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Research paper

The Effect of Pre-Damaged Level on Repair Damaged Columns by Using Steel Straps Tensioning Technique

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Abstract

To date, repair of damaged columns has become increasingly more significant. The failure of columns structure contributes to the serious consequences in structural stability. Most of the existing repairing techniques are based on lateral passive confining pressure. However, this passive-type of confinement is ineffective in restoring the performance of damaged concrete columns. In this regards, active confinement was selected in this study to repair damaged concrete columns which can actively confine concrete in this study. Steel strapping tensioning technique (SSTT) allows pre-tensioning low-cost recycled steel straps around the damaged column was chosen herein to represent active confinement. A total of 12 columns were prepared and loaded axially to certain degree of their respective ultimate strength. Hence, a pre-damage level of the columns was developed. Then, the damaged columns repaired by using mortar and confined with SSTT. Finally, the repaired columns were then tested under monotonic uniaxial load. The structural performances of the confined repaired columns were compared with those of the repaired columns without confinement. It is expected that as the concrete compressive strength increases, the effectiveness in restoring the load carrying capacity of the damaged column becomes more significant.

Keywords: *Confinement, pre-damaged level, steel strapping tensioning techniques, pre-tensioning force.*

1. Introduction

Over the years, repair of damaged concrete structures has become a major part in the construction industry. They contributed nearly half of the total expenditures from the total construction cost. Apart from that, repairs are required for other cases such as: (i) arising service loads; (ii) altering usage of structure; (iii) errors in design or during construction; (iv) seismic action; (v) corrosion; (vi) fire effects; and (vii) exposure to environmental effects such as the variance of temperature (Achillopoulou and Karabinis, 2015). The purpose of confinement is either to repair or strengthen a concrete structure. "Strengthening" is referred to the method used to increase the load carrying capacity of the structure more than the actual design. Meanwhile, "repairing" of a concrete structure is the process to restore the load carrying capacity of a damaged structures to its initial performance. There are few types of repairing techniques using confinement which have been reported in literature such as ferrocement (Kondraivendhan and Pradhan, 2009; Kaish *et al*., 2013; Bansal *et al*.,2014; Jayasree *et al*., 2016), FRP (Tastani and Pantazopoulou, 2004; Prabhu and Sundarraja, 2013; Zahran, 2016) and steel jacketing (Ghobarah *et al*., 1997; Nam *et al*., 2009). Presently, the confinement model developed by previous researchers were dedicated for strengthening works (Fardis and Khalili, 1982; Shehata *et al*., 2001; Al-Salloum, 2007; Benzaid *et al*., 2010).

2.Descriptions of Columns and Test Procedure

A total of nine of circular reinforced concrete columns were prepared for testing. All the columns were 150 mm in diameter and 600 mm in height. The concrete strength used were 30 MPa, 60 MPa and 90 MPa with the longitudinal reinforcement ratio 1.78%, 2.56% and 4.56% respectively. The pre-damaged level varied between 85% to -85% from ultimate load capacity. Each of the columns were confined with confining volumetric ratio of 0.12. The details of specimen are as shown in Fig 1. The column specimens were tested under concentric axial loading using the Tinius Olsen machine. The test was set-up with three LVDT and and pi-gauges oriented 120º to determine the deflection and strain value. The test was carried out by using displacement control rate of 0.01 mm/s. The loads and axial displacement were recorded at the 1/3 portion of mid-height of specimens. The data were recorded by using an automatic data-acquisition system that were connected directly to computer. Fig2 shows the instrumentation setup for concentric loading.

3. Repair Technique Using Steel Straps Tensioning Technique (SSTT)

SSTT is a type of active confinement. The mechanism of active confinement was that it allows lateral pressure to be applied to the column at the initial stages of confinement without lateral dilations by pre-tensioning forces. The usage of concrete confinement increases the ductility and load carrying capacity of structure

Confinement is less ineffective for square and rectangular area rather than circular section. In this study, steel straps confinement is used to improve the ductility and load carrying capacity of damaged concrete column. The steel straps used are the steel straps used in packaging industry. The steel straps were tensioned by using pneumatic tensioner with applied pressure within the range of 10-15 MPa. The tensioned steel straps were then secured using connection clips to ensure that the lateral pressure remains around the column section. In order to provide effective lateral confinement, the column need to be strengthened properly for prevent from premature crushing of the column structure as the axial load was applied. The steps to repair concrete column by using SSTT were as follows: (1) removing loose concrete, (2) repairing with mortar (3) preparing the column surface and (4) installing steel straps. The processes on the specimens are illustrated in Fig 3: (a), (b), (c), and (d).

