Seismic Analysis and Design of Smart Parking System

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***Abstract*—**. *Fundamental design information is given to illustrate In the construction of multi-storey car parks, the idea of profitability is essential and covers a number of aspects. Steel construction makes it possible to reduce construction costs, optimise the occupation of the car park and improve return on investment by gaining floor area. This publication gives examples of good practical design that enable the structure to blend with all environments whilst utilising the inherent versatility, elegance and economy of a steel framehow steel, with its ability to accommodate long clear spans and minimise column sizes, can create aesthetically pleasing, economic, secure, user-friendly car parks.*

Keywords—*Seismic Analysis, Seismic Design and Progressive Collapse Analysis*

I. INTRODUCTION

In today parking lots there are no standard system to check for parking spaces. The system heavily relies on human interaction with the physical space and entity. This leads to wastage of human manpower and also parking spaces at times. Most of the time when users go to malls and commercial complex, they experience that there is a limited space for parking spots especially on prime hours. Hence, there is a desperate need of a robust parking system that will enable us to reserve the parking spots. For that it is necessary to build a centralized system to gather all the information on parking spots of malls, commercial complexes, and multilevel car parking systems.

Seismic collapse is defined as the inability of a structural system or a part of it to sustain gravity loads under earthquake loadings. Earthquake loadings may trigger vertical or lateral dynamic instability collapse. Progressive collapse is defined as total or remarkable partial collapse of structure following local damage at a small portion of the building. The damage can be caused by an explosion, earthquake, being hit by a vehicle or a sudden collapse etc. The damage is often applied to the structure dynamically and during a short time period.

Progressive collapse is a well-understood physical occurrence. However, its mathematical representation still requires clarifications, explanations, and improvements. In this paper we attempt to simplify and conceptually explain the progressive collapse phenomenon by performing real analysis using ETABS software. This is done through analyzing a six-story steel moment-resistant frame building with a loss of one primary column.

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II. OBJECTIVE

The main objective of this paper is to provide clear step-by-step descriptions of four increasingly complex methods for progressive collapse analysis, using commercially available structural analysis software such as SAP2000. Our aim is that explanations be clear enough to be readily understood and used by practicing engineers. The approach is as follows:

1. Analyze a sparking building using linear static method
2. Provide explanations of analysis procedures including input screen snapshots;
3. Identify advantages, disadvantages, and limitations for all four procedures, based on the example analysis;
4. Identify the analysis procedure that resulted in the most conservative response and required the most resources; and
5. Give conclusions and recommendations for the preferred analysis procedure on the basis of its accuracy and ease of Perfomance.

Table 1. Girder Section and Material Properties

Girder section	ISMB 350
Yield strength Fy	345 MPA
Modulus of elasticity E	2×10^5 N/mm^2
Moment of inertia I	1.363×10^{-4} m^4
Plastic modulus Z	7.789×10^{-4} m^3
Plastic moment Mp=FyZ	268 KNm

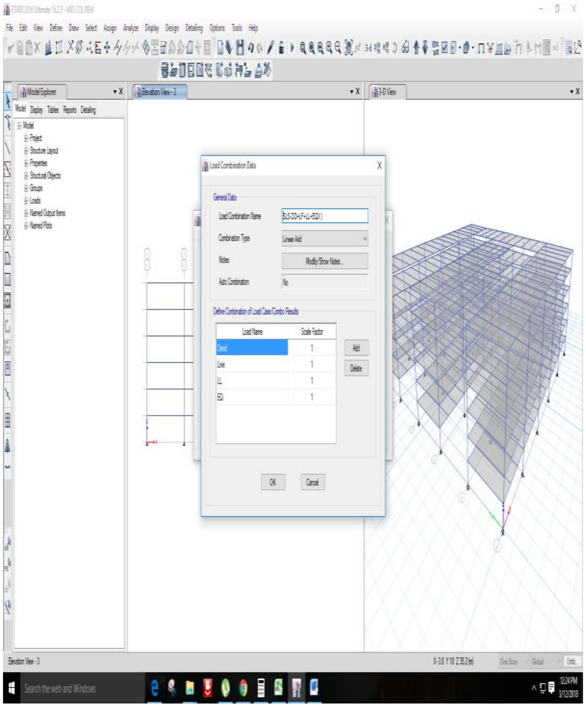


FIG. 1. THREE-DIMENSIONAL MODEL OF BUILDING

III. LOADS

GSA Progressive Collapse Guidelines (GSA 2003) mandate the following loading combinations when evaluating for progressive collapse:

For static analysis procedure:

Load = 2 x (DL + 0.25LL) -------------------------(I)

For dynamic analysis procedures:

Load = DL + 0.25LL --------------------------(II)

where DL = dead load, which is automatically generated by ETABS based on element volume and material density; and LL = live load and is assumed to be 5KN/m^2 distributed uniformly across the entire floor area including roof. The factor of 2 in Eq. (I) appears to function as a dynamic amplification factor to simulate dynamic response when using static analysis procedures.

