Hz	703 X	21-th	22.22 Hz	707 Y	74-th	64.50 Hz	109 Z
13	36-th	32.01 Hz	703 X	23-th	24.11 Hz	707 Y	76-th	68.18 Hz	109 Z
14	41-th	37.30 Hz	702 X	26-th	25.76 Hz	707 Y	78-th	69.95 Hz	201 Z
15	43-th	38.07 Hz	702 X	27-th	26.27 Hz	702 Y	79-th	74.20 Hz	707 Z
16	46-th	41.99 Hz	702 X	29-th	28.35 Hz	707 Y			
17	52-th	49.71 Hz	707 X	30-th	28.94 Hz	702 Y			
18	53-th	51.08 Hz	107 X	31-th	29.02 Hz	702 Y			
19	54-th	51.17 Hz	107 X	33-th	31.76 Hz	703 Y			
20	58-th	53.81 Hz	709 X	35-th	31.92 Hz	703 Y			
21	61-th	55.46 Hz	709 X	39-th	35.29 Hz	702 Y			
22	65-th	59.27 Hz	107 X	40-th	35.68 Hz	702 Y			
23	69-th	61.05 Hz	702 X	42-th	37.47 Hz	702 Y			
24	70-th	61.38 Hz	702 X	44-th	39.91 Hz	702 Y			
25	72-th	63.05 Hz	702 X	45-th	41.81 Hz	702 Y			
26	73-th	63.07 Hz	702 X	47-th	42.20 Hz	710 Y			
27				49-th	43.47 Hz	710 Y			
28				50-th	47.07 Hz	101 Y			
29				51-th	48.26 Hz	710 Y			
30				55-th	51.52 Hz	107 Y			
31				57-th	52.44 Hz	107 Y			
32				59-th	53.88 Hz	709 Y			
33				62-th	55.49 Hz	709 Y			
34				64-th	57.53 Hz	107 Y			
35				67-th	60.08 Hz	703 Y			
36				71-th	62.52 Hz	702 Y			
37				75-th	66.91 Hz	103 Y			
38				77-th	69.33 Hz	104 Y			
39				80-th	75.07 Hz	205 Y			
40									
41									
42									
43									
44									
45									

Note: It was confirmed from the eigenvalue analysis results that the number of dynamic degrees of freedom is no less than twice the number of modes below the highest structural frequency of interest, 50Hz. (reference : RAI 3.4-24)

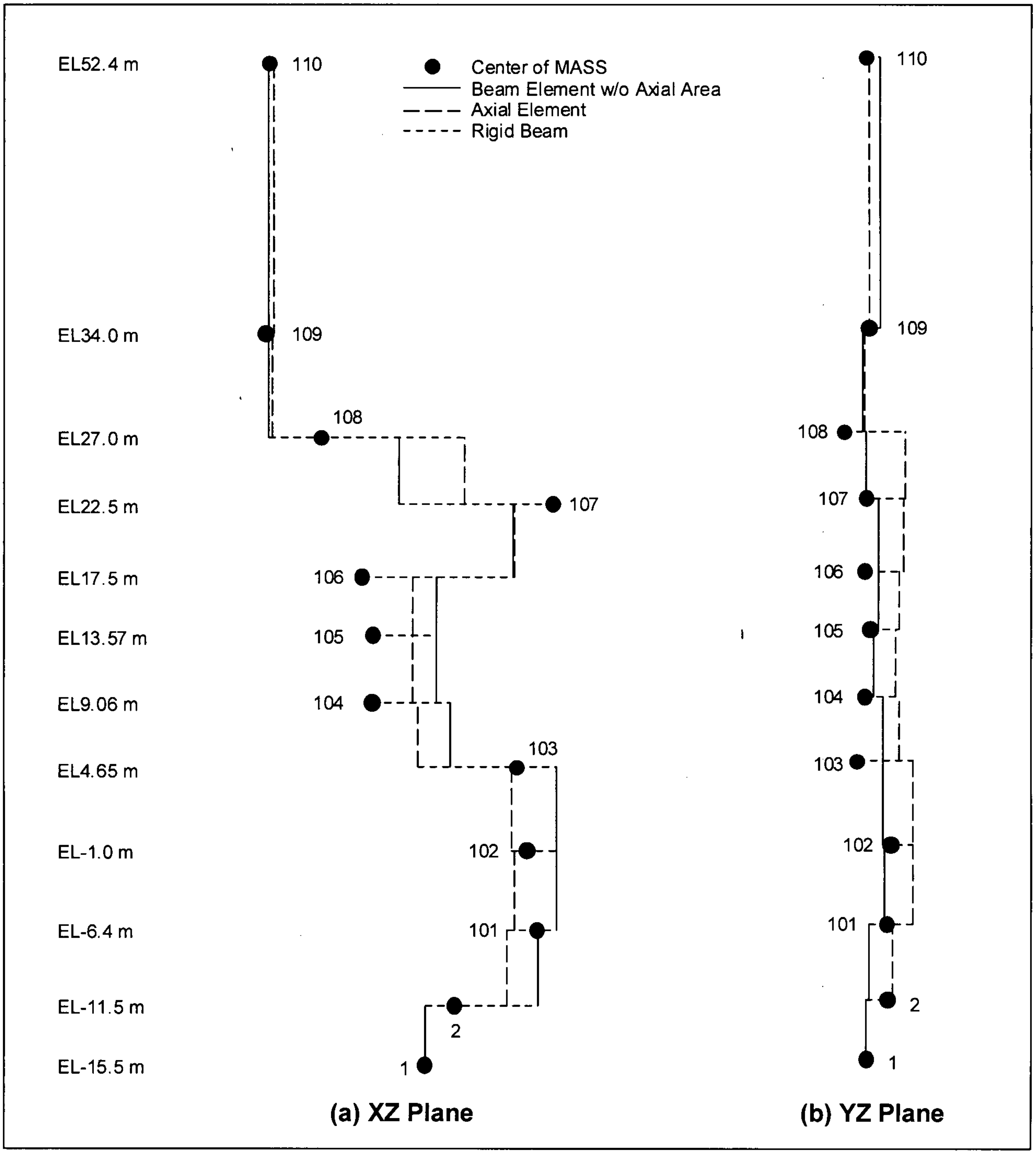


Figure 1 RBFB Stick Model

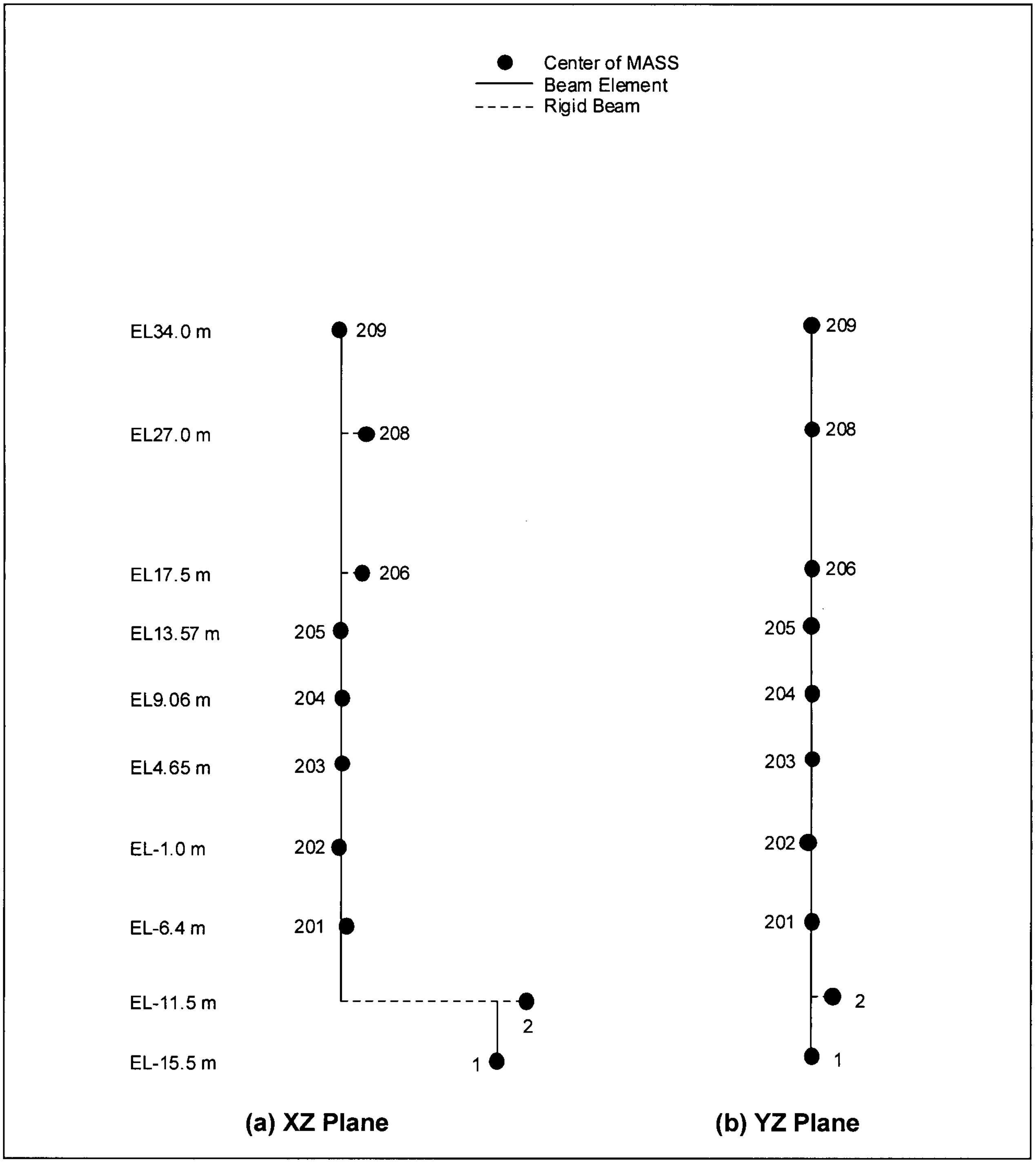


Figure 2 RCCV Stick Model

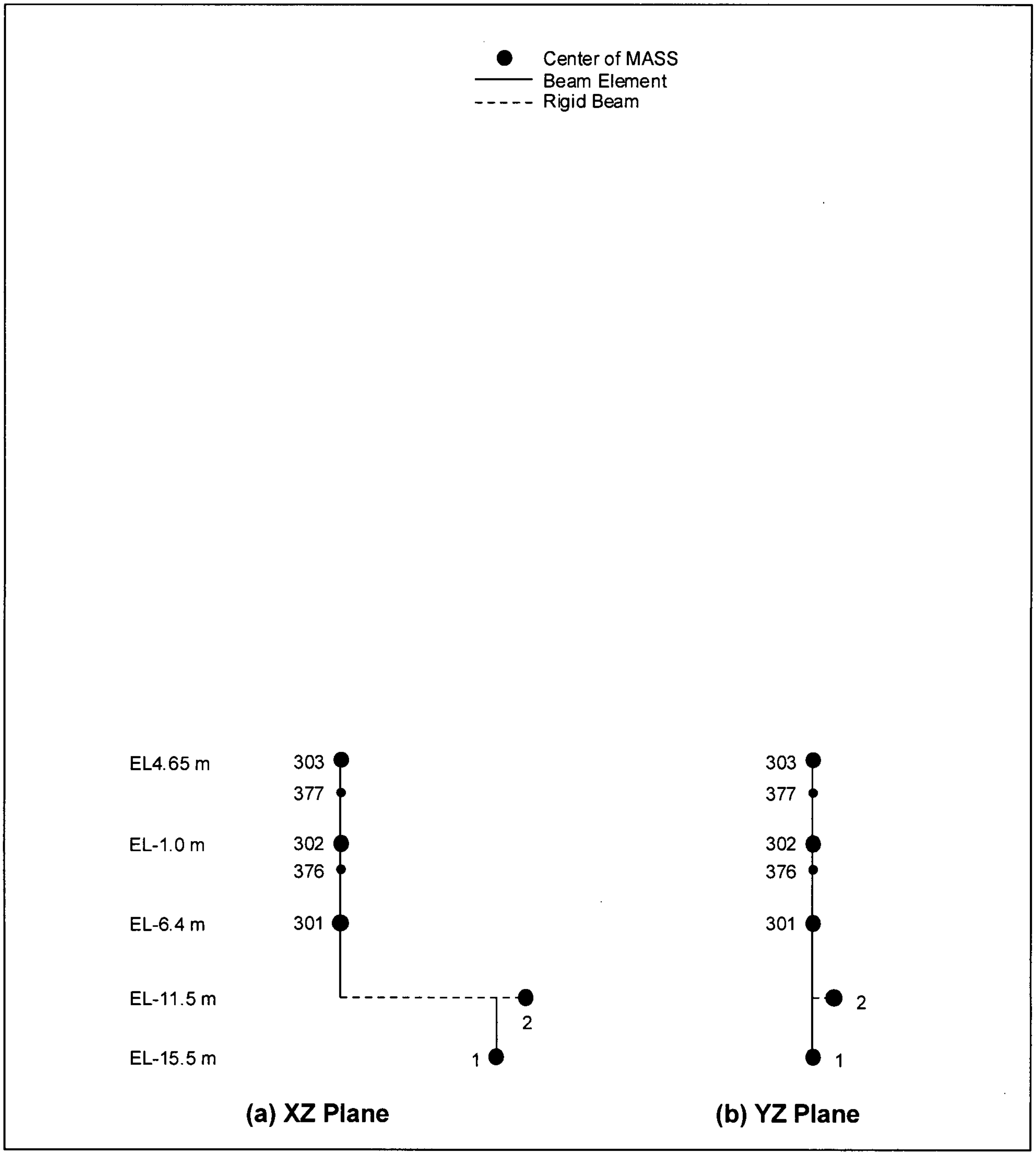


Figure 3 Pedestal Stick Model

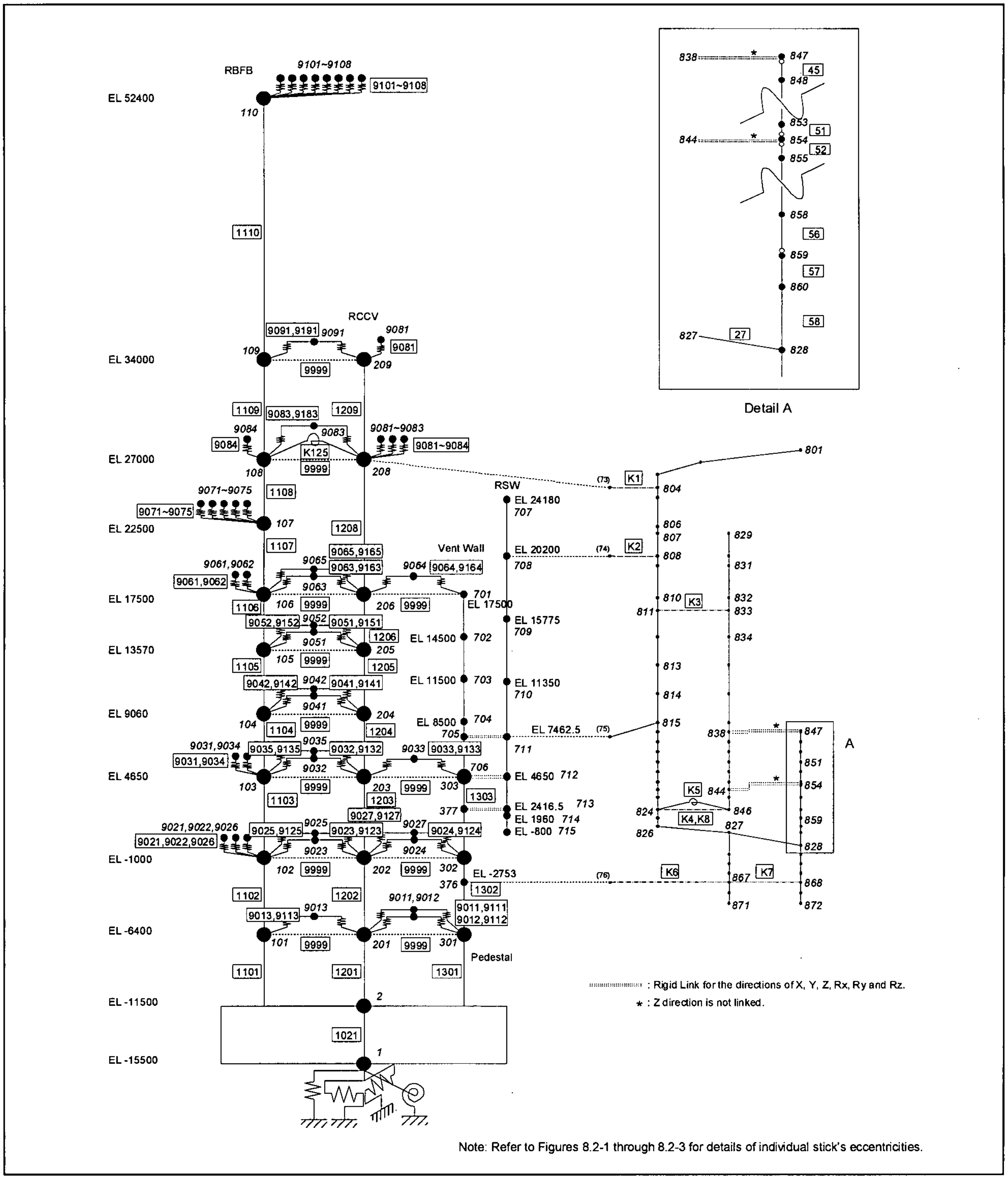


Figure 4 ESBWR RBFB Complex Seismic Model

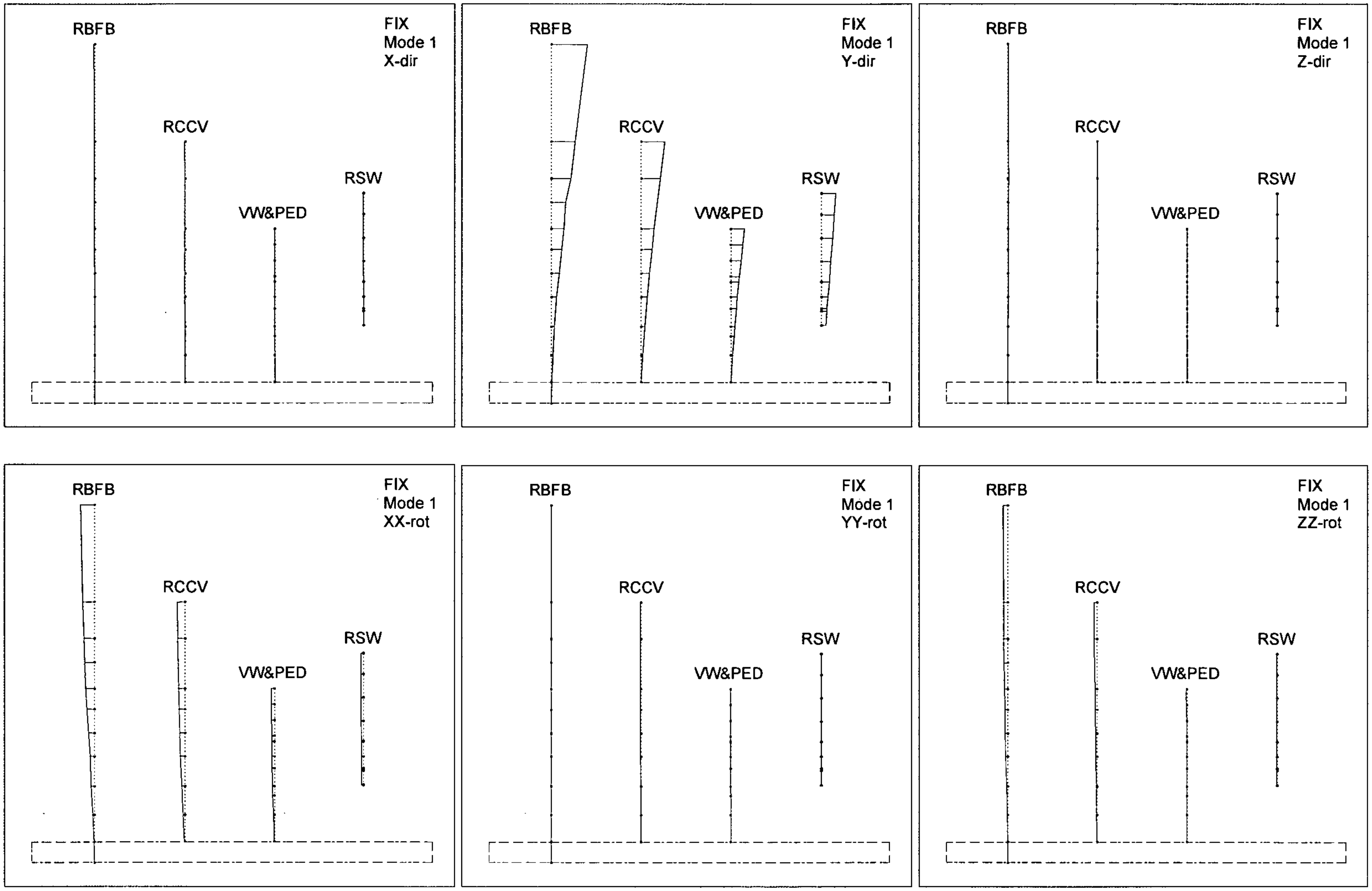
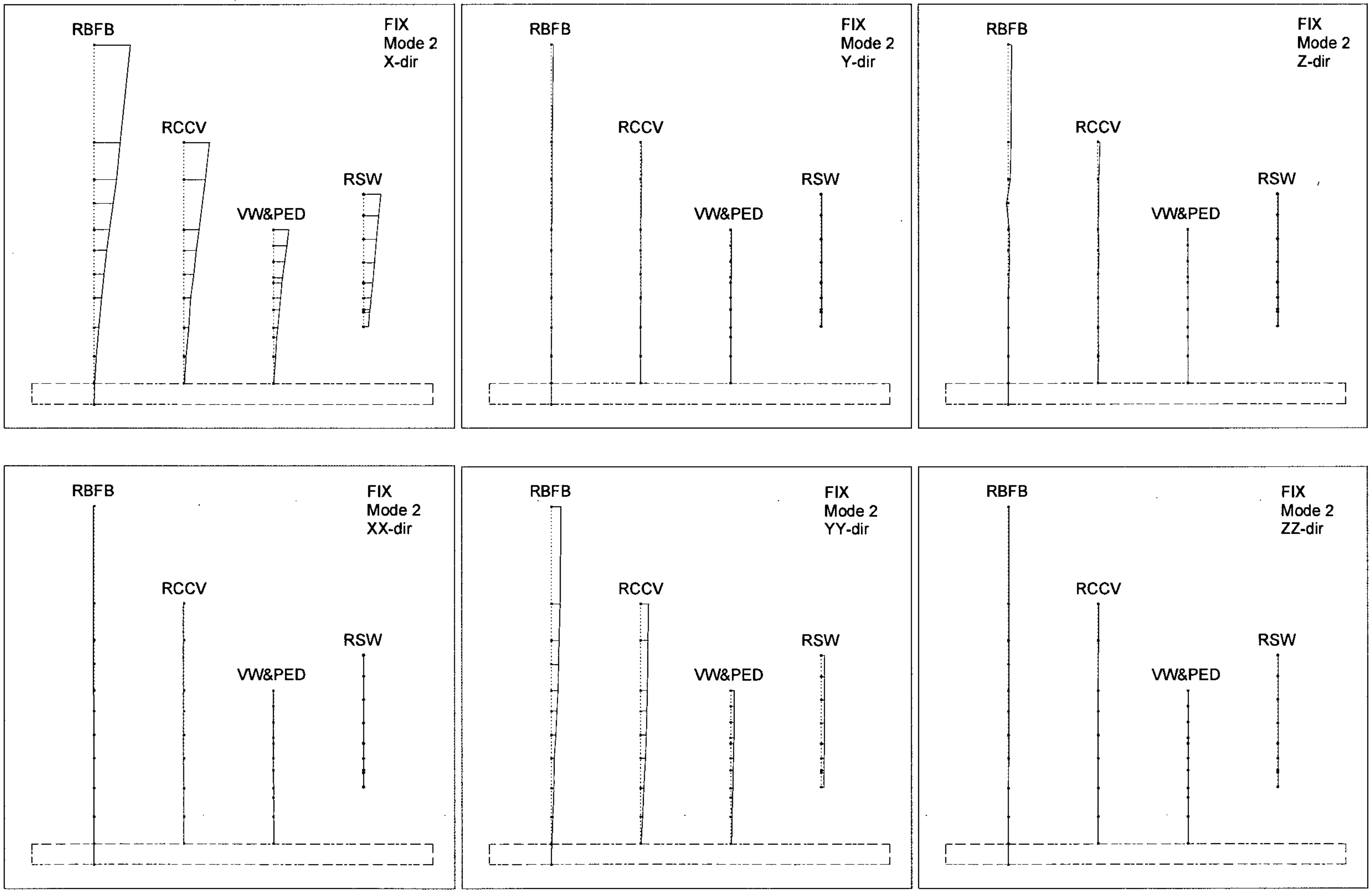


