DESIGN AND STABILITY ANALYSIS OF GRAVITY DAM USING STAAD PRO SOFTWARE

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree Of

BACHEOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

Mr. Niraj Singh Parihar

(Assistant Professor)

By

Gaurav Sharma[181612]

Abhay Joshi[181625]

To

JAYPEE UNIVERSITY OF INFORMATION AND TECHNOLOGY

WAKNAGHAT, SOLAN-173234

HIMACHAL PRADESH, INDIA

May-2022

STUDENT DECLARATION

I hereby declare that the work presented in the Project report entitled
"DESIGN & STABILITY ANALYSIS OF GRAVITY DAM USING STAAD PRO SOFTWARE" submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Niraj Singh Parihar**. This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of our project report.

Signature of Students Name & Roll no:

Gaurav Sharma
181612
Department of Civil Engineering
Jaypee University Of Information Technology, Waknaghat, India

Abhay Joshi
181625
Department of Civil Engineering
Jaypee University Of Information Technology, Waknaghat, India

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **DESIGN AND STABILITY ANALYSIS OF GRAVITY DAM USING STAAD PRO SOFTWARE** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by Gaurav Sharma during a period from August, 2021 to December ,2021 under the supervision of Mr. **Niraj Singh Parihar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date:-14-5-22

Mr. Niraj Parihar

Assistant Professor
Department of Civil
Engineering
JUIT,Waknaghat

Dr. Ashish Kumar

Professor and Head
Department of Civil
Engineering
JUIT,Waknaghat

External Examiner

ACKNOWLEDGEMENT

I'd like to express my heartfelt thanks to all who assisted us in completing this mission. We encountered many hurdles during the project due to our lack of skills and experience, but these individuals assisted us in overcoming these obstacles and in the final transformation of our concept into a formed sculpture. I would like to thank **Mr.Niraj Singh Parihar sir** for his guidance monitoring and continuous help during the project work. In the last I would like to thank staff of department of civil engineering JUIT for providing us such an opportunity to learn from these experience I am also thankful to our whole class and most of all to my parents who have inspired me to face all the challenges and win all the hurdles in life

Thank you all

Date :

Gaurav Sharma
181612

Abhay Joshi
181625

B.Tech-Civil Engineering

Table of Content

List of Tables

List of Figures

Abstract

A gravity dam is a strong structure, made up of concrete and steel, built across a waterway to make supply on its upstream. The gravity dam is roughly three-sided fit as a fiddle, with its summit at its top and greatest width at base. The part is proportioned to the point that it opposes the different powers following up on it by its own weight. In this paper examination of gravity dam is done utilizing STAAD Pro programming. STAAD Pro is generally utilized for high rise structures with shaft and columns.

STAAD Pro can also investigate each and every kind of component, for example, plate, shell or strong notwithstanding shaft only. STAAD Pro uses Time History Analysis method for long time deflection. Consequence of stresses and stress shapes are depicted toward the finish of paper. The target of paper is to have a bearing of investigation of dam considering strong components utilizing STAAD Pro.

CHAPTER 1
Introduction

1.1   Introduction to Gravity Dam

Dams created out of workmanship concrete and which rely completely upon its self burden for sufficiency fells under the characterization of gravity dams. Masonry dams had been being utilized in past routinely yet after opportunity, last critical block work dam structure that was built was Nagarjunsagar. Dam on stream Krishna which was worked between 1958-69. Consistently, streamed rubble stone work was used which was supported together by lime concrete or solid concrete. In any case block work dam is finished being arranged in our country likely in light of essence of substitute viably open dam improvement material and need advancement development.

Truly, gravity dams are as of now being worked of mass strong, whose arrangement and improvement points would be discussed in this part. …………..
Designing of Dams, Volumes I, II, and III by W P Smith is a generally outdated distribution. Creager, J D Justin, and J Hinds passed on by John Wiley and Children (1917) has in addition been for quite a while considered a laudable in dam arranging, at any rate different new advances have don't discover mention here. It is essential to see that, it isn't just adequate to plan a solid dam structure, at any rate it is relatively fundamental to check the establishment too for key uprightness. For solid dams, the squeezing factor made at the intersection point of the base winds up being uncommonly high, which the establishment has to resist. Usually concrete gravity dams are constructed across a river by excavating away the free overburden till firm stone is able which is considered as the certifiable establishment. Everything considered not all stones are of a similar quality; they fluctuate with various land materials and the cycle by which they have been laid out all through the long stretch. For instance, the inclinations of the Himalayan degree of the mountains are viewed as topographically youthful, comparably as more fragile than the massif of the Deccan level. The possibility of establishment not just effects the game plan, it in addition controls.

1.2 Introduction to Software

STAAD or (STAAD Pro) is an essential examination and plan PC program at first made by Exploration Specialists Global in Yorba Linda, CA. In late 2005, Exploration Designer Global was bought by Bentley Frameworks. A more settled variation called STAAD-III for windows is used by Iowa State College for educational purposes for normal and hidden modelers. The business version STAAD Pro is maybe the most by and large used hidden assessment and plan programming. It contains Steel, Concrete and Timber plan codes. It can use various kinds of examination from the standard first solicitation static assessment, second solicitation assessment, numerical to time history and Response spectrum analysis. This software is particularly extraordinary and includes rich than AutoCAD, which is another well known programming in the development field. AutoCAD permits a client to deal with 2 measurements just in little detail. Then again, STAAD Pro permits the client to deal with 3D or three-dimensional models in generous detail. STAAD Pro significantly lessens your manual computation and time as well.

CHAPTER 2
Literature Review

2.1 State of the art

DeepikaMettal(2017)[1]This paper introduced time records approach for off
ering the seismic conduct and firmness of a gravity dam. The designing
and evaluation of   the mannequin was   once achieved the   usage   of the
Staad.Pro v8 software. As per the IS code, the dynamic examination was
once finished for a dam with quite a number staturesas 70m, 80m and 1
20m and the effects obtained have been analyzed, to figure out the simple
 execution of strong gravity dam. The have an impact on of sure parameters
which affects the seismic presentation, peak of dam and loading designs
have been researched.

From the outcomes, it can be concluded that the maximum pressure is estimated
about(14.5N/mm2),for 120mvdam and it is good in distinction with differe
nt regarded dam models.It is discovered that there used to be no longer t
ons distinction between 90mdam's features than others (14.2N/mm2).The
creator regarded most intense and least chief burdens (6.97N/mm2, 0.893
N/mm2)90m dam used to be productive when in contrast with the differe
nt two dams.Thevshear pressure values (0.259N/mm2,0.372N/mm2)   for
80m dam have been higher as in contrast to 90m and 120m dams. At last,
the   dynamic traits for a   variety of statures   of   the   90m   dam   such as
recurrence,period,mass activity was once smart than every other dam.The p
recept benefit is that the strain varies all through the physique of dam and
the   inclines may   want to be   structured with   the   aid of the stress design.
Thus, whilst evaluating these three wonderful statures of the dam, the 90m
dam was once found extra educated than others.

Shou-yan JIANG and Cheng-bin DU (2015) [2] A research paper explored
parameters such as geometric inaccuracies and severe deformities and the state of
communication at the point of fracture. The location of the imported separation
was first identified using a solid plastic injury model based on the process of the
indirect component (FEM) process. At that time, complex communication
calculations were used to replicate the break connection in the normal way, and
the Columb grinding model was used to reconstruct the separator bonding in
disruptive load. After examining statistical models by context analysis, the
seismic impact of the Koyna Dam with cracks was further described with varying
degrees of earthquake, and the mechanisms for the collapse of the broken dam
were even revealed. Results have shown that the strength of a dam with two types
of induced fractures can be confirmed in the strong earthquake of the first Koyna
earthquake, and the broken dam has a high limit for safe earthquakes. Disruption
processes of a broken dam in a strong earthquake can be divided into two stages:
the slope phase and the collapse stage. The slide stage ends near the deadline

quickly, and the upper square slides long distances and splits before the split occurs. Excessive slide removal of the upper square will be reduced by an extended grinding coefficient in the separated area. For the results shown, the durability of the dam may be enhanced by the erosion coefficient of the growing interlayer, as the high grating coefficient may prevent the high slide square. High-slide slide removal of the slide can be considered by extending the erosion coefficient in the separated area. Due to the critical non-linear structures at the fracture point, the combined aperture aperture increases with a separate erosion coefficient when the grinding coefficient is less than 0.8. At a time when the grating coefficient was significantly higher or equal to 0.8, the opening changes slightly.

