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Analysis & Design of A Wood Structure with A Flat Roof in The Risa

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ABSTRACT

The use of multi-story wood construction is becoming more and more common among design professionals around the nation since it is economical and environmentally beneficial. The International Building Code (IBC) currently permits wood-frame construction to exceed five stories for commercial, governmental, and residential occupancies. Due to its modeling and evaluation capabilities, RISA Floor is gaining popularity among structural designers. The software offers a wide range of design components including diaphragms, gravity frames, and shear walls. Using a variety of materials including steel, concrete, wood, masonry, aluminum, and cold-formed steel, RISA Software is a central hub for engineers to model, analyze, design, and document projects of all sizes and complexities. An integrated suite of finite element analysis programs for structural design is the RISA Construction System from RISA Technologies. RISA is a program that combines several materials, including steel, masonry, cold-formed steel, concrete, and wood. This article delves into a more detailed analysis of light-frame timber construction, while also briefly developing its flood and wind properties. To understand how the G+3 story building plan performs under combined flood and wind loads, the building is flat-roofed, ground level, and elevated. Assuming similar wind load conditions, a detailed study is conducted to identify the local and global failure modes for each building type under different flood scenarios. Based on the overall performance of a slab-type building in a high wind area, it was concluded that an unplanned building built only to the minimum requirements set by the building authority is likely to collapse locally into the wall. - foundation shear joint.

Keywords: Wood Structure, Flat Roof, Risa, Foundation, Building, International Building Code (IBC)

1. INTRODUCTION

Wood frame construction is one of the most widely used methods to build residential, commercial and industrial buildings. Wood frames are not only very economical to build but are also resistant to extreme climatic variations, and offer residents a high degree of comfort. Added to that, wood frames are sustainable and absorb carbon and offset greenhouse gasses.Wood frames can be used to construct different styles of buildings and there cannot be any restriction on architectural possibilities when wood is the medium. In order for a wood building to perform its expected functions, it is necessary to construct it judiciously and this can be achieved by using sound construction and erection practices. For instance, wood frames are light in weight and hence it does not require cranes and other heavy machinery for the erection process therefore contributing to the economic aspect of construction.

Flat roofs are commonly used for warehouses and commercial buildings, but there are also a number of residential designs that incorporate flat roofs.Many modernist buildings have flat roofs that complement their streamlined geometric design, and they are also characteristic of traditional Arabic, Egyptian and Persian houses.The design style is often found in buildings in warmer climates, where the roofs can be used as an additional living space.Flat roofs can be constructed from a wide range of materials, including masonry, concrete and brick, while flat steel roofing sheets are often used for industrial buildings.

Objectives of the Study:

1. To create a building with flat-roofed & crawl space in RISA for analysis and design.
2. Study of various past flood and wind disasters and their combined effect on timber low rise building.
3. To study the overturning moment per unit length for the elevated type 3-story building.
4. To study lateral sliding force per unit length on a 3-story elevated type building.
5. To study vertical uplift force per unit length on elevated type 3-story building.

II. LITERATURE REVIEW

2.1 Review of Literature

The research paper and literature collected on the various topics are listed below.

2.1.1 Ruifeng Liang *, Daniel Stanislawski, GangaraoHota, et. al. 2021:

Material characterization of soil and wood samples collected from the field included scanning electron microscopy and mechanical evaluations. In SUST, 2021, 1(1): 000003 000003-16, Liang et al. report on the compressive strength and modulus of five different aged Hakka Tulou. Despite the fact that each wall is built differently, the results show that Hakka Tulou pressed earth walls are strong and long-lasting. Surprisingly, the strength and modulus statistics seem to show a trend where the hackearth wall gets stronger over time, making modeling more difficult. Elemental modeling was used to evaluate material and structural responses to thermal and seismic loads to better understand the exceptional earthquake resistance of Hakka Tulou. A major earthquake in 1918 probably caused a significant breach in the pressed earth embankment of HuanjiTulou. According to people, the rift healed by itself and Huanji was considered the strongest Tulu. According to these extensive studies, no evidence supported the authors' claim of a self-healing process. The compressed earth wall of HuanjiTulou was found without reinforcements. As predicted by computer modeling, the crack formed and propagated as a result of the earthquake loading. According to FE modeling, Hakka Tulou has higher earthquake resistance due to its unique compressed earth wall structure combined with internal wooden floor systems.

