5. POST-EARTHQUAKE INSPECTION

When required by the building official, or recommended by the Interim Guidelines in Chapter 4, post-earthquake inspections of buildings may be conducted in accordance with the Interim Guidelines of this Chapter. In order to determine, with certainty, the actual post-earthquake condition of a building, it is necessary to inspect all elements and their connections. However, it is permissible to select ~~An~~ an appropriate sample (or samples) of WSMF connections ~~should be selected~~ for inspection in accordance with the Chapter 4 Guidelines. These connections, and others deemed appropriate by the engineer, should be subjected to visual inspection (VI) ~~and~~ supplemented by non-destructive testing (NDT) as required by this Chapter.

Commentary: The only way to be certain that all damage sustained by a building is detected is to perform complete inspections of every structural element and connection. In most cases, such exhaustive post-earthquake inspections would be both economically impractical and also unnecessary. As recommended by these guidelines, the purpose of post-earthquake inspections is not to detect all damage that has been sustained by a building, but rather, to detect with reasonable certainty, that damage likely to result in a significant degradation in the building's ability to resist future loading. The connection sampling process, suggested by Chapter 4 of these Interim Guidelines was developed to provide a low probability that damage in buildings that had sustained a substantial reduction in load carrying capacity would be overlooked while avoiding the performance of exhaustive investigations of buildings that have sustained relatively insignificant damage.

Where greater certainty in the detection of damage is desired for a building, a more extensive program of inspection can be conducted. For those cases in which it is desired to perform an analytical determination of the residual load carrying capacity of the structure, complete inspections of elements and connections should be performed so that an analytical model of the building can be developed that reasonably represents its post-earthquake condition.

5.1 Connection Types Requiring Inspection

5.1.1 Welded Steel Moment Frame (WSMF) Connections

The inspection of a WSMF connection should start with visual inspection of the welded bottom beam flange to column flange joint and the base materials immediately adjacent to this joint. If damage to this joint is apparent, or suspected, then inspections of that connection should be extended to include the complete joint penetration (CJP) groove welds connecting both top and bottom beam flanges to the column flange, including the backing bar and the weld access holes in the beam web; the shear tab connection, including the bolts, supplemental welds and

beam web; the column's web panel zone, including doubler plates; and the continuity plates and continuity plate welds (See Figure 3-1). In addition, where visual inspection indicates potential concealed damage, visual inspection should be supplemented with other methods of nondestructive testing.

Commentary: The largest concentration of reported damage following the Northridge Earthquake occurred at the welded joint between the bottom girder flange and column, or in the immediate vicinity of this joint. To a much lesser extent, damage was also observed in some buildings at the joint between the top girder flange and column. If damage at either of these locations is substantial (d_j per Chapter 4 greater than 5), then damage is also commonly found in the panel zone or shear tab areas.

When originally published, ~~These~~ these Interim Guidelines recommended complete inspection, by visual and NDT assisted means, of all of these potential damage areas for a small representative sample of connections. This practice ~~is~~ was consistent with that followed by most engineers in the Los Angeles area, following the Northridge Earthquake. It requires removal of fireproofing from a relatively large surface of the steel framing, which at most connections will be undamaged.

In the time since the Interim Guidelines were first published, extensive investigations have been conducted of the statistical distribution of damage sustained by buildings in the Northridge earthquake, the nature of this damage and the effect of this damage on the future load-carrying capacity of the buildings. These investigations strongly suggest that the W1a and W1b conditions at the weld root are unlikely to be earthquake damage, but rather, conditions of discontinuity and defects from the original construction. Further, studies have shown that NDT methods are generally unreliable in the detection of these conditions. As a result, the current recommendation is not to conduct exhaustive NDT investigations of connections in order to discover hidden damage, as was originally recommended.

