Introduction of National Freeway Bridge Seismic Design - Nantou Section of National Freeway No. 6

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1. Introduction

National Freeway plays the major roles for the Taiwan traffic network and the proportion of bridges in the network increases with the time. It is an inevitable trend for Taiwan's engineers to enhance the professional knowledge, adopt the advanced technology and utilize the modernized construction methods to overcome Taiwan's seismic active geographic characteristics and to response to various conditions of bridge construction. This paper first introduces the modification of Taiwan's "Highway Bridge Seismic Design Specifications" after the 921 Chi-Chi earthquake, then illustrates the impact of 921 Chi-Chi earthquake on the bridges in Taiwan. One project, Nantou section of National Freeway No. 6 located in the strong seismic zone and near the active faults (Figure 1), is introduced as an example to explain the considerations of structural system, structural type and construction method for the bridges in order to meet the seismic requirements under the influence of near-fault effects.

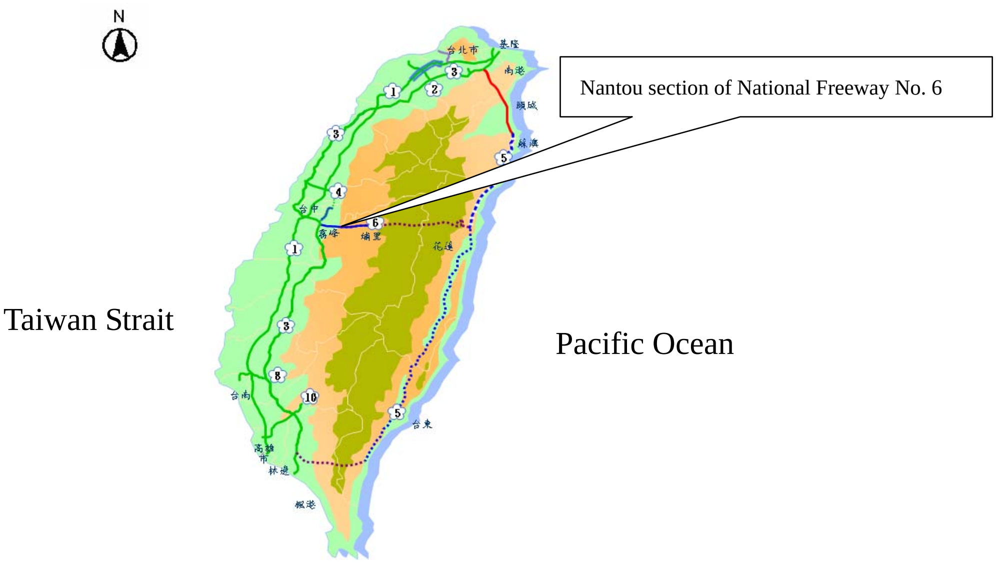

Figure 1 Location of Nantou Section of National Freeway No. 6

2. Taiwan Highway Bridge Seismic Design Specification Changes

This section focuses on the changes of Taiwan's "Highway Bridge Seismic Design Specification". Taiwan bridge design consideration for the seismic force can be traced back to November 1960, the "Highway Bridge Design Code" issued by Ministry of Transportation and Communications (MOTC). Then on years 1995, 2000 and 2008, modifications were done for different versions of seismic design specification. All seismic design specifications are described as follows:

(1) Before 1987

"Highway Bridge Design Code" issued by MOTC in 1960 was referred to AASHTO 1957 version. There was no design seismic force specified in the Code. However, National Freeway No.1 was under construction at that time, concerning bridge site location, geological condition and the importance, seismic coefficients of 0.1, 0.15 and 0.2 were established by Taiwan Area National Freeway Bureau. While others highway bridges were using seismic force coefficients 0.1 and 0.15 for different regions referring to the Chinese Institute Engineers' suggestion.

(2) In 1987 to 1984

Seismic design of highway bridge was adopted to the specifications in this version which was mainly referring to the "Road Bridge Design Book with Commentary V, Seismic Design Code" published by Japan Road Association in 1980. Static seismic coefficient method was used for the seismic design. Geological factors and the dynamic response were taken into account. The design seismic coefficient should be greater than at least ten percent of self-weight.

(3) In 1995 to 2000

"Highway Bridge Seismic Design Specification" was separated from "Highway Bridge Design Specifications" at that time. The seismic design code was referred to the U.S. AASHTO 1992 edition. Ductility design concept was integrated in the specification. Design seismic force was determined based on different structural system and ductility behavior, seismic force reduction factor. A return period of 475 years seismic force was considered, and under this design seismic force, no bridge collapse was allowed. In moderate earthquake, the structure was not allowed to be yielded prematurely. The horizontal acceleration was by 0.18g, 0.23g, 0.28g and 0.33g four partitions.

(4) In 2000 to 2008

In response to the 921 earthquake, the associate units in Taiwan during this period were actively engaged in revising the seismic design specification. The horizontal acceleration was changed from 0.18g, 0.23g, 0.28g and 0.33g four partitions to 0.23g and 0.33g two partitions, a specified acceleration response spectrum was established for the Taipei Basin. The specification was also adding the combination of two horizontal directions and vertical seismic effect, and the near-fault effect. The near-fault adjustment factors N_A and N_V were introduced and put into consideration for seismic design.

(5) After 2008

This version was modified according to the research results of Taiwan research units and the United States, Japan and other countries newest bridge seismic design codes. The specification was adding the concern of maximum seismic force and near-fault effect. The design concept is that (i) mediate earthquake ,about the design earthquake 1/3.25, the bridge can maintain its original function; (ii) design earthquake, return period of 475 years, the bridge is allowed to be damaged, but repairable; (iii) maximum considered earthquake, return period of 2500 years, the bridge can not falling or collapse. The main amendments can be briefly summarized as follows:

A. In the case of near-fault region, further adjustment factors N_A and N_V were adopted to consider the near-fault effect. The first type active fault near-fault adjustment factors could be obtained by checking the township, cities or countries built-up tables, the old calculation method using distance between the bridge site and adjacent fault was no longer used.

B. In addition to the1995 version, under design earthquake (return period of 475 years) allowed structures to have plastic deformation to allowable ductile capacity R_a. The maximum considered earthquake (return period of 2500 years) allowed structures to have plastic deformation to structural ductility capacity R.

C. Results of reinforced concrete bridge column section design should fulfill the plastic hinge regions shear strength requirements in order to ensure RC pier ductility behavior and development of plastic hinge mechanism.

D. Adding the "Seismic isolation and energy dissipation design" section, detailed provisions related to the design, analysis, and the testing standards of isolation components were established.

