# Strengthening of Historic Reinforced Brick Wall Building Implemented with Energy Dissipation devices *

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**ABSTRACT :**

This research compared with the seismic response analysis of two stories historic reinforced brick wall building stand up Di-Hwa street of famous historic area in the north of Taipei city, which implemented or not implemented with energy dissipation devices (fluid viscous damper-FVD).
The analysis results shows a two stories historic reinforced brick wall building set to two rigid plate is more reasonable, structural strengthening by implemented with FVD is much better than the other structural strengthening method, for structural seismic resistant design, the earthquake induced building horizontal shear force decrease in 87.8 %; the response of acceleration decrease in 90.7%; the response of floor displacement decrease in 93.22%; The response of story drifts decrease in 91.4% in the minimum requirement of building base shear force under seismic resistant design code of Taiwan.

**KEYWORDS:** Reinforced Brick Wall Building, Energy Dissipation devices, Seismic Response

## INTRUDUCTION

「Da-dao-cheng」is an important commercial and good distribution place of north Taipei in Ching dynasty, it is also named「Young-le-ting」in Japanese colonial ruled period. It was the famous street in Taipei city at once. That reason makes it so different and is worthy to preserve (fig.1). There are a few documents about the retrofit of historic building safety in Di-hwa street around「Da-dao-cheng」area. It is really serious that the damage by earthquake in Taipei basin, we must consider the seismic resistant ability when we repair or strengthening the historic building.

After investigate and collect the information of the structure system of historic buildings in Di-hwa street and the structure rehabilitation methods. This paper concentrated in how to simulate the analysis model and strengthening method that are usually used and suggested by population in section 1.3 shown in this paper, then analysis the seismic response and seismic resistant ability. Finally, it hopes that the result of simulation could be the quid line of the historic building retrofit work in Taiwan.

## 1. STRUCTURAL ANALYSIS MODELING and CASE STUDY

### *1.1 Di-Hwa Street House Structural System Type and Characteristic*

#### *1.1.1 Di-Hwa street existing historic building structure system type*

This research method is the structure form that compiles Di-Hwa street historic building, and after compiling know the historic building that the Di-Hwa Street dissimilarity structure form can induce seven types：(1) Brick (2)Reinforced Brick (3)Brick and Masonry wall (4)Adobe masonry and Brick (5)Adobe masonry and Masonry wall (6)Wood-framed (7)Reinforced Concrete Conformation.(fig.2) Among them with 1 to 5, these five types of structure in the Di-Hwa Street historic building structure form most for greatly, believe in to lately bear earthquake standard evaluation to seismic assessment, the along the street direction all can't comfort the demands and need carry on a structural repair.

*1.1.2 Traditional repair and strengthening method*

The repair compensation of historic building often adopts original method; original material to recover most and it also can't promote seismic assessment of historic building.

***1.2 Di-Hwa Street Historic Building Structure System Strengthening Type and Characteristic***

Di-Hwa street historic building structure for seismic resistant strengthening have following 8 types: (1)Adding shear wall (2)Adding diagonal bracing (3)Adding steel frame (4)Adding reinforced concrete frame (5)Implemented with steel frame and energy dissipation device (6) Implemented with reinforced concrete frame and energy dissipation device (7) Implemented with seismic isolator (8) Part dismantle(decrease no. of story) or rebuilding( for the non historic building ).

***1.3 Di-Hwa Street Historic Building Seismic Resistant Ability Evaluation***

Di-hwa street historic building case (two house with an open space, as shown in fig. 3), the structure analysis model simulated to 6 types ：(1) type 0-original structure set to one rigid plate with two hinged beam at the middle open space wall ;(2) type 1-original structure set to two rigid plate with two hinged beam at the middle open space wall ;(3) type 2-original structure divided to two rigid plate with equivalent diagonal bracing at the middle open space wall ;(4) type 3-adding steel frame without 2nd story girder at middle open space ; (5) type 4-adding steel frame with 2nd story girder at middle open space ;(6)type 5-adding 2 steel column at middle open space;(7) type 6-implemented with steel frame and fluid viscous damper(FVD) as shown in fig. 4～fig. 10. Analysis result to compare with story displacement、shear force of each story、fundamental period and top-level acceleration response as shown follows.

