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Dense Rib Lateral Reinforcement for Confining Concrete

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Abstract

This study introduces a new reinforcing method laterally to confine concrete with dense reinforcement. The dense reinforcing technique can provide more confinement for concrete and increase the performance of concrete such as ductility and peak strength. However, the application of the dense reinforcement is not practical with conventional reinforcing method since the movement of gravels would be interrupted. Thus, this study places the lateral reinforcement just underneath of concrete not to prevent the gravel flowing. In the case, the reinforcement would be exposed to the problem of corrosion. To solve the problem, this study adapts stainless steel and FRP(Fiber Reinforced Polymer) that are not corrodible. Two types of concrete cylinders (300mm x 150 mm; L x D) reinforced laterally by stainless steel and FRP rings are prepared with two different volumetric ratios, and axial compressive tests are conducted to assess their performance. The dense reinforcing method with rings is successful to increase the peak strength of concrete. The effectiveness to increase peak strength is assessed according to materials and volumetric ratios. The failure mode of the dense reinforced concrete by rings laterally is different from that jacketed by steel or FRP sheet wholly. The failure is gradually processed with the fracture of each ring.

Keywords: dense reinforcement;stainless steel ring; FRP ring; concrete; peak strength.

1. INTRODUCTION

It is well known that the performance of concrete such as peak strength and ductility is improved by using lateral confinement which is generally provided steel reinforcement for new constructions and steel or FRP (Fiber Reinforced Plastic or Polymer) jackets for retrofits of existing structures (Park and Palulay, 1975; Seible et al. 1997). For new constructions, the lateral confinement is provided by tie or spiral bars.

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When a specific rebar is selected for lateral confinement, the less vertical spacing of the bars produces more effect to improve the performance (Richart et al. 1928). However, such a dense reinforcement in lateral direction may obstruct the flow of materials in concrete, especially gravels. Thus, ACI-318 (2007) regulates the minimum clear spacing between spirals shall not be less than 25 mm since the G_{max} (maximum size of gravels) in concrete generally is less than 25 mm. The provision guarantees enough spacing between ties or spirals to flow or move of materials or gravels. Recently, Self-consolidating concrete (SCC) is on developing to solve materials blockage between dense reinforcements (Hassan et al. 2010). The SCC is able to flow freely under its own weight both horizontally and vertically and, thus, fill out completely the formwork of any shape. However, the enough spacing lateral reinforcement would not provide enough confinement to obtain satisfactory ductility of reinforced concrete structures under severe lateral loading conditions such as earthquakes. Also, the SCC does not make the gravels flow when the spacing of ties or spirals is less than the size of the gravels.
Thus, this study proposed a new dense reinforcing method in lateral direction for reinforced concrete columns. In general, the lateral reinforcements are made of steel and located under cover-concrete whose thickness is usually 50 mm or more a little than that to protect the reinforcement inside from the corrosion hazards outside. However, if materials free from corrosion are used for the lateral reinforcements, ties or spirals can be located just under the concrete surface. Figure 1 shows the dense reinforcing method that has reinforcements additionally between the existing reinforcements and concrete surface. The additional lateral reinforcements can be placed densely to provide effective confinement. Also, the spacing distance can be less than the G_{max} of concrete since the gravels do not need to be placed outside the dense reinforcements. The dense reinforcements are used only for critical sections such as the plastic zone of reinforced concrete columns.