3. The Impact of 921Chi-Chi Earthquake

Taiwan is situated at the western side of the Pacific Rim area, at the junction of Philippine Sea Plate and the Eurasian Plate. There are faults everywhere on the island and the seismic events are very active. Taiwan might suffer a major earthquake at any time. Year 1999 at 01:47AM on September 21, a magnitude 7.3 earthquake occurred in central Taiwan, more than 2,400 people were killed and over 11,300 people were injured. More than 53,500 houses were completely collapsed and more than 53,600 houses were partially collapsed. Damage was so severe, it was Taiwan's most devastating earthquake disaster in the century. The earthquake also brought the attention for the Government on the structural seismic problem. For the bridge structure, the damage caused by the earthquake can be roughly summarized as follows:

(1) Sever and large area of surface rupture

The Chi-Chi earthquake was triggered by Chelungpu thrust fault and caused enormous surface dislocation, several meters of surface dislocation. The destruction was astonishing. When earthquake striking, the length of surface rupture along the main fault was about 83km, another surface rupture was about 22km long from Fengyuan to the northeastern direction. The thrust fault length is about 105km, which is the longest one in the world. There were severe and large areas of surface rupture and damage. Such huge dislocation of the surface can damaged almost all types of bridge. So far, it is very difficult for the engineer to overcome such problem.

(2) High ground acceleration and long duration

According to Taiwan Central Weather Bureau measured from strong motion observation network of Sun Moon Lake, three stations, the maximum ground accelerations were 989gal (east-west), 423gal (north-south) and 312gal (vertical), respectively. Especially the east-west PGA was 1.2 times higher than Kobe earthquake horizontal PGA (817.8gal) in Japan, measured by Kobe marine meteorological station. The main earthquake was lasted for 25 seconds, and its frequency was widely distributed. That was the reason the structures were seriously destructed, also the major factor that causing damage to the bridges.

(3) Low design seismic force

The earthquake caused serious damages to the bridges in Nantou County, Taichung County and other regions, which were considered non-strong seismic areas in the past. Especially in Nantou County, it was considered as a low seismic hazard zone. The design seismic force of previous bridge seismic design specifications on Nantou area was only medium, relatively low for the strong earthquake. Thus, it led to the bridges been damaged severely.

(4) Insufficient support length and lack of anti-falling devices

During the earthquake, if a relative large displacement occurred on the superstructure and substructure of the bridge that exceeding the bearing capacity, the bearing would be damaged. Moreover, if the support length is insufficient or lack of suitable anti-falling devices, the bridge will fall. Parts of bridges were damaged in this earthquake due to the lack of anti-falling device to prevent falling.

(5) Improper seismic details

The stirrups provide not only the shear strength for RC pier, but also the confinement of RC central core which can increase the bearing capacity of pier and improve its ductility. In the past, bridge seismic design specifications did not emphasize the ductility design, so that the importance of stirrups was ignored. If it could be improved, the seismic capacity of bridge can be upgraded significantly.

(6) Low structural system redundancy, poor seismic performance

Most of the bridges suffered severe damage in the earthquake belongs to the simple beam structures, and substructures are mostly single column. Due to its low structural redundancy, it is easy to damage locally and causes bridge unstable and collapsing. In addition, the simple supported beam is also easy to falling.

(7) Significant near-fault effect

The earthquake caused 105km long Chelungpu thrust fault surface dislocation. Near the fault line, lots of bridges were damaged. According to the research report of Taiwan's National Center for Research on Earthquake Engineering (NCREE), it showed that both short period and median period bridges in the near-fault region were subject to near-fault high PGA and high-speed pulse. The destruction of bridges were severe than the ones in other regions. Obviously, there are significantly differences between near-fault ground motion characteristics and long-distance fault. How to make adequate design specifications to adjust this phenomenon needs further research and appropriate study.

4. The Nantou section of National Freeway No.6, Bridge Engineering Seismic Considerations

Nantou section of National Freeway No.6 was designed after 921 Chi-Chi earthquake. The route started at National Freeway No. 3 Wufeng System Interchange in west, to eastern direction along with Wu Hsi, Nankung Hsi and Mai Hsi valleys, and mountain, Nantou County Caotun town, Guoshing township, then intersected to Provincial Highway No.14 in Puli town. The total length of the project was 37.6km. Viaducts and tunnels were designed with a smaller disturbance to the in-situ ecological. The route included embankment and open-cutting length 6.9km (19%), bridge length 26.4km (70%), tunnel length 4.3km (11%). (Figure 2) The whole project was divided into 9 lots (Lot C601 ~ C609). The construction began in 2004 and the main route was opened to service in March 2009.

Figure 2 Location map of Nantou section of National Freeway No.6

There were total 40 bridges in this project. In the design stage, the seismic design was referring to "Highway Bridge Seismic Design Specification" in 1995, "Highway Bridge Seismic Design Specifications Partial Section Commentary" in 2000. Since the route was located in strong seismic zoon, several active faults were passing through the project site, large span bridge, full-rigid-frame and LRB bridges were adopted for seismic design. The considerations of seismic design were summarized as followings:

(1) Strategies for route passing through the faults

According to the active fault definition and domestic reference at that time, there were four active faults identified near the project, including Chelungpu fault, Ailiao fault, Shuangdong fault and Shuichungliu fault (Figure 3). Structure layout and design strategies were considered only for the active faults. The other inactive faults such as Maenliao fault, Shuiliudong fault, Guohsing fault, Sanchiaoping fault and Meiyuan fault were not considered

In addition, for those bridges were passing through the fault line, continuous girder bridge type of PC box girder or steel box girder were used. Continuous girder bridge has a better structural stability (higher structural redundancy), which can lower the possibility of bridge falling and can better protect the safety of road users. However, if the assessment indicates that it is not appropriate to across the terrain by bridges, then it would change to the embankment or open-cutting structures, because of its great flexibility, in addition to reducing the damage caused by the dislocation in earthquake. The restoration tasks can be simpler and construction time can be shorter after earthquake.

