

## Experimental study on the seismic performance of PUFA confined RC bridge pier

Fangda, Hao<sup>1, a</sup>, Lianzhen, Zhang<sup>2, b</sup>

<sup>1</sup>Harbin Institute of Technology, Harbin, Heilongjiang Province, China, 150006

<sup>2</sup>Harbin Institute of Technology, Harbin, Heilongjiang Province, China, 150006

<sup>a</sup>1367297350@qq.com, <sup>b</sup>zhanglianzhen79@163.com

**Keywords:** Seismic Performance, PUFA, Bridge Pier, Strengthened, Pseudo-static Test

**Abstract:** Polyurethane Fly Ash (PUFA) is a new type of environmentally friendly material, with high strength, light weight, easiness of construction, and many other advantages. In this paper, according to the ductility design method, PUFA is bonded to the surface of the existing reinforced concrete bridge pier reinforcement to improve the aseismic capability of bridge pier. Through experiments and numerical simulation analysis, the article will evaluate and analyze the seismic resistance of PUFA. Several experiment samples are made out and tested in the lab. The relevant data is collected and analyzed. At the same time, using finite element analysis software OpenSees, the numerical simulation analysis of the test process are carried out, the numerical simulation results are in good agreement with the test results. Test and numerical simulation results show that axial compression ratio increases the ductility of the structure after the reinforcement of PUFA materials and after using PUFA, the maximum bearing capacity and elastic stiffness of the RC bridge pier have been improved.

### Introduction

The earthquake damage of the bridge indicates that the lower structure is the main load-bearing structure, and the destruction of the bridge pier or large longitudinal deformation directly causes continuous collapse of the whole upper structure for girder bridge and continuous arch bridge. The bridge pier is the only vertical force member of the single-tower bridge. After the destruction, it directly causes the collapse of the whole structure, making it difficult for bridges to be repaired quickly after the earthquake [1]. One of the important issues of the current bridge technology workers is that how to use the appropriate reinforcement and maintenance method to improve the seismic capacity of piers in active service and ensure that when the earthquake strikes, the structure of the damage will not occur big damage.

Over the past two decades, many scholars have proposed a variety of bridge pier reinforcement methods, such as concrete enlarging section method, FRP wrapping method, steel plate reinforcement method and so on [2,3]. As for the concrete enlarging section method, the interface of old and new concrete has poor adhesion and the constraint ability of the core concrete is generally limited, and it also increases the structure self-weight. The FRP wrapping method is of high cost. It is necessary to use structural glue to paste the interface and the process is complex. In addition, the interface bond quality is not easy to guarantee. The steel plate reinforcement method needs to embalm the steel plate and steel plates are difficult to surface with concrete surface.

In order to overcome the shortage of the existing pier reinforcement methods mentioned above, this paper puts forward a new type of composite material PUFA method of seismic strengthening of reinforced concrete bridge piers. The material is of high quality and light quality. It is actively bonded with concrete without any additional structural adhesive tapes. It can mix and pour on site like concrete, and the reinforcement process is simple and reliable [4,5]. In this article, we have made seven reinforced concrete piers, one as a contrast column, and the other six were reinforced with different PUFA reinforced thickness and axial pressure ratio. And then we carried out the ultimate load test. Test and numerical simulation results showed that axial compression ratio increased the

ductility of the structure after the reinforcement of PUFA materials and after using PUFA, the maximum bearing capacity and elastic stiffness of the RC bridge pier have been improved.

