Briefing Paper 4

Seismic Response of Concrete & Masonry Buildings

Part D: The Importance of Ductility

Introduction

Briefing Paper 4, *Seismic Response of Concrete and Masonry Buildings*, consists of four parts. Part A provides a brief overview of how earthquakes affect reinforced concrete and masonry buildings. Part B describes the detailed response of a floor (or roof) diaphragm to the horizontal forces generated within it, and how the forces are transmitted horizontally to the building walls and frames. Part C describes the vertical load path carrying the horizontal loads down the building walls and frames, through the foundations and into the ground. This Part D explains that as well as providing the load paths, some specific components must have the ductility necessary to handle the large distortions from major earthquakes.

Ductile Behavior

While the concept of horizontal and vertical load paths to transmit horizontal seismic forces to the foundation is enlightening, it is not the whole story of good seismic performance. In large earthquakes, forces are expected to exceed the yield strength of the links in the load paths. Good behavior requires that the links deform plastically while dissipating energy, without breaking in a brittle and abrupt manner. This is a property known as ductility. When you bend a pencil, it snaps without warning. Do the same to a coat hanger and it will bend without breaking. The coat hanger is ductile.

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Concrete and masonry are inherently nonductile. Both can satisfactorily take compression, but added reinforcing steel is required to resist any tension. Reinforcing steel is also used to confine concrete. Confinement enhances both strength and ductility in several respects. Confinement can be visualized as a cardboard tube holding marbles. The marbles themselves are not very stable, but when placed in a surrounding tube they can actually support loads. This type of confinement is important where there are zones of high compressive or shear forces. Confinement is also important in zones where longitudinal steel is spliced. As the two pieces of spliced, deformed reinforcing are pulled apart in opposite directions, there is a tendency for the surrounding concrete to split and expand. The confinement restrains this splitting and expansion, and it allows the splice to be effective in developing the tensile strength of the bars.

Confinement is usually provided by what is termed special transverse reinforcing (see Figure 1). These are small-diameter ties in columns, and stirrups in beams, placed at close intervals. Proper confinement is particularly critical at the joints between beams and columns. At these points, when both building interstory drifts and joint rotations are high, tension must be transmitted from the top of the beam on one side of the joint to the bottom of the beam on the other. At the same time, the tension must be transmitted from one side of the column to the other through the same region of the joint, known as the panel zone. These actions give rise to high shear forces in the panel zone. The joint is a congested volume of both vertical and horizontal transverse reinforcing, and longitudinal reinforcing.

Resources

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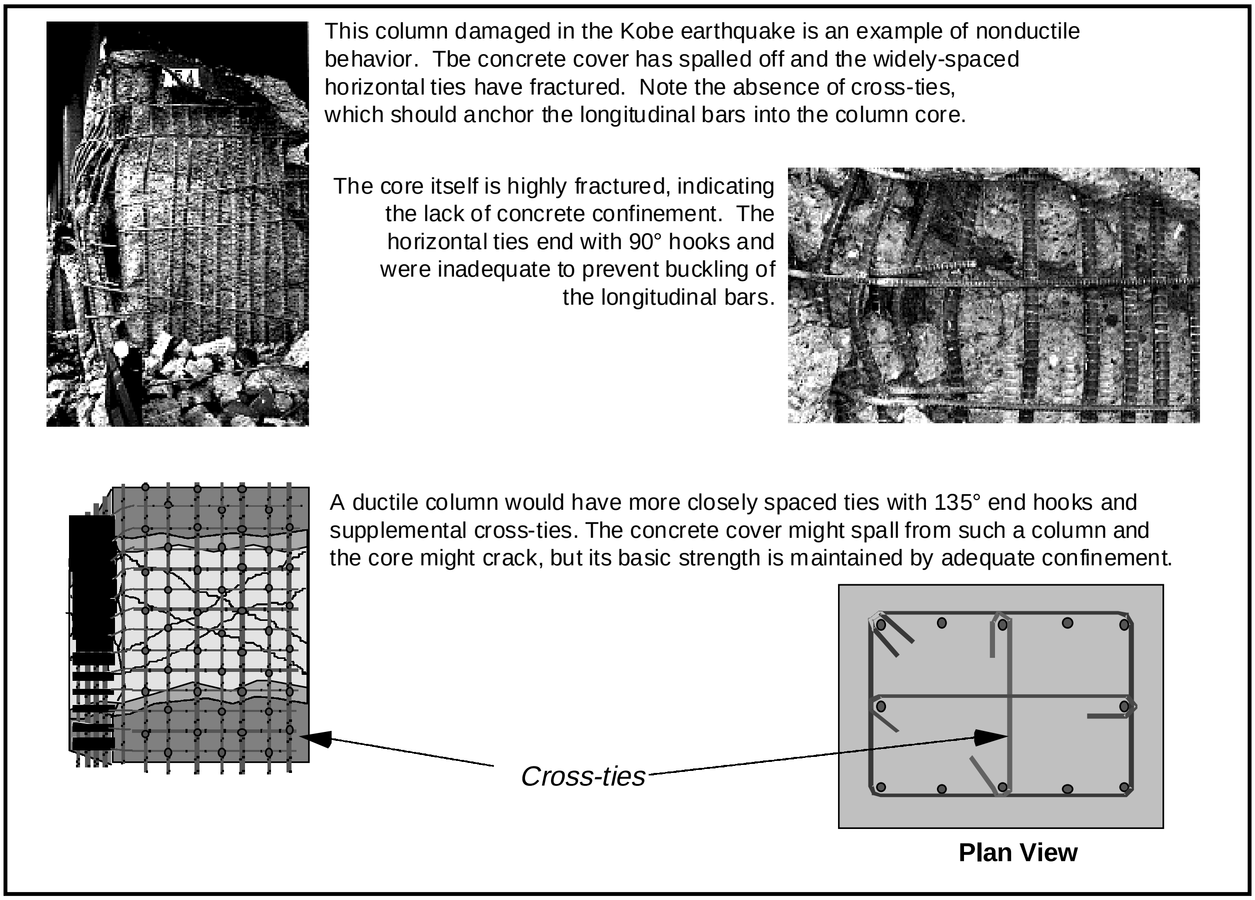

Figure 1. The effect of confinement on column ductility

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About this Briefing Paper Series

Briefing papers in this series are concise, easy-to-read summary overviews of important issues and topics that facilitate the improvement of earthquake-resistant building design and construction quality.

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