Figure 5 Mode Shape No. 1



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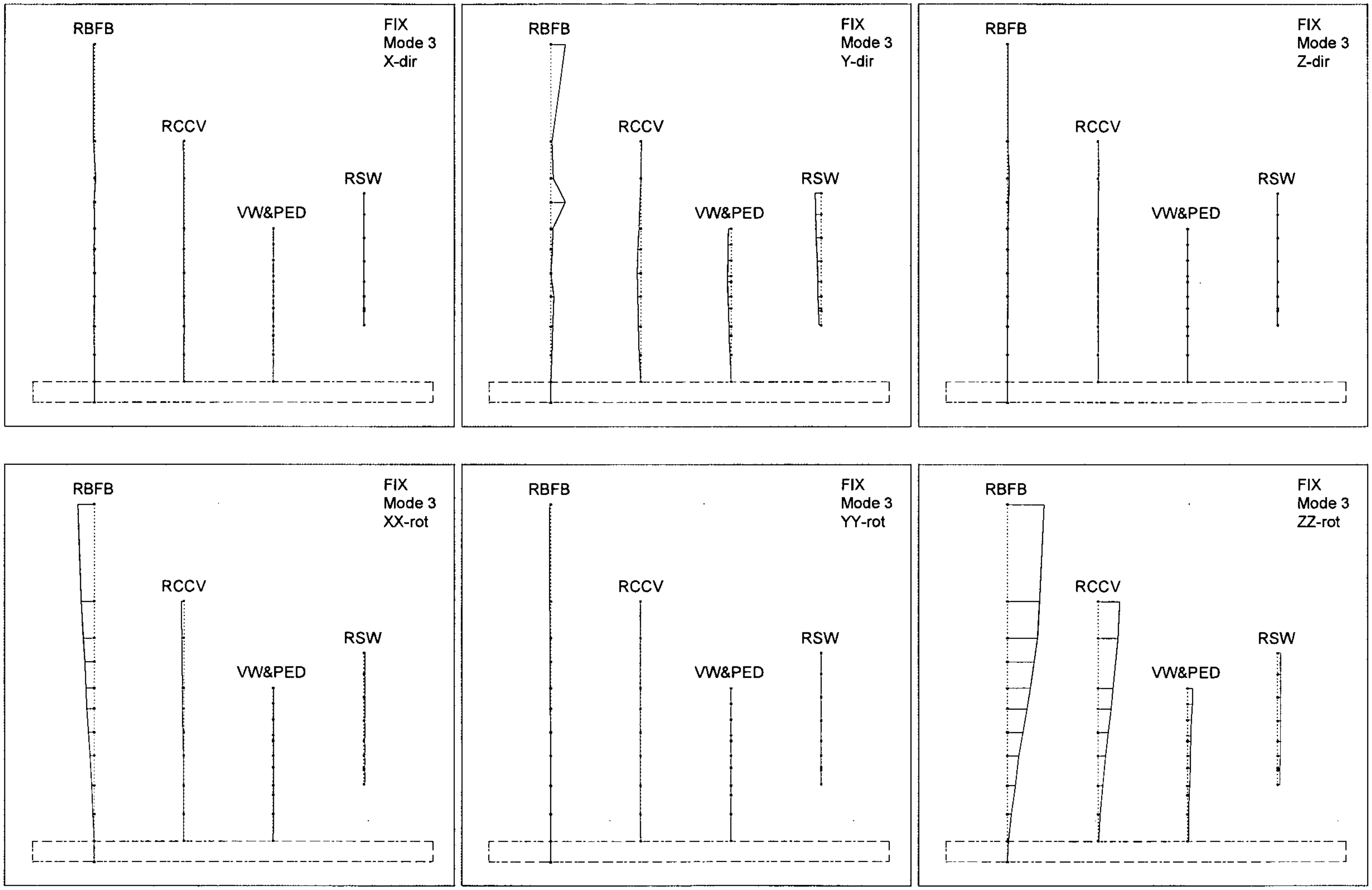

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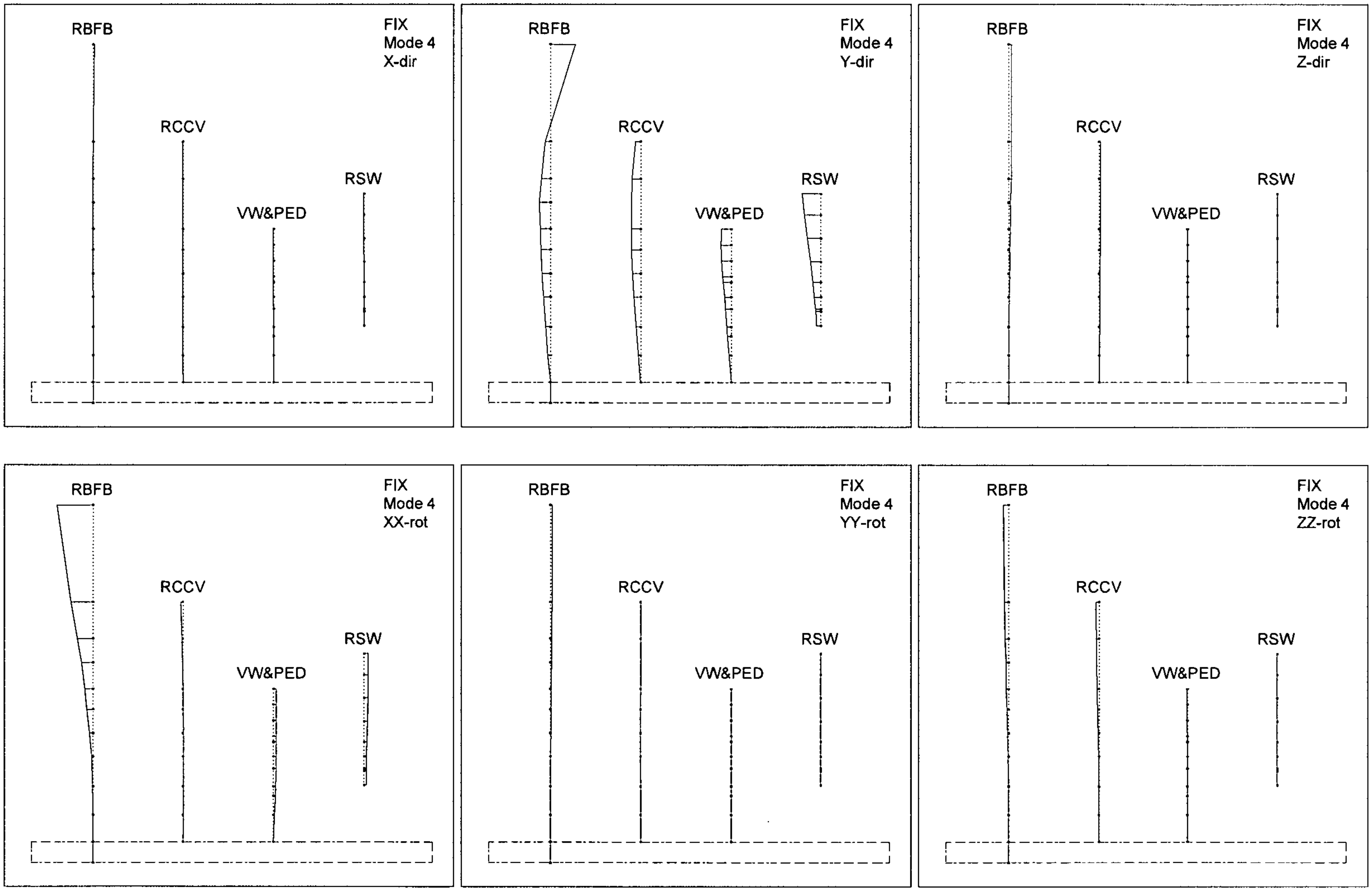

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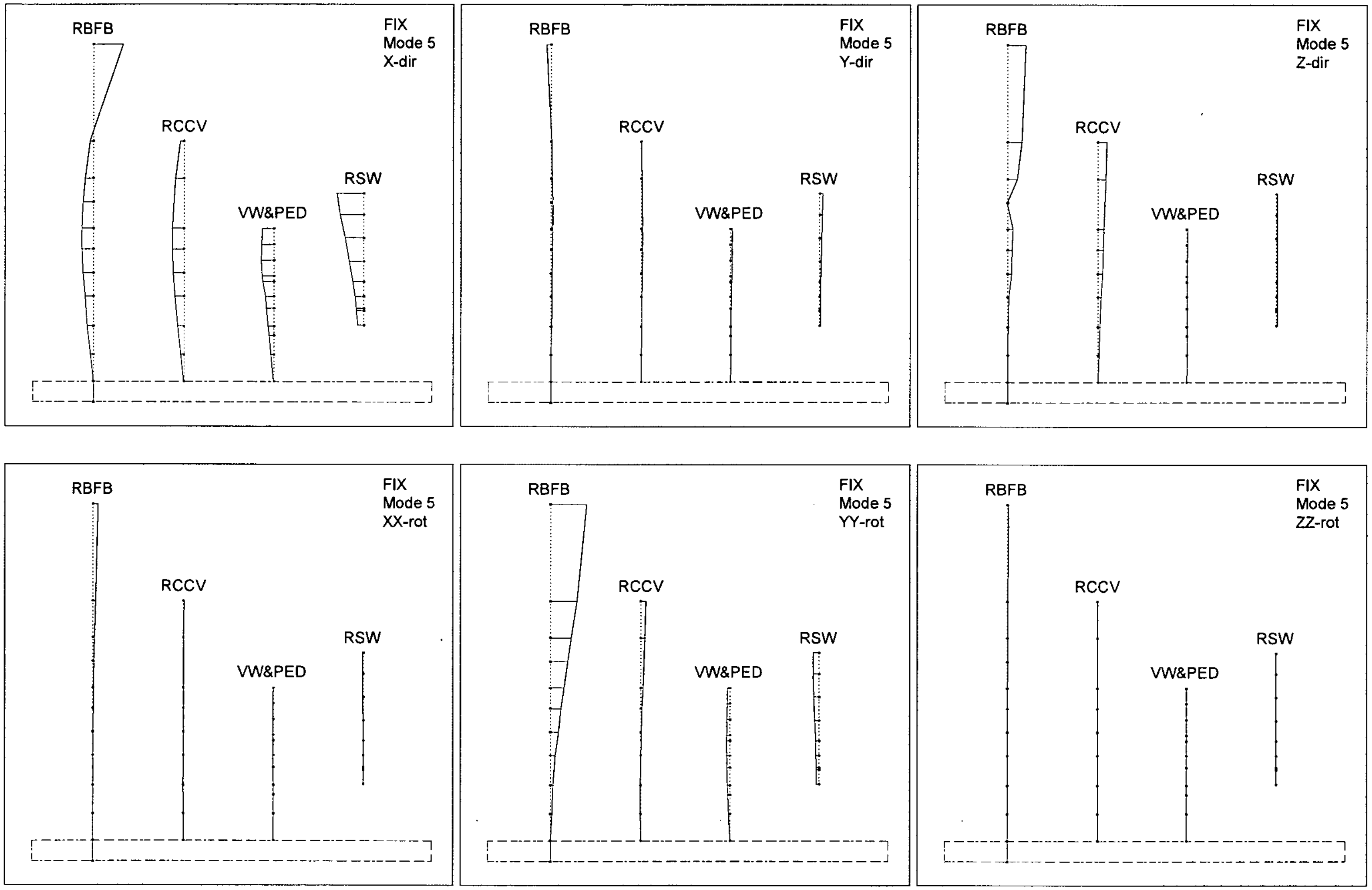

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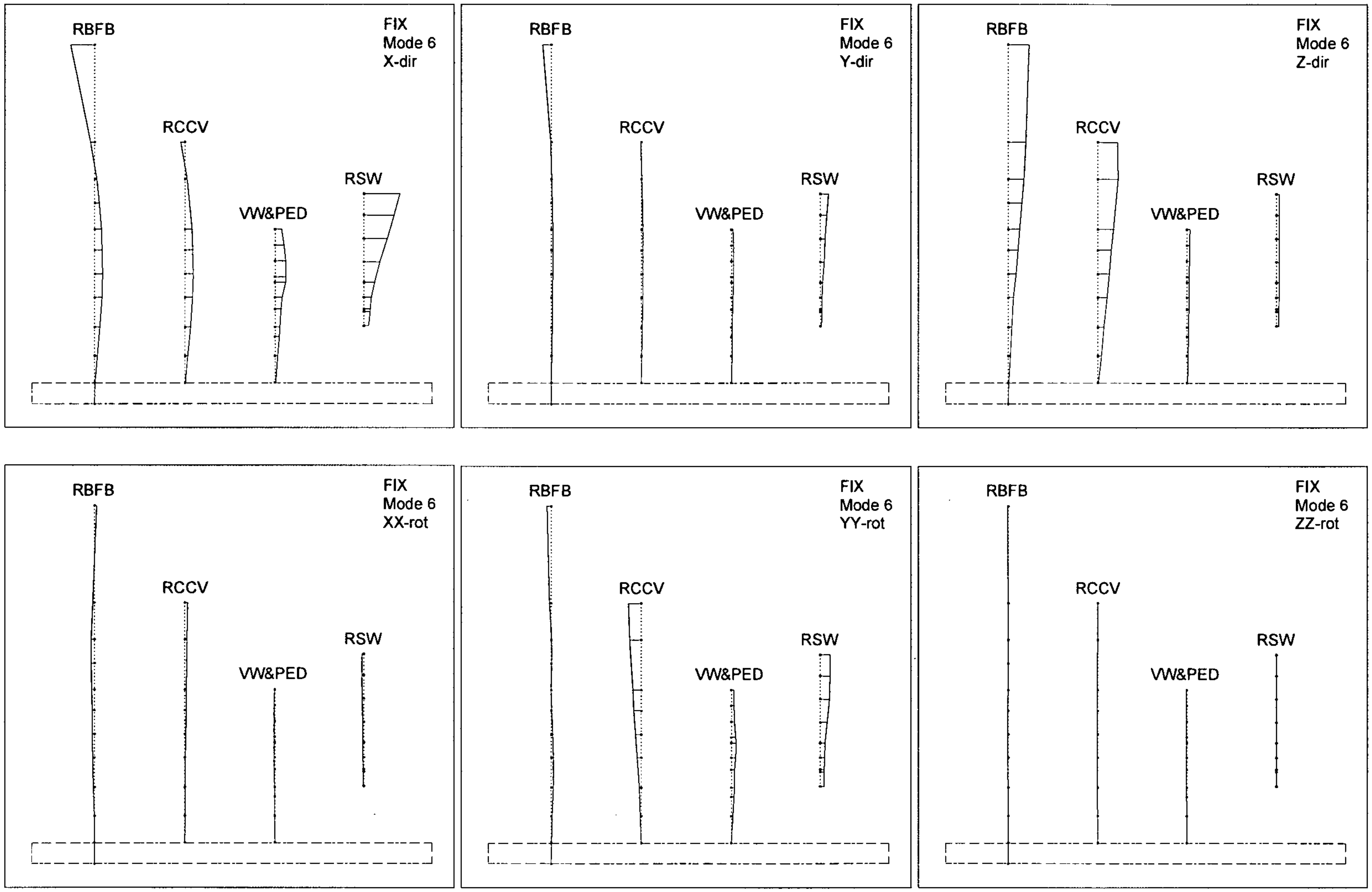

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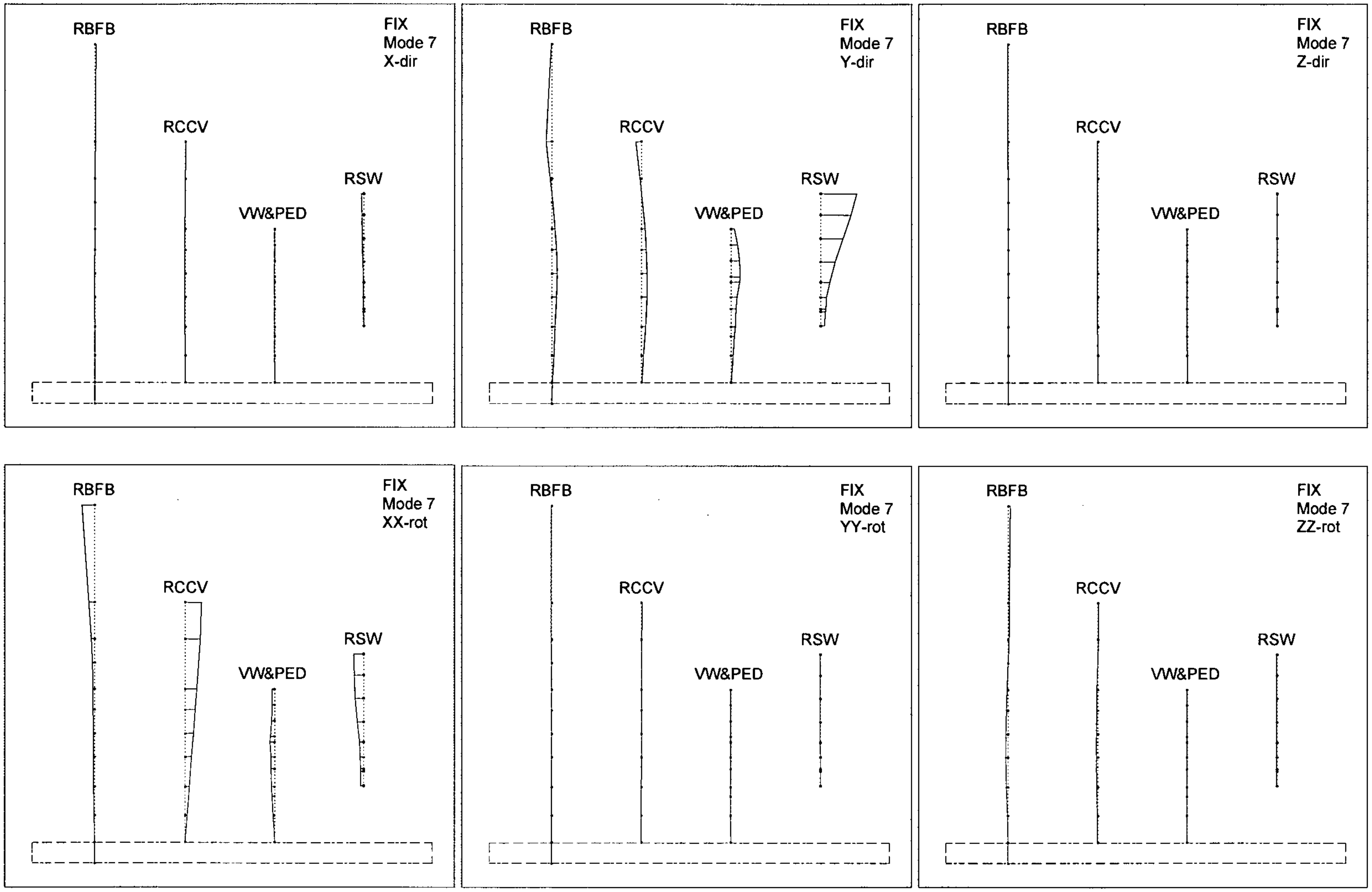

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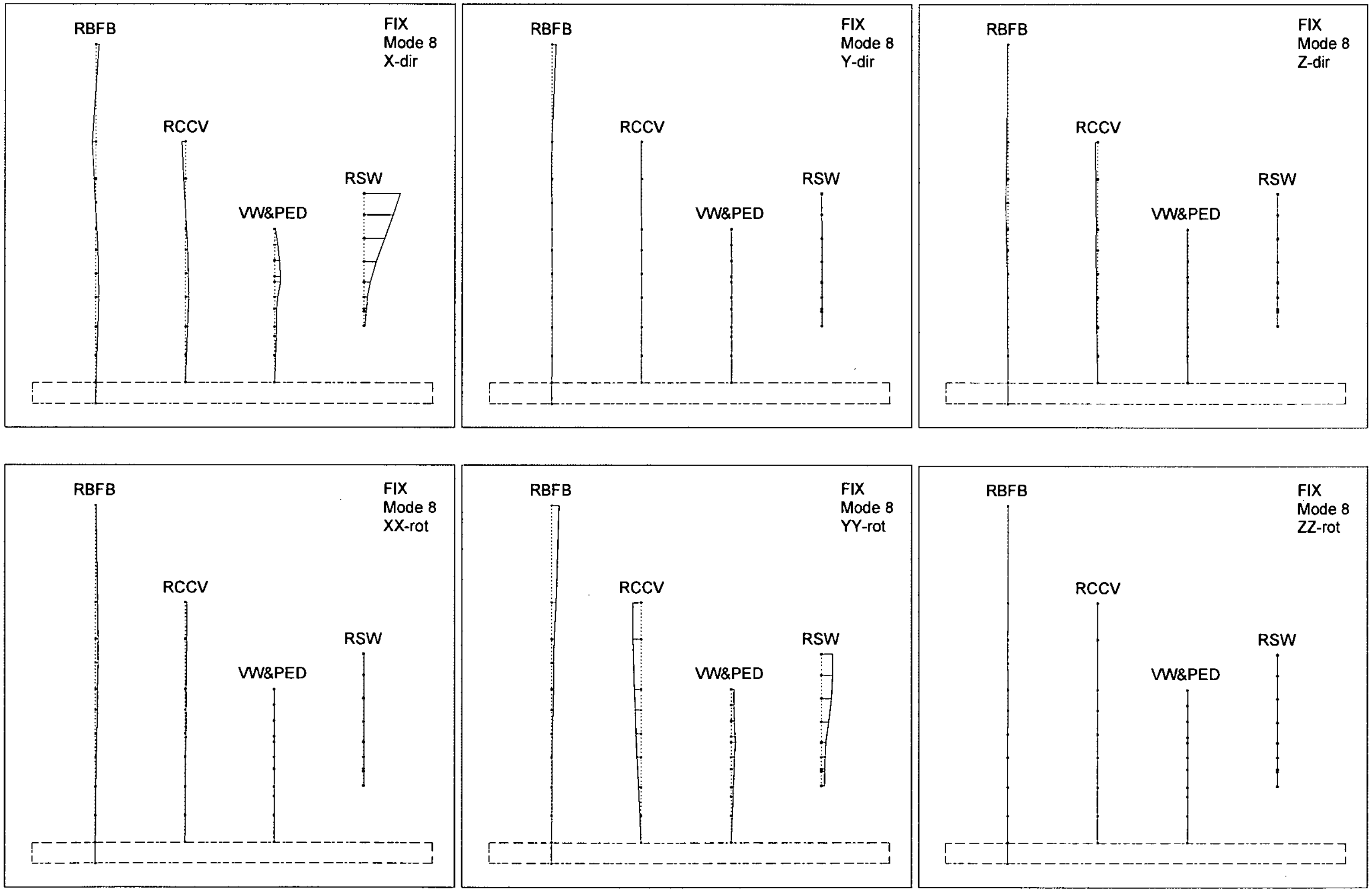

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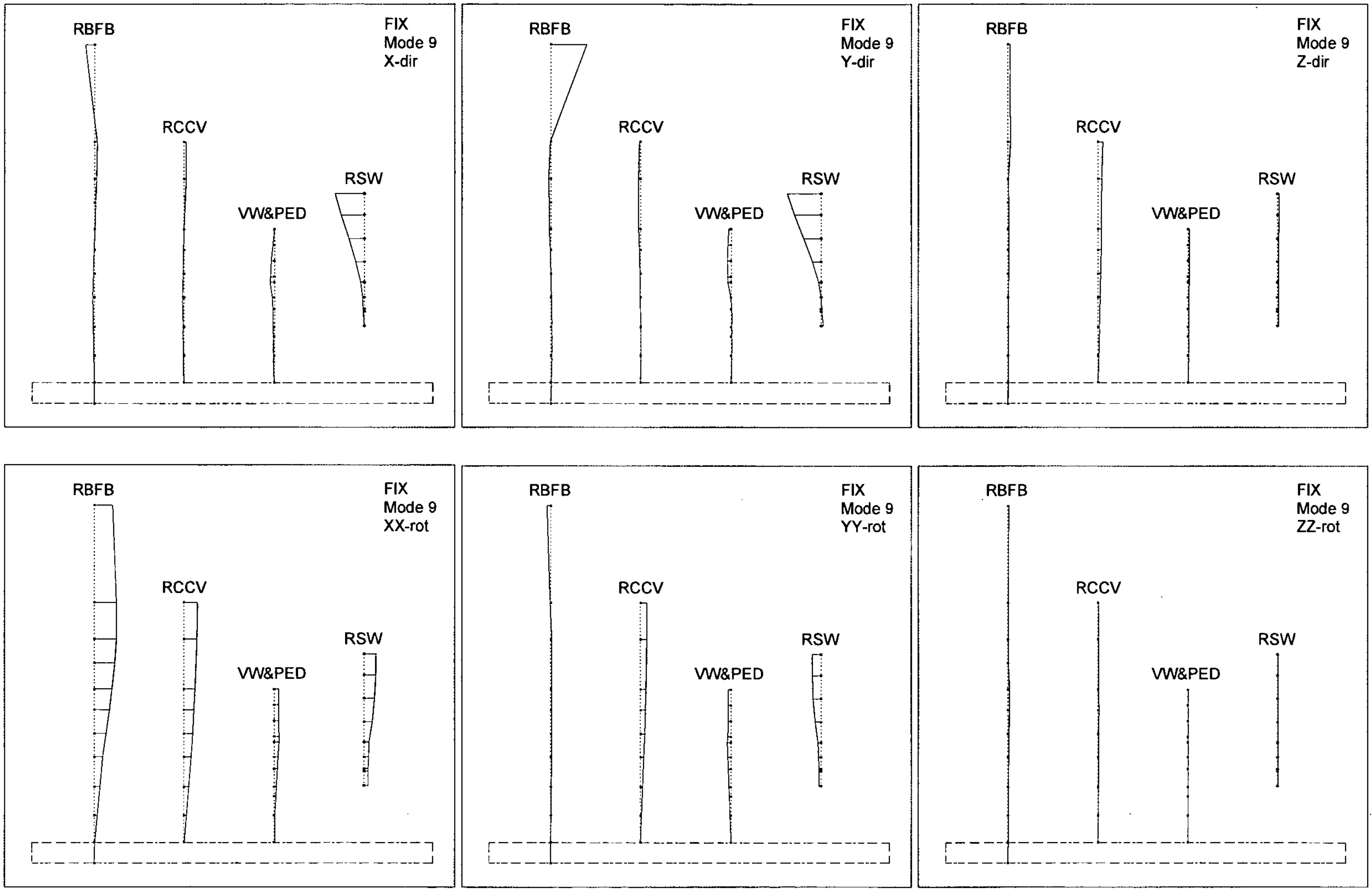

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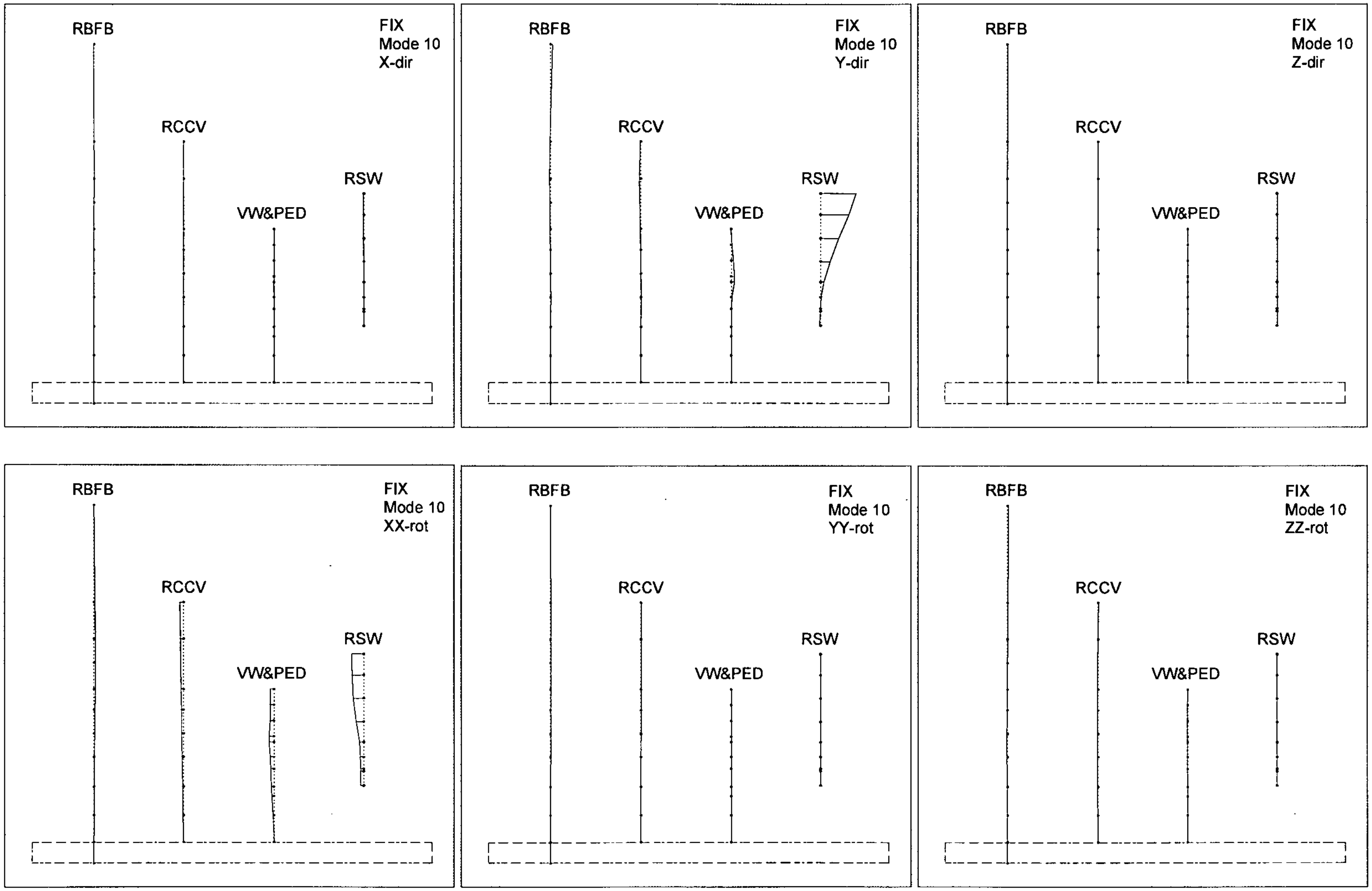

