Table 7-1 Behavior Modes for Non-Wall URM Elements

Element		Source of Deficiency	Behavior Mode	Intensity of Ground Shaking Usually Required to Produce Behavior Mode
Parapet		Out-of-plane flexural tension	Parapet falls	Low-to-moderate
Appendages		Connection failure	Falling hazard	Low-to-moderate
		Missing headers or veneer ties	Veneer delamination	Moderate
		Stiffness incompatibility	Cracking and spalling	Low-to-moderate
		Pounding	Local spalling	Moderate
Wall-Diaphragm Ties				
	Tension Ties	Inadequate or missing ties	Wall-diaphragm separation	Moderate
	Shear Ties	Diaphragm slides	Perpendicular walls punched out	Moderate
Diaphragms				
	Rigid Concrete Slab	Not typically damaged	NA	NA
	Hollow Concrete Plank	Lack of interconnection	Incomplete load path, excessive deflection	Moderate-to-high
	HCT/Brick Arch on Steel Beams	Lack of tie rods between steel beams	Localized falling hazard as beams separate	Moderate-to-high
	Flexible	Inadequate strength/stiffness	Excessive deflection can cause wall damage	Moderate-to-high

diaphragm ties, it is important to include their behavior and characteristics in modeling efforts.

7.2.2 Wall Components

URM wall elements can be subdivided into five Component Types as shown in Figure 7-9, based on the mode of inelastic behavior. Figure 7-9 also shows some of the common behavior modes. The majority of modes relate to in-plane damage, but out-of-plane damage can occur as well in each of the systems, often in combination with in-plane damage. The five component types are described below.

URM1: Solid cantilever walls. Such walls are typically found adjacent to other buildings or on alleys, and they act as cantilevers up from the foundation.

URM2: This component is a weak pier in a perforated wall. In this system, inelastic deformation occurs in the piers.

URM3: This component is a weak spandrel in a perforated wall. Inelastic deformation occurs first in the spandrels, which may create multistory piers similar to URM1 or URM2 and then lead to inelastic deformation and damage in the piers.

URM4: This component is a strong spandrel in a weak pier-strong spandrel mechanism. By definition, it should not suffer damage, and it is not discussed further in the report.

URM5: Perforated wall with panel zone weak joints. Inelastic deformation occurs in the region where the pier and spandrel intersect. Such damage is not observed generally in experimental tests, nor is it seen in actual earthquakes, except at outer piers of upper stories. In this document, such damage is considered a case of corner damage and, when caused by in-plane demands, is addressed as part of the URM3 spandrel provisions.

Table 7-2 summarizes behavior types for URM wall components identified above. The table provides an

Table 7-2 ***Behavior Modes for URM Walls***

Ductility Category	Behavior Mode	Likelihood of Occurrence and Damage Guide Reference		
		Solid Wall (URM1)	**Weak Piers (URM2)**	**Weak Spandrels (URM3)**
Higher Ductility	Foundation Rocking	Common in field; no experiments; see text	NA	NA
	Wall-Pier Rocking	Possible; similar to URM2A Guide	Common in field; experiments done; see URM2A Guide	NA
	Bed Joint Sliding	Common in field; has experiments; similar to URM2B	Common in field; experiments done; see URM2B Guide	Unlikely; no guide
	Bed Joint Sliding at Wall Base	Possible; similar to URM2B Guide	NA	NA
	Spandrel Joint Sliding	NA	NA	Common in field; no experiments; see URM3D Guide
Moderate Ductility	Rocking/Toe Crushing	Seen in experiments; similar to URM2A Guide	Possible; similar to URM2A Guide	NA
	Flexural Cracking/Toe Crushing/Bed Joint Sliding	Seen in experiments; see URM1F Guide	Possible; similar to URM1F Guide	Unlikely; no guide
	Flexural Cracking/Diagonal Tension	Possible	Seen in experiments; similar to URM2K Guide	Unlikely
	Flexural Cracking/Toe Crushing	Seen in experiments; see URM1H Guide	Possible; similar to URM1H guide	Possible; no guide
	Spandrel Unit Cracking	NA	NA	Common in field; see URM3I guide
Little or No Ductility	Corner Damage	Common in field; no experiments; no specific guide; see text	NA	Common in outer pier of upper stories; no specific guide; see text
	Preemptive Diagonal Tension	Possible; similar to URM2K guide	May be common in field; seen in experiments; see URM2K Guide	May be common in field; no experiments; similar to URM2K Guide
	Preemptive Toe Crushing	Theoretical; similar to URM1H Guide	Theoretical; similar to URM1H Guide	Unlikely; no guide
	Out-of-Plane Flexural Response	Common in field; see URM1M Guide	Possible; similar to URM1M Guide	Unlikely; no guide