*1.3.1 Story displacement*

While taking original structure (Two separate buildings to regard as one building (One Rigid Diaphragm Model)) as analytical basis:

(1) X direction displacement: Original structure-0 more decrease -11.57% than original structure-1. Original structure-2 more increase +15.07% than original structure-1.（Table 1）
(2) Extension steel frame can decrease about 44.98%~47.82% displacement.
(3) Extension energy dissipation can decrease about 78.60% displacement.（Table1, Fig. 11）
(4) The Y direction frame containing the equivalent brace of brick wall so analysis maximum displacement 0.98 cm (Maximum angle of displacement=0.0016), therefore it displacement although have difference to -57.14%, actual influence very tiny.（Table 2, Fig. 12）

*1.3.2 Shear force of each story*

Analysis of the basic standards for (prototype-1)

(1) X direction's construction -( 0 and construction) - consider 2 construction - one is added -7.96% and +8.10% Seismic force(Table 3，Fig 13）

1. To add part of steel-frame’s cement, the Seismic force is reduced about 34.71% to 36.54%
2. To add part of ENERGY DISSIPATION DEVICE cement, the Seismic force is reduced about 5.177%

(2) Y direction's construction -( 0 and construction) - consider 2 construction - one is added -6.25% and +24.08% Seismic force ( Table4 , Fig14 )

1. To add part of steel-frame’s cement, the Seismic force is reduced about 29.11% to 32.54%
2. Energy dissipation device is forced in X direction, so the affecting is feeble to Y direction.

*1.3.3 Fundamental Period*

In the first building and the second building, the fundamental period of X direction is similar. It is twice longer than Y direction. That means the effect on the X direction of traditional two stories masonry building is smaller than Y direction. ( Table 5 )

*1.3.4 Top-level acceleration response*

Analysis of the basic standards for (prototype-1) :

(1). X direction's construction -( 0 and construction) - consider 2 construction - one is added -32.35% and +12.28% Top-level acceleration response
(2). To add part of steel-frame’s cement , the Top-level acceleration response is reduced about 41.73% to 51.47%
(3). To add part of ENERGY DISSIPATION DEVICE cement , the Top-level acceleration response reduced about 72.66% ( Table6 , Fig15 )
(4). Y direction's construction -( 0 and construction) - consider 2 construction - one is added -7.92% and +28.52% Top-level acceleration response
(5). To add part of steel-frame’s cement , the Top-level acceleration response is reduced about 27.10% to36.68%
(6). To add ENERGY DISSIPATION DEVICE is forced in X direction, so the affecting is feeble to Y direction ( Table7 , Fig16 )

## 2. CONCLUSION and SUGGESTION

### *2.1 Conclusion*

This study collects the data which is before and after reinforcement of two historic buildings to build the analysis model for simulation, and makes simulation analysis to compare the influence of design parameters on building’s seismic response and control capacity in conjunction with the three normalized horizontal earthquake records (Taipei-01, 02, and 03) consistent with the Taipei basin design response spectra. The results are as below:

1. The influence of building with energy dissipation devices on building vibration cycle is as follows:
   The cycle in X direction of the first house and the second house are similar, and are about twice as long as Y direction cycle. It shows that the seismic response in X direction cycle of traditional brick building is less effective by brick wall.
2. The influence of building with energy dissipation devices on floor acceleration reaction of the buildings is as follows:
   When we command that「The original structure -1」as an analyzed standard, we acquire that :
   ( 1 ) First constructed -0 X and the original structure -2 respectively over the original structure to increase -1% -32.35% +12.28 with top-level acceleration response.
   ( 2 ) Reinforcement of the increase in steel framework of top-level acceleration response reduced by about 41.73% to 51.47%.

（3）Increased energy dissipation system of the steel framework of top-level acceleration response reduced by about 72.66%.

（4）First constructed -0 Y and the original structure -2 respectively over the original structure -1 increased +7.92% -28.52% with top-level acceleration response.

（5）Reinforcement of the increase in steel framework of top-level acceleration response reduced by about 27.10% to 36.68%.

（6）Increased energy dissipation system for the X direction so the Y direction of the earthquake have little effect.

3. The influence of building with energy dissipation devices on story displacement is as follows:
   When we command that「The original structure -1」, I will, as a binary , One Rigid Diaphragm Model Method Simulation as an analyzed standard, we acquire that :

（1）First constructed -0 X and the original structure -2 respectively over the original structure -1 reduce -11.57% +15.07% and the increase in displacement.

（2）Increased steel reinforcement of the framework to reduce displacement of about 44.98% to 47.82%.