Design strategies for the planed route passing through multiple faults are listed in Table 1 as follows:

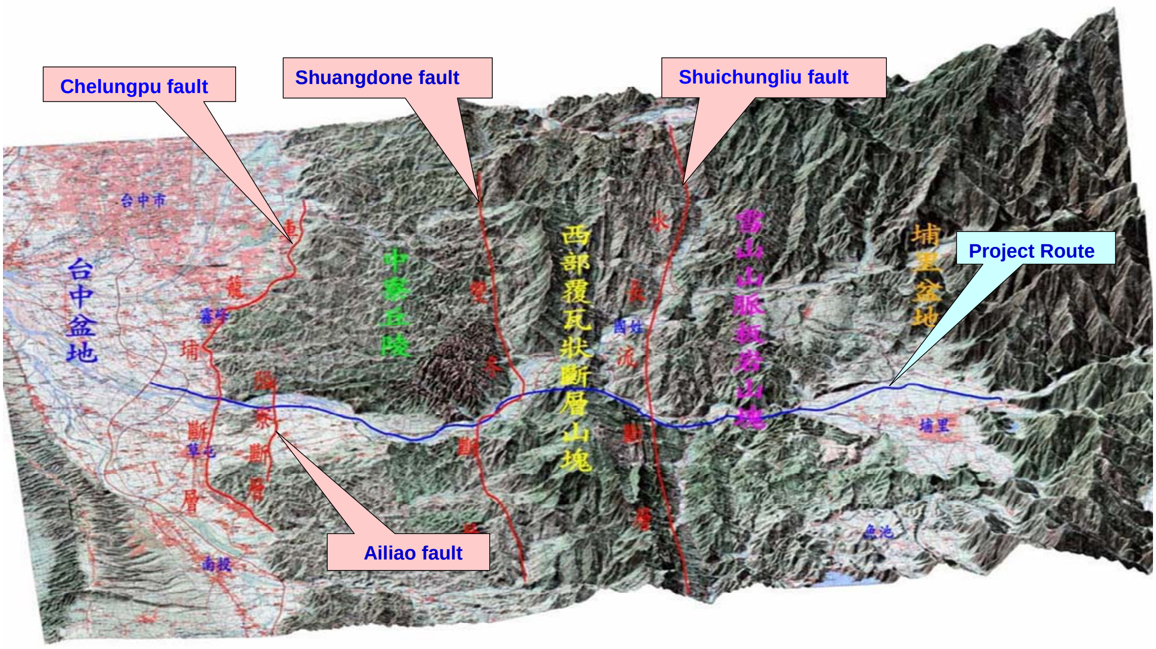

Figure 3　Locations of active faults on Nantou County

Table 1 Structure layout and design strategies for Nantou section of National Freeway No. 6 passing through faults

	Name of fault	STA.	Fault Type	Structure Type	Strategies
1.	Chelungpu	2K+930±	Active	Embankment	High tolerance for fault rupture, easy repair
2.	Ailiao	5K+500±	Active	Embankment	High tolerance for fault rupture, easy repair
3.	Shuangdong	14K+160±	Active	Open-Cutting	-
		15K+330±		Embankment	High tolerance for fault rupture, easy repair
		16K+800±		Steel Bridge	Long span continuous steel box girder, good ductility, low bridge falling risk
4.	Maenliao	17K+750±	Inactive	Tunnel	—
5.	Shuiliudong	19K+750±	Inactive	Tunnel	—
6.	Guohsing	20K+450±	Inactive	PC Bridge	No consider
7.	Shuichungliu	22K+700±	Active	PC Bridge	Long span continuous rigid frame type structure, increase the ultimate bending strength and ductility by using longitudinal rebar, full span prestressing increase the bridge integrality
8.	Sanchiaoping	25K+700±	Inactive	Open-Cutting	—
9.	Meiyuan	29K+500±	Inactive	PC Bridge	No consider

A. Passing by embankment (Open cutting)

(i) Station 2K +9306 - Chelungpu fault

The route layout and Chelungpu fault were intersected roughly orthogonal. After 921 earthquake, the surface on both sides were dislocated relative about 5m vertically. After review and assessment, bridge structure was not adequate under this condition, 300m of embankment was designed. (Figure 4)

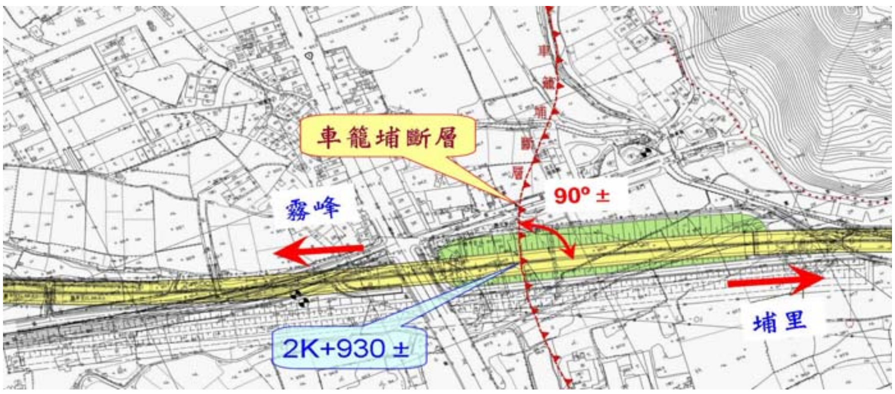

Figure 4 Location map for route station 2K +9306

(ii) Station 5K +5006 - Ailiao fault

The route layout and Ailiao fault were intersected roughly in 70°. The route vertical alignment was relatively close to the ground, so the embankment was designed and constructed for passing through Ailiao fault. (Figure 5)

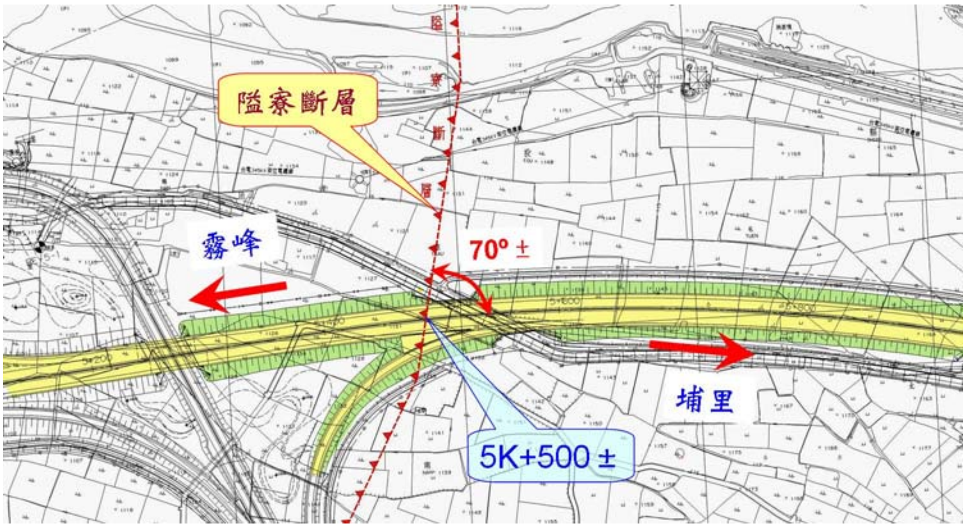

Figure 5　Location map for route station 5K +5006

(iii) Station 14K +1606 - Shuangdong fault

From west to east, the route layout was first time intersected with Shuangdong fault roughly in 35°. Because the ground was higher than the designed vertical alignment, the open-cutting structure was designed (Figure 6).　This structural configuration can reduce the dislocation resulting from earthquake and repairment difficulty, thus improving the feasibility of repair.

