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Comparative Study on Behaviour of Intze type Water Tank with Different Lateral Load Resisting Structural Systems

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Abstract— It is observed that the Intze type water tanks were collapsed or damaged during earthquake and this might have occurred due to various reasons like lack of understanding the behavior of the supporting structure (staging) of the Intze type water tank due to seismic loading or selection of improper geometric shape of the staging structure. There are different types of staging patterns that can be used for the Intze type water tank according to the requirement. Framed staging pattern is widely used for the Intze type water tank. It has variety of configurations that can be used. In this study, an attempt has been made to study the behavior of the reinforced concrete Intze type water tank with different staging patterns under the lateral loading. Various types of bracing configurations are used as the supporting frame staging of the Intze type water tank. In this paper, the study is carried out on the reinforced cement concrete Intze type water tank supported on frame type staging. The capacity of the Intze type water tank is taken as 18 Lac litres with staging height of 23 m. Grade of concrete and steel used are M-25 and Fe 415. Medium soil and seismic zone as III are considered in the analysis. Each model is analyzed for tank empty condition, tank partially filled condition and tank full condition.

Keywords— Intze type Water Tank, Bracing Configurations, Frame type staging, Cross Bracing, Seismic analysis

I. INTRODUCTION

Liquids are stored in various structures like underground reservoir, ground supporting reservoir and elevated storage reservoir. Among these structures, elevated reservoirs are mainly use for the distribution of liquid under pressure for storing water, chemicals, inflammable liquids etc. These structures can be made of masonry, steel, reinforced concrete and prestressed concrete. Out of these, masonry and steel reservoir are used for smaller capacities. The cost of steel reservoir is more as compare to other and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, the construction and design being simple, they are cheap, monolithic in nature and can be made leak proof.

Elevated storage reservoirs are frequently used in seismic regions too. It consists of large mass of liquid at top of staging which is most critical consideration for the failure of tank during earthquake. Thus, elevated tanks need to be designed in such a way that it remains functional even after the occurrence of an earthquake. Hence, seismic behavior of tank needs to be investigated in detail and some provision needs to be made for preventing the failure. Various types of bracings configurations can be provided to the staging for effective resistance of seismic forces.

II. MODELING AND ANALYSIS OF INTZE TYPE WATER TANK FOR EARTHQUAKE

Two mass model idealization of the Intze type water tank is more appropriate as compared to a one-mass idealization. Two-mass idealization model for elevated storage reservoir was proposed by Housner (1963) and it is being commonly used in most of the international codes and also in IS code 1893(part 2):2014. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and base. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis,

spring mass model is adopted for ground-supported tanks and two-mass model for Intze type water tanks.

In spring mass model convective mass (mc) is attached to the tank wall by the spring having stiffness (Kc), where for Intze tanks two-mass model is considered, which consists of two degrees of freedom system. Spring mass model can also be applied on Intze tanks, but two-mass model idealization is closer to reality. The two- mass model is shown in Fig 1(a). where, mi, mc, Kc, hi, hc, hs, etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility. For Intze tanks, if the shape is other than circular or rectangular, then the values of spring mass parameters can be obtained by considering an equivalent circular tank having same capacity with diameter equal to that of diameter at top level of liquid in original tank. The two-mass model was first proposed by G. M. Housner (1963) and is being commonly used in most of the international codes. The response of the two degree of freedom system can be obtained by elementary structural dynamics. However, for most of Intze tanks it is observed that both the time periods are well separated. Hence, the two mass idealizations can be treated as two uncoupled single degree of freedom system as shown in Fig.1 (b). The stiffness (Ks) is lateral stiffness of staging. The mass (ms) is the structural mass and shall comprise of mass of tank container and one-third mass of staging as staging will acts like a lateral spring. Mass of container comprises of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided.