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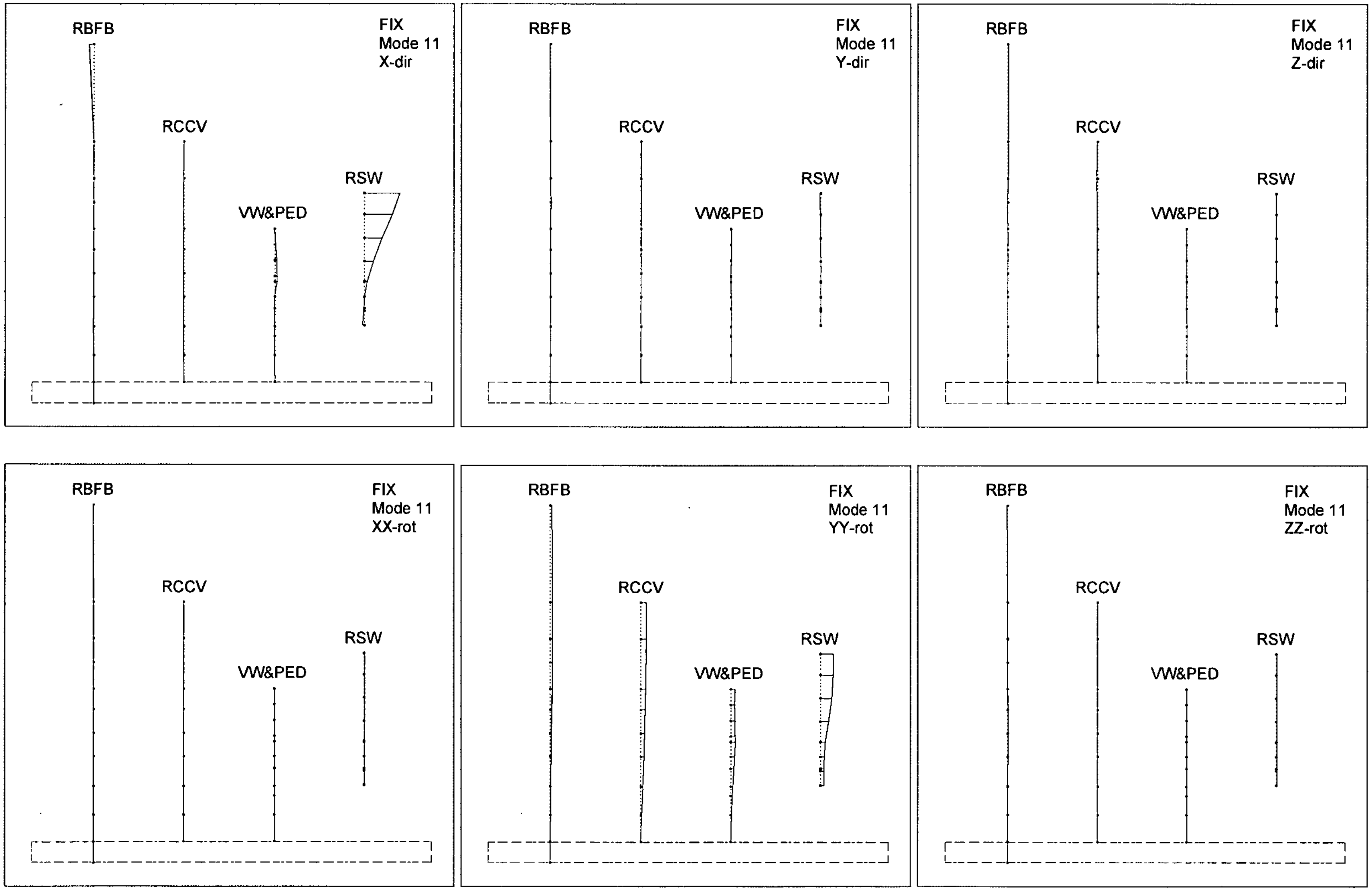

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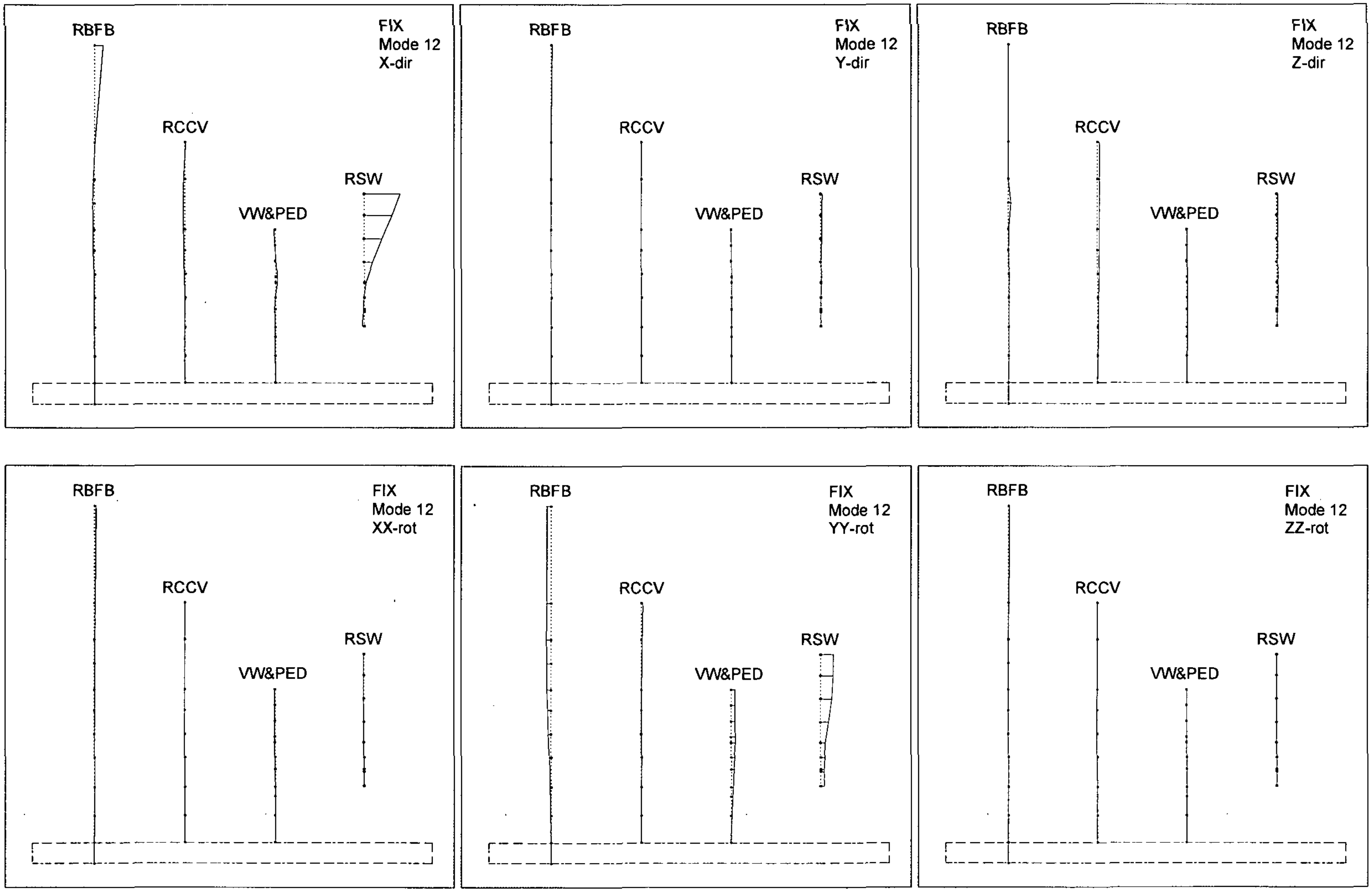

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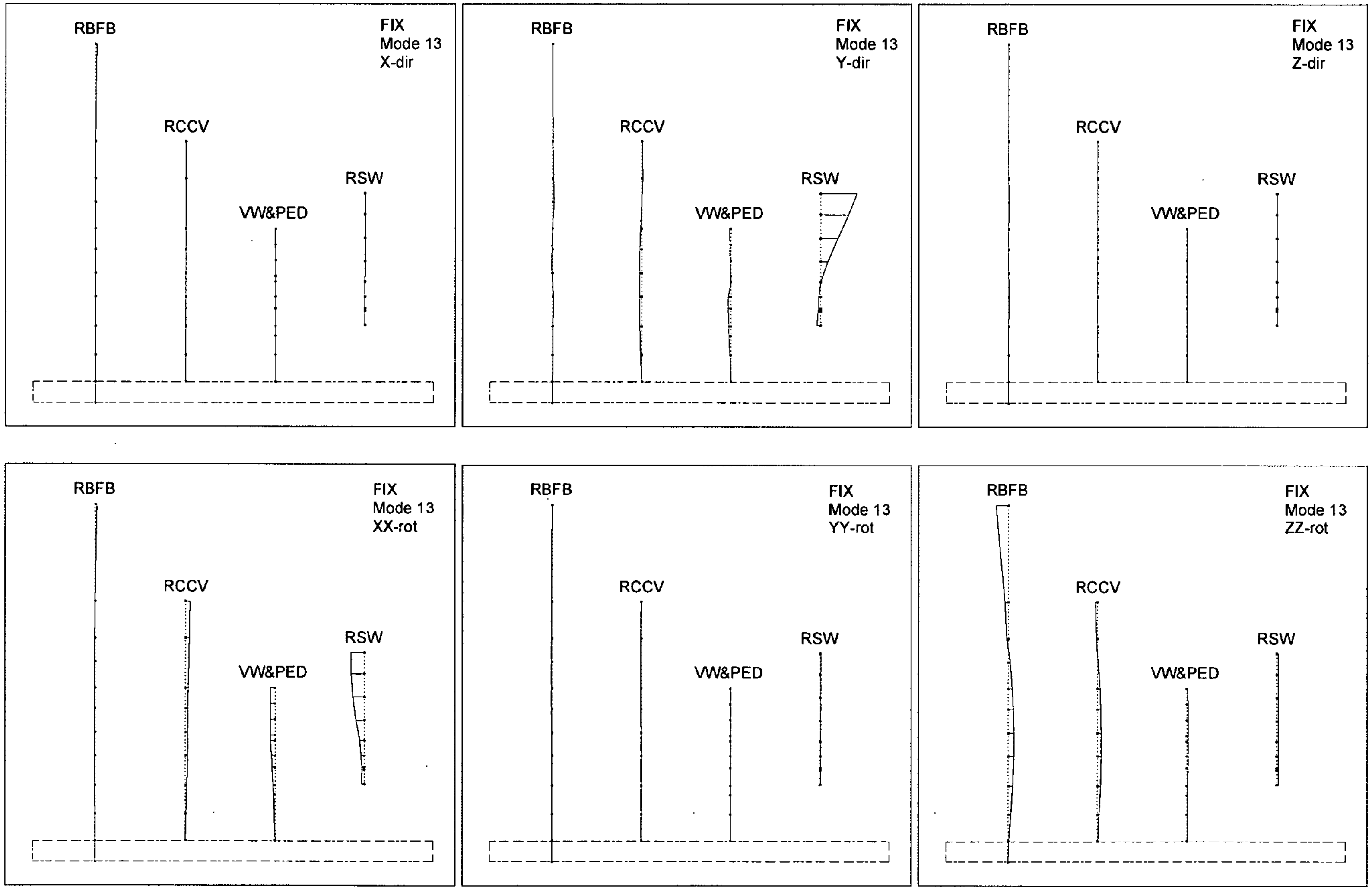

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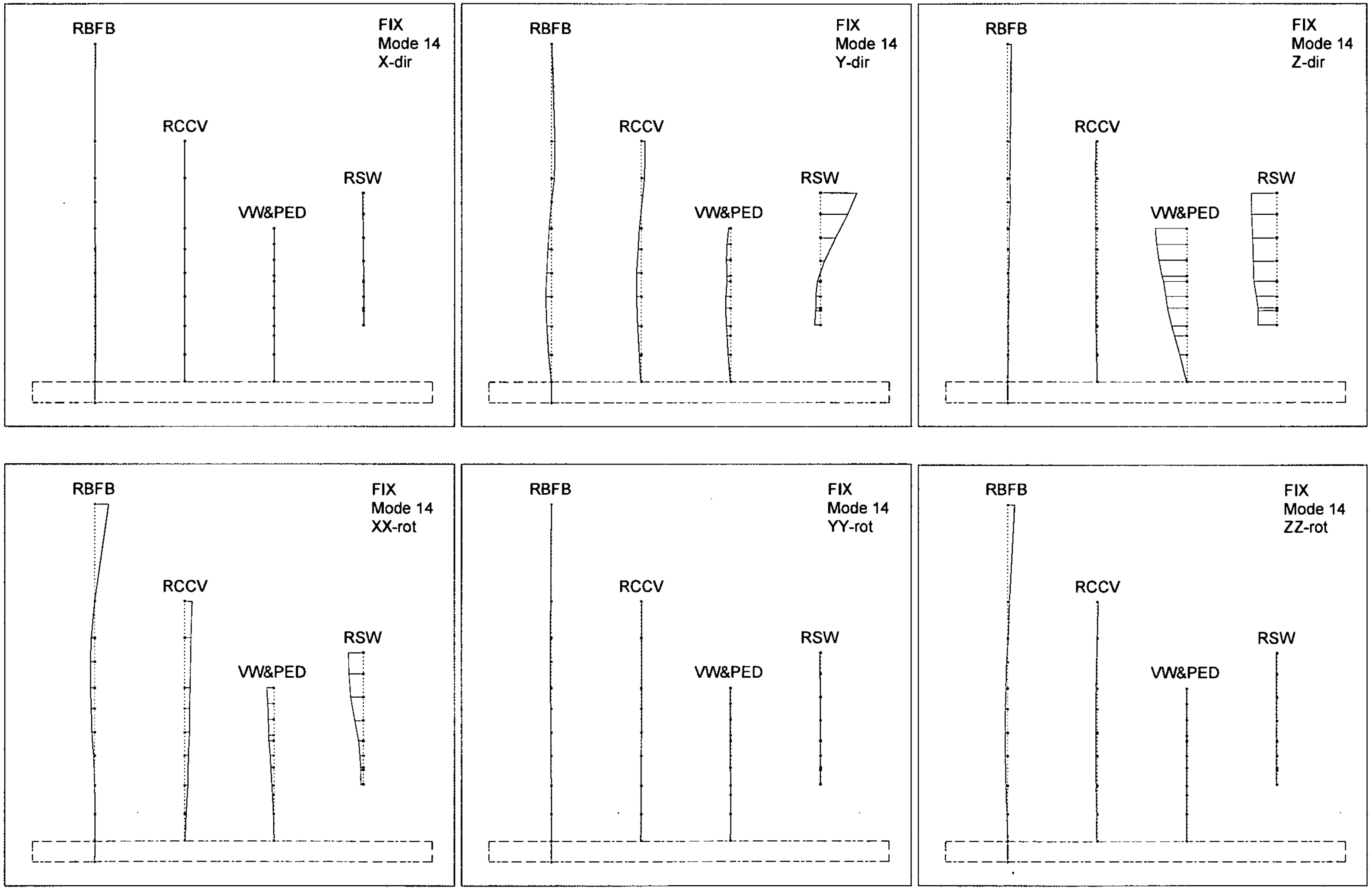

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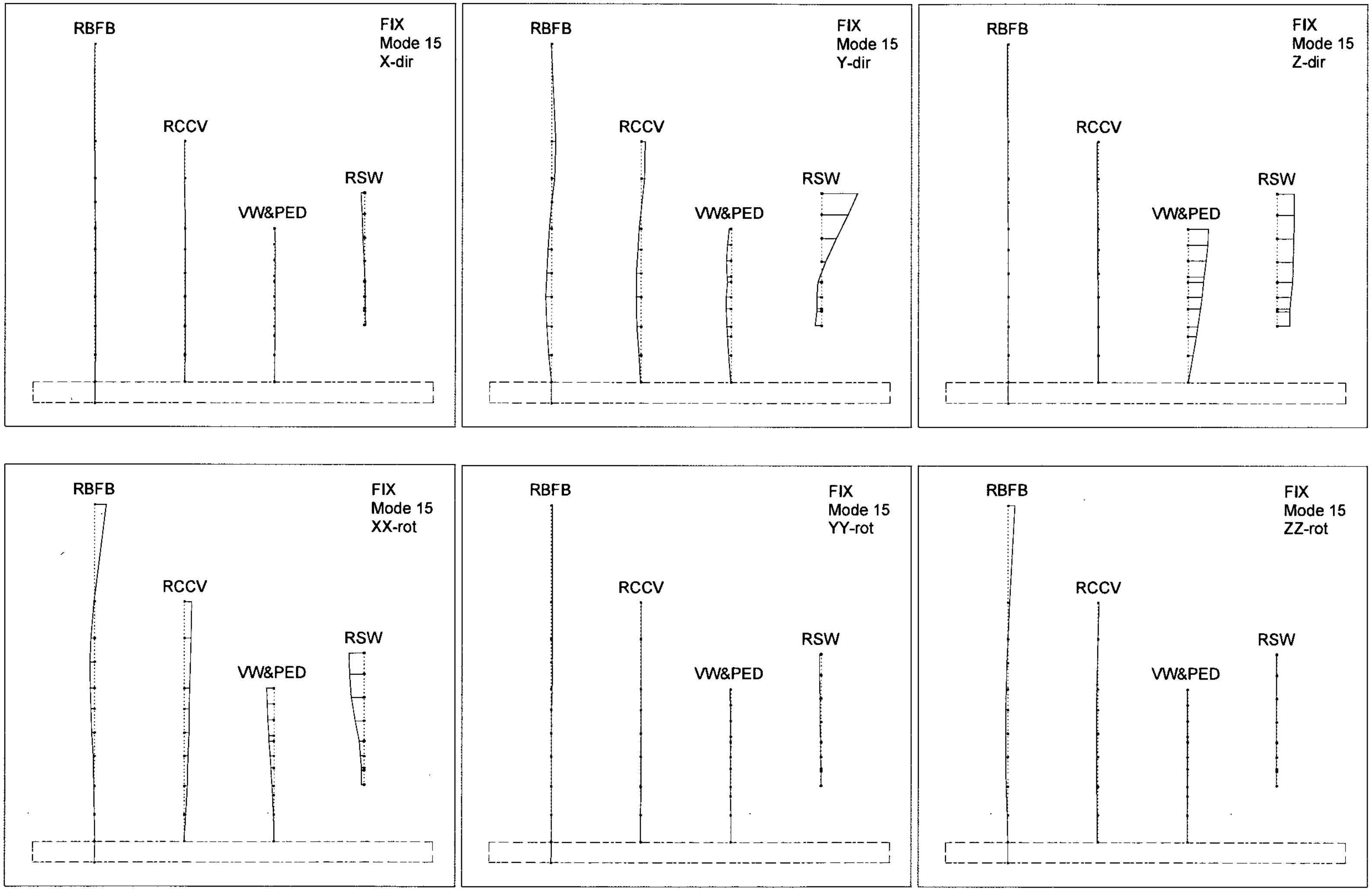

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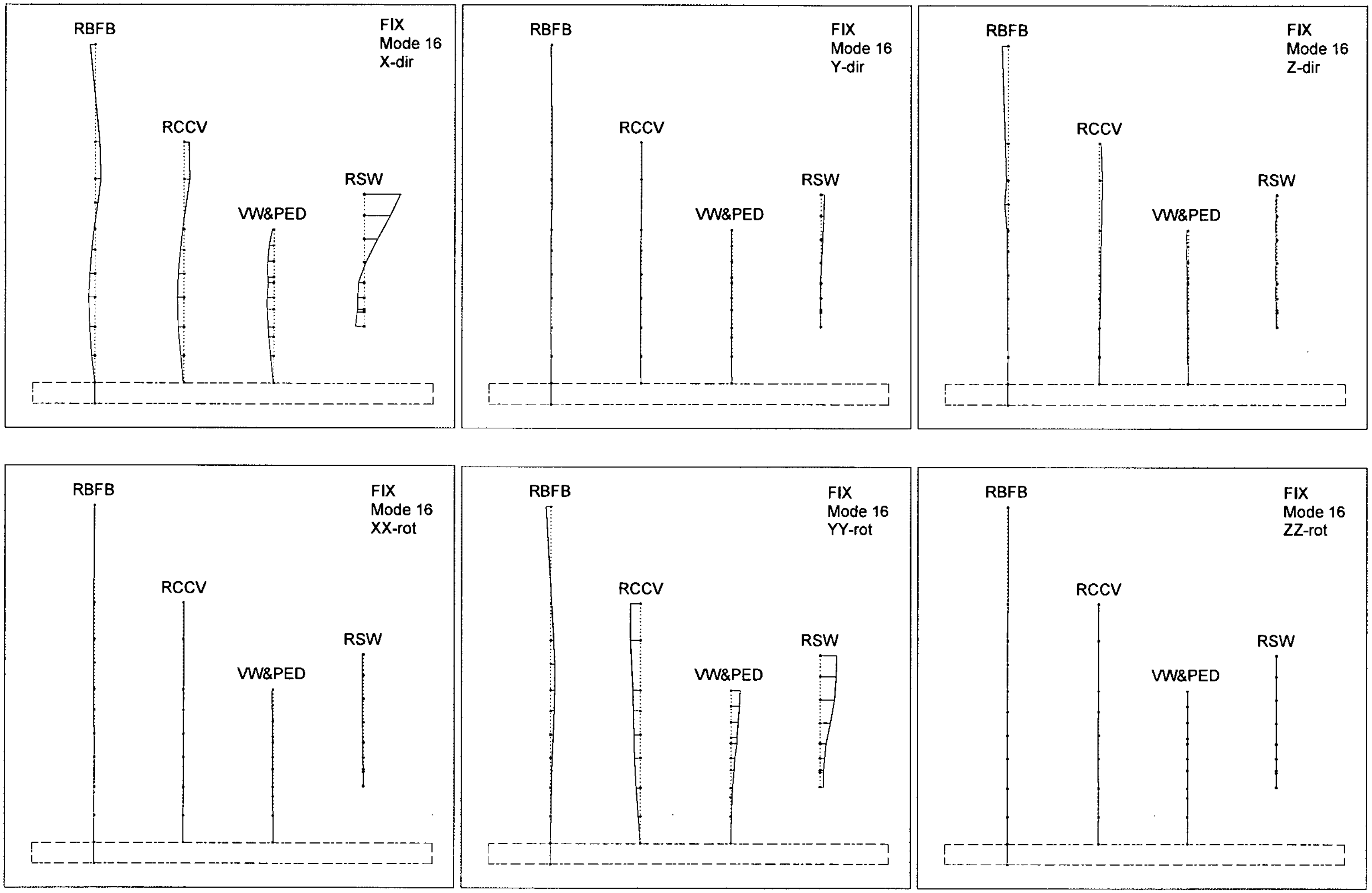

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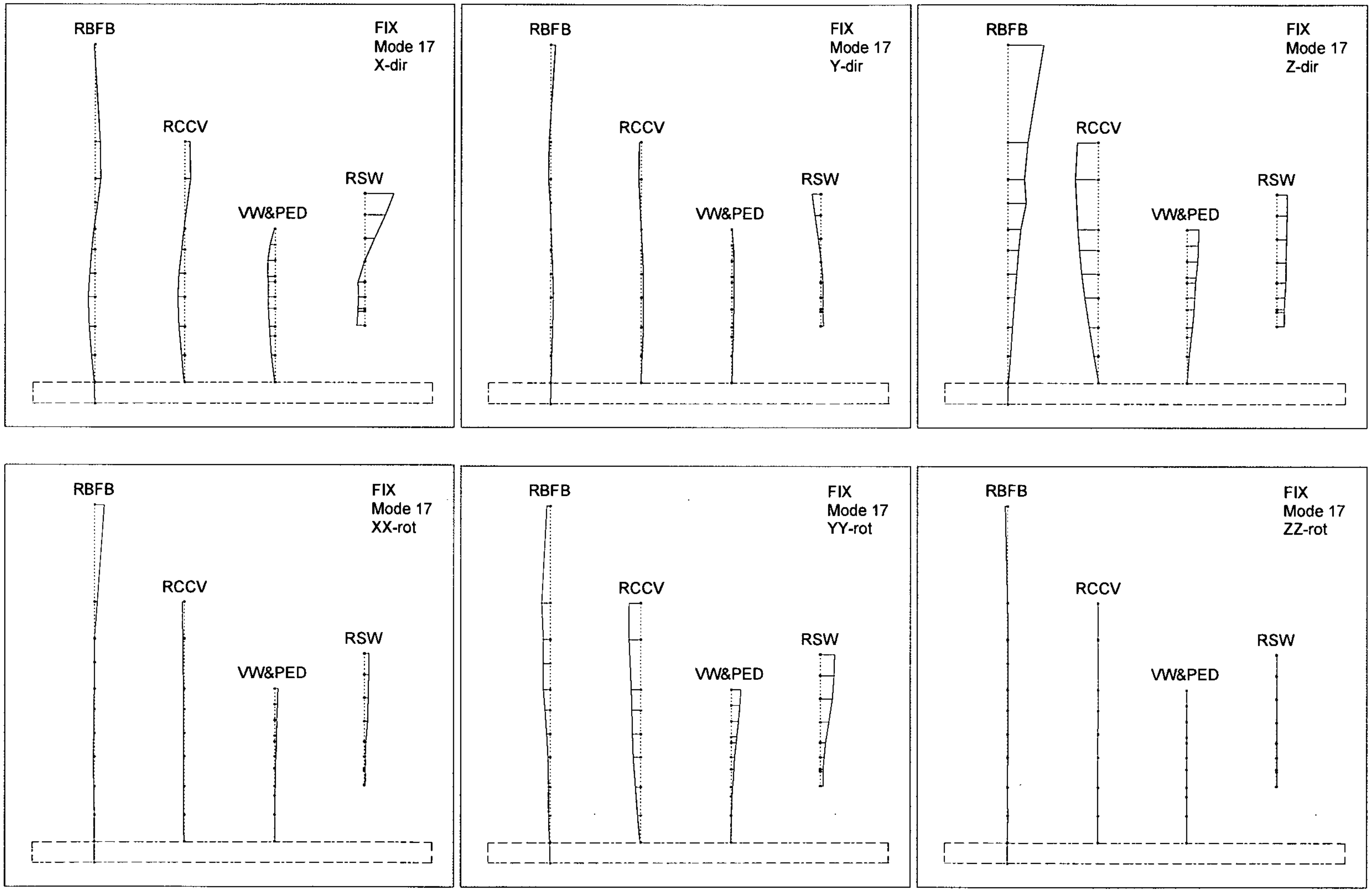

