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Behaviour of Non-Structural Elements During An Earthquake

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Abstract-In this paper the study is done for behaviour of non-structural elements during an earthquake. Non-structural elements are the architectural, mechanical and electrical components of a building that directly cater to human needs. Loss or failure of these elements can affect the safety of the occupants of the building and safety of others who are immediately outside the building. Non structural elements of a building are not a part of the main load resisting system. Therefore, these are neglected from the structural design point of view. Many damages occurs in non structural elements. By definition, non structural earthquake damage is damage to components that are not structural. For example, a partition, which is non load bearing is non structural, while load bearing wall is structural. The architectural spandrel material underneath and above windows that fills in between reinforced concrete frame bays is non structural while the concrete material is structural. With the development and implementation of performance-based earthquake engineering, harmonization of performance levels between structural and non structural elements becomes vital. Even if the structural elements of a building achieve a continuous or immediate occupancy performance level after a seismic event, failure of architectural, mechanical or electrical elements can lower the performance level of the entire building system.

Keywords-Non-structural elements, load resisting system, safety, Performance level, Sensitivity.

I. INTRODUCTION:

Non-structural elements are the architectural, mechanical and electrical components of a building that directly cater to human needs. Loss or failure of these elements can affect the safety of the occupants of the building and safety of others who are immediately outside the building. Architectural components include non-bearing walls, partitions, infill walls, parapets, veneers, ceilings, door and window panes, glasses, cladding etc. Roofing units such as tiles and other individually attached relatively heavy roof elements, stairway and elevator enclosures and architectural equipment including racks etc., are also included in architectural components. Mechanical and electrical components include boilers and furnaces, chimneys and smoke stacks, tanks and pressure vessels, machinery, piping systems, communication systems, electrical wire ducts, electrical motors, transformers, lighting fixtures, fire and smoke detection systems, etc. Although in most buildings, they represent a high percentage of the total cost of the building, the seismic behaviour of non structures has not received adequate attention and thus effective design specifications are practically non-existent. Difference between structural and non-structural elements given as below.

Table No.1.1:Difference between structural and non-structural elements:

Sr.No.	Items	Structural elements(SEs)	Non- Structural elements (NSEs)
1	Shaking at the base	(1) Random, high frequency (2) Non-uniform in long buildings	(1) Predominantly cyclic, low frequency (2) Non-uniform in NSEs with multiple supports
2	Damping	(1) High, increases with damage (2) Classical damping gives good Approximation	(1) Low (2) Non-classical
3	Response to shaking at the base	(1) Depends on characteristics of earthquake ground motion (2) Low response amplification	Depends on characteristics of both earthquake ground motion and building High response amplification
4	Interaction between SEs and NSEs	(1) Seismic responses of SEs affect that of NSEs	Seismic response of NSEs may affect that of SEs and building, depending on mass of NSE and on stiffness and

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			strength of connection between NSEs and SEs. In such cases, responses of NSEs and building should be estimated considering combined building-NSE system
5	Seismic Demand	Depends on (1) Seismic zone (in which building is located), and (2) Building characteristics (e.g., mass, structural system, ductility)	Depends on location of NSEs within the building, in addition to seismic zone (in which building is located), and building characteristics (e.g., mass, structural system, ductility), and NSE characteristics and connection of NSE to SEs in the building

II. CLASSIFICATION OF NON-STRUCTURAL ELEMENTS:

Non structural elements are classified into three groups:

Non structural elements are classified on the basis of their use and function.

1) Contents of buildings:

Items required for functionally enabling the use of spaces, such as

(1) Furniture and minor items, for ex.- storage shelves

(2) Facilities and equipments, for ex.- refrigerators, washing machines, gas cylinders, TVs, multi-level material stacks, false ceilings, generators and motors and

(3) Door and window panels and frames, large-panel glass panes with frames i.e., windows or infill walling material and other partitions within the buildings.

2) Appendages to buildings:

Items projecting out of the buildings or attached to their exterior surfaces, either horizontally or vertically, such as chimneys projecting out from buildings, glass or stone cladding used as façade, parapets, small water tanks rested on top of buildings, sunshades, advertisement hoardings affixed to the vertical face of the building or anchored on top of building, and small communication antennas mounted a top buildings. Thus, some of these are architectural elements, while the rest are functional.

