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Seismic Rehabilitation Objectives and a Simplified Seismic Evaluation and Design Program for Equipment in Hospitals

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ABSTRACT

From the experience gained from recent earthquakes, it has been recognized that the earthquake resisting capacity of so-called responsibility hospitals for acute services in Taiwan should be upgraded. A report (Chai et al. 2015) was published to determine the seismic rehabilitation objectives of essential medical equipment and nonstructural components in responsibility hospitals. Owing to the onerous work required to improve the seismic performance of various nonstructural components, a simplified program is established using Microsoft Excel to execute a preliminary seismic evaluation to retrofit individual pieces of medical equipment. Users fill in details about the hospital information and the specifications of selected equipment; then, based on these entries, the program identifies the performance objective of each piece of equipment and determines whether the equipment requires retrofitting. In addition, the program can automatically check the preliminary designs of post-installation anchor bolts for seismic retrofitting against specified seismic demands.

1. INTRODUCTION

The most important issue for a designated responsibility hospital (a hospital assigned by government and with responsibility to provide emergency treatment) for acute services is to maintain its emergency medical function continuously. However, during recent earthquakes, not only the hospital building structures but also the medical equipment inside were damaged, which resulted in a significantly limited emergency medical capacity of hospitals. This implies that the earthquake-resistance capacity of the designated responsibility hospitals for emergency treatment should be upgraded to remain functional with regard to their engineering structures, medical facilities, electricity and water supply, and information services after major earthquakes. Therefore, the National Centre for Research on Earthquake Engineering released a report, “Rehabilitation Objectives and Evaluation Criteria for Hospitals” (Chai et al. 2015), to facilitate upgrading of hospital buildings such that hospitals possess the

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desired functional conditions for emergency services.

Furthermore, this study follows the aforementioned criteria, and to promote the evaluation process efficiency, a program is established to execute preliminary seismic evaluation for individual medical equipment. The framework and the user interface of the program and the detailed algorithm for each step will be described in this paper. In addition, the program can evaluate the seismic performance of anchor bolts according to the criteria specified by the ACI 318 code (ACI 2002). In order not to underestimate the most critical seismic demand on the bolts, the demands are calculated first using generic equations based on the assumption that the structure of the equipment behaves as a rigid body, and they are then adjusted by modification coefficients that are determined statistically from the numerical analysis results of finite element models.

2. PROGRAM FRAMWORK

Fig.1 shows the framework and flowchart of the proposed program. For the purpose of seismic evaluation for a hospital, users should follow the steps shown in the flowchart. First, to estimate the hazard level of an earthquake, the *Hospital Information Spreadsheet* needs the basic parameters of the hospital; second, the *Equipment Spreadsheet* requires the details of each piece of equipment for seismic evaluation, including its name, classification, location, and dimensions. Finally, for the equipment-strengthening evaluation, information such as dimensions and test data of anchor bolts need to be entered into the *Bolt Information Spreadsheet*, which would be then referenced to evaluate whether the equipment strength reaches the desired performance level.

In Fig.1, the frame with dotted lines indicates the spreadsheets in the program and all the items in it. The frame with the gray background represents the data output by the program, determined from the information that the users filled in previously. For equipment that needs to be strengthened, additional cells in *Equipment Spreadsheet* are used to display the seismic design of equipment retrofitted with anchor bolts.

