SEISMIC ANALYSIS AND DESIGN OF R.C.C SOLIDS STORAGE STRUCTURE BY USING IS 1893:2016

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Abstract: *Research paper is to compare and briefly describe about the advantage and limitations of solid storage structure by using Staad Pro Structural software. Solid storage structures are considered as special structures as its design is based on the properties of materials stored. The pressure exerted by the stored material on the side of a bin varies with the processes and arrangements of filling and emptying operations. Due to this variation, it is extremely difficult to analyze the pressure exerted on the walls of the bins. In our research work, we are designing the RCC solid storage structure located in all seismic zones with the help of structural software Staad Pro. The design concept include, all dimensions of structural component based on trial and error method, using Equivalent lateral force method in term of Comparison of different models of concrete solid storage structure for earthquake such as nodal displacement, stress and vertical or horizontal pressure on walls etc. for volume of 180 m3. All the designs have been based on the recommendations of I.S 4995 -1974 (part 1&2) and I.S 456 – 2000 codes, Based on these designs, that dimension of solid storage structures shows least amount of concrete and steel. Main objective of our research work is to compare of different models of concrete solid storage structure for earthquake in terms of stress, vertical or horizontal pressure on walls etc.*

Keywords: *Staad-Pro, Baseshare, Base moment, Absolute wall stress, Bending moment, IS1893:2016 etc.*

1. INTRODUCTION

The word “solid storage structure” or “Silo” includes equally deep bins and shallow bins; the latter are on occasion called bunkers. Wherever the term “solid storage structure” is used in the Design requirement, it should be interpreted as meaning a solid storage structure, bin, or bunker of any proportion, shallow or deep. Solid storage structures and bunkers are remarkable structures, and countless engineers are unknown with computation of their design loads and with other design and detail requirements. It is important that the design and the preparation of project drawings and project specifications for solid storage structures and bunkers be done under the supervision of an engineer with specialized knowledge and experience in design of such structures. If possible, the properties of the stored materials to be used in the design should be obtained from tests of the actual materials to be stored or from records of tests of similar materials previously stored. Solid storage structure failures alerted design engineers to the danger of designing solid storage structures for only static pressures due to stored material at rest. Those failures have inspired wide- spread research into the variations of pressures and flow of materials. The research thus far has established beyond doubt that pressures during withdrawal may be significantly higher or significantly lower than those present when the material is at rest. The excess (above static pressure) is called “overpressure” and the shortfall is called “under pressure.” One of the causes of overpressure is the switch from active to passive conditions which occurs during material withdrawal Under pressures may occur at a flow channel in contact with the wall and overpressures may occur away from the flow channel at the same level. Under pressures concurrent with overpressures cause circumferential bending in the wall. Impact due to filling may cause total pressure to exceed the static. While overpressures and under pressures are generally important in deeper solid storage structures, impact is usually critical only for shallow ones (bunkers) in which large volumes are dumped suddenly. Solid storage structure a substantial capacity in the cement industry may cause large eccentricities during discharge due to their individual bottom aeration sections. A large eccentricity is classed as when a discharge flow channel is more than half the radius of a solid storage structure from the solid storage structure mid-point. From different investigations, it is known that horizontal pressures in a flow channel are smaller than in the bulk material outside the flow channel. This results in a reduction in horizontal pressures in the zone in which the flow channel contacts the wall, compared to the horizontal pressure on the remaining wall circumference that corresponds with the fill pressures.[2] In the transformation from flow zone to static zone, horizontal pressures even higher than the fill pressure occurs due to the load balance. The result was an alternating pressure distribution when discharging large capacity solid storage structure, which could lead to critical wall loads in certain cases. Solid storage structure with bottom aeration was generally viewed as ‘slender’ solid storage structures.

Indian Standard - IS 4995: 1974:

The guidelines recommended by the Bureau of Indian Standard for the design of reinforced concrete solid storage structures were explained in ‘Criteria for Design of Reinforced concrete bins for the storage of Granular and Powdery materials. The solid storage structures load determination is described in Part 1 – General Requirements and assessment of Bin loads. The criteria for the design of the solid storage structure are given in Part 2 – Design Criteria. In 1968, this standard was published by considering the requirements of structural design for food grain storage bins (solid storage structures). In the year 1974, the revision was adopted to design solid storage structure for storing all kinds of materials in addition to food grains. The physical nature of the materials to be stored in the bins are taken into account and the code classified the stored materials as granular and powdery materials as shown in Table1.

Table 1.1: classification of materials

Materials	**Particle size**
Granular	> 0.2 mm
Powdery	< 0.06 mm

The Part 1 of this standard has given the guidelines for the assessment of bin loads exerted by the stored material based on the different treatments taking into account the granular or powdery nature of the material. This standard deals with various types of bins namely circular, polygonal or interstice bins. The definition of terms such as solid storage structure, bunker and interstice bins is presented in Table 2.

Table 1.2: definitions of terms

Solid storage structure	Bunker
Bins of circular or polygonal in plan	Bins of square or rectangular in plan

The governing factors for the computation of bin loads are bulk density W, angle of internal friction Φ, angle of wall friction δ and pressure ratio λ. The values of W and Φ are based on the type of the stored material. The δ and λ values depend on the physical nature of the material and it’s filling conditions (i.e. filling or discharged). The bin loads are categorized as

a) Horizontal load or horizontal pressure (Ph), b) Vertical load or vertical pressure (PV) and c) Frictional wall load or frictional wall pressure (Pw). In general, the Janssen’s theory is used for the assessment of bin loads. The maximum value of the above-mentioned pressures (Ph, PV & Pw) exerted by the stored material during normal filling and emptying operations is calculated. The condition of homogenization, rapid filling and pneumatic emptying is to be considered, when the powdery materials are to be stored in the bin. During homogenization condition, the lateral and vertical pressures depend on the volume of empty space in the bin. Therefore, the following condition is adopted. Ph = Pv = 0.6 WZ, which should not be less than the pressures evaluated for normal filling and emptying. The lateral pressure during rapid filling and pneumatic emptying of a solid storage structure is calculated. In the unloading stage, the eccentric emptying of bin causes increase in bin loads. The following loading conditions and effects are considered while designing the various components of solid storage structure namely roof, bin walls, ring girder, hopper bottom, supporting columns and foundation.

