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# Research on Earthquake Failure Pattern Recognition and Reinforcement of RC Bridge Columns

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## Abstract

**With the frequent earthquakes in recent years, bridge piers, as the weak link in the seismic resistance of Bridges, have attracted extensive attention from scholars at home and abroad. In this context, combined with the summary of the seismic damage mechanism of reinforced concrete bridge piers in many major earthquakes at home and abroad, with reference to the study of domestic and foreign scholars on the seismic behavior of reinforced concrete bridge piers, a systematic analysis is carried out. The reasons and process of three forms of damage of reinforced concrete bridge pier under earthquake action are obtained, and the advantages and disadvantages of existing seismic reinforcement measures and the applicable conditions are summarized.**

## Keywords

**Reinforced concrete; Bridge columns; Earthquake; Failure pattern recognition; Reinforcement.**

## 1. Introduction

Reinforced concrete bridge pier is widely used in China, which has the advantages of strong bearing capacity, large stiffness and good corrosion resistance, but its ductility is relatively poor. And our country is an earthquake prone country. After the tangshan earthquake, wenchuan earthquake and ya 'an earthquake, the damage problem of reinforced concrete bridge piers in major earthquakes is becoming more and more obvious. In order to solve this problem, the ductile seismic idea is put forward to absorb earthquake energy through structural deformation, so as to resist the damage caused by earthquake[1-3]..

## 2. Identification of failure mode of reinforced concrete pier

At present, the determination of seismic failure mode of pier mainly depends on the relationship between shear demand and shear capacity of plastic hinge section. According to scholar ZHU L, shear failure occurs when. When bending failure occurs; When, bending shear failure occurs [4]. In addition, scholar Sezen H proposed that considering the influence factors of displacement ductility, the reduction coefficient k was introduced to reduce the shear bearing capacity of reinforced concrete piers. When the displacement ductility coefficient was 2, k = 1. When the displacement ductility coefficient is 6, k=0.7; The rest is determined by linear interpolation. When the shear demand is greater than the shear capacity, shear failure occurs; At that time, bending failure occurred; At that time, bending shear failure occurred [5]. In the above formula, the shear demand of the cross section is obtained from h, the shear span; Is the maximum bending moment of reinforced concrete pier section, which is determined by the moment curvature analysis of the section[6].

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# 3. Reinforced concrete pier failure pattern

## 3.1 Bending failure

In the process of reinforced concrete pier failure, because the flexural strength of the section is less than the shear strength, the failure of the reinforced concrete pier is mainly controlled by the flexural strength of the section. The failure mainly focuses on the plastic hinge area at the bottom of the bridge pier, which is dominated by the yield of longitudinal reinforcement, the failure of stirrup and the crushing of axial concrete. The seismic performance is ideal, belongs to the ductile failure[7].

FIG. 1 bending failure of pier

Destruction process:

(1) bending cracks begin to occur on the protective layer of reinforced concrete bridge piers.

(2) with the continuous development of cracks, the protective layer of concrete starts to fall off.

(3) the longitudinal bar yields and the plastic hinge area is formed at the bottom of the reinforced concrete pier.

(4) the deformation at the bottom of the pier increases, and the plastic hinge length increases.

(5) the longitudinal bar will yield or break under pressure, and the axial concrete will be crushed.

## 3.2 Shear failure

Shear failure of reinforced concrete bridge piers usually occurs when the section size is too large or the shear span is too small or the hoop is insufficient. In the process of reinforced concrete pier failure, the shear strength of section is less than the flexural strength, so the failure of reinforced concrete pier is mainly controlled by the shear capacity. The plastic hinge area at the bottom of the pier will form an obvious shear plane when the pier is damaged[8].

Failure characteristics: stirrup yield, longitudinal reinforcement did not yield, the pier plastic deformation is small, belongs to brittle failure.

FIG. 2 shear failure of bridge pier

Destruction process:

(1) bending cracks begin to occur on the protective layer of reinforced concrete bridge piers.

(2) with the expansion of cracks, oblique shear cracks gradually appear.

(3) the cracks continue to increase, the stirrup yield, the bridge pier shear failure.

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### 3.3 Bending shear failure

Bending shear failure mainly occurs under the coupling action of bending and shear failure.

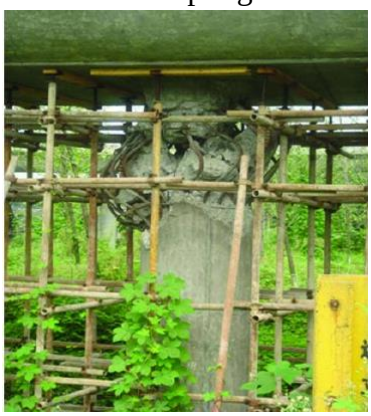

FIG. 3 bent shear failure of bridge pier

Destruction process:

(1) the protective layer falls off and the steel bar shows.

(2) when the center concrete is crushed, the longitudinal bar and stirrup yield.

(3) shear failure in plastic hinge area[10].

