# NUMERICAL INVESTIGATION OF CLOSELY SPACED ANCHOR GROUPS UNDER DIFFERENT GEOMETRIC AND LOADING CONDITIONS

**Muhammad Fasih ur Rehman**

## Abstract

Post-installed bonded anchors find a wide range of application in construction industry due to their versatility and flexibility in accommodating diverse engineering needs. Engineering practices often encounter situations where space constraints within a building member lead to unusual anchor group geometric configurations. Multiple anchor groups with small inter-group spacing (closely spaced anchor groups) emerge as a result. The stress-field and overall behaviour of individual anchor groups is affected by the presence of other closely spaced anchor groups. Situation become more intricate when these closely-spaced anchor groups are installed in close proximity of edge, subjected to different loading conditions and involve different eccentric loading scenarios.

The current design standards provide limited and very conservative guidelines for designing and analysing closely spaced anchor groups where spacing between neighbouring anchor groups is less than the critical anchor spacing. This paper presents a 3-dimensional (3D), Finite Element (FE) study on the tension and shear behaviour of closely spaced anchor groups under various geometric and loading conditions. Different parameters such as inter-group spacing, presence of nearby edge and loading positions (eccentricities and symmetry of loading) for models loaded in tension, are numerically investigated. In case of shear loads, anchor groups with similar / different edge distance in the direction of loading and different loading positions are investigated. In this study, concrete cone break-out failure for tension loaded anchor groups and concrete edge failure for shear loaded anchor groups are considered as critical failure modes.

Numerical analysis is carried out using microplane model for concrete with relaxed kinematic constraint as the constitutive law. 3D, finite element, Mascroscopic Space Analysis (MASA) program is used to numerically investigate the behavior of closely spaced anchor groups under different geometric and loading conditions. The numerical modelling approach is first verified and validated against available experimental results on anchor groups and then used to

carry out a detailed and systematic study. Parametric study on a wide range of geometric configurations containing multiple anchor groups subjected to different loading positions (centric / eccentric) is carried out.

Comparison study is conducted to check the numerical resistance capacities against analytical values calculated using existing concrete capacity design (CCD) method incorporating newly developed virtual edge approach which considers a virtual edge to assign individual tributary areas to individual anchor groups in calculating the concrete breakout resistance of anchorages. Evaluation of results indicate that virtual edge approach is appropriate, rational and reasonably conservative to consider the influence of presence of neighbouring anchor group on the capacity of given anchorage. A new set of guidelines is recommended to design closely space anchor groups for arbitrary geometric and loading conditions.