Notes:
- Shaded areas of the table with notation "*See ...Guide*" indicate behavior modes for which a specific Component Guide is provided in Section 7.5. The notation "*Similar to ...Guide*" indicates that the behavior mode can be assessed by using the guide for a different, but similar component type or behavior mode.
- *Common in field:* Frequently observed in earthquakes, even those of moderate size.
- *Possible:* May not be explicitly documented but is assumed to have occurred or to occur in future.
- *Seen in experiments:* Reported in experiments and may have occurred in earthquakes.
- *Theoretical:* Theoretically possible but not widely reported, if at all.
- *Unlikely:* Although reported for another component, it is unlikely for this one.
- NA indicates that the failure mode cannot occur for this component.

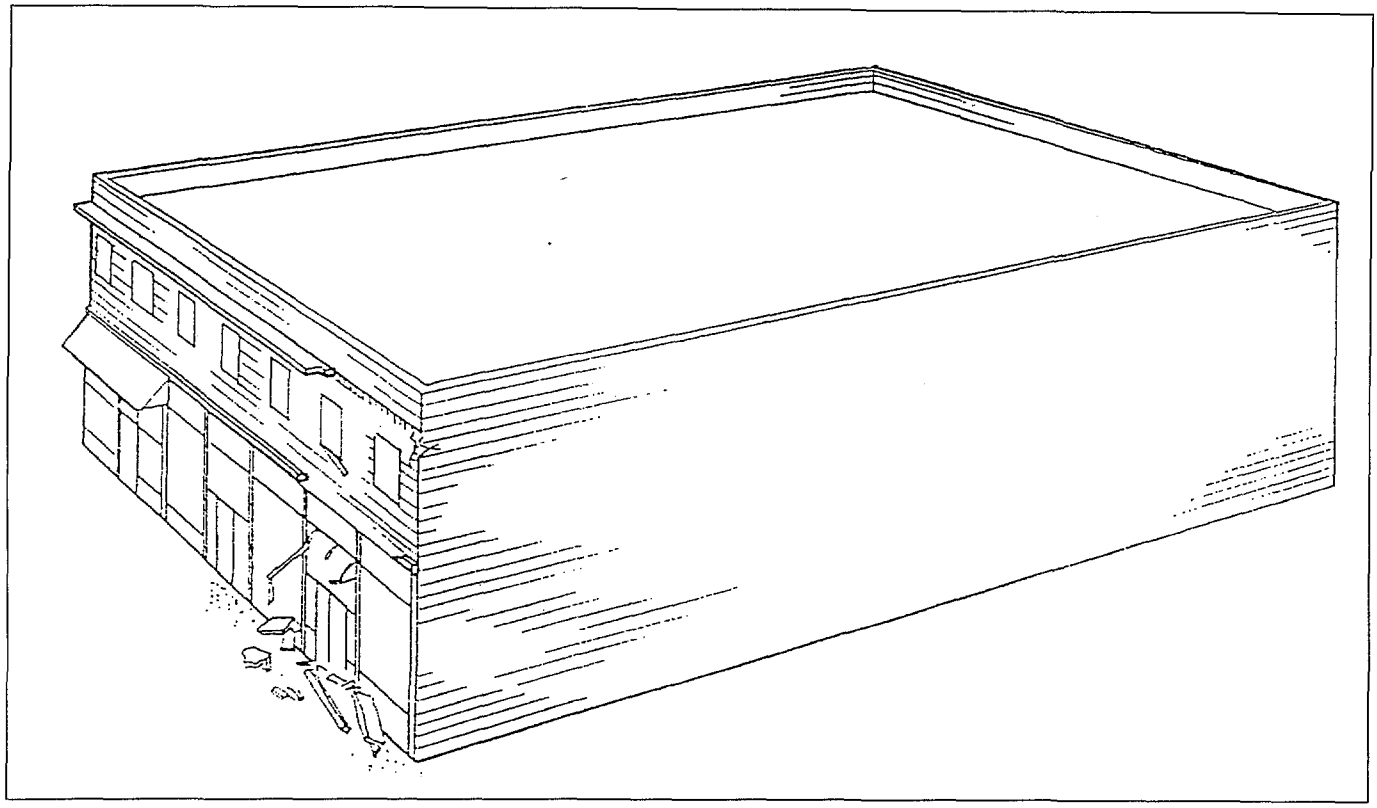


Figure 7-3 Diagram of an Appendage Failure (from Rutherford and Chekene, 1990)