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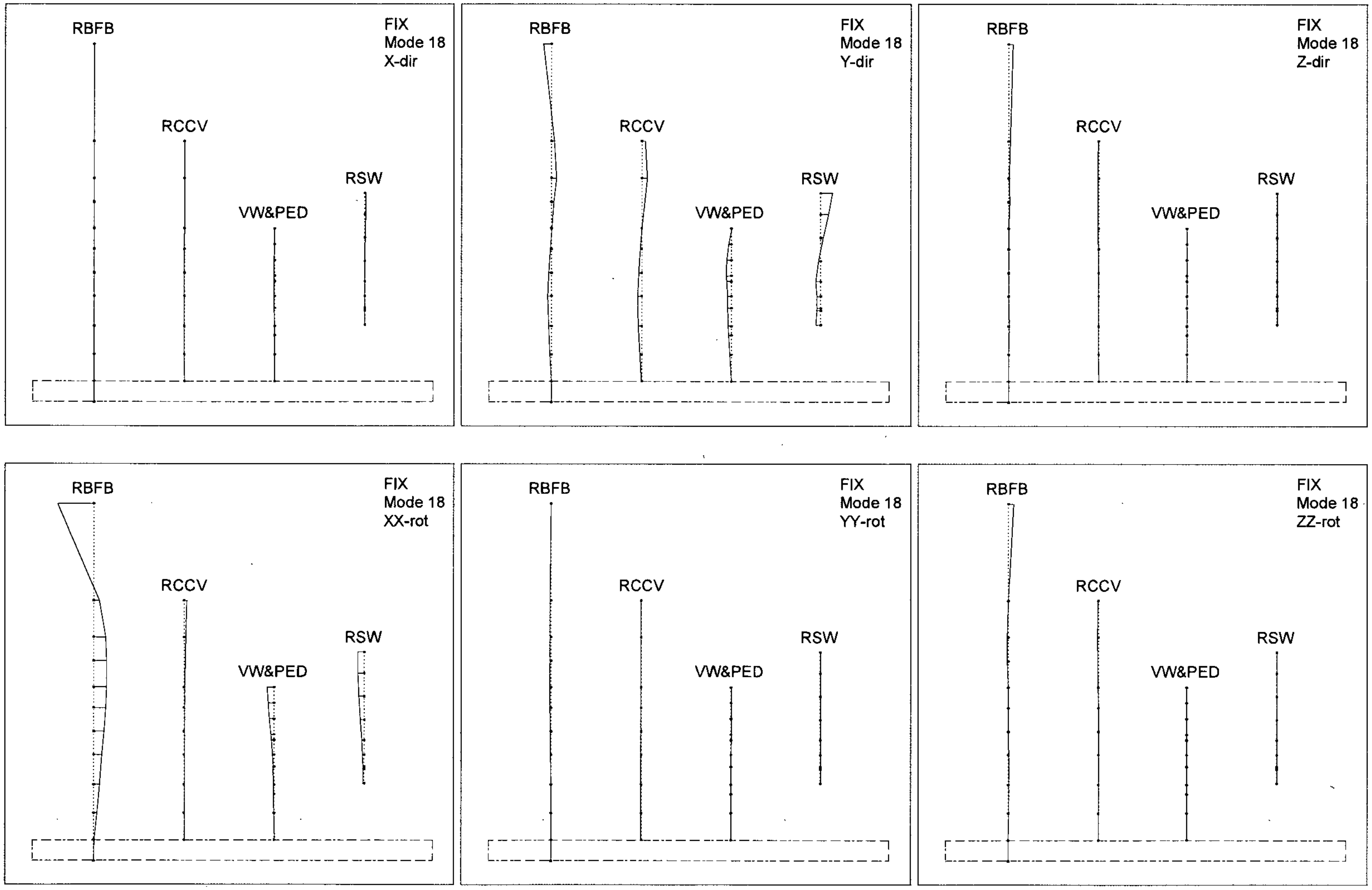

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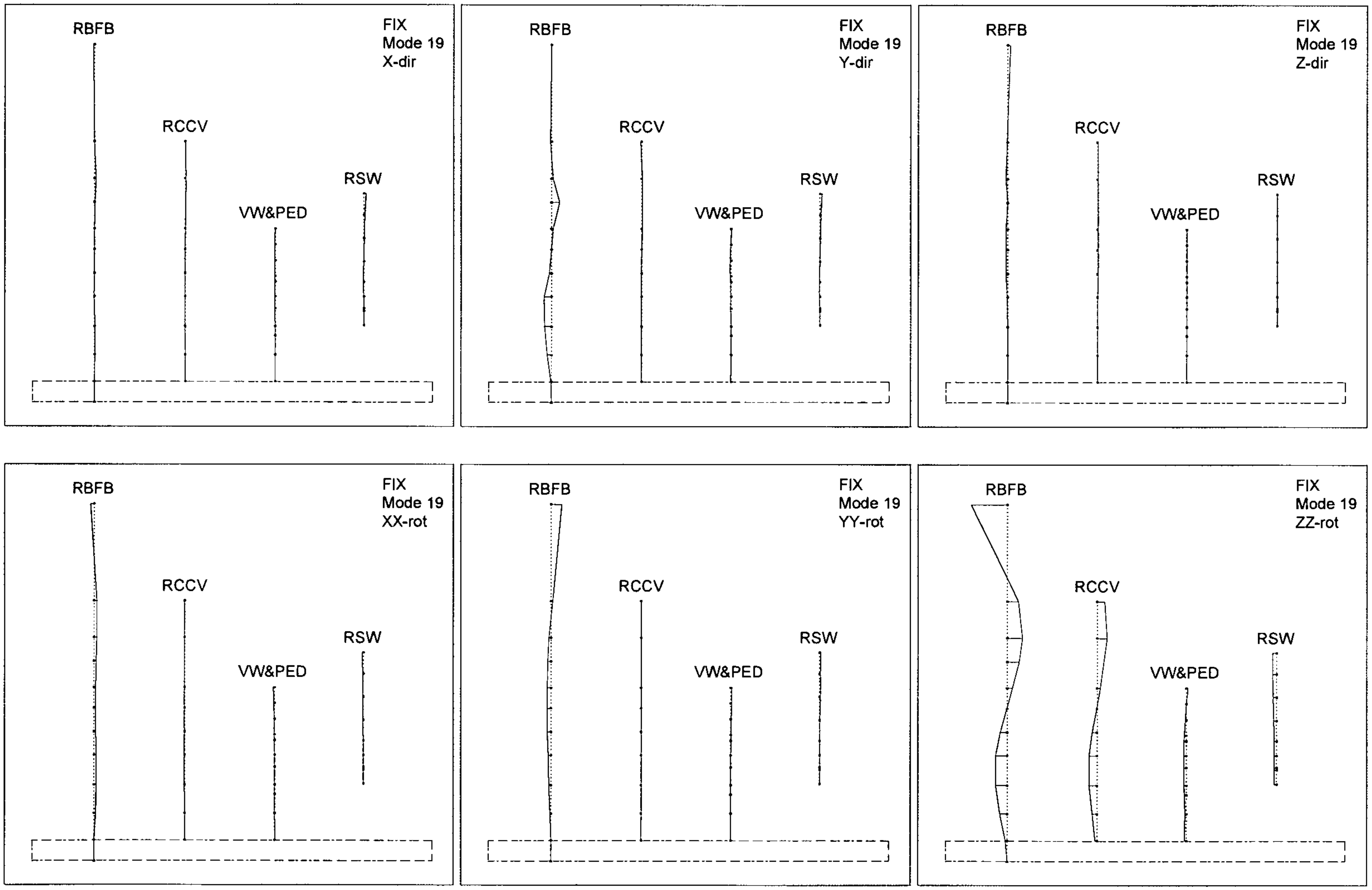

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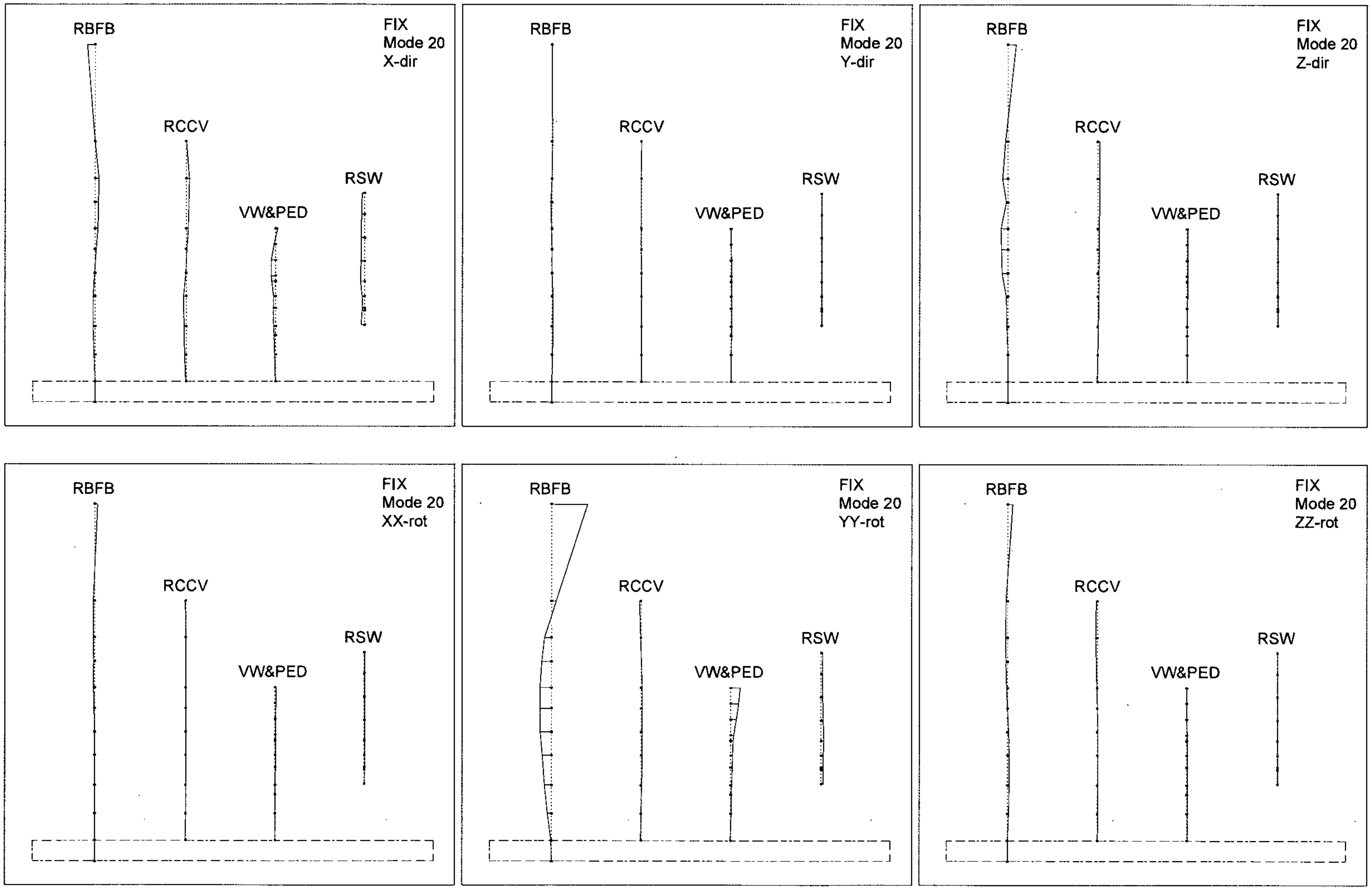

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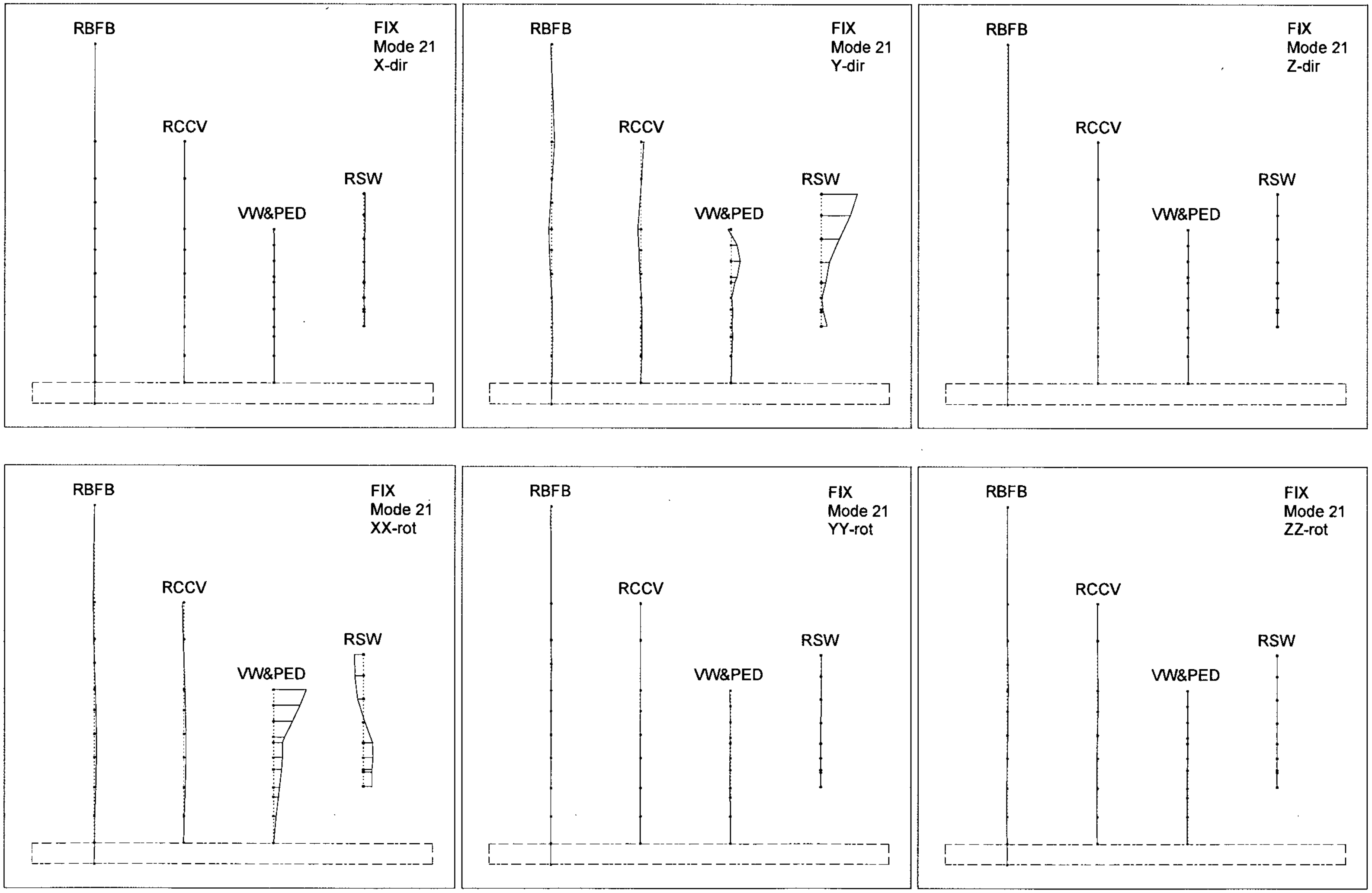

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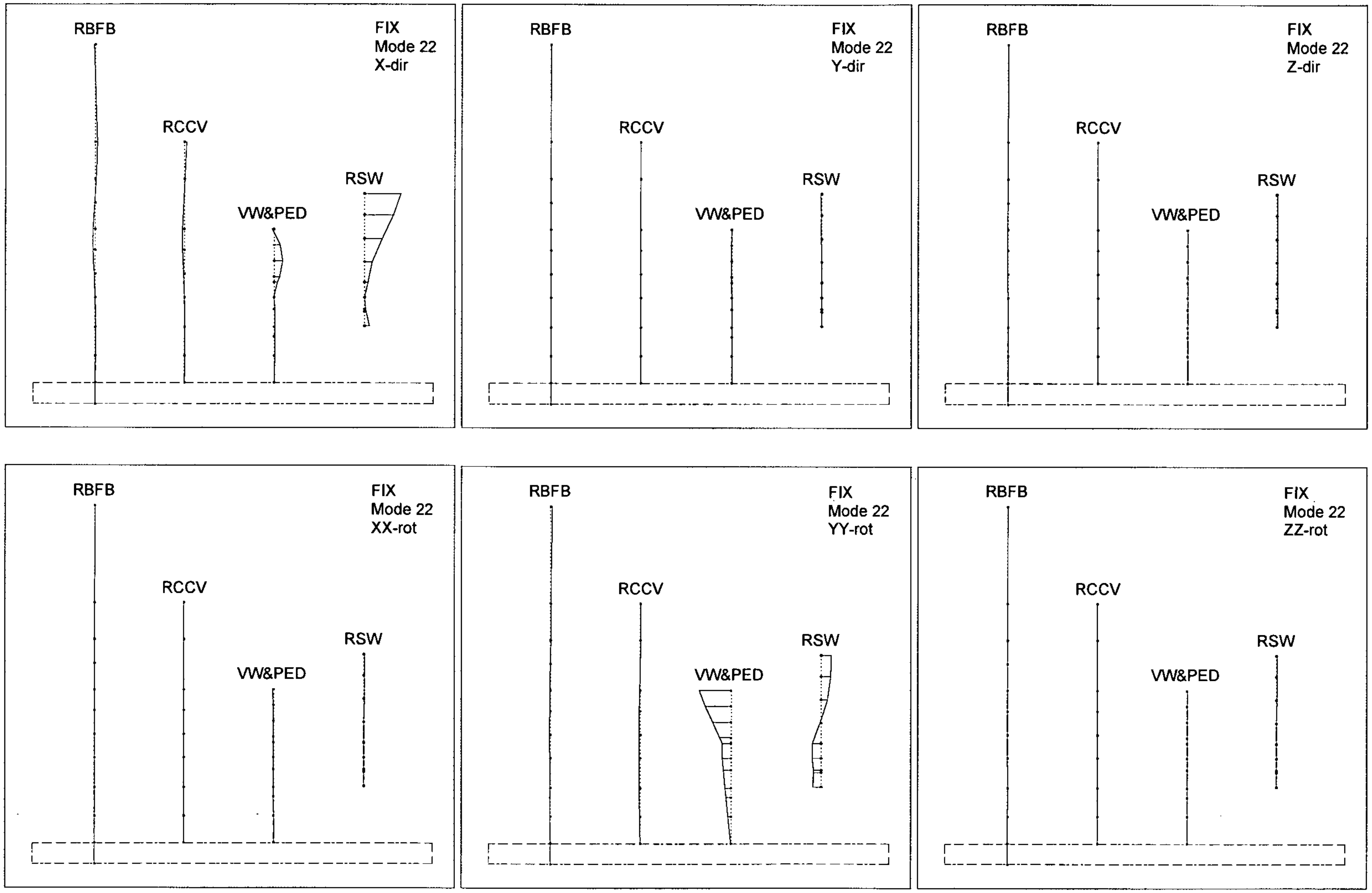

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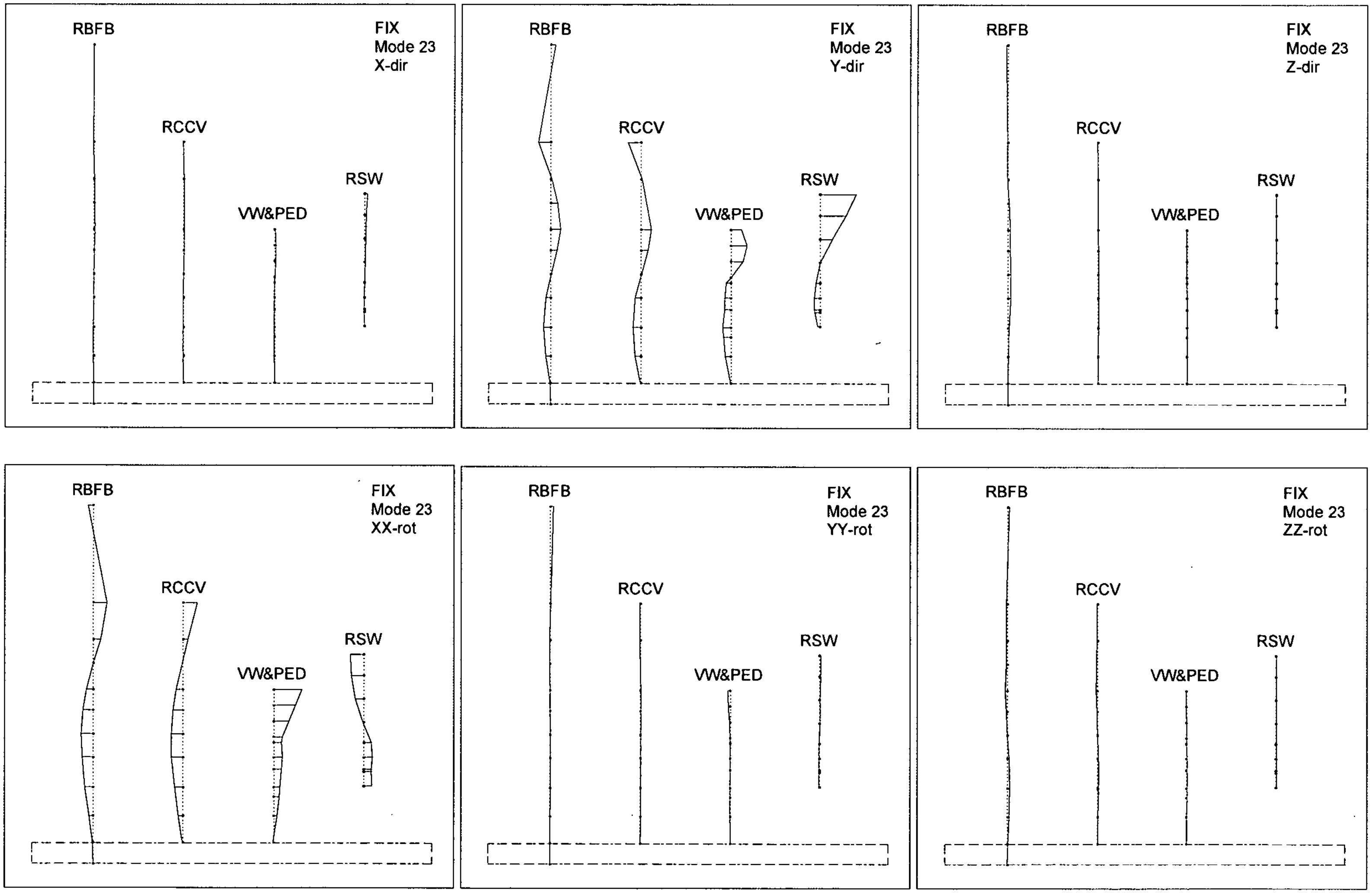

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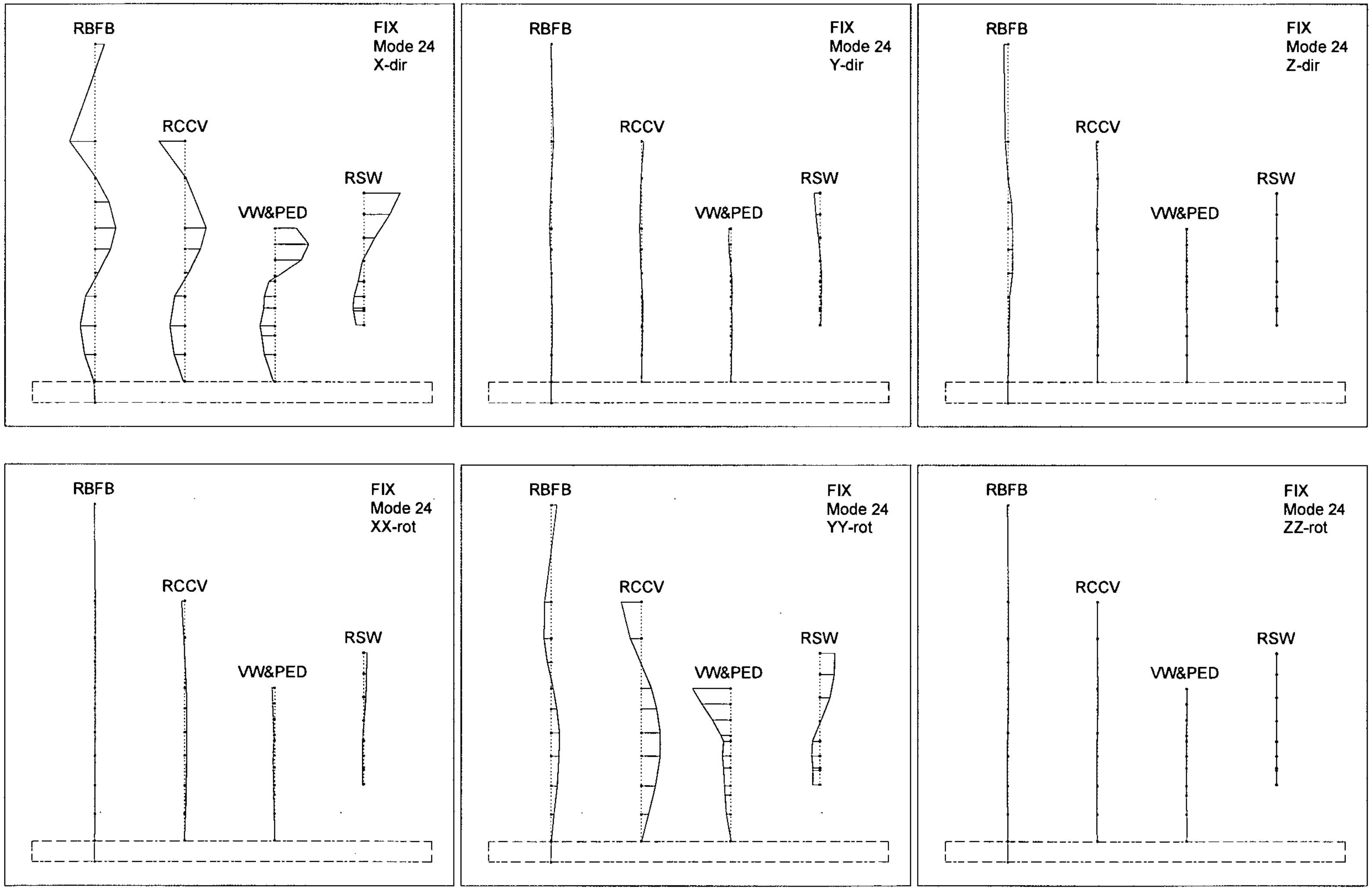