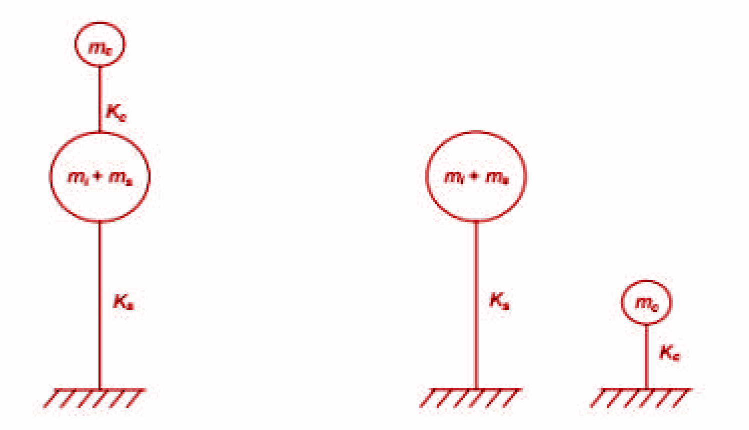


Fig.1 (a) Two-mass idealization of Intze tank *Fig.1 (b) Equivalent uncoupled system*

III. METHODOLOGY

Finite element software Staad Pro v8i is used to find out stiffness of the model. Computer program has been prepared for seismic analysis using the MS-Excel according to IS 1893 (part 2):2014. Formulae and values for various parameters are taken from IS1893(part 2):2014. Each model is analyzed for tank empty condition, tank partially filled condition and tank full condition.
Fig 2 shows the models for staging of Intze type water tanks with different types of bracing.

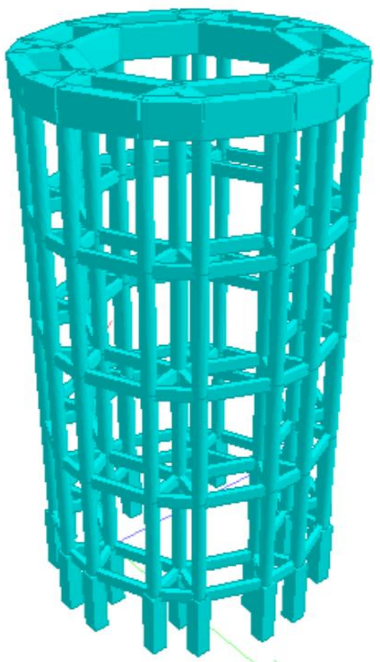


Fig.2 (a) Horizontal Braced Configurations

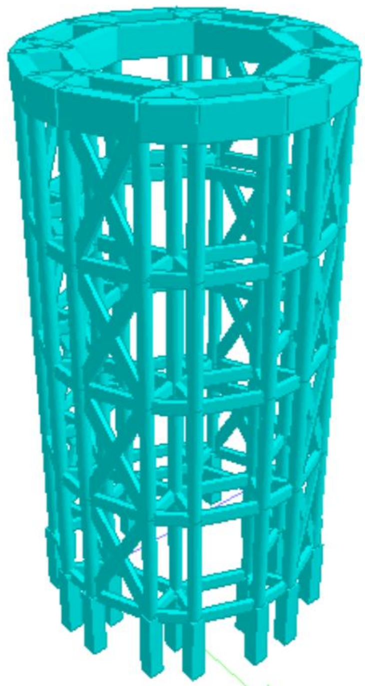


Fig.2 (b) Cross Vertical Bracing Alternate

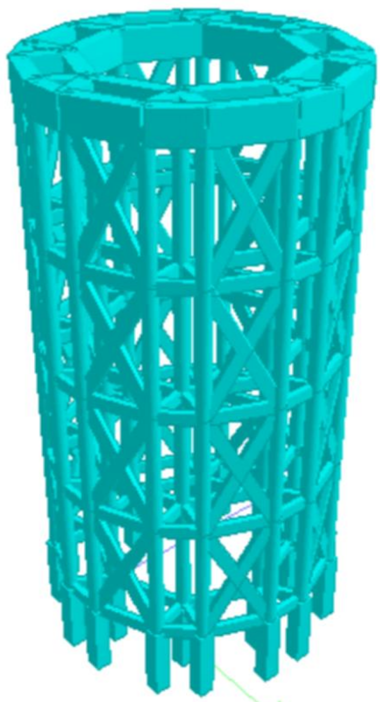


Fig.2 (c) Cross Vertical Bracing (X)

