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Strengthening of Reinforced Concrete Structures Exposed to Fire

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Abstract: Fire disaster caused by various reasons leads a serious damage to buildings and loss of life. Although buildings are constructed according to the regulations, fire disasters can cause serious damage to buildings. In some cases, it may be necessary to repair and strengthen the structural elements that are partially damaged in fire exposed structures. In this study, investigation and research based of column and beam reinforcement of burned area as the result fire breakout during concrete pouring at a 9th floor of reinforced concrete structure was discussed. During the analysis carried out, it was aimed to strengthen the damaged elements also not to overdesign lower floor column sections of the column load flow between the floors and to complete the reinforcement on the damaged floor. For this purpose, the column sections are modeled in one and two variables linear.
Keywords: *Reinforced concrete, reinforcing, repairing, fire, strengthening*

INTRODUCTION

Elimination of structural problems of carrier elements of the reinforced concrete structures due to; concrete strength is lower than anticipated, exceeding the project design loads due to the use of the structure other than project planning purpose, exiting the project details of the building during construction, design and / or construction defects and natural disasters (earthquake, fire) and etc.requires repairing and / or reinforcement of these elements.

Fire safety regulations in Turkey became functional in 2007 and these regulations was updated in 2009 TBYKHY [1,2].Occasional fire outbreaks in reinforced concrete buildings result in loss of life and property.The high temperature resulting from the duration of the fire outbreak can lead to a decrease in the strength of the concrete and steel causing partial or total structural failure Erdem [3].If the concrete remains under the influence of high temperature, significant decreases in strength can be observed. The limit temperature of the concrete is considered to be between 250-300℃.Although the arising damages under this temperature are insignificant, but exceeding the limit temperature raises concern about the resultant significant damages Uysal [4].The concrete cover should be increased as necessary where fire, corrosion and other harmful external factors are concerned TS500 [5].The ACI committee issued a report to determine the fire resistance of concrete elements, and it contains practical information that can be used by engineers ACI216 R-89 [6].Nadjai et al., examined the structural behavior of reinforced concrete beams reinforced with FRP and steel reinforcement at high temperature using slicing method Nadjai et al [7] . Hsu and Lin, used the finite difference method to determine the temperature distribution within the beam to calculate the carrying capacities of the reinforced concrete beams after the fire Hsu and Lin [8]. Desai, proposed a way to approximate the strength of the concrete section Desai [9].Erdem, examined the change in the bearing capacity of the reinforced concrete slab under the effect of high temperature Erdem [10].

Principally in reinforcement techniques, it is intended to increase the carrying capacity of the element sections by enlarging the element sections, in order to provide integrity with the existing construction in terms of reinforcement and concrete.

MATERIAL AND METHOD

Actions to be taken during the process strengthening of the damaged buildings are;determination of the fire damages in the existing building, determination of the concrete strength used in the structural system elements by the coring test method, determination of steel reinforcement suitabilityfor the project using x-ray device, performance analysis of an existing building by considering the principles of Earthquake Codes, preparation of reinforcements if the sections are inadequate, strengthening of reinforced concrete beam and columns to eliminate fire damage.

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In this article, an example of application of column and beams reinforcement of a fire-damaged structure is discussed. Initially, construction of 8 floors of a9-storey reinforced concrete structure were successfully completed and the 9th floor which had brick walls got burned in fire outbreak during pouring concrete and the section shown in Figure 1 was significantly damaged.Before the fire, the reinforced concrete construction of this floor was continued intermittently andmain part was completed. On the day of the fire outbreak, concrete pouring of the remaining 1/16 section of this floor were started. At the end of the fire, this part which its reinforcements were newlyinstalled collapsed.Furthermore, the whole reinforced concrete mold burned out except the area between the A and B axes on the right side of the entrance accordingly.