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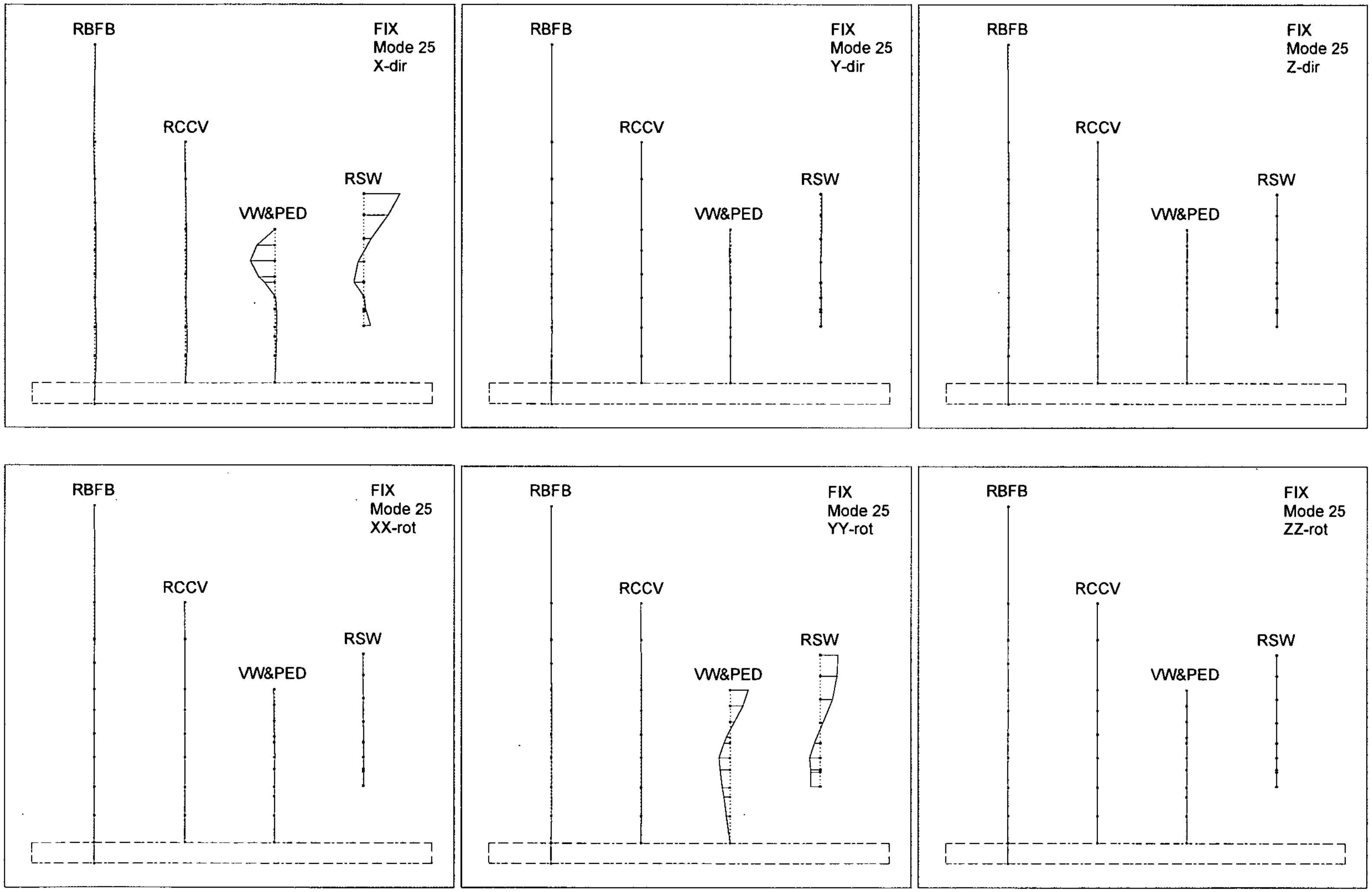

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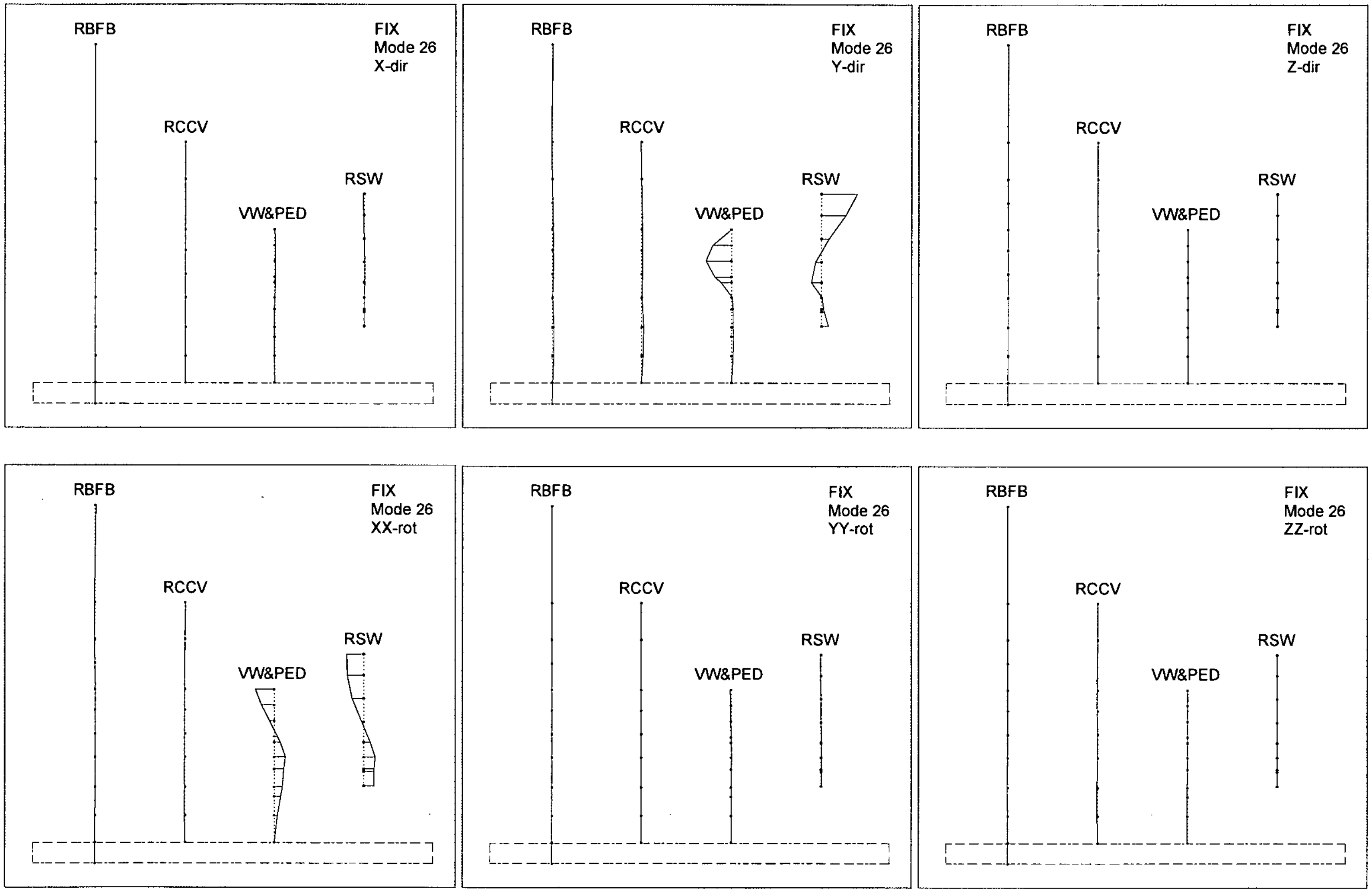

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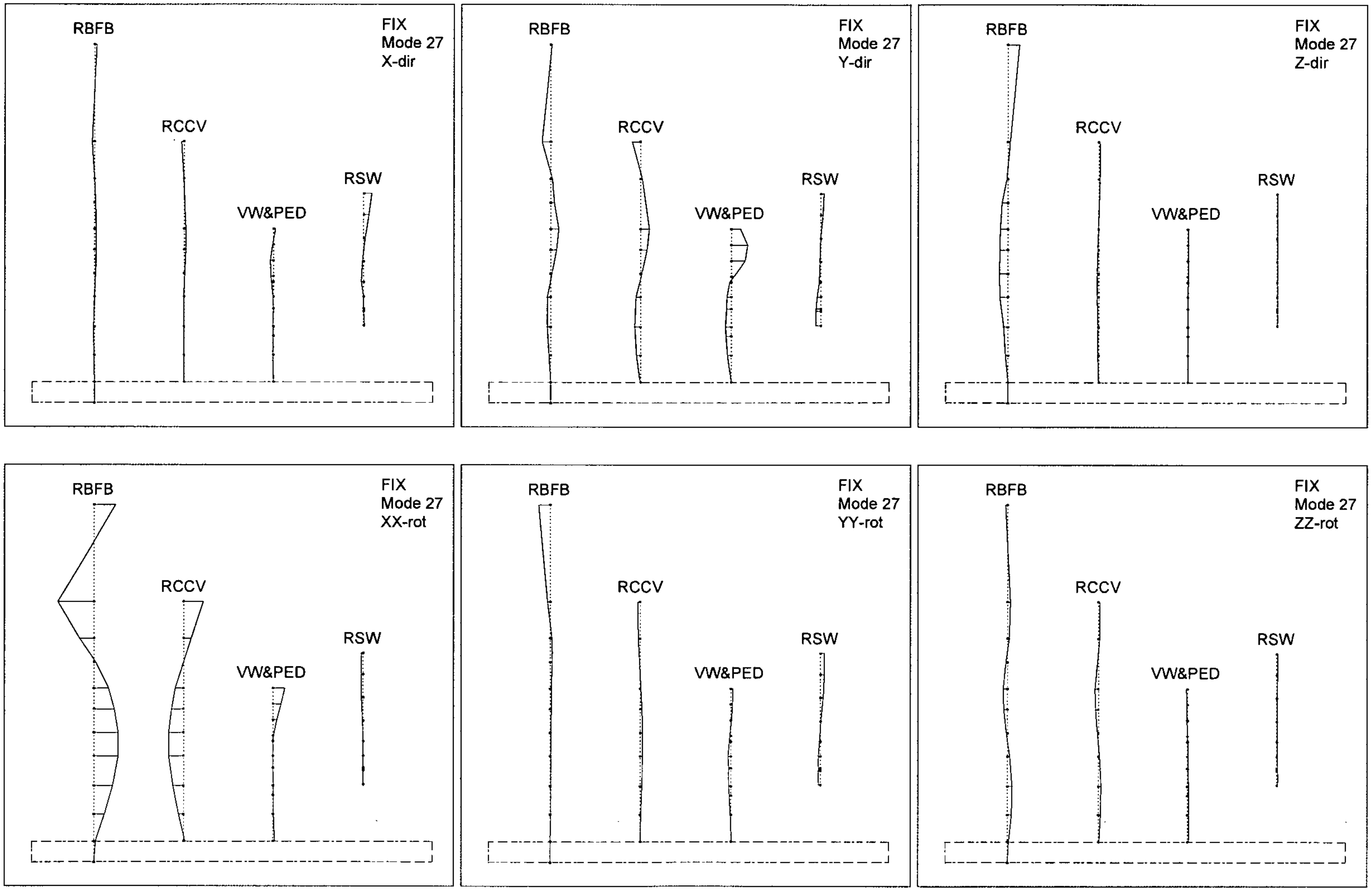

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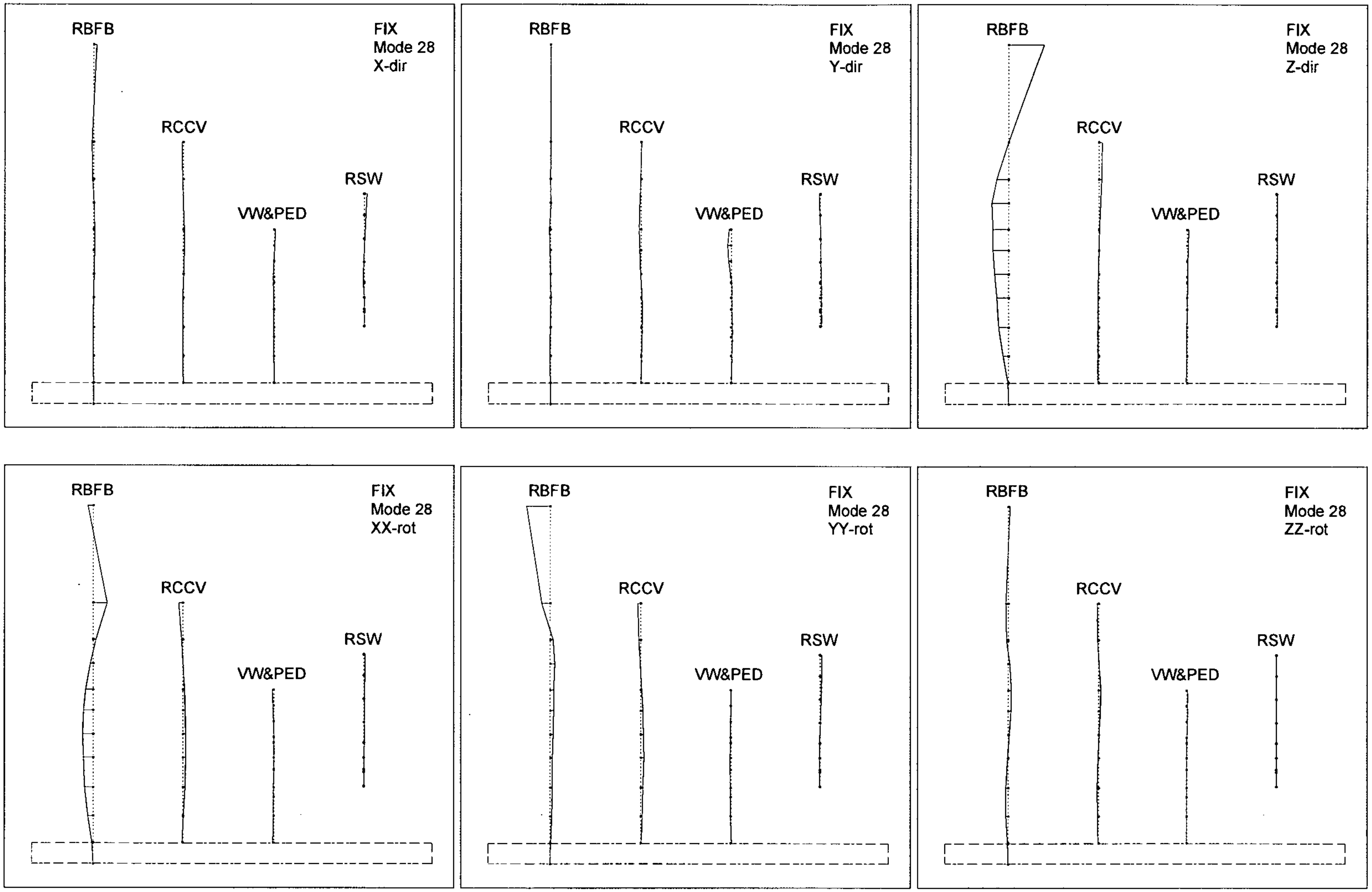

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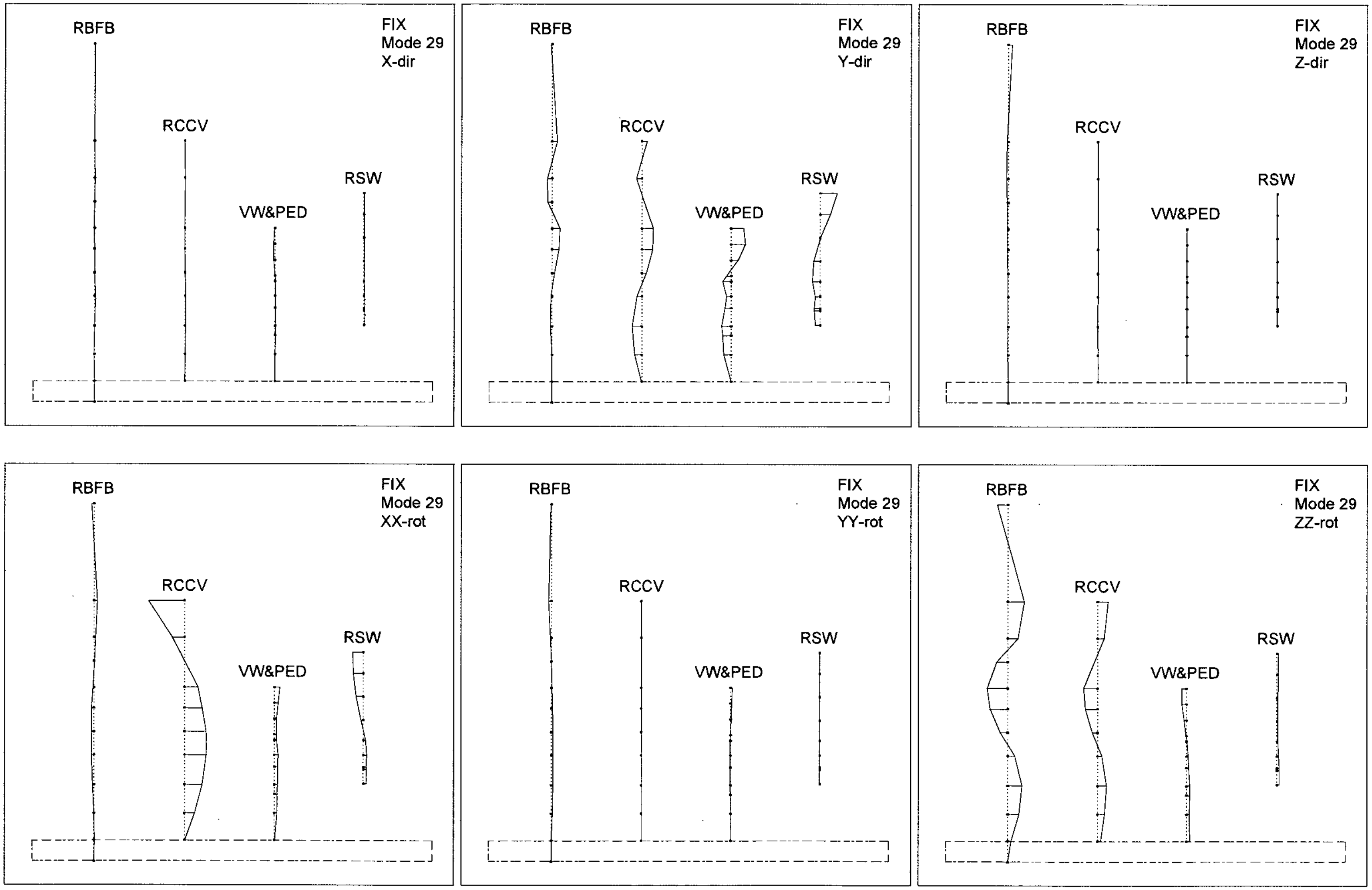

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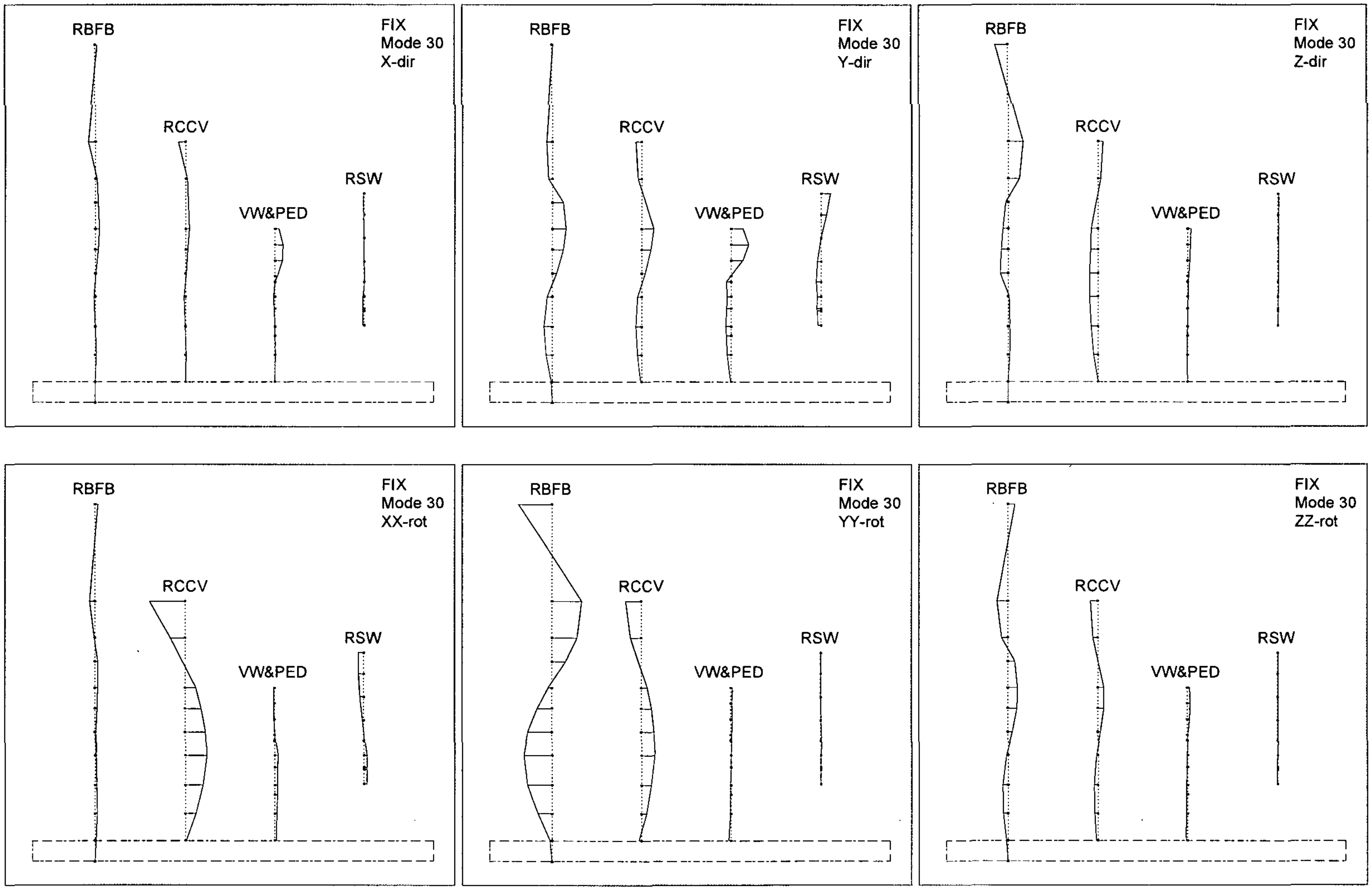

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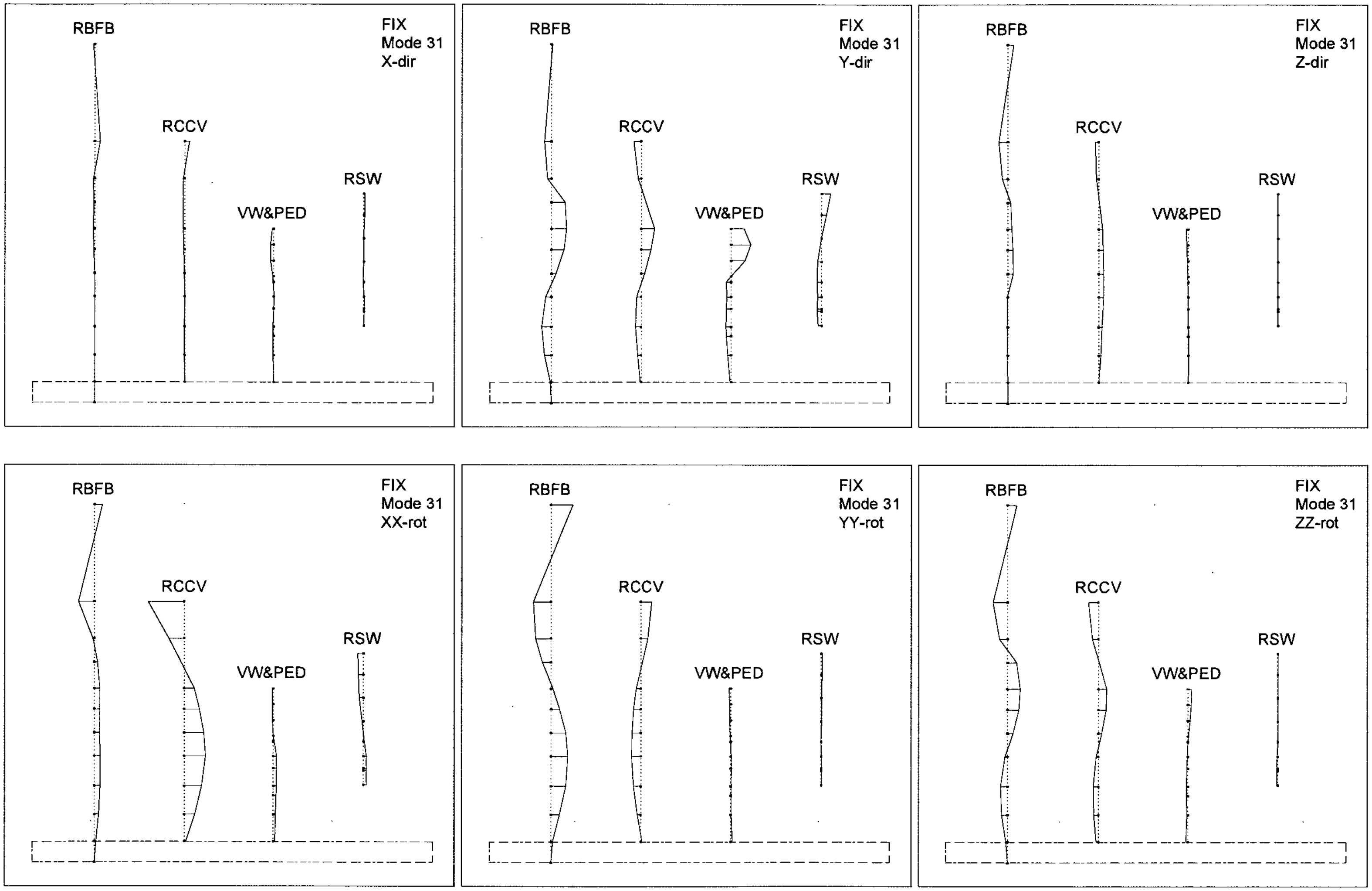