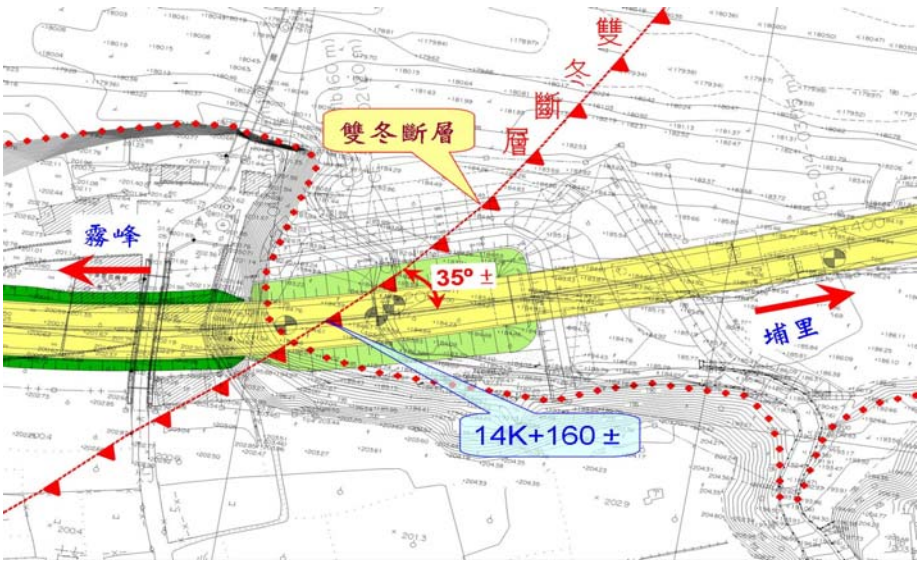

Figure 6　Location map for route station 14K +1606

(iv) Station 15K +330± - Shuangdong fault

From west to east, the second intersection of route layout and Shuangdong fault was angled roughly in 50°. After reviewing the site condition, flexible embankment was constructed. (Figure 7)

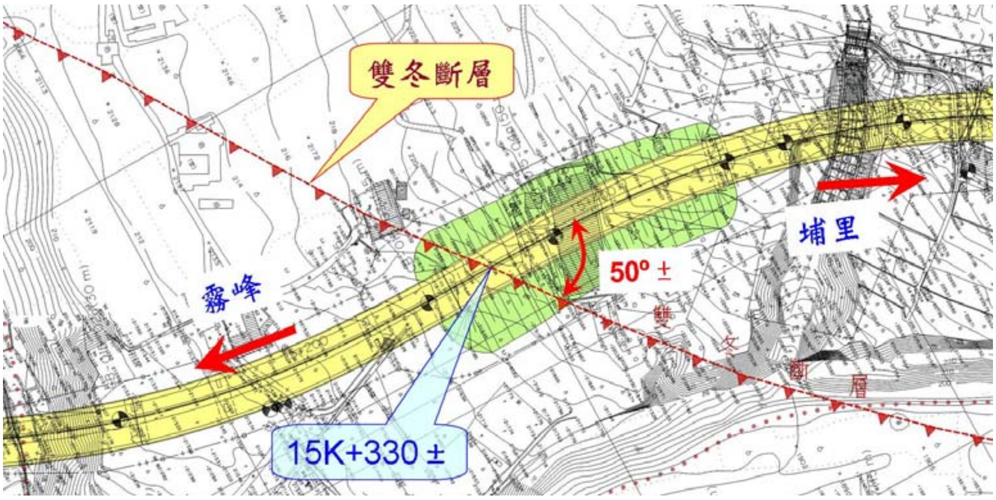

Figure 7　Location map for route station 15K +330±

B. Continuous steel box girder bridge

From west to east, the route layout was intersected third time to Shuangdong fault at 16K +800± roughly in 30°. The vertical alignment was up to 60m or more. And the fault was within the Wu Hsi stream channel management plan. Therefore, it could be passed only by bridges. Continuous steel box girder bridge (Guohsing viaduct No.2) in large span (span length in 150m) was adopted. The main idea was utilizing high strength and good ductility and light weight of steel beams to reduce the potential of the bridge collapse, and increase its survival rate under a major earthquake. (Figure 8~10)