2.1.2 Amol L. Murhekar, Manish Chudare, et. Al. 2018:

The goal of BIM is to provide a "methodology to handle important project and building design data in digital format throughout the building's life-cycle." BIM is an interconnected system of laws, regulations, and technologies. Contractors are important players in the project life cycle since they guarantee that the project is finished on schedule and on budget. A case study is presented to show how BIM can help an architect, engineer, and builder. BIM uses scheduling and cost estimating. In the global architecture, engineering, and construction (AEC) sectors, building information modelling (BIM) is a relatively new technology. BIM technology gives users precise and 17 consistent data and information about the building or project, enabling them to model and virtually see the structure. Autodesk Revit building information modelling software is used by structural engineers, MEP engineers, and designers.

2.1.3 Kuldeep Mishra and Amit Goel et. al. 2019:

Shapes are generated using a variety of models when an energy simulation is performed in Revit and Green building studio. To achieve the most efficient and cost-effective use of space, renewable energy, and the preferred orientation, percentage of glazing, and opening ratio of the building, various settings on the construction and display, as well as in relation to the Energy simulation model, were tried. This results in energy analysis. Applications: It is important to assess the resources needed for such buildings while taking sun and weather conditions into account as space becomes increasingly scarce and energy demand rises in India.

2.1.4 Comparative Study of Flat Slab Structures with Steel Bracings et. al. 2021:

Many past researches show that the flat slab building is weak on lateral load resistance induced due to seismic action. To enhance the seismic performance of flat slab building, it needs an effective lateral load-resisting system. In this present work, G+5, G+7 and G+9 stories conventional building and flat slab building systems were modelled. For lateral load resistance, various types of steel braces were modeled on flat slab structure. Equivalent static analysis method and Response spectrum analysis method were performed using IS 1893 2016. The comparative study of seismic parameters such as maximum storey displacement, drift ratio, base shear and fundamental natural time period were performed among braced and unbraced models. The study 19 shows that, the use of steel bracings as a lateral load-resisting system enhances the seismic performance of a flat slab system.

2.1.5 Coupling of highrise building earthquake retrofit and building information management (BIM) system et. al. 2023: Highrise buildings that have structural irregularities are in general more susceptible to damage from earthquakes. Such damage is primarily due to the coupling of torsional and translational vibrational response whereby the building twists even though it is being excited in translational modes only. For optimal earthquake design and retrofit of such structures, several cycles of iterations of structural analysis followed by design change are often needed. To provide efficiency and accuracy of iterative assessment-adjustment cycles in the design process, this study proposes an integrated seismic design and assessment framework. The 'Revit Structure' platform from Autodesk, a prominent member of the Building Informational Modeling software family, and ZEUS-NL from Mid-America Earthquake Center, one of the most advanced earthquake simulation programs, are utilized for seismic design and analysis tools, respectively. An advanced bi-directional linkage interface is developed so that two distinct and complex computer codes can exchange essential structural or non-structural member data in both directions without any loss of information. This coupled approach also provides improved earthquake analysis and design guidelines which can address damaging torsional effects. The feasibility of the proposed framework and its components are successfully evaluated and verified through an application example. It is observed and verified that more reliable and better seismic design for irregular buildings can be achieved using the proposed framework.