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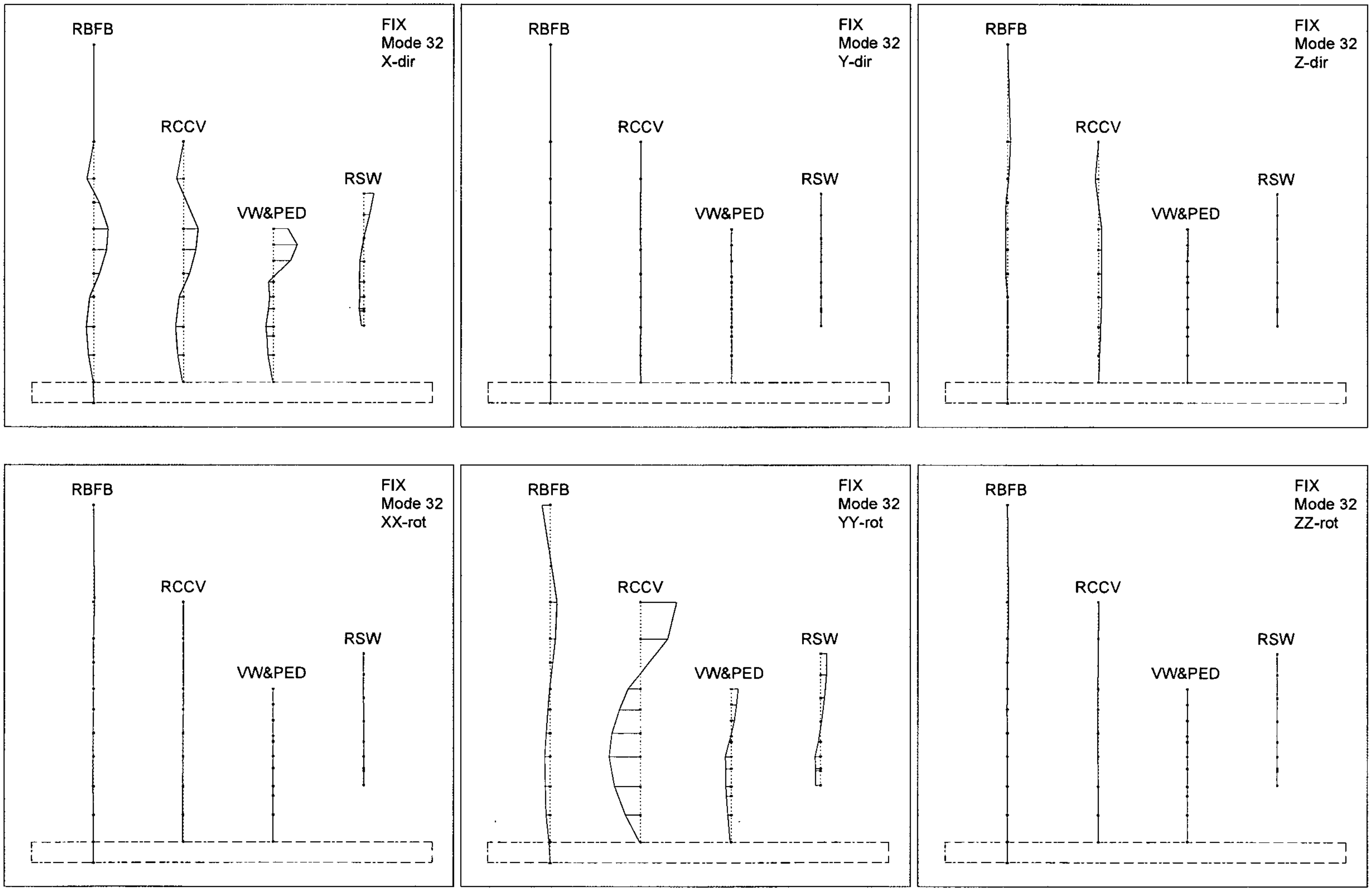

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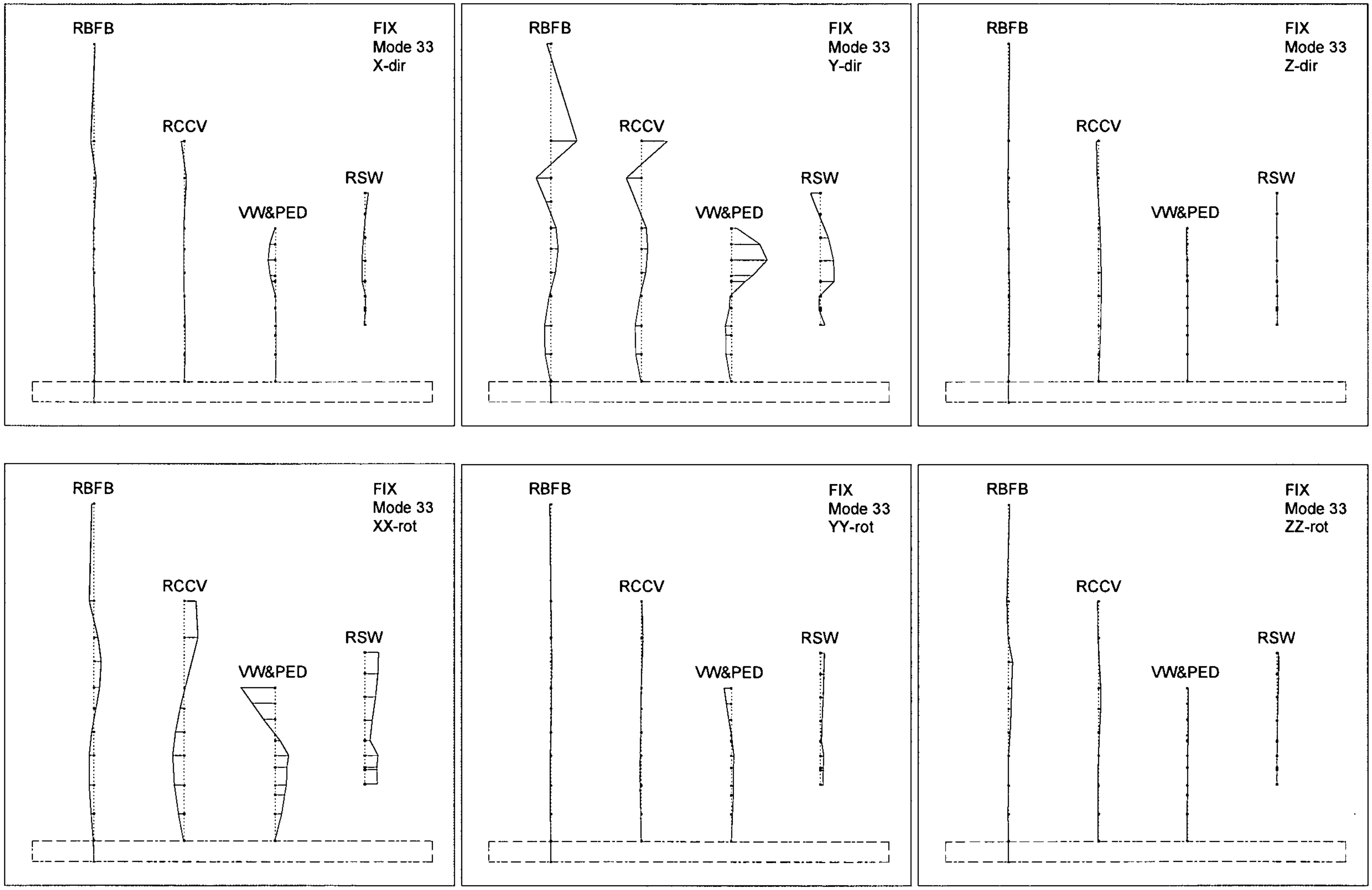

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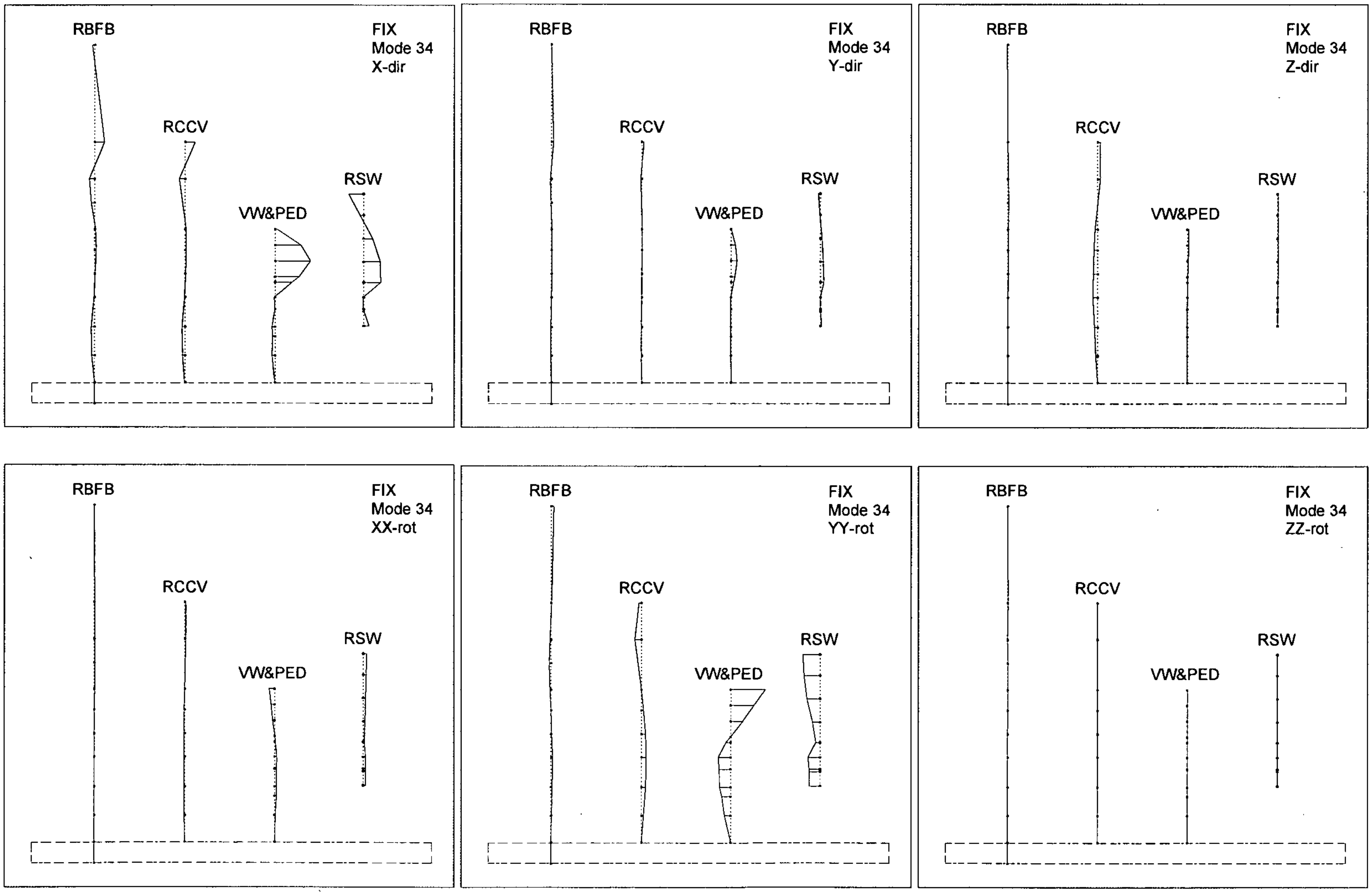

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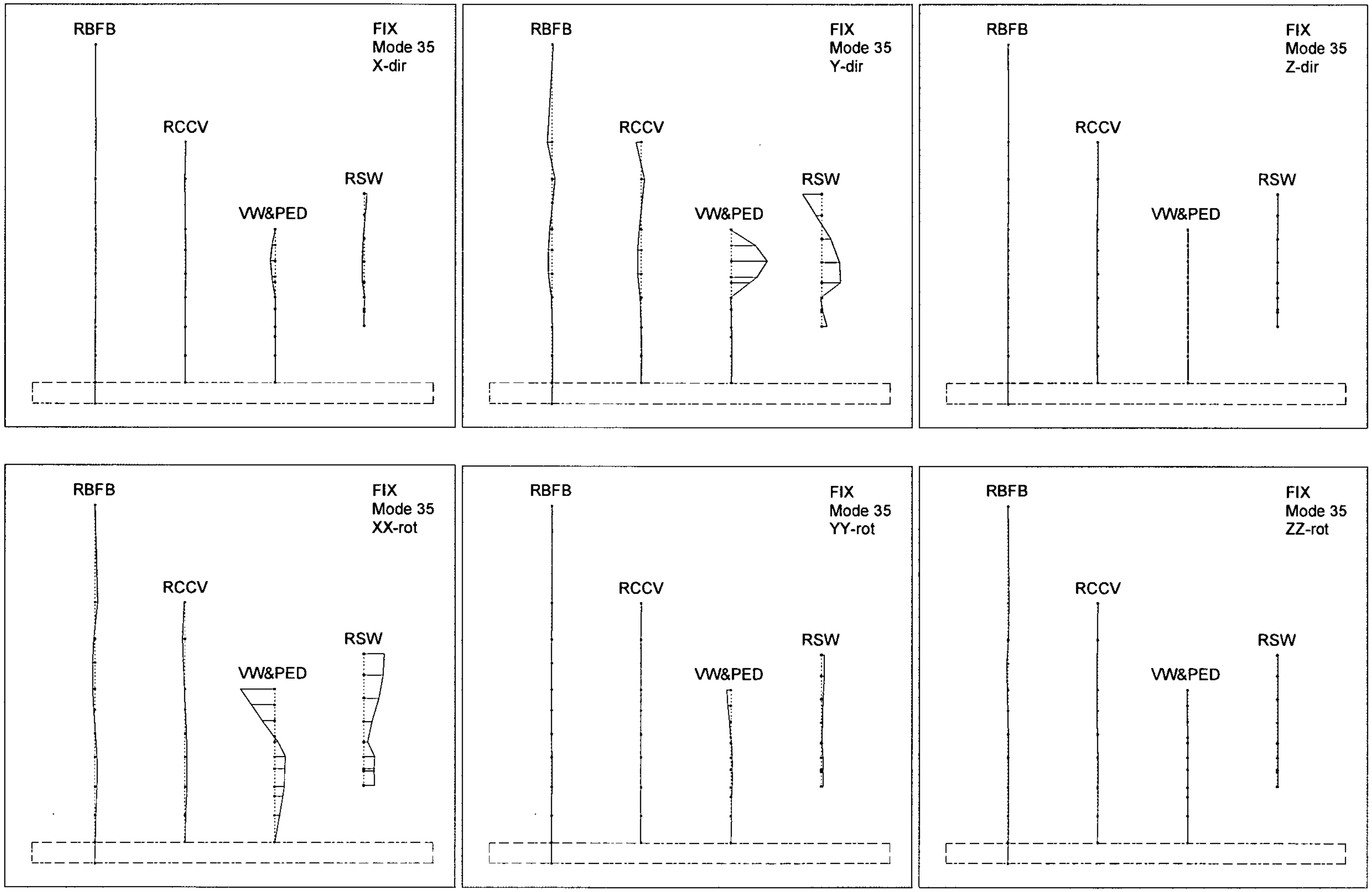

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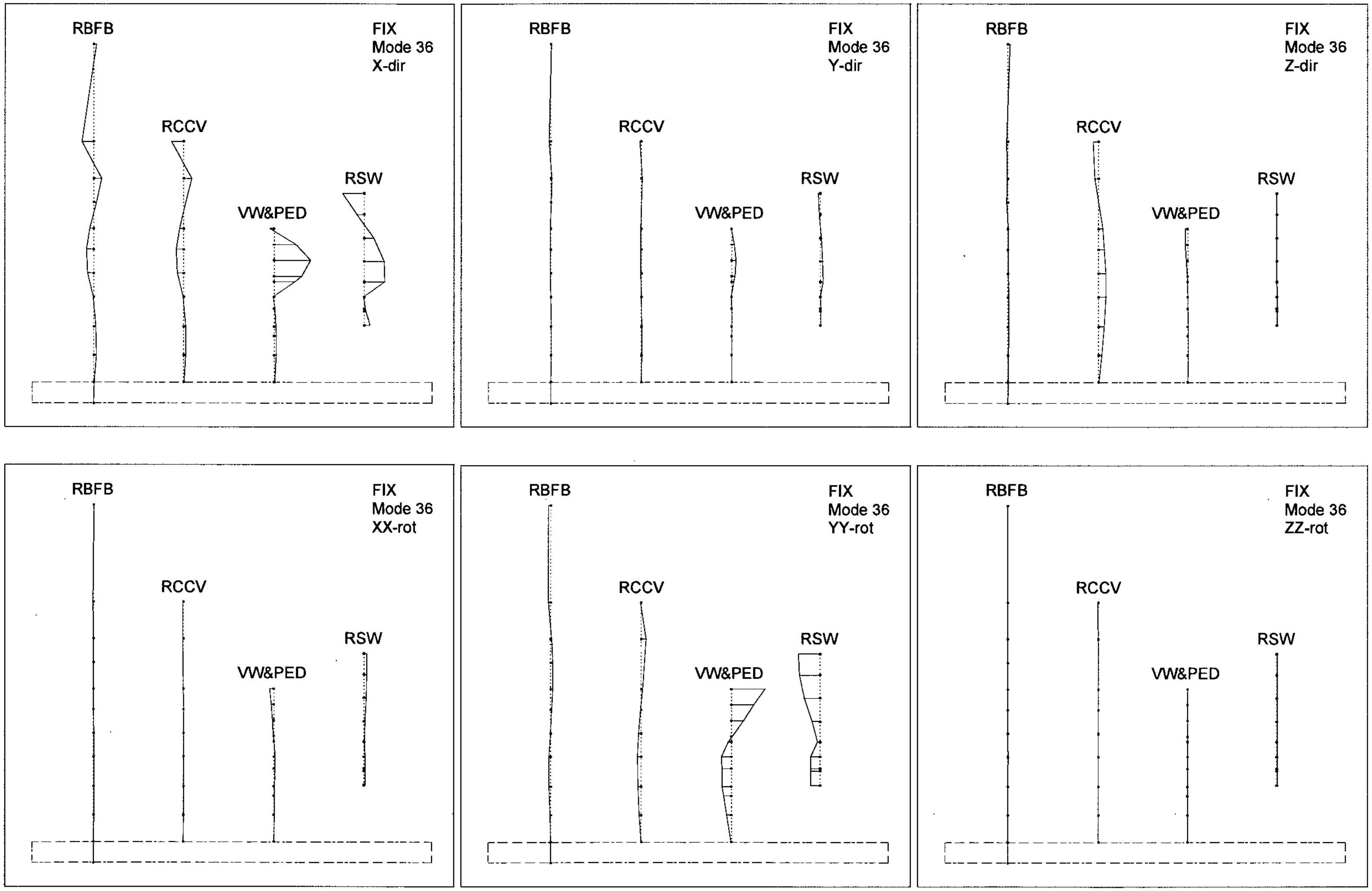

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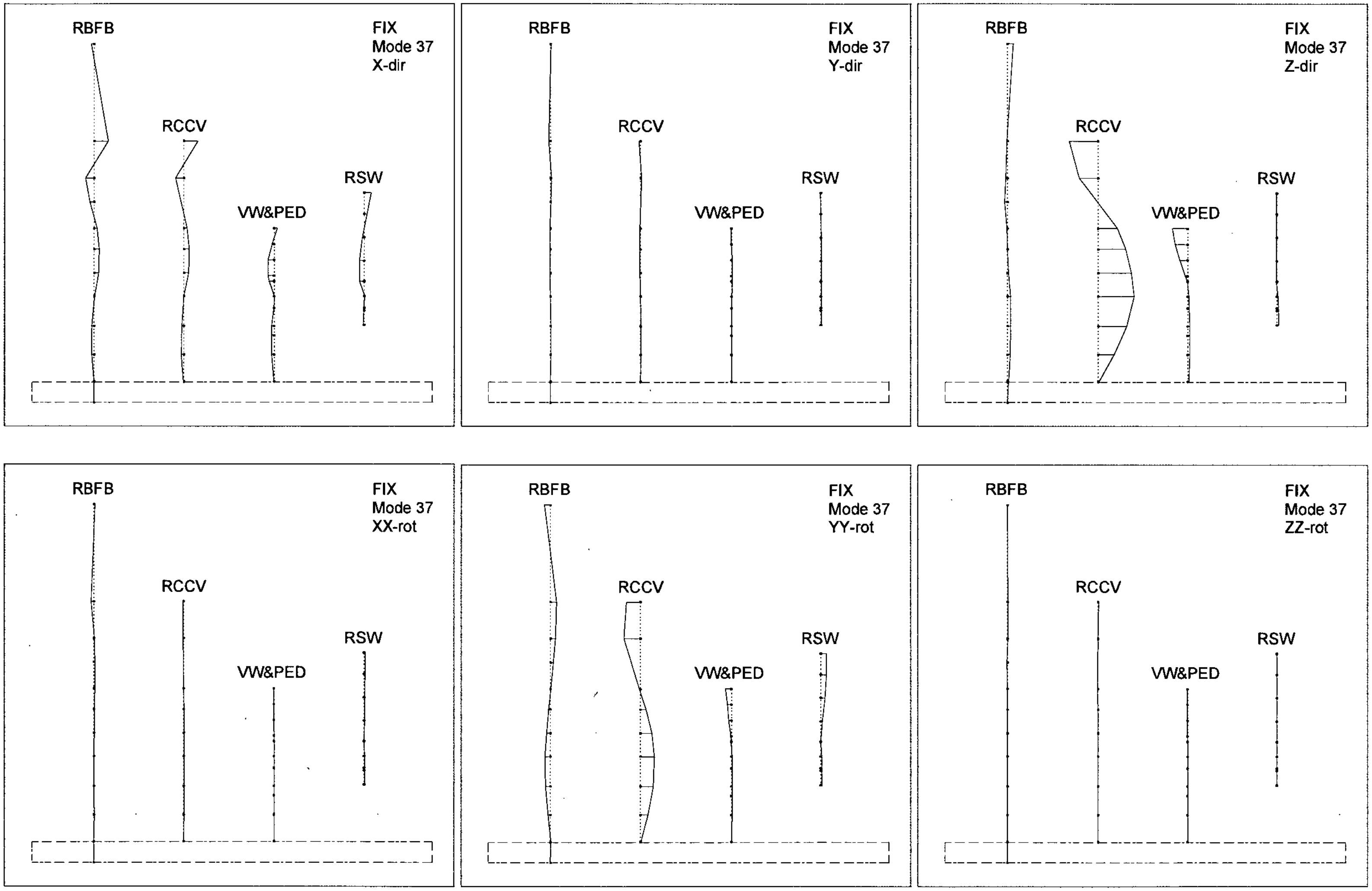

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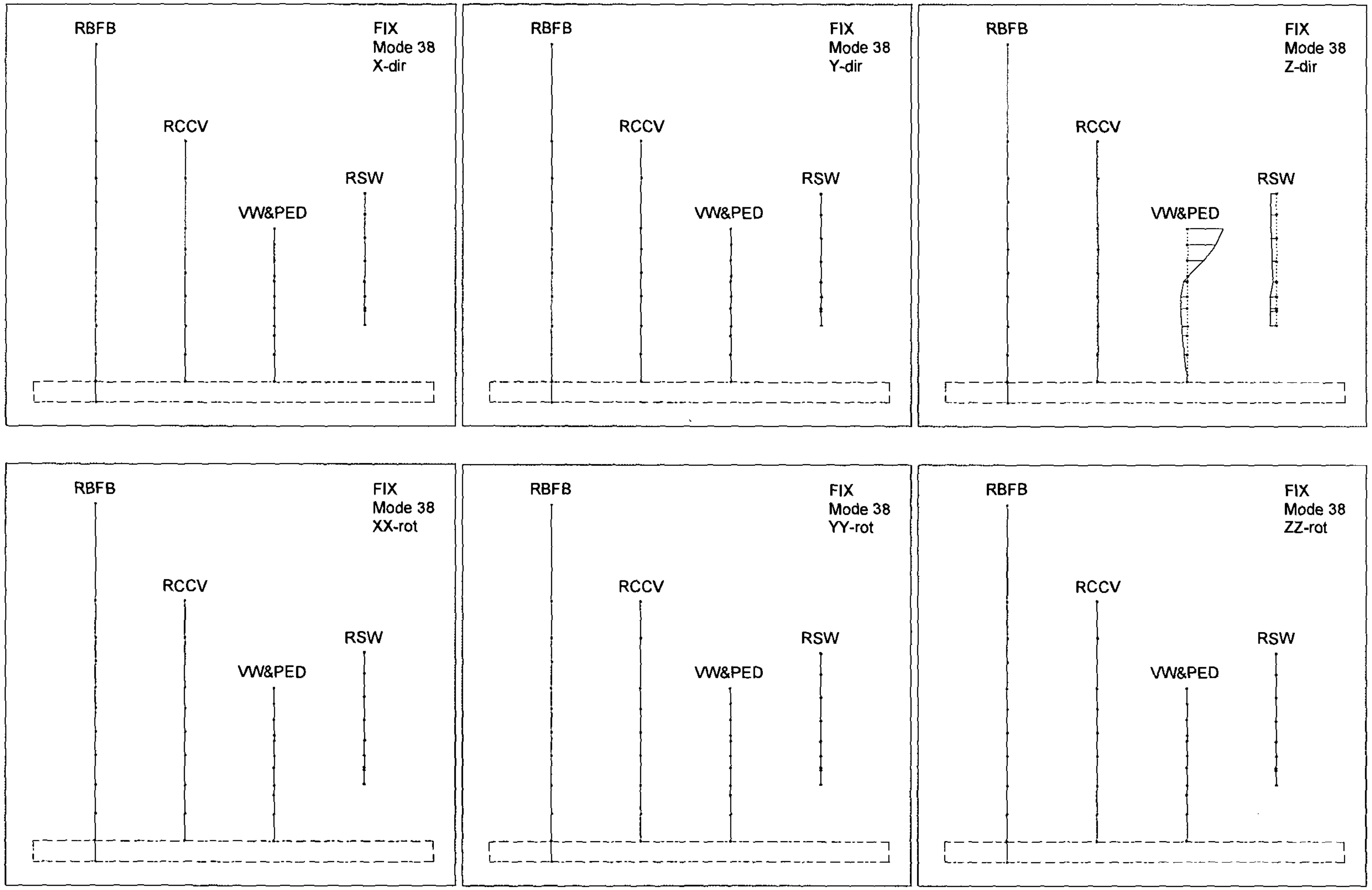