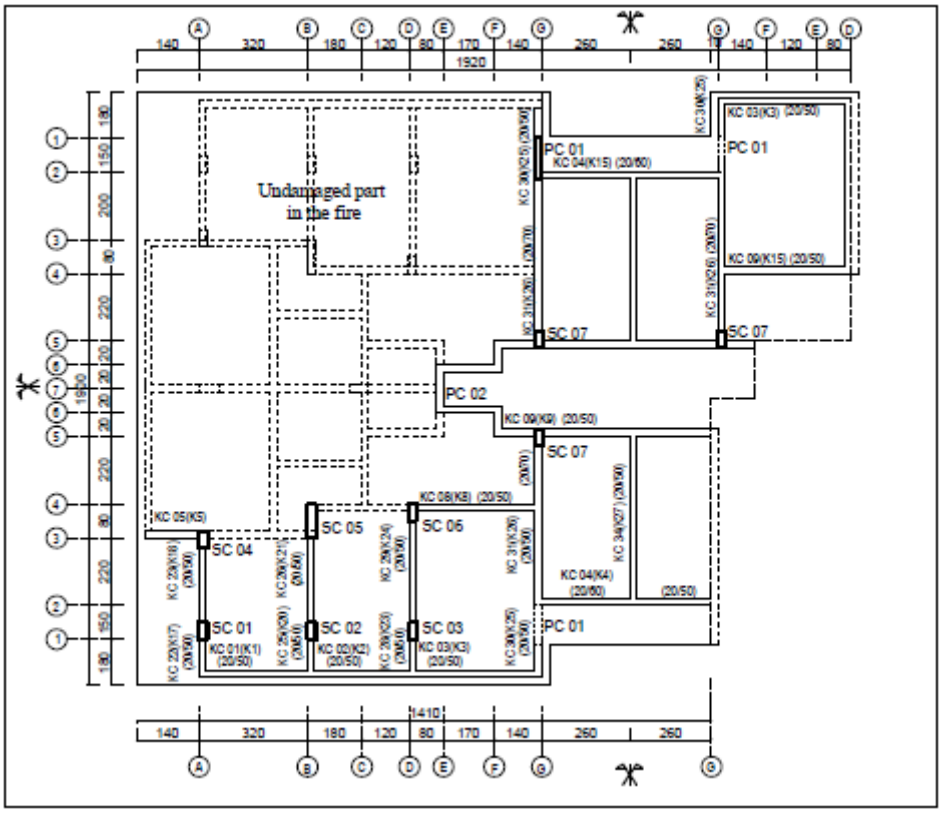

Figure 1. The floor plan with fire damage

After the fire, the burnt remains were removed and the floor was cleaned. The strength test of the various elements (columns, beams, slabs) were carried out using concrete rebound test, also the boundary of the undamaged region was determined and marked on the site according to the concrete reinforcement projectapplication.It is determined that the concrete strength is not sufficient in the fire-damaged area and the reinforced concrete elements which are only a few days old at the time of fire.
All of the reinforced concrete damaged by the fire which were beyond restoring (until the upper level of 8th floor) were removed and the removal process was carried out by leaving a 1/4 'section from the boundary on the adjacent slabs.For this reason, the reinforcement process was carried out on the columns, shear wall and beams marked in this area. Necessary measures were taken to ensure the integrity of both the existing concrete and newly placed reinforcements.

Preparation and implementations of reinforcement project

This section provides details on the arrangement and implementation of the reinforcement project. Figure 2 shows a one-sided reinforcement detail of the column SC04 carrying a cantilever beam.