1. Dead load of the structure
2. Superimposed loads due to material handling & transportation machinery
3. Bin loads as specified under Part I of IS 4995 - 1974
4. Live load (for roof only) recommended as per IS: 875-1964
5. Wind load recommended as per IS: 875-1964
6. Seismic loads recommended as per IS: 1893-1975
7. Thermal load

TYPES OF SOLID STORAGE STRUCTURE:

Solid storage structures are deep bins in which the plane of rupture of material store meets the opposite sides of the structure before meeting the top horizontal surface of the material. It is a tall cylindrical structure.

1. Reinforced concrete solid storage structures
2. Prestressed concrete solid storage structures
3. Steel solid storage structure
4. Concrete block solid storage structure
5. Fibre Reinforced Polymer Solid storage structures

2. LITERATURE REVIEW

Literature Review for Paper [1] shows a Fly ash storing in solid storage structure and check stresses, bending moment and design of solid storage structure in this paper. Also, done a comparison between manual load calculation for three solid storage structures and calculating results of stresses and bending moment in STAAD Pro software After both load calculation and find the stresses, bending moment of three of solid storage structures comparing and design best solid storage structure. In this paper, author comparing the three types of solid storage structure such as square, rectangular & circular. On these solid storage structure what effects (shear stresses, bending moment) takes places after applied load such as ash loading, seismic load & wind load with the help of STAAD-PRO software.

In these analyses, the different results of stress and bending moment during comparison of three types of solid storage structures in staad pro software, It is concluded that, the change of in manual calculation of load circular solid storage structure is very easy. Value of these loading is very less. Applied the loading in staad pro v8i is very easy in the circular solid storage structure comparative other solid storage structures and load combination also very easy. Stress and bending moment value very low of circular solid storage structure and near same value of rectangular and square solid storage structure. But in literature surveys, more storage capacity in rectangular solid storage structure and square solid storage structure. The power tool for computerized structural engineering STAAD Pro is the most popular structural engineering. Analysis & multi material design prepare 3D finite model of solid storage structure in STAAD.

The aim of paper [2] is to compare and briefly describe about the superiority and limitations of four codes. This paper looks over the superiority and limitations of the four codes namely Bureau of Indian Standard (BIS), American Concrete Institute (ACI), German Standard (DIN) and British Standards Institution (BSI). For the sake of complete, logical and relevant analysis, this study has been divided into two parts. In the first part, each code was thoroughly studied and the basic concepts behind each code were explained. The second part presents the comparison and discussion of similarities and dissimilarities of each code and the analysis of the parameters involved in the design of the solid storage structure. The insight of loads exerted by the stored materials and external forces to the solid storage structure is significant for designing the safe solid storage structure. A slight modifications in the parameters, namely the effect of the thermal variation and the properties of stored materials, if taken into account in the analysis of solid storage structure, the discrepancies associated with various codes can be further reduced.

Paper [3] describes a brief descriptions of each of codes, their limitations, and common design conditions that are not covered are identified. Users of solid storage structure codes will find this information invaluable, as will code writers who will benefit by being given direction as to how to improve their codes to make them more useful. External equipment such as electric or pneumatic vibrators, vibrating bin discharger (bin activator), localized aeration devices, and air cannons impart significant forces to a solid storage structure structure that must be taken into account. They can also affect the stored bulk solid in such a way that its properties change, resulting in different solid storage structure loads. AS 3774-1996 provides some limited guidance on this phenomenon, but it does not cover loads acting on external equipment itself by the stored bulk solid. The other three solid storage structure design codes do not cover these at all Feeders and gates are also critical to a safe and properly functioning solid storage structure. AS 3774-1996 provides guidance regarding loads imposed on them, but the other three codes do not. Knowledge of the loads applied to the walls and internals (if any) of a solid storage structure is extremely important. Such loads must not be ignored if a stable, safe solid storage structure is to be designed. Much progress has been made in the last 50 years in providing solid storage structure load guidance to design and structural engineers. EN 1991-4:2006 is a significant advance over all previous codes, but even it does not cover many common load cases.

For load cases not covered by the codes, the design/structural engineer is left with two choices: Be extremely conservative in estimating applied loads. This approach can be quite expensive and yet still may not be conservative enough to prevent the solid storage structure from failing and Rely on design engineers who have significant experience in calculating solid storage structure loads.

In Paper [4] study the most economical configuration of solid storage structures to store a given volume of a material, twenty eight samples of solid storage structures have been designed by changing the ratio of height to diameter for storing a given material, namely, bituminous coal. In this investigation, for volume of 125m3, the diameter to height ratio is varied and has been designed and finally, the most economical size is found out. This method is carried out for volume of 125m3. All the designs have been based on the recommendations of I.S 4995 - 1974 (part 1&2) “Criteria for Design of Reinforced Concrete Bins for The Storage of Granular and Powdery Materials” and I.S 456 – 2000 codes Based on these designs, those dimensions of solid storage structures which will lead to least amount of concrete, steel and total cost to store a given amount of material have been found out. These findings will be useful for the designers of solid storage structures. H/D ratio and Total cost in INR are taken in x and y axis respectively. The most economical solid storage structure has been found to the dimension of height: 8.35m. And diameter: 4.2m. The total cost required for economical solid storage structure is Rs. 116682.48 and for uneconomical one is Rs. 163763.56. It is found that the requirement of cost for construction of solid storage structure is directly proportional to height and inversely proportional to that of diameter.

In [5] paper Manual design of circular solid storage structure for various material and also done .net programming for different material storing in solid storage structure & check pressure and design of reinforcement and also done a comparison between manual design and.net programming. In both designs, influence of different parameters discussed. The same result of stress and area of steel has been found during comparison of manual design and .net (VB) programming. When increasing height and diameter ratio decreases thickness of wall . It is concluded that, ease to various results of various material storing in solid storage structure in Design of .net (VB) programming.

