Ultimate Deformation of Seismic Retrofitted of RC Piers using Continuous Fiber Sheet with Large Fracturing Strain

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1. Introduction

Nowadays, retrofitting of structure is as important as building a new structure as it may preserve the existing building and save the cost and resources. Many retrofitting methods have been discovered and developed for this purpose for the last decade. One of them is the application of fiber in retrofitting the structure. One of the main purposes of the application of fiber in the structure is seismic retrofitting, whether improving the seismic performance or repairing the existing structure to fulfill the requirement by the code.

Many kinds of fibers have been used in the field of structural engineering such as Carbon, Aramid and Glass. However recent researches have shown that these fibers do not exhibit large strain that may limit the ultimate deformation.

This paper, a continuation of the study[1)] done by Hadiyono, etc; proposes a new breed of fiber, PET (Polyethylene Terephthalate), which is normally used as a material for soft drink bottles and has been commonly recycled by remelting it and then extruded it as fiber. The main feature of this material is its high fracturing strain. Even tough PET does not exhibit high strength or stiffness, this problem can be compensated by adding more amount of material. However just adding material cannot compensate large fracturing strain, which is needed for resulting high ductility. Fig 1 shows the stress strain relation of various materials

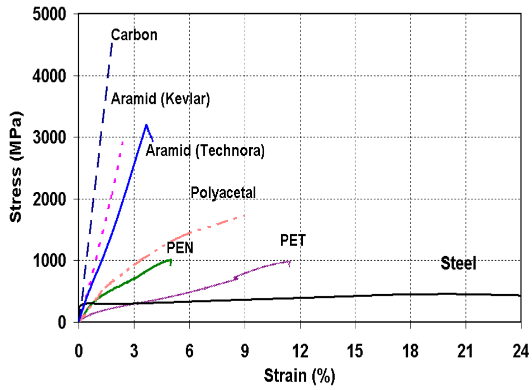

Fig 1. Stress-strain curves for various materials

The objective of the experiment is to investigate the shear strengthening and ductility enhancement effect from retrofitting of RC pier with large fracturing strain continuous fiber sheet materials.

2. Outline of Experimental Work

The experimental configuration and loading history are shown in Table 1 and Figures 2 and 3. A compressive vertical load of 160 kN (1 MPa) corresponding to the dead load of the superstructure was applied. Loading point displacement at the time when reinforcement strain at the bottom of the column reached the yield strain was used as yield displacement (Δ_y), while using the load at that time as yield load (P_y). Cyclic loads were applied gradually by increasing the displacement amplitude. Only one cycle was applied for each increasing of displacement amplitude. The ultimate deformation was defined as the displacement amplitude after passing maximum flexural capacity until it drops back to P_y under either push or pull loading condition. Strain in the fiber and displacement of the specimens are measured through extensive use of dial gage and transducer, respectively.

