International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 8, pp: 482-486 www.ijaem.net ISSN: 2395-5252

Study on Progressive Collapse of Multi-Storied Structures

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Date of Submission: 15-10-2020 Date of Acceptance: 02-11-2020

ABSTRACT: The term “progressive collapse” has been used to describe the spread of an initial local failure in a manner analogous to a chain reaction that leads to partial or total collapse of a building. The mentioned characteristic of progressive collapse is that the end state of failure is unproportionately higher than the failure that strarted the collapse. Based on the above description, it is proposed that the professional community adopt the following definition, which is based largely on ASCE 7-05:
Progressive Collapse—"The spread of local damage, from an initiating event, from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it; also known as disproportionate collapse."

KEYWORDS: Collapse of Structure, Collapse types, Collapse methods.

I. INTRODUCTION

The majority of accidents occur in take-off or landing operations. NTSB figures indicate that over half of all such accidents occur at airport sites and only 30 % occur at distances greaterthan 8 km (5 mi) from the airport. The building collision rate for military aircraft is lower. Thus, for buildings some distance removed from airports, the impact probability clearly is less than the de minimis threshold. Although aircraft impact does not appear to pose a credible threat to the vast majority of buildings, certain key facilities within 10 km (6 mi) of an airport may require a site-specific analysis.

The fire hazard lies at an intersection between normal and abnormal loads. Traditionally, structural engineers have rarely been responsible for structuralfire protection, and such protection was provided by non-structural means, such as thermal insulation.

When a building contains materials that pose a high fire hazard, involving high fuel loads, flammable liquids or explosive materials, or compartment areas greater than 1000 m2 (10000 ft2), a special analysis of fire hazard and fire exposure (temperature and duration) should be conducted. A structurally significant fireresults in an imposed deformation on the building structure, and the forces developed in an indeterminate building frame are self-limiting in nature. Moreover, the strength and stiffness of structural materials are temperature-dependent and degrade to a fraction of the room temperature values at temperatures as high as 1 000 °C (1 800 °F) that may occur in a fully developed compartment fire.

II. METHODOLOGY

A majority of structural failures and damage costs in ordinary buildings (some estimates range as high as 80 %) occur as a result of errors in planning, design, construction, and use rather than stochastic variability in resistance and load. Errors in concept, analysis and execution, and other unforeseen circumstances occur even when qualified personnel are involved in design and construction and when accepted methods of quality assurance and control are employed. Such errors result from human imperfections and are difficult to quantify.

While an interior charge may be smaller, the blast pressures can be large because the

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explosion is not able to vent, and reflections from interior surfaces will amplify the gas pressures. If the charge were to be placed strategically near a main vertical load-bearing element, more extensive damage could occur, possibly resulting in progressive collapse. The incidence data do not distinguish exterior and interior explosions.

The structural effects of a large exterior explosion can be summarized as follows (FEMA-427):

• The pressure wave acts on the exterior of the building and may cause window breakage and wall or column failures.

• As the pressure wave continues to expand into the building, upward pressures are applied to the ceilings and downward pressures are applied to the floors.

• Floor failure is common due to the large surface area upon which the pressure acts.

• Failure of floor slabs eliminates lateral support to vertical load-bearing elements, making the structure prone to progressive collapse.

For a smaller interior explosion, the type of expected damage may include (FEMA 427):

• Localized failure of the floor system below the detonation.

• Damage and possible localized failure of the floor system above the detonation;

• Damage and possible localized failure of nearby walls (concrete or masonry); and

• Failure of non-structural elements (partitions, ductwork, windows).

While an interior charge may be smaller, the blast pressures can be large because the explosion is not able to vent, and reflections from interior surfaces will amplify the gas pressures. If the charge were to be placed strategically near a main vertical load-bearing element, more extensive damage could occur, possibly resulting in progressive collapse. The incidence data do not distinguish exterior and interior explosions.

The technology necessary to determine the impact force is available, but there are large uncertainties in the determination of the kinetic energy to be dissipated during the collision. A specific accident scenario—velocity of vehicle, distance of building from traffic-way, direction of impact, coefficient of restitution—must be postulated to estimate the impact force.

III. MODELLING AND ANALYSIS

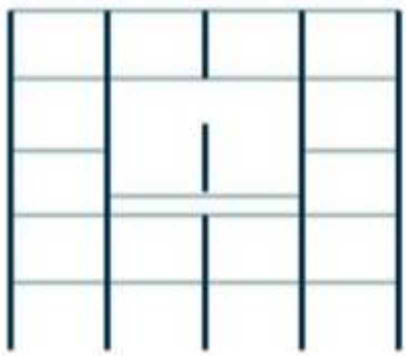
The various models of collapse are:

- Pan-Cake type collapse
- Zipper type collapse
- Domino type collapse
- Instability type collapse
- Section type collapse

Pan-Cake type collapse

The steps of a pancake-type progressive collapse are:

- Initial destruction of the construction element carrying vertical load
- Changing of the structures potential energy to kinetic energy until the fall
- Impact of the destroyed structure to the rest load bearing parts
- Failure of the vertical load bearing part hit
- Promotion of the failure in vertical direction