### Test design

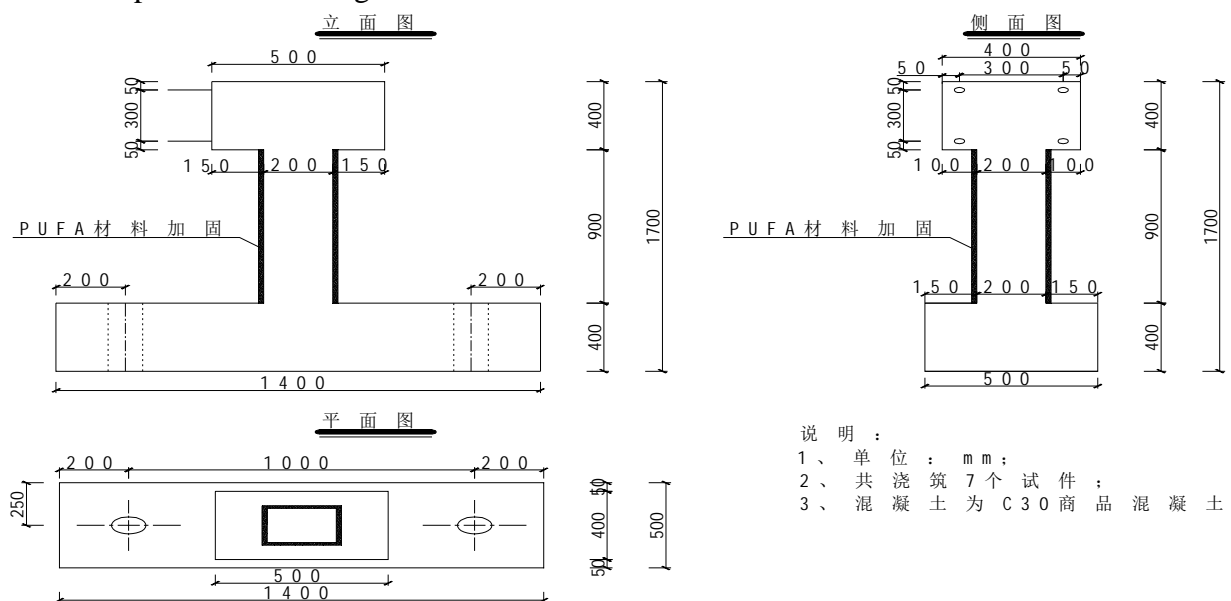
Seven reinforced concrete columns were designed in the laboratory, including six PUFA reinforced specimens and one unreinforced comparison test. The reinforcement specimens were tested by different reinforcement thickness and different axial compression ratios. The cross section of the test section was 200 by 200 mm and the height was 900mm. HRB335 steel with a diameter of 12mm was used in vertical. The stirrup adopted the 8mm HPB235 reinforcement, and the stirrup spacing was 10mm. The base of the specimen was 1400mm x 500mm x 400mm cuboid reinforced concrete block, and the internal longitudinal and stirrup were HPB235. The top of the body was made of a cuboid of 500mm x 400mm x 400mm, with a HPB235 reinforced structure with a diameter of 8mm. The concrete label was C30. The reinforcement of colum1-colum7 is shown in table 1.

**Table 1**

A summary of the specimens reinforcement

specimen	the original cross-section size	the thickness of reinforced	axial compression ratio
Colum1		without reinforcement	0.2
Colum2		10mmPUFA reinforcement	0.3
Colum3		15mmPUFA reinforcement	0.2
Colum4	cross section 200mm×200mm, height 900mm	15mmPUFA reinforcement	0.3
Colum5		15mmPUFA reinforcement	0.4
Colum6		20mmPUFA reinforcement	0.3
Colum7		2mm steel angle, 15mmPUFA reinforcement	0.3

The test sample is shown in figure 1.



**Fig. 1.** Component reinforcement diagram (unit: mm)

Polyurethane Fly Ash (PUFA) is a new type of environmentally friendly material, with high strength, light weight, easiness of construction, and many other advantages. This material does not require any other interface binders and it can be bonded to the existing concrete surface only by the