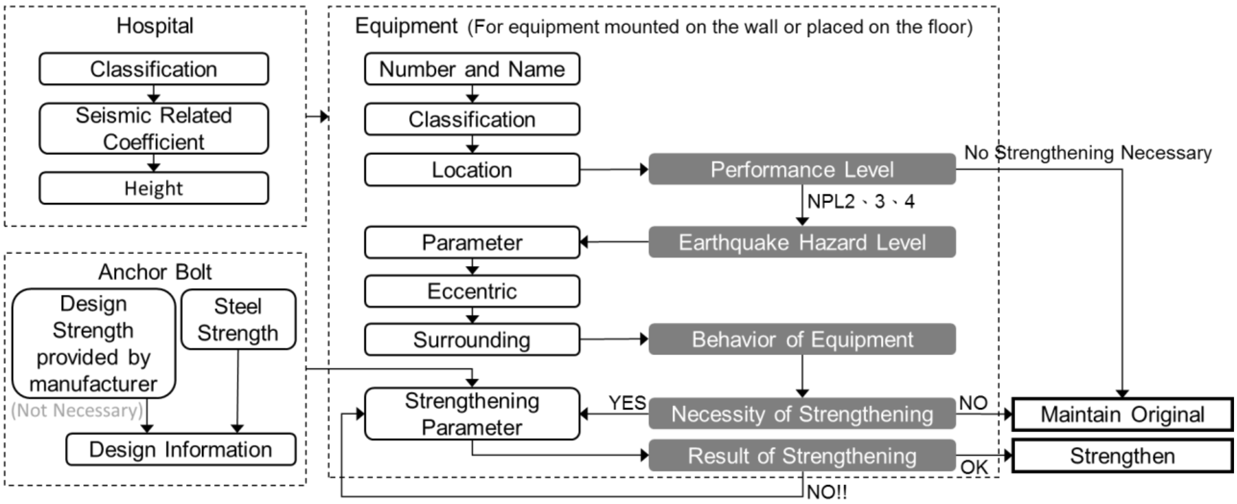

Fig. 1 Framework and flowchart of the program

3. PROGRAM INTERFACE

3.1 Spreadsheet for Hospital Information

Fig.2 shows the spreadsheet for Hospital Information. The spreadsheet includes the classification and location of the hospital of interest, seismic parameters according to the Seismic Design Code (CPAMI 2011), and the heights of each floor in the hospital.

For the first cell, hospitals are classified into three levels according to hospital accreditation: academic medical centers, metropolitan hospitals, and local community hospitals. Furthermore, for the second cell, hospitals designated responsible for acute services are classified into three levels: severe, moderate and general, according to their assigned capability for particular emergency treatments. For seismic site and other coefficients, the Code (CPAMI 2011) is referenced to accomplish the spreadsheet. The red bordered cells can be filled by choosing from a drop down list of options, while the others cells need to be filled by typing in the information directly.

Hospital Accreditation :	Medical Center
Emergency Responsibility Hospitals :	General Designated Responsibility Hospitals
Coefficient in seismic code of Taiwan	
Site :	Near Fault
DBE Coefficient of Horizontal Design Spectrum Acceleration-factor (S_S^D) :	0.8
DBE Nea-Fault Factor(Na) :	1.42
DBE Coefficient of Fa :	1
MCE Coefficient of Horizontal Design Spectrum Acceleration-factor (S_S^M) :	1
MCE Nea-Fault Factor(Na) :	1.32
MCE Coefficient of Fa :	1
Floor	**Height of Each Floor(cm)**
RF	5450
15F	
14F	
13F	
12F	5050
11F	4650
10F	4250
9F	3950
8F	3450
7F	3050
6F	2650
5F	2100
4F	1580
3F	1050
2F	540
1F	0

Fig. 2 Spreadsheet for hospital information

3.2 Spreadsheet for Equipment

Fig.3 and 4 show similar spreadsheets, to be filled for details regarding equipment placed on the floor and that mounted on the wall, respectively. For equipment placed on the floor, the program estimates whether the equipment has the potential to slide or overturn, while for equipment mounted on the wall, the program checks the seismic ability of the original anchorage.

In the Equipment spreadsheet, the first column shows the titles of the items to be filled, while the second column indicates the contents or the unit for each item. The cells that must be filled by a drop down list of options are noted in a corresponding cell.

In the third column onward, the user must fill in each column with the details of each piece of equipment in the hospital in order to check their seismic ability. The items consist of the information of the selected equipment.

Equipment can be classified according to types, sorts, and categories, whose details can be found in the criteria (Chai et al. 2015). The location of each piece of equipment (e.g. Essential Care Areas) can be chosen from the drop down list. Next, the specification including length, width, and height, and the eccentric condition should be input in the “Parameter” cells based on catalogues or in-situ measurement.

According to the values input in all the above-mentioned cells, both of these two spreadsheets, the results of “Seismic Evaluation Required”, “Performance Level”, and “Earthquake Hazard Level” are shown in the cells with yellow background in the spreadsheet. Finally, for equipment placed on the floor, data regarding the surrounding situation should be input in order to determine the behavior of the equipment. For equipment having potential to slide or overturn, the output for the item “Strengthening Necessary” will be ‘Y’. For equipment mounted on the wall, the current situation about the anchor bolts should be entered in order to estimate the original seismic ability. If the anchor bolt does not have sufficient capacity, the output for the item “Strengthening Necessary” will be ‘Y’. Based on these outputs, the program determines whether the equipment should be retrofitted. For equipment that needs strengthening, the items under “bolt strengthening” can be used for a preliminary design of the anchor bolts for seismic retrofitting against the seismic demands specified automatically by the program.