Manoj Nallanatheltal (2018) [3] The research paper described the analysis of concrete stability with the use of analytical application STAAD.pro and compared the results against conventional methods. STAAD.pro was for the stability and stress analysis of the structure. The stability analysis was done in absence of seismic forces. The results demonstrated that various aspects such the dead load, water/hydrostatic weight, elevated pressure, combined estimations of the positive bending moment and negative bending moment, the combination of level & upward and downward forces were answerable for dam steadiness. The investigation expressed that moment derived about because of self-weight goes about as a resistive moment against moment delivered because of water, inspire pressure and so forth. Such implied that dependability against moment was accomplished when the positive moment was more prominent than negative moment. Dependability against sliding relies on the coefficient of contact, the entirety of every vertical forces and every single even force. Consequently sliding was represented by elevated pressure. If flat forces builds soundness against cascading reductions if upward/downward forces remain around the equivalent. Third soundness of dam was on-premise of sheer erosion factor, which relies on the coefficient of grinding, the summation of every single vertical forces, the summation of every single flat forces, the geometry of dam and materials shear quality.

S.Sree Sai Swetha [4] Drainage dams are solid structures that maintain their stability against suspension loads from geometric shapes, weight and solid quality.The motives behind dam development may include route, reduced damage, hydropower period. , fish and uncontrolled development of water, water quality, hydro supply. Design and analysis of a strong gravitational dam to accommodate earthquakes should be based on a measure of quality that reflects both the desired quality of life and the decision of the system and the methods of testing. The dam referred to in this paper is 130m where a consistent and consistent investigation and feature assessment is carried out using a time history strategy. Most organizations demolish dams with flexible strategies that give

negative results. Finite Element Method Approach is used to investigate a "Gravity Dam" that has dried up in those buildings. Tests were performed among similar statistical methods of seismic investigation by feature testing using time history. Any building under construction will face many forces such as (wind force, earthquake, gravity) or forces such as ice / snow etc. Among these, earthquake power is a natural phenomenon as we know that earthquakes are a natural and unpredictable disaster. To protect the structure from collapsing, it's important to follow the designing gridlines of earthquake design while modeling the structure. The wave that rises during an earthquake event is very high and when it hits any building it passes from the base to the roof which leads to the collapse of the In-elastic. it may be possible to demolish the entire building or it will probably get through, depending on the design approved but certainly the building will have some major repair and reinforcement work that will cost.

Varsha V Deshpande [5] In this study, hydrostatic pressure up to FRL, normal pressure and excessive lift, tail water pressure up to 194.5m level and hydrodynamic power. The seismic intake assumed to be equal to 0.156 of the horizontal force and 0.05g of the direct force, considering area 3. Lifting is considered equal to the hydrostatic pressure at the end. Considered 100mm free board. The results are directly related to the STAAD Pro software. Variety of stress in the body can be expressed in different colors. The results of the stability analysis which includes a rolling, sliding and lifting check are shown in the tables in Table 1, it can be seen that the safety factor is more than 1 in all cases; which is why it is safe to slip. From Table 2, the safety feature of the most important compound is found to be safe from heights. From Table 3, it appears that the safety factor against overturning is more than 1.5 and is therefore safe. Of particular concern to the stability of the dam is the pressure created on the heel. A small amount of strong pressure is allowed on the heel in cases of overload. Dam safety for all forces according to IS 6512-1984 in all compounds was made and found to be safe and acceptable. As it is a fragmented phase, reinforcement will be provided in situations of extreme stress. The pressure difference of the empty case is shown in Figure 4, where it appears that the solid pressure is within the permissible limits. The concentration of pressure can be seen near the pedestrian junction and the spillway and near the drainage gallery. At pressurized feet of 0.902 MPa appear to be within the permissible concrete pressure.

Venkata Raju Badanapuri [6] Gravity Dam behavior for stability and response to seismic forces is read in this paper. In considering the problem the stability analysis of the "Gravitational Dam" was performed without the presence of an initial earthquake force. Therefore, the analysis highlighted that in the presence of various loads such as dead load, water / hydrostatic pressure, lifting pressure, aggregate values of + ve and minute -ve, the horizontal force and vertical force are bound to the stability of the dam. Continuing with the

analysis it is clear that the resulting moment of survival acts as a strong moment against the moment produced due to water, high pressure etc. Which means that stability against overturning is achieved when the moment + ve is greater than -ve times. Although stability against slipperiness depends on the coefficient of friction, the sum of all direct and indirect forces is horizontal. Therefore, the slide is dominated by high pressure. The coefficient of increased collision and the further reduction of direct force lead to stability against slides. However, when the horizontal force increases the stability against the slide it decreases when the vertical force remains approximately the same. Thirdly the stability of the dam is based on the shear friction factor, this depends on the coefficient of friction, the sum of all vertical forces, the sum of all the horizontal forces, the geometry of the dam and the shear strength. In the same shear strength problem, the geometric collision remains unchanged, so stability must depend on the value of all direct and indirect forces. With the problem considered in the study, the dam gains stability in all aspects namely rolling, sliding and cutting. The dam is not only safe for sliding and also S.F.F., With which the shaving key can be provided etc.

K Janardhana [7] The conclusions from the study are as follows, The main advantage is that the variability of stress through the body of the dam can be carefully studied and the roads can be designed according to the stress pattern. gallery. STAAD-PRO is the simplest and most annoying feature of dynamic analysis and provides computer space to investigate modeling and calculation processes related to the seismic structure of groundwater dams.

Ayman A. Seleemah [8] Based on the results presented in this study, the following conclusions can be reached: The strength of the base affects the modal structures and an increase from EF / EC = 0.50 to 5 leads to a significant decrease in natural time. In the EL-Centro-earthquake-S00E segment, when the EF / EC rate fluctuates from 0.50 to 5.0 a significant difference in removal and acceleration occurs. This difference explains the effect of the solidity of the foundation on the seismic behavior of a dam. For static and earthquake analyzes, the solidity of the foundation has a clear effect on the displacement of dams and the normal pressures up to EF / EC = 2.0. To this end, the strength of the foundation should not be neglected in the imitation and analysis of the dam especially if the foundation is solid less than twice the solidity of the dam concrete. If the EF / EC is 5.00, it is recommended to take a solid foundation to make the problem easier. Earthquake fluctuations affect the vibration of the dam, although different ground movements have the same acceleration. This difference depends on the magnitude of the earthquake and the changing characteristics of the dam.

Considering the geometric differences and the significant degradation in the fracture zone, a solid communication algorithm and a Columb friction model

were used to mimic the process of collapsing a dam with an internal crack. Other conclusions are made. Resistance to earthquakes in a gravity dam will reduce when the gravity dam has a gap in it, but still has a high safety factor. A gravity dam with a vertical slope will collapse when the top speed reaches five times the magnitude of the original Koyna earthquake, while a dam with a curved slope will vibrate at eight times the speed of the original Koyna earthquake. Thus, the shape of the crack has a significant effect on the edges of the dam that can withstand the earthquake of the broken gravity dam. To assess the safety of a broken dam, the structure of the crack should be carefully considered. , and the main movement mode for determining whether a dam is stable or not, tangential sliding. However, in a dam with a curved edge, the leading motion mode is the combined opening movement of the closure. Dam stability can be enhanced by increasing the coefficient of interlayer friction, as a high collision coefficient can prevent a high block slide. The high slide displacement that may occur in the slide block is reduced by increasing the coefficient of collision at the fracture site. Due to the strong non-linear structures in the crack area, the upper joint opening increases with the crack friction coefficient only if the friction coefficient is less than 0.8. a little.