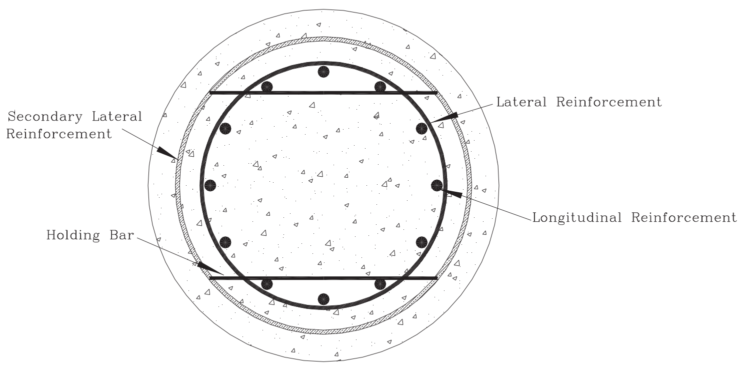


Figure 1: Dense reinforcing method for RC columns

This study chooses stainless steel and FRP as free-corrosion materials. The goals of this study are to explain how to construct the new lateral reinforcing method and prove the performance to increase peak strength and ductility of concrete using axial compressive tests of concrete cylinders.

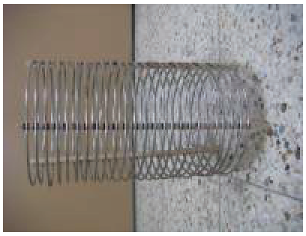
2. Materials and Specimens

The circular rings made of stainless steel (SS) and FRP were used for dense lateral reinforcements. The stainless steel bars with the diameter of 3 mm and the length of 450mm were prepared and welded face-to-face to make a ring with outside diameter of 146 mm that was less by 4 mm than the inside diameter of the mold of concrete cylinders. The area of cross-section of the SS ring was 7.065 mm^2. FRP rings are cut from a FRP tube with the outside diameter of 142 mm and the thickness of 7 mm. The height of the

FRP rings was 5 mm, and the area of the cross-section was 35 mm^2. The used cylinders had the dimensions of 300 mm x 150 mm (LxD).

Generally, lateral reinforcements are attached onto longitudinal ones using thin steel wires. However, the dense lateral reinforcements are located outside longitudinal reinforcements and, thus, other supporting bars are required. This study used wood sticks to place the dense reinforcements inside the mold of a concrete cylinder. Figures 2 and 3 show the procedure how to prepare specimens with dense reinforcements of each material. The clear spacing distances for SS ring dense reinforcements were 10 mm and 20 mm that was less than the general G_{max} of 25 mm. Thus, the volumetric ratios of the reinforcements were 0.942% and 0.471%, respectively. Those for FRP rings were 20mm and 30 mm, and the volumetric ratios were 2.333% and 1.556%, respectively. Three specimens were prepared for each type including plain concrete. The 30 mm at the both sides of a specimen was not reinforced and, thus, the reinforced length was 240 mm.

(a)

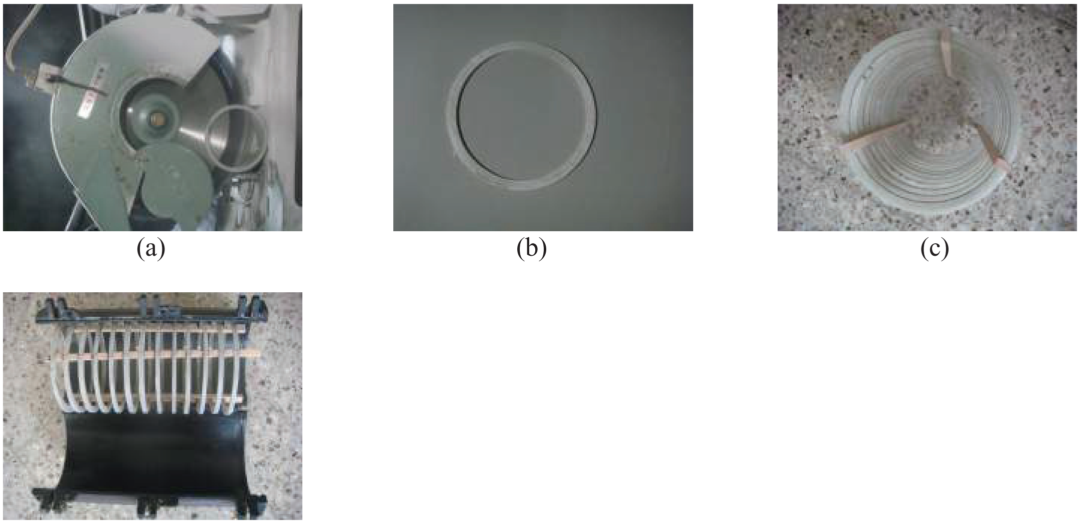


(b)