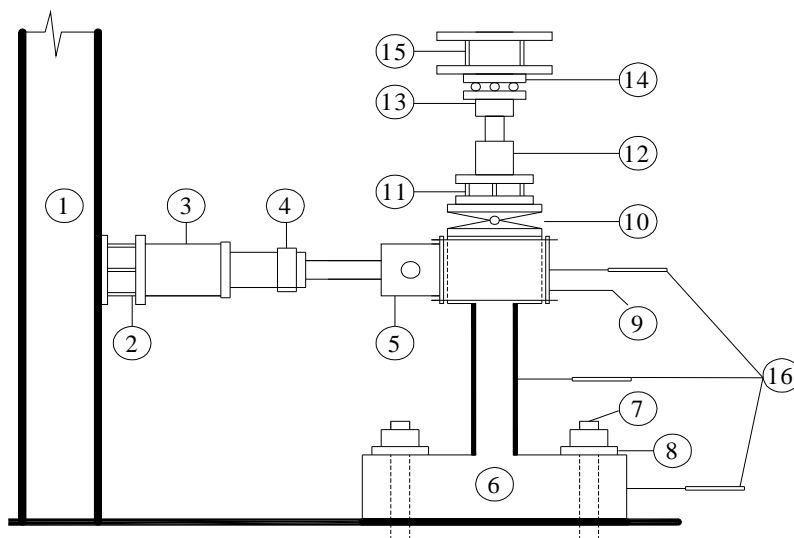
adhesion of the material itself. It has overcome that the previous steel plate reinforcement and FRP reinforcement require other bonding materials. It effectively avoids the problem of interface stripping. The PUFA is mainly composed of two materials: PolyUrethane and Fly Ash. They are mixed and solidified according to proportion. And it has the advantages of high strength and high elasticity. The hardness of the new material is between 10 and 100 irhd. The mechanical parameters of PUFA material used in this test are shown in table 2.

**Table 2**

PUFA material parameters table

density	compression test	compressive	bending tensile test
$\gamma$	intensity $f_c$	modulus of elasticity $E_c$	Intensity $f_{bt}$
$t / m^3$	$N / mm^2$	$\times 10^4 N / mm^2$	$N / mm^2$
1.4	62	0.63	24

The test load was carried out by quasi static test load tester. It adopted equal displacement control and hierarchical loading. The displacement of each step was 3mm with reciprocating cycle. The loading device is shown in figure 2.



1.Shear wall 2.beam counterforce 3.Push-pull jack 4.load sensor 5.connection hinge 6.test piece 7.anchor bolt 8.Pressure beam 9.thrust frame 10.vertical rotation hinge 11.vertical plate 12.vertical jack 13.vertical sensor 14.block 15.vertical anti-force frame 16.displacement meter

**Fig. 2.** Test loading device

After the debugging device, the load was tested. During the test, we observed the experimental phenomena and recorded horizontal loading, deflection, strain, crack width and other test data. We should try to eliminate external factors that affect the test.

## Test results

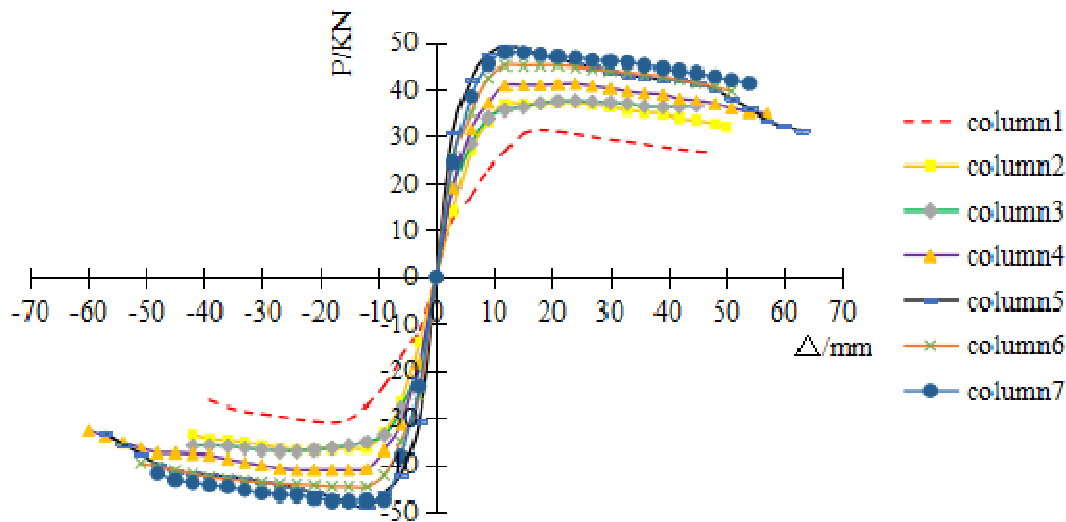
The purpose of this test was to test the ability of the concrete pier to improve the earthquake bearing capacity after the reinforcement of the material. The test results are summarized in table 3. Fig. 3 shows the load displacement skeleton curve of seven components.