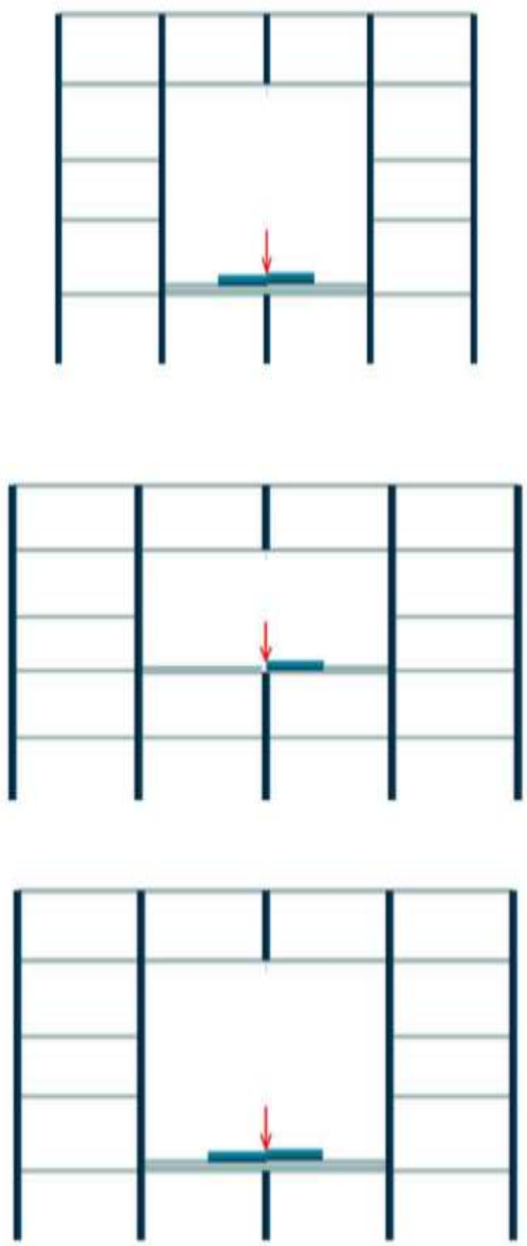


Fig: Pan-Cake type collapse

Zipper Type Collapse

The phases of the zipper-type mechanism are:

- Initial failure of one or a few vertical load bearing members
- Dynamic increase in loading to the remaining members due to the load redistribution.
- Overloading of the remaining members, loaded the most
- Failure of the members situated in a transverse direction to the falling elements
- Application of forces in load-bearing elements which are same in type and function and adjacent to the initially failing elements due to the sum of static and dynamic structural response to that failure

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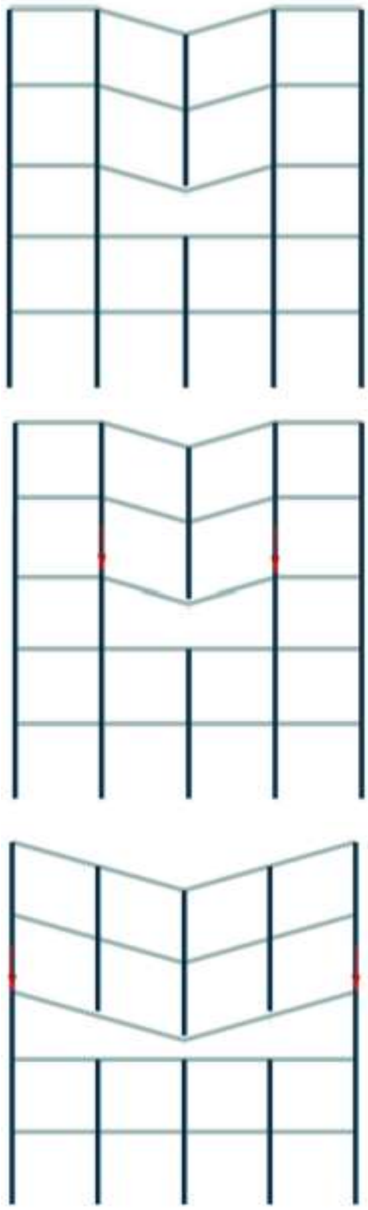

Fig: Zipper type collapse

IV. RESULTS AND DISCUSSION

- The building considered in this study was designed to the requirements to the Chinese concrete code ;however it is expected that the general conceptual finding reported year in also valid for building design to ACI318-02 based on observation and findings from the experimental study described in this paper ,the following conclusions can be drawn:
- Failure resulting from progressive collapse of the RC concrete frame structure was ultimately controlled by the rupture of the reinforcing steel bars in the floor beams. clearly this is different from the normal limit state for beam bending ,which is controlled either by crushing of concrete in compression or shear failure. If the strain in the tensile steel bars can be distributed more uniformly along the length.
- During the progressive collapse process, the RC frame structure experienced these distinct phases in its response: elastic or plastic factor, and catenary phases. In the experiment, both the horizontal displacement and the concrete strains in the columns confirmed the first force, transfer process of the frame structures from an elastic mechanism dominated by

bending to a beam catenary mechanism dominated by tension.

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