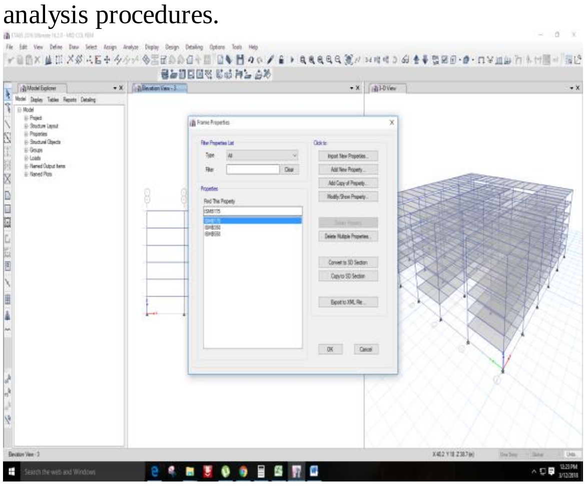


Fig. 2. INPUTS IN ETABS

To estimate dead load, we have assumed uniform concrete slab thickness of 90 mm with normal weight concrete density.

IV. PROGRESSIVE COLLAPSE ANALYSIS

The analysis for progressive collapse is carried out using static analysis procedure. To simplify and to demonstrate the steps of progressive collapse analysis more clearly, we have made following assumptions:

1. A symmetric building with a symmetric loss scenario was used to avoid potential analysis complications introduced by asymmetry;
2. Secondary beams are pin–pin connected and do not contribute to progressive collapse resistance;
3. Out-of-plane bending stiffness of floor slabs was reduced to ensure that they do not resist progressive collapse;
4. All perimeter frames are special moment resistant frames with connections that are stronger than beams, forcing plastic hinges into the beam and not in the connection or column;
5. Effects of large deflections are not included in our analyses;

A. Linear Static Analysis

The linear static analysis procedure is performed using an amplified by a factor of 2 combination of service loads, such as dead and live, applied statically. This analysis procedure is the simplest and easiest to perform. However, it is limited to relatively simple structures where both nonlinear effects and dynamic response effects can be easily and intuitively predicted. Response is evaluated by demand to capacity ratios (DCR), which for our study shall not exceed a value of 3.

This analysis procedure involves the following steps:

1. Build a finite-element computer model;
2. Apply the amplified static load combination as defined by Eq. 1
3. Perform static linear analysis, a standard analysis procedure in ETABS and
4. Evaluate the results based on demand to capacity ratios DCR.

Total analysis time is approximately 3 min.

Now that the member forces are known, the DCR can be found by taking the ratio of the maximum moment in the beam to its ultimate capacity as illustrated in equation below

DCR = Mmax / Mp = 740.45 kNm / 268 kNm

= 2.76 < 3

Where, Mmax = maximum negative moment at the beam supports

M_P = ultimate moment capacity

We can conclude that this structure does satisfy the GSA progressive collapse criteria.

Additionally, by examining calculated DCR values, it can be seen that this structure satisfies criteria by a comfortable margin.

