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PERSPECTIVES

A Comprehensive Guide to Substantial Structural Damage: Criteria, Repairs, and Code Compliance

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INTRODUCTION: SUBSTANTIAL STRUCTURAL DAMAGE AND ITS IMPACT ON BUILDING REPAIRS

Substantial structural damage (SSD) is a defined term within the International Code Council (ICC) building code library, which assesses the reduction in load-bearing capacity of a damaged building and may trigger required code upgrades during repair. An understanding of SSD and its implications is not only pivotal in ensuring public safety but also serves as a key determinant in the assessment of insurance claims and defining the scope of repairs in a damaged building. This paper will explore the criteria for SSD and its broader impact on the building repair process, and may help answer questions including, but not limited to:

- "What code upgrades are required for damaged buildings?"
- "Do I need to upgrade my building?"
- "When are building code upgrades required?"

EVOLUTION OF *SUBSTANTIAL STRUCTURAL DAMAGE* IN THE INTERNATIONAL EXISTING BUILDING CODE (IEBC)

The International Code Council (ICC) has developed a series of model building codes and standards that have been widely adopted throughout the United States or have been used as the basis for more stringent building codes. The various ICC model codes are updated on a three-year cycle, with intermediate versions and amendments, as needed. The term substantial structural damage is defined within the International Existing Building Code (IEBC) which outlines evaluation methods to be applied to existing, legally permitted structures that have sustained structural damage.

The first edition of the IEBC was published with the 2003 edition of the ICC model code library and was intended to apply to the repair, alteration, change of occupancy, addition, and relocation of existing buildings. The original IEBC, 2003 Edition, provided a definition for *substantial structural damage* that included two criteria, one relating to damage to the vertical components of the lateral force-resisting system (structural components resisting lateral forces, such as wind or seismic) and one relating to damage to the vertical components of the gravity load-carrying system (structural components that carry the weight of the building and items within the building). In subsequent editions of the IEBC, the definition of *substantial structural damage* has been revised on several occasions for clarity and changes in the minimum damage threshold for triggering SSD. One of the most significant changes to the definition of SSD was the addition of a third criteria relating to damage to any components of the snow load-carrying system, which first appeared in the 2018 Edition of the IEBC following a significant increase in documented roof collapses resulting from snow overloading.

The following definition of SSD is taken from the recently published 2024 Edition of the IEBC:

> ***SUBSTANTIAL STRUCTURAL DAMAGE.*** *A condition where any of the following apply:*
>
> 1. *The vertical elements of the lateral force-resisting system have suffered damage such that the lateral load-carrying capacity of any story in any horizontal direction has been reduced by more than 33 percent from its predamage condition.*
>
> 2. *The capacity of any vertical component carrying gravity load, or any group of such components, that has a tributary area more than 30 percent of the total area of the structure's floor(s) and roof(s) has been reduced more than 20 percent from its predamage condition, and the remaining capacity of such affected elements, with respect to all dead and live loads, is less than 75 percent of that required by the International Building Code*

for new buildings of similar structure, purpose and location.

3. *The capacity of any structural component carrying snow load, or any group of such components, that supports more than 30 percent of the roof area of similar construction has been reduced more than 20 percent from its predamage condition, and the remaining capacity with respect to dead, live and snow loads is less than 75 percent of that required by the International Building Code for new buildings of similar structure, purpose and location.*

For purposes of this definition, work done to implement repairs shall not be considered damage that reduces structural capacity.

The code discussions in the following sections of this paper are intended to provide clarification and guidance on the definition and application of SSD as it relates to structural evaluations and required repairs, as outlined in the IEBC. For the purposes of this paper, SSD will be defined as provided above and within the International Existing Building Code, 2024 Edition (IEBC 2024), and repair requirements per the code are based on the IEBC 2024. In practice, the applicable code adopted by the authority having jurisdiction (AHJ) shall be used to determine if SSD has occurred and what code-driven upgrades are required.

EVALUATING SSD CRITERIA #1: LATERAL FORCE RESISTING SYSTEM

DEFINITION: *The vertical elements of the lateral force-resisting system have suffered damage such that the lateral load-carrying capacity of any story in any horizontal direction has been reduced by more than 33 percent from its predamage condition.*

The first criteria for evaluation of SSD relates to damage sustained by the vertical elements of the lateral force-resisting system (LFRS). Vertical elements of a building's LFRS typically include shear walls (concrete, masonry, wood, etc.), braced frames, columns of moment-resisting frames, and/or diagonal bracing. A lateral force-resisting system also contains horizontal elements (i.e., roof and/or floor decking); however, horizontal elements are not considered in the determination of SSD for Criteria 1.