（3）Consumers can increase the steel framework of the system reduce the displacement of about 78.60%.

（4）Y to the framework for containing the equivalent of the brick wall with braces, the largest amount of displacement in only 0.98 cm (the largest displacement angle 0.0016), despite differences in their displacement of -57.14%, but have little practical impact。

### *2.2 Suggestion*

1. To enact the technique of reinforcement and the code of structure safety of historical building.
   We program a model to examine the effect on the building by any sort of Strengthening because there is no united follow-up direction ,like everyone has his own way or some trick is over or under ,for Construction Strengthening aspect at Di-Hwa.
   In future, it could be a direction for related case, and we hope that it could fill up the deficiency of Safe Design Code.
2. To enforce the measure of seismic resistance.
   We found that some Strengthening cases that were carried out just were considered the situation the moment, were not focused on long-way development. It could be the second harm to historical architecture. If we could consider the quake factor in the first Repair Strengthening, we can avoid that the building were destructed after Repair Strengthening.
3. Introduction of the new material and new technique of seismic isolation and energy dissipation.
   It is so universal overseas in using Seismic Isolation System and Passive Energy Dissipation System to decrease the damage caused by quake to historical architecture, but in our country it is just in first step. We know less about the Seismic Isolation System and Passive Energy Dissipation System were applied to historical architecture. Through this research we hope that we could inspire the career's interest in Seismic Isolation System and Seismic Isolation, and hope that there would be a new outstanding thought at historical architecture restoration in the future.

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## 4.APPENDIX

Fig.1 Di-Hwa street historic building


Fig.2 The type of Di-Hwa street historic building structure

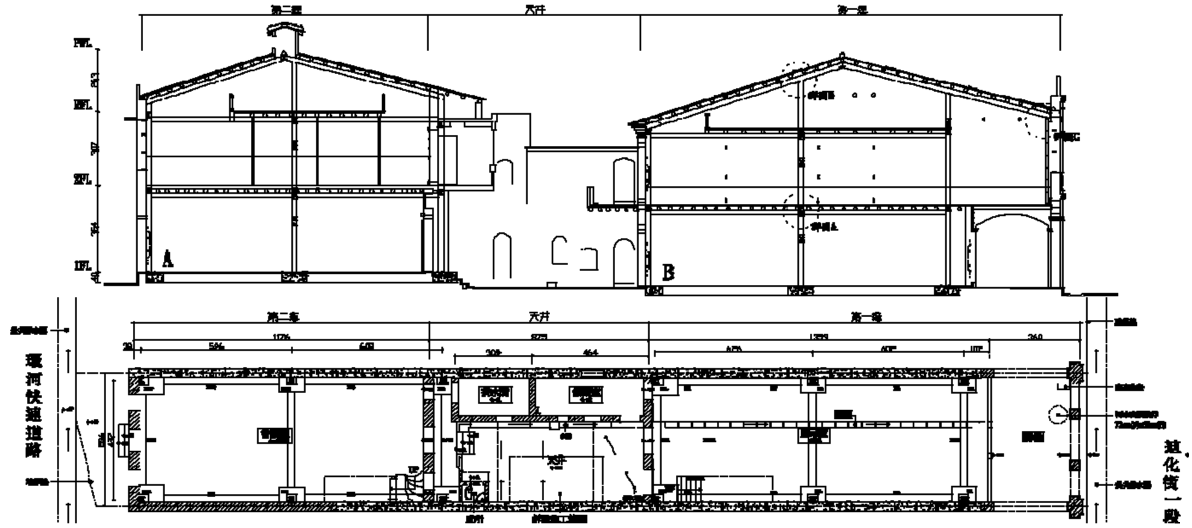

Fig.3 First level plan and elevation

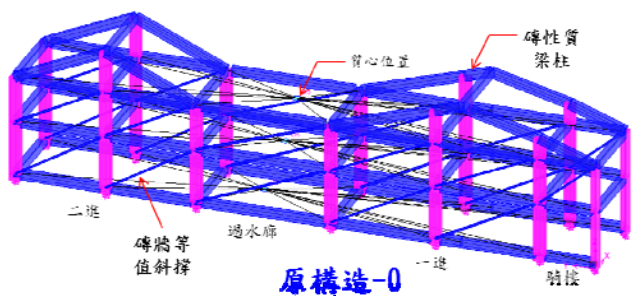


Fig.4 type 0-original structure set to one rigid plate with two hinged beam at the middle open space wall

