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Research Article

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Repair and reinforcement method for reinforced concrete beam-column joints

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ABSTRACT

It is becoming increasingly more common that the original structure of a building fails to meet new specifications in structural earthquake resistance and other behaviors due to construction deficiency. In terms of reinforcement and repair of deflection, deformation, and frame joints in the frame structure, however, no clear requirements are specified in China's technical specifications for seismic strengthening of buildings. Given the deficiency in the existing techniques, a repair and reinforcement method, based on a high-rise building in Xi'an, is proposed for reinforced concrete beam-column joints. Sequential steps were taken as follows: First, a bowl-coupler bracket around the concrete frame columns under repair was set up, and then a jacking support was mounted on the bracket to restore the beams from deflection. Then, achain block was utilized to pull the deformed cap of a concrete frame column against the deformation to eliminate it. And third, the cavities at frame column-beam joints were filled with composite grout layer by layer to repair them. Finally, carbon fiber material was pasted on the concrete frame beams and columns to repair cracks on the surfaces until all defects of the frame beams and columns were completely repaired. With this method, the concrete strength at the beam-column joints reached C45; and the centerlines of the concrete columns were deflected from the original design axes for 1.5mm, meeting the specifications for design and construction standards. Therefore, the results that were achieved can be considered as reference for follow-up repair and reinforcement of existing reinforced concrete beam-column joints.

Key words: reinforced concrete structures, beam-column joint, repair and reinforcement

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INTRODUCTION

In *Technical Specifications for Seismic Strengthening of Buildings* (JGJ116-2009) published in our country, seismic strengthening of frame beams and columns are specified, but no clear requirements about strengthening of deflection, deformation, and frame joints in the frame structure are defined [1]. Traditional reinforcement methods for reinforced concrete beams and columns mainly include [2-4]: enlarging sections, steel-bondedand steel-enclosed reinforcements, adding support, epoxy glue sealing, and pasting carbon fiber. Huang Binhui [5] studied the reinforcement and reconstruction design for multistory buildings. He discussed the main technical problems and solutions in reinforcement projects for masonry and concrete frame structures, and put emphasis on the adjustment of computational models of reinforcement and choices among the different methods in practical projects. Experts at home and abroad have added immense knowledge from their research [6-9] of the assessment of seismic behavior and reinforcement of buildings. Yu Jiangtao, et al.[10] have conducted experiments to test the seismic behavior of earthquake-damaged concrete frame joints after reinforcement using basalt fiber reinforcement and steel sleeve reinforcement methods. During their experiments, different degrees of earthquake pre-damage, crack pouring, and other factors affected the strengthening measures. Xu Chenyu [11] put forward his seismic reinforcement design based on a number of reconstruction works of original buildings. His work mainly emphasizes seismic reinforcement by reconstructing old elements and adding new elements, connecting the new elements to the old, and strengthening the joints between elements in accordance with the new specifications, through which new functions of old buildings can be created. It's also very common for reinforced concrete beam-column joints to be damaged by

improperly adding construction load on concrete before the concrete reaches its design strength. On account of the inadequacy and defects in existing techniques, this paper aims to present a repair and reinforcement method for concrete columns in existing building frames.

1 Project Overview

A building in Xi'an with 31 stories above-ground and 2 stories underground was researched in this study; its platform is a 2-story underground garage with a height of 4500mm. As for the concrete frame structure of the plarform, the concrete column section dimensions are 600*600mm and their strength is rated at C40. The concrete pouring for its top plate was finished on April 10, 2012, and during the process of pouring, big cavities appeared due to the excessively concentrated steel rebar at the concrete beam-column joints. By April 23, 2012, the concrete top plate was covered with 2100mm of soil transferred by large-scale mechanical equipment. Before the concrete strength reached the design requirement, and loaded with the large-scale equipment, the joint areas were damaged. For the columns, each cap was deflected from its axis 60mm, and horizontal cracks approximately 0.2-0.3mm wide appeared in many locations within the range of the column height. Moreover, the beam bottoms connected to the columns also suffered different degrees of cracking.