## 4. Seismic reinforcement measures

### 4.1 Section augmentation method

This method mainly USES the increase of section size and amount of reinforcement to improve the stiffness, strength and stability of bridge piers. Because of its convenient construction, it is widely used in the reinforcement of various components. The disadvantages are large amount of construction work, long maintenance cycle, more space occupied, the destruction of the construction site environment is more serious. In addition, according to the construction process can be divided into: shotcrete mortar reinforcement method through the pressure gun will be directly sprayed fine stone concrete in the pier around the reinforcement network, the final use of coating for outer protection. The method of concrete outsourcing reinforcement is to add longitudinal bar and stirrup bar around the pier and increase the cross section area by means of outsourcing concrete[11].

### 4.2 Embedded reinforcement

The embedded reinforcement method is to improve the structural performance of the pier by adding reinforcement rods to the damaged pier and then using resin bonding materials to make it work together with the pier as a whole. Compared with section enlargement method, this method has the advantages of higher construction efficiency, simpler construction technology, better corrosion resistance, higher safety and more economical and reasonable[12].

### 4.3 External prestressing reinforcement method

The method of external prestress reinforcement can reduce the crack load of the pier and improve the bearing capacity of the concrete pier. External prestressing method can not only repair existing cracks, but also effectively avoid new cracks. It is often used in combination with FRP to provide longitudinal and lateral prestress for concrete piers[13].

### 4.4 Steel casing reinforcement method

The steel casing reinforcement method is to provide transverse restraint by using steel casing wrapped around reinforced concrete pier. The advantage of steel casing reinforcement method is that it can greatly improve the shear strength, ductility and axial bearing capacity of reinforced concrete on the basis of increasing the section size of the members. The disadvantage is that the consumption of steel is large, the construction machinery is more complex. In engineering application, there are two

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methods, dry and wet, according to whether the cementing material is filled or not. Dry reinforcement is to surround the steel plate directly on the bridge pier, without filling and bonding materials, and no shear force and tension can be transferred between the steel plate and the bridge pier interface. Wet reinforcement method is to reserve bond joints between bridge piers and steel plates, and then fill them with bond materials, so that the two can be a good bonding into a whole, common force[14].

### 4.5 Polymer impregnated concrete reinforcement method

The method of polymer impregnated concrete reinforcement mainly USES the small hole structure of concrete material to immerse methyl methacrylate organic matter into the concrete so as to increase the cohesion of the concrete and reduce the stress concentration caused by cracks and pores. This method does not change the shape of the structure and does not have the problem of stress hysteresis. The main disadvantages are high cost and complex production process[15].

### 4.6 "Dog bone type reinforcement" method

The "dog bone reinforcement" method restores the bearing capacity of the piers by replacing the damaged longitudinal ribs. The design principle of this technology is to ensure that the tensile strength of its section is about 95% of the original longitudinal bar strength, so as to prevent the damage of steering between the bar and longitudinal bar due to the high strength[16].

### 4.7 FRP sheet strengthening method

The FRP sheet method can limit the deformation of concrete in the core area of reinforced concrete pier. Sticking vertical FRP can improve the flexural ability of reinforced concrete piers. Therefore, when FRP sheets are used for reinforcement, the adhesion should be carried out along the direction of force, so as to achieve the goal of joint force between FRP sheets and concrete piers. In addition, the effect of reinforcing different pier sections is different. In the reinforcement of reinforced concrete pier with circular section, because the FRP sheet has good contact with the pier and can produce uniform and effective constraints, the reinforcement of this section has obvious effects on the strength and ductility. The fulcrum of the four corners of reinforced concrete piers with square or rectangular sections is the main constraint point for reinforcement, so the chamfering radius should be larger to achieve the optimal reinforcement effect[17].

### 4.8 Reinforcement by wrapping wire

The method of wire winding reinforcement is to use high strength steel wire rope to wind on the surface of reinforced concrete pier, using the restraint principle similar to the hoop reinforcement, and finally to obtain the purpose of strengthening the concrete pier. The method of wire - wound reinforcement is suitable for reinforced concrete piers which have great demand on bearing capacity and seismic performance. The advantages of the method of wire reinforcement are less consumption of high strength wire rope and less change of section size after reinforcement. At present, the research on the method of wire winding reinforcement in Japan is relatively mature and can be widely used in the seismic reinforcement of pier structures. The research on the method of wire wrapping reinforcement in China is not mature[18].

## 5. Looking forward

Because of the frequency of earthquakes in recent years, and the earthquake scale is also larger. Although a variety of reinforcement measures under different conditions have been explored, there are still some shortcomings.

(1) in the reinforcement of concrete bridge piers after the earthquake, there are disadvantages such as high cost and complex overall process.

(2) the damage to the original environment is serious, and the utilization efficiency of materials is low.

(3) the time period of reinforcement is long, which cannot better meet the security needs of personnel and property after the earthquake.

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Therefore, it is urgent to study more simple, accurate, efficient and low-pollution reinforcement measures.

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