2.2. Patent Search

[1] Ajay Baniya, et. Al. 2017: The only structure used for the studies was a straight, rectangular structure with a gable roof. For roofs with overhangs, additional uplift wind forces applied in the overhang section must be calculated; this will negatively affect the computation of the overturning moment about the assumed pivot. When the structure is flooded up to 11 feet, the wind load is not reduced. While a structure is submerged in water, wind pressures are not applied to it. Although it is believed that both wind and flood loads are acting in the same direction, a building's performance may vary if flood and wind loads are acting at an angle. For the complete study formulation, the flood velocity is taken to be 10 ft per second (fps) for all building types and flood depths. Velocities can be greater for deeper flows and lower for deeper flows. Through the analysis of a large number of structures with various dimensions, it is possible to determine the aspect ratio (B/H) of a building that is parallel and perpendicular to the direction of the lateral wind and flood load. For the proper establishment of an analytical conclusion, an experimental study of the time-variant effect of buoyancy in a structure for various soil types can be conducted. Wall-to-floor connections for structures with crawlspaces can be tested for local collapse. Building performance can be calculated analytically and confirmed for various velocities.

III. PROPOSED METHODOLOGY

3.1 Methodology

To examine the effect of the combined action of flood and wind in a Light Frame Wooden Structure (LFWS) located in Zone A (100-year flood plain) detailed analytical models are developed, G+3. The analytical model assumed is a typical residential wooden building located in the US in Flood and hurricane-prone areas.

3.1.1 Foundation

A building foundation located in 500-year plain is assumed to be having crawl space. The buildings located in 500-year plan is not required to be elevated because the ground level in 500-year flood plain is above the 100-year Base Flood Elevation (BFE). Complying the requirement as provided in the Technical guide by Home of Texas (1995), the adopted size of stem walls are 8 inches, concrete pier use is of 18 inches X 18 inches (Figure 1 and Figure2). Similarly, the minimum thickness of concrete floor slabs elevated on the ground shall not be less than 3.5 inches (IBC, 2015), so the slab on grade is taken as 4 inches. All the calculation of dead load is based on the assumption that foundation is made up of normal-weight concrete, which has a density of 150 pound/cubic ft (lb/ft3) (IBC, 2015).

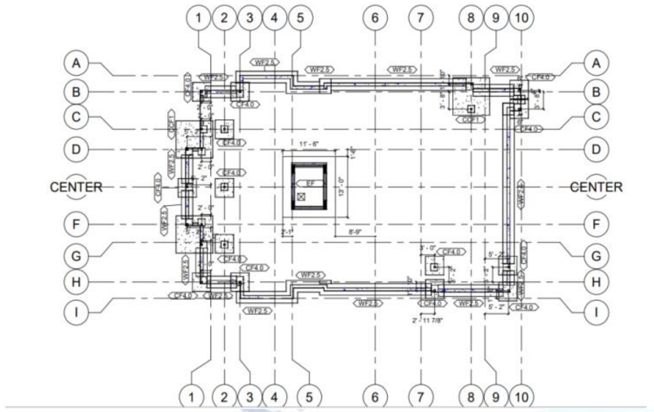


Fig: 1 – Layout of foundation plan.

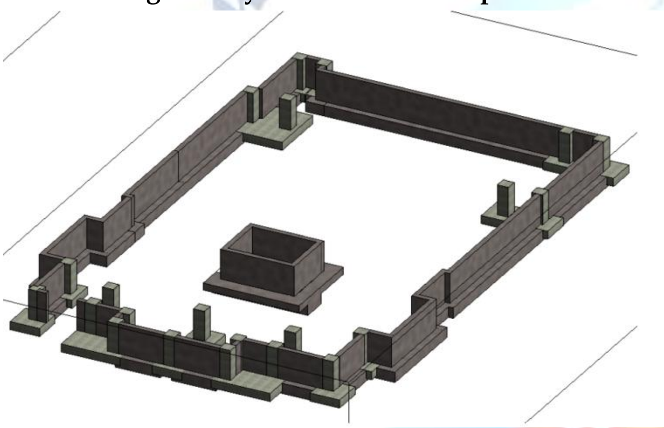


Fig: 2 – Layout of foundation plan(3D)

