Analysis of Underground Parking Structure

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ABSTRACT

Ever since the 1960s, parking has turned out to be a major user of developable land. Multi-storey car parks, underground or basement car parks, and car parks in a multi-function building are common. Even though multi-storey car parks are mainly found in city and town centers, they as well feature in airports, retail centers, conference centers, hotels, housing developments, places of employment (both offices and factories), places of entertainment, railway stations, and sports facilities.

Underground parking provides many long-term benefits such as preserving prime real estate, offering convenient, centrally located parking, and removing parking structures from street frontage.

Deep underground basements that are integrated into urban development projects early in the overall project design offer many inherent improvements to the overall quality and value of the project and its surrounding community.

Understanding the primary design and construction issues is significant while planning an underground parking structure.The current study involves the seismic behavior of reinforced concrete buildings with multiple underground stories.The study involves analyzing the behavior of the ramps and decks due to single vehicle movement and multi vehicle movement and also the vehicle impact into a column.

Key words: Parking structure, Ramps, Vehicle Impact

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INTRODUCTION

Parking structures are one of the most conspicuous “solutions” to a society’s parking challenges. In a number of cases parking structures are the best solution and numerous cases are present where parking structures make sure improved parking conditions, the global transportation network and quality of the neighborhood, also allowed for transit oriented development that would not take place otherwise[1]. At the same time, if not properly evaluated, parking structures can be built in places and in methods that have significant negative impacts

Effective parking structures are designed to meet the consumer’s demands, which usually take account of feeling safe and welcome, and more knowing that their cars are in a secure environment.Given the choice, people all the time park in light and bright car park where they feel their car and its contents will be safe and secure.

This design procedure is influenced by the parking purpose, how frequently consumer’s visit, payment and control systems, and connection to the external highway network[2]. Hence, for short-stay parking such as for shoppers – where higher dynamic and turnover capacities are required – wider bays are recommended.

Underground structures are constrained by the neighbouring soil or rock and cannot move independently so they are not generally subjected to significant dynamic amplification effects. They are usually affected by the deformation of the surrounding ground and not by the inertia forces acting on the structure[3].

Many factors influence whether a user will find the car park easy to use and be comfortable in the car park. The most important elements are outlined below:

- Size of car park and ease of circulation
- Layout in terms of column spacing, ability to find available spaces easily, aisle and ramp widths, headroom and ramp gradients
- Safety and security
- Level of visibility
- Lighting
- Quality and style of internal surface finishes
- Clear and concise user information and signage.

MATERIALS AND METHODS

Modeling of Structure

The plan layout of the underground RC frame building, chosen for this study is shown in Fig. 1 by SAP2000. The overall plan layout of the building is 58.5m X 34.5m and external circular ramp with an inner diameter of 5.5m and outer diameter of 10.5m. The number of underground storeys considered in this study is 3.All the buildings are assumed to be fixed at ground level and the storey heights is 3.5m. Taking concrete grade M30, Steel of grade FE 415 and the poison's ratio is 0.2 has been assumed for analyses of all the models.

A minimum clear height or headroom of 2.10m measured normal to surfaces, for vehicles is provided at entrances, exits, bays, aisles and ramps.The maximum gradients for a vehicle ramps is applied as given is the table 1.

Table 1 –Maximum Gradients for Vehicle Ramps

Ramp Type	Rise	Maximum Gradient
Straight Ramps	Not greater than 1.50m	1:6
	Greater than 1.50m	1:10
Curved Ramps	Not greater than 3.0m	1:10
	Greater than 3.0m	1:12