In a series of analytical investigations of the effect of moment-resisting connection damage on building behavior, it was determined that even if a large number of connections experience fracture at one beam flange to column joint, there is relatively little increase in the probability of global collapse in a future earthquake. Similarly, these investigations indicate that if both the top and bottom beam flange to column joints fracture in a large a number of connections, a very significant increase in the probability of global building collapse occurs. Therefore, to reduce the costs associated with post-earthquake inspections, with the publication of Interim Guidelines Advisory No.2 it is recommended that post-earthquake inspections initially be limited to visual inspection of the beam bottom

flange to column joint region. If there is evidence of potential damage in this region that is not directly observable by visual means, for example, a gap between the weld backing and column flange, then supplemental investigations of this joint should be conducted using NDT. Similarly, if it is determined that fractures have occurred at the beam bottom flange joint, then inspections of that connection should be extended to encompass the entire connection including the top beam flange joint, the shear tab and column panel zone. This approach was permitted as an alternate, in the original publication of the Interim Guidelines.

~~*Some engineers have suggested an alternative approach consisting of visual-only inspections, limited to the girder bottom flange to column joint, but for a very large percentage of the total connections in the building. These bottom flange joint connections can be visually inspected with much less fireproofing removed from the framing surfaces. When significant damage is found at the exposed bottom connection, then additional fireproofing is removed to allow full exposure of the connection and inspection of the remaining surfaces. These engineers feel that by inspecting more connections, albeit to a lesser scope than recommended in these Interim Guidelines, their ability to locate the most severe occurrences of damage in a building is enhanced. These engineers use NDT assisted inspection on a very small sample of the total connections exposed to obtain an indication of the likelihood of hidden problems including damage types.*~~

~~*If properly executed, such an approach can provide sufficient information to evaluate the post-earthquake condition of a building and to make appropriate occupancy, structural repair and/or modification decisions. It is important that the visual inspector be highly trained and that visual inspections be carefully performed, preferably by a structural engineer. Casual observation may miss clues that hidden damage exists. If, as a result of the partial visual inspection, there is any reason to believe that damage exists at a connection (such as small gaps between the CJP weld backing and column face), then complete inspection of the suspected connection, in accordance with the recommendations of these Interim Guidelines should be performed. If this approach is followed, it is recommended that a significantly larger sample of connections than otherwise recommended by these Interim Guidelines, perhaps nearly all of the connections, be inspected.*~~

5.1.2 Gravity Connections

There are no modifications to the Guidelines or Commentary of Section 5.1.2 at this time.

5.1.3 Other Connection Types

There are no modifications to the Guidelines or Commentary of Section 5.1.3 at this time.

5.2 Preparation

5.2.1 Preliminary Document Review and Evaluation

5.2.1.1 Document Collection and Review

There are no modifications to the Guidelines or Commentary of Section 5.2.1.1 at this time.

5.2.1.2 Preliminary Building Walk-Through.

There are no modifications to the Guidelines or Commentary of Section 5.2.1.2 at this time.

5.2.1.3 Structural Analysis

There are no modifications to the Guidelines or Commentary of Section 5.2.1.3 at this time.

5.2.1.4 Vertical Plumbness Check

There are no modifications to the Guidelines or Commentary of Section 5.2.1.4 at this time.

5.2.2 Connection Exposure

Pre-inspection activities to expose and prepare a connection for inspection should include the local removal of suspended ceiling panels or (as applicable) local demolition of permanent ceiling finish to access the connection; and cleaning of sufficient fireproofing from the beam and column surfaces to allow visual observation of the area to be inspected. If initial inspections are to be limited to the beam bottom flange to column joint and the surrounding material, fireproofing should be removed from the connection as indicated in Figure 5-1a. Removal of fireproofing need only be sufficient to permit observation of the surfaces of base and weld metals. Wire brushing and cleaning to remove all particles of fireproofing material is not necessary unless ultrasonic testing of the joint area is to be conducted. In the event that damage is found at the bottom beam flange to column joint, then additional fireproofing should be removed, as indicated in Figure 5-1b, to expose the column panel zone, the column flange, continuity plates, beam web and flanges. The extent of the removal of fireproofing should be sufficient to allow adequate inspection of the surfaces to be inspected. Figure 5-1b suggests a pattern that will allow both visual and NDT inspection of the top and bottom beam flange to column joints, the beam web and shear connection, column panel zone and continuity plates, and column flanges in the areas of highest expected demands. The maximum extent of the removal of fireproofing need not be greater than a distance equal to the beam depth "d" into the beam span to expose evidence of any yielding.