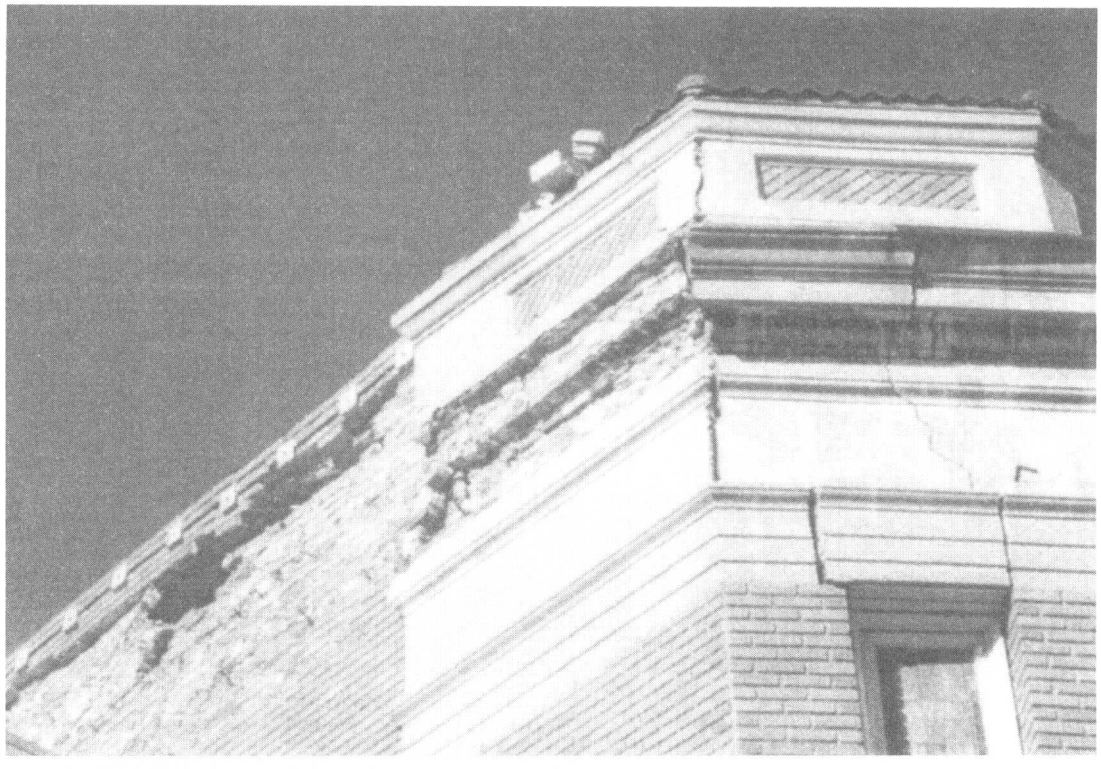
indication of the ductility associated with a behavior mode, and the frequency with which such modes are observed. There are several categories for frequency of occurrence: "common in field" means that the mode has been frequently observed in earthquakes, even those of moderate size; "possible" means that the mode may not be explicitly documented in the literature, but it seems reasonable to assume it has occurred or will occur in earthquakes; "seen in experiments" means that such modes have been reported in experiments and may have occurred in some earthquakes; "theoretical" means that the mode, while theoretically possible, has not been widely reported in the literature, if at all. "Unlikely" means that, even though a mode has been reported for another component, it is unlikely to occur in the component under consideration. The modes listed in Table 7-2 are described in greater detail in the following sections. Component Guides have been developed for the damage resulting from the common modes and are shaded in Table 7-2; the designations such as "URM2A" refer to a specific guide.

7.2.3 Foundation Rocking

Rocking of a wall and its foundation on the supporting soil has been observed in the field. Though recognized as a potentially favorable mode of nonlinear response and a source of damping rather than significant damage, excessive rocking could theoretically lead to some instability and nonstructural damage in the superstructure, particularly if various walls rock out-of-phase or elements attached to the walls cannot tolerate the wall drift. See FEMA 273 and ATC-40 for an evaluation methodology for foundation rocking.

7.2.4 Wall-Pier Rocking

In the wall-pier rocking behavior mode, after flexural cracking develops at the heel, the wall or pier acts as a rigid body rotating about the toe. The rocking mode typically occurs when material shear capacity is high, piers are slender, and compressive stress is low. Post-cracking deformations can be large and relatively stable for many cycles. The ultimate limit state and the deflection at which it occurs are not well defined by the research, but three possible damage types can occur: in-



1994 Northridge Earthquake: Santa Monica.

1989 Loma Prieta Earthquake: Watsonville.

Figure 7-4 Photos of Appendage Failures (from Rutherford &Chekene, 1990)