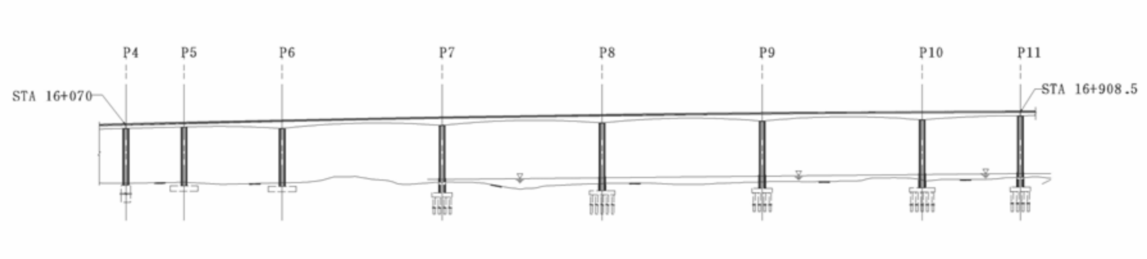

Figure 8　Elevation of Guohsing viaduct No.2

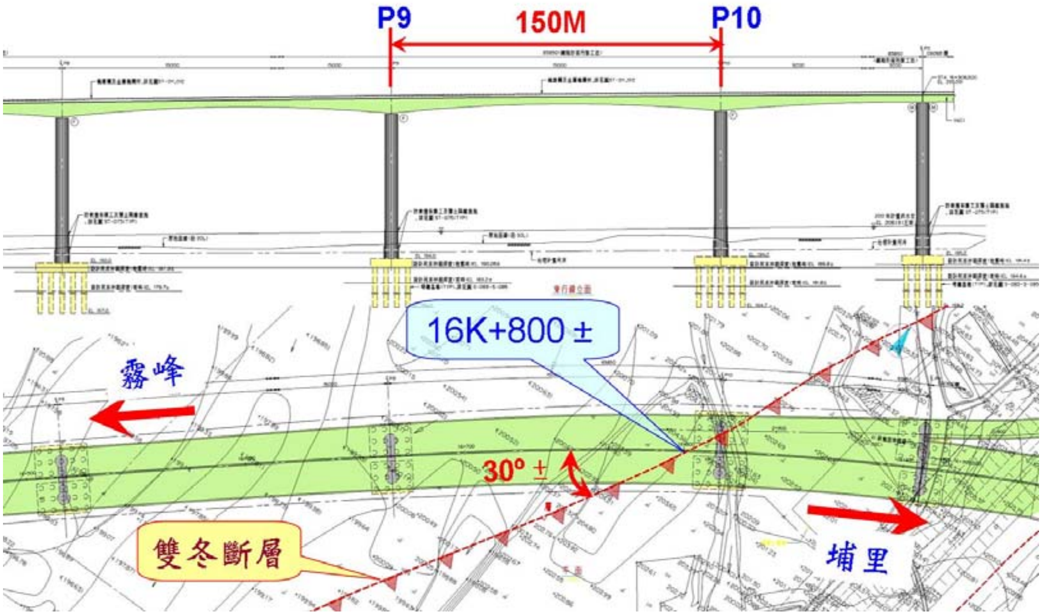

Figure 9 Location map of Guohsing viaduct No.2

Figure 10 Perspective drawing of Guohsing viaduct No.2

C. Enhancing self-stability of free cantilever girder avoiding falling

The route layout and Shuichungliu fault was intersected at 2K+700± roughly in 60°. Since the site was in Wu Hsi river valley, the vertical alignment was up to 30m or more. Viaduct was the only adequate structure in here. After detail investigation, prestressed concrete continuous box girder was adopted (Doosan No.2 viaduct). Rather than the conventional free cantilever PC viaduct, Doosan No.2 viaduct increased the longitudinal reinforcement to provide better ductility and improve cross-section of the positive and negative moment ultimate flexural strength. Whole bridge unit was applied continuous longitudinal prestressing tendons to improve the self-stability of free-cantilever girder. Expansion joint was located at P24, and P24 was designed for the serviceability purpose not the structural need. Therefore even P24 was collapsed due to the fault dislocation, the superstructure between P23 to P25 would not fall down which could reduce the risk of total bridge collapsing. (Figure 11~13)

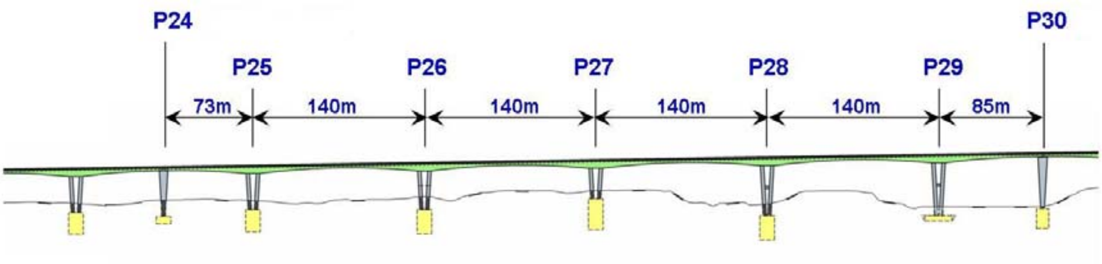

Figure 11 Elevation of Doosan No.2 viaduct

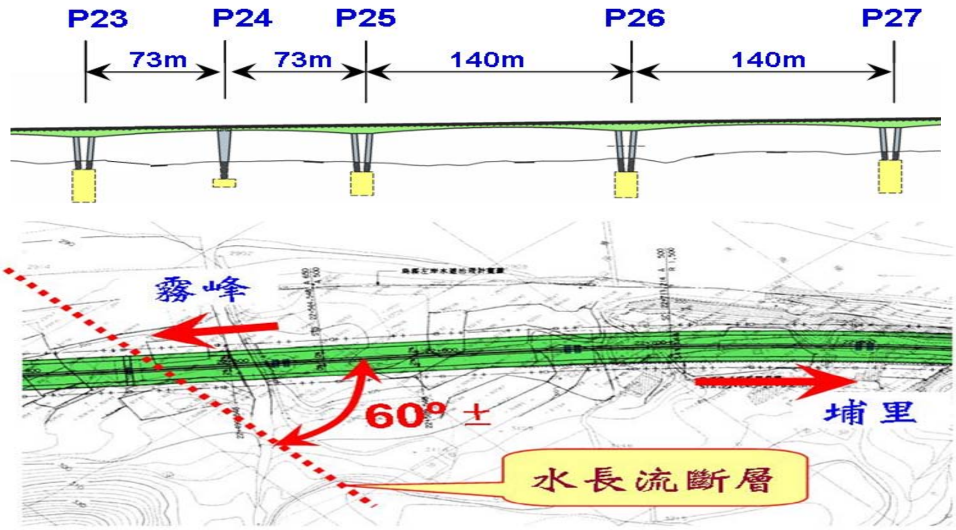

Figure 12 Location map of Doosan No.2 viaduct

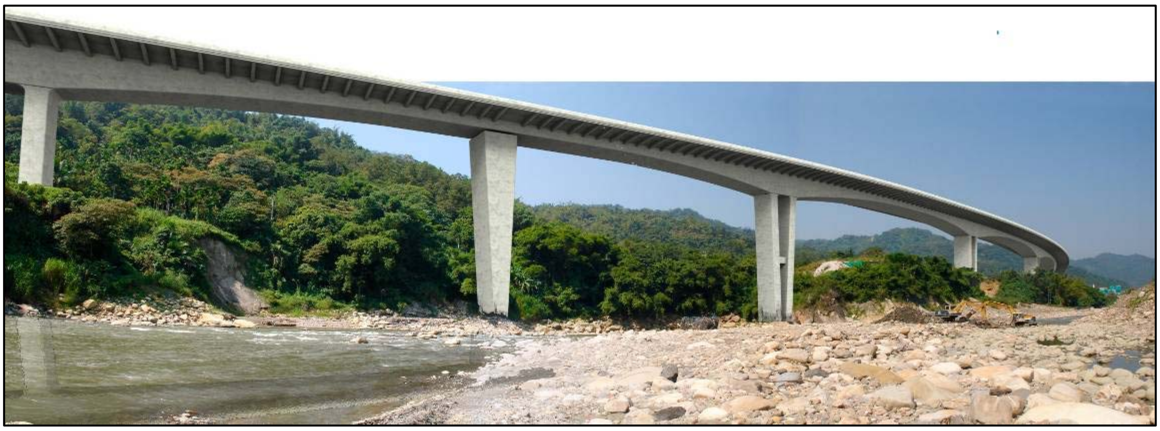

Figure 13 Perspective drawing of Doosan No.2 viaduct

(2) Bridge near-fault seismic design considerations

In the design stage, based on MOTC issued "Highway Bridge Seismic Design Specification (draft) Review Report" in March 1992, there were only 7 group faults that needed to consider near-fault seismic force amplification factors, not all faults. Therefore, for the economic reason, the project was only to consider the near-fault effect of Chelungpu fault after evaluation the report. In response to the near-fault effect of Chelungpu fault and/or low vertical alignment (piers high less than 10m), parts of bridges were designed by using full-rigid-frame viaduct (i.e. longitudinal: multi-column piers, transverse: double-column piers) and part of bridges were using LRB seismic isolation bearing to overcome the negative impacts on the pier design.