Figures 1 and 2 provide an example of a building which has sustained damage to vertical elements comprising the LFRS which required an evaluation to determine if Criteria 1 of SSD had been triggered.

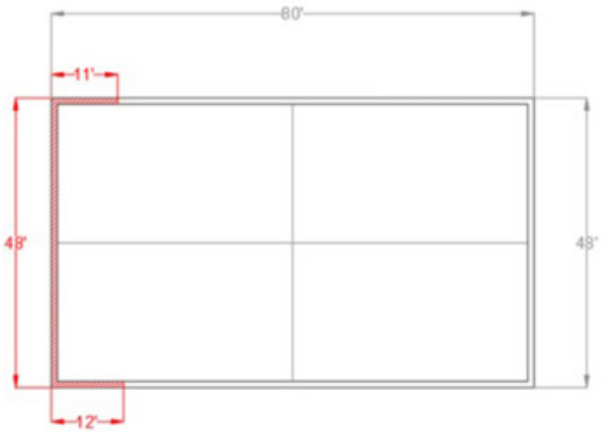

Figure 1 *- Plan view of a building with areas of collapsed wall denoted in red.*

In this example, the vertical elements of the lateral force-resisting system are the concrete masonry unit (CMU) shear walls around the perimeter of the building.

First, it is important to determine if the damaged portions of the building would be capable of triggering SSD. The undamaged portions of the lateral load-carrying components are expected to retain their full lateral load-carrying capacity. The damaged portions of the lateral load-carrying components are expected to retain only a portion of their lateral load-carry capacity. However, for the purpose of this preliminary calculation, it is assumed that the damaged elements have lost 100% of their lateral load-resisting capacity to obtain a conservative estimate of the percentage of reduction in lateral load-resisting capacity of the building from its pre-damage condition. If this preliminary calculation yields a result of less than 33 percent of the total length

of shear wall in any direction in any story, then SSD will not be triggered by the damage, based on this conservative approach. If this preliminary calculation yields a result that exceeds the 33 percent threshold, further analysis may be necessary. Sometimes, the reduction may be obvious, such as a collapsed shear wall section that has lost 100 percent of its lateral force-resisting capacity. However, in other instances, further engineering analysis and calculations may be required. For example, if a section of a shear wall has significant cracks and/or out-of-plumb condition, it will retain a portion of its lateral force-resisting capacity; however, the exact percentage would have to be calculated based on review of the original design, material testing, and in-depth engineering calculations.

In many instances, if the preliminary calculation exceeds the 33 percent threshold, the building is considered to have triggered Criteria 1 of SSD, without further in-depth analysis, due to the possible limitation of data, cost, and time required to conduct an in-depth analysis and calculations.

EVALUATING SSD CRITERIA #2: GRAVITY LOAD CARRYING SYSTEM

> ***DEFINITION:*** *The capacity of any vertical component carrying gravity load, or any group of such components, that has a tributary area more than 30 percent of the total area of the structure's floor(s) and roof(s) has been reduced more than 20 percent from its predamage condition, and the remaining capacity of such affected elements, with respect to all dead and live loads, is less than 75 percent of that required by the International Building Code for new buildings of similar structure, purpose and location.*

The second criteria for evaluation of substantial structural damage relates to damage sustained by the vertical elements of the gravity load-carrying components (GLCC). Vertical elements carrying gravity loads typically include load-bearing walls and/or columns. Gravity load-carrying components can also be horizontal elements (i.e., joists, beams, etc.); however, horizontal elements are not considered in the determination of SSD for Criteria 2.

First, the tributary area of the floor and/or roof systems supported by each damaged vertical element, or group of elements, should be calculated. If the total percentage of tributary area of each floor and/or roof supported by damaged vertical elements is less than 30 percent of the total area of each floor and/or roof, then Criteria 2 of SSD will not be triggered. If the tributary area of any individual floor and/or roof supported by damaged vertical elements exceeds the 30 percent threshold, there are two separate requirements that must be evaluated to determine if Criteria 2 of SSD has been triggered. The damaged gravity load-carrying components must undergo an in-depth analysis, and calculations must be completed to determine if a) the GLCCs have been reduced by more than 20 percent from their pre-damage capacity; and b) the remaining capacity of elements carrying dead and live loads is less than 75 percent of that required by the current version of IBC adopted for new buildings. **Figure 2** provides a plan view example of how the tributary area of each supporting vertical element is determined.