In Paper [6] Structures used for storing bulk solid are called bins, bunkers, solid storage structures, or tanks. There is no generally accepted definition for these terms, shallow structures containing coal, crushed stone, gravel, and similar materials are called bins or bunkers and tall structures containing materials such as grain, cement and wheat are usually called solid storage structures. Elevated solid storage structures generally consist of a conical roof, a cylindrical shell and a conical hopper and they could be elevated and supported by frames or reinforced concrete columns. Circular solid storage structures (both steel and reinforced concrete) are used to store material in various industries like cement plants (clinkers), power plants(raw coal), oil and gas industry(sulfur pellets) etc. Elevated steel and reinforced concrete circular solid storage structure for storage show performance in earthquake reinforced concrete solid storage structure stability increases by using shear wall but loss of steel solid storage structure in earthquake stability increases using steel panel on opposite side Displacement of structure decreases in case of shear wall panel and stiffness increases, R.C.C. Solid storage structures and steel solid storage structures in RSM method with shear wall displacement of structure is reduce compare to without shear wall. Due to using shear wall time period of structure is reduces. In Time history analysis acceleration of solid storage structure structure is decreases and base shear is increases in both cases R.C.C. Solid storage structures and steel solid storage structures with shear wall.

The paper [7] shows an industrial solid storage structure analyzed and designed according to the Indian standards (IS 4995) and also by referring Euro code (EN 1998 -4: 1999 & EN 1991-4: 2006) and ACI code (ACI 313). In this study, a 450 cum capacity flat bottom solid storage structure design & analysis. Concrete flat bottom circular solid storage structures are often deployed to store material in various industries like cement plants, power plants, oil and gas industry etc. Solid storage structures are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Failure of a solid storage structure can be devastating as it can result in loss of the container, contamination of the material it contains, loss of material, cleanup, replacement costs, environmental damage, and possible injury or loss of life. The best design of solid storage structure has helped in safe structure.

Paper [8] describes four and a half decades and resulted from all and introduced the first integrated method for characterizing powders for flow, and using this information to design a solid storage structures and bunkers that would discharge without hang-up. Sadly, many users and designers of solid storage structures and bunkers still do not benefit from this, so a lot of process vessels in industry still suffer from rat-holing, arching and bridging. Objections of cost, time and questionable accuracy were levelled at the original hopper design method, in spite of the breakthrough it represented. However, over the last 40 years these problems have been overcome with the introduction of faster, easier to use and more sensitive powder flow ability measurement techniques, and a lot of experience of what measurements matter with which materials and in what operational scenarios. Solid storage structure and bunker failure can occur due to many reasons, following these1) Due to design, 2) Fabrication and erection error, 3) Improper usage,4) Improper maintenance. Now this design project will pull together various lessons learned from many years of solid storage structures and bunkers design projects, and show a practical approach to deciding) Flow pattern is required (mass flow or core flow), b) Measurements need to be made of the powder properties, c) Design models should be used, based on the material being handled and the operational requirements of any given case.

In paper [9] Thin shell structures have given considerably attention for the at least six decades especially during the war time because of their importance in aircraft and missile applications. Shells of various shapes were investigated such as elliptical hemispherical, conical and cylindrical shells. These structures are mostly failing by bucking under external pressure. Cylindrical steel solid storage structures are tall slender structures used for storing materials like cement, grains, fly ash, carbon black, coal saw dust etc. They are special structures subjected to many different unconventional loading conditions, ranging from few tones to hundreds to thousands of tones which results in unusual failure modes.[3] Failure of a solid storage structure can be devastating as it results in loss of the containers, contamination of material it contains, loss of materials environmental damages, and possible injuries and loss of life. Solid storage structures are subjected to normal pressure and axial compressive loads along with the self-weight. They also carry lateral loads due to wind and seismic forces[10]. The major assumptions used in many or all the above theories are summarized and discussed below:

1. The stored material is isotropic and homogeneous.

2. The angle of internal friction is used to describe the strength of the stored material. Soil strength is dependent on the stress path to failure. The stress path is determined by the solid storage structure aspect ratio and the solid storage structure wall stiffness. The angle of internal friction represents the strength for a single stress path to failure and so it does not necessarily represent the strength of all the material in the solid storage structure.

3. Many theories assume that the major principal stress aligns with the vertical axis and the minor principal stress aligns with a horizontal axis perpendicular to the bin wall when the stored material is static. Some researchers have incorporated a distribution factor to allow for the effect of wall friction on the direction of the principal stresses but none have allowed for any change due to wall slope on a horizontal plane.

4. The ratio of horizontal to vertical pressure is usually assumed to be constant with the stored material in either an at-rest or an active state of equilibrium. This is not however a limitation of the theories, but users have generally adopted a single value of K which suggests that the walls are rigid and non-deforming or that they arc rigid and rotate about the base. Other modes of wall deformation have not been incorporated into design calculations.

5. Wall friction is usually assumed to be constant and fully mobilized at every point on the wall although again this is not a limitation of the theory.

6. The stored material is assumed to be incompressible. This may lead to errors in the calculation of hopper pressures. In compressible stored materials consolidation during or after filling will cause slip along the inclined hopper walls. Lateral contraction of the contents will change the stress state toward a passive plastic state of equilibrium.

7. The effect of discharge on the stored material stress state in the bin has usually only been incorporated into design using an overpressure factor applied to the static pressure. Two factors are specified, one for mass flow and one for funnel flow. They arc applied to all solid storage structures that fall within these categories without consideration of the structural form or susceptibility to different load conditions.

- Conclusion Based on Literature Review

Resolve of masses play considerable responsibility in the design of solid storage structure. The solid storage structure is an arrangement used for storeroom of bulk materials, in which the loads due to stored materials has to be taken into account in addition to seismic load. The different codes and standards specify guidelines for the solid storage structure design, a) Indian Standard IS 4995 - 1974 b) American Concrete Institute

ACI 313 – 97 c) German Standard DIN 1055 – 6: 2005 – 03 and d) British Standard BS EN 1991-4: 2006.