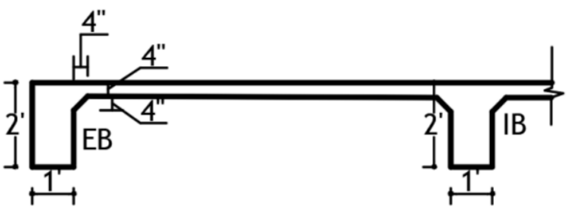


Fig: 3 – Foundation detail

3.2 Flow Chart of present work

Flow Chart of Project Process Block Diagram showing the process of the project and concluding results in comparison of time for analysis and design.

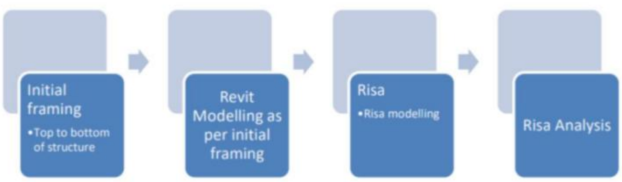


Fig. 4. Planning of work

3.3. Research Design

• Light-Frame Wooden Structure (LFWS)

Light-Frame Wooden Structure (LFWS) Typically, studs are spaced 16 to 24 inches on center but building code requires maximum spacing be based on maximum nominal design wind speed, Vasd (IBC, 2015). The height of each floor is assumed to be 10 ft. As per IBC (2015), the maximum floor-to-floor height shall not exceed 11 ft and 7 inches, and the height of the exterior bearing wall and interior braced wall shall not exceed a stud height of 10 ft. For a building located in Houston (Exposure category B, Risk category II), when 10d common nail is used with1.5 inches penetration, as per IBC (2015):

Vult= 150 mph

Vasd = Vult (0.6)0.5 = 116.2 mph Equation 16-33 (IBC, 2015)

Maximum wall stud spacing = 16 inches Table 2304.6.1 (IBC, 2015)

Minimum nominal panel thickness = 7/16 inches Table 2304.6.1 (IBC, 2015)

Minimum wood structural panel = 24/16 Table 2304.6.1 (IBC, 2015)

Thus, for external walls, maximum wall stud spacing in the analytical model is 16 inches and minimum nominal panel thickness is 7/16 inches. However, for internal walls, the stud spacing, and nominal panel thickness is based on the lateral and vertical loads. Maximum span for Structural I Sheathing to be used in roof is 24 inches (Table 2304.8(5) IBC, 2015). However, thickness of sheathing depends on maximum live load and total load conditions. For a roof of residential building.

Live load (L) = 20 psf (ASCE 7-10)

Dead load (except self-weight) = 10 psf (ASCE 7-10)

Thickness of sheathing = 7/16 inch Table 2304.8(5), (IBC, 2015)

• Frame geometry and material properties:

The assumed LFWS model is a four-story building with total height of 43'10", each story being 11 ft and the roof is assumed to be flat. The RISA model of the geometry for LFWS Slab-on-grade type building is shown in Figure 5.

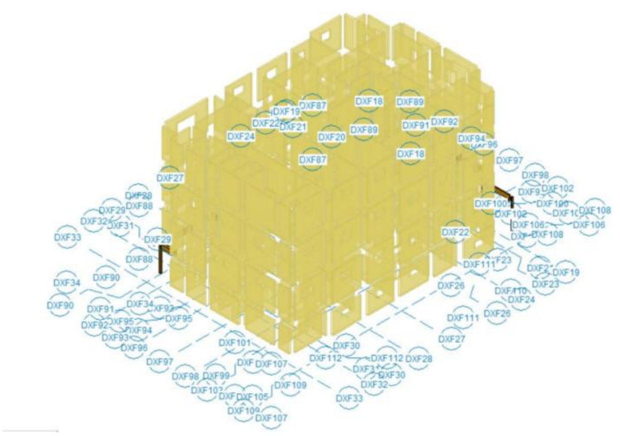


Fig. 5. Three-dimensional view of four-story building (obtained from RISA-3D)