2 Traditional Repair and Reinforcement Methods

With the recognition of the significance of environmental protection and sustainable development, large-scale demolition and construction are no longer harmonious with the current trend, and more old buildings are being renovated for reuse. The design of structural reinforcement and renovation is more complex than that of a new building's structures. The design has to consider the state of original building and the existing specifications, and reduce materials and costs as much as possible. Among the traditional repair methods for reinforced concrete frame beams and columns, the method of steel-enclosed reinforcement is mainly used in cases where damage to the concrete columns is not extensive (i.e. no deformation occurs)and the repairs are concentrated on broken edges and corners of beams and columns. However, it is not appropriate to repair damaged concrete beam-column joints or the restoration of deformed or deflected concrete beam-column joints. The epoxy glue sealing method, mainly utilized when a relatively high fire-resistance rating is required, is not applicable to restore deformed concrete columns and beams. Moreover, the large weight of epoxy glue can easily induce secondary damage to the repaired columns. Another method of pasting carbon fiber sheets is suitable for ordinary low-load structures and elements, but it can't substantially improve the overall strength of a structure or element.

In conclusion, the methods mentioned above are incapable of solving such problems as the occurrence of large cavities at joints between reinforced concrete column capitals and frame beams, deformation and deflection of concrete column caps, and multiple cracks on beams and columns.

3 The Design Proposal

In view of the inadequacy and defects in existing techniques, this paper aims to propose a repair and reinforcement method for existing building's concrete frame columns. The detailed steps are as follows:

(1) Erect a work platform around a concrete column of the existing building at the height of 3/4 column height. Design a bowl-coupler steel bracket for the platform in accordance with related requirements of the steel support. The distance between adjacent steel pipes forming the bracket should be 600mm and determined by the weights of the beam and column to be repaired,both vertically and horizontally. Then lay two layers of U-steel under the platform. (See Fig. 1).
(2) On the platform, use the jacking supports around the concrete frame column to support the four ends of the beam intersecting with the upper column perpendicularly;
(3) Remove the external loads on the frame column and beam;
(4) Arrange two underpinned jacks at both sides of the bottom jacking support under each beam end to jack the four ends of the beam at a synchronized pace. When the beam bottoms are lifted to the location of 3mm higher than the original design height, the jacks should be removed and replaced by steel spacers. (A schematic diagram of the jacking system is shown in Figure 2.)
(5) Use a chain block to pull the deformed cap of the concrete frame column in the direction against its deformation until the lateral deformation is eliminated;
(6) Clear away the unconsolidated and broken concrete at the joint between each column cap and beam to unveil the solid, new structural surface;
(7) Fill the cavities at the frame column-beam joints, layer by layer, with a composite grout with high-tensile strength. Then use fast-setting and -hardening cement grout to further fill and close the cavities. Keep the grouting material wet during grouting. Maintain the repaired concrete frame columns for 2-3 days.
(8) Paste carbon fiber sheets onto the cracks on the concrete beams and columns. A 300mm-wide carbon fiber strap should be added onto the caps of the concrete frame columns to strengthen them; Place a 100mm-wide carbon fiber

strap for horizontal cracks on the middle part of the columns with an interval of 200mm (See Figure 3);