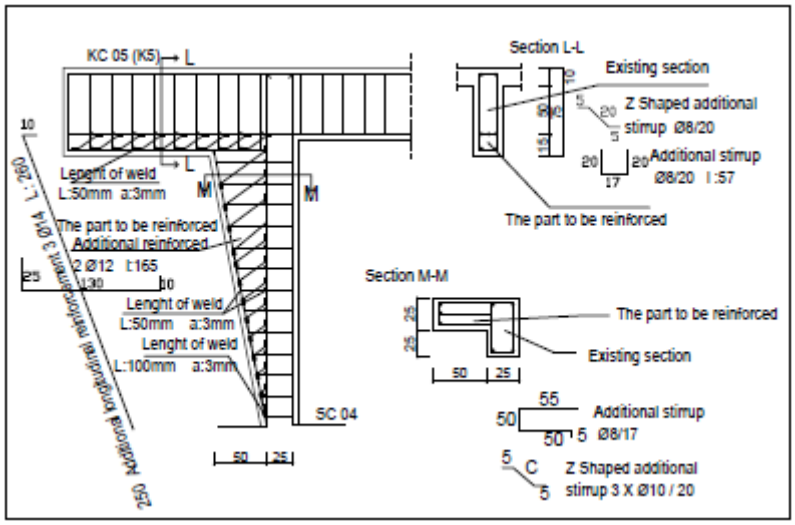

Figure 2. Unilateral reinforcement detail of SC04 column carrying a cantilever beam

In order to complete reinforcement of a single floor and to transfer the load to the bottom column was thought to be linearly modified so as to provide an upward section increment, thereby reducing the cantilever beam span. Before the reinforcement process, the concrete covering layer above the reinforcement was removed unilaterally and the reinforcements were exposed.In the reinforcement of the shear wall and columns, longitudinal reinforcement with curved Z-shaped (⌒└) and lateral U-shaped (⊔) reinforcements have been used. The Z-shaped reinforcement bars are firstly welded to the existing reinforcement and then to the column longitudinal reinforcements, and finally arranged in the lateral reinforcement arrangement with the U-shapedstirrups.

Likewise, the cover concrete at the bottom of the cantilever beam reinforcement bars were removed, and the Z-shaped reinforcements were first installed to the existing reinforcement bars and then to the newly assembled reinforcement bars of the beam, also the U-shaped stirrups were welded to the existing reinforcement bars in the bottom of the beam.

With the column SC05 in Figure 3, the P002 screen in Figure 4 was reinforced by two sides and the sections were enlarged. In the reinforcement application, the above sequence was also followed.The above sequences were followed throughout theinstallation of the reinforcement. The additional moment formed on the S-shaped (⌐┘) column section as the result of reinforcement were neglected considering the span of beams supporting the column and the small load difference and the size of the existing column.