Besides the above mentioned considerations, steel shear box, the support length enlargement and anti-seismic bracing were concerned and designed to fulfill the safety needs. The detail concerns are summarized as follows:

A. Near-fault adjustment factor, N_A and N_V

As mentioned in previous section, only Chelungpu fault was considered the near-fault effect. The near-fault seismic force design considerations were made based on the NCREE's research published in 2000.

Area within 10km from the surface rupture line of Chelungpu fault, the near-fault effect for design seismic force should be considered. The near-fault adjustment factors of N_A and N_V are listed as follows:

Distance (km)	r ≦ 2	r = 4	r ≧ 6
N_A	1.34	1.16	1.0

Distance (km)	r ≦ 2	r = 6	r ≧ 10
N_V	1.70	1.30	1.0

Note: The distance r is defined as the shortest distance between bridge site and the Chelungpu fault horizontal surface rupture line. For other distances, near-fault adjustment factors can be obtained by linear interpolation.

B. Full-rigid-frame bridge

This system were using horizontal elements (intermediate and end diaphragms) to connect the original separated two-way bridge on piers, thus forming the piers rigid frame structure in transverse direction. The structure system had a better redundancy which could reduce the lateral seismic force substantially. By reducing near-fault effect, the pier size could be smaller and the design difficulty could be lesser. Since the both direction of the bridge structure were rigid, the structural system was called “Full-rigid-frame Structure”. C601 Nanwufeng viaduct was designed by utilizing the abovementioned concept (Figure 14~19). Since part of the piers of Nanwufeng viaduct were high, the piers already had a large ductility (large deformation) and LRB was inadequate in this situation. The full-rigid-frame system could reduce the size of pier under the influence of Chelungpu fault near-fault effect. The bridges that used full-rigid-frame structural system were shown in Table 2.

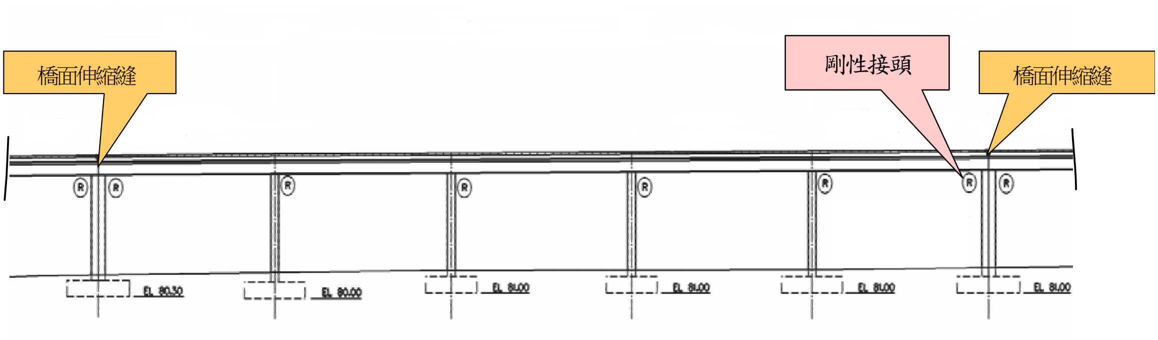

Figure 14 Elevation of full-rigid-frame type viaduct

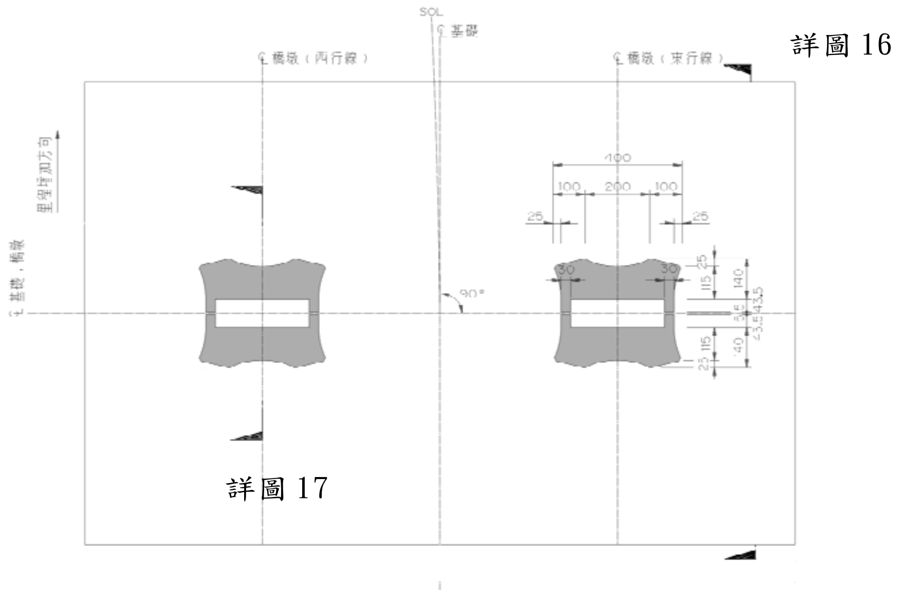

Figure 15 Elevation of full-rigid-frame type viaduct

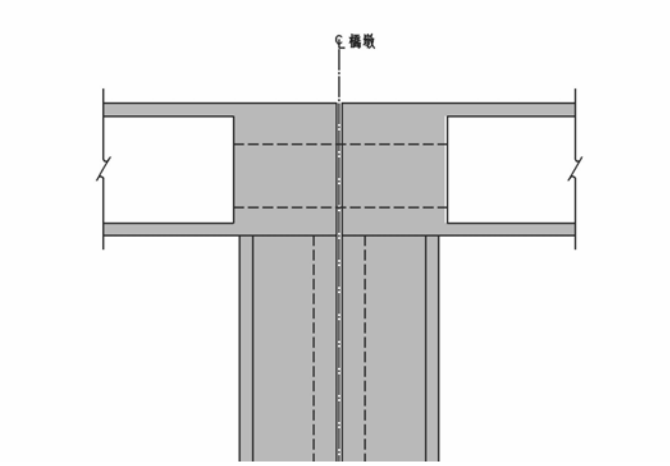

Figure 16　Longitudinal section of full-rigid-frame type viaduct (1/2)