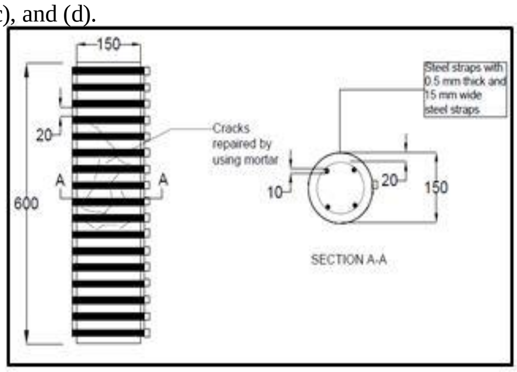


Fig. 1 Details of columns specimen

Fig. 2 Test setup

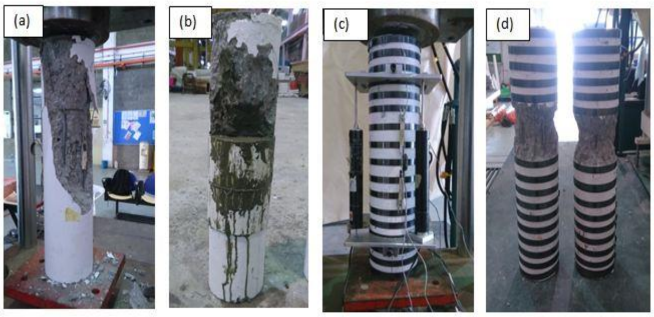
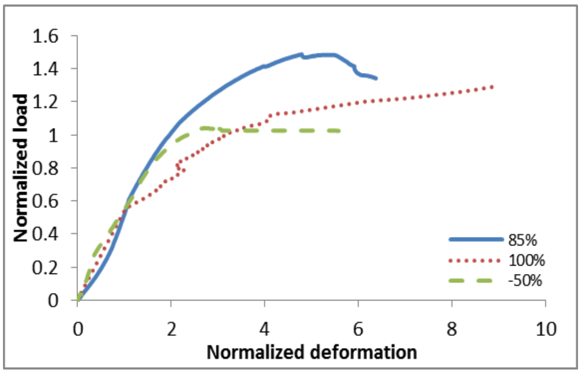


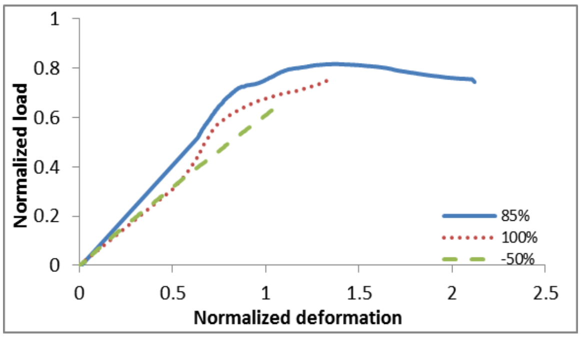
Fig. 3 The processes on the specimens: (a) damaging specimen; (b) repairing using mortar; (c) column after repair and ready for testing; and (d) column testing after repair.

4. Test Results

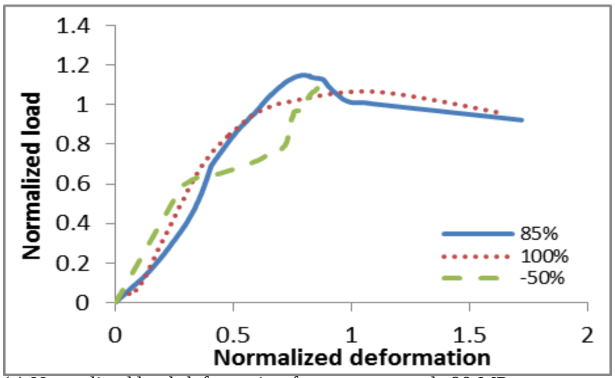
Fig 4 shows the effects of various pre-damaged level and concrete strength on the load-deflection curves. Figure 4(a) shows the load-deflection curves of specimens with 30 MPa while; Fig 4(b) shows the results of specimens with 60 MPa; and figure 4(c) shows the results of specimens with 90 MPa. The comparison was based on identical confining volumetric ratio for each specimen which is 0.12. Based on Figure 4(a), the repaired column with 85% pre-damaged level showed an increase in load carrying capacity by 35% from control specimen. Meanwhile, the load carrying capacity rised up by 20.5% for specimens with 100% pre-damaged level. As for specimens with -85% pre-damaged level, the strength of repaired column increased only by 2.5%. It was observed that the longitudinal reinforcement bar buckled and concrete cover spalled upon the failure of each specimen. The main failure mechanism of the repaired column with SSTT was the rupture of the longitudinal reinforcement and crushing of concrete. From Fig 4(c). the strength of the repaired column with -85% pre-damaged level increased up to 10.5% compared to the control specimen. The load carrying capacity of specimen with damage level 85% and 100% was dropped gradually. From Fig. 4(c), the graph represents that confinement can increase the load carrying capacity of damage column with 90 MPa. The repaired column with 85% pre-damaged level had the highest percentage increment of strength, 15%; followed by 13.2% and 6.7% for both specimens with pre-damaged level of 100% and -85% respectively. The failure mode of repaired HSC column for specimens with -85% pre-damaged level were mostly column crushed at surface without explosive sound. In general, according to the results for concrete 30 MPa and 90 MPa, the concrete repair by using SSTT can increase the load capacity of column for damage condition between 85% damage and -85% of damage.



(a) Normalized load-deformation for concrete grade 30 MPa



(b) Normalized load-deformation for concrete grade 60 MPa



(c) Normalized load-deformation for concrete grade 90 MPa

Fig. 15 Normalized load deformation in effect of pre-damaged level

5. Conclusions

This study presented an approach in concrete repair technique by using steel straps confinement. The use of low cost steel straps to apply external active confinement pressure on concrete surfaces requires only a short time. Nine reinforced concrete columns had been damaged at different damage level and were repaired using the newly proposed concrete repair technique by using SSTT. The repaired reinforced concrete columns were retested under axial load. The test results show that the load carrying capacity and the ductility of repaired columns were improved significantly at certain levels of damage. It is important to notice that the restoring load carrying capacity of the repaired columns were attributed to the applicability of SSTT confinement in order to maintain active confinement pressure on the repaired area of the columns, which increased the load capacity of the damaged concrete and delayed its damage by increasing its ultimate strain.

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