Number and Name				
Number:		001	002	003
Name:		Electric Cabinet	Electric Cabinet	Electric Cabinet
Classification				
Types:	Drop Down List	Mechanical Equipment	Mechanical Equipment	Mechanical Equipment
Sorts:	Drop Down List	Electrical and communications	Electrical and communications	Electrical and communications
Categories:	Drop Down List	Electrical and communications	Electrical and communications	Electrical and communications
Location				
Location:	Drop Down List	Essential Care Areas	Essential Care Areas	Essential Care Areas
Floor:	Number (R for Roof,-1~-5 for Basement)	5	5	1
Parameter				
Weight (W_p) :	kgf	1100	1100	1100
Supporting Structural Component	Drop Down List	Floor	Floor	Floor
Dimension:	Length of X-Axes (L_x) m	0.80	0.80	0.80
	Length of Y-Axis (Ly) m	0.40	0.40	0.40
	Height (Container Included) (h) m	2.00	2.00	2.00
Distance between top to floor:	(Container Included) m	2.00	2.00	2.00
Eccentric				
X-Axis Eccentric :	(Filled with Y or N)	N	N	N
X-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (L_{xG})			
Y-Axis Eccentric :	(Filled with Y or N)	N	N	N
Y-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (L_{yG})			
Z-Axis Eccentric :	(Filled with Y or N)	N	N	N
Z-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (h_G) m			
Surrounding				
Connection with Structure :	Drop Down List	Non-Fixed	Non-Fixed	Non-Fixed
Material of Floor Surface :	Drop Down List	Rubber	Rubber	Rubber
Material of floor :	Drop Down List	Concrete	Plastic flooring	Concrete
Lean on the Wall :	Drop Down List	Independent	Independent	Independent
Seismic Evaluation Required		Y	Y	Y
Performance Level		NPL3	No Necessary	NPL3
Earthquake Hazard Level		MCE	-	MCE
Seismic Response of Equipment		Sliding	-	Non
Necessary for Strengthening		**Y**	-	-
Bolt Strenrthening	(Blank Space for No Strenrthening Necessary)			
Total Number of bolts :		4		
Number of bolts on X-Axis:		2		
Number of bolts on Y-Axis:		2		
Type or Size:	Drop Down List	Hilti-M8		
Depth in concrete:	in	3.00		
Anchorage on Concrete or Other Material :	Drop Down List	Concrete		
Strength of Base Material :	psi	2700		
Result		**OK**	-	-

Fig. 3 Spreadsheet for equipment placed on the floor

Number:		001	002	003
Name:		Electric Cabinet	Electric Cabinet	Electric Cabinet
Classification				
Types:	Dorp Down List	Mechanical Equipment	Furninture contents	Mechanical Equipment
Sorts:	Dorp Down List	Electrical and communications	Cabinent	Electrical and communications
Categories:	Dorp Down List	Electrical and communications	Cabinent	Electrical and communications
Location				
Location:	Dorp Down List	Essential Care Areas	Others	Emergency exit access
Floor:	Number (R for Roof,-1~-5 for Basement)	5	5	1
Parameter				
Weight (W_p) :	kgf	200	1000	4000
Dimension:	Length of X-Axies (L_x) m	0.40	1.00	0.40
	Length of Y-Axies (Ly) m	0.40	0.40	0.40
	Height (Container Included) (h) m	1.00	2.00	1.00
Distance between top to floor:	(Container Included) m	2.00	2.00	2.00
Eccentric				
X-Axis Eccentric :	(Filled with Y or N)	N	N	N
X-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (L_{xG})			
Y-Axis Eccentric :	(Filled with Y or N)	N	N	N
Y-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (L_{yG})			
Z-Axis Eccentric :	(Filled with Y or N)	N	N	N
Z-Axis Distance between the Edge to the Center of Gravity :	(Blank Space for Non-Eccentric or Uncertain) (h_G) m			
Original Bolt	(Blank Space for No Necessary Strenthen)			
Total Number of bolts :		2	2	2
Number of bolts on X-Axies:		2	2	2
Number of bolts on Y-Axies:		4	4	4
Type or Size:	Dorp Down List	Hilti-M8	Hilti-M8	Hilti-M8
Depth in concrete:	in	3.00	3.00	3.00
Anchorage on Concrete or Other Material :	Dorp Down List	Concrete	Concrete	Concrete
Strength of Base Material :	psi	2500	2500	2500
Seismic Evaluation Required		Y	Y	Y
Performance Level		NPL3	NPL1	NPL2
Earthquake Hazard Level		MCE	-	MCE
Necessary for Strengthening		**N**	**N**	**Y**
Bolt Strenthening	(Blank Space for No Necessary Strenthen)			
Total Number of bolts :				3
Number of bolts on X-Axies:				2
Number of bolts on Y-Axies:				6
Type or Size:	Dorp Down List			Hilti-M10
Depth in concrete:	in			3.00
Anchorage on Concrete or Other Material :	Dorp Down List			Concrete
Strength of Base Material :	psi			2500
Result			-	**OK**