(c)

(d)

Figure 2 : Procedure to prepare specimens with SS ring reinforcements: (a) SS ring; (b) dense reinforcements with SS rings; (c) SS rings inside the mold; (d) concrete casting



(a) (b) (c)

(d)

Figure 3 : Procedure to prepare specimens with FRP ring reinforcements: (a) cutting; (b) FRP ring; (c) dense reinforcements with FRP rings; (d) FRP rings inside the mold

3. Compressive tests and results

Figure 4 shows the set-up for the compressive tests. The axial deformations at three locations were measured by displacement transducer to calculated axial strains, and the circumferential deformation was measured by an extensometer. Also, the axial deformation was measured by a compressometer with the gage length of 20 mm at the middle of specimens; this measurement was used for a reference. The load was applied by displacement control with 0.5 mm/min. The G_{max} of the concrete was 20 mm.

3.1. Stress-strain relationship

Figure 5 shows the stress-strain curves for the unconfined and the confined concrete cylinders. The results of tests are summarized in Table 1. In the table, the last number represented the spacing distance. The peak strengths of the three plain specimens were, 23.3, 20.9, and 24.6 MPa, respectively, and the average was 22.9 MPa. The average peak strengths for SS ring-10 and -20 were 38.2 and 27.2 MPa, respectively. Thus, the SS ring dense reinforcements increased the peak strength by 66.8% and 18.8%, respectively. The average peak strengths for FRP ring-20 and -30 were 52.5 and 38.9 MPa, respectively, increasing by 2.29 times and 1.70 times comparing to that of the plain concrete. Based on the failure strain, the confined concrete cylinders showed approximately 6 times ductile behavior comparing to the plain concrete cylinders.

Figure 4 : Test set-up

Table 1: Test results

Specimen	Plain (MPa)			SS ring- 10 (MPa)			SS ring-20 (MPa)			FRP ring-20 (MPa)			FRP ring-30 (MPa)		
$f_{co}^{'} / f_{cc}^{'}$	23..4	21.0	24.6	38.7	37.4	38.5	27.2	27.4	27.1	51.7	54.4	51.6	38.3	37.2	41.2
ε_f	0.008	0.006	0.004	0.04	0.035	0.045	0.055	0.055	0.045	0.045	0.05	0.04	0.043	0.035	0.035

* $f_{co}^{'} / f_{cc}^{'}$: peak strength in MPa; ε_f : failure strain

Thus, the dense reinforcements of SS rings and FRP rings were effective to increase the peak strength and the ductility of concrete.