**Table 3**

Summary of test results

specimen number	yield load $F_y$ /kN	yield displacement $x_y$ /mm	maximum load $F_m$ /kN	displacement of maximum load $x_m$ /mm	ultimate load $F_u$ /kN	limiting displacement $x_u$ /mm	ductility factor $m_\Delta$
Column1	26.08	11.51	31.24	16.77	26.55	45.61	3.96
Column2	32.74	8.78	39.72	12.00	33.76	53.14	6.05
Column3	33.07	8.58	37.40	24.92	31.79	55.59	6.48
Column4	35.37	8.14	41.02	13.37	34.87	55.06	6.77
Column5	43.97	6.26	50.45	13.37	42.88	42.86	6.85
Column6	38.26	7.30	45.04	11.60	38.28	54.80	7.51
Column7	41.65	7.27	47.75	9.93	40.59	57.64	7.93

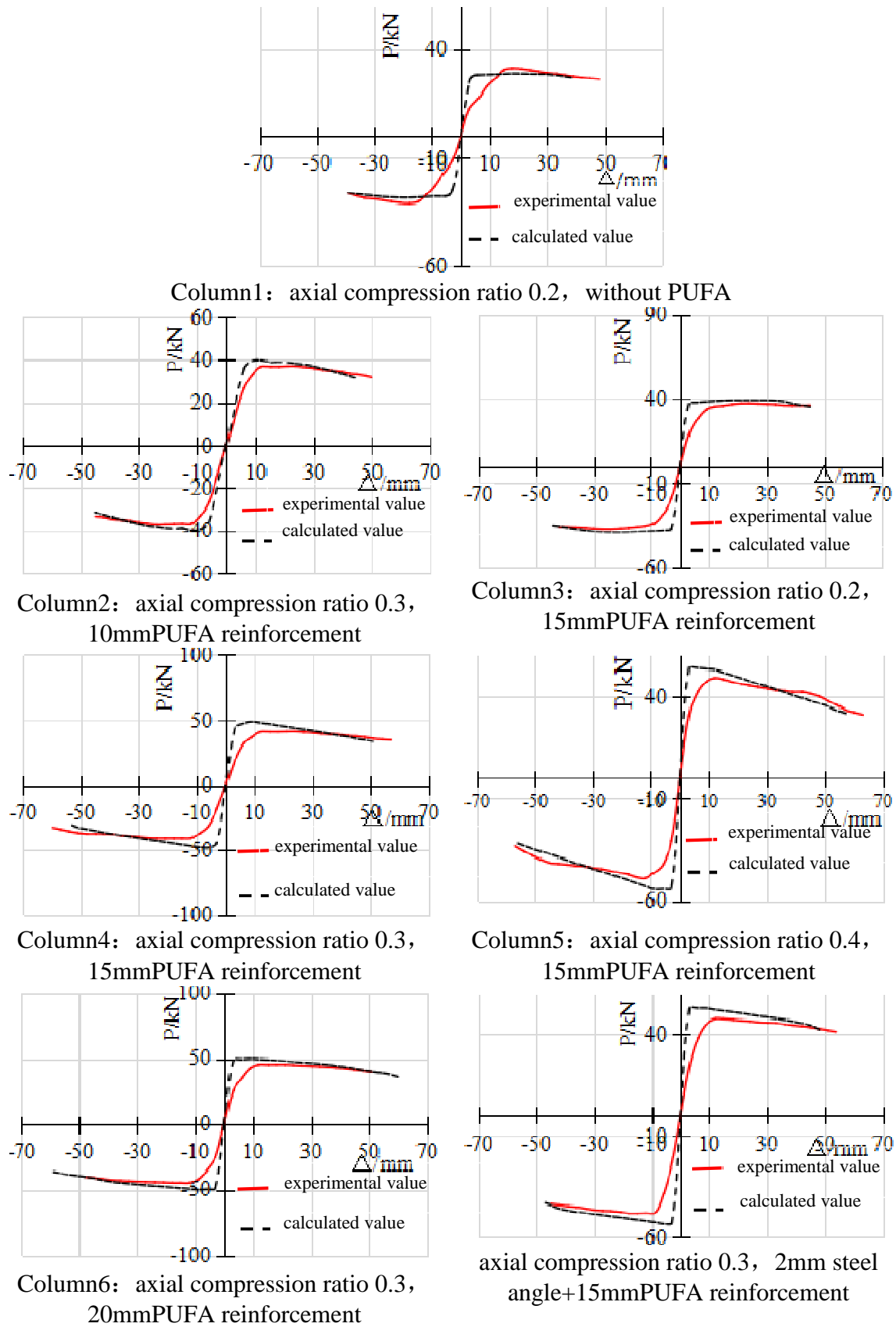
As can be seen from table 3, the ductility of concrete pier column has been improved after reinforcement of PUFA materials. When PUFA material was thick and thin, the ductility of the specimen can be greatly increased by applying the material of PUFA. With the increasing of the reinforcement thickness of PUFA materials, the degree of ductility of the specimens gradually decreased, rather than the linear growth. Therefore, when the PUFA material is used for seismic reinforcement, it should be used reasonably and avoid waste of materials.



