Review of Economic Evaluation of Base isolation structure

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Abstract

Earthquake disasters have caused serious economic losses and social impacts. Improving the seismic performance of civil engineering structures is the most direct method to reduce the economic losses and casualties of earthquake disasters.The current base isolation technology is considered to be one of the most effective ways to improve the seismic performance of the structure, but its economy is not clear.Therefore, this paper summarizes and analyzes the economic evaluation of the initial construction cost, seismic economic loss, life cycle cost and value engineering analysis of the base isolation structure.It is concluded that the economic evaluation of the basic isolation structure still has defects, and the economic evaluation index system and evaluation model without scientific and reasonable standards are not formed.Therefore, the economic analysis of the basic isolation structure is still the focus of current research.

Keywords

Review, Economic Evaluation, Base isolation structure.

1. Introduction

As is known to all, earthquakes are sporadic natural disasters. Earthquakes with higher magnitudes have a large destructive power and wide spread, often causing a large number of casualties, economic losses and widespread social impact. Since the beginning of the 20th century, global earthquakes have occurred frequently, resulting in rapid economic losses. Table 1-1 [1] lists the many earthquakes and their losses since the 20th century. It is concluded from the table that China is a country with relatively high earthquakes. Located at the junction of the Asia-Europe plate and the Indian Ocean plate, Sichuan Province belongs to the Mediterranean-Himalayan volcanic seismic zone, with active crust and more earthquake-prone areas. In the past 6 years, there have been 621 earthquakes of magnitude 3 or above in Sichuan. Among them, the earthquakes with large losses and serious losses are mainly the Ya'an Lushan earthquake in 2013 and the Jiuzhaigou earthquake in 2017 [2].

Table 1-1 Multiple earthquakes and their losses

Years	Earthquake name	Magnitude	Death toll	Economic losses	Location
1976	Tang Shan Earthquake	7.8	About 243,000	Missing data	China
1985	Mexico City Earthquake	8.1	About 5000	About $5 billion	Mexico
1989	Loma Preta	7.1	About 60	About $7 billion	America
1994	Northridge Earthquake	6.6	About 60	About $30 billion	America
1995	Hanshin Earthquake	7.2	About 5500	About $100 billion	Japan
1999	Chichi Earthquake	7.6	About 2400	About $9.2 billion	China

2008	Wenchuan Earthquake	8.0	About 87000	About 845.1 billion yuan	China
2010	Chile Earthquake	8.3	About 560	About $20 billion	Chile
2010	Yushu Earthquake	7.1	About 2800	About 26 billion yuan	China
2011	Tokyo Earthquake	9.0	About 20000	About $200 billion	Japan
2011	Christchurch Earthquake	6.3	About 180	About $25 billion	new Zealand
2013	Earthquake in Yaan	7.0	About 200	About 170 billion yuan	China
2016	New South Island Earthquake	7.8	2	About $1.5 billion	new Zealand
2017	Jiuzhaigou Earthquake	7.0	25	About 22.45 billion yuan	China
Note: Some earthquake statistics are derived from Baidu search summary.					

The Ya'an earthquake and the Jiuzhaigou earthquake have brought enormous harm and burden to the country and the people, both economically and socially. From the disaster scenes after the earthquake, Figure 1-1 [3] and Figure 1-2 [3], it can be seen that the most direct cause of economic losses and casualties is the destruction and collapse of civil engineering structures. Therefore, improving the seismic performance of civil engineering structures is the most direct and effective way to reduce the economic losses and casualties of earthquake disasters. At present, structural vibration control is one of the most effective methods for improving structural seismic performance. The passive control technology based on energy consumption and filtering principle (isolation and energy dissipation technology) is the most mature and widely used method. In particular, the isolation technology has been widely used in housing reconstruction and structural reinforcement in Wenchuan earthquake reconstruction, and the isolation structure has basically corresponding specifications or standards in terms of product, design, construction and acceptance. The current isolation technology not only guides the design and construction, but also gradually standardizes the standardization and withstands the actual earthquake test. It is proved that the isolated structure has good damping effect in the earthquake, and the maximum horizontal acceleration of the isolated structure is only 1/3~1/5 [4] of the non-isolated structure (the traditional seismic structure). However, the construction transaction market of the isolated structure is still in its infancy, and the owners, designers, construction engineering authorities and other parties have a one-sided and doubtful understanding of their economics, and the acceptance of the construction transaction market is not high. Dong Yu [5-6], Xu Ruonan [7], Zhang Yin [8], Wei Caixia [9], Ma Yuhong [10], Wang Wei [11], Chen Chong [12] and other economic development of isolated structures Part of the research, but has not yet formed a scientific and reasonable index of economic evaluation indicators and evaluation models, so the economic analysis of the isolated structure is still the current research hot spot.

