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Modelling and Parametric Study of Typical Multi Level Car Parking System

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***Abstract* - Multi level car parking systems has become quite popular in recent times in cities which have become population hubs due to growth of industrial areas, commercial activities etc. as compared to conventional type of parking. Multi level car parking system is just the extension of the conventional surface parking lots in the vertical direction in the particular area. Hence some suitable structural system should be enveloped in order to store large number of vehicles in the particular space. This structural system may be made either of concrete, steel concrete composite or the precast concrete. Conventional concrete has become quite common whereas the precast option if employed then it can be erected fast and thus can be completed faster saving valuable time and money. Another most effective way of constructing multi level car parks is by utilizing the steel concrete composite frame option which can give savings in steel weight of about 30% to 50% over non-composite construction thus reducing the overall cost of structure. For the present work, a typical G+5 storey multi level self car parking system with capacity to store 448 cars has been considered in earthquake zone III with medium class soil. Various models has been modeled and then analyzed and designed. The building geometry has been modeled, analyzed and designed using software STAAD.Pro. Analysis has been done by the approximate method of earthquake analysis i.e. Equivalent Static Method of Analysis along with the dead loads & live loads and designing for the same. For the purpose of result comparison, best efficient and economical section sizes have been selected through optimization process.**

INTRODUCTION

India is a democratic country. People of different caste, creed, community etc. reside in all over the country. As a result present population of India has crossed the figure of 110 crore mark. It is said that India will overtake china in population chart in the year 2020. People of India nowadays are in every part of the world. The cities in India like Delhi, Bangalore, Ahmedabad etc have become population hubs. The reasons for attraction towards the city may be either of the following reasons i.e. searches for jobs, education, business etc. Industrial and commercial areas are the main areas where the cities heart lies. People working therein are in constant need of vehicles like bikes, cars etc. As a result nowadays there is problem of parking, be it a two wheeler bike or a four wheeler car. On-street parking system has also failed to accommodate the vehicles of the city. This is where an effective system is needed for solving the problems of parking. One of such system which can be effectively used in solving the problem of parking is Multi Level Car Parking System.

STRUCTURAL MODELLING ANALYSIS & DESIGN

For the present work, typical 3D model of multi level car parking structure has been taken, situated in Vadodara. A 3D view of the frame building is also shown in Fig. 1. In this problem only slabs and beams are composite while columns are built up of steel. Concrete wall of 1.2 m height & 150 mm thickness is used as outer periphery throughout the building acting as a barrier. No internal walls are considered as the building deals with the storage of vehicles. The building has been analyzed and designed for medium class soil, for earthquake zone III using Equivalent Static Method of Analysis. The same building has also been analyzed and designed with concrete members with minimal changes in the geometry. Designs are based as per the present Indian standard codal provisions. Limit state method in IS 800:2007 is referred for the design. American codes are followed where Indian code lacks in design. The building is modeled, analyzed and designed with the help of software STAAD.Pro V8i. Here, for the comparison of the results, best possible economical and efficient section sizes have been selected from optimization process and trial-error methods using advantages of post processor mode of STAAD.Pro, for both concrete as well as composite structure.

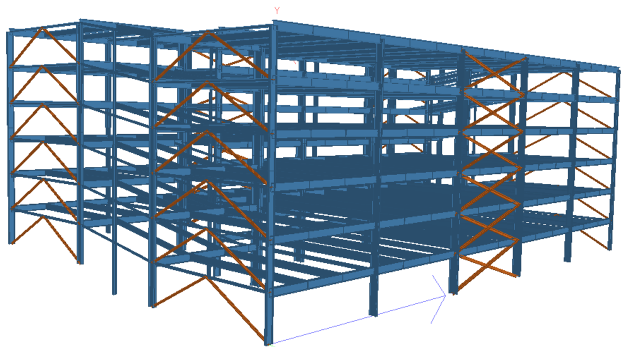

Fig. 1. 3D view of steel framed building

PROBLEM STATISTICS

- Geometrical Data
  - Type of building : Car Parking Structure
  - Location of building : Vadodara (Gujarat)
  - Height of building from GL : 20.8 m
  - Typical storey height : 3.2 m
  - Dimensions of building :
    - Length (L) : 50.00 m (in X– direction)
    - Breadth (B) : 34.40 m (in Z – direction)
- Material Data
  - Grade of concrete : M 20
  - Yield strength of steel section : 250 N/mm2
  - Yield strength of reinforcement : 415 N/mm2
  - Unit weight of concrete : 25 kN/m3
- Loading Data

Dead Load (DL) at any typical floor level & roof level.