2.1 Objectives

1. To determine the stability of concrete and earth filled dam.
2. To determine the seismic hazard over concrete and gravity dam.
3. To determine the utilization of analysis tool of staad foundation in DAM analysis considering hydrostatic pressure and soil interaction.
4. To determine stresses induced due to medium type of soil condition with bearing capacity of 160 KN/m².

Chapter 3
Designing in Software

3.1 General

General analyses and design Gravity Dam using Staad pro software intended for storing of water and then use it for various purposes like electricity generation
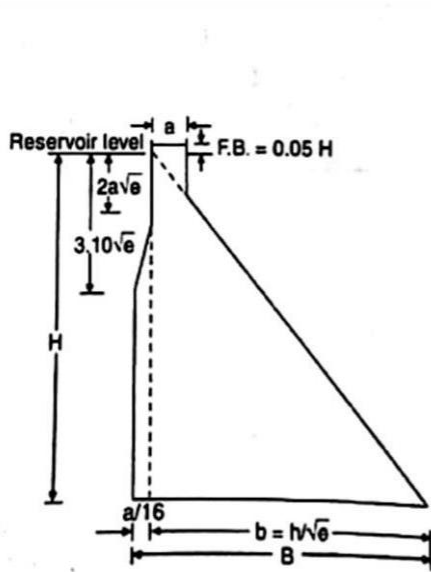
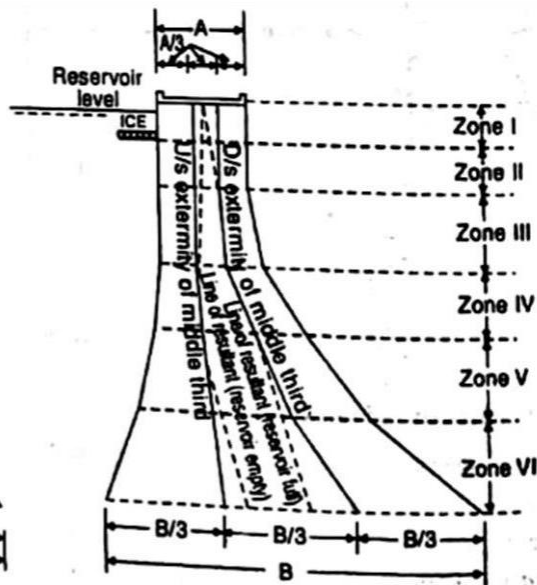**Fig. 18.14.** Practical profile of gravity dam.

Fig. 18.15. Zoning of dam.

3.2 Scope

- The fundamental extent of this venture is to apply Indian Standard code information/Data in reality by planning a gravity dam, this plan presents investigation and plan direction for solid gravity dams., or their experts, should focus on the suppositions utilized in the investigation.
- The reason for basic suppositions like passable burdens, shear qualities, channel viability, and stacking conditions ought to be painstakingly analyzed. The specialist's reports, displays, and supplemental data should give defense to these suspicions like establishment investigation and testing, solid testing, instrumentation information, and records kept up during the real development of the task.
- Additionally, the staff architect's autonomous information on the dam acquired through site investigations or survey of activities examination report just as experience with past reports and examinations, ought to be utilized to check that the displays introduced are illustrative of real conditions. Techniques for investigation ought to adjust to the regular strategies utilized in the designing calling.

3.3 Background

The research that went into establishing this Major Qualifying Project is detailed in this portion of the history. The knowledge gathered about the different elements of the Dam, as well as the structural design and research processes for those elements, is presented in the sections below

3.4 Time History Analysis

A direct /linear time records investigation conquers the drawbacks of mannequin response vary examination mannequin of response spectrum analysis, furnish non-linear conduct isn't included.
The approach requires greater noteworthy computational endeavors for ascer -taining the response at discrete period.One charming favorable role of such approach is that the typical indication of response quantities in exhibited in the response history.This is vital for cooperation influences are regarded in shape amongst stress resultant.Dynamic response of the design side exhib it with infill's to a foreordained time records to IS code go for 5% Damping share of disagreeable tough soil has been evaluated the use of way of superposition technique.Time records is essentially a approach of seismic eva luation for the simulation of an earthquake motion. It is an closing device to find out about the dynamic response of a structure. In this paper stresses at heel and toe of Dam with gallery and Dam besides galley are

analyzed by means of Time records approach for Various fundamental masses and load mixtures in accordance to IS 6512:1984.

The Conclusions from above find out about are as follows:-
(a) The compressive and tensile stresses at heel /toe of the Dam with gallery are much less as evaluate to Dam except gallery.
(b) The important gain is that stress version via the dam physique can be studied cautiously and the slopes can be designed in accordance to the stress pattern.
(c) From the response of dam we can conclude that there is impact in stress version in the dam due to the building of gallery.
(d) STAAD-PRO is the most handy and much less tedious for dynamic analyses and it presents a computing surroundings to inspect modeling assumptions and computational techniques associated to the static and seismic structural balance of gravity dams.
Non-linear time records evaluation is an fantastic device for overall
performance primarily based comparison of a structure.As we comprehend STAAD is the most handy and much less tedious for any non-linear dynamic analyses. In these paper a non-linear dynamic evaluation is carried out on gravity dam. From outcomes we can conclude that acceleration is extra at pinnacle flooring of the dam and minimal at backside ground of the dam. This is due to the fact of tension is extra at bottom. In case of deformation also, it is extra at pinnacle and much less at bottom. Fixity reduces the deformation. In case of modal analysis, the percentage of UX (accl in X-direction) is a lot greater than different two directions. Its participation in UX is additionally a lot greater so there will be extra likelihood of dam to get displaced in x-direction throughout earthquake event. It can be viewed that frequency goes on reducing at every mode form and for first mode it is 0.85.It holds desirable due to the fact for hydraulic shape time duration have to be round 1 so that it will operate suitable for the duration of seismic tournament .From envelope it is determined that dam yields extra at middle.It is absolutely anticipated due to the fact ofrigidity and stiffness of dam at abutments sides

Chapter 4
Results and Discussion

4.1 General

STAAD or (STAAD.Pro) is a basic assessment and plan PC program at first made by Exploration Architects Global in Yorba Linda. In late 2005, Exploration Architect Worldwide was bought by Bentley Frameworks. A more prepared interpretation called Staad-III for windows is used by Iowa State College for enlightening purposes for normal and hidden planners. The business transformation STAAD.Pro is maybe the most by and large used hidden assessment and plan programming. It can moreover use various kinds of dynamic examination from measured extraction to time history and response range assessment. The dam body is shown in STAADpro utilizing the SOLID isoperimetric limited components with eight hubs. Every hub has three translational levels of opportunity.

The Dam is examined for a couple of fundamental loads and weight blends possiblymetwithduringitsservice.Concretedamsareusedmoreoftenthanfilldamsto produce hydroelectric power because of the way that doorways (similarly called conduits) or various kinds of outlet plans can be fused into the strong to believe water to be conveyed from the stock in a controlled manner. Right when water for power, drinking water, or water framework is required downstream, the doorways can be opened to convey the whole needed all through a predefined time. Water can be kept spilling in the stream downstream so fish and other normal life can persevere. Both concrete and fill dams are expected to have emergency spillways so that rising waters can be safely conveyed downstream before the water streams over the top.