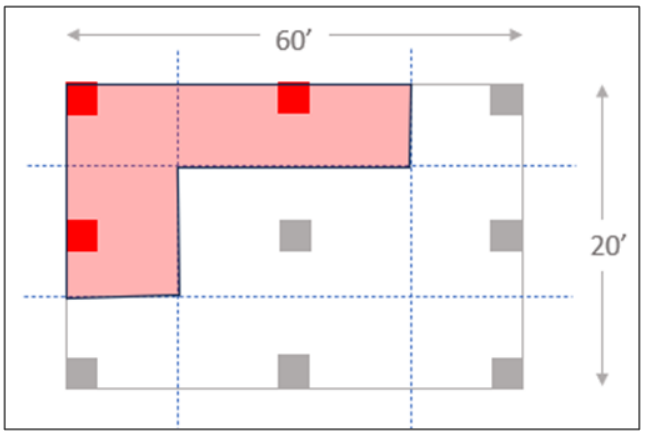

Figure 2 *- Plan view of a roof supported by a system of columns with damaged columns denoted in bright red and the tributary area of the roof supported by the damaged columns shaded red.*

Like Criteria 1, in many instances, if the tributary area of damaged vertical GLCCs exceeds the 30 percent tributary area threshold, the building is considered to have triggered Criteria 2 of SSD, without further in-depth analysis, due to the possible limitation of data, cost, and time required to conduct an in-depth analysis and calculations.

EVALUATING SSD CRITERIA #3: SNOW LOAD CARRYING SYSTEM

> ***DEFINITION:*** *The capacity of any structural component carrying snow load, or any group of such components, that supports more than 30 percent of the roof area of similar construction has been reduced more than 20 percent from its predamage condition, and the remaining capacity with respect to dead, live and snow loads is less than 75 percent of that required by the International Building Code for new buildings of similar structure, purpose and location.*

The third criteria for evaluation of substantial structural damage relates to damage sustained by both vertical and horizontal elements of the snow load-carrying components (SLCC). Elements which carry snow loads typically include vertical load-bearing walls and/or columns as well as horizontal roof framing (trusses, rafters, joists, beams, sheathing, etc.).

First, the area of the roof supported by damaged elements, or group of elements, should be calculated. This can be done using a tributary area method. If the total percentage of tributary area of damaged elements, horizontal or vertical, is less than 30 percent of the total area of the roof, then Criteria 3 of SSD will not be triggered. If the tributary area of damaged elements supporting the roof exceeds the 30 percent threshold, there are two separate requirements that must be evaluated to determine if Criteria 3 of SSD has been triggered. The damaged snow load-carrying components must undergo an in-depth analysis, and calculations must be completed to determine if a) the SLCCs have been reduced by more than 20 percent from their pre-damage capacity; and b) the remaining capacity of elements carrying dead, live, and snow loads is less than 75% of that required by the current version of IBC adopted for new buildings. **Figure 3** provides a plan view example of how the tributary area method of supporting elements is determined.

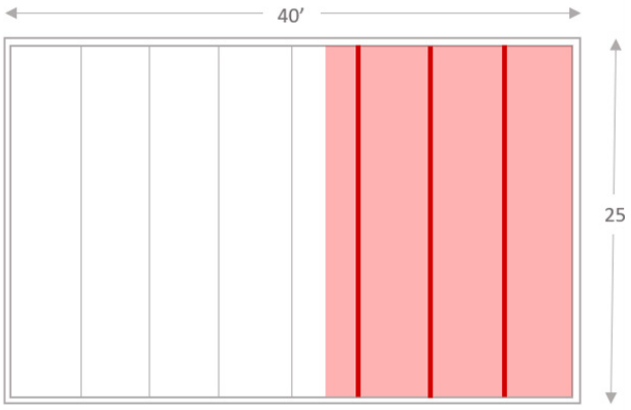

Figure 3 *- Plan view of a roof with damaged SLCCs denoted by red lines and red shaded areas.*

Like Criteria 1 and 2, in many instances, if the tributary area of damaged SLCCs exceeds the 30 percent tributary area threshold, the building is considered to have triggered Criteria 3 of SSD, without further in-depth analysis, due to the possible limitation of data, cost, and time required to conduct an in-depth analysis and calculations.