3) Services and utilities:

Items required for facilitating essential activities in the buildings, such as plumbing lines, electricity cables, and telecommunication wires from outside to inside of building and within the building, air-conditioning ducts, elevators, fire hydrant systems.

Some of these NSEs are shown in Figure 1.4. There is significant dependence of NSEs on SEs; well-designed NSEs transfer their earthquake-induced inertia forces to adjoining SEs and accommodate the relative movement imposed by adjoining SEs between their ends.

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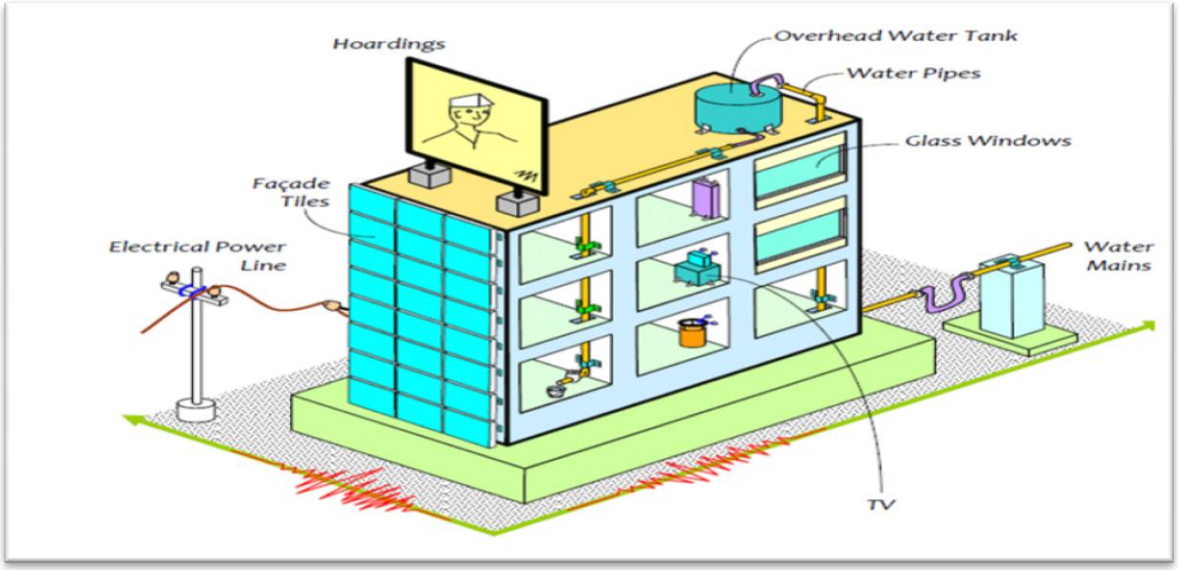

Figure 2.1: Non structural elements use load paths available in each direction: NSEs pass on their own inertia forces to SEs and move relative to the SEs, if freedom of movement is provided between NSEs and adjoining SEs.

III. FAILURE IN NON STRUCTURAL ELEMENTS:

Generally, non structural elements fail during an earthquake. The reason behind it is nothing but the maximum or excessive inertial forces acting on it or excessive deflection caused by deformation of the structural system.

Non structural items that are suspended, such as ceiling systems and light fittings perform badly at the time of earthquakes. Appendages such as parapets also suffers high levels of damage, especially where they function as single-degree-of-freedom inverted pendulums. Damage also increases on multi-storey structures towards the roof and roof tanks and also penthouses are subjected to high forces. Some common earthquake failures of non structural components are given as below:

Table No.3.1: Common Earthquake Failures of Non Structural Components

Sr.No.	Item	Type of damage
1	Pumps and Boilers	Movement of anchored supports
2	Tanks	Support failure
3	Motor Generators	Failed isolation supports
4	Control Panels	Overturning of tall units
5	Piping	Rupture due to excessive movements, failure at bends
6	Elevators	Guide rails broken, counter-weights misaligned, car misaligned
7	Parapets	Toppling
8	Concrete, stone cladding	Separation and falling
9	Windows	Glass breaking , frames detaching
10	Storage Racks	Toppling and/or contents falling
11	False Ceiling	Racking, Panels falling
12	Suspended Light Fittings	Excessive movements causing damage or falling

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IV. EFFECT OF NON STRUCTURAL ELEMENTS ON STRUCTURAL SYSTEM:

In normal practice of structural design, non structural elements are not taken into account. Buildings, however, contain various non-structural elements which influence structural behaviour under earthquakes, which cannot ignored in some situations. The influence is found to be small if flexible non structural elements are added to a stiff structural system. Following are the effects of non-structural elements on structural behaviour are as follows:

- The natural period of the structural system may be shortened resulting in a different input level to the system.
- Distribution of storey shear in columns may change and some columns may sustain more force than that assumed in the original design.
- An unsymmetrical arrangement of non structural walls may cause significant torsion in the system.
- Local force may be concentrated if non-structural walls are rearranged non uniformly in height.