4.2 Load considered

4.2.1 Dead Load
The Dead Load involves the heaviness of the solid design of the dam body notwithstanding dock doors and extensions, if any ludicrous. Cement's thickness is assessed to be 2400 kg/m³.

4.3 Primary load
(a.) Hydrostatic Load: - The dam's upstream and downstream faces are subjected to water pressure. The most destabilizing (or overturning) force acting on a gravity dam is the pressure of the water on the u/s face. Stability is aided by the tail water pressure. The tail water pressure is modest in comparison to the water pressure on the u/s forehead.

To the surface, the water pressure is still natural. It is easier to compute the components of factors at work in the horizontal and vertical directions rather than the overall force on the inclined surface explicitly when calculating the forces due to water pressure on an inclined surface. Water pressure forces are discussed separately for non-overflow and portion and overflow sections below.

4.4 Secondary Load

Wave Pressure (hydrodynamic wave load): Swirling winds produce waves on the reservoir's top, causing pressure to shift to the d/s side. The highest point of the waves determines the wave pressure.

Seepage loads

The uplift is supposed to act on the whole width of the foundation

Wind load

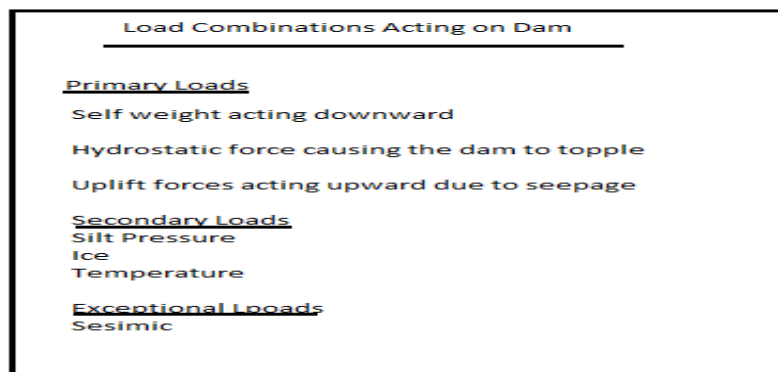When the dam is full, wind acts only on the downstream side thus contribute to stability

4.5 Exceptional Loads

Under reservoir full conditions, the most adverse seismic loading will then occur when a ground shock is associated with: – Horizontal foundation n acceleration operating up stream, an–Vertical foundation acceleration operating downwards.

4.6 General

The STAAD input document is the manner by which the GUI (or Graphical User Interface) interfaces with the STAAD.pro research motor. The info document is a book record that contains a bunch of orders that are run all together. The orders either give guidelines or information about examination or additionally design. A content tool or the GUI Modeling office might be utilized to produce the STAAD input design. Any content manager can be utilized to alter/make the STD input record by and large. The info record is produced by the GUI Modeling.

Load Combinations

Load Combinations Acting on Dam

Primary Loads
Self weight acting downward
Hydrostatic force causing the dam to topple
Uplift forces acting upward due to seepage

Secondary Loads
Silt Pressure
Ice
Temperature

Exceptional Loads
Sesimic

4.7 Types of structure

A plan can be portrayed as a variety of segments STAAD.Pro is prepared for exploring and arranging structures containing packaging, plate/shell and solid parts. Essentially any kind of configuration can be destitute somewhere near STAAD.Pro programming. A space structure which is a three dimensional, laid out plan with loads applied in any plane, is the most get onto a plane development is restricted by an overall X-Y work with system with loads in a comparable plane. A Bracket structure contains of truss people which can have recently crucial part controls and no curving in the people. A story structure is a couple of dimensional development having no even (overall X or Z) improvement of the plan [FX, FZ & MY are controlled at each joint]. The floor laying out (in overall X-Z plane) of a design is an ideal representation of a story structure. Portions can similarly be exhibited with the floor in a story structure as long as the development has no level stacking. On the off chance that there is any sort of even weight, it ought to be decayed as a space structure.

4.8 Generation of the structure

The design might be produced from the info document or referencing the co-ordinates in the GUI. The figure underneath shows the GUI age strategy

Fig-1 General Design in Staad Pro
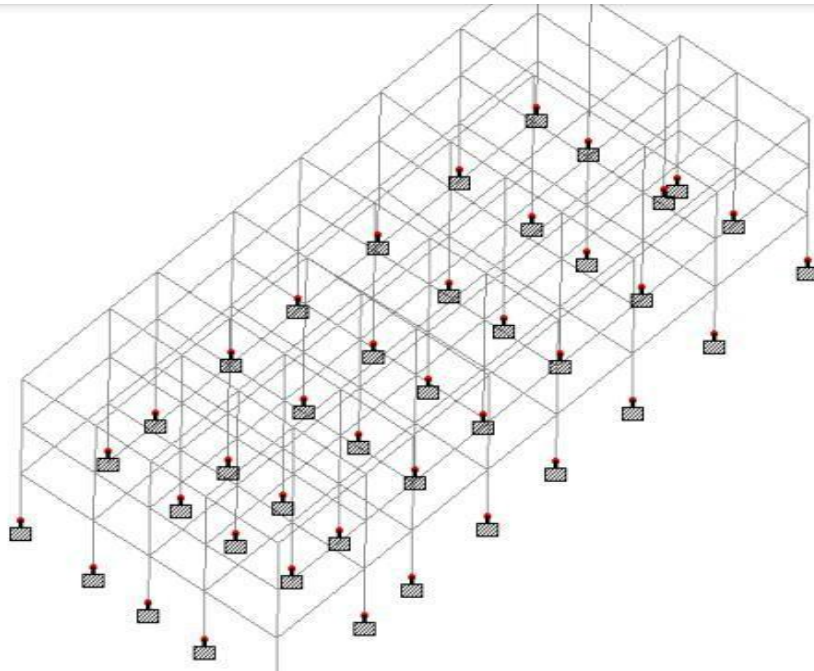
4.9 Supports

Supports are demonstrated as Stuck, FIXED, or FIXED with different conveyances (known as FIXED However). A stuck assistance has limitations against all translational turn of events and none against rotational turn of events. With everything taken into account, a stuck assist will with having reactions for all forces anyway will go against no minutes. A fixed assistance has limitations against all headings of advancement. Translational and rotational springs can moreover be shown. The springs are tended to the extent their spring constants. A translational spring steady is described as the ability to remove an assistance joint one length unit the foreordained overall way. Also, a rotational spring steady is portrayed as the ability to turn the assistance joint one degree around the foreordained overall course.

Loads

A structure's joint loads, member loads, temperature loads, with a permanently attached terminal member loads can all be specified. STAAD is an acronym for "Standardized Transportation Authority In addition, Pro will calculate the structure's self-weight and use it in analysis as uniformly distributed member loads. Any fraction of this self-weight can be directed in any direction

Joint loads

Every free joint of a system may be subjected to joint loads, including all forces and moments. These loads operate on the structure's global coordinate scheme. The positive coordinate directions are affected by positive powers. A single joint will have any amount of loads attached to it, and the loads would be additive on that joint.

Member load

Three sorts of part loads may be applied directly to a person from a development. These piles are reliably appropriated loads, concentrated weights, and straightly moving weights (checking trapezoidal). Uniform weights circle back without limit or inadequate length of a section. Assembled troubles act at any moderate, decided point. Straightforwardly changing weights act preposterous length of a section. Trapezoidal straightly changing weights act over the full or midway length of a section. Trapezoidal weights are changed over into a uniform weight and a couple of concentrated weights. Many weights may be shown to circle back to a section in any free stacking condition. Part loads can be shown in the part put together structure or the overall work with system. Reliably coursed part stacks gave in the around the world sort out structure may be demonstrated to act along the full or projected part length.

