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Assessment of a cracked reinforced concrete beam: Case study

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ABSTRACT

This paper presents the analysis and repair of a cracked reinforced concrete beam in a 3-story office building in Riyadh, KSA during its construction and near completion. In October 2015, a reinforced concrete beam with a cross section of 300 mm x 1500 mm and a clear span of 16.5 m in this building cracked at the connection with one of its supporting columns. This crack propagated on both sides of the beam. To investigate the main reason of the beam cracking, a site visit was conducted to visually inspect the cracking beam and the connecting structural elements. After that a detailed analysis of the beam using PLAXIS and SAP2000 to investigate the stresses developed in the beam, spot the most stressed parts and to check the adequacy of the design. The analysis revealed the inadequacy of flexural resistance of the beam as well as the shear and torsion capacity. The main reason of the crack is underestimating the cladding weight. Based on the results, a repair methodology was selected using CFRP sheets to increase the flexural capacity of the beam section with enhancement to its torsional and shear carrying capacity to meet the design demand.

1. Introduction

Beam-column joint plays an important role in the structural response of reinforced concrete structures, especially when these structures are subjected to cyclic or seismic loads. These joints usually experience high flexural and shear stresses from vertical and lateral loads. Shear stresses may arise from shear forces and/or from torsion straining actions in some cases such as edge beams, especially if loaded by heavy cladding. The stress distribution due to flexural and shear forces produce a diagonal crack pattern in the panel which leads to crush of the compressive strut, and consequently, to deterioration of strength and stiffness of the joint [1,2].

The behavior of beam-column joint in reinforced concrete structures was investigated by many researchers over last decades through experimental tests as well as finite element analysis to address many aspects such as failure modes, ductility, energy dissipation capacity and sudden decrease of strength [3–5]. There are two common types of joint failure based on the ductility of the joint. These types are non-ductile joint shear failure prior to beam yielding or ductile joint failure after beam yielding. The global capacity of the structural system is controlled by shear strength of beam-column joints [6]. For reinforced concrete beams with plain steel bars, the sliding of steel bars may govern the failure mode of the beam and the diagonal shear failure has less effect [7].

Rules and guidelines for design structure to have better response considering the beam-column joint are presented in many building codes [8–10]

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Many researchers considered different techniques in strengthening reinforced concrete beams. Some used external layers of Ultra High Performance Fiber Reinforced Concrete, UHPFRC, on the tensile side or compressive side or three side jacket of the beam [11,12]. M.A. Al-Osta et al [13]. investigated the effectiveness of strengthening reinforced concrete beams by sand blasting RC beams surfaces and casting UHPFRC around the beams and by bonding prefabricated UHPFRC strips to the RC beams using epoxy adhesive. Other researchers used steel angles prestressed by cross ties for seismic retrofit [14]

Esmaeel et al. [15] used a combination of GFRP sheets and steel cage for seismic strengthening of reinforced concrete beam-column joint without perforating the concrete elements. Carbon-fiber-reinforced polymer, CFRP strips and sheets were used to strengthen defected beam-column joint. The failure characteristics of the defected joint were effectively enhanced by using the CFRP strips and sheets. It was found that strengthening using CFRP increased the joint ultimate capacity and reduced the ductility [16].

The objective of this research is to present the results of investigation that the author conducted based on the owner request to check the accuracy and appropriateness of the builder analysis and conclusion. The request was done after observing a crack in the beam-column joint in a newly constructed building and during the finishing period. The building was not opened for use yet. The investigation is based on the detailed analysis using PLAXIS and SAP2000 to check the stresses developed in the beam and determine whether the stresses developed in the beam exceed those expected by the design and to propose a repair method, if needed.

2. Cracked beams details

A crack of more than 10 mm width was detected in an edge reinforced concrete beam of the second floor of a three-story office building in Riyadh. This beam has a clear span of 16.5 m with a section of 300 mm x 1500 mm. A plan showing this beam is presented in Fig. 1, and the beam reinforcement is presented in Fig. 2. It was reported that the crack was first noticed after erection of the heavy, exterior cladding on the inflected beam. The crack is located at the beam-column joint. The adjacent beam cross section is 400 mm width and 700 mm height with a span of 4.0 m.

Review of the beam design loads indicated that the beam carries its self-weight, centric brick wall of about 4.5 m height plus heavy external cladding of about 4.5 m height, weighing about 15 kN/m. This heavy cladding represents more than 40% of the load on the beam. Accordingly, initiation of the crack right after installation of the cladding should be considered carefully in the structural sense during this investigation. It is worth noting that the beam does not carry floor self-weight since it is on the edge of the building on the back entrance with the whole building height.

3. Crack description

After observing the crack, the builder diagnosed the crack and concluded that it is non-structural in nature, with no associated risk. The builder diagnosed the crack as being temperature induced due to lack of the side reinforcement that was supposed to prevent the crack in the first place. He suggested that the crack needs mere aesthetic treatment for architectural reasons.

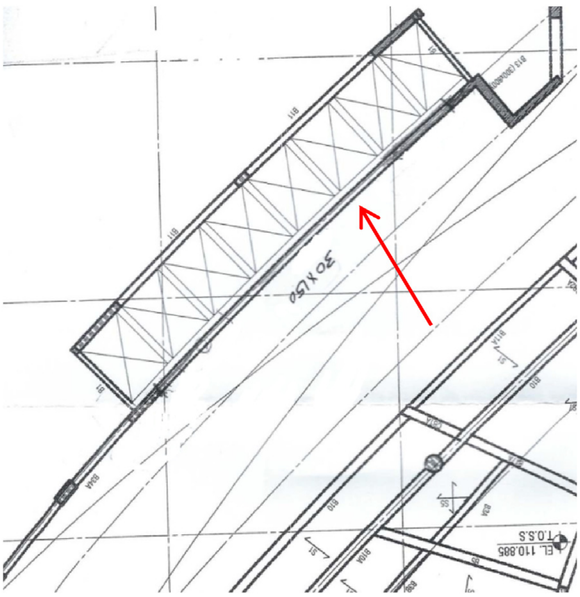

Fig. 1. The cracked beam location on the floor layout.