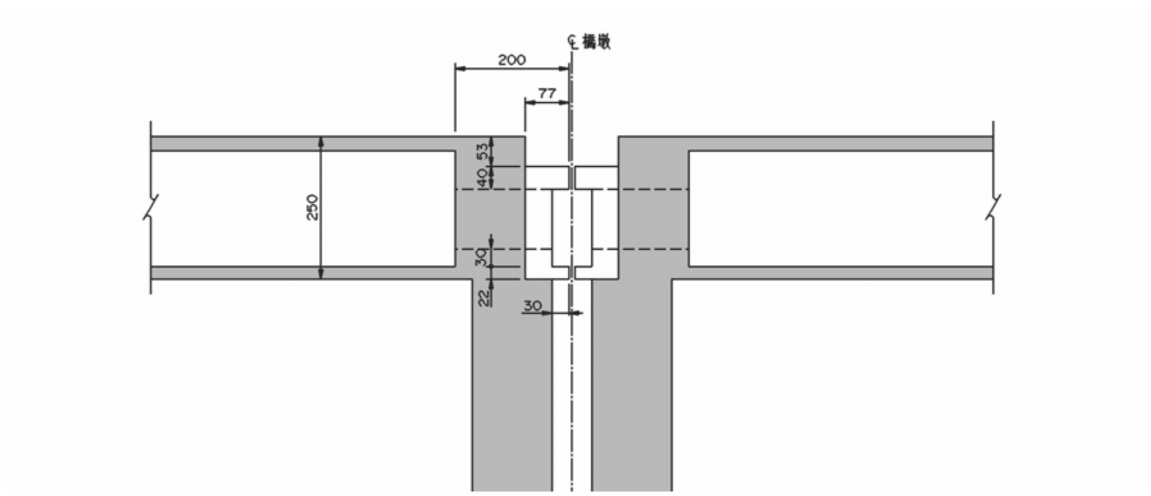

Figure 17　Longitudinal section of full-rigid-frame type viaduct (2/2)

Figure 18　Photo of full-rigid-frame type viaduct (1/2)

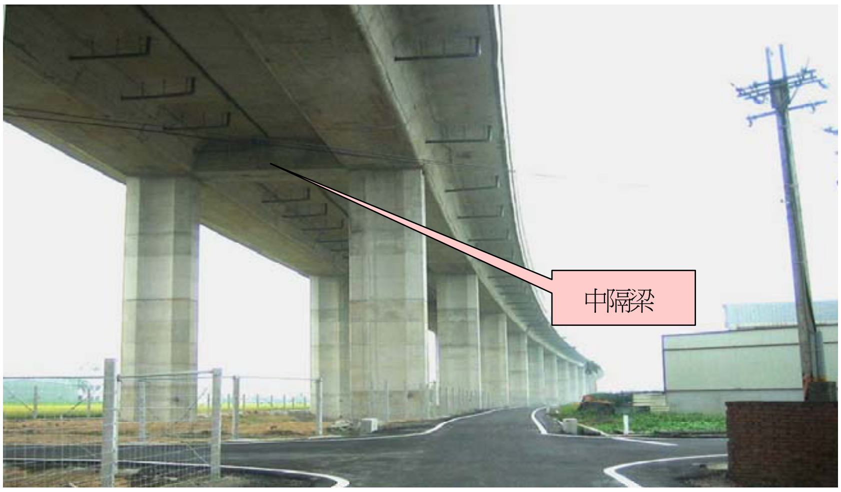

Figure 19　Photo of full-rigid-frame type viaduct (2/2)

Table 2　Full-rigid-frame bridges designed in Nantou Section of National Freeway No. 6

Lot	Bridge Name	Begin & End Station	Span Arrangement (m)	Length (m)	Height (m)	Notes
C601	Nanwufeng Viaduct (P25~P30) (P33~P53)	1K+080~1K+305 1K+570~2K+474	5@45 2(5@45)+2(2@45+2@46+45)	1,129	15~21	Pier Height 17m Girder Depth 2.5m
C602	Donshoutun interchange connection viaduct (A1~A2)	10K+147.716~ 10K+687.716	3(4@45)	540	4~20	Pier Height 12m Girder Depth 2.5m
C604	Pinlin Viaduct (span-by-span full staging II) (P28~P90)	9K+361~12K+137	(39+3@45)+6(4@45) +6(5@45)+(37+3@45)	2,776	14~22	Pier Height 15m Girder Depth 2.5m

C. LRB isolation Bridge

Seismic isolation and dissipation design was applied in New Zealand, the United States, Italy and Japan years ago, and had accumulated a considerable experience. From the past earthquake events, the isolation and dissipation devices had been proven that they were performed well for energy dissipation, and effectively reducing the earthquake damages. In recent years, Taiwan also actively focused on seismic isolation and dissipation technology and research, and had many relevant design examples. Bridge seismic isolation and dissipation design is generally placed isolation and dissipation devices in between the bridge superstructure (main girder) and substructure (abutment or pier) to reduce the seismic effect. Isolator can provide an adequate flexible stiffness to extend the bridge basic vibration period, and reduce the seismic input energy. The damper (shock absorber) is using energy dissipation mechanism to dissipate seismic energy input to avoid destroying the bridge or other components. The considerations of seismic isolation and dissipation design include bridge configuration, bridge length, pier height and foundation type. The criteria should meet the existing bearing functions and alignment demand, in addition to fulfill the seismic isolation design requirements for safety and cost reduction dual purposes. Theoretically, as long as the bridge basic period can be extended more than twice after the seismic isolation and dissipation design, and no tension on the isolation bearing, the structural system is benefited form the seismic isolation design. The energy of seismic wave is mainly located at a shorter period for condensed soil, the isolation system can shift the bridge period from this part, therefore, it can effectively reduce the seismic force. On the contrary, the energy of seismic wave is distributed in the longer period for soft soil, in this case, the isolation system is not able to reduce earthquake effectively.

Among the seismic isolation and dissipation devices, LRB (Lead Rubber Bearings, Figure 20) is currently the most commonly used isolation device. The basic components of LRB are laminated rubber (made of natural or artificial rubber) and laminated steel plates, with one or more lead rod(s). The vertical stiffness is provided by lamination rubber. For the smaller lateral loads such as wind load, braking force or small earthquake, lead rod provides sufficient lateral stiffness to reduce distortion. For the larger earthquake, the lead rod begins to yield and the lateral stiffness of bearing is significantly reduced, resulting in longer structural period to reduce the seismic force. When the LRB resists earthquakes and occurs repeated displacement, plastic deformation of lead rod creates a hysteresis damping to absorb the energy, attenuate the bridge acceleration response in the earthquake, reduce the level of deformation. The effective damping ratio of LRB is generally about 15-35%. The biggest advantage of LRB is that one single device can have a sufficient stiffness in normal time and small lateral stiffness in large earthquake. LRB can also provide sufficient damping function, coupled with the advantages of simple structure, clear mechanics behavior and easy manufacture.

Lots C601, C607 and C608 of the project were using LRB because the near-fault effect of Chelungpu fault, and/or low vertical design alignment (average pier high <10m±). LRB could extend the period of bridge and lower down the design seismic force, so that the size of pier and foundation could be reduced. The LRB bridges designed in Nantou Section of National Freeway No.6 were shown in Table 3 and Figure 21.