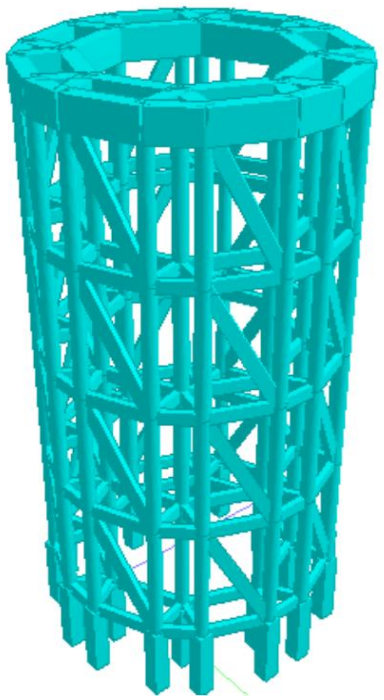


Fig.2 (d) Diagonal vertical braced system

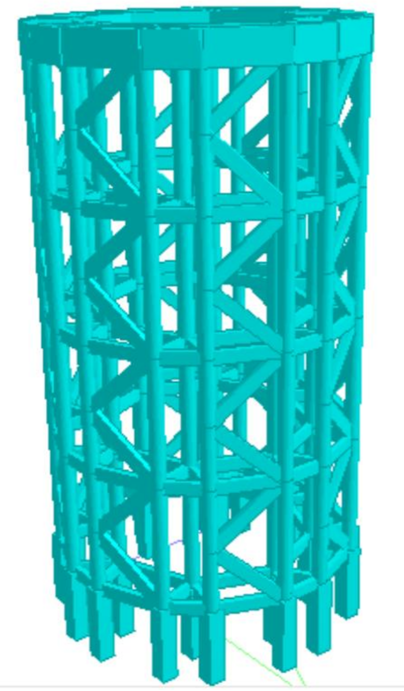


Fig.2 (e) K-bracing system

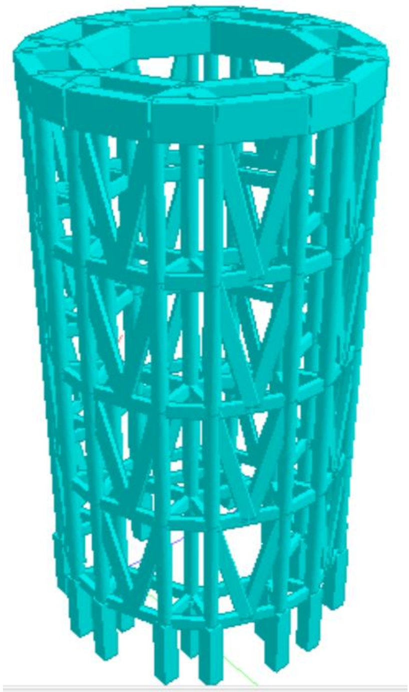


Fig.2 (f) V-Type Bracing

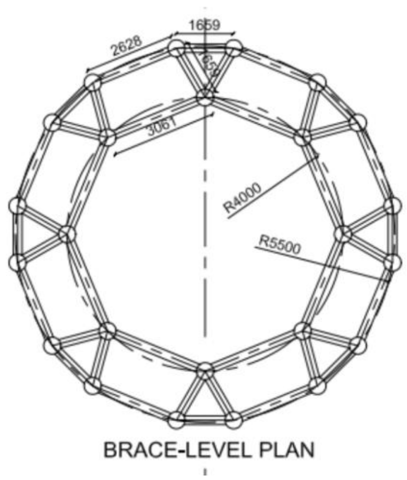
IV. STUDY PARAMETERS

In this paper, the study is carried out on the reinforced cement concrete Intze type water tank supported on frame type staging. The capacity of the Intze type water tank is taken as 18 Lac litres with staging height of 23 m. Grade of concrete and steel used are M-25 and Fe 415. Medium soil and seismic zone as III are considered in the analysis. Table 1 gives the size of various parts of Intze type water tank.