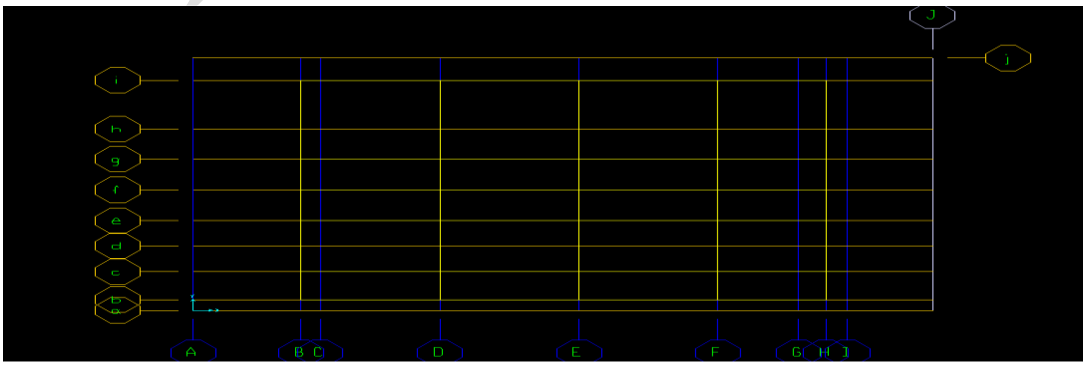

Fig. 1: Typical Structural plan Layout

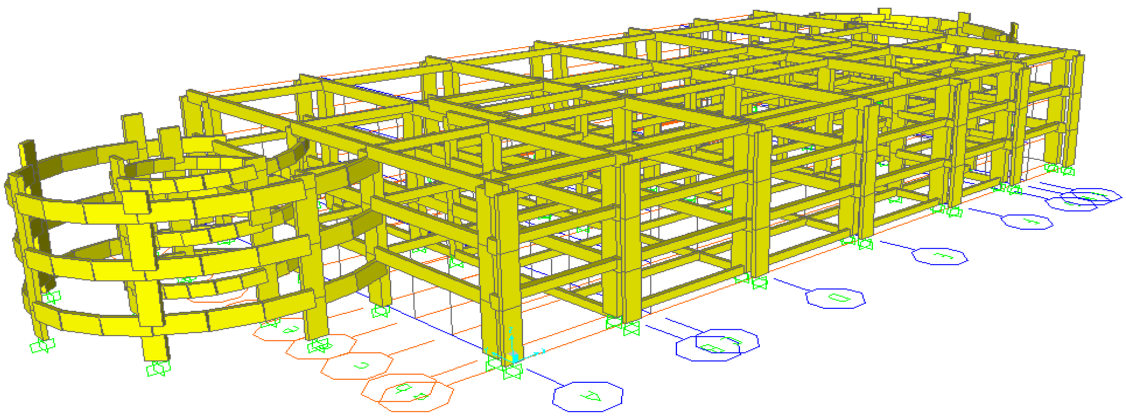

Fig. 2: 3-D view of Model

Sectional Dimensions of Main Components

Beams and columns have been modeled as 3-D frame elements. Slab is modeled as rigid diaphragms of thickness 250mm, and Retaining wall of thickness 250mm
The sectional dimension of column and beam are given in the table.

Table 2–Sectional Dimensions of Column and Beams

Frame	Section Type	Dimension
Column	Rectangular	600X1200
Column	Rectangular	300X1200
Column	Square	600X600
Beam	Rectangular	300X600
Beam	Rectangular	300X900
Beam	Rectangular	600X600
Ramp Column	Rectangular	300X1200
Ramp Beam	Rectangular	300X1200
Ramp Beam	Rectangular	300X900

Loading

Design Loads

The imposed loading applicable to the decks and ramps in car parks are considered as given in the IS 875:1987

Uniformly distributed imposed load

The uniformly distributed load for Garage floors including car parking are for vehicles not exceeding 4 tonnes gross weight is taken as 5 KN/m^2 and floor finish of 1.5 KN/m^2 as per IS 875:1987.The horizontal earth pressure on the retaining wall is calculated considering saturated soil having unit weight of 18 KN/m^3 over a height of 10.5m using the following equation.

$$P = \frac{1}{2} k \gamma H^2$$

Where,
H- Total height
γ – Unit weight of soil
$k = \frac{1 - \sin \emptyset}{1 + \sin \emptyset}$

