ANALYSIS AND DESIGN OF REINFORCED CONCRETE STRUCTURE AGAINST PROGRESSIVE COLLAPSE

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ABSTRACT

Progressive collapse in high rise structures due to man-made or natural disasters urged structural engineers to design a safe structure considering all possible loads that a building may encounter throughout its lifetime. This progressive collapse is catastrophic as collapse occurs in an instance, not allowing time for residents to escape. There are certain guidelines such as General Service Administration (GSA) and Department of Defence (DOD) concerning the design and retrofitting of structures to resist the progressive collapse that should be followed, especially for materials such as concrete and steel. The main methodology in this paper is based on a concept "column removal method" as stated in GSA guideline can reduce a chance of progressive collapse by providing alternate load path for structures through additional reinforcement. Using STAAD.Pro software, the G+11 storey is designed and considering several cases: a) an exterior column near the middle of the long side of the building. b) an exterior column near the middle of the short side of the building. c) a column located at the corner of the building. d) a column interior to the perimeter column lines. These columns are removed at an instance as per GSA and for these cases, reinforcement is found for the elements adjacent to the removed column. The results are found for a) reinforcement for adjacent/nearby beam and column, with and without loss of an exterior column near the middle of the long side of the building. b) reinforcement for adjacent/nearby beam and column, with and without loss of column located at the corner of the building. c) reinforcement for adjacent/nearby beam and column, with and without loss of an exterior column near the middle of the short side of the building. d) reinforcement for adjacent/nearby beam and column, with and without loss of a column interior to the perimeter column lines of building. By replacing reinforcement details of both beam and column (without removal of column) with reinforcement details of beam and column (after removal of column) might reduce the chance of structure failure when subjected to natural or man-made disasters. Hence, this prevents the building from Progressive collapse.

ABSTRAK

Runtuhan progresif bagi struktur bertingkat tinggi disebabkan perbuatan manusia atau bencana alam menggesa jurutera struktur untuk merekabentuk satu struktur yang selamat bagi menghadapi kemungkinan lebihan beban yang boleh ditanggung di sepanjang jangka hayat. Terdapat garis panduan tertentu seperti Pentadbiran Perkhidmatan Am (GSA) dan Jabatan Pertahanan (DOD) mengenai reka bentuk dan meretroasi struktur untuk menghalang runtuhan progresif yang harus diikuti, terutamanya untuk bahan seperti konkrit dan keluli. Metodologi utama dalam kertas kerja ini adalah berdasarkan konsep "kaedah pembuangan tiang" seperti yang dinyatakan dalam garis panduan GSA bagi mengurangkan peluang runtuhan progresif dengan menyediakan laluan beban alternatif untuk struktur melalui pengukuhan tambahan. Menggunakan perisian STAAD. Pro, bangunan G+11 tingkat direkabentuk dan pelbagai kes dipertimbangkan, iaitu a) tiang luaran berhampiran tengah-tengah bahagian panjang bangunan. b) Ruang luaran berhampiran tengah-tengah bahagian pendek bangunan. c) ruang yang terletak di bahagian bucu bangunan. d) bahagian dalaman tiang ke garisan lajur perimeter. Tiang ini dialih keluar pada satu kedudukan seperti dinyatakan oleh GSA dan untuk kes ini tetulang ditemui untuk elemen yang bersebelahan dengan tiang yang dialih keluar. Keputusan ditemui untuk a) pengukuhan untuk rasuk bersebelahan/berdekatan dan tiang, dengan dan tanpa kehilangan ruang luaran berhampiran tengah-tengah sebelah panjang bangunan. b) pengukuhan untuk rasuk dan tiang bersebelahan/berdekatan, tanpa kehilangan ruang yang terletak di bahagian bucu bangunan.c) pengukuhan untuk rasuk bersebelahan/berhampiran dan tiang, dengan dan tanpa kehilangan ruang luaran berhampiran tengah-tengah sebelah pendek bangunan. d) pengukuhan untuk rasuk dan tiang bersebelahan/berdekatan, dengan dan tanpa kehilangan bahagian dalaman tiang ke garisan tiang perimeter bangunan. Dengan menggantikan butiran tetulang bagi kedua-dua rasuk dan tiang (tanpa penyingkiran tiang) dengan butiran tetulang rasuk dan tiang (selepas penyingkiran tiang) boleh mengurangkan peluang kegagalan struktur apabila terlibat kepada bencana alam atau perbuatan manusia.