- Floor Finishes including : 1.50 kN/m2
  weight of metal deck, plaster etc.
- barrier loads : 4.50 kN/m

Live Load (LL) at any floor level : 2.50 kN/m2

Earthquake Load (EL)

- Zone factor : 0.16
- Importance factor : 1.0
- Response reduction factor : 4.0(Concentric braced frame)
  (For composite building)
  : 5.0 (SMRF) 3.0(OMRF)
  (For concrete building)

Load factors

- For dead load : 1.50
- For live load : 1.50

Material Safety factors

- For structural steel : 1.15
- For reinforcement steel : 1.15
- For concrete : 1.50

ASSUMPTION

Following are some assumptions made for general arrangement of building, analysis and design:

- Floor is made of reinforced cement concrete with steel deck acting as form work and bottom reinforcement, with topping for floor finish.
- All beams, columns and bracings are made of steel.
- Propped method of construction has been considered in this design.
- Steel concrete composite structure is designed by the limit state method using partial safety factors for loads and material strengths as specified in IS 456:2000
- Composite beam design is made as per AISC LRFD & AISC ASD both.
- The effective width of beam is taken as span/4 for T-beams and span/8 for L-beams as per codal provisions.
- The model is analyzed & design with rigid condition prevailing in steel structure and for concrete complete fixidity is assumed to act.
- The model is assumed to have fixed support at base constructed on medium type of soil, located in zone III with depth of foundation of 1.8 meters.

TABLE I. NODAL DISPLACEMENTS

CODE	AISC LRFD S.S FIX			AISC ASD S.S FIX			LOAD NO:	CASES
	Horizontal	Vertical	Horizontal	Horizontal	Vertical	Horizontal	LRFD/ASD	
	X mm	Y mm	Z mm	X mm	Y mm	Z mm		
Max X	**14.2**	-5.68	-0.05	**10.94**	-4.48	0.06	12/12	1.5(D.L+EQx)
Min X	**-14.14**	-4.83	0.2	**-10.9**	-6.2	0.13	18/18	0.9D.L-1.5EQx
Max Y	1.87	**0.67**	-0.07	1.03	**0.52**	-0.04	1/1	EQx
Min Y	-0.11	**-100.62**	0.12	-0.01	**-63.12**	0.09	5/5	1.5(D.L+L.L)
Max Z	-0.13	-42.42	**12.09**	-0.04	-20.92	**6.9**	13/13	1.5(D.L+EQz)
Min Z	0.08	-44.61	**-12.78**	0	-21.9	**-7.31**	15/15	1.5(D.L-EQz)

TABLE II. SUPPORT REACTION

CODE	AISC LRFD S.S FIX			AISC ASD S.S FIX			LOAD NO:	CASES
	Horizontal	Vertical	Horizontal	Horizontal	Vertical	Horizontal	LRFD/ASD	
	Fx KN	Fy KN	Fz KN	Fx KN	Fy KN	Fz KN		
Max Fx	**434.97**	5419.55	93.47	**339.52**	3367.7	-24.2	14/14	1.5(D.L-EQx)
Min Fx	**-435.03**	5424.81	96.1	**-339.55**	3311.65	-50.08	12/12	1.5(D.L+EQx)
Max Fy	6.53	**12868.2**	83.56	1.02	**13377.3**	36.39	5/5	1.5(D.L+L.L)
Min Fy	-249.27	**-615.08**	-1.29	-149.49	**-482.72**	-2.11	1/1	EQx
Max Fz	-61.6	2241.3	**309.89**	-62.39	1013.32	**269.96**	15/15	1.5(D.L-EQz)
Min Fz	-74.89	3028.48	**-360.73**	-100.09	2680.86	**-432.38**	13/13	1.5(D.L+EQz)