**Fig. 3.** Comparison of load displacement skeleton curve of concrete pier

## Comparison between experiment and numerical simulation analysis

In order to verify the correctness of the test, OpenSees was used to simulate the experiment. The comparison between the load-displacement skeleton curve of the finite element analysis and the test results is shown in figure 4.



**Fig. 4.** Comparison diagram of the test value of the skeleton curve and the calculated value

It can be seen from figure 4 that the calculated and experimental values fit well. In the process of initial loading, the calculation stiffness of the structure was larger than the experimental value. After the structure entered the ductility phase, the comparison showed that the slope of the skeleton curve between the numerical simulation and the experimental value was basically consistent.

## Conclusions

This paper presented a new type of bridge pier aseismic reinforcement material. Test results and numerical simulation showed that axial compression ratio increased the ductility of the structure after the reinforcement of PUFA materials and after using PUFA, the maximum bearing capacity and elastic stiffness of the RC bridge pier have been improved. Meanwhile, the method is simple and fast, which can effectively reduce the cost of reinforcement.

## References

- [1] Aiwen Liu, Xiaojun Li, Endong Guo. The impact of strong earthquakes on small and medium-sized cities in the near towns of Yushu and Ninger [J]. Journal of applied foundation and engineering science, 2010(7):152-156(in Chinese).
- [2] Sheikh, S. A. Field and laboratory performance of bridge columns repaired with wrapped glass-fiber-reinforced polymer sheets. Can. J. Civ. Eng., 2007,34: 403–413.
- [3] Halil Sezen, M.ASCE and Eric A. Miller. Experimental Evaluation of Axial Behavior of Strengthened Circular Reinforced-Concrete Columns. Journal of bridge engineering, 2011,16:238-247.
- [4] Haleem, Lianzhen Zhang, Guiwei Liu. An experimental study on strengthening reinforced concrete T-beams using new material poly-urethane-cement. Journal of Construction and building material. 2013,40: 104–117.
- [5] Haleem k. Hussain, Guiwei Liu, Yu wen Yong. Experimental study to investigate mechanical properties of a new material poly-urethane-cement(PUC). Journal of construction and building material. 2014, 50:200-208.