Despite the fact that, the analysis and design of solid storage structure cannot be performed using single code, the lack of compatibility among various codes make the designers laborious in designing the solid storage structure. The consideration of compact modifications in the analysis and design of solid storage structure makes it possible to construct and operate safe and economical solid storage structure. The aim of this paper is to compare and briefly describe about the advantage and limitations of solid storage structure by using Staad Pro Structural software. Solid storage structures are considered as special structures as its design is based on the properties of materials stored. In addition to the loads that are acting on the normal structures such as seismic and external loads, the solid storage structures are specially designed for the loads that are induced by the stored materials. Engineers ensure that the solid storage structure is built to be strong and stable enough to resist structural loads and loads due to materials stored. The pressure exerted by the stored material on the side of a bin varies with the processes and arrangements of filling and emptying operations. Due to this variation, it is extremely difficult to analyze the pressure exerted on the walls of the bins. The approximate methods suggested by Janssen are commonly followed for the calculation of pressure in this study. In this project, we are designing the RCC solid storage structure located in all seismic zones with the help of structural software Staad Pro. The design concept include, all dimensions of structural component based on trial and error method, using Equivalent lateral force method in term of Comparison of different models of concrete solid storage structure for earthquake such as nodal displacement, stress and vertical or horizontal pressure on walls etc. for volume of 180 m3. All the designs have been based on the recommendations of I.S 4995 -1974 (part 1&2) and I.S 456

– 2000 codes, Based on these designs, that dimension of solid storage structures shows least amount of concrete and steel. These findings will be useful for the designers of solid storage structures.

3. OBJECTIVE OF RESEARCH WORK

Aims and objectives present an outstanding agenda for the container for support in a research allowance application. The principle objectives of research project can be shortening as follows:

1. A clear and broad learning of recent available international paper on solids storage structure (silos).
2. To perform the Analysis of solids storage structure (silo) using Equivalent lateral force method and to study the performance of structure located in all seismic regions.
3. Design of different models of RCC silo in STAAD pro for different seismic zones by using IS-4995:1974(Part-I,Part-II).
4. Comparison of different models of RCC silo for earthquake as per IS 1893:2016 in terms of nodal displacement, stress and vertical or horizontal pressure on walls etc.
5. To compare the results obtained to assess their potentiality and suitability in understanding the true behavior of such a structure.
6. Presentation of the result in tabular appearance to simply be familiar with the analysis of structure.

4. RESEARCH METHODOLOGY

STEP 1: FIX THE DIMENSIONS:

To create a model for the analysis in software dimensions is necessary for the given requirements, Dimension of Silo being drawn based on the requirements.

STEP 2: LOAD CALCULATIONS AND LOAD COMBINATIONS:

Load calculations are carried out based on various Indian Standards such as IS: 875(Part – 1)-1987 for Dead loads (Unit weight of Building materials and Stored materials), IS: 875(Part –2)-1987 for Imposed loads and IS: 1893(Part 1)-2002 for Seismic loads. Horizontal pressure acting on Silo wall at various depths and forces due to horizontal pressure are calculated based on IS: 4995(Part I)-1974. Temperature stresses and Hoop steel required to resist those stresses are calculated based on IS: 4995(Part II) - 1974. Loads mentioned above are considered to be Primary load cases.

STEP 3: ANALYSIS USING STAAD PRO:

The created model in the STAAD has to be analyzed after the assignment of properties of members. Load cases details and definition of loads should be defined carefully based on the calculation of loads and IS codes. Load cases details be in the order of Dead load, Live load, Ash load, & -z, Seismic +x & +z and other load combinations for the analysis.

STEP 4: DESIGN AS PER INDIAN STANDARDS:

Design of R.C.C. solids storage structure (Silos) is based on the values obtains from analysis where IS: 456 -2000 and SP are be use for the design procedure and for various checks.

STEPS INVOLVED IN STAAD-PRO:

The methodology includes the selection of type of BINS as solid storage structure, fixing the dimensions of components for the selected solid storage structure and performing equivalent Static Method of Analysis) by IS: 1893-1984 and IS: 1893-2002 (Part 2) draft code. In this study, Single solid storage structure structure for fine grain 1300m3 capacity rectangular shapes is considered for analysis. It is analyzed for four different zones (zone-II to V), and for solid storage structure-fill conditions, i.e. solid storage structure full conditions. Lastly, the results of the analysis of solid storage structure performed on the basis of IS: 1893-1984 and IS: 1893-2002 (Part2) draft code have been compared by using the STAAD PRO software.

Step 1: Open STAAD.Pro and click on new project again click on space give file name and location, click on next add beam complete the task with proper directions.

Step 2: Now Go to Geometry then run structure wizard then Select Prototype model and Select Model Type Composite Models there will be a symbol appear just below the box Bunker or Solid storage structure Double click on them, a dialog box will appear for Select Meshing Parameter after filling these parameter as per requirement select Enable edge beam generation then click on apply.

Step 3: Now go to file and Merge Model with staad-pro model. At the time of merging this model in staad-pro they ask about co-ordinates. Select X, Y & Z coordinates as (0, 0, and 0). Then ok.

Step 4: After appearing the solid storage structure model in staad-pro screen select the entire Beam and Provide Column at desired height.

Step 5: Assigning Properties: click on property then property dialog box will opens and click on define rectangle or circular, give the property of column and click on add close now select all the columns, assign to selected beams make a proper completion assign yes.

Step 6: Go to define and rectangle or circular finally give the property of lower beams and click on add close and select lower beams for assign to selected beams. As this is already defined as from Run Structure wizard No need to define again also.

Step 7: Go to define and thickness to give the property of plates and click on add close the select plates and assign to selected plates and assign. Thickness of plate is mandatory to define.

Step 8: Assigning Loads, Click on load and definition, then loads dialog box will opens click on load case details add give load or self-weight to solid storage structure assign to view assign yes.

Step 9: Go to load case details Add seismic load items dialog box will opens click on seismic load select type 1 Go to load case details add live load give name as hydrostatic load click on hydrostatic load items dialog box will opens click on plate loads select trapezoidal plate load direction of pressure Global Z Variation along element Y Give intensity as per calculation of the solid storage structure select required plates for hydrostatic force Assigned to selected plates Assign yes select lower plates of solid storage structure give intensity according to its calculation assign hydrostatic load on lower portion of solid storage structure.