Area/Floor load

A uniformly distributed load is also applied to a floor (bounded by the X-Z plane). Calculating the member load for each floor's individual members might take a long time. Using the AREA or FLOOR LOAD commands, the user may define the area loads (unit load per unit square area) for members. For these participants, the software will measure the tributary region and calculate the appropriate individual loads. One-way distributions are handled by the Area Load, and two-way distributions are handled by the Floor Load.

Section types of concrete dam
Concrete members may be constructed for there are several different kinds of Cross sections. Prismatic Beams for (Rectangular) Prismatic Columns.

Design parameters
A range of parameters are included in the software that is needed for IS 13920 architecture. It accepts all of the parameters required for IS: 456 architecture. It also has some additional criteria that are only available when the design is completed according to IS: 13920. The default parameter values were chosen to be numbers that are often found in traditional architecture specifications. This manual includes a comprehensive list of the available parameters as well as their default values, which can be modified to accommodate the specific design being done. Before beginning the concrete plan, the length and force units must be declared in millimeters and Newton's.

Beam
Arrangement Pillars are planned for flexure, shear and curve. At whatever point required the effect of the center force may be considered. For all of these forces, all unique bar loadings are pre sifted to recognize the essential weight cases at different spaces of the shafts. For design to be continued by IS: 13920 the width of the part won't be under 200mm. Similarly the part will in a perfect world have a width-to significance extent of more than 0.3.

4.9 Design for flexure
Plan strategy is same as that for IS 456. Regardless while arranging following measures are satisfied by IS-13920:
1 The base assessment of concrete will in a perfect world be M20.
2 Steel fortresses of assessment Fe415 or less will be used.
3 The base pressing factor steel extent on any face, at any part, is given by:
4 Pmin = 0.24 √ fckfy
5 The best steel extent on any face, at any section, is given by Pmax = 0.025 6.

The positive steel extent at a joint face ought to be invany occasion comparable to an enormous part of the negative steel at that face. 7. The steel gave at all of the top and base face, at any fragment, will at any rate be identical to one-fourth of the best regrettable second steel gave at the substance of either joint.

Design for Shear

The IS 13920:1993 revision specifies the shear force that vertical hoops must resist. When measuring shear power, elastic sagging and hogging moments of resistance of the beam section tare taken into account. Plastic drooping and hoarding snapshots of opposition can likewise be utilized for shear plan if the plastic boundary is characterized in the information document. Shear support is utilized to oppose torsion and shear powers.

4.10 Column Design

Sections are proposed for significant forces and biaxial minutes per IS a456:2000. Portions are similarly proposed for shear powers. All critical models for picking longitudinal and get over help as determined by IS: 456 have been managed in the section plan of STAAD.Pro Anyway following stipulations have been satisfied to unite courses of action of IS 13920: 1. The base assessment of concrete will preferably be M20 2. Steel fortresses of assessment Fe415 orvless will be used. 3. The base component of area part won't be under 200 mm. For segments having unsupported length outperforming 4m, the most concise component of fragment won't be under 300 mm. 4. The extent of the briefest cross-sectional estimation to the contrary estimation will in a perfect world be in any event 0. 5. The partitioning of circles won't outperform a huge bit of the most un-sidelong segment of the portion, except for where uncommon restricting help is given. 6. Unprecedented limiting help will be given over a length lo from each joint face, towards mid reach, and on either side of any part, where flexural yielding may occur. The length lo won't be not by and large a) greater sidelong component of the part at the portion where yielding occurs, b) 1/6 of clear scope of the part, and c) 450 mm. 7. The scattering of circles used as remarkable keeping backing won't outperform ¼ of least part estimation anyway need not be not by and large 75 mm nor more than 100 mm.
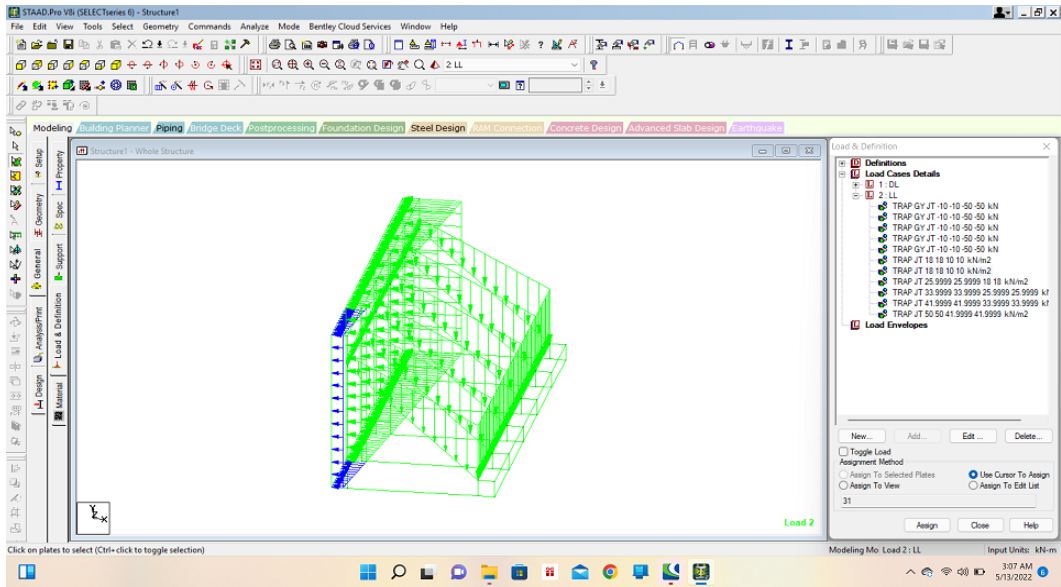
Fig-2 Seismic load acting on dam

Value of seismic load acting on dam =490.339kN.m
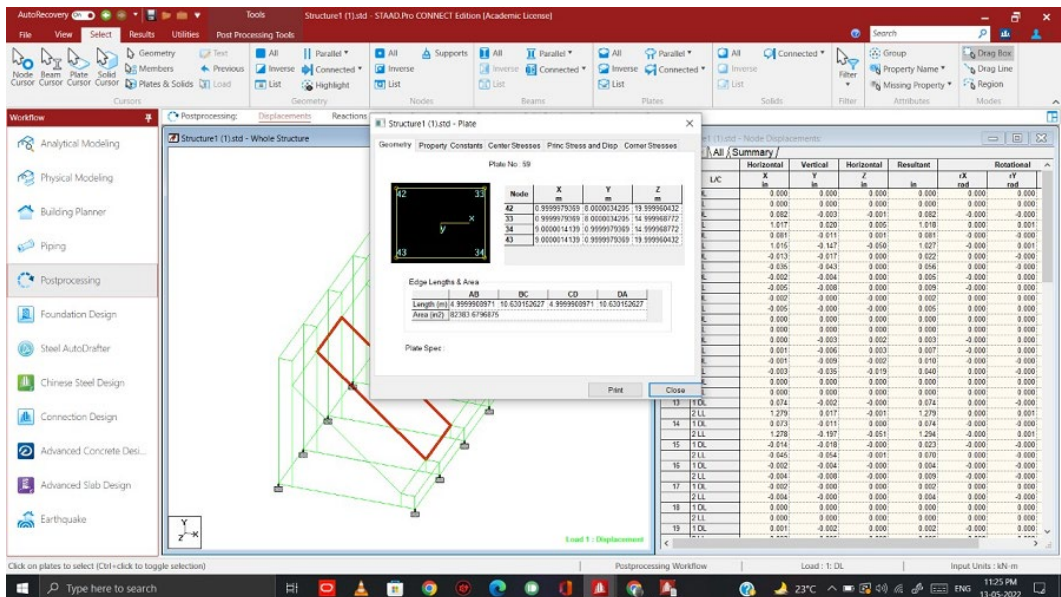
Fig-3 Rendered View of Dam

