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Structural performance of rectangular section confined by squared spirals with no longitudinal bars influencing the confinement

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ABSTRACT

Structural performance of rectangular concrete section confined by squared spirals was investigated. Through the uni-axial compression test using concrete prisms with squared spirals and without longitudinal bars, the enhancement of strength and deformation capacity of rectangular concrete section was scrutinized. By the experimental observations on the properties of lateral expansion of concrete prism, a moment of reaching the axial peak stress in section was predicted in a good accuracy. Qualitative relationships between the structural performance (the enhancement of strength and deformation capacity) of concrete prism and confinement efficiency were studied. Also, for the effective use of normal- and high-strength lateral reinforcement, a design implication using the qualitative relationship of the tensile stress in lateral reinforcement at failure of concrete prism with parameters was proposed.

1. Introduction

Effective application of lateral reinforcement to column in the skyscraper is very important in the enhancement of strength and deformation capacity of column which significantly influences the structural behavior of the buildings. Development of high-strength materials has led to a reduction of member section sizes and economical design of the skyscrapers. The use of the high-strength lateral reinforcement to columns in skyscraper has been facilitating the rational and economical design of columns due to reduction of section size of members. Although concrete of up to 200 MPa (29.0 ksi) compressive strength have been recently developed, concrete of up to approximately 70 MPa (10.15 ksi) only has been adopted in the structural design because of the brittle behavior of the high-strength concrete. For the effective use of high-strength concrete to columns in buildings, therefore, it is essential to investigate the structural characteristics of column with high-strength concrete in terms of the enhancement of strength or deformation capacity.

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Confinement effect is a thought to be related to the lateral reinforcement and the enhancement of strength or capacity of concrete section in members. A number of researches on the confinement effect of rectangular section subjected to axial compression have been conducted. Mander [1] proposed the strain–stress relationship of confined concrete modifying the stress–strain relationship by Popovics [2] and using the confinement effective coefficient, k_e. The coefficient, k_e, is defined as A_e/A_{cc} where A_e is area of effectively confined concrete core and A_{cc} is the area of concrete core, respectively. Mander's approach was developed based on the normal strength concrete up to 41 MPa (5.95 ksi). For the confinement effect of rectangular section using normal- or high-strength concrete, strain–stress relationships of confined concrete based on the compressive strength of concrete from approximately 25 MPa (3.63 ksi) to 130 MPa (18.85 ksi) have been proposed [3–11]. El-Dash [3] proposed the stress–strain relationship of confined concrete using the Sargin's model [4], the peak strength and strain enhancement coefficients, k_1 and k_2. Cusson [5] proposed the stress–strain curve based on Popovics' [2] and Fafitis' [6] model. Also, Cusson proposed the peak strength and strain of the confined concrete using the regression approaches. Razvi [7] proposed the stress strain relationship using the Popovics' [2] and Mander's model [1] for normal strength concrete and Nagashima's [8] and Cusson's [5] model for high strength concrete. Bing [9] has conducted the test for the investigation of structural behavior of the confined concrete depending on the difference of lateral reinforcement ratio. Also, necessities of the minimum lateral reinforcement ratio to achieve the appropriate ductile behavior were also pointed in the research. Suzuki [10] proposed the stress–strain relationship using the Fafitis' [6] model. Further, the peak strength and strain enhancement were proposed by the regression analysis. Cusson [5], Razvi [7], and Suzuki [10] proposed the calculation method to predict the tensile stress of lateral reinforcement at the peak compressive stress of concrete while El-Dash [3] and Bing [9] assumed the lateral reinforcement yield at the peak stress of concrete. Kim [10] proposed the prediction procedures for the axial stress–strain relationship of circular concrete columns. Since majority of the previous research covers the circular concrete section with longitudinal bars, the confinement effect of squared concrete section has been hardly studied. Paulay [12] and Englekirk [13] showed the lateral reinforcement starts to contribute for the lateral confinement effect after the spalling of the cover concrete. Therefore, this paper covers the concrete prisms without longitudinal bars and cover concrete to investigate the pure lateral confinement pressure of lateral reinforcement. It will lead to the proposition of the minimum requirement for the amount of lateral reinforcement.

In this study, in order to investigate the structural properties of confined rectangular section subjected to uniaxial compression, monotonic axial loading test for rectangular concrete sections with squared spiral reinforcement and without longitudinal bars is undertaken. Through the test, expansion properties of the sections will be investigated. Also, the design implications on the enhancement of strength, deformation capacity, and tensile stress of lateral spirals in squared confined section will be proposed.

2. Research significance

Most of researches which have been conducted on the confinement effect of reinforced concrete columns have covered the reinforced concrete section with longitudinal bars. On the other hand, this study handles the squared confined section without longitudinal bars as a fundamental research. It will lead to an accurate evaluation of the structural performance of concrete section and possibility in terms of the effective usage of longitudinal bars. Also, a design implication to ensure the appropriate the stress level of transverse reinforcement was proposed. Using the implication leads to easy and effective RC column design due to the qualitative relationship between stress level of transverse reinforcement and the material properties, ρ_s, f_c, and f_y.

3. Experimental program

3.1. Specimen details

In order to investigate the structural behavior of concrete section confined by squared spirals, eighteen reinforced concrete rectangular prisms was constructed and tested. As mentioned earlier, to investigate the confinement effect of concrete section without longitudinal bars and cover concrete as a fundamental research, longitudinal bars and cover concrete were excluded from the specimens. Fig. 1 shows reinforcing details of specimens. In order to consider the section which has same area with circular section of cylinder in which the diameter equals to 150 mm (5.91 in), both the section width and depth was set to 133 mm (5.24 in.). Height of the specimen was 266 mm (10.47 in.). Since no cover concrete was set to the specimens, squared spirals were arranged outside the concrete core. Three strain gauges were attached on the squared spirals in each face of specimen. Three experimental parameters, compressive strength of concrete, f_c, yield strength of spirals, f_y, and volumetric ratio of lateral reinforcement, ρ_s, were selected in this study. Table 1 shows the parameters allocated to each specimen. Notation f_{dc}, f_y, and ρ_s indicate the design compressive strength of concrete, yield strength of spirals, and volumetric ratio of spirals, respectively. First letter

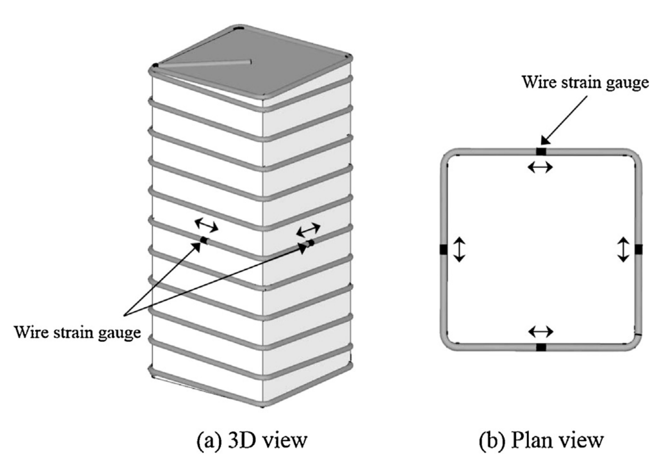

Fig. 1 – Reinforcing details of specimen.