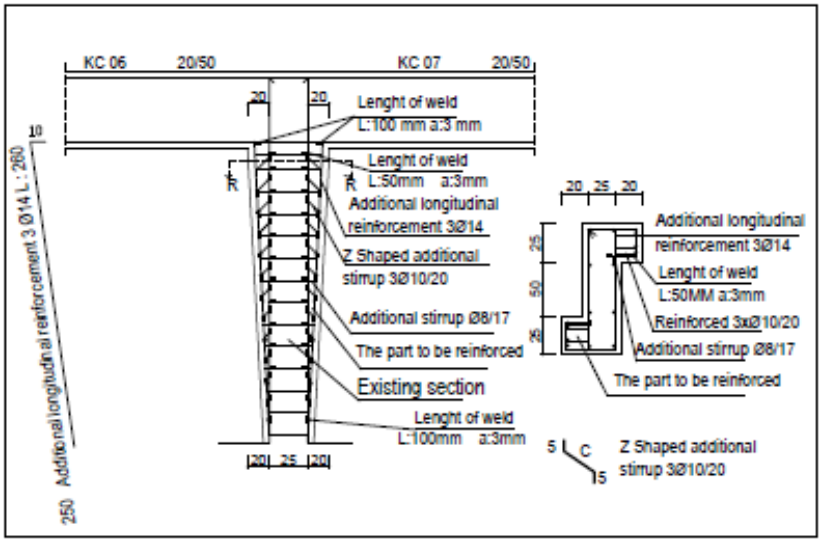

Figure 3. Bilateral reinforcementdetail of SC05 column

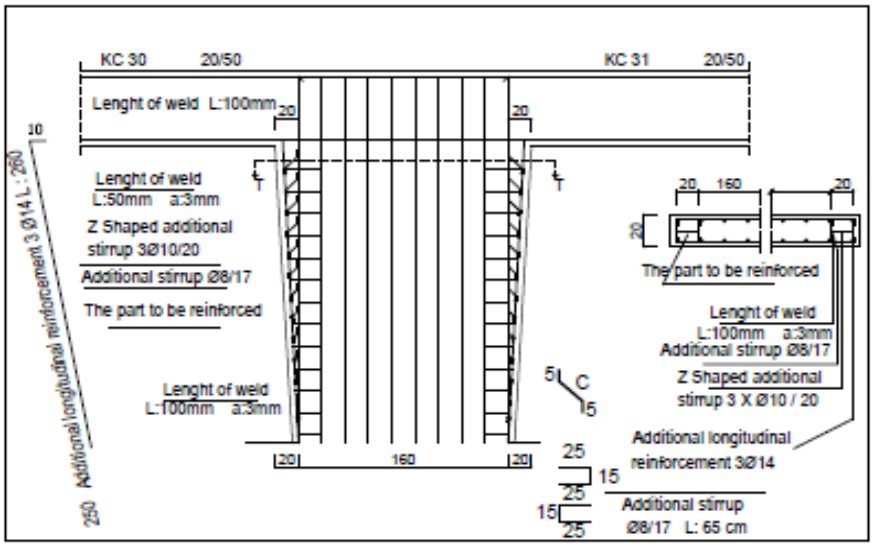

Figure 4. Bilateral reinforcementdetail of PC02 shearwall

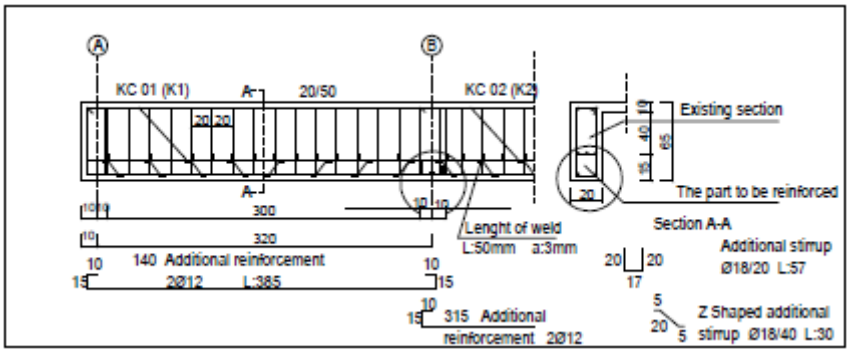

Figure 5. Reinforcement detail of beamsupportedbeam

Figure 5, shows a beam supported by a beam and Figure 6, shows the reinforcement detail of a beam supported on the column. Figure 7, shows the point details of beam and column combinations.