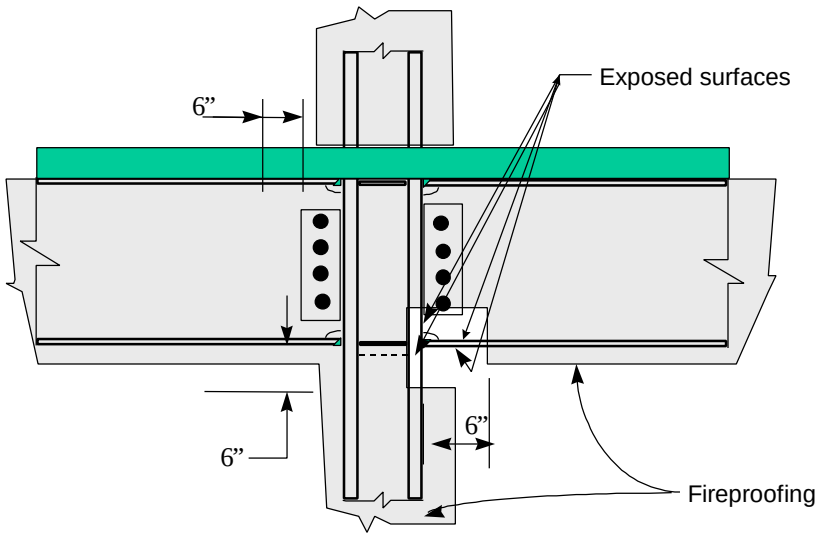

Figure 5-1a Recommended Zone for Fireproofing Removal for Initial Inspections

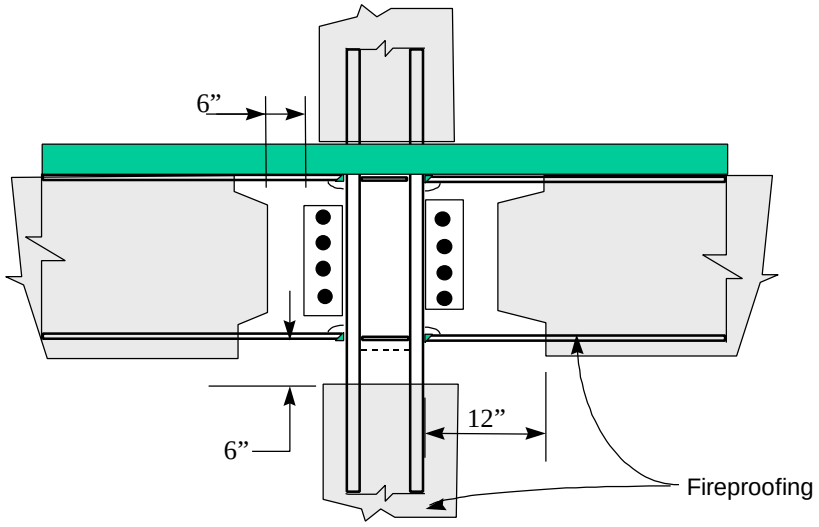

Figure 5-1b Recommended Zone for Removal of Fireproofing for Complete Inspections