V. ANALYSIS OF NON STRUCTURAL ELEMENTS:

When the non-structural element affects the structural response of the building, the non-structural elements should be treated as structural elements, and structural provisions should apply to them. Depending upon the response sensitivity, non structural elements can be classified as deformation sensitive, acceleration sensitive or both deformation and acceleration sensitive. Non-structural elements analysed by two different methods on the basis of importance of it.

1. Dynamic analysis method
2. Equivalent static analysis method respectively. Now,

1. Dynamic analysis method:

When rigid non structural element is tightly clamped on the floor of a structure, the response of the element is identical with the floor response. The magnification factor, defined as the ratio of the element response to the floor response, is therefore unity. When a rigid non structural element is installed by a flexible connecting device on the floor of a structure, the element response is greater than the floor response. Such behaviour can be represented by a one mass system with damping. In this dynamic analysis method, different systems are used such as- single-degree-of-freedom(SDOF) and MDOF System for analysis purpose.

2. Equivalent static analysis method:

Where dynamic analysis is not feasible, it is desirable to establish a suitable equivalent static force. The sub-system is modelled as a separate structure with fixed support conditions. Calculations of the equivalent static forces for acceleration sensitive and displacement sensitive of non-structural elements only by this two methods. Some provisions are given in the IS:1893:2002 for the non structural elements. Following table shows the non structural element with sensitivity.

Table No.5.1. Categorisation of commonly used Non Structural Elements based on earthquake behaviour

Category	Sub- category	Non Structural Elements	Sensitivity		
			Force	Displacement	Both
Consumer Goods inside buildings	Furniture and minor items	1.Storage Shelves 2.Multi-level material stacks	Yes		
	Appliances	1.Refregirators 2.Washing machines 3.Gas cylinders 4.TVs 5.Diesel generators 6.Water pumps(small) 7.Window ACs 8.Wall mounted ACs	Yes		
Architectural finishes inside buildings	Openings	1.Doors and windows 2.Large panel glass panes with frames(as windows or infill walling material)	Secondary	Primary	Yes

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		3.Other partitions			
	False ceiling	Directly stuck to or hung from roof	Yes		
		Suspended integrated ceiling system	Secondary	Primary	Yes
	Stairs		Primary	Secondary	Yes
	Partitions not held snugly between lateral load resisting members		Secondary	Primary	Yes
Appendages to buildings	Vertical Projections	1.Chimneys & stacks 2.Parapets 3.Water tanks (small)	Yes		
		4.Hoardings	Yes		
	Horizontal Projections	Sunshades	Secondary	Primary	Yes
	Exterior & interior facade	Tiles	Secondary	Primary	Yes
	Exterior Structural Glazing System		Secondary	Primary	Yes
Services & Utilities	From within & from outside to inside the building	1.Water supply pipe lines 2.Electricity cables & wires 3.Gas pipelines 4.Sewage pipelines		Yes	
	Inside the buildings	Fire hydrant piping system	Secondary	Primary	Yes
	Storage Vessels and water heaters	Structurally supported vessels	Yes		
	Mechanical Equipments	Boilers & furnaces	Yes		

VI. CONCLUSION:

In this paper the study is done for behaviour of non structural elements during an earthquake. By detailed study it is seen that-

1. Study of non structural elements is essential.
2. Various methods of analysis are there.
3. Use dynamic analysis method as per the conditions.
4. Mostly SDOF System is used.
5. Maximum damages are due to the highest seismic force.
6. Effects of non structural elements on structure are more.
7. IS Code provisions for non structural elements are most important.
8. Diagnosis the past failures during an earthquake.
9. Different damages occurs in non structural elements.
10. Effects of non structural elements – on natural period of structural system, unsymmetrical arrangement of non structural walls, position of column and many more.

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