Figure 1-1

Figure 1-2

2. Research Status of Economic Evaluation of Isolated Structures

According to the literature reviewed, only the current status of economic evaluation of the base isolation structure is explained. The current economic evaluation of the basic isolation structure focuses on the following aspects: initial construction cost of base isolation structure, seismic economic loss of base isolation structure, life cycle cost of base isolation structure and value engineering analysis of base isolation structure(Functional and cost analysis). Here, the current status of economic evaluation of the base isolation structure will be described from the following four aspects.

2.1 Initial construction cost of base isolation structure

For the initial construction cost of the base isolation structure, domestic and foreign researchers compare the initial construction cost of the isolated structure with the initial construction cost of the non-isolated structure(Traditional seismic structure). The main factors that affect the initial construction cost of the isolated structure are summarized as follows: site type, seismic fortification category, seismic fortification intensity, type of structure, number and height of buildings, building area, building materials, whether there is a basement, selection and arrangement of seismic isolation bearings, isolation design and construction level, special purposes, etc. The isolated structure of the base-isolated structure without a basement is designed compared to the unseparated structure, the base isolation structure increases the isolation bearing, the damping device, the upper and lower buttresses of the seismic isolation bearing, the connecting parts and the embedded parts, the seismic isolation layer conversion beam plate, etc. in the isolation layer; and in accordance with Articles 12.2.5 and 12.2.7 as stated in the provisions of the Code for Seismic Design of Buildings GB 50011-2010 (2016) [14], the upper structure above the isolation layer after the isolation can appropriately reduce the design of the fortification intensity. According to this, the initial construction cost of the base isolation is increased and decreased compared with the non-isolated structure, as shown in Table 2-1[10] and 2-2 [10].

Table 2-1 Increasing cost analysis of isolated structure

Project	Specific situation
Upper and lower parts of the isolation layer	If the isolation layer is located in the lower part of the basement, the amount of excavation around the earth and the cost of adding a retaining wall. Upper and lower structure of the isolation layer: An RC conversion beam and a cast-in-place RC plate of at least 160 mm thickness are added to the top of the isolation layer; Supporting the upper and lower piers; When the isolation layer is disposed at the top of the basement or at the top of the large chassis, the lower structure increases the cross-section to meet the requirements of the embedded stiffness ratio.
Isolated layer	Additional design fees (including isolation design fees, corresponding isolation measures design fees and special review fees). Isolator, damper or wind-resistant device, tensile device cost. Flexible connection of pipelines, other construction measures. Seismic layer construction and installation costs.

Table 2-2 The reduced cost of the upper structure for base-isolated system

Project		Specific situation
Structural part	Structural reduction	Reduction of the section of the member (beam, column, shear wall, etc.);Save the amount of steel and steel hoop required for ductile design; SRC structure can be changed to RC structure.
	Structural component standard	Component section is easy to unify

Non-structural part	Reduced inter-layer deformation reduces decoration costs	Reduced interior and exterior decoration connections; reduction of door and window frames; improved waterproofing of expansion joints.
	Save material	The shape, thickness and amount of reinforcing steel of the interior and exterior decoration members are reduced, and the cross-section of the force-receiving members for interior and exterior decoration is reduced.
	Equipment and its seismic strengthening members are reduced	Improved vibration resistance of raised floor and ceiling; elevator, machine room and its stressed members, anchor bolts; reduced foundation.
	Simplification of decoration materials and equipment pipeline connections	Reduced number of equipment pipeline support members; coordination of interlayer deformation.