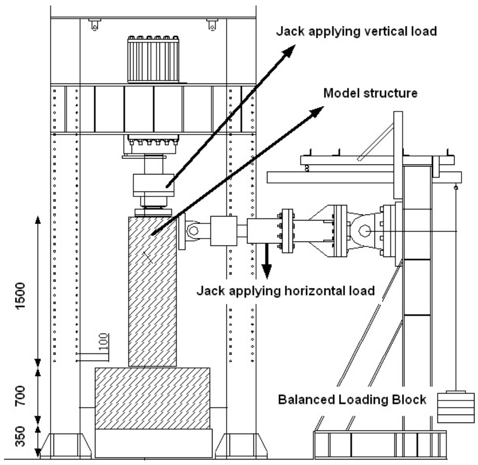

Fig2. Experimental device

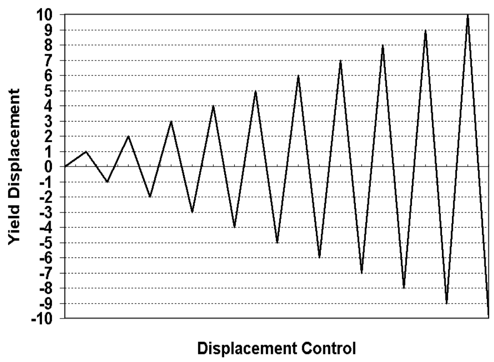

Fig 3. Loading History

Tab 1. Specimen properties

Items	Unit	SP-6	SP-7	SP-8	SP-9
Dimension	mm	400 x 400			
Shear Span (a)	mm	1500			
Axial Load	MPa	1			
ρ_t		0.0098			0.0118
ρ_s		0.0016			
M_y	kNm	257			310
M_u	kNm	327			393
V_u	kN	218			262
V_c	kN	118			120
V_s	kN	73			
$(V_c+V_s)/V_u$		0.88			0.74
Sheet Reinforcement above Plastic Hinge Zone					
Material Type		Kevlar	Kevlar	-	Kevlar
ρ_f		0.00024	0.00024		0.00024
V_f	kN	67	67		67
$(V_c+V_s+V_f)/V_u$		1.18	1.18	0.88	0.99
Sheet Reinforcement on Plastic Hinge Zone					
Material Types		PET	PET	-	PET
ρ_f		0.00125	0.00063		0.00125
V_f	kN	60.5	30.3		60.5
$(V_c+V_s+V_f)/V_u$		1.15	1.01	0.88	0.97
Ductility (Exp)		9.06	8.45	6.77	8.96

3. Experimental Result

3.1. Flexural Enhancement

As it can be seen on figure 4 and table 1 for SP6, SP7 and SP8, there is no significant increase for various application of sheet ratio for specimen with the same value of tensile reinforcement. However the application of fiber sheet improves ductility of the specimen and prevents sudden degradation of load carrying capacity after buckling occurs because of the confinement effect of the concrete. Meanwhile the more the amount of tensile reinforcement only gives more strength in the load carrying capacity

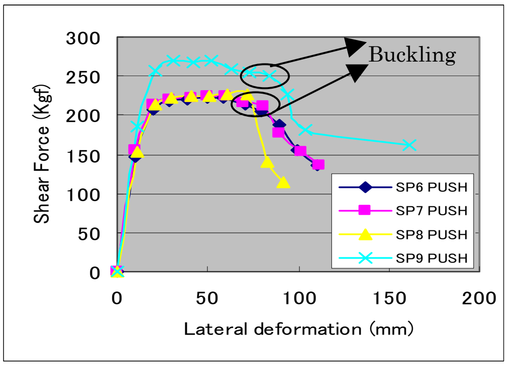

Fig4. Envelope curves of specimen

3.2. Shear Enhancement

Sheet application in the plastic hinge zone gives a form of lateral confinement after the lateral reinforcement yields. The application of fiber sheet does not give contribution to the yielding of the lateral steel tie reinforcement. As it can be seen in Fig 5, the higher sheet reinforcement ratio the lower the shear deformation at the same value of displacement. This shows that the higher the sheet reinforcement ratio the higher the confinement given by the sheet thus reducing the shear deformation. This phenomenon can also be noticed in figure 6.

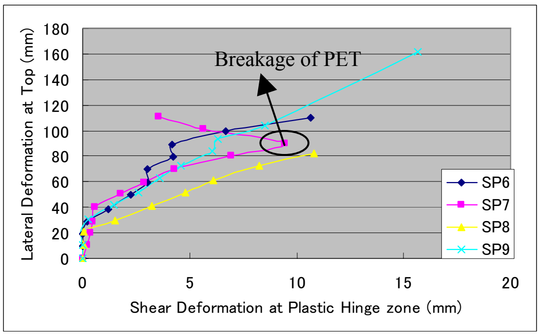

Fig 5.　Shear def. versus lateral def.

As it can be seen in Figure 6, the buckling of tensile reinforcement causes the drop of load carrying capacity. In SP8 once buckling occurs there is a sudden drop of load carrying capacity corresponds to rapid shear deformation and the specimen no longer able to carry cyclic loading. In contrast with SP6 and SP7, even though buckling occurs, there is no significant drop of load carrying capacity and specimens are still able to carry on cyclic loading until the breakage of PET.

It can also be noted the rapid shear deformation development of SP8 compared to SP6 and SP8. This phenomenon occurs because the appliance of fiber sheet adding the stiffness and compression force in the plastic hinge zone therefore reducing the shear deformation. One thing to be put in attention is that after breakage of PET, the specimen can no longer carry the load given resulting in a drop of load carrying capacity and marks the failure of the specimen that can be seen in Figure 6 and Figure 7.