METHOD OF ANALYSIS:

Dynamic Analysis

Dynamic analysis is performed for building with the help of soft computing technique as per IS 1893 (Part-1): 2002. The building is considered to be located in all seismic zones from zone II to V and intended as Public building.The model is analyzed for various combinations of loads as per IS 1893(Part-1):2002

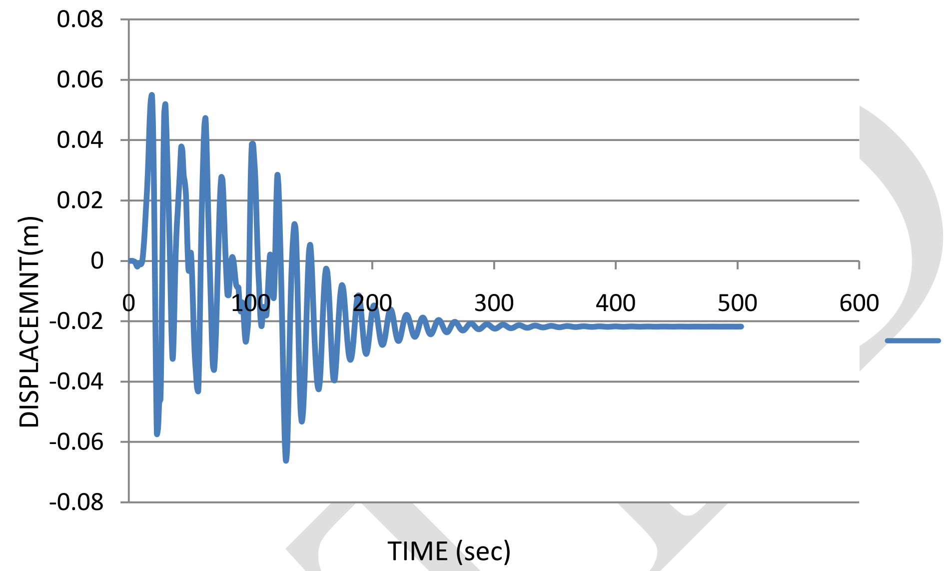

Fig. 3: Time Displacement graph of the joint at 3.5m height

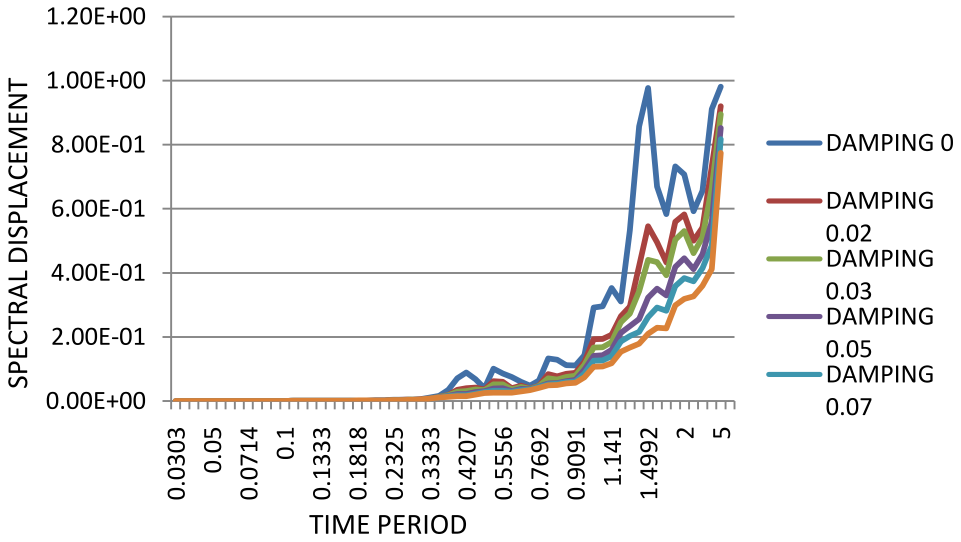

Fig. 4: Spectral Displacement v/s Time period graph of the joint at 3.5m height

Dynamic Impact on Ramp

When a vehicle moves onto a ramp with a grade, there is an impact force on the ramp that should be added to the static force. The impact force depends on the ramp grade, the vehicle velocity, and the vehicle dynamic characteristics. From dynamics, the maximum deflection of the mass under an impact type of force is equal to the deflection under a static force multiplied by an impact magnification factor.

