博士論文（要約）

Structural Similarity on Cyclic Responses and Corrosion Impact for Circular and Square Sectional Reinforced Concrete Members

（矩形および円形断面を有するRC部材の構造応答に及ぼす鋼材腐食の影響と応答相似性）

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ABSTRACT

Plenty of research has been carried out in order to understand the flexural and shear behavior of columns. It resulted in a comprehensive design procedure for the rectangular columns. On the other hand, the circular columns' design is based upon the same techniques as used in case of the square columns by converting the circular shape to a square shape using some specific set of rules. These rules have been described in the design/evaluation codes e.g. JSCE and ACI. A detailed numerical and experimental study was carried out on the behavior of circular and square columns under flexural and shear controlled conditions in this research. For numerical simulations an experimentally verified FEM package COM3D was used. Initially monotonic loading was used for both numerical and experimental study. It was found that the two types of columns behave (load-deflection relation) in quite similar way especially the initial stiffness and maximum load capacity. Based upon these results a new and simplified method was proposed for the design of the circular columns. According to this new proposal, there is no need to use the complex rules to convert the circular shape to the square shape

for the design purposes. Instead a circular column can simply be converted to an equivalent area square column. In this equivalent area column, the cross-sectional area of concrete and steel reinforcement provided is kept same. The circular and square columns used in this study were having two types of reinforcement patterns, dense and sparse, but the total area of steel was kept constant. The results showed that the similarity of circular and square columns hold under dense and sparse both type of reinforcement detailing.

The study was continued with cyclic loading situation. Both numerical (using COM3D) and experimental studies were carried out for this purpose. A combination of cyclic and reverse cyclic loading was used to study the similarity of equivalent area circular and square columns in detail. A number of positive cyclic loads were applied followed by reversal of loading and applying negative loading cycles. It was found that the circular and square columns similarity does not necessarily hold under the cyclic-reverse cyclic loading conditions. During the initial stages of loading the circular and the square columns behave in a perfectly similar way (as in case of monotonic loading) but after some cycles the similarity is disturbed. Under low cycles fatigue loading the circular column was found to be relatively more ductile then the square column but at the same time the maximum load capacity of the circular column was lesser than the square column. The results also show that the columns with dense reinforcement exhibit more ductility as compared to the columns with sparse reinforcement.

This study was continued with high cycle fatigue loading with number of cycles reaching around 200. Both circular and square columns were tested under the fatigue loading with and without the shear stirrups and in flexure and shear controlled conditions. The results from testing of columns without shear stirrups show that the square column has better ductility as compared to the circular column. This difference was observed even with the shear stirrups but it was smaller. The shear stirrups definitely improve the performance against fatigue

loading while this improvement is more in case of circular column then the square column.

More studies were carried out on the similarity of circular and square column in the corroded conditions. It is already expected that the corrosion of steel reinforcement will impact the loading capacity of the columns but this impact was found to be different for square and circular columns. The study showed that the circular and square column similarity does not hold after the corrosion of the reinforcement. In most of the cases circular column proved to be relatively better than the square column but it is very complex to establish which of the two types is better under the corroded conditions.

Further a few more parameters were studied like effect of different reinforcement layouts (dense and sparse reinforcement patterns) and the different clear cover thickness in the columns under corroded conditions. It is suggested that lesser number of larger diameter steel reinforcing bars should be preferred in the environment where corrosion is expected like marine environment. Also, study showed that larger clear cover which is primarily a good defense against corrosion of steel reinforcement may cause more damage in case chloride manages to reach the reinforcement and cause corrosion. To study the effect of corrosion in details, a full scale building (2-Dimensional numerical model) was simulated and analyzed under earthquake accelerations. It was found out that very low corrosion rate at axial loads lesser than 10% of the axial load capacity might not affect the overall behavior of the building rather the ductility seems better. But at higher corrosion rate and higher axial load values the corrosion damage may cause serious deterioration of structures and cause poor performance during an earthquake.

In general cases, the expansion of the corrosion gel produced after corrosion of steel reinforcement along with a reduction in the steel area and bond loss is used to determine the impact of corrosion on the structural elements. A new approach

“poro-mechanical approach” was studied in order to include the effect of absorption of corrosion gel in the pores surrounding the steel reinforcement and migration of corrosion gel in the cracks. The impact of corrosion was found to be very sensitive to the viscosity parameter which will determine the amount of corrosion gel transported and the remaining amount applying pressure against the concrete wall and causing cracks. This approach gave good results in terms of the delayed pressure generation due to the corrosion gel which was found parallel to experiments.