TABLE III. SUPPORT MOMENTS

CODE	AISC LRFD S.S FIX			AISC ASD S.S FIX			LOAD NO:	CASES
	Horizontal	Vertical	Horizontal	Horizontal	Vertical	Horizontal	LRFD/ASD	
	Fx KN	Fy KN	Fz KN	Fx KN	Fy KN	Fz KN		
Max Fx	**434.97**	5419.55	93.47	**339.52**	3367.7	-24.2	14/14	1.5(D.L-EQx)
Min Fx	**-435.03**	5424.81	96.1	**-339.55**	3311.65	-50.08	12/12	1.5(D.L+EQx)
Max Fy	6.53	**12868.2**	83.56	1.02	**13377.3**	36.39	5/5	1.5(D.L+L.L)
Min Fy	-249.27	**-615.08**	-1.29	-149.49	**-482.72**	-2.11	1/1	EQx
Max Fz	-61.6	2241.3	**309.89**	-62.39	1013.32	**269.96**	15/15	1.5(D.L-EQz)
Min Fz	-74.89	3028.48	**-360.73**	-100.09	2680.86	**-432.38**	13/13	1.5(D.L+EQz)

TABLE IV. BEAM END MOMENTS

CODE	AISC LRFD S.S FIX			AISC ASD S.S FIX			LOAD NO:	CASES
	Moments			Moments			LRFD/ASD	
	Mx KNm	My KNm	Mz KNm	Mx KNm	My KNm	Mz KNm		
Max Mx	**53.74**	0	406.19	**41.25**	0	340.08	5/5	1.5(D.L+L.L)
Min Mx	**-51.97**	0	406.34	**-40.55**	0	339.46	5/5	1.5(D.L+L.L)
Max My	0	**605.17**	-404.24	0	**726.73**	908.96	5/5	1.5(D.L+L.L)
Min My	0	**-647.79**	-407.28	0	**-746.37**	529.39	5/5	1.5(D.L+L.L)
Max Mz	-0.89	0	**927.96**	-1.1	0	**944.52**	5/5	1.5(D.L+L.L)
Min Fz	0	0	**-1389.88**	0	0	**-1454.48**	5/5	1.5(D.L+L.L)

CONCLUSIONS

1. This kind of car parking system is suitable for the Indian environment as the number of cars is increasing day by day. Hence it is adoptable as this system provides maximum density by storing large number of cars in the particular area.

2. Modelling, analysis & design of the structure with staad.pro V8i is found to be user friendly as it deals with powerful GUI, easy syntax, advance analysis and multi material design.

3. Displacements percentage reduction of about 65.48 & 40.13 are noticed in the respective +ve X & Z direction when ductile code is used for analysis & design compared to conventional code. Similarly 65.8 & 40.24 percentage reduction in displacements are noticed in the respective –ve X & Z direction.

4. The cost of the substructure is found to be more since the reaction & moments governing the foundation design seem to be higher when ductile code is used for analysis & design.

5. When IS 456-2000 code is utilized, concrete & steel quantity are about 733.7 & 102.35 tonnes. This concrete & steel quantity increases to 1079 & 107.26 tonnes for IS 13920-1993 code when used for analysis & design. A difference of about 10,25,120 rupees is seen between both the concrete codes when they are utilized for analysis & design purpose.

6. Galvanized steel is maintenance- free for 50–80 years. Life-cycle costs of galvanized steel frames are two to five times less than painted structural steel frames. So if used we can have structural system which is maintenance free and long term durability is achieved.

7. Percentage displacement reduction of about 22.96 & 42.93 is noticed in the +ve X & Z direction when steel framed structure is analyzed & design with AISC ASD code having solid slab as floor element Compared to LFRD design. Similarly 22.91 & 42.8 percentage displacement reduction is noticed in respective –ve X & Z direction. This is because of the difference of the codes how it deals with the steel structure. LRFD Specification is to provide a uniform reliability for all steel structures under various loading conditions. This uniformity cannot be obtained with the allowable stress design (ASD) format.

8. The cost of the substructure is found to be more since the reaction & moments governing the foundation design seem to be higher when AISC ASD code is used for analyzing & designing the framed structure having fixidity at the joints with solid slab & composite slab acting as floor elements.

9. AISC LFRD code when used for analysis & design having fixidity at joints with solid slabs as floor element consumes about 573.07 tonnes of steel. This steel consumption increases to value of 956.93 tonnes when AISC ASD code is used. Hence it is desirable to follow the AISC LRFD code since it provides uniform reliability for steel framed structure together with economy. This both codes differ drastically from each other as the ASD results are based on actual stress values compared to the AISC allowable stress values whereas LRFD results are based on the actual forces and moments compared to the AISC limiting forces and moments Capacity.

10. In composite construction different types of slab system are adopted i.e. solid slab, precast slab units and prolife sheet decking with concrete. Total period of construction is less when precast slab system/profile decking is used when compared to solid slab system. Hence economy is achieved while using precast slab system/profile deck floor system.

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