Fig. 4 Spreadsheet for equipment mounted on the wall

3.3 Spreadsheet for Bolt Information

For equipment that needs the evaluation of anchor bolts, a database for target bolt strength should be prepared. The user must fill the anchor bolt spreadsheet shown in Fig.5. The data about the yield and ultimate stress and the various parameters of the anchor bolts in each specification provided by the manufacturer must be entered here. Furthermore, if available, the program prioritizes experimental test data provided by the manufacturer.

Once the details for strengthening anchor bolts information are filled, in the equipment-related spreadsheets, the program will determine whether the strength of the anchor bolts are sufficient or not based on the target values. After all, the target is that the seismic ability of all the pieces of equipment is satisfactory. If strengthening is required for any equipment, the user should make different trail-and-error entries (e.g., bolt diameter, embedded length, etc.) under the bolt strengthening spreadsheet until the result displays ‘OK’.

Steel Strength of Anchor Bolt	(psi)				
	f_{ya}	92800			
	f_{uta}	116000			
Design Information of Anchor Bolt	Data	d_o	he(min)	Ase	Np
	Item Number	in	in	in^2	lb
	Hilti-M8	0.47	2.36	0.057	2810
	Hilti-M10	0.59	2.76	0.090	4496
	Hilti-M12	0.71	3.15	0.131	
	Hilti-M16	0.94	3.94	0.243	
Design Strength (Design Strength of Anchor Bolt in Different Base - Provided by Manufacturer)	ϕ Tn (psi)	Strength of Concrete			
	Item Number	2500	3000	4000	6000
	Hilti-M8	1825	2000	2310	2830
	Hilti-M10	2920	3200	3695	4525
	Hilti-M12	4360	4775	5515	6755
	Hilti-M16	6095	6675	7705	9440
	ϕ Vn (psi)	Strength of Concrete			
	Item Number	2500	3000	4000	6000
	Hilti-M8	2160	2365	2730	3345
	Hilti-M10	7685	8420	9720	11905
	Hilti-M12	9390	10285	11880	14550
	Hilti-M16	13125	14375	16600	20330

Fig. 5 Spreadsheet for bolt information

4. DETERMINATION ALGORITHM IN THE PROGRAM

Referring to the criteria (Chai et al. 2015), each component can be identified and tagged as NPL2, NPL3, NPL4, or NPL5 according to its particular characteristics and contribution towards meeting the target performance level. Even for the same type of NSCS, the identified performance levels may be different if they are located at or serve different areas. In the proposed Excel software, the target nonstructural performance levels NPL2, NPL3, or NPL4 can be identified for each NSCS by its location, type, sort, and category. Fig.6 shows the identification algorithm. On the other hand, the associated earthquake hazard level can be determined according to the nonstructural performance matrix mentioned in the criteria to meet the performance objective. The process to determine the associated earthquake hazard level is shown in Fig.7.

At the beginning of seismic evaluation, the response of freestanding equipment is offered based on Ishiyama's theory (Ishiyama 1982):

$$A > \mu g \Longrightarrow Sliding \tag{1}$$

$$B/h < A/g \Longrightarrow Rocking \tag{2}$$

$$V > 10 \times B^*/\sqrt{h} \Longrightarrow Overturning \tag{3}$$

where μ is the static friction coefficient between bottom side of equipment and floor surface, g is gravitational acceleration, A and V are the peak floor acceleration and velocity, respectively . B and h are shown in fig.8, B^* can be calculated as $2B$ if the other side leans against the wall (Chung 2001). The process to determine seismic response is shown in Fig.9. The steps for strengthening will be followed for the components determined to be 'sliding' or 'overturning'.