TABLE I
SIZE OF VARIOUS PARTS OF INTZE TYPE WATER TANK

Sr. No.	**Parameter**	**Value**
1	Diameter of column	500 mm
2	Number of columns	24
3	Size of bracing	250 X 500 mm
4	Top dome thickness	150 mm
5	Top ring beam	700 X 450 mm
6	Side wall thickness	150 mm
7	Bottom ring beam	700 X 500 mm
8	Bottom dome	150 mm
9	Conical Dome	450 mm
10	Circular ring beam	600 X 1200 mm

Fig. 3
Brace level plan(All dimensions are in mm)



V. OBSERVATIONS

The Intze type water tank with various types of stagings as shown in figure 2 have been analysed using the program prepared in MS-Excel as per IS provisions. From the analysis, time period of vibration, stiffness of supporting staging, base shear and base moments have been obtained for various staging cases are same have been presented in figure 4(a), 4(b), 4(c), 4(d) and 4(e).

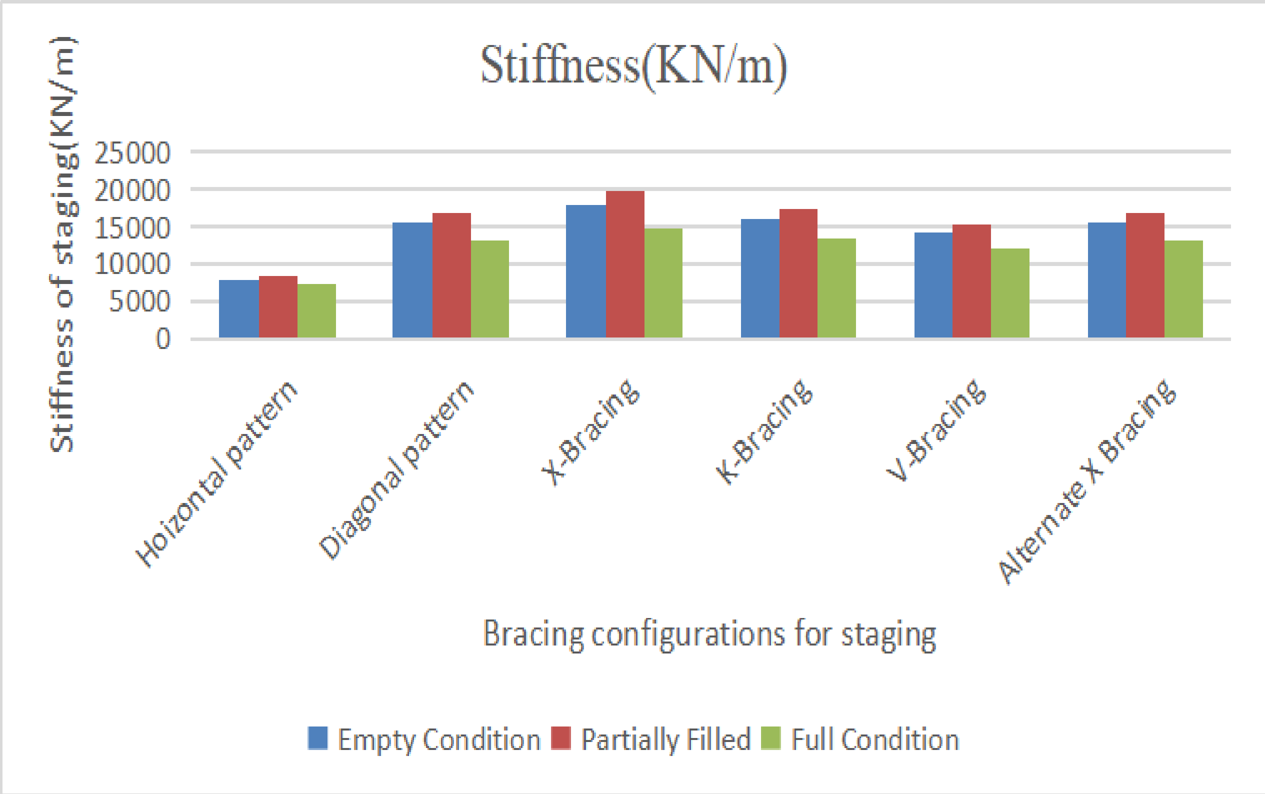


Fig 4(a). Stiffness(KN/m)

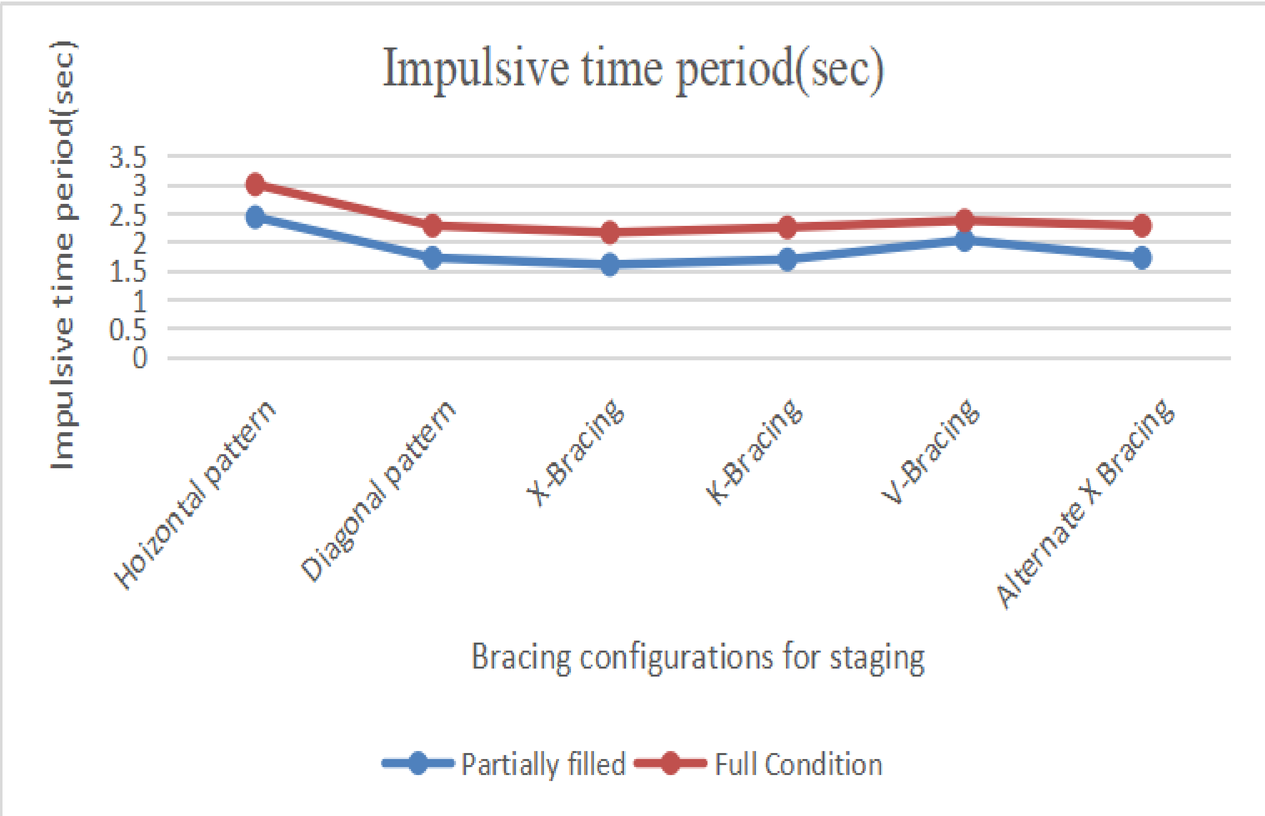


Fig 4(b). Impulsive time period(sec)