The windows and doors are assumed to be 5 ft x 4.5 ft and 4 ft x 7.5 ft, respectively. Risa floor 9.0 is used to model all the lateral and vertical load bearing members. All the gravity loads are applied to the model in Risa Floor 9.0 and members only bearing gravity loads are analyzed and designed. The model is then exported to Risa 3D 13.0 for applying lateral loads: flood and wind loads. After application of lateral loads members are analyzed for all load cases and load combinations as obtained from IBC 2015 and designed accordingly. All internal and external walls are designed for both lateral and vertical loads. 2 x 6 stud with minimum spacing 16 inches and maximum spacing 24 inches along with 2 numbers of 2 x 6 top plate, 2 x 6 sill plate and 6 x 8 header, all made of Douglas Fir material is modeled as Wood wall. Schedule for Wood wall fasteners is obtained from IBC2012 Panel database and wood structural panels are double sided with minimum panel thickness of 0.375 inch and maximum panel thickness of 0.75 inch. Two number of chords each 2 x 6 is considered and hold downs are considered from SIMPSON catalog. Similarly, maximum and minimum nail spacing is 6 inches and 2 inches respectively. Floor system of first floor (Figure A.1) consist of 1-inch wood deck, which is supported by 2X10 dimension lumbers designed to carry only gravity loads. 2X10 dimension lumbers are supported by Glulam Southern Pine (24F-1.8 DF Balanced) beam, which is designed to carry both gravity and lateral loads. Similarly, roof sheathing is supported by Southern Pine Glulam (24F-1.8E DF balanced) rafters which are supported on walls, so the wall at center of building is extended to all the way top of the building.

- **Load definition and iterations**

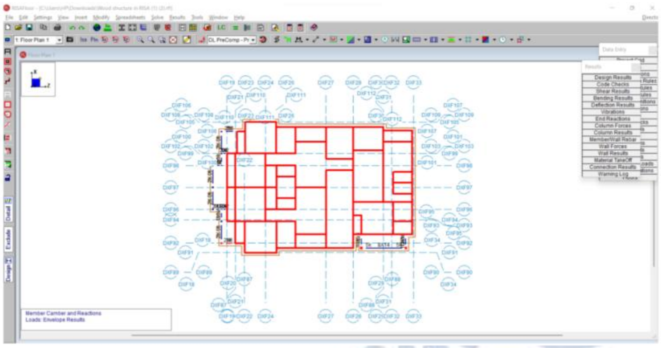
Both gravity and lateral loads are defined according to the provisions of IBC (2015) and are applied accordingly in the building models. The gravity loads being considered in building models are included in Appendix A.5. Similarly, the lateral flood load and wind loads being considered in models are computed in Appendix A.3 and Appendix A.4, respectively, based on the assumption made in Appendix A.2. To understand the behavior of LFWS Slab-ongrade type building in 500-year flood plain, model is created with different flood loading parameters, keeping wind and gravity loads constant. 12 different models with different stillwater depth, ranging from 0 ft to "11 ft" are prepared to study the impact of variation in stillwater depth, assuming flood velocity, debris weight and water properties to be constant. The scouring depth is assumed to be 2 ft so the stillwater elevation is measured from the bottom of the foundation, which is 2 ft below the ground surface (Figure 4.2). Again, to understand the behavior of building when subjected to different stillwater elevation in internal and external face of building, each of the 12 models prepared earlier are modeled assuming different level difference in internal and external face, ranging from 0 to 4 ft, when possible, to attain the difference. For instance, design stillwater depth of 4 ft cannot achieve more than 2 ft level difference because stillwater depth is measured 2 ft below the floor level. stillwater elevation is assumed to be higher in external face than in internal side. It is assumed that the building and the foundation slab is reasonably symmetrical and uniform. Therefore, it is assumed the center of gravity for the dead loads is at center grid.