Step 10: Go to load case details click on auto load combination select load combination type- Indian select load combination category –general structures click on generate loads add or add load combination as per prescribed or required now go to analyze Run analysis go to post processing.

IS: 4995-1968* covered the requirements of the structural design for storage bins (solid storage structures). It has been, felt that instead of bringing out one separate standard to cover the requirements of all materials other than food grains it would be useful to cover the subject under one standard in which the requirements of different materials could be dealt with adequately. The different stored materials, such as coke, coal, ores, food grains, fertilizers, cement, flour etc. can be classified either as granular or powdery materials. Extensive research work all over the world has indicated that assessment of bin loads caused due to a stored material would require different treatment depending upon whether it is a granular or powdery material. Taking this into consideration this standard is being revised and is published in two parts namely, Part I General principles and assessment of bin loads and Part II Design criteria.

Solid storage structure - A unit consisting of several tall bins having height greater than their diameter used for storage and handling of grains in bulk and fitted with necessary equipment and accessories.

Aeration - A process in which air is moved through the stored material for ventilation. Arching - A phenomenon in the bin during the emptying of a stored material giving rise to formation of arches of the material across the bin walls.

Bin - A storage structure circular or polygonal in plan and meant for storing bulk materials in vertical direction. Solid storage structure is a bin circular for polygonal in plan. Bunker is a bin whose cross section in plan would be square or rectangular.

Bin Loads - Loads exerted by a stored material on the walls of a bin.

Granular Materials - All materials having mean particle size more than 0.2 mm and No cohesion between the particles is assumed.

Powdery Materials - All materials having mean particle size less than 0.06 mm

Angle of Repose - An angle formed with the horizontal plane, at which the loose grain, when piled, will retain its position.

Garner - An intermediate hopper for storage of grains to ensure desired flow for further handling of grains.

The solid storage structure structure shall rest on reinforced cement concrete raft foundation supported on piles or laid directly on soil, depending on the soil condition. The type of foundation for the storage bins shall be decided taking into account the layout, nature of soil and the loads transferred. The solid storage structure failures such as cracking in the walls of the bin, buckling of unsupported walls and the settlement of the soil and foundation are caused mainly due to unequal loads, pressures, moments and stresses. The main reasons which induced these failures are categorized as material loads, flow pattern and its filling conditions.

4.1 Material Loads:

The material load is considered as the first category in which the failure of solid storage structure takes place. The walls of solid storage structures can expand during the day and contract at night as the temperature drops. If there is no discharge taking place and the material inside the solid storage structure is free flowing, it will settle as the solid storage structure wall expands. However, it cannot be pushed back up when the solid storage structure walls contract, so it resists the contraction, which in turn causes increased tensile stresses in the wall. The arches and rat holes cause unexpected structural loading by the formation of material caking and segregation. The material to be stored in the solid storage structure should be same at the time of design and usage. Otherwise the load may vary which leads to the formation of arches and rat holes. Gas or liquid pressure is constant around a solid storage structure. But the pressure exerted by the bulk solid against a solid storage structure wall increases in areas where the walls are deforming inward, and decreases where the walls are expanding. This provides a significant restraining effect once buckling of unsupported wall begins. Support beams, inverted cones and other types of internals can impose large concentrated loads or non-symmetric pressures on a solid storage structure wall. The weight of the material and the structure produce large axial stresses at the base which in turn cause the settlement of soil and the foundation.

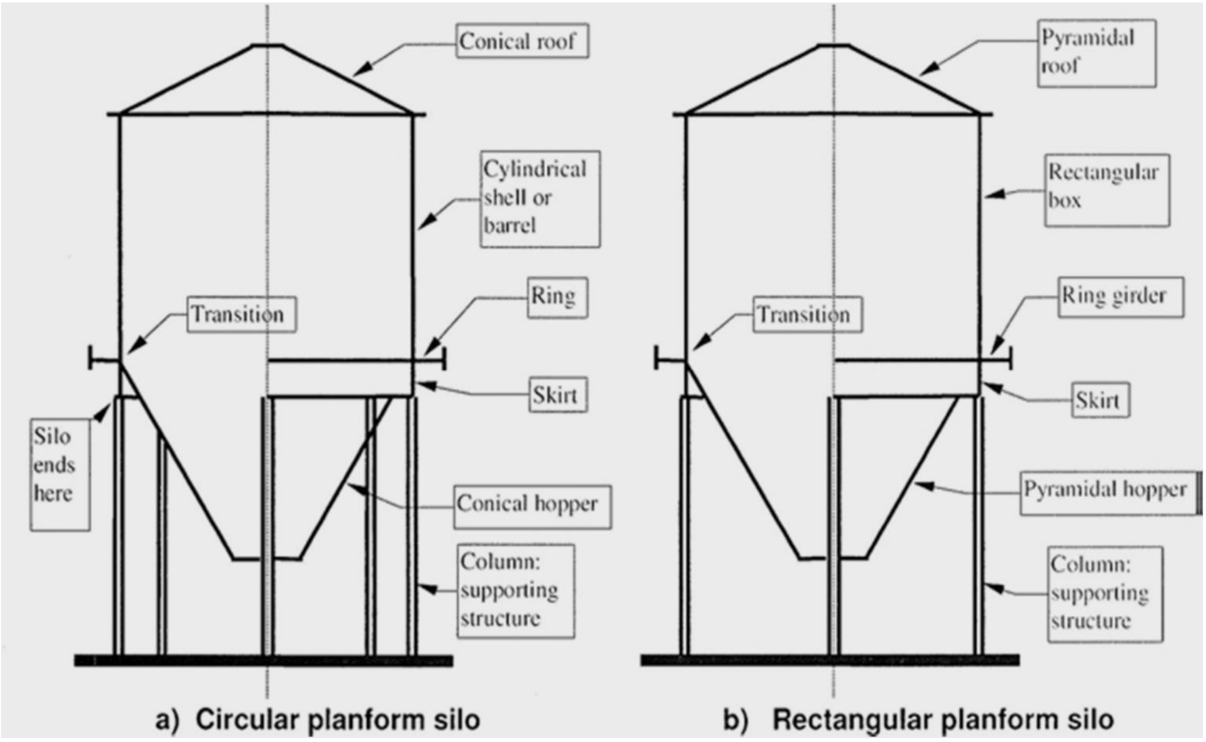

Figure 1: Terminology used in solid storage structure structures

4.2 Load Calculation:

Load consider for Solid storage structure Design Loads should be applied to the structural design of a solid storage structure according to its intended use, size, structure type, materials, design lifetime, location and environment, in order to assure life safety and to maintain its essential functions. The applied loads should be as follows, and their combinations should be defined considering the actual probability of occurrence.