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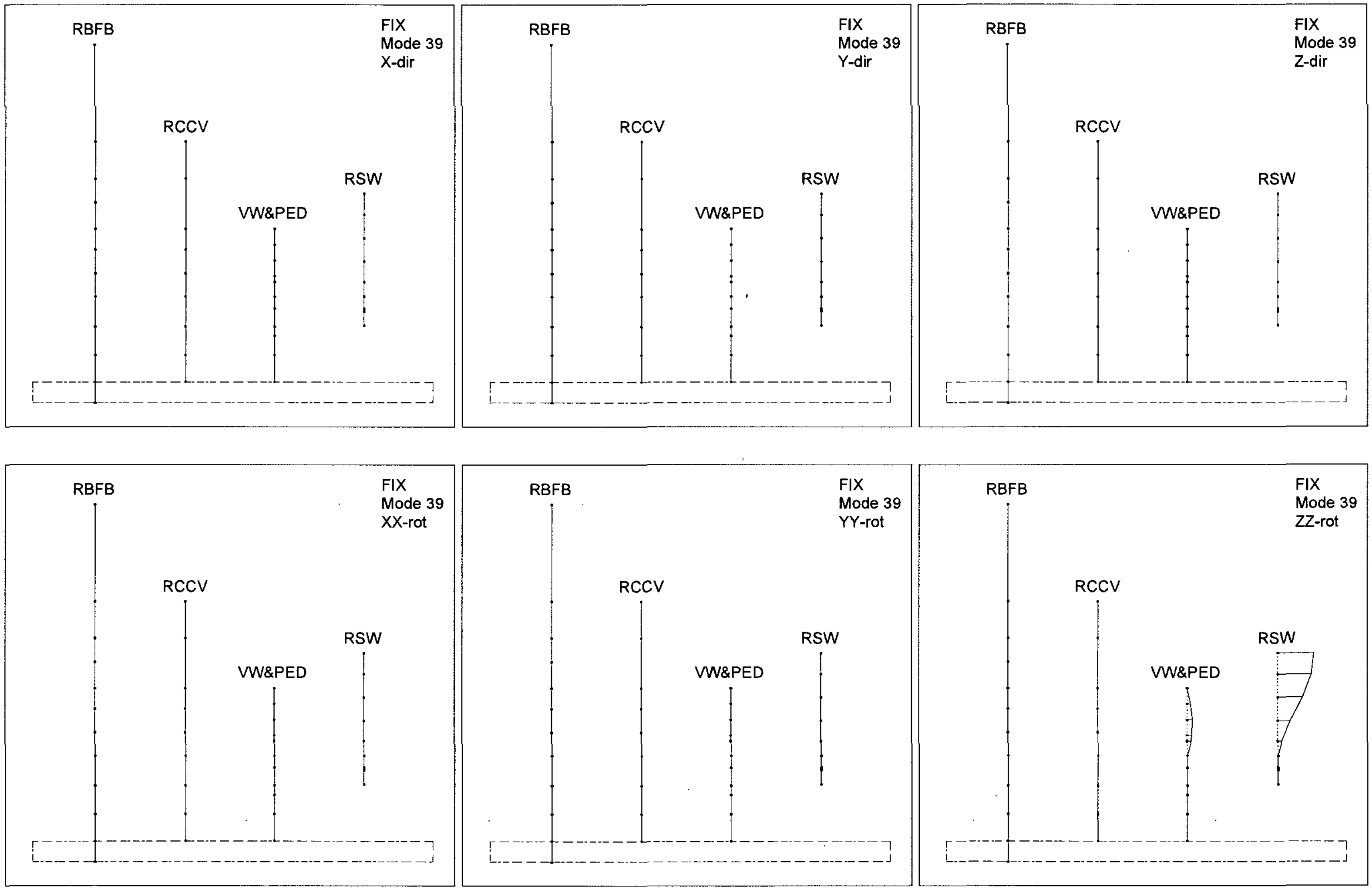

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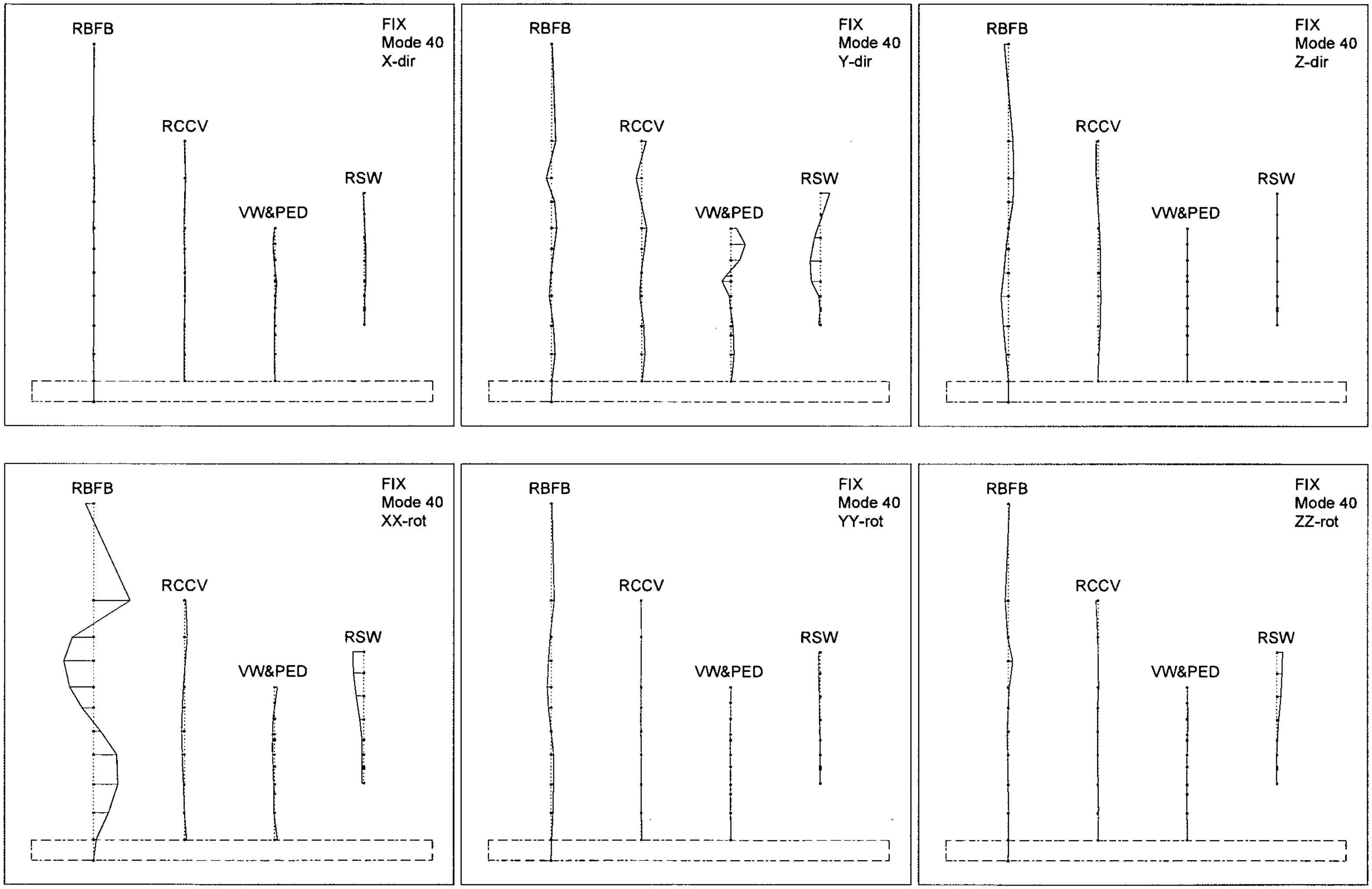

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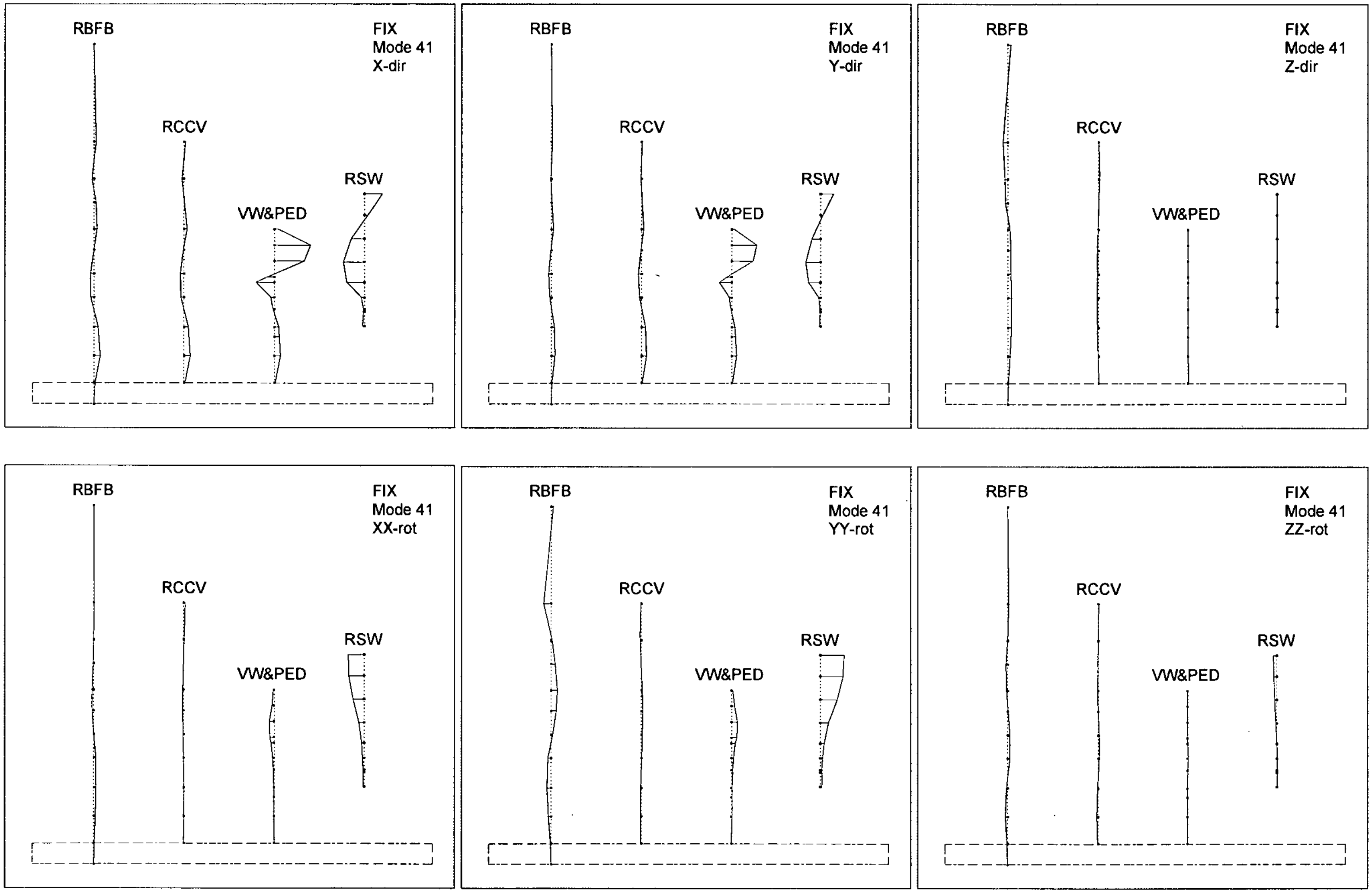

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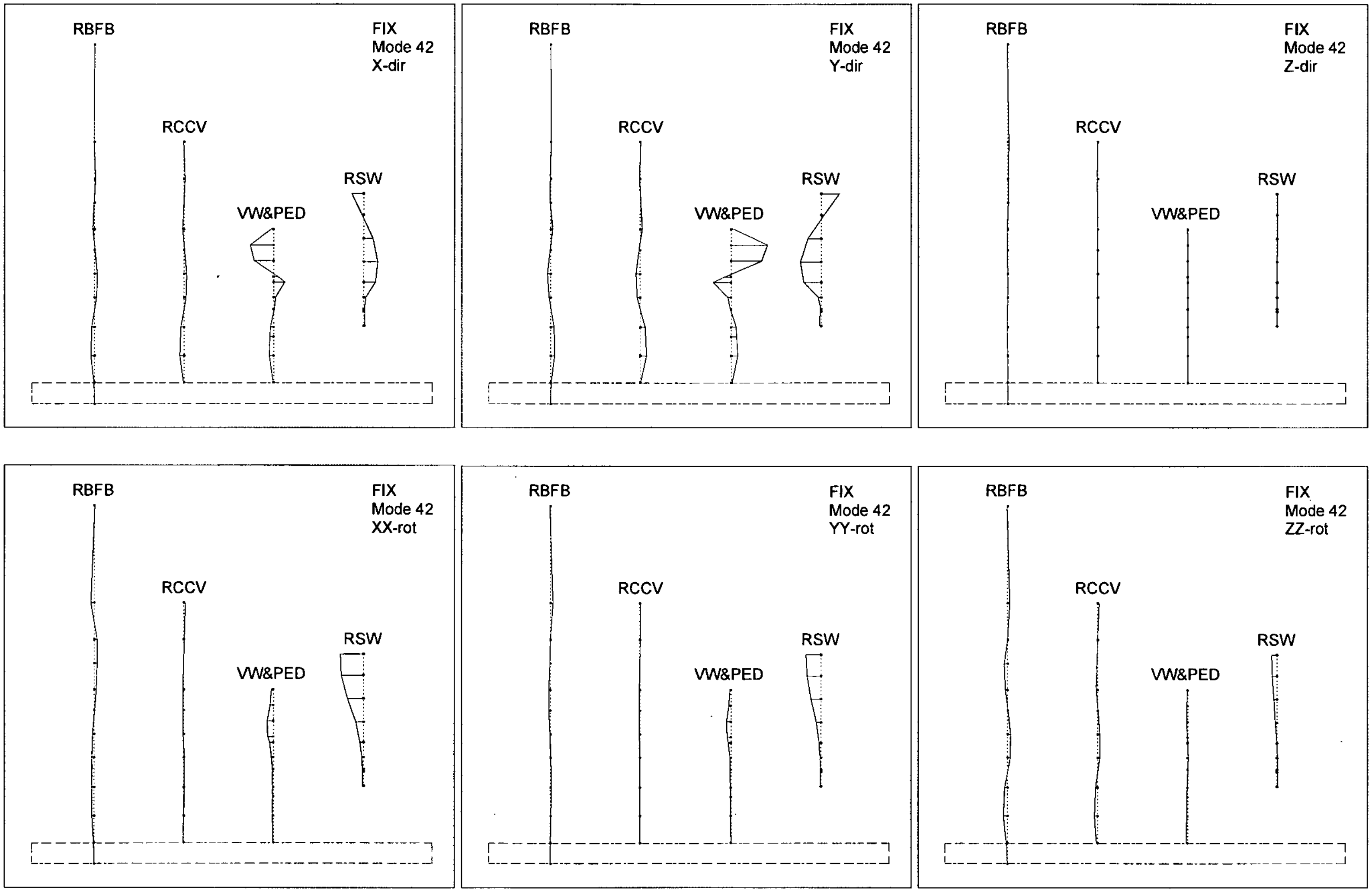

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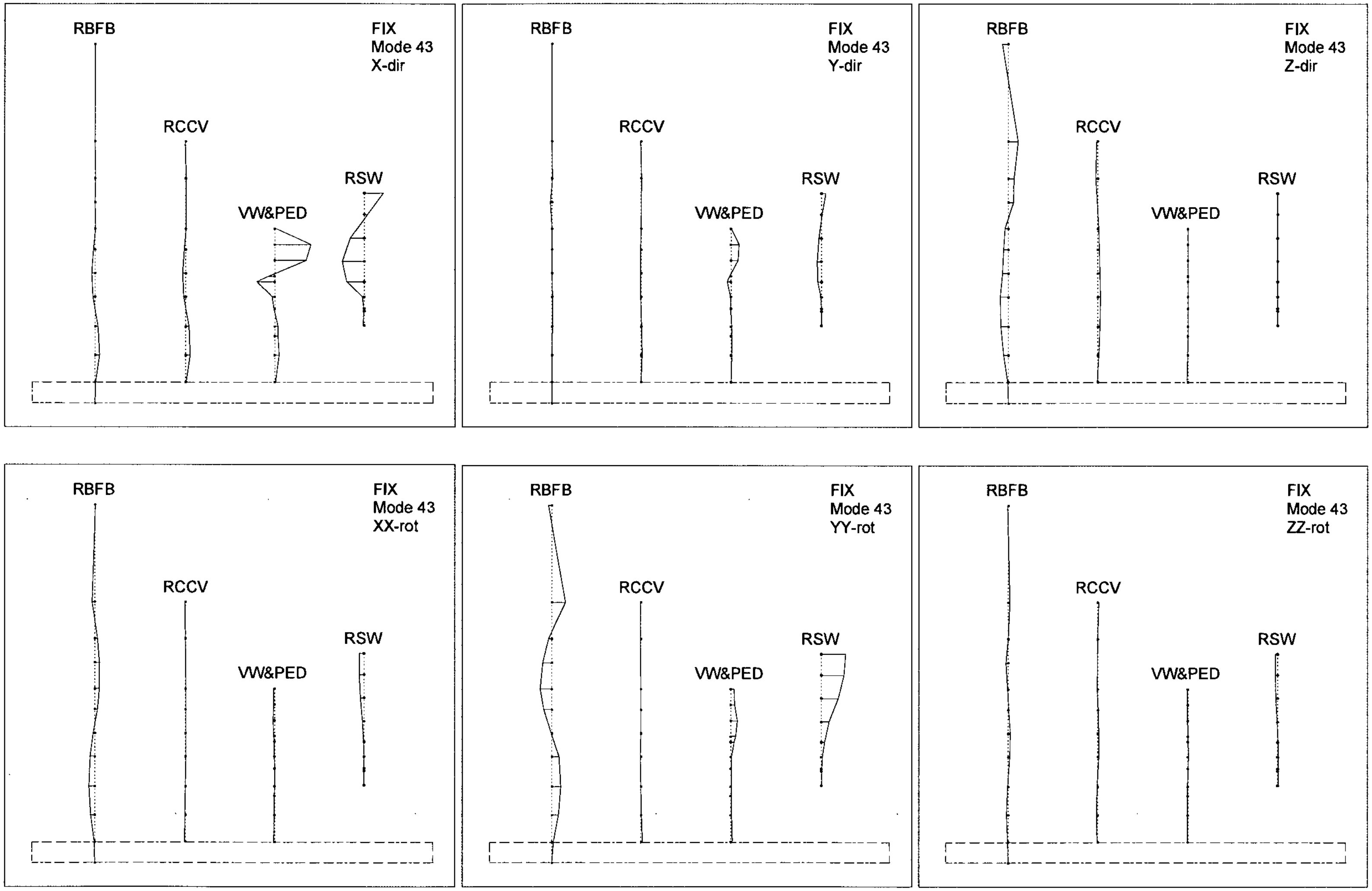

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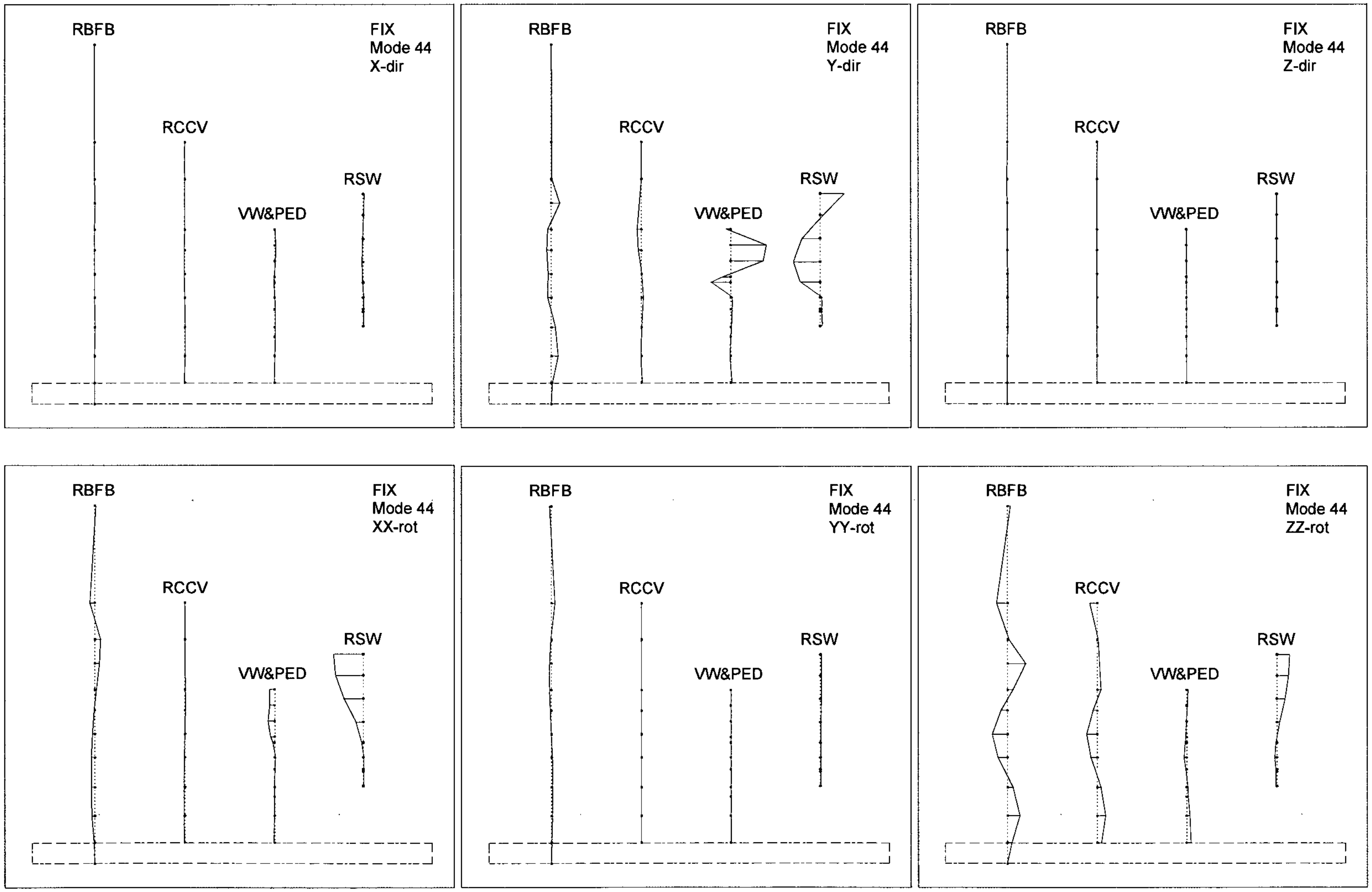

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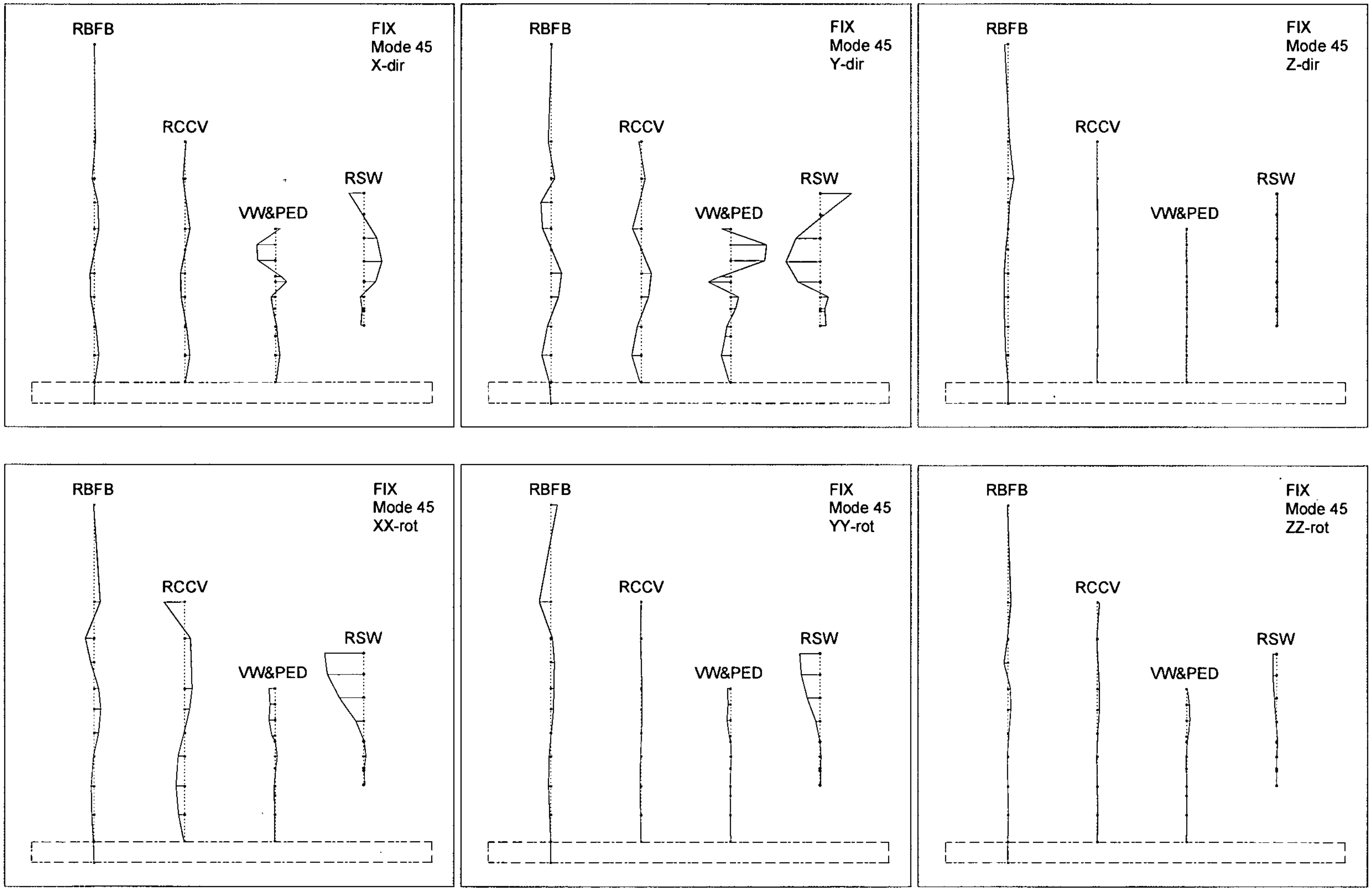