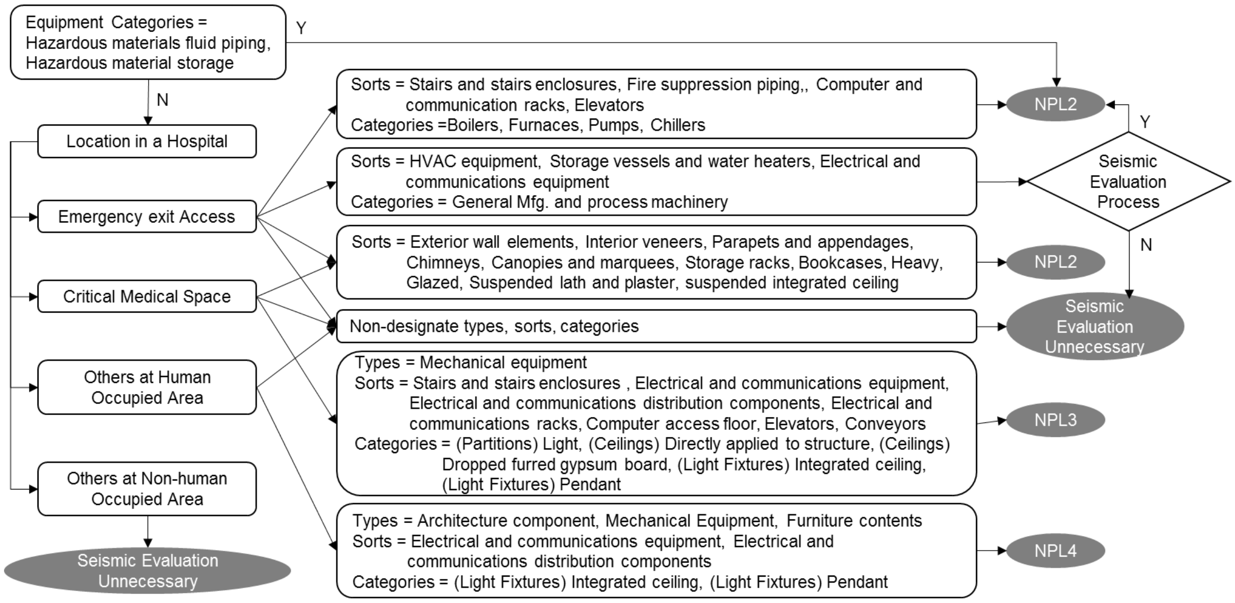

Fig. 6 Process to determine performance level

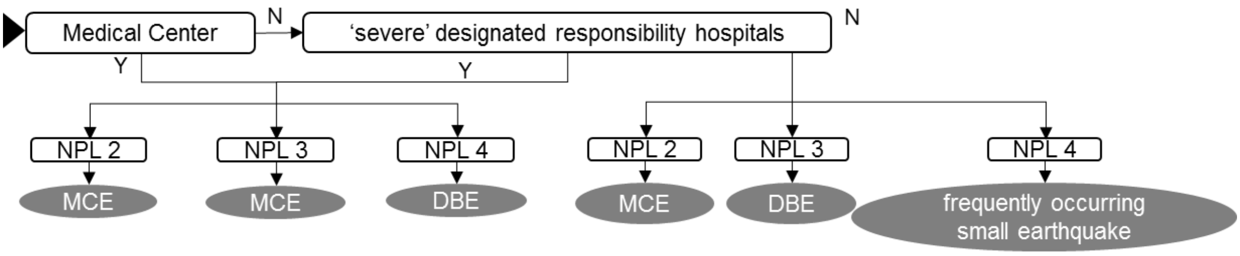

Fig. 7 Process to determine earthquake hazard level for seismic evaluation

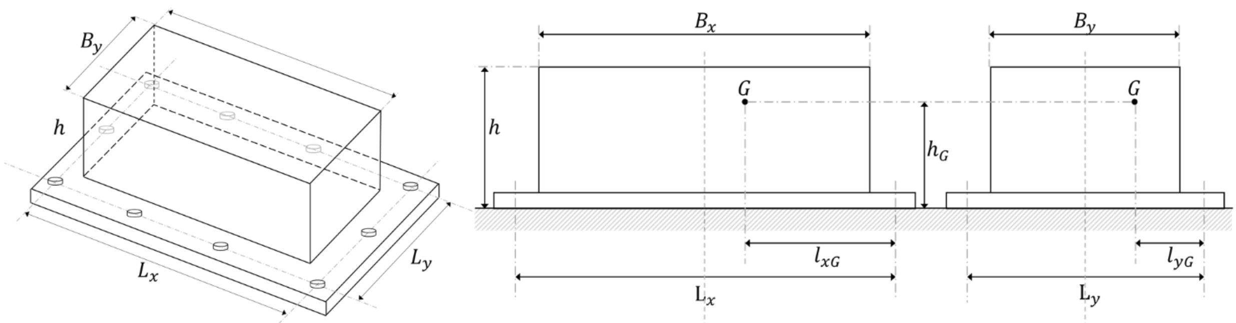

Fig. 8 Notes for rigid rectangular equipment

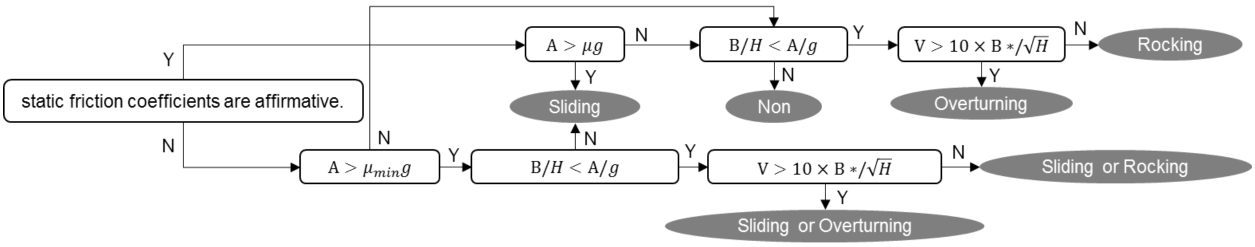

Fig. 9 Process to determine seismic response

The algorithms mentioned previously are all used in the background of spreadsheet for equipment placed on the floor. For equipment mounted on the wall, the process to determine the performance level and earthquake hazard level are also used, the earthquake hazard level decides the seismic demand for each equipment to calculate the seismic ability of the original anchorage.

5. SEISMIC EVALUATION CRITERIA FOR ANCHOR BOLTS

5.1 Seismic Demand on the Rigid Equipment

For equipment places on the floor, in general and based on the rigid body assumption, Eq.(4) and Eq.(5) are adopted to calculate the tension and shear demands (T_{ua} and V_{ua}, respectively) that act on one anchor bolt.

$$T_{ua} = \left[F_{ph} \times h_G - \left(W_p - F_{pv}\right) \times l_G\right] / \left(L \times n_t\right) \tag{4}$$

$$V_{ua} = F_{ph} / n \tag{5}$$

Herein, n is the total number of bolts and n_t is the number of bolts along one side. Other symbols are shown in Fig.8. The dead load (W_p) and seismic force (F_{ph} and F_{pv}) are combined to determine the tension force. For shear demand V_{ua},, it is assumed that the horizontal seismic force is equally borne by all bolts.