- Dead loads
- Live loads
- Snow loads
- Wind loads
- Seismic loads
- Impulse and suction due to content sloshing, and pressure due to content
- Thermal stresses
- Shock, e. g., by crane
- Fatigue load

In general, the loads determined for designing the normal structures as per codal provisions are Dead load, Live load, Wind load, Seismic load, Temperature load and Load combinations. For the design of Solid storage structure, the load due to stored materials is to be considered in addition to the loads acting on the normal structures. The loads for the design of solid storage structure are explained in detail.

Dead Load

Dead loads shall include the weight of all structural components such as beams, floor slabs, columns and walls and other permanent applied external loads. In solid storage structures, the dead loads shall be calculated by taking the weight of the components such as ring beams, stiffeners, internals and shell. The dead loads are static forces exerted in vertical plane and relatively constant throughout the life time. The building materials are not considered as dead loads till they are constructed in the position permanently. The unit weight of the building materials, parts and components are given in the Indian Standard IS 875 – 1987 "Code of Practice for Design loads (Other than earthquake) for buildings and structures. Part 1: Dead loads – Unit weight of building materials and stored materials" (Bureau of Indian Standard, 1987)

Imposed Loads

Live loads are the temporary loads which occur over the short duration of time. The imposed loads are produced by live loads, dust loads, minor equipment loads, erection loads, operation/maintenance loads and load produced by personnel, tools, and other items placed on the structure, but not permanently attached to it. The floor live loads and roof live loads is to be taken for the load calculation of solid storage structure. Unless specified otherwise, the minimum live load values are to be considered as per the IS specifications. The Indian Standard IS 875–1987 "Code of Practice for Design loads (Other than earthquake) for buildings and structures. Part 2: Imposed loads", provides the roof live loads and floor live loads for the structure (Bureau of Indian Standard, 1987).

Seismic Load

The inertia force created by ground accelerations during an earthquake results in the seismic loads. The application of earthquake generated agitation to the building structure is the concept of seismic load. The mass of the building, the dynamic properties, intensity, duration and frequency of the ground motion are the functions in which the magnitude of loads depends. The national building codes prescribed the requirements of buildings under seismic performance. Seismic analysis for foundation of solid storage structure structure is determined as per IS 1893 – 2002 "Criteria for Earthquake resistant design of structures.

Part 1: General Provisions and buildings" (Bureau of Indian Standard (BIS), (2002)

The seismic pressure on the solid storage structure walls is calculated as per the guidelines for calculations of seismic actions provided by Indian standards.

Load Combination

More than one type of load that acts on the structure will result in the load combination. The load combination is to be calculated for the structure contains more than one type of loading. As per the Building codes, the safety of the structure is ensured by specifying the load combinations with the factors. The structure shall be analyzed for the load combinations and each structural element (wall, beam, column etc) shall be designed for the load combination producing most unfavorable effect on it. The special loads and the load combinations are given in the Indian Standard IS 875–1987 "Code of Practice for Design loads (Other than earthquake) for buildings and structures. Part

5: Special loads and Load combinations" (Bureau of Indian Standard (BIS), 1987) Moments (horizontal and vertical) due to temperature gradient shall be combined.

7. STRUCTURAL MODELING AND CALCULATION

An idea of considering the earthquake loads for the analysis of Rectangular RCC Solid storage structure. Analysis of solid storage structure is done using Equivalent lateral force method. These solid storage structures are studied for varying zones of seismicity. The analysis is done using Staad Pro as per IS 1893 (Part I): 2002 in order to compute the Nodal displacements, stresses and lateral and vertical pressure on wall of the solid storage structure for different conditions is tabulated.

Table 5.1: stored material load calculation

SN	DESCRIPTION (Assumed Standard)	VALUES	UNITS
1	Fuel required for produce powdered material	430	T/Hrs
	After its processing,		
2	Powdered materials found in the hopper (41.2 % of Total) =430 X (41.2/100)	177.16	T/Hrs
3	From Hopper to solid storage structure powdered materials coming 70% =177.16 x (70/100)	124.012	T/Hrs
4	safety factor taking .09 =177.16 X 0.09	159.444	T/Hrs
	For 12 Hrs, Powdered materials found =159.44 X 12	1913.328	T/12Hrs
5	Density of powdered material	1.4	T/CUM
		14.12	KN/CUM
6	Angle of repose	30	Degree
7	n=((1-sin$)/(1+sin$))	1	
8	Height of solid storage structure	20	M
9	Max pressure on hopper γ x h x k, Where k is 0.25, Janssen constant	75	KN/M2

8. RESULT ANALYSIS

The analysis is done using Staad Pro as per IS 1893 (Part I): 2002 in order to compute the Nodal displacements, stresses and lateral and vertical pressure on wall of the solid storage structure for different conditions is tabulated.

- **Maximum Base Shear:**

Table 8.1 shows the maximum base shear in Z direction. Where model 1 means zone II has least amount of base shear in Z direction and model 4 means zone V has maximum base shear so when we compare all 4 model the zone 2 is more safe than other model.