The maximum calculated deflection due to the amplified load 38mm

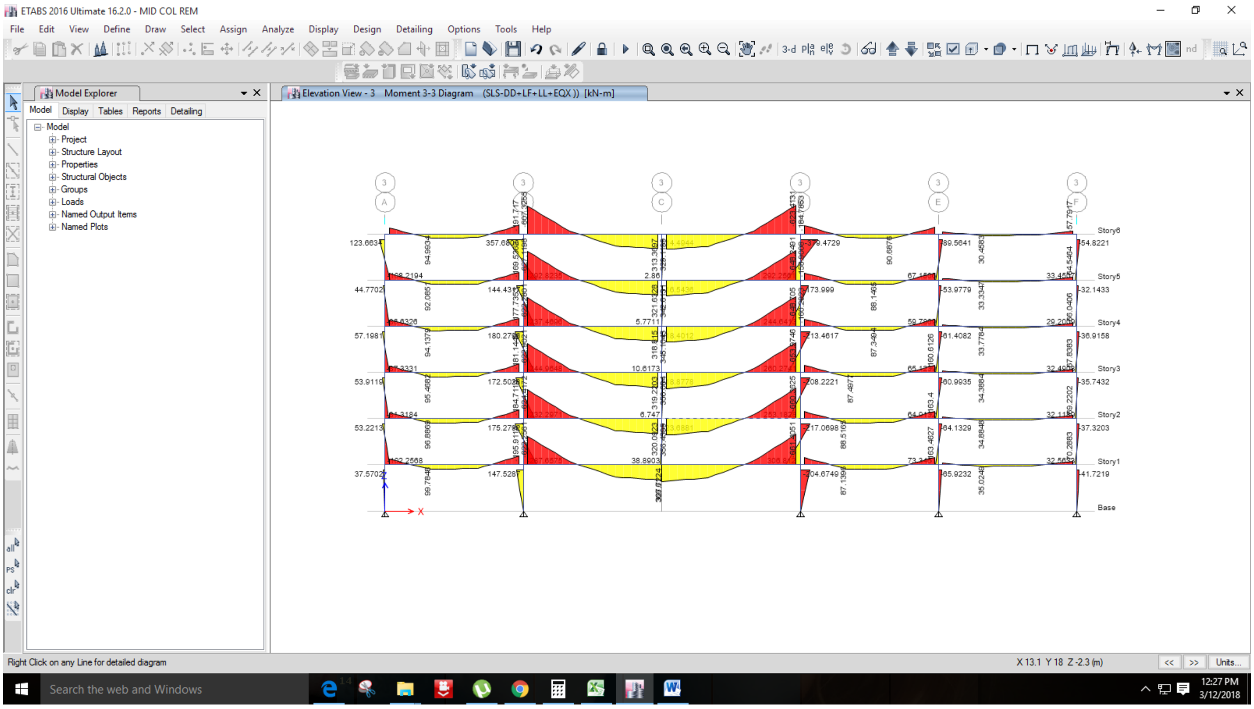


Fig. 3. Moment due to Mid column removal

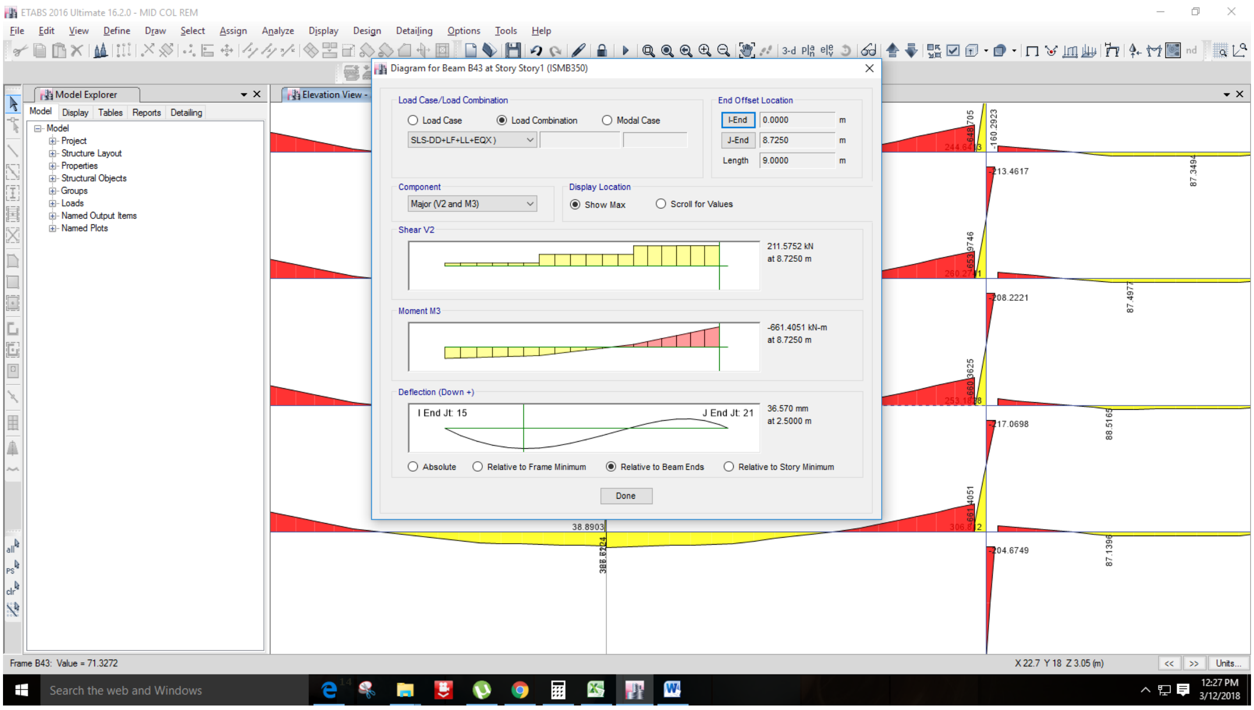
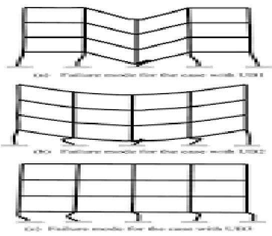


Fig. 4. Deflection due to Mid column removal

With linear analysis procedures, this structure satisfies the progressive collapse criteria according to GSA criteria, since DCR values do not exceed 3. Furthermore, according to the linear dynamic analysis procedure, the structure has a safety margin of 8%. The progressive collapse analysis was done for all the six columns removal and for the no column removal condition.



V. CONCLUSION

We draw the following conclusions from our analysis:

1. Dynamic analysis procedures for progressive collapse determinations, if modeled using initial conditions methodology, are fairly simple to perform and are readily available to practicing engineers through finite element computer programs.
2. Dynamic analysis procedures can be carried out using any finite-element computer program capable of nonlinear dynamic analysis, such as ETABS, which was used in our study.
3. The dynamic amplification factor of 2 used in Eq.1 is a good estimate for static analysis procedures since linear static analysis procedures yield approximately the same maximum deflections.
4. Evaluation criteria for linear analysis procedures for static appear to be very generous, since in our analysis we found that the example structure passes linear performance criteria.

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