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LIST OF ABBREVIATIONS

RC	-	Reinforced concrete
BM	-	Bending Moment
SF	-	Shear force

LIST OF SYMBOLS

fck	-	Compressive strength of concrete
Ecm	-	Youngs modulus of concrete
fyk	-	Tensile strength of steel
Es	-	Youngs Modulus of steel
cnom	-	Nominal cover
φdia	-	Diameter
MEd	-	Bending Moment
As max	-	Area of Reinforcement
VEd	-	Shear force

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE PROBLEM

Increase in natural disasters and terrorist actions carried out on landmark buildings, it is important to introduce new concepts in designing a safe structure which could resist the structure from destruction, damage, and also save people. It is difficult to predict what exact, very high load is induced on a building, so the most important factor is progressive collapse when designing for structural integrity. The outcome is progressive collapse when a localized failure extends to a greater part of the structure. Several examples of progressive collapses occurring due to abnormal loading in structures will be given. There are certain guidelines regarding the design of structures that should be followed to avoid progressive collapse, especially for materials such as concrete and steel [1].

As a result of rising catastrophic events in recent years, the prevention of collapse has become a necessity in design and analysis. Several solutions have been suggested in controlling the collapse of the new and existing building. Among variety of building codes and guidelines, the General Services Administration (GSA) and Department of Défense (DoD) specifically discuss progressive collapse prevention. They provide design procedures to resist progressive collapse. [8]

Progressive collapse is described as the process of failure of whole part of the building due to the small local failure of the structure.

Figure 1.1 represents about the building which is safe before a collapse and the second one shows how a primary column is damaged due to natural or manmade disaster and it causes the collapse of the whole building. This leads to loss of many lives. Hence designing a safe structure is a must.

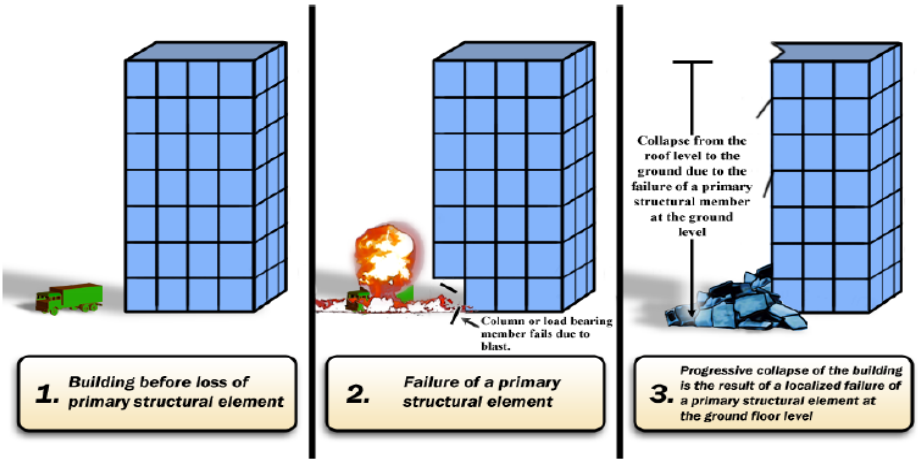

Figure 1.1 Example of progressive collapse

1.2 PROBLEM STATEMENT

The progressive collapse guidelines stated in General Service administration (GSA) and Department of Defence (DOD) is mainly limited to special buildings like army buildings and important security buildings, because for residential buildings this procedure doesn't seem to be economical due to the addition of more reinforcement. Hence not only limited to certain type of building this progressive collapse design procedure to be updated for all type of structures.

Figure 1.2 and Figure 1.3 shows that when the structure is exposed to an external blast loading, the conventionally designed structure will collapse entirely. The main reason for this is that systems designed for gravity-load are not sufficiently detailed to transfer the load paths after removing a primary vertical support. Buildings designed for seismic & wind loads can be capable of resisting lateral loads and creating alternate load paths after loss of column. [3] Hence, the special moment resisting frames (SMRF) have less chance of collapse on external blast loading. (Figure 1.4)

Figure 1.2 Exterior loading (blast)

Figure 1.3 Conventional design: Progressive collapse

Figure 1.4 Alternate load path design: No progressive collapse

1.3 OBJECTIVE OF THE PROJECT

The Objectives of this project are

- To examine the inherent resistance of conventionally designed building for which progressive collapse requirements have not been included in the design.

- To propose simple concepts in designing a more robust structure with respect to progressive collapse threat.

- To propose a robust G+11 structure using STAAD.Pro software for different column removal cases respect to GSA and providing additional reinforcement for alternate load path to maintain structural integrity.

- Progressive collapse design guidelines to be outlined and to discuss the assessment of ordinary structural design vulnerabilities.

1.4 SCOPE OF THE PROJECT

The scope of this project is

- To change the load path of the structure in emergency crisis by introducing alternate load path method in design procedure.

- To apply the specified load combination after removing first storey columns at each of the four locations of the buildings as specified in guidelines and demand forces are found for each element using STAAD.

- To design a safe structure which resist all natural and man-made disasters which could save both money and lives.

1.5 SIGNIFICANCE OF THE RESEARCH

Significance of the research are

- To develop a safe structure which resist all lateral and vertical load and forming a perfect path for the loads.

- To safeguard important buildings like army weapon storage building, army buildings and main Government buildings by introducing new concepts in design procedure.

- To transfer the load path by the alternate load path design procedure when an element fails saving both life and money.

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