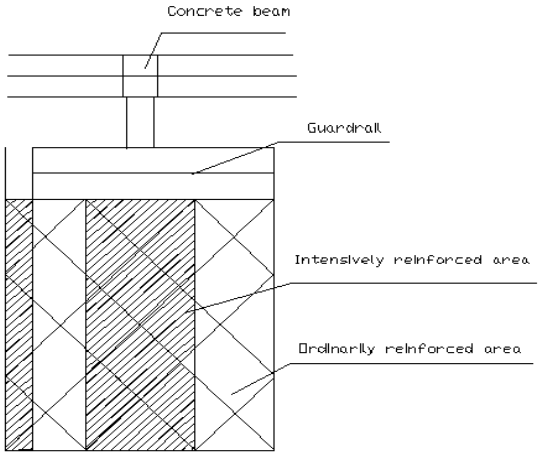

Fig.1. Schematic diagram of bowl-coupler steel bracket layout

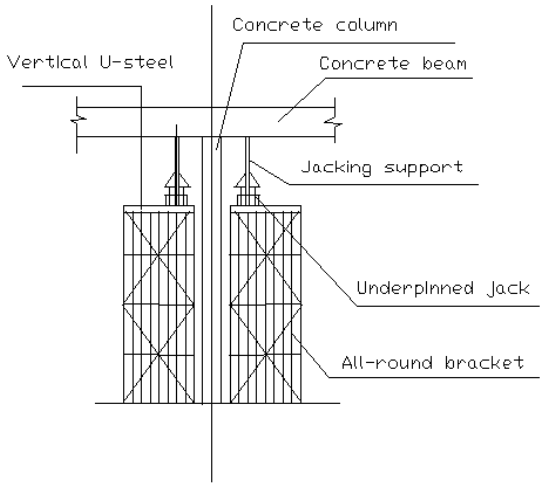

Fig.2. Schematic diagram of beam support & jacking system for restoring beam bottoms

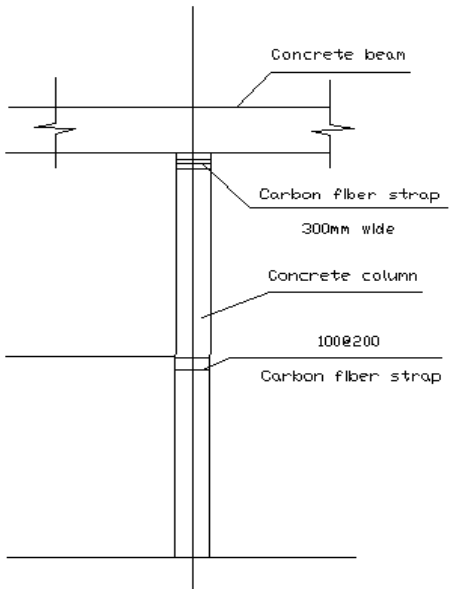

Fig.3. Schematic diagram of carbon fiber reinforcement

(9) Maintain the carbon fiber-reinforced concrete frame beams and columns for 7 days, and then dismantle the platform and jacking support system.

4 Effects of the New Method

In response to the problems in the existing building, repair and reinforcement were carried out on the beam-column joints in the building's concrete frame in accordance with the new technical proposal and design plan. With this method, the concrete strength of beam-column joints are now rated C45, which is one grade higher than the original strength of the beams and columns. Furthermore, the centerlines of concrete columns were deflected from their original design axes 1.5mm, meeting the requirements of design and construction acceptance specifications. The beams have also been restored to their original design locations, and no secondary damage to beam-column joints has occurred.

CONCLUSION

In this paper, it is recommended that the work platform be erected around the concrete frame columns under repair, and appropriate layout of steel brackets for the work platform should be made so that the work platform can share the load on the frame joints in a scientific and effective way. The jacking supports should be arranged to support the beams above the concrete frame columns and the underpinned jacks should be fit to jack and restore the bottoms of the beams.

When the top of the beam is elevated to the hoisting height, the cap of the concrete frame column should be pulled against the deformation so as to remove the deformity and restore the column to a sound condition. Filling and repair layer by layer should be implemented for cavities in the concrete frame beam-column joints.

In the last stage, reinforcement and repair with carbon fiber should be carried out for cracks on the concrete frame beams and columns until an overall repair of defects is accomplished. A good example has been achieved by applying this method to an existing building in Xi'an to repair its problems, and it also provides a reference for follow-up repair and reinforcement of concrete columns in existing building frame structures.

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