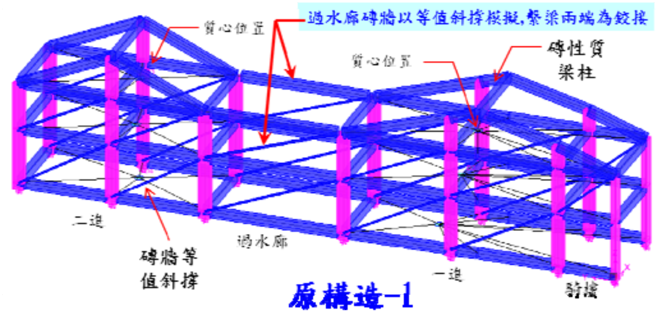


Fig.5 type 1-original structure set to two rigid plate with two hinged beam at the middle open space wall

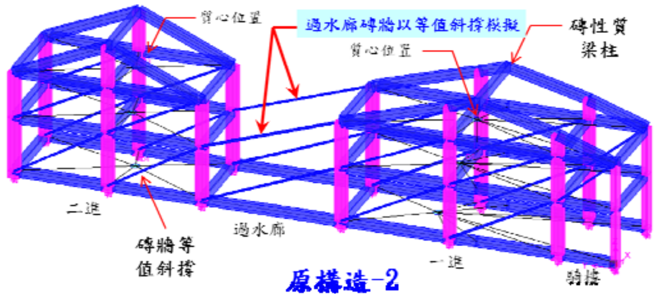


Fig.6 type 2-original structure divided to two rigid plate with equivalent diagonal bracing at the middle open space wall

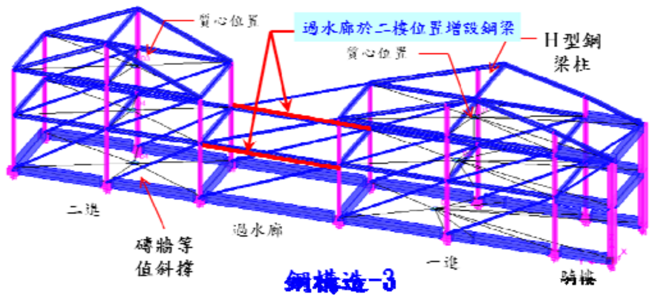


Fig.7 type 3-adding steel frame without 2nd story girder at middle open space

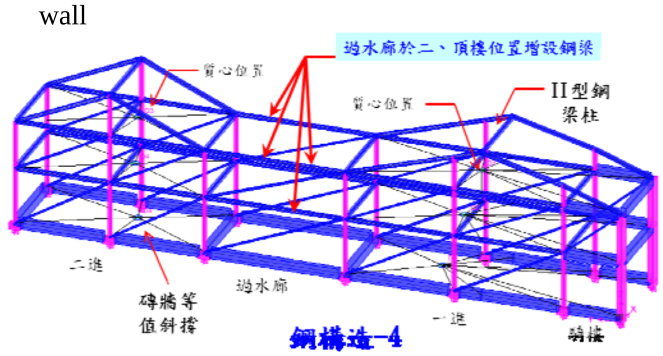


Fig.8 type 4-adding steel frame with 2nd story girder at middle open space

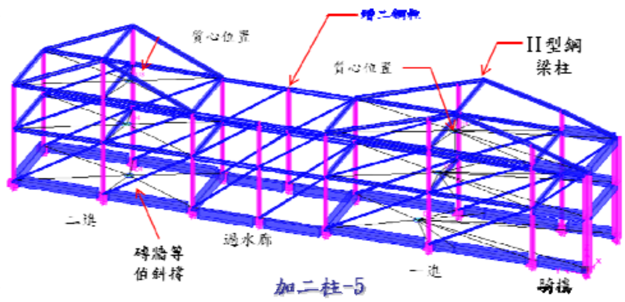


Fig.9 type 5-adding 2 steel column at middle open space

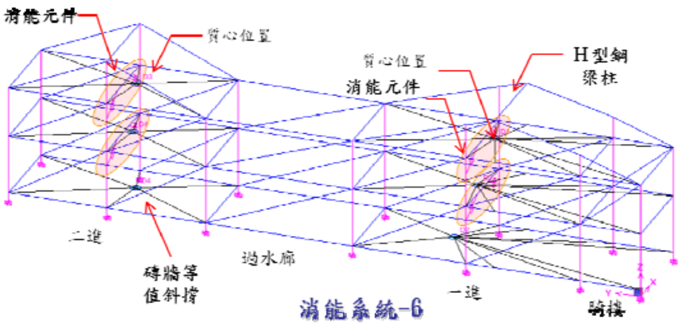


Fig.10 type 6-implemented with steel frame and fluid viscous damper(FVD)