5.2 Modification Coefficients for Real Equipment

As aforementioned, Eq.(4) and Eq.(5) are defined under the rigid equipment assumption without considering the response of the equipment's structure. In addition, it is noted that only one component of the horizontal seismic force is considered in the simplified equation, and then the maximum values determined from seismic force in the x- or y-direction are used for the design. Therefore, in order not to underestimate the critical seismic demands on the bolt, the tension and shear demands in the proposed program are defined by:

$$T_{ua} = 0.9 \times \varphi_{TW} \times T_W \pm \varphi_{TE} \times T_E \tag{6}$$

$$V_{ua} = \varphi_{VE} \times V_E \tag{7}$$

where under the rigid body assumption, T_w, and T_E are the calculated tension forces caused by the dead load and seismic loads, respectively, and V_E is the shear force caused by the seismic load. The generic equations to calculate T_w, T_E and V_E are defined by:

$$T_W = min\left(\frac{W_p \times min(l_{xG}\ ,\ L_x - l_{xG})}{L_x \times n_y}\ ,\ \frac{W_p \times min\big(l_{yG}\ ,\ L_y - l_{yG}\big)}{L_y \times n_x}\right) \quad (8)$$

$$T_E = max\big(T_{QX} + 0.3T_{QY} + T_{QZ}\ ,\ 0.3T_{QX} + T_{QY} + T_{QZ}\big) \quad (9)$$

$$V_E = \sqrt{\left(\frac{F_{ph}}{n}\right)^2 + \left(\frac{0.3 \times F_{ph}}{n}\right)^2} \quad (10)$$

where T_{QX}, T_{QY}, and T_{QZ} are the tension demands caused by a seismic force F_{ph} in the x- and y-directions (Eq.(11) to Eq.(13)), and F_{pv} in the z-direction, respectively, and they are defined by:

$$T_{QX} = \frac{F_{ph} \times h_G}{L_x \times n_y} \quad (11)$$

$$T_{QY} = \frac{F_{ph} \times h_G}{L_y \times n_x} \quad (12)$$

$$T_{QZ} = F_{ph} \times max\left(\frac{max(l_{xG}\ ,\ L_x - l_{xG})}{L_x \times n_y}\ ,\ \frac{max\big(l_{yG}\ ,\ L_y - l_{yG}\big)}{L_y \times n_x}\right) \quad (13)$$

where *n* is the total number of bolts, and n_x and n_y are the number of bolts located on one side along x- and y-directions, respectively. It is noted that the loading combination 0.9D+1E is adopted to determine the tension demand for an anchor bolt. In addition, the 100-30 rule is adopted to consider the effect caused by two horizontal directions, i.e., 100% of the effect in one direction is combined with 30% of the effect in the other orthogonal direction. The seismic base shear V_E in Eq.(10) is defined by the vector sum of the two horizontal components following the 100-30 rule.

5.3 Coefficients for Modification

In order to determine the modification coefficients φT_W, φT_E, and φV_E, the finite element software SAP2000 was adopted to determine the reaction forces at the supporting points of real equipment. The parameters included aspect ratio, bolt-installation location, and eccentricity affect each other, all parameters should be considered simultaneously to calculate the results. In this study, only some conditions in each parameter were selected for analysis. For example, the aspect ratio 1:10 was considered as a critical situation. To be conservative, the meaning of “eccentricity” was simulated in $l_G/(L-l_G)=1/3$ as a critical situation. Three eccentric conditions were identified: None, Single-axis, and Double-axes. Fig.10 shows variables along the x- and the y-axes in the Single-axis eccentric condition, where x-axis is the aspect ratio, y-axis is bolt-installed in different distribution (numbers and side).

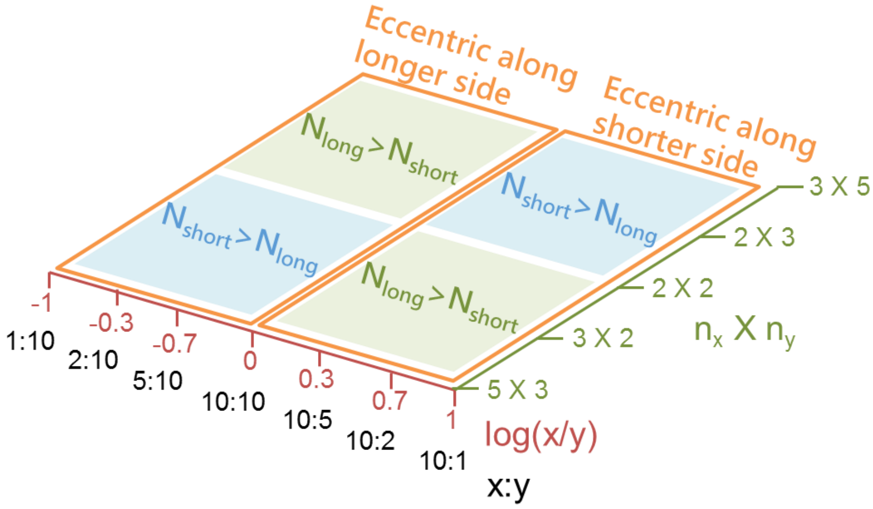

Fig. 10 A coordinate system for different parameters.

The equipment is modeled by a frame-type structure with multi-supports. For a piece of equipment with a specific aspect ratio, eccentricity, and distribution of anchor bolts, the tension forces caused by dead load and seismic load exerted on each bolt can be determined. Then, the most critical seismic demands of the bolt can be compared with the values determined by generic equations (Eq.(8) to Eq.(11)), and hence, the associated modification coefficients can be determined for the specific case. As shown in Tables 1 to 3 and based on the scenario involving equipment with different aspect ratios, the eccentricity, distribution of anchor bolts, the modification coefficients φT_W, φT_E, and φV_E can be determined statistically. The most critical demand for a bolt can then be determined by Eq.(6) and Eq.(7).