- **Design Basis Report- LFWS elevated type on 100-year flood plain**

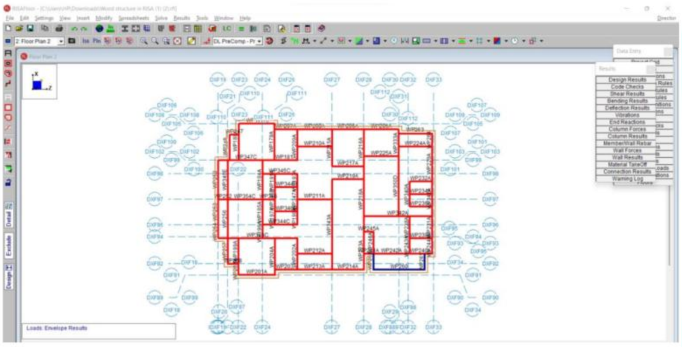
Foundation A building located in the 100-year flood plain is assumed to be elevated on a timber pile foundation. It is not recommended to build a building in A zone with the wall or a solid type of foundation because such type of foundation will be subjected to higher hydrodynamic force, breaking wave load and wave slam forces as compared to open foundations like moment frame, piles or pier type of foundation. NFIP allows buildings to be elevated and supported by fill-in A-zones, however, the fill must be protected against erosion. It is possible to protect the foundation against erosion, but it is rather economical to construct a timber pile foundation.

3.4 Data collection Method

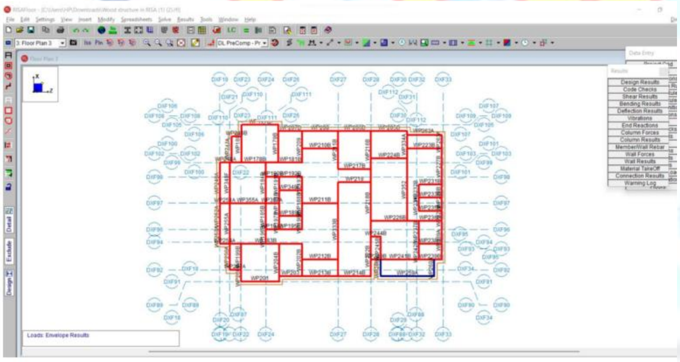
- **RISA FLOOR PLANS- 1 ST FLOOR**



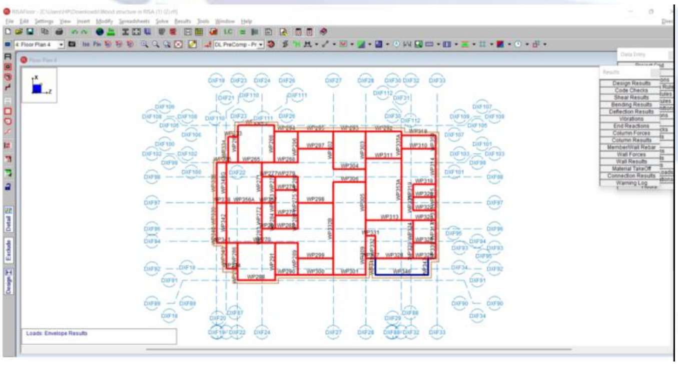
- **RISA FLOOR PLANS- 2 ND FLOOR**



- **RISA FLOOR PLANS- 3 RD FLOOR**



- **RISA FLOOR PLANS- 4 TH FLOOR**



IV. RESULTS AND DISCUSSION

4.1 Result

As shown in Figure 3 The overturning moment per unit length for the elevated type 3-story building is subjected to a 100-year flood plain due to the combined action of flood and wind for different flood depths; The X-axis runs parallel to the ridge, while the Z-axis runs perpendicular to the ridge. The difference in flood elevation between the interior and exterior faces is 3 feet.