Table 1 X-direction story displacement

| Story | original structure-0 displacement X(cm) | original structure-1 displacement X(cm) | original structure-2 displacement X(cm) | steel frame-3 displacement X(cm) | steel frame-4 displacement X(cm) | add two column-5 displacement X(cm) | energy dissipation-6 displacement X(cm) |
|---|---|---|---|---|---|---|---|
| 3F | 4.05 | 4.58 | 5.27 | 2.39 | 2.52 | 2.48 | 0.98 |
| 2F | 2.57 | 2.89 | 3.28 | 1.47 | 1.53 | 1.49 | 0.65 |
| 1F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| % | -11.57% | 0.00% | 15.07% | -47.82% | -44.98% | -45.85% | -78.60% |

Table 2 Y-direction story displacement

| Story | original structure-0 displacement Y(cm) | original structure-1 displacement Y(cm) | original structure-2 displacement Y(cm) | steel frame-3 displacement Y(cm) | steel frame-4 displacement Y(cm) | add two column-5 displacement Y(cm) | energy dissipation-6 displacement Y(cm) |
|---|---|---|---|---|---|---|---|
| 3F | 0.72 | 0.77 | 0.98 | 0.57 | 0.53 | 0.33 | 0.52 |
| 2F | 0.44 | 0.46 | 0.56 | 0.33 | 0.32 | 0.21 | 0.32 |
| 1F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| % | -6.49% | 0.00% | 27.27% | -25.97% | -31.17% | -57.14% | -32.47% |

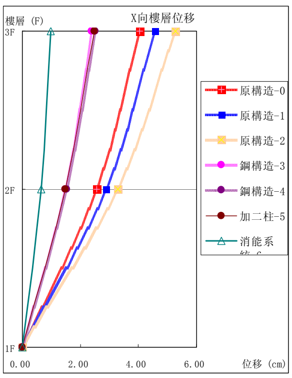


Fig.11 Y-direction story displacement

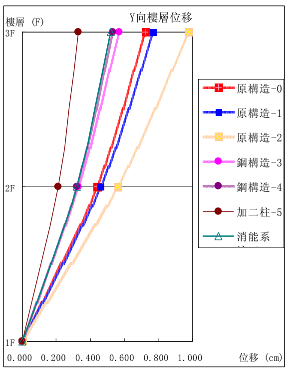


Fig.12 X-direction story displacement

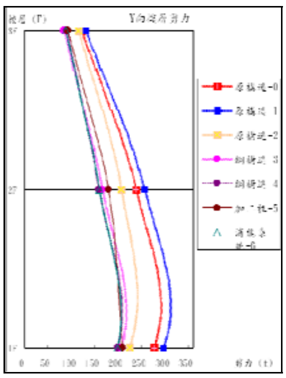

Fig.13 X-direction shear force displacement

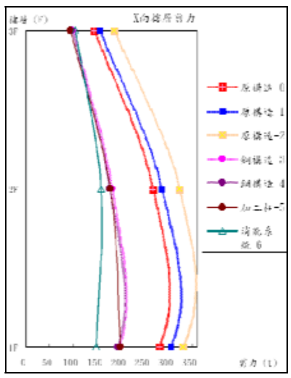

Fig.14 Y-direction shear force displacement

Table 3 X-direction shear force of each story

| | prototype -0 | prototype -1 | prototype -2 | steel architecture -3 | steel architecture -4 | increase two pillars -5 | energy dissipation device-6 |
|---|---|---|---|---|---|---|---|
| Story | shear force VX(t) | shear force VX(t) | shear force VX(t) | shear force VX(t) | shear force VX(t) | shear force VX(t) | shear force VX(t) |
| 3F | 142.753 | 154.453 | 184.844 | 98.648 | 95.671 | 94.032 | 103.518 |
| 2F | 266.310 | 285.151 | 322.027 | 181.004 | 176.343 | 178.293 | 158.147 |
| 1F | 280.572 | 304.852 | 329.543 | 195.472 | 193.467 | 199.040 | 147.028 |
| % | -7.96% | 0.00% | 8.10% | -35.88% | -36.54% | -34.71% | -51.77% |