4.11 Design operation

STAAD.Pro contains a broad course of action of workplaces for arranging basic people as individual sections of a took apart plan. The part plan workplaces outfit the customer with the ability to pass on out a number of different arrangement exercises. These workplaces may design issue. The exercises to play out an arrangement are:

1. Decide the people and the stack cases to be considered in the arrangement.
2. Demonstrate whether to perform code checking or part assurance.
3. Decide plan limit regards, if not equivalent to the default regards.
4. Show whether to perform part decision by headway. These exercises may be repeated by the customer many occasions depending on the arrangement essentials. Seismic quake development oftentimes instigates power sufficiently huge to cause inelastic misshapenness in the plan. In case the development is frail, sudden frustration could occur. However, in case the development is made to carry on malleable, it will really need to help the seismic quake impacts liked with some redirection greater over the yield evasion by maintenance of energy. As such pliability is furthermore required as a key segment for prosperity from sudden breakdown during outrageous dazes. STAAD.Pro has the capacities of performing strong arrangement as per IS 13920. While arranging it satisfies all plans of IS 456 – 2000 and IS 13920 for columns and sections

Allowable stress

STAAD's participant design and code testing. Pro are based on the IS: 800 allowable tension design process (1984). It's a technique for proportioning structural members under duty conditions by using construction loads and pressures, permissible stresses, and design limits for the required material.
In this textbook, it will be impossible to cover any part of IS: 800. However, the main features of the permissible stresses defined by IS: 800 and applied in STAAD will be discussed in this section. Advantageous During the consideration of different forms of permissible pressures, appropriate parts of IS: 800 will be cited

Multiple Analysis

Multiple studies in a single run can be needed for structural analysis/design. To enable numerous analyses in the same run, STAAD.Pro allows the user to modify input such as member properties, support requirements, and so on in an input file. For design purposes, the results of various analyses may be integrated. It may be possible to render those members disabled for one load case and then allow them for another in systems with bracing. For this form of study, STAAD has an INACTIVE choice.

Post processing facilities

The STAAD could use all of the output from the run for additional processing. The user interface is excellent.
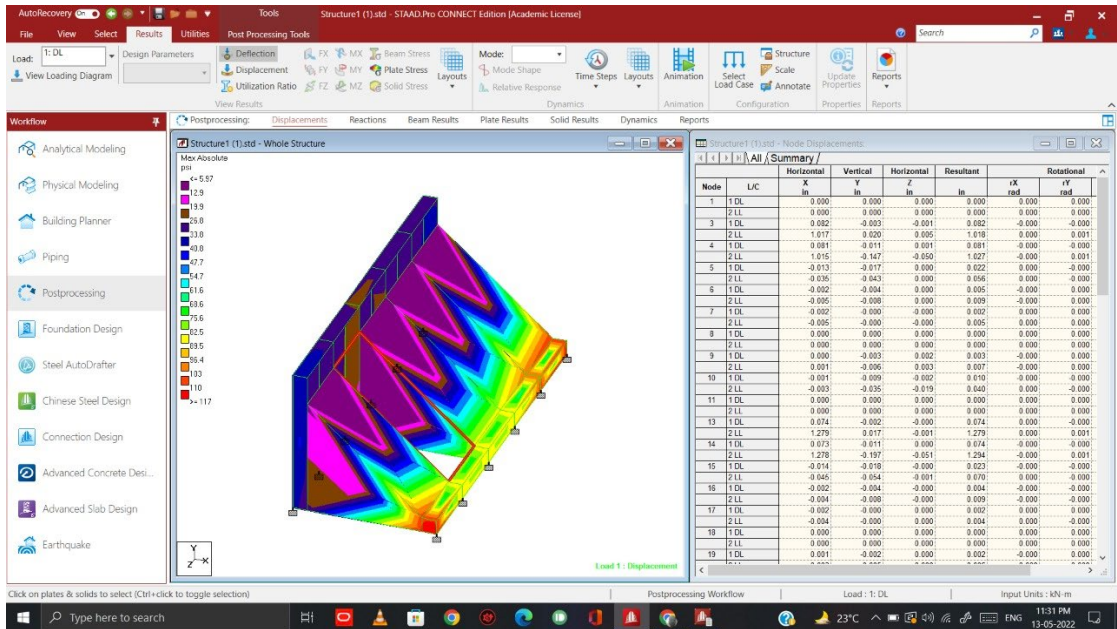
Fig-4: Shear force diagram
Value of shear at base i.e. p= 65.539kN/m² at the middle section
Value of shear at base i.e. p=133.810KN/m² at the end

p=W/T (+/-)6M/T^2
where W is the weight of dam
M is the base moment = .9 *W*h*alpha

Stability Requirements

The two individuals' thinness proportions are estimated and contrasted with the most noteworthy qualities. The generally speaking slenderness ratios for different classifications of individuals are summed up in the IS: 800. An appropriate maximal thinness proportion for every part can be given in the STAAD execution of IS: 800. Pressure individuals will be checked against a most extreme worth of 180, while strain individuals will be checked against a greatest worth of 400 if no greatest thinness proportion is determined.

Deflection Check

The software allows the customer to consider a virtual model and compare it with the standard codes. The evasion check may be controlled using three limits. Redirection is used despite other strength and robustness related

principles. The close by aversion assessment relies upon the latest assessment results

4.12 Code Checking

The purpose of code testing is to determine if a certain section will fulfil the requirements of the relevant specification code. The code verification is founded on IS: 800 requirements (1984).The code checking equations use forces and moments at specific parts of the participants. The BEAM parameter or the SECTION command may be used to specify sections. When no parts are mentioned, the code is checked using powers.

Chapter 5
Design for concrete dam

Design of concrete gravity Dam sections

From an overall perspective a gravity dam should satisfy the going with measures:

1. It will be ensured against overturning at any even circumstance inside the dam at the contact with the foundation or inside the foundation.

2. It should be secured against sliding at any level plane inside the dam, at the contact with the foundation or along any topographical segment inside the foundation.

3. The part should be comparing so much that the reasonable weights in both the concrete and the foundation should not exceed.

Security of the dam structure is to be checked against likely loadings, which may be designated fundamental, discretionary or excellent. The gathering is made similar to the fittingness and also for the general meaning of the store.

1.   Essential weights are perceived as all around material and of

prime significance of the heap.

2. Discretionary weights are all around discretionary and of lesser degree like sediment trouble or warm tensions in view of mass establishing.
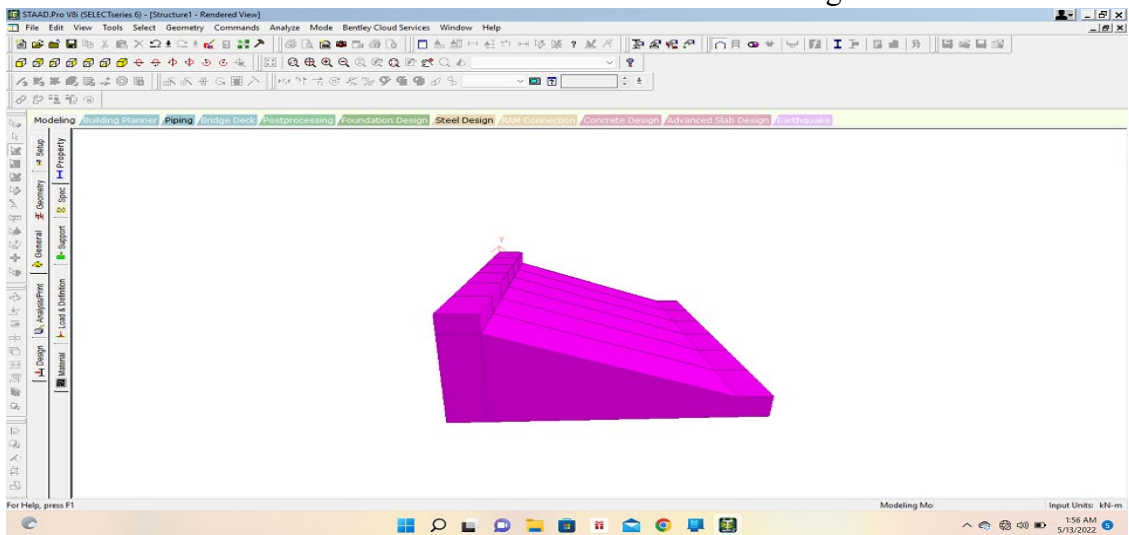

Fig- 5: 3D view of dam

Outstanding weights are arranged dependent on limited general fittingness or having low probability of occasion like inertial weights related with seismic activity.