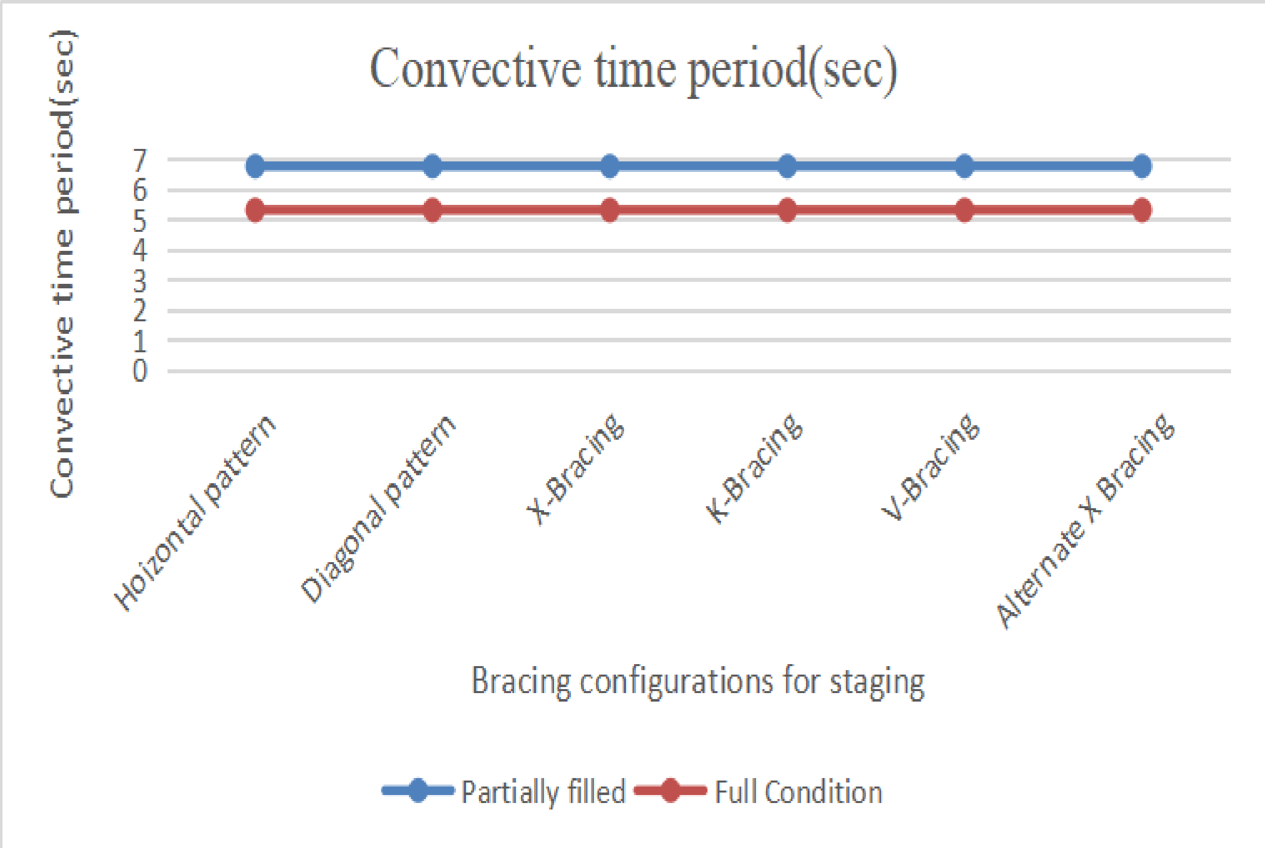


Fig 4(c). Convective time period(sec)