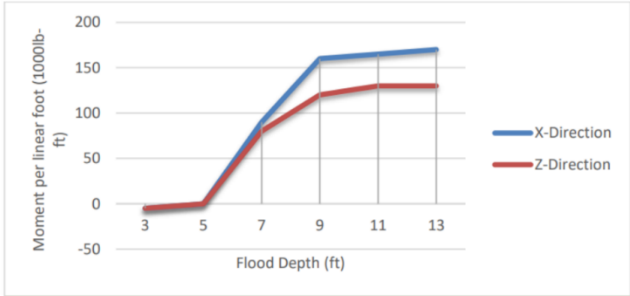


Fig. 3. The overturning moment per unit length for the elevated type 3-story building.

As shown in Figure 4 Lateral sliding force per unit length on a building of elevated type due to the combined action of flood and wind for different flood depths, 3-story on a 100-year flood plain; X-direction parallel to the ridge and Z-direction perpendicular to the ridge; flood elevation difference in the interior and exterior face is 3 ft.

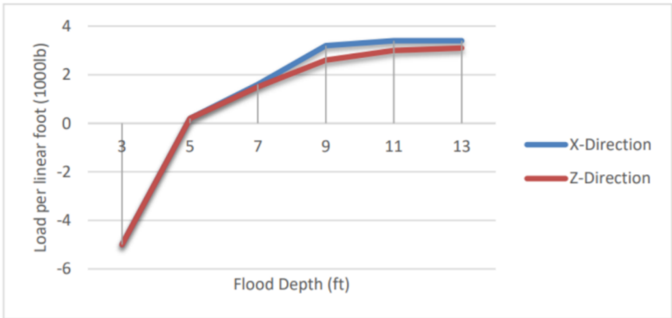


Fig. 4. Lateral sliding force per unit length on a 3-story elevated type building.

As shown in Figure 5 Vertical uplift force per unit length on elevated type 3-story building on a 100-year flood plain due to combined action of flood and wind for different flood depths; X- dir is parallel to the ridge and Z-dir is perpendicular to the ridge; The difference in flood elevation between the interior and exterior faces is 3 feet.

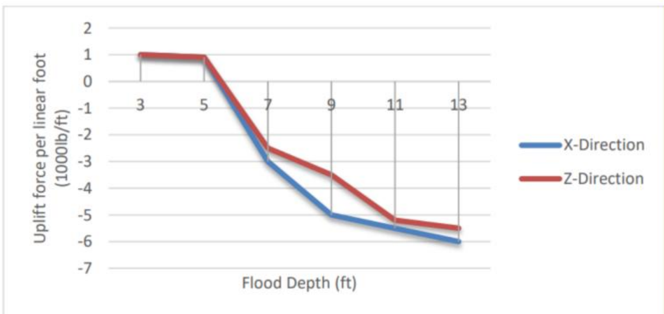


Fig. 5. Vertical uplift force per unit length on elevated type 3-story building.

V. CONCLUSION

- RISA will go into more detail about each relationship and analysis.
- By examining various structures with different dimensions, it is possible to determine the best ratio (B/H) of buildings parallel to and perpendicular to the direction of cross wind and flood load.
- An experimental study of the time-varying effect of building buoyancy can be performed to obtain reliable analytical results for different soil types.
- Shear joints between wall and floor of crawl space buildings can be checked for local defects.
- Building performance can be calculated analytically and experimentally at different speeds.

  Elevating the building will undoubtedly help to reduce non-structural damage. It also improves global stability against the combined lateral action of flood and wind when floodwater depth is less than elevated height, so lifting the building above possible floodwater depth is recommended.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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