Effective anchorage strategies in retrofit and strengthening

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Abstract

Retrofit and strengthening of structures is increasingly required for enhancement of survivability and sustainability under extreme loading conditions. The success of such efforts is generally dependent on the robustness of the connection strategies employed, e.g., between the structure and its foundation, between the walls and the diaphragms, and between the strengthening elements and the primary structural frame. Fundamental concepts include connection/system ductility, maximum carrying capacity, maximum displacement capacity, and connection overstrength. This discussion reviews the concepts of anchorage design in the context of seismic demand as framed by the provisions of ACI 318 and ASCE 7; the concepts presented have equal applicability to design for other extreme loading events. Examples of successful connection strategies are presented and a brief review of ongoing research is included.

Keywords: retrofit; strengthening; seismic; concrete; anchors.

1 Introduction

The success of seismic retrofit and strengthening strategies for buildings and bridges alike is often dependent on the ability of connections between primary structural elements to resist overload and imposed deformations well beyond the elastic limit. Where the connections are between steel and concrete members, or between reinforced concrete elements, principles of anchorage to concrete must be understood and observed.

2 Basic principles

Design principles for anchors in concrete have evolved over the past several decades. Based largely on research conducted at the University of Stuttgart, the University of Texas at Austin, and the University of Florida [1], the current concrete capacity approach used in Europe and the U.S. relies on simple engineering models to represent the complex interaction of local stresses in the concrete that arise in response to anchor loading.

2.1 Concrete breakout

The phenomenon of concrete breakout, whether in tension or in shear (where there are proximate edges in the direction of load) is relatively well understood.

In the typical case, concrete breakout emanates from a discrete point of concentrated loading within the concrete. At the ultimate limit state, the tri-axial stress levels in the concrete at the point of concentrated load introduction are typically an order of magnitude beyond the measured concrete uniaxial strength, owing to the confinement provided by the surrounding concrete mass. Concrete fracture initiates at or near the centroid of load introduction into the concrete and progresses in a roughly conical fashion toward the free concrete surface (Fig. 1). The progression of cracking can be remarkably stable, depending on the geometry of the anchorage, and is preceded by the development of the crack process region described by Bazant, et al. [2]. It is the stable nature of crack growth in

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