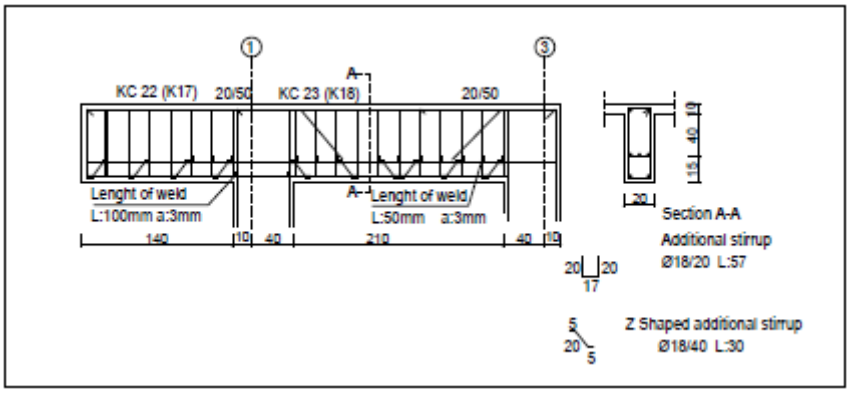

Figure 6. Reinforcement detail of cantilever beam supported column

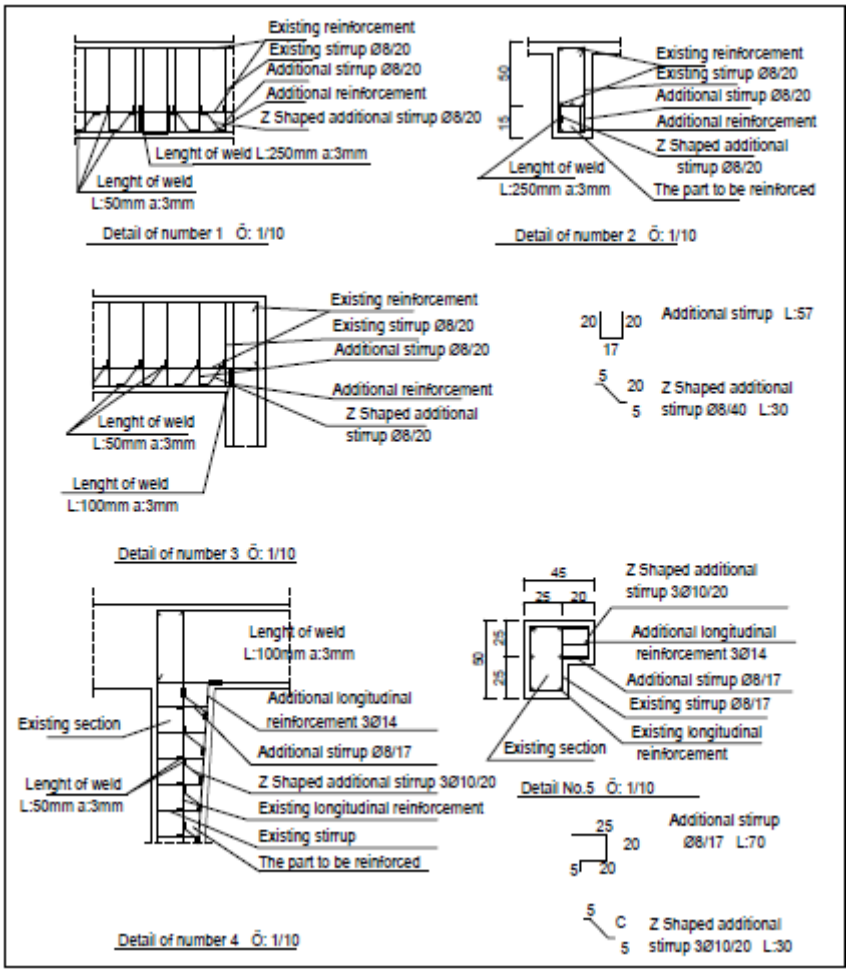

Figure 7. Details of beam column joint

The steel material used was S420 and the concrete was C30. The emphasis on the application and considerations carefully performed is given below.

1. The concrete on the reinforcement was removed.
2. Metal bars according to the reinforcement project were carried out in the following order;
   - FirstZ-shaped reinforcements welded to existing bars,
   - Longitudinal reinforcements welded to existing reinforcements and Z-shaped reinforcements,
   - Stirrups welded on existing bars and reinforcement bars,
3. The concrete was poured on the installed mold.
4. During preparation and casting of concrete;
   - Material used were 2 cm maximum grain diameter
   - The existing concrete surface was cleaned and precaution was taken to ensure the connection with the newly poured concrete.

The work done at each of the steps mentioned above has been checked and the other step has been passed after this check.

RESULTS

Structural problems that arise due to various reasons in reinforced concrete structures can be remedied by repair and reinforcement of carrier elements.In the exemplary embodiment detailed above, the reinforcement of the columns and beams in the reinforced concrete building, which was damaged in the fire, was carried out by increasing the cross sections so that the building could be used.In order to complete the reinforcement on only the damaged floor, the cross-section changes in the reinforcedcolumns were ensured by linear increment from bottom to top along the column.In this type

of repair and reinforcement work, preparation of a research-based reinforcement project and rigorous examination, as well as a high quality of workmanship and effective inspection are required.

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