Indeed a strong gravity dam gets its solidarity from the force of gravity of the materials in the portion and hereafter the name. The gravity dam has sufficient load to withstand the forces and the disturbing second achieved by the water seized in the stock behind it. It moves the stores to the foundations by cantilever action and along these lines incredible foundations are pre basic for the gravity
dam.

The powers that offer strength to the dam include:

1.   Weight of the dam

2.   Thrust of the tail water

The powers that attempt to destabilize the dam include:

1.   Reservoir water pressure

2.   Uplift

3.   Forces because of waves in the reservoir

4.   Ice pressure

5.   Temperature stresses

6.   Silt pressure

The powers to be opposed by a gravity dam fall into two classes as given underneath:
Premise of suppositions of fluctuating level of dependability. Indeed to assess this class of powers, unique consideration must be taken and dependence put on accessible information
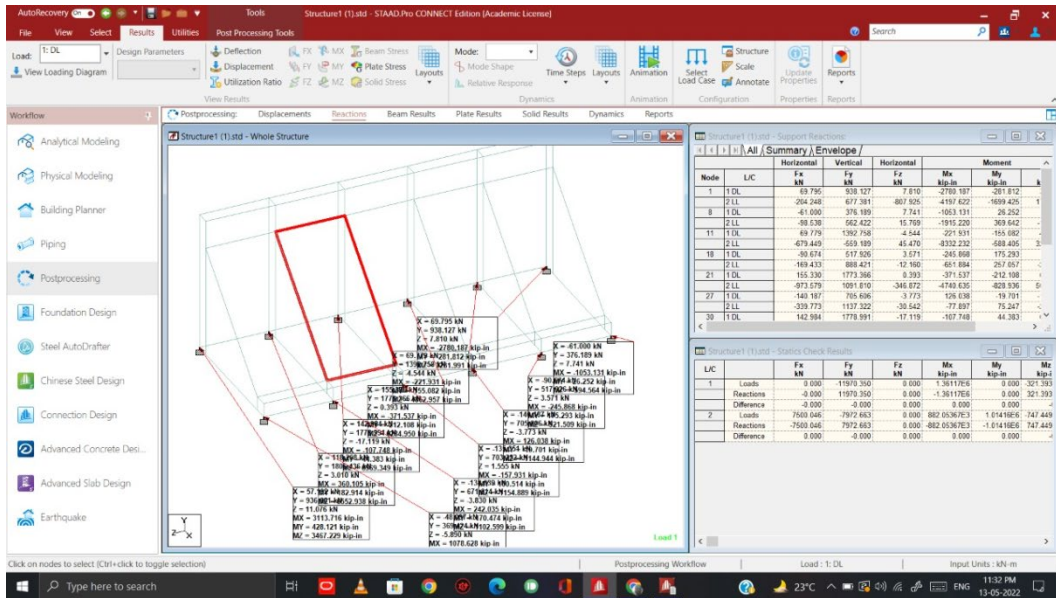
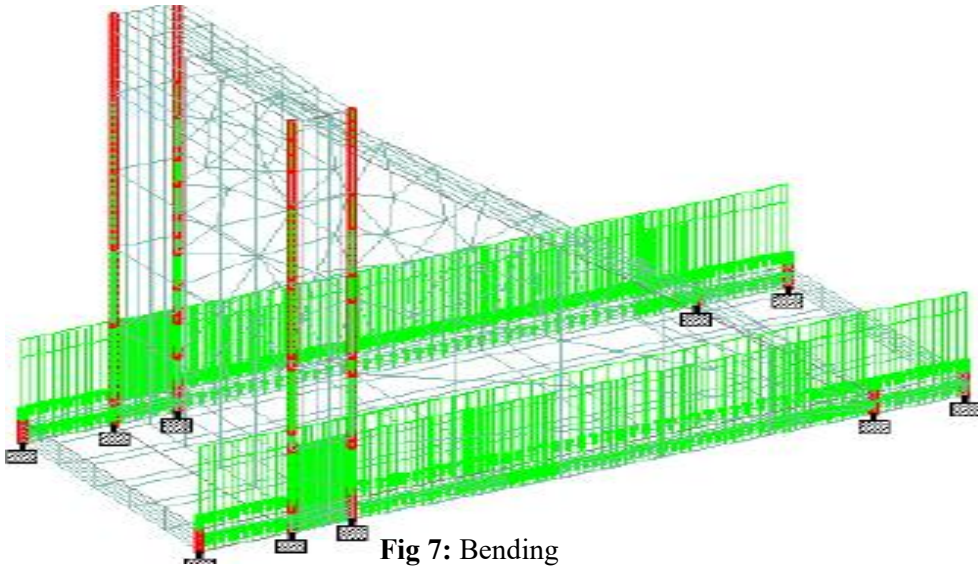## Design in STAAD Pro