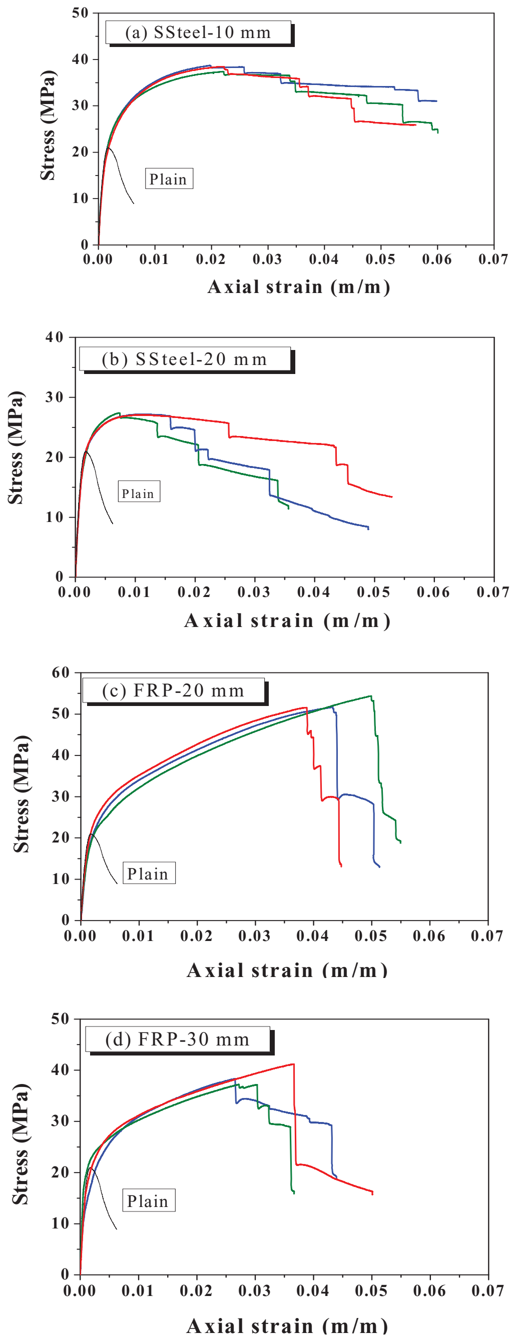


Figure 5: Stress-strain curves for strengthened concrete cylinders

3.2. Failure modes

Figure 6 shows the deformed shapes of the confined specimens by SS and FRP rings according to the increment of loads. Under the peak strength as shown in Figures 6(a), the surface of the cylinder was peeled off, and a ring was fractured at the welding point after the peak strength with more peeling off surface concrete. In Figures 5(b) and (c), the strength decreased abruptly with the fracture of a ring. The SS rings were fractured gradually one by one with increasing the stroke displacement, and the cylinder was crushed finally. Thus, the failure of the confined cylinders by SS rings was initiated by the fracture of a ring at the middle. The failure mode of the cylinders confined by FRP rings was similar to that of the SS ring confined specimens. The peel off was also observed. However, the fracture of the FRP rings occurred rapidly different from the SS ring fracture.

(a) SS ring specimen

(b) FRP ring specimen

Figure 6: Deformed shapes and failure mode of the confined cylinders

4. Conclusions

This study suggested a method to provide dense lateral reinforcements for RC structures using stainless steel and FRP. Also, the performance of the method was verified through experimental tests; the SS and the FRP ring jackets increased the peak strength and the ductility of the confined concrete cylinders. However, the failure mode of the SS ring confined specimens was different from that of the existing jacketing methods of steel. Especially, the SS rings were fractured gradually after the peak strength. The fracture of the SS rings occurred at the welding point and, thus, other welding methods such as overlapping welding that will not be fractured with large compressive deformation is necessary. Then, the abrupt decrease in the strength of the SS ring confined specimens would be disappeared. The failure mode of FRP ring confined specimens showed a similar one to the failure modes of the existing FRP jackets such as FRP sheets or tubes. The proposed method can provide a detail to secure the ductile behavior of RC structures during strong earthquakes.

5. Acknowledgments

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REFERENCES

[1] ACI 318M-08 (2007). Build Code Requirements for Structural Concrete and Commentary, ACI, pp.89-90.

[2] Hassan AAA, Hossain KMA, and Lachemi M (2010). Bond strength of deformed bars in large reinforced concrete members case with industrial self-consolidating concrete mixture. Construction and Building Materials 24, pp.520-530.

[3] Park R, and Paulay T (1975). Reinforced Concrete Structures, John Wiley & Sons, New Zealand, pp.17-30.

[4] Richart FE, Brandtzaeg A, and Brown RL (1928). A study of the Failure of concrete under combined concrete stresses University of Illinois engineering experimental station, Bulletin No.18574.

[5] Seible F, Priestly MJ, Hegenier GA, and Innamorato D (1997). Seismic Retrofit of RC Columns with Continuous Carbon Fiber Jackets, *Journal of Composite for Construction*, **1(**2), pp.52-62.