Table 8.1: Max base shear in Z direction

Sr. No.	Model Name	Max Base Shear
1.	M1	202.468 KN

2.	M2	323.069 KN
3.	M3	483.871 KN
4.	M4	725.073 KN

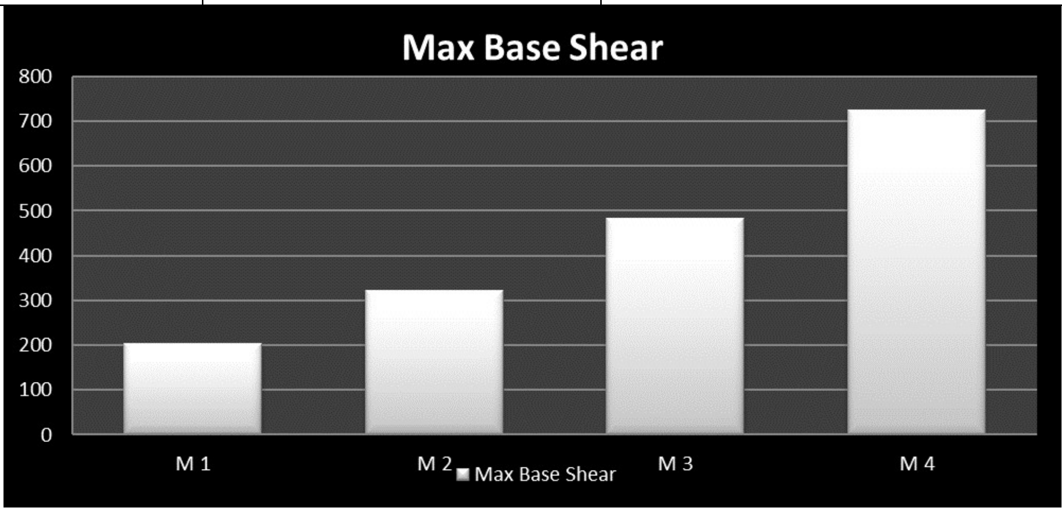

Figure 2: maximum base shear in z direction for zone V

- **Maximum Base moment:**

Table 8.2 shows the maximum base Moment in solid storage structure. Where model 1 means zone II has least amount of base shear Moment and model 4 means zone V has maximum base Moment so when we compare all 4 model the zone 2 is more safe than other model

Table 8.2: Maximum base moment

Sr. No.	Model Name	Max Base Moment
1.	M1	1035.723 KN-M
2.	M2	1654.198 KN-M
3.	M3	2478.831 KN-M
4.	M4	3715.78 KN-M

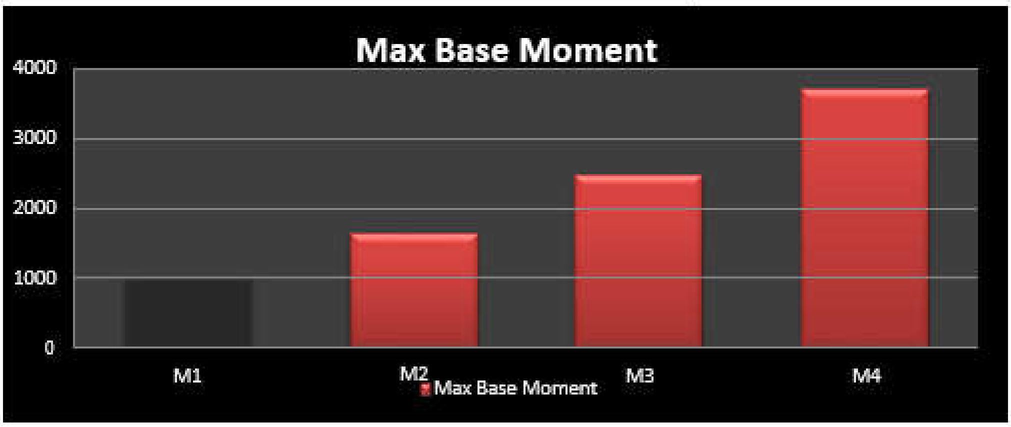

Figure 3: maximum base moment in x direction for zone V

- **Max Absolute Wall Stress:**

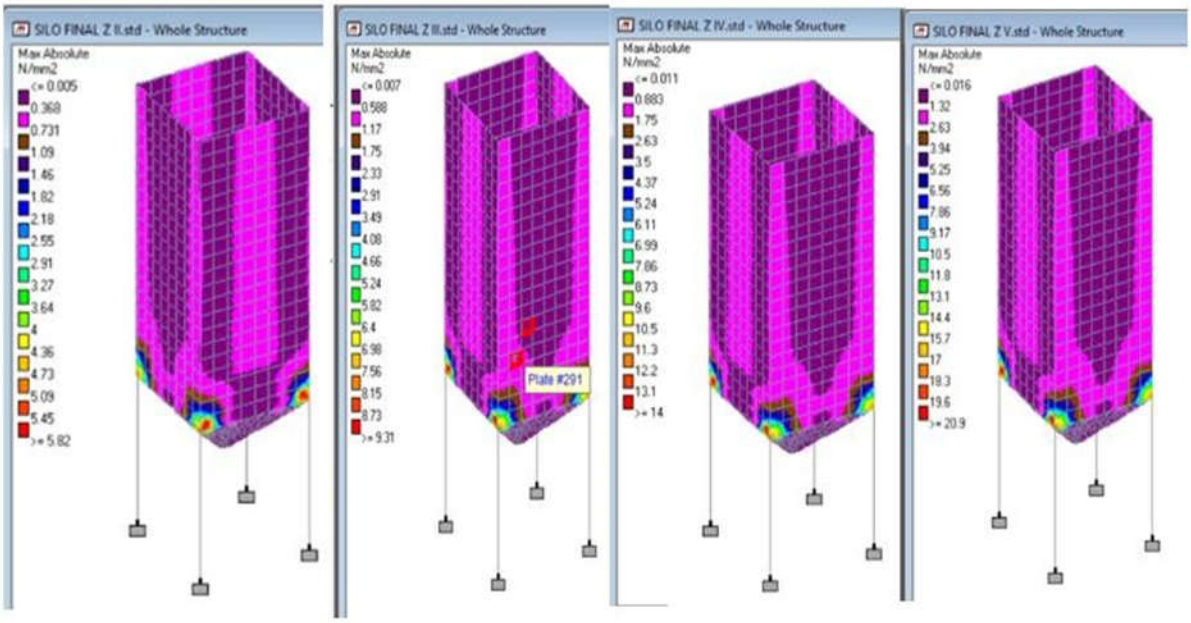

Table 8.3: Max Absolute Wall Stress

Sr. No.	Model Name	Max Absolute Wall Stress
1.	M1	5.817 N/MM2
2.	M2	9.307 N/MM2
3.	M3	13.961 N/MM2
4.	M4	20.942 N/MM2

Table 8.3 shows the maximum Absolute Wall Stress in solid storage structure. Where model 1 means zone II has least amount of Absolute Wall Stress and model 4 means zone V has maximum Absolute Wall Stress in Beam so when we compare all 4 model the zone 2 is more safe than other model.