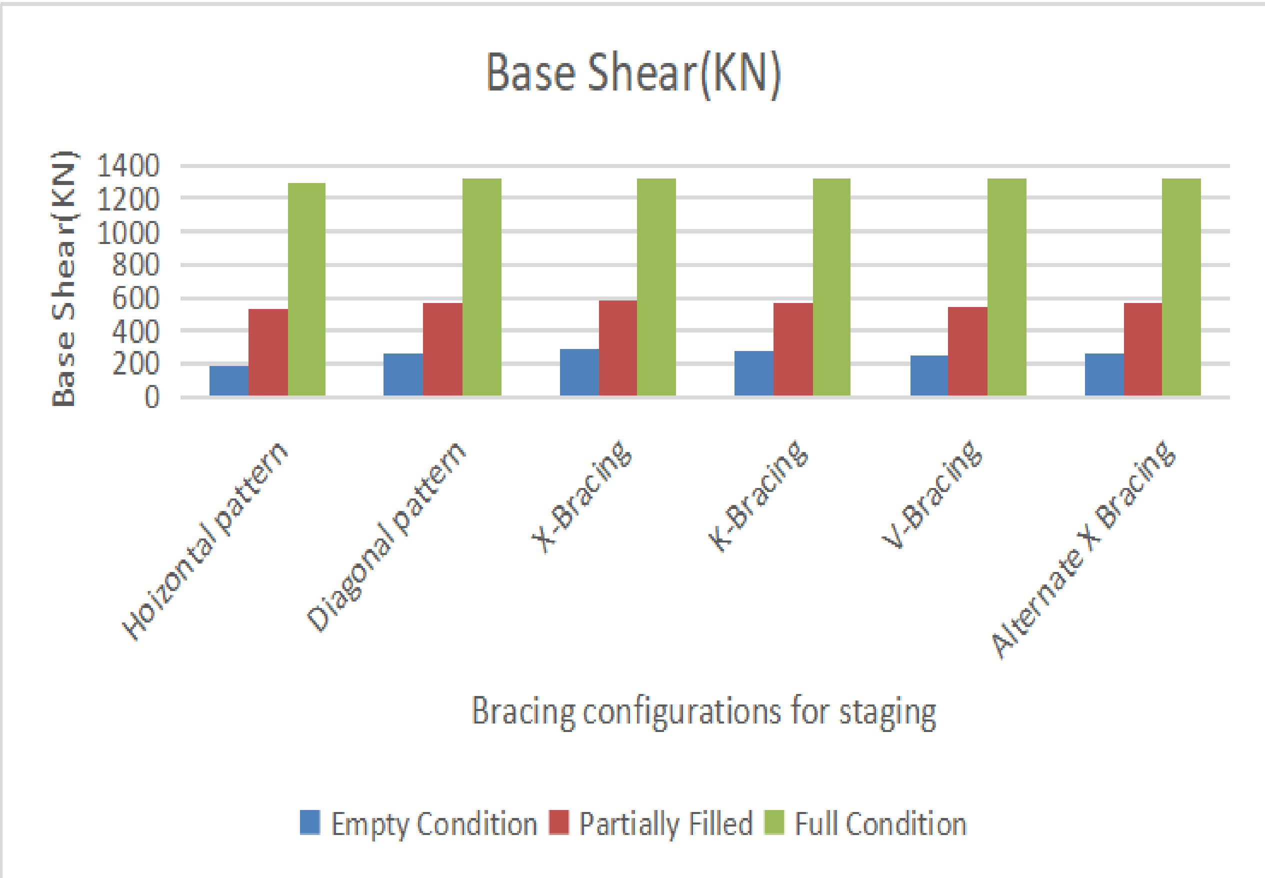


Fig 4(d). Base Shear(KN)

