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Local Failure of High Rise Buildings

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A Thesis

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الله

بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا
عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ .

صدق الله العظيم
البقرة - ٣٢ -

بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain-Shams University for the degree of MASTER of SCIENCE in structural engineering.

The work included in this thesis was carried out by the author in the department of Structural Engineering, Ain-Shams University from October 1986 to March 1993.

No part of this thesis has been submitted for degree or a qualification to any other university or institution.

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INTRODUCTION

1.1 : GENERAL :

Engineers have always been interested in studying the behaviour of the various types of structural systems in their normal active conditions. Recently the effect of local failures in the different types of structures have been considered as an important target for research work in many countries. This has been emphasized through various research works and publications. The main reasons for local failures can be presented as follows:-

1- Changing the function of the structure .
2- The actual loads on the structure may be higher than the designed values .
3- Ignorance in using modern equipment in these structures may destroy some of their structural elements .
4- Ignorance of traffic rules and speed limits, which increases the possibility of column failure in the different parts of the structure as a result of vehicle accidents to structures.

This research work aims to study the effect of local failures in different structural systems, combined girders and columns ; shear wall and columns ; and core and columns, to provide the designer with the sufficient knowledge and information about the residual factor of safety of structures after the incidence of a local failure in some main elements such as, side;corner or intermediate column , as well as intermediate shear wall and core corner.

A computer program based on the stiffness method was written in 'C' Language to analyze these structures as a space frame using an equivalent single line element. This program calculates the displacements of the structure at each node (X , Y , Z , θ_x , θ_y , θ_z) . Accordingly the strains and consequently the stresses of the structure at any point can be determined .The considered cases were analyzed in their active cases before local failures by considering the gross sectional area of their structural elements as homogeneous cross sections. The local failure of each structural element was treated by considering the inertia and cross sectional area of the crushed element to be equal to 1/10000 of its original value .

A comparison was made between the previous presented systems to show their general behaviour before and after the occurrence of the local failures. This study also provides the researcher and the designer with sufficient knowledge and information about the reliability of the structure against these local failures without affecting the other structural elements. Also this study is beneficial in applying the ideal approach for repairing these structures after the occurrence of these failures .

1.2 : CONCEPTS OF HIGH RISE BUILDINGS :

High rise buildings are closely related to crowded cities, they are a natural response to dense population concentration,scarcity of land,and high land costs. The massing of the high rise building evolves out of the designer's interpretation of the environmental context and his response to the purpose of the building. The high rise building may be free standing vertical and slender or horizontal and bulky - or it may be placed directly adjacent to other tall buildings, thus forming a solid building block. In both approaches the building is basically an isolated object. However, the tall building of the future may be an integral part of one large building organism. In the cities , these buildings or activity cells are interconnected by multi level movement systems .

High rise buildings range in height from below 10 to more than 100 storeys . A rather complex planning process is necessary to determine the height or the massing of a building. Some of the factors to be considered are the client's needs versus the land available and the location of the land as related to facets of the environmental context. However, the utility services are designed to support the inhabitants needs, and the ecological impact of the building. It can be also considered as the scenic character of the landscape .

The selection of a high rise building structure is not based merely on the understanding of the structural context. The selection concepts are related to the cultural, social, economical and technological needs . One should bear in mind that the structural concept is only one important consideration among many. Some of factors which are primarily related to the technological planning of high rise buildings are as follows :-

1- General economic considerations.
2- Soil conditions.
3- Height-to-width ratio of the building.
4- Fabrication and erection considerations.
5- Mechanical systems considerations.
6- Fire rating considerations.
7- Local considerations.
8- Availability and cost of the main construction materials.

1.3 : STRUCTURAL SYSTEMS :

The most common structural systems for concrete tall buildings are as follows :-

1- The frame structure.
2- Infilled frame structure.
3- The shear wall structure.
4- The complex structure.
5- The central core structure.
6- The tubed structure.

Frame structure offers reasonable stiffness and stability for tall buildings, see fig.(1.1). When the frame structure is flexible, brick or block infill can be used to increase its stiffness. However, flexible frames have a small resistance to lateral forces and produce large deformations within the structure. Similarly, block or brick walls, fail mainly under shear stresses produced by comparatively small loads. Experiments and analyses show that the combined action of the two media (concrete and bricks) is greater than the sum of the two separate mediums particularly in resisting lateral forces, where it increases the lateral stability and reduces the deformations. The effectiveness of the combined action depends greatly on the standard of workmanshop and the material used. It has been shown by Stafford Smith(1) and others that the stiffness of an infilled panel depends on the area of contact between the frame and the wall, and the quality of the infill as shown in fig. (1.2).

As buildings are constructed taller, it becomes increasingly important to ensure adequate lateral stiffness to resist wind and earthquake forces as well as normal vertical loads, and make better use of space and material. To fulfill these requirements "shear-wall" system is frequently used. Fig. (1-3) shows the shear wall system.

Complex systems can be formed using the shear-wall combined with floor slabs and columns to increase the stiffness of the structures against lateral forces. Fig. (1-4) shows an example of a complex system.

The use of central core system is suitable for areas in which the foundations of the structure are in close proximity to the foundations of other buildings and additionally maximizes open space at the base of the structure. In some cases, all the horizontal loads acting on the structure are taken by the core, while in other cases the perimeter's columns form with the girders a structural grid which contributes mainly to the stability of the structure under lateral loading. Fig. (1-5) shows examples of the core system.

Bundle tube system and tube in tube system, consisting of a heavy central shear core coupled with floor decks to closely spaced perimeter columns is known as mullions. Fig. (1.6) shows an example of a tubular structure. Fig. (1.7) shows the suitable systems for concrete tall buildings of different heights.(Soliman (8)).

For steel tall buildings, the most common structural systems which can be framed are as follows :-

1 - Rigid framing.

2 - Simple framing.

3 - Tube framing.

4 - The staggered truss-system.

In the case of rigid framing structures, all connections are rigidly joined. The lateral stability depends on the stiffness of the beams and columns ,and particularly on the moment resisting connections. In the simple framing system, a vertical bracing system is generally used to provide lateral stability. Fig. (1-8) shows an example of these systems. When tube framing is used, lateral stability is achieved by the rigid exterior walls, the interior beams are usually simply