POST-SUBSTANTIAL STRUCTURAL DAMAGE EVALUATION: REPAIR PROTOCOLS AND COMPLIANCE STEPS

The protocol for repair of the damaged structural components must be completed in compliance with the requirements outlined in **CHAPTER 4 REPAIRS, SECTION 405 STRUCTURAL of IEBC 2024**, or other applicable IEBC edition adopted by the AHJ. Of note, triggering a single criterion of SSD does not trigger the repair requirements of all three criteria; rather, each criterion that is triggered requires only the specific repairs associated with that specific criterion.

DAMAGE LESS THAN SUBSTANTIAL STRUCTURAL DAMAGE

According to IEBC 2024, §405.2.1, for damage less than *substantial structural damage*, the damaged elements can be restored to their pre-damage condition. As such, when none of the criteria of SSD are triggered, there are no required code upgrades to the building's structural systems.

CRITERIA 1 REPAIRS

When Criteria 1 of SSD has been triggered, §405.2.3 of IEBC 2024 requires that the building be evaluated by a registered design professional to determine if the building, if returned to its pre-damage condition, would comply with the provisions of the current International Building Code for load combinations that include wind and sometimes seismic. Seismic loads do not need to be considered for one- and two-family dwellings or for buildings assigned to Seismic Design Category A, B, or C whose SSD was not caused by an earthquake.

If the result of this evaluation establishes that the building returned to its pre-damage condition would be compliant with the requirements of the current IBC, the damaged elements can be restored to their pre-damage condition. However, if the result of this evaluation establishes that the building would not be compliant with the load requirements of the current IBC, the building would require retrofitting. In this case, if the damage was caused by wind, the building would have to be retrofitted to comply with the wind load requirements of the current IBC. If the damage was not caused by wind, the wind loads for the retrofit would be the wind loads required by the building code in effect at the time of original construction. Seismic loads for the required retrofit are those required by the building code in effect at the time of original construction, provided they are not less than the reduced seismic criteria, as defined within §304.3.2 of the IEBC.

CRITERIA 2 REPAIRS

When Criteria 2 of SSD has been triggered, §405.2.4 of IEBC 2024 requires that damaged gravity load-carrying components be retrofitted to comply with the applicable provisions for dead loads, live loads, and snow loads in the current International Building Code. Undamaged GLCCs, including foundation components, can remain in place unless they receive dead, live, or snow loads from damaged GLCCs that will require retrofitting, in which case the undamaged elements must also be retrofitted.

There is an additional requirement in the IEBC that requires an evaluation of the lateral force-resisting system if Criteria 2 of SSD was triggered by damage caused by wind or seismic, regardless of the level of damage to lateral load-carrying components (i.e., even if Criteria 1 was not triggered by the damage).

CRITERIA 3 REPAIRS

When Criteria 3 of SSD has been triggered, §405.2.5 of IEBC 2024 states that any components required to carry snow loads on roof framing of similar construction (i.e., all areas of wood roof framing vs steel roof framing) shall be repaired, replaced, or retrofitted to comply with the snow load requirements of the International Building Code only when the damage was caused by or related to snow load effects. If the damage was not caused by snow load effects, the snow load-carrying components can be returned to their pre-damage condition, provided that is not less than the snow load-carrying capacity required by the building code in effect at the time of original construction.

THE IMPORTANCE OF UNDERSTANDING SUBSTANTIAL STRUCTURAL DAMAGE CRITERIA AND REPAIR IMPLICATIONS

Understanding the criteria for substantial structural

damage and the associated repairs is crucial for engineers, loss consultants, insurance professionals, and contractors. These criteria and repairs can significantly impact the scoping, design, permitting, and execution of repairs to a damaged building. A common misconception is that building codes mandate "full code upgrades" for a building, which is not accurate. As outlined in this paper, the SSD criteria are specifically designed to address deficiencies and damage in particular structural systems. While repairs to these systems may necessitate upgrades, they do not require comprehensive code upgrades for the entire building. Each SSD criterion only triggers upgrades for the specific part of the structural system it pertains to, such as the lateral force-resisting system, gravity load-carrying system, or snow load-carrying system. These requirements aim to ensure the building's safety without imposing the financial burden of upgrading undamaged components.

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