Table 3 LRB Bridges designed in Nantou Section of National Freeway No. 6

Lot	Bridge Name	Length (m)	No. of Piers	No. of LRB (Set)	Ave. Pier Hight (m)	Notes
C601	Nanwufung Viaduct P1~P25	1,080	40	80	±9	2 separated ways, 4 lanes
C607	Doosan No.1 Viaduct PE15~AE2 PW15~PW21	256 263	10	20	±9	2 separated ways, 4 lanes
C608	Mei Hsi Bridge A1~A2	252	10	20	±10	2 combined ways, 4 lanes

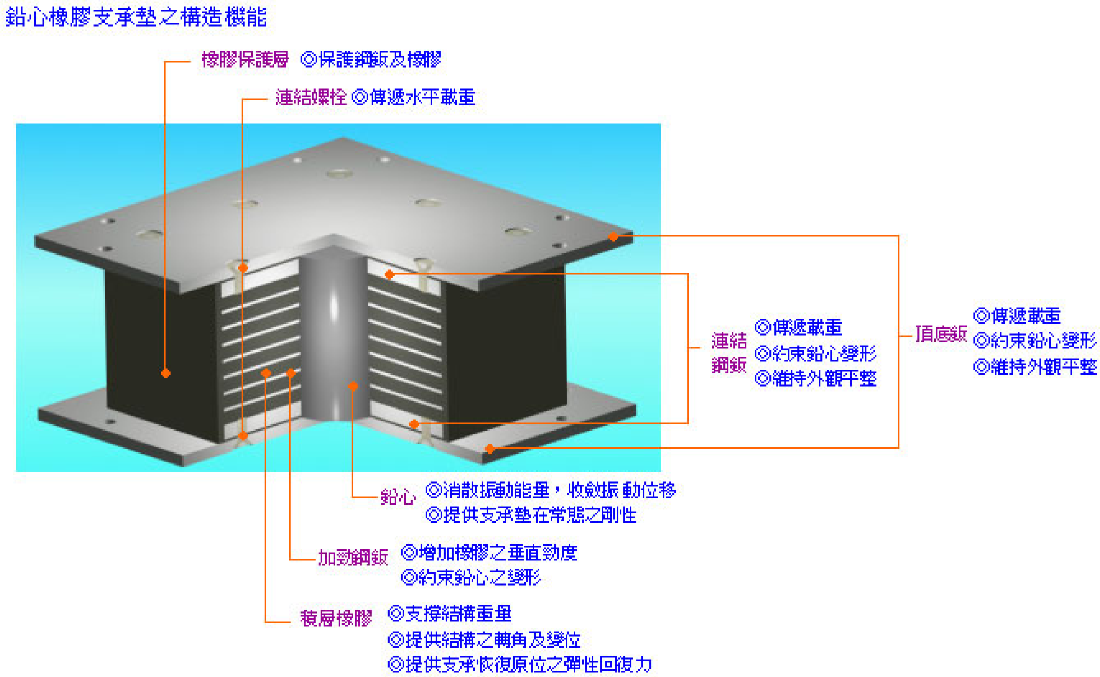

Figure 20 Schematic drawing of Lead Rubber Bearing

Figure 21 Photo of Lead Rubber Bearing

D. Other concerns

The steel shear box on the top pf pier is designed to take the horizontal seismic force. In order to prevent the bridge from falling, there is sufficient support length designed on the dividing pier. In additional, anti-seismic bracing (Figure 22) is used for bridge falling presentation.

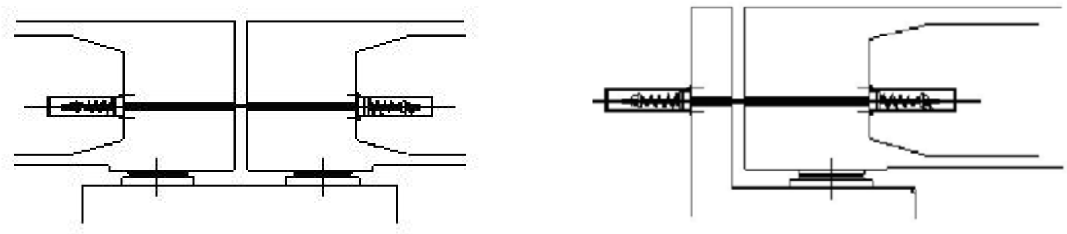

Figure 22 Schematic drawing of anti-seismic bracing

(3) SCC (Self-Compact Concrete) for piers

The SCC has the ability that "the pouring process without imposing any vibration tamping, the concrete can be completely filled reinforcement gap and all corners of the formwork by their own liquidity and performance". A larger amount of pier reinforcement was designed to meet the demand of seismic design specification. Densely arranged steel rebar caused concrete pouring work more difficult and led some casting quality problems. Some of piers was using self-compact concrete (SCC), so the concrete quality could fulfill the design needs (Figure 23, 24).

However, SCC is more sensitive than conventional concrete for the ratio change, in order to get the quality of concrete and have the best performance of SCC, engineers need to fully understand the SCC characteristics. There are four characteristics of SCC, (i) SCC has high mobility; (ii) anti-segregation (maintain the homogeneity of concrete during the flow process); (iii) self-compact ability (passing through the rebar and filling the gap of formwork effectively) and (iv) economics (no vibration needed, reducing construction labor costs). SCC should be tested by actual model to find out the appropriate mix ratio, pouring procedure and other associated notes.

Figure 23　Photo of self-compact concrete, high slump

Figure 24　Photo of pier using self-compact concrete, smooth surface

5. Conclusion

Bridges have been playing as a traffic connection of the two arteries in the human civilization. Taiwan situated in high-risk earthquake zone, bridges seismic-resistant construction technology is progressed with the times. Since the 921 Chi-Chi earthquake, advanced engineering and research units in Taiwan have actively taken into account of Europe and USA standards, to develop succession edition of Taiwan "Highway Bridges Seismic Design Specifications". Now the seismic design code has considered the near-fault effects for domestic bridge engineers as a design guideline.

The evolution of Taiwan's bridge seismic design is begun from elastic design to plastic design or seismic isolation design, also changed from simple beam type structure to the better seismic resistant continuous beam in rigid frame type, and incorporated with anti-falling measures and/or devices, such as increasing support length, steel shear box, anti-seismic bracing, etc. The bridge location according to the route, size of the project, through or near faults, geological condition, environment, landscape and economic factors are assessed comprehensive in order to select the most appropriate structural type of bridge(such as steel bridge, full-rigid-frame bridge, LRB isolation bridge, enhancing self-stability of free cantilever girder avoiding falling, etc.) or built the road in embankment. New construction methods and new technologies are implemented in Taiwan, hoping that the bridge seismic resistant construction technology in Taiwan can meet world class level or even better.

6. References

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