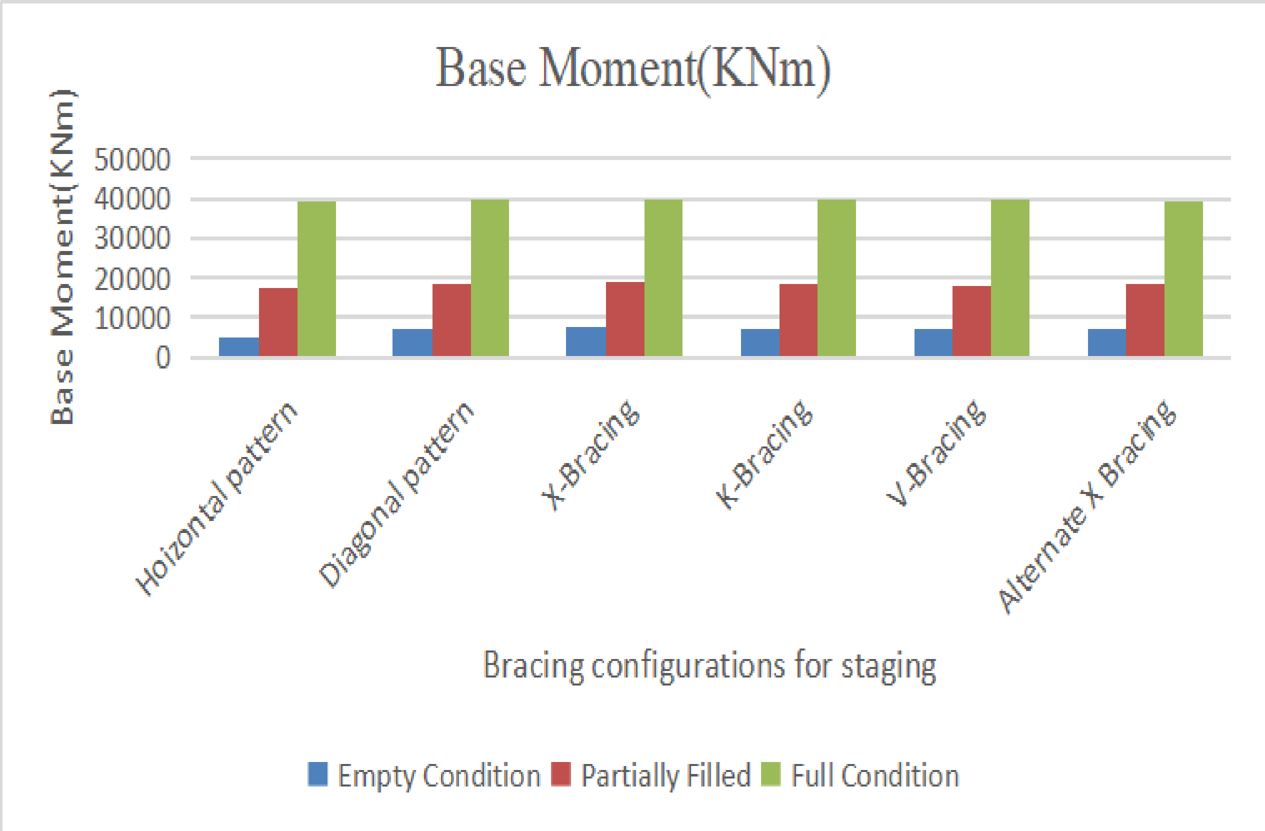


Fig 4(e). Base Moment(KNm)

VI. Conclusions

- The stiffness of the Intze type water tank with X-bracing configuration is maximum.
- The natural time period in impulsive mode for partially filled condition is lower than that of tank in full condition. This indicates that partially filled condition is more critical.
- The type of bracing configurations does not affect the natural time period in convective mode for a given depth of water, as the h/D is constant for a particular depth of water.

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