Table 1. Values of modification coefficients φT_W

<table>
<tr><th rowspan="2">φT_W</th><th colspan="7">Eccentricity</th></tr>
<tr><th>none</th><th colspan="3">in single x- or y- axis</th><th colspan="3">in both x- and y- axes</th></tr>
<tr><td rowspan="2">$n_x < n_y$</td><td></td><td>Log(x/y) ≤ 0</td><td colspan="2">0 < Log(x/y)</td><td colspan="2">Log(x/y) ≤ 0.3</td><td>0.3 < Log(x/y)</td></tr>
<tr><td>0.5</td><td>0.2</td><td colspan="2">-0.1</td><td colspan="2">-0.2</td><td>-0.5</td></tr>
<tr><td>$n_x = n_y$</td><td>1.0</td><td colspan="3">1.0</td><td colspan="3">0.3</td></tr>
<tr><td rowspan="2">$n_x > n_y$</td><td></td><td colspan="2">Log(x/y) ≤ 0.3</td><td>0.3 < Log(x/y)</td><td>Log(x/y) < -0.3</td><td colspan="2">-0.3 ≤ Log(x/y)</td></tr>
<tr><td>0.5</td><td colspan="2">0.4</td><td>0.1</td><td>-0.5</td><td colspan="2">-0.2</td></tr>
</table>

Table 2. Values of modification coefficients φT_E

φT_E	Eccentricity				
	none	in single x- or y- axis		in both x- and y- axes	
$n_x < n_y$		log (*x*/*y*) < -0.3	-0.3 ≤ log (*x*/*y*)	log (*x*/*y*) < -0.3	-0.3 ≤ log (*x*/*y*)
		1.4	1.0	1.5	1.3
$n_x = n_y$	1.0	1.2		1.3	
$n_x > n_y$		log (*x*/*y*) < -0.3	-0.3 ≤ log (*x*/*y*)	log (*x*/*y*) ≤ 0.3	0.3 < log (*x*/*y*)
		1.3	1.0	1.3	1.5

Table 3. Values of modification coefficients φV_E

φV_E	Eccentricity					
	none		in single x- or y- axis		in both x- and y- axes	
$n_x < n_y$	Log(x/y) ≤ 0	0 < Log(x/y)	log (*x*/*y*)<0.3	0.3 ≤ Log(x/y)	log (*x*/*y*) < 0	0 ≤ log (*x*/*y*)
	1.1	1.4	1.9	1.4	2.0	1.7
$n_x = n_y$	1.0		1.5		1.5	
$n_x > n_y$	Log(x/y) < 0	0 ≤ Log(x/y)	log (*x*/*y*)<0.3	0.3 ≤ Log(x/y)	log (*x*/*y*) ≤ 0	0 < og (*x*/*y*)
	1.4	1.1	1.6	1.1	1.7	2.0

The tables of the values of the modification coefficients φT_W, φT_E, and φV_E have been well defined already in the proposed evaluation and design program. The program can automatically determine the values of modification coefficients and the most critical demand on a bolt from the parameters as filled in by users in the *Equipment Spreadsheet* (Fig.3).

5.3 Acceptance Criteria for Anchor Bolts

The seismic design of the anchorage in concrete was in compliance with ACI 318 code (ACI 2002). The acceptance criteria is defined by

$$\left(\frac{T_{ua}}{\phi T_n}\right)^{1.5} + \left(\frac{V_{ua}}{\phi V_n}\right)^{1.5} \leq 1.0 \qquad (14)$$

The capacity of anchor bolts ϕT_n and ϕV_n is evaluated in the *Bolt Information Spreadsheet* (Fig.5), and the tension and shear demands, T_{ua} and V_{ua} respectively, are calculated by Eq.(6) and Eq.(7). For those satisfying Eq.(14), the blank ‘Result’ in Fig.3 replies ‘OK’, otherwise it replies ‘NO!!’. For those not satisfying the acceptance criteria, users should redesign of the anchor bolt following the steps in paragraph *3.3*.

6. CONCLUSIONS AND PERSPECTIVE

To facilitate the issuing of governmental policies and practical engineering services for the seismic upgrading of hospitals, the project “Seismic Evaluation and Strengthening Guidelines for Hospital Buildings” (Chai et al. 2015) was organized by the National Centre for Research on Earthquake Engineering. The seismic rehabilitation objectives of nonstructural components and systems in a hospital and the associated evaluation criteria were defined. Here, a program using Microsoft Excel was established for executing the seismic evaluation and retrofitting the design of individual items of medical equipment more easily and conveniently. Further studies are underway, including the development of a seismic evaluation and design program for equipment attached to the ceiling as well as for equipment strengthened by z-shape stoppers or welding.

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