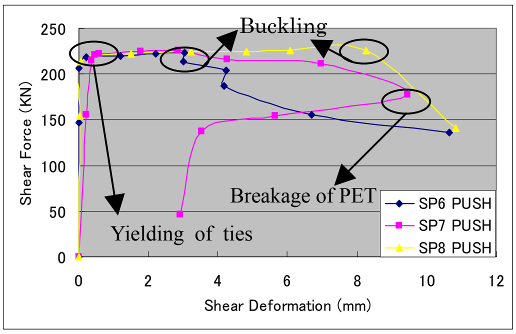

Fig 6. Shear force versus shear deformation

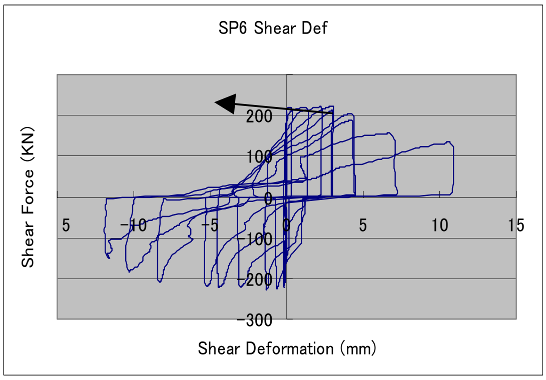

Fig 7. Shear force versus shear deformation SP6

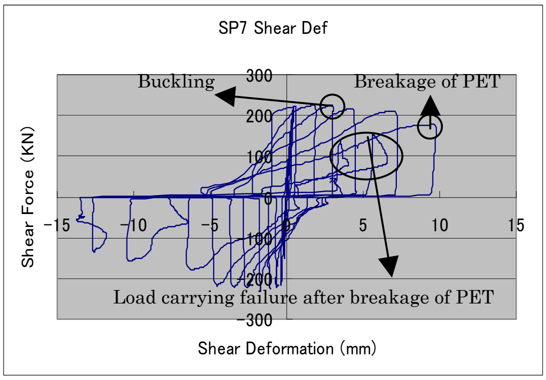

Fig 8. Shear force versus shear deformationSP7

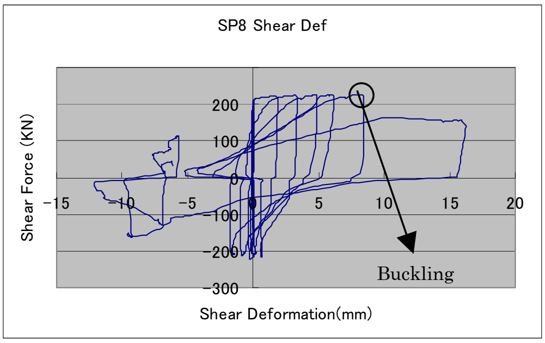

Fig 9. Shear force versus shear deformation SP8

From Figure 7 to Figure 9, it can be seen that the application of PET in the plastic hinge zone keeps stable shear force carrying capacity both after yielding of ties and after buckling occurs and once again the sudden drop of load carrying capacity can be prevented, however it is different in case of un-retrofitted specimen. This is caused by the good confinement effect of the sheet so that there is no spalling of concrete cover under cyclic loading. It is important that spalling of the concrete may caused the crack to inhibit to the concrete core as the load increases

4. Conclusion

From the experimental data, it can be concluded that:

1. The application of PET fiber in reinforced concrete pier enhances its ductility
2. PET sheet, a high fracturing strain material, gives good confinement effect which prevents sudden drop of load carrying capacity due to buckling and rapid increase of shear deformation
3. The application of PET prevents the spalling of concrete cover and the area of concrete can participate fully in bearing the load. Therefore PET can cause stable load carrying capacity.
4. The more PET sheet is provided, the less shear deformation occurs when the load carrying capacity starts to decrease and the more slowly the load carrying capacity decreases with deformation

5. Reference

1. Hadiyono, J., Hiroshi, N., Ueda, T., Yasuhiko, S., Dai, J., "Seismic Retrofitting of RC Piers using Continuous Fiber Sheet with Large Fracturing Strain", *Journal of Structural Engineering Vol.51A (March 2005), JSCE*

2. Priestley, M.J.N.; Seible, F.;Xiao Y.; and Verma. R., "Steel Jaclet Retrofitting of Reinforced Concrete Bridge Columns for Enhanced Shear Strength-Part 2", ACI Structural Journal, V. 91, No. 5, Sept.-Oct. 1994,pp 537-551