Table 4 X-direction shear force of each story

| | prototype -0 | prototype -1 | prototype -2 | steel architecture -3 | steel architecture -4 | increase two pillars -5 | energy dissipation device-6 |
|---|---|---|---|---|---|---|---|
| Story | shear force VY(t) | shear force VY(t) | shear force VY(t) | shear force VY(t) | shear force VY(t) | shear force VY(t) | shear force VY(t) |
| 3F | 120.464 | 129.984 | 114.288 | 84.343 | 88.956 | 92.156 | 88.836 |
| 2F | 237.384 | 255.154 | 205.533 | 165.313 | 159.033 | 179.756 | 159.112 |
| 1F | 277.027 | 295.493 | 224.346 | 205.620 | 199.337 | 209.482 | 199.405 |
| % | -6.25% | 0.00% | -24.08% | -30.41% | -32.54% | -29.11% | -32.52% |

Table 5 building fundamental period

| cycle | Prototype -0 | prototype -1 | prototype -2 | steel architecture-3 | steel architecture-4 | increase two pillars-5 | energy dissipation device-6 |
|---|---|---|---|---|---|---|---|
| X-direction | (一進) 0.4107 | 0.3999 | 0.4027 | 0.3629 | 0.3610 | 0.3564 | 0.3610 |
| | (二進) | 0.3904 | 0.4003 | 0.3549 | 0.3312 | 0.3269 | 0.3312 |
| Y-direction | 0.1700 | 0.1724 | 0.1795 | 0.1705 | 0.1691 | 0.1622 | 0.1691 |

Table 6 X-direction acceleration response on top floor

| acceleration | prototype -0 | prototype -1 | prototype -2 | steel architecture -3 | steel architecture -4 | increase two pillars -5 | energy dissipation device -6 |
|---|---|---|---|---|---|---|---|
| | Ax(g) | Ax(g) | Ax(g) | Ax(g) | Ax(g) | Ax(g) | Ax(g) |
| MAX | 0.73426 | 1.08535 | 1.21858 | 0.63241 | 0.56784 | 0.52670 | 0.29677 |
| MIN | -0.72600 | -1.02037 | -1.02763 | -0.63778 | -0.51656 | -0.46108 | -0.40736 |
| % | -32.35% | 0.00% | 12.28% | -41.73% | -47.68% | -51.47% | -72.66% |

Table 7 Y-Direction acceleration response on top floor

| acceleration | prototype -0 | prototype -1 | prototype -2 | steel architecture -3 | steel architecture -4 | increase two pillars -5 | energy dissipation device -6 |
|---|---|---|---|---|---|---|---|
| | Ay(g) | Ay(g) | Ay(g) | Ay(g) | Ay(g) | Ay(g) | Ay(g) |
| MAX | 0.89739 | 0.83154 | 0.59436 | 0.52652 | 0.58054 | 0.60622 | 0.56964 |
| MIN | -0.87175 | -0.78590 | -0.55868 | -0.56099 | -0.59426 | -0.57010 | -0.59632 |
| % | 7.92% | 0.00% | -28.52% | -36.68% | -30.19% | -27.10% | -31.50% |

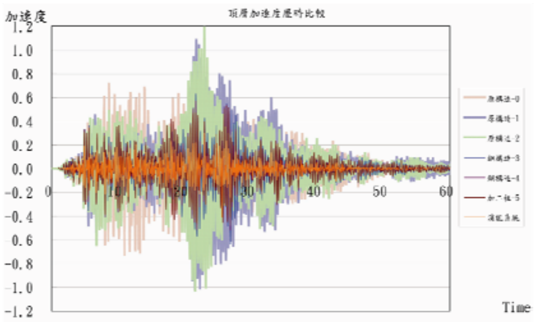


Fig.15 X-direction acceleration comparison graph

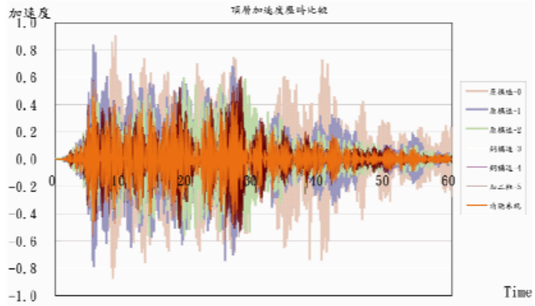


Fig.16 Y-direction acceleration comparison graph