Commentary: If inspection is to be limited to visual observation of the surfaces of the base metal and welds, cleaning of fireproofing need only be sufficient to expose these surfaces. However, if ultrasonic testing is to be performed, the surface over which the scanning will be performed must be free ~~Cleaning of weld areas and removal~~ of mill scale and weld spatter. Such cleaning should be done with care, preferably using a power wire brush, to ensure a clean surface that does not affect the accuracy of ultrasonic testing. The resulting surface finish should be clean, free of mill scale, rust and foreign matter. The use of a chisel should be avoided to preclude scratching the steel surfaces which could be mistaken for yield lines. Sprayed-on fireproofing on WSMFs erected prior to about ~~1980~~1970 is likely to contain asbestos and should be handled according to

applicable standards for the removal of hazardous materials. Health hazards associated with asbestos were recognized by industry in the late 1960s and by 1969, most commercial production of asbestos containing materials had ceased. In April, 1973, the federal government formally prohibited the production of asbestos containing materials with the adoption of the National Emission Standards for Hazardous Air Pollutants. Allowing for shelf life of materials produced prior to that date, it should be considered possible that buildings constructed prior to 1975 contain some asbestos hazards. To preclude physical exposure to hazardous materials and working conditions in such buildings, the structural engineer should require by contractual agreement with the building owner, prior to the start of the inspection program, that the building owner deliver to the structural engineer for his/her review and files a laboratory certificate that confirms the absence of asbestos in structural steel fireproofing, local pipe insulation, ceiling tiles, and drywall joint compound.

~~*The pattern of fireproofing removal indicated in Figure 5-1 is adequate to allow visual and UT inspection of the top and bottom girder flange to column joints, the beam web and shear connection and the column panel zone. As discussed in the commentary to Section 5.1.1, some engineers prefer to initially inspect only the bottom beam flange to column joint. In such cases, the initial removal of fireproofing can be more limited than indicated in the figure. If after initial inspection, damage at a connection is suspected, then full removal, as indicated in the figure, should be performed to allow inspection of all areas of the connection.*~~

5.3 Inspection Program

5.3.1 Visual Inspection (VI)

There are no modifications to the Guidelines or Commentary of Section 5.3.1 at this time.

5.3.1.1 Top Flange

There are no modifications to the Guidelines or Commentary of Section 5.3.1.1 at this time.

5.3.1.2 Bottom Flange

There are no modifications to the Guidelines or Commentary of Section 5.3.1.2 at this time.

5.3.1.3 Column and Continuity Plates

There are no modifications to the Guidelines or Commentary of Section 5.3.1.3 at this time.

5.3.1.4 Beam Web Shear Connection

There are no modifications to the Guidelines or Commentary of Section 5.3.1.4 at this time.

5.3.2 Nondestructive Testing (NDT)

NDT ~~should~~ may be used to supplement the visual inspection of connections selected in accordance with the Interim Guidelines of Chapter 4. The testing agency and NDT personnel performing this work should conform to the qualifications indicated in Chapter 11 of these Interim Guidelines. The following NDT techniques ~~should~~ may be used at the top and bottom of each connection, where accessible, to supplement visual inspection: These techniques should be used whenever visual inspection indicates the potential for damage that is not directly observable.

a) Magnetic particle testing (MT) of the beam flange to column flange weld surfaces may be used to confirm the presence of suspected surface cracks based on visual evidence. Where fractures are evident from visual inspection, MT should be used to confirm the lateral extent of the fracture.~~All surfaces which were visually inspected should be tested using the magnetic particle technique.~~

Commentary: The color of powder should be selected to achieve maximum contrast to the base and weld metal under examination. The test may be further enhanced by applying a white coating made specifically for MT or by applying penetrant developer prior to the MT examination. This background coating should be allowed to thoroughly dry before performing the MT.

b) Ultrasonic testing (UT) may be used to detect the presence of hidden fractures, where visual inspection reveals the potential for such fractures.~~ of all faces at the beam flange welds and adjacent column flanges (extending at least 3 inches above and below the location of the CJP weld, along the face of the column, but not less than 1-1/2 times the column flange thickness).~~

Commentary: The purpose of UT is to 1) locate and describe the extent of internal defects not visible on the surface and 2) to determine the extent of cracks observed visually and by MT. These guidelines recommend the use of visual inspection as the primary tool for detecting earthquake damage (See commentary to Sec. 5..1.1). UT can be a useful technique for confirmation of the presence of suspected fractures at the beam flange to column flange joints. Visual evidence that may suggest the need for such testing could include apparent separation of the base of the weld backing from the face of the column.