Edge Protection

Edge protection against vehicle impact is provided to withstand load representing vehicle impact, they should not deflect excessively, fail catastrophically or permit the vehicle to ride over the top.

Dynamic Effects of moving vehicles

For the dynamic analysis, we use afloor slab model of a flat, homogeneous, rectangular slab, supported bybeams.We use young's modulus of $2x10^5$and poisson's ratio of 0.3 with a slab thickness of 250mm.

Floor Response under Moving Vehicle

For a simply supported plate on all four edges, the mode shapes under free vibration can be stated in terms of simple sinusoidal functions.The dynamic response of the slab under a singlemoving concentrated load depends on the speed of the movingload and the span length. We focus on the dynamic responseat the center of the slab, which would be most severe.

The combined effect of the movement of several vehiclesacross the concrete slab can be obtained by superposing theslab displacement due to each vehicle under the assumptionthat the plate response is linear.

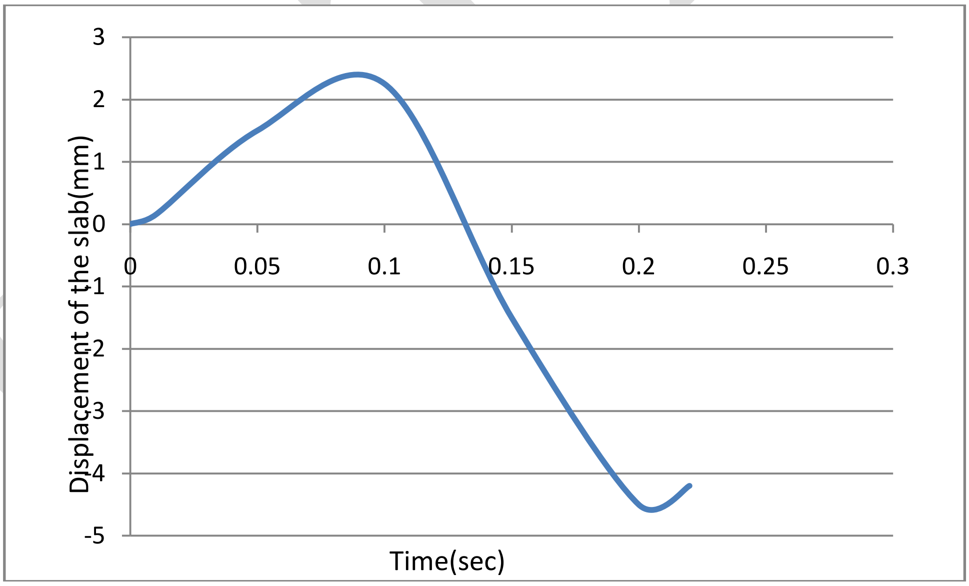

Fig. 5: Displacement at the center of the slab

CONCLUSION

During seismic vibrations the underground structure act as a closed box structure and experience less damage during seismic effects. The temperature movements are restrained by the lateral stability systems. To avoid the large forces being generated by restrained thermal movement careful consideration should be given to the location and interaction of the systems.The dynamic effect due to moving vehicles on the deck is mainly a function of vehicle speed, and is less than two times that of the static deflection for a single moving vehicle.The net effects of moving vehicles are found to be not higher than in the case of the driving aisles being fully occupied by stationary vehicles.The impact force on the ramps is estimated to be 1.5 times a single vehicle weight.

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