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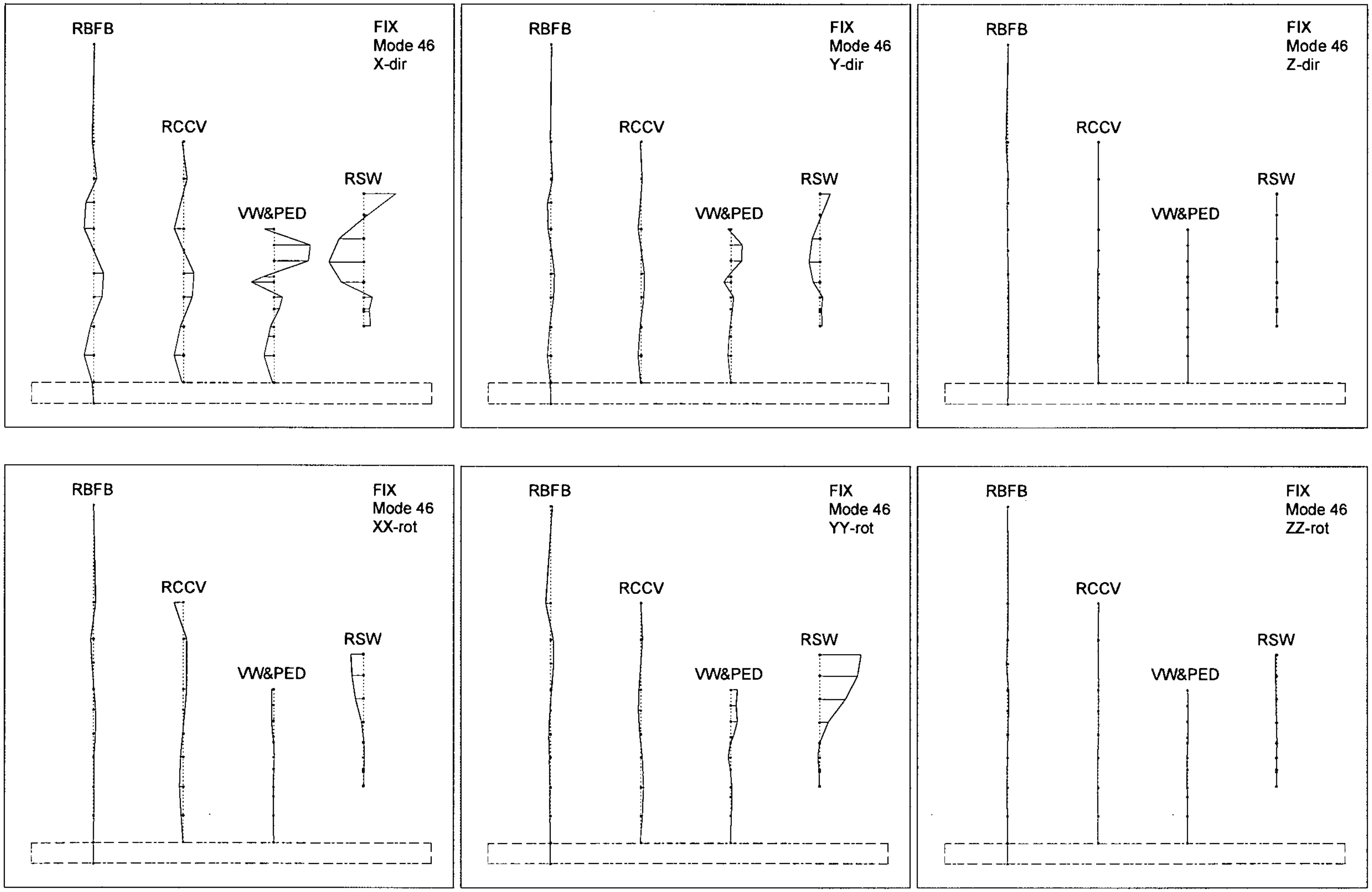

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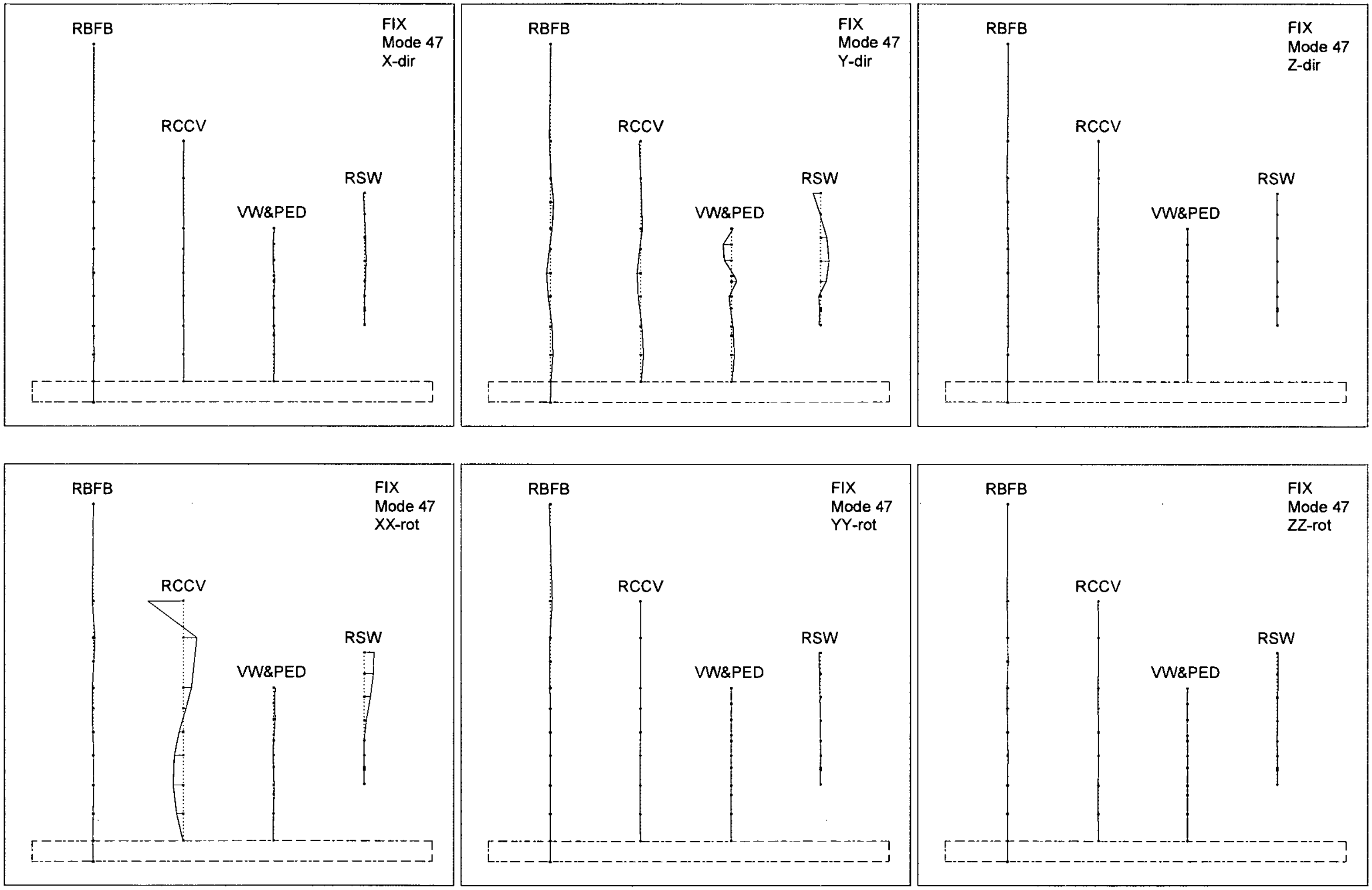

Figure 51 Mode Shape No. 47

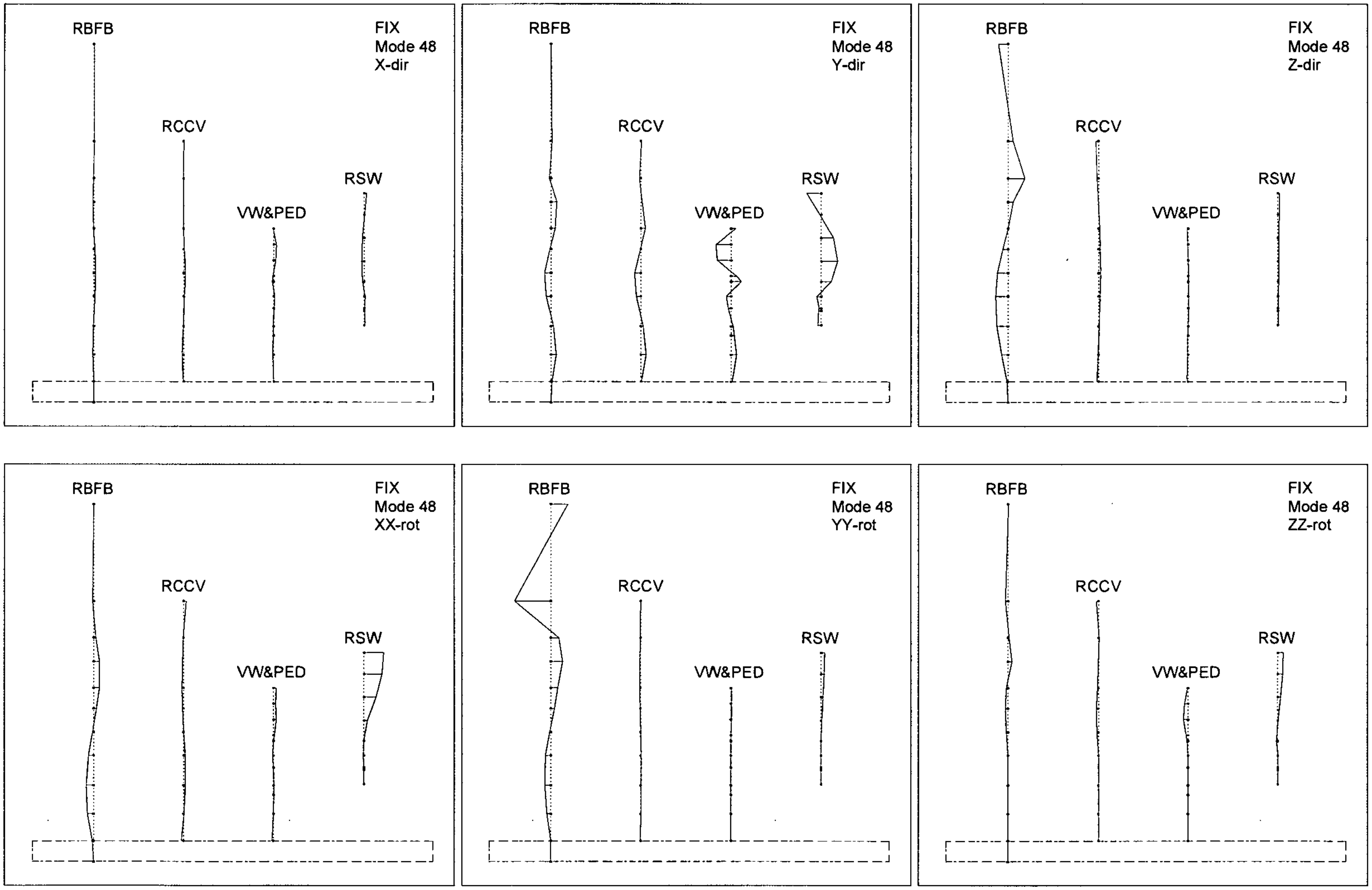

Figure 52 Mode Shape No. 48

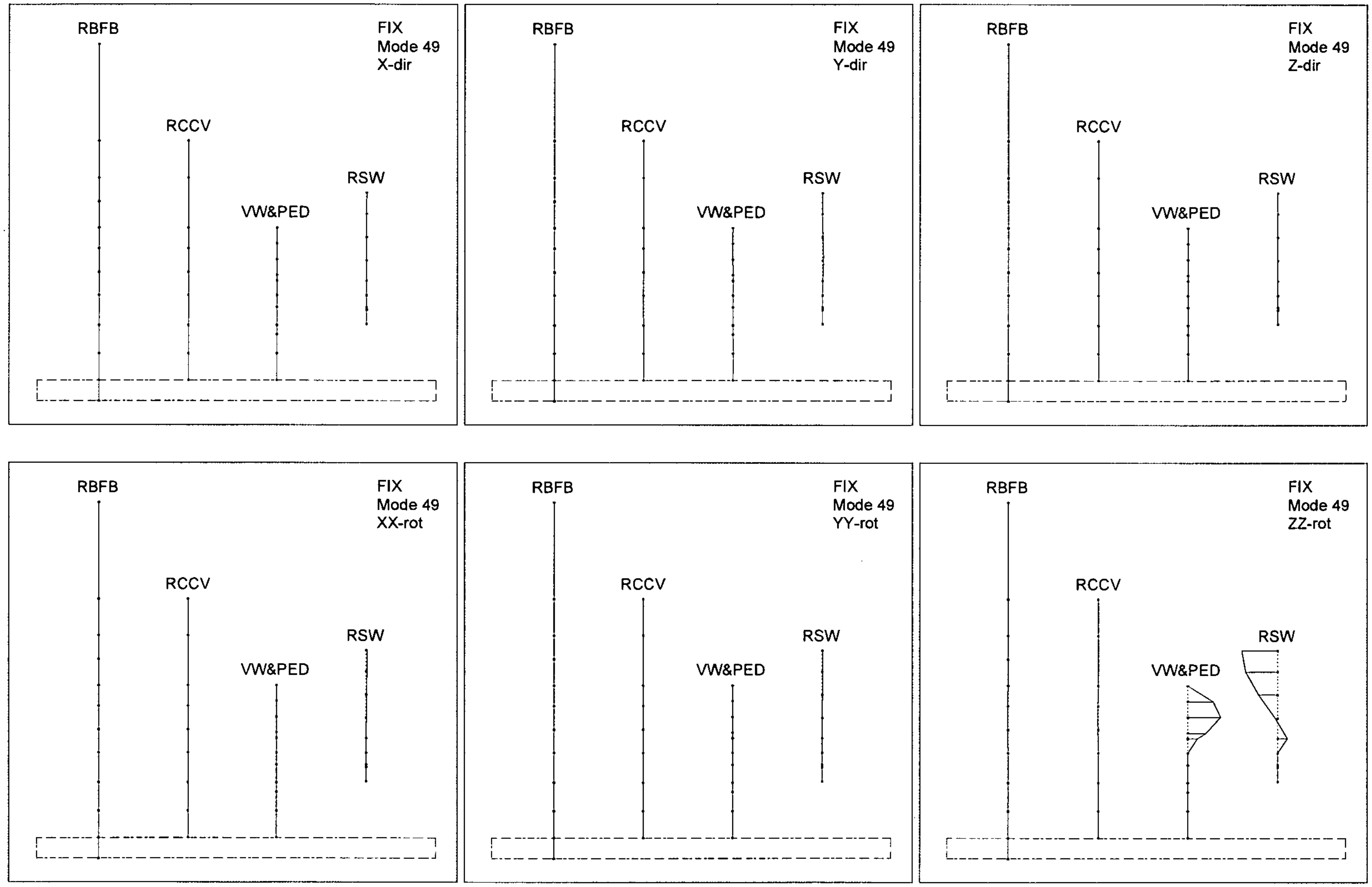

Figure 53 Mode Shape No. 49

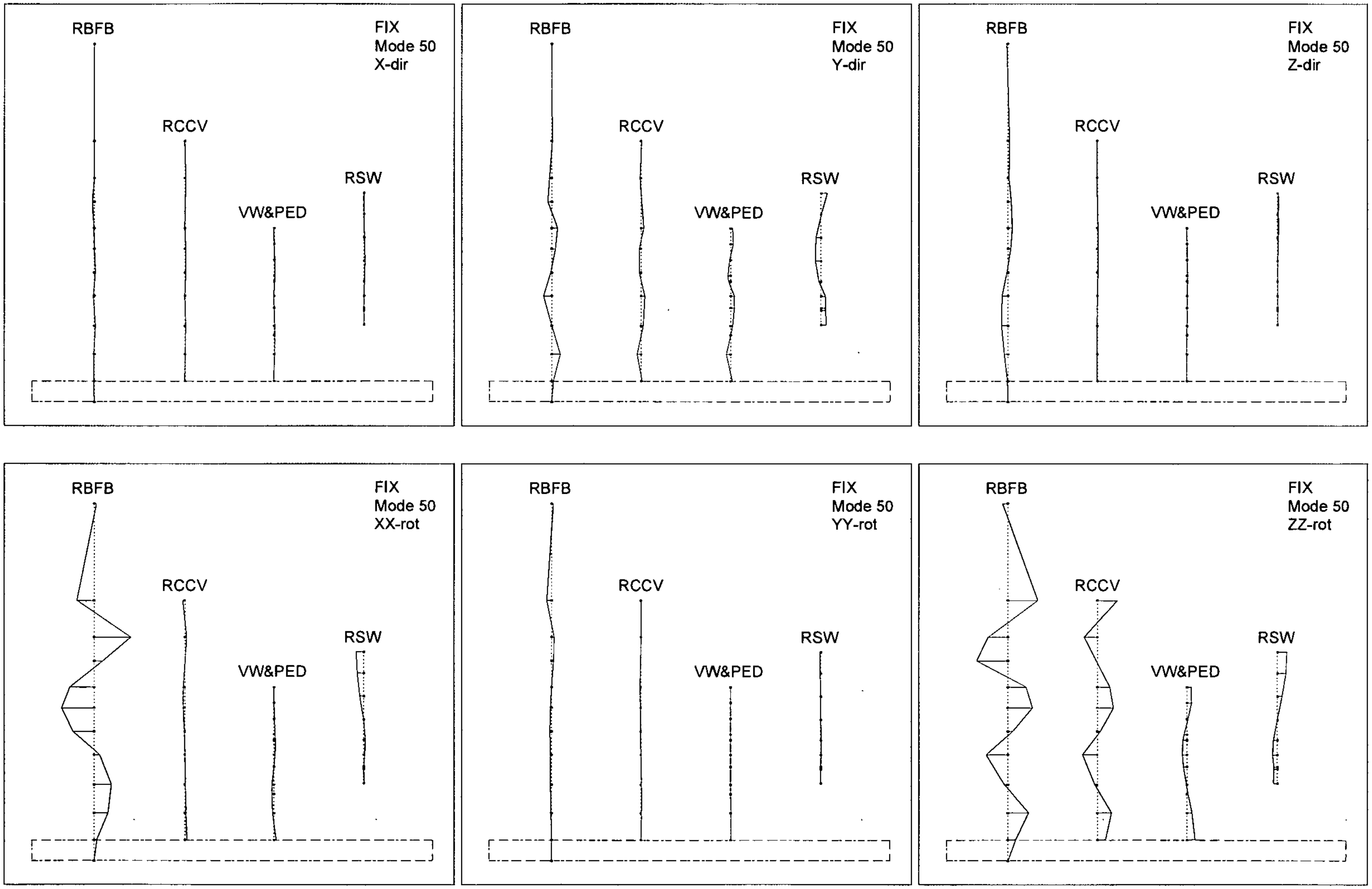

Figure 54 Mode Shape No. 50

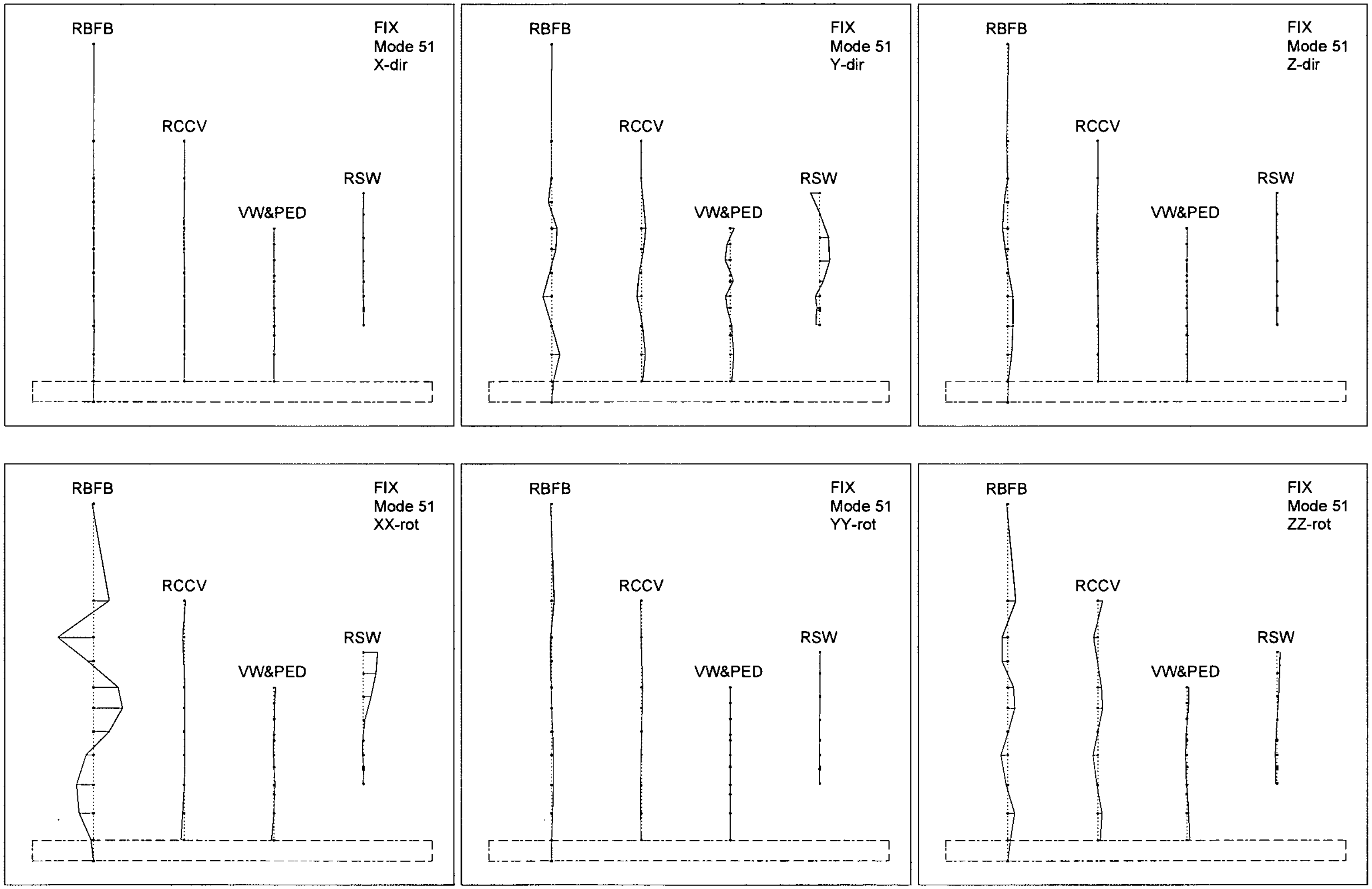

Figure 55 Mode Shape No. 51

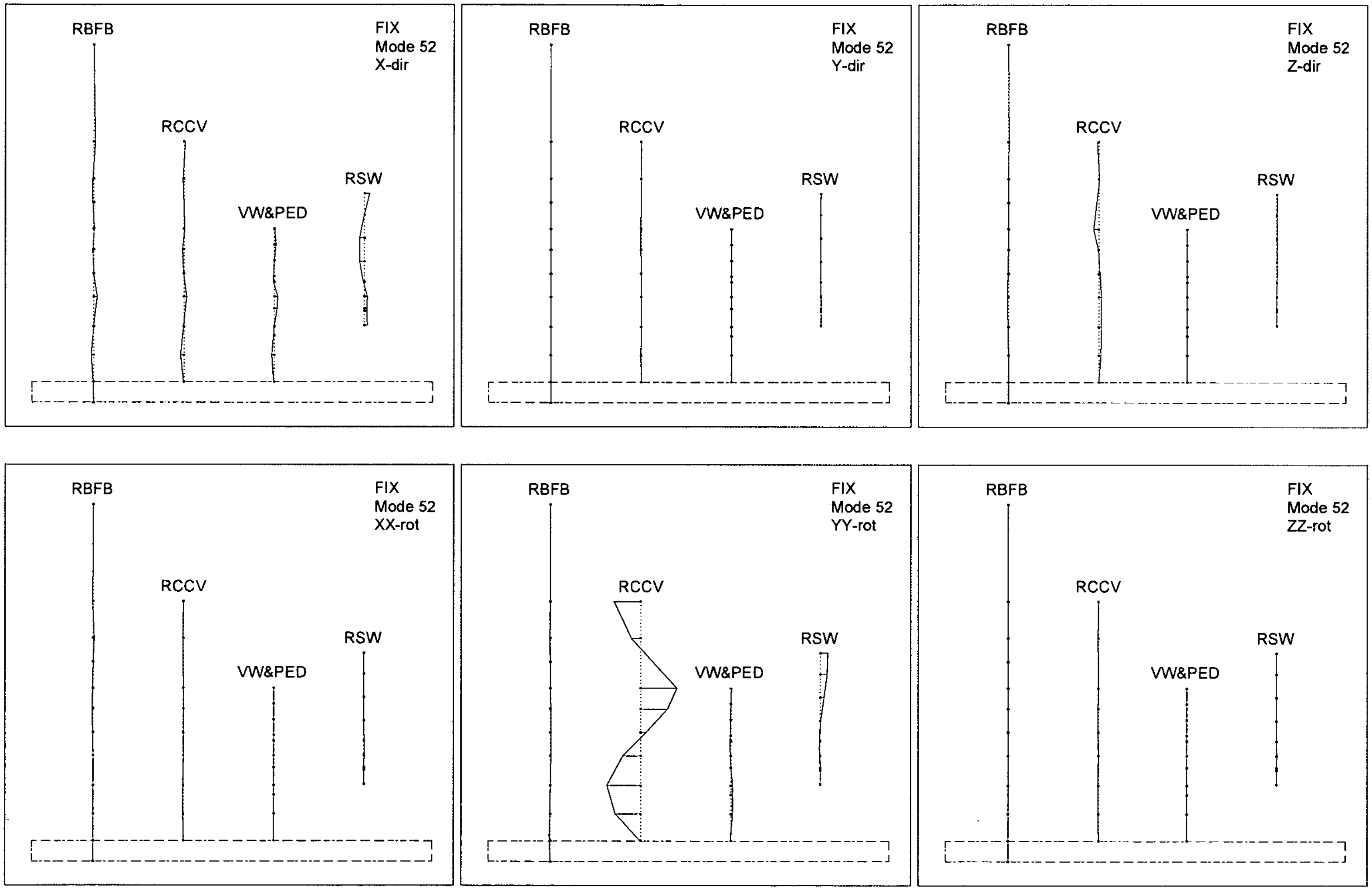

Figure 56 Mode Shape No. 52