Requirements and acceptance criteria for NDT should be as given in AWS D1.1-98 Section~~s~~ 6 ~~and 8~~. Acceptance or rejection of planar weld discontinuity (cracks, slag inclusion, or lack of fusion), including root indications, should, as a minimum, be consistent with AWS Discontinuities Severity Class designations of cracks and defects per Table ~~8.2~~6.2 of AWS D1.1-98 for Static

Structures. ~~Beam flange welds should be tested as "tension welds" per AWS D1.1 Table 8.15.3, Note 3.~~ Backing bars need not be removed prior to performing UT.

Commentary: The value of UT for locating small discontinuities at the root of beam flange to column flange welds when the backing is left in place is not universally accepted. The reliability of this technique is particularly questionable at the center of the joint, where the beam web obscures the signal. There have been a number of reported instances of UT detected indications which were not found upon removal of the backing, and similarly, there have been reported instances of defects which were missed by UT examination but were evident upon removal of the backing. The smaller the defect, the less likely it is that UT alone will reliably detect its presence.

Despite the potential inaccuracies of this technique, it is the only method currently available, short of removal of the backing, to find subsurface damage in the welds. It is also the most reliable method for finding lamellar problems in the column flange (type C4 and C5 damage) opposite the girder flange. Removal of weld backing at these connections results in a significant cost increase that is probably not warranted unless UT indicates widespread, significant defects and/or damage in the building.

The proper scanning techniques, beam angle(s) and transducer sizes should be used as specified in the written UT procedure contained in the Written Practice, prepared in accordance with Section 5.3.3 of these Interim Guidelines. The acceptance standard should be that specified in the original contract documents, but in no case should it be less than the acceptance criteria of AWS D1.1~~, Chapter 8, for Statically Loaded Structures.~~

~~The base metal should be scanned with UT for cracks. Cracks which have propagated to the surface of the weld or beam and column base metal will probably have been detected by visual inspection and magnetic particle tests performed earlier. The purpose of ultrasonic testing of the base metal is to:~~

~~1. Locate and describe the extent of internal indications not apparent on the surface and,~~

~~2. Determine the extent of cracks found visually and by magnetic particle test.~~

Commentary: Liquid dye penetrant testing (PT) may be used where MT is precluded due to geometrical conditions or restricted access. Note that more stringent requirements for surface preparation are required for PT than MT, per AWS D1.1.

~~*If practical, NDT should be performed across the full width of the bottom beam flange joint. However, if there are no discontinuity signals from UT of*~~

~~*accessible faces on one side of the bottom flange weld, obstructions on the other side of the connection need not be removed for testing of the bottom flange weld.*~~

Slabs, flooring and roofing need not be removed to permit NDT of the top flange joint unless there is significant visible damage at the bottom beam flange, adjacent column flange, column web, or shear connection. Unless such damage is present, NDT of the top flange should be performed as permitted, without local removal of the diaphragms or perimeter wall obstructions.

It should be noted that UT is not 100% effective in locating discontinuities and defects in CJP beam flange to column flange welds. The ability of UT to reliably detect such defects is very dependent on the skill of the operator and the care taken in the inspection. Even under perfect conditions, it is difficult to obtain reliable readings of conditions at the center of the beam flange to column flange connection as return signals are obscured by the presence of the beam web. If backing is left in place on the welds, UT becomes even less reliable. There have been a number of reported instances in which UT indicated apparent defects, that were found not to exist upon removal of the backing. Similarly, UT has failed in some cases to locate defects that were later discovered upon removal of the backing. Additional information on UT may be found in AWS B1.10.

5.3.3 Inspector Qualification

5.3.4 Post-Earthquake Field Inspection Report

There are no modifications to the Guidelines or Commentary of Section 5.3.4 at this time.

5.3.5 Written Report

There are no modifications to the Guidelines or Commentary of Section 5.3.5 at this time.

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