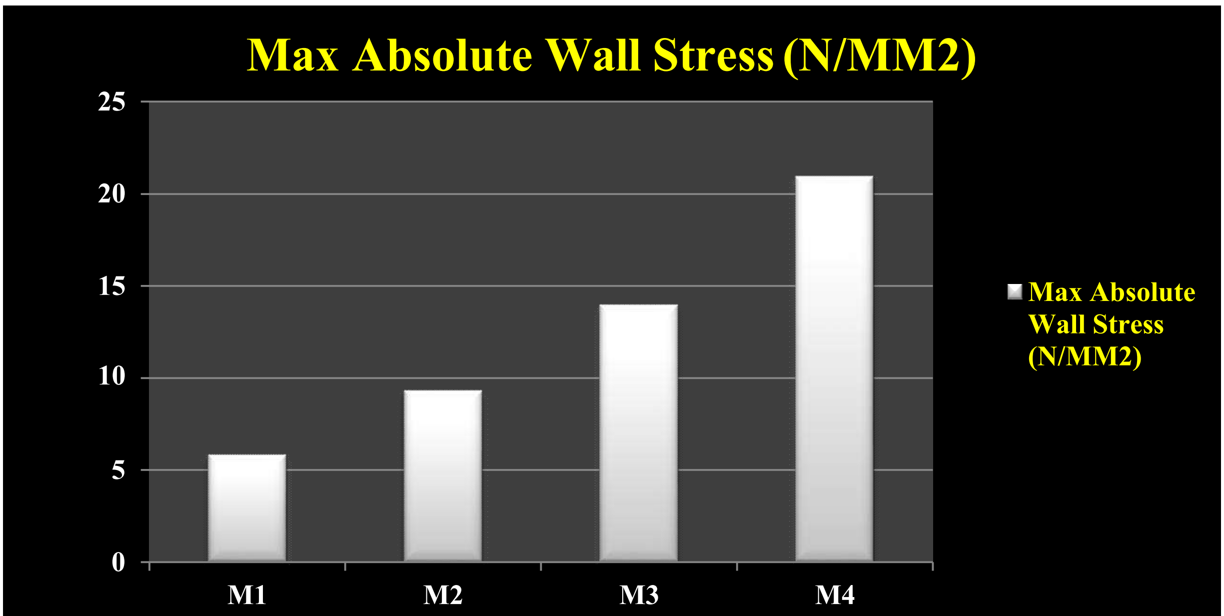

Figure 4: maximum Absolute Wall Stress for zone II to V

Figure 4 shows the maximum absolute wall stress for all zone II, III, IV, V in N/MM2. in staad pro post processing mode where dark purple color shows the minimum stress on infill wall and red color shows the maximum amount of stress in wall. This range varies for different seismic zone where seismic zone II have least amount of maximum stress and on the other hand seismic zone V has maximum stress as compare to all zones.

9. CONCLUSION AND FUTURE SCOPE

This paper has to study the behaviour of the RCC solid storage structure structure in different seismic zones, which means the study was carried to observe RCC solid storage structure structure under the influence of horizontal force i.e. earthquake force or seismic force. According to my literature review lot of authors have mentioned how difficult it is to design a thick rcc solid storage structure with a single country's building standard code. The design and analysis of rcc solid storage structure was done on ' Staad Pro ' software which is used widely for similar purpose.

- In the study this is observed that the structure placed on the greater seismic zone have shown greater horizontal displacement than the one's placed in lower seismic zones.
- The maximum nodal displacement in x direction was noted in model M4 displacing 1453.397mm; other models have shown relative decrease in the displacement as the zone was lowered.
- The least value of displacement was noted on the model M1 located in the seismic zone II showing 514.556mm displacement.
- Model 3 and 4 have shown about 1 m nodal displacement in X direction which is necessary in revision of structural dimension and grade of materials.
- The maximum force at the base was noted in model M4 725.073 KN the value of base force kept decreasing as the seismic zone is lowered hence giving least base moment in model M1 202.468 KN.
- The maximum moment at the base was noted in model M4 3715.78 KN-m; the value of base moment kept decreasing as the seismic zone is lowered hence giving least base moment in model M1 1035.723 KN-m.
- The maximum Shear Force in Beam was noted in model M4 6058.655 KN; the value of maximum Shear Force in Beam kept decreasing as the seismic zone is lowered hence giving least maximum Shear Force in model M1 4882.82 KN.
- The maximum Bending Moment in Beam was noted in model M4 3715.78 KN-M; the value of maximum Bending Moment in Beam kept decreasing as the seismic zone is lowered hence giving least maximum Bending Moment in model M1 1277.66 KN-M.
- The maximum Absolute Wall Stress was noted in model M4 20.942 N/MM2; the value of maximum Absolute Wall Stress kept decreasing as the seismic zone is lowered hence giving least maximum Absolute Wall Stress in model M1 5.817 N/MM2.
- In manual estimate of load in RCC solid storage structure is very easy. Value of these loading is very less and when applied the loading in staad pro v8i is very easy.

Future Scope

1. H/D ratio of all types of solid storage structures needs to be studied this result can be used in IS: 9178 part II 2006. Comparison should be made under various type of eccentricity hopper bottom for various soil conditions.
2. Comparison should be made for different H/D ratios.

3. Solid storage structure structures can also be strengthened and upgraded using certain new materials and techniques including Post-Tensioning.
4. The study may be carried out with an opening for the movement of vehicles (i.e. removing diagonal bracings either on one side or two sides for the first storey).
5. The Study may be carried out with other materials carrying different flow pattern.
6. Analysis study can be carried out for typically filled conditions where there is no pressure induced on the wall (i.e. only for material filled in hopper plus the repose material forming cone).
7. The study may be carried out with other types of solid storage structure with different specifications.

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