Based on the above, the research on the initial construction cost of the base isolation structure at domestic and foreign mainly includes: Ma Yuhong and Chen Ruihai [10 15] proposed the initial cost commonality and personality evaluation model of the base isolation structure. It is concluded that the initial cost of the base isolation structure is generally higher than that of the non-isolated structure when the superstructure does not reduce the intensity and only increases the safety reserve; from the experience of Japan's earthquake isolation engineering [17],For structures below 8 floors, the initial construction cost of the isolated structure is 4% to 5% higher than that of the traditional seismic structure; with a structure of about 10 layers, the cost of the two design schemes is basically the same; in the case of 15 to 20 layers, the cost of the isolated structure can be reduced by 5%; Naeim.F et al. [18] conducted statistical analysis on some buildings in the United States that used basic isolation technology, and concluded that the direct construction cost of isolated buildings increased by about 5% to 10% compared with traditional seismic buildings; Some researchers such as Dong Yu [5], Penny [19], Guo Qijian [20], Xu Ruonan [7], and Miu Chi [21] have compared the direct construction costs of isolated structures and non-isolated structures, it is concluded that the initial construction cost of the isolated structure is generally about 1% to 5% lower than that of the non-isolated structure without improving the structural safety reserve; Other researchers, such as Wei Caixia [9] and Wang Wei [11], cut through the technical and economic perspectives and compared the initial cost of the isolated and non-isolated structures, buildings that are isolated from the base will increase the initial cost of the structure.

2.2 Seismic economic loss of base isolation structure

The seismic economic losses for the base isolation structure are mainly divided into direct economic losses and indirect economic losses. Direct economic loss refers to the loss of damage to buildings or structures themselves, the loss of indoor property (items, instruments, equipment, etc.) and the loss of natural resources; indirect economic loss refers to the loss of economic benefits caused by the loss of use function after the destruction of the enterprise building, which can be divided into the loss of production and the loss of industrial association [10]. The main researches on seismic economic loss of base isolation structures at home and abroad are as follows: Ma Yuhong, Chen Ruihai [10, 15, 16], Dou Weilin [23] introduced the mathematical fuzzy comprehensive evaluation into the loss expectation evaluation of the base isolation structure, and discussed the composition and calculation method of the loss cost of the isolated structure; Dong Yu [5], Miu Chi [21], Ma Yuhong, Yuan Chao [22] and so on use the literature statistics, and compared with the non-isolated structure, it is concluded that the use of basic isolation can reduce the economic loss of the earthquake by about 8% to 52%.

2.3 Life cycle cost of base isolation structure

The total life cycle cost of the base isolation structure refers to the total cost of the basic isolation structure from conception, design, construction, use, and dismantling. It mainly consists of three parts:

Initial cost or initial cost, inspection maintenance cost and failure cost(Including direct losses, indirect losses, casualties, etc.). At domestic and foreign, the research on the life cycle cost of the base isolation structure mainly includes: Dou Weilin [23], Zhang Yin [8], Wei Caixia [9], Dang Yu [6], Ma Yuhong, Chen Ruihai, Yuan Chao [10, 15,16, 22] evaluated the basic isolation technology from the perspective of technology and economy, respectively "Investment-benefit criterion", functional relationship and mathematical fuzzy comprehensive evaluation method to construct a full life cycle economic evaluation model of the base isolation structure, and calculate the full life cycle cost of the base isolation structure and compare it with the full life cycle cost of the non-isolated structure, it is concluded that the comprehensive economic benefit of the base isolation structure is much higher than that of the non-isolated structure; in addition, Lin Zhimin [24] and Chen Chong [12] built the economic evaluation framework and evaluation index system of the isolation structure based on the life cycle cost theory and economic evaluation theory of the construction project, and a grey comprehensive evaluation model based on grey system theory is established.

2.4 Value Engineering Analysis of Base Isolation Structure

For the value engineering analysis of the base isolation structure; Jiang Yong [25], Wu Yingxiong [13], Jiang Dongheng [26] introduced the value engineering method to analyze the economics of isolated buildings, and established the evaluation index system for seismic isolation decision-making function from the three perspectives of applicability, safety and comprehensiveness. Using fuzzy comprehensive analysis method for functional evaluation, based on the full life cycle method to develop cost analysis, comprehensively establish the value engineering method evaluation model of isolation and non-isolation scheme; it is concluded that although the cost of the isolation design is slightly improved, the function is improved and the overall value is improved.

3. Summary

The above-mentioned researchers conducted a series of studies on the economics of the base isolation structure, and the relevant economic evaluation indicators, economic evaluation systems and economic evaluation models have taken shape. But all belong to the static economic evaluation, and the investment in the actual project is a dynamic process affected by various factors. It is also necessary to consider the dynamic factors such as the opportunity cost, sunk cost and time value of the funds. Therefore, the existing economic evaluation of the base isolation structure is directly used to guide the actual project and still has certain defects. The economic evaluation of the base isolation structure is still a long way from the formation of scientific and reasonable economic standards and evaluation models. It still needs further research and discussion.

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