Fig-6: Support Reactions

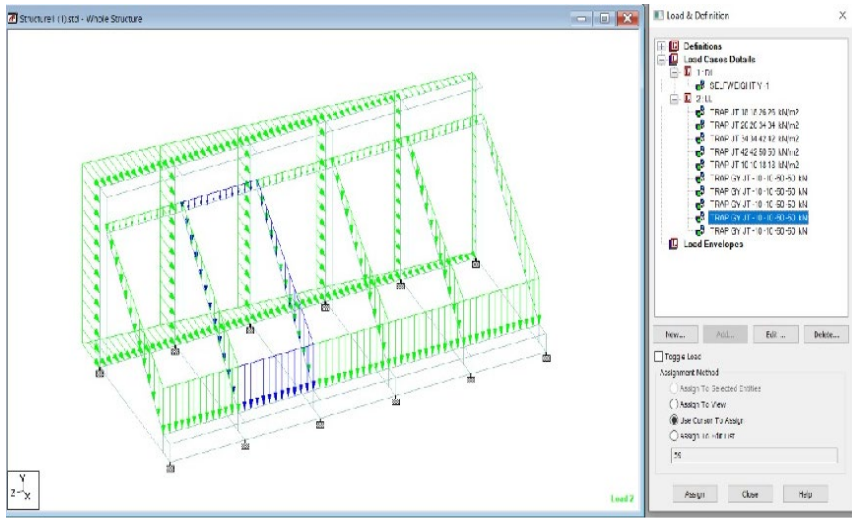**Fig 7:** Bending

Fig 8- Bending
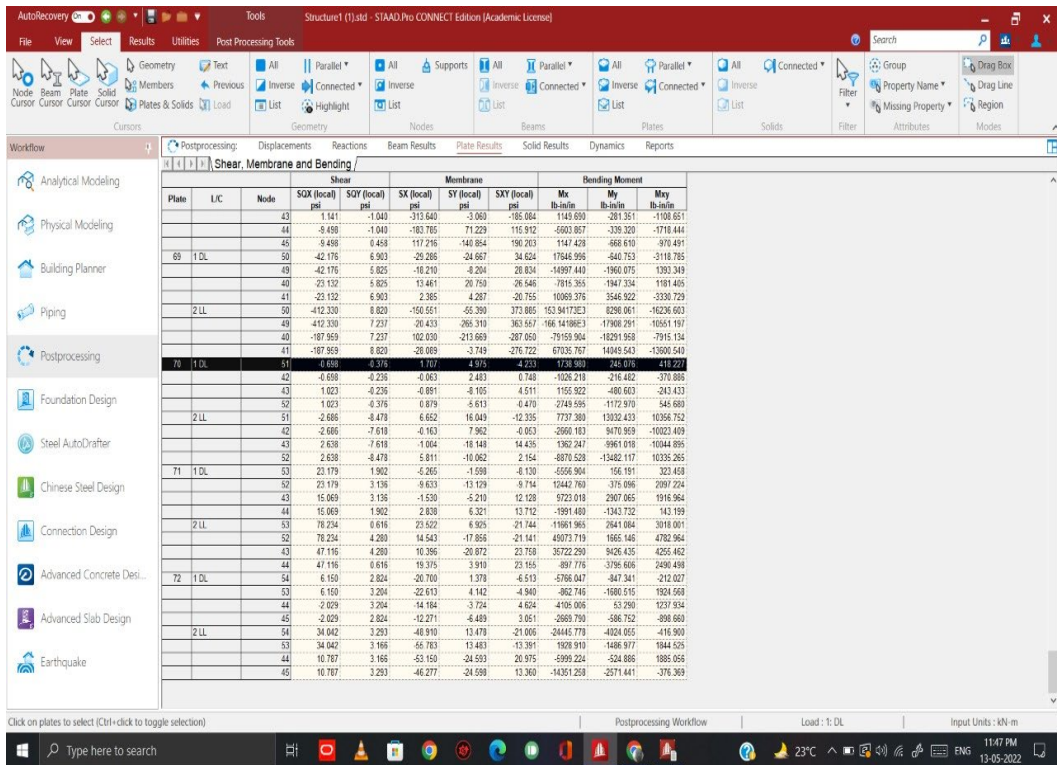
Fig-9: Value of Bending due to various loads
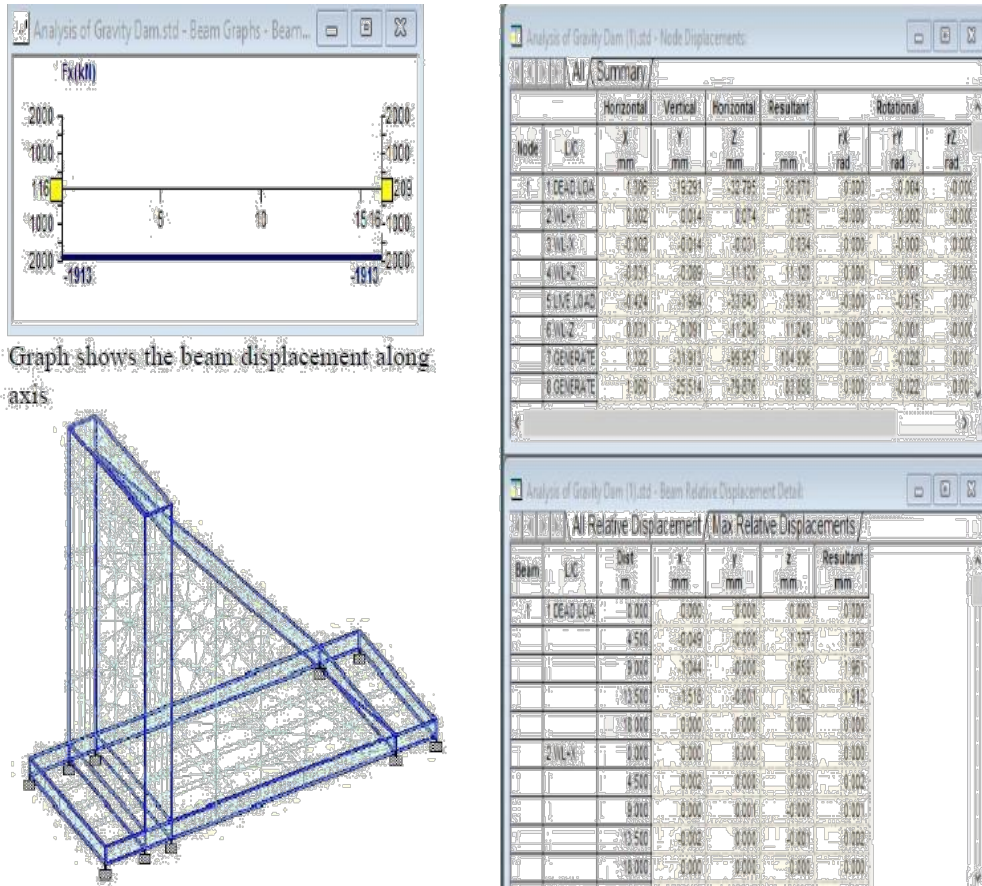
Graph shows the beam displacement along axis

Fig- 10: Displacement of structure

Design steps in STAAD Pro

1: Development of nodal centers. Considering, arranging of the plan we entered the center concentrations into the STAAD record.

2: Portrayal of plates. By utilizing, add plate order we had drawn the plates between the relating hub focuses.

3: 3D viewpoint on structure. Here we have used the Momentary intermittent request in Y bearing get the 3D point of view on structure.

4: Supports and property relegating. After the formation of construction, the backings at the foundation of design are determined as fixed. Furthermore, the Materials were indicated and cross segment of plate individuals was alloted.

5: 3D conveying view. Ensuing to designating the property the 3d conveying point of view on the development can be showed up.

6: Doling out of wind loads. Wind loads are portrayed by IS 875 Section 3 ward on power decided and transparency factor. By then loads are incorporated weight case nuances in +X,- X, +Z,- Z course.

7: Appointing of dead loads.

8:- Relegating of weight blends DL+LL, DL+LL+UPL,DL+LL+UPL+WL Worldwide Diary of Unadulterated and Applied Science Extraordinary Issue 300 various factor of 1,1.5& breeze load having different headings of X+ ,X-,Z+

9:- For the analysis part, use STAAD.pro software and assign all required parameters as well. IS 456: 2000 and SP 16:2000 are the code books.

10:-keep and run the file for evaluation print. Check how many mistakes for dam from this process, if no longer getting any consequences so can we modified & discover out the place did we mistaken.Finally submit process ing & print out of evaluation can be taken out.

11:- Following the study, only a portion of the entire gravity dam is applicable to be constructed in STAAD Pro. Foundation v8i is used to plan the whole house independently. We may build styles of foundations and footing depths depending on our needs.

Calculations

Case 1 :-**when the reservoir is empty**
Self weight W= l x b x h x γcon
Where W1=4.6mx47mx100mx24x9.81=509021.28kN

W2=1/2x30.4x40x2.4x9.81x100 =1431475.2kN

The only single force on the dam when the reservoir is empty is the self weight of dam Acting at a distance of H/3 from the heel , It provides maximum possible stabilizing moment about the top without causing tension =>

Pressure(max)=2w/b and Pressure(min)= 0

Case 2:- **when the reservoir is maximum level**
Therefore
Self-weight W1=509021.28kN
W2= 1431475.2Kn
Water pressure:- PW= ρgh = 1000x9.81x40mts
PW=392400N/m = 392.4KN/m2
Water pressure= 1/2 x 40 x 392.4 =7848kN
Uplift pressure: 40/30 = 13.34mts from base-
At heel P'=γh =1000 x 9.81 x 40 = 392400N/m = 392.4kN/m
At toe P''=γh' =1000x9.8x10 =98100N/m =98.1kN/m
Moments of topple - 509021.28x32.7 =16644995.
M1=w1x32.7 =509021.28x32.7 =16644995.
M1=w1x32.7 = 509021.28 x 32.7 = 16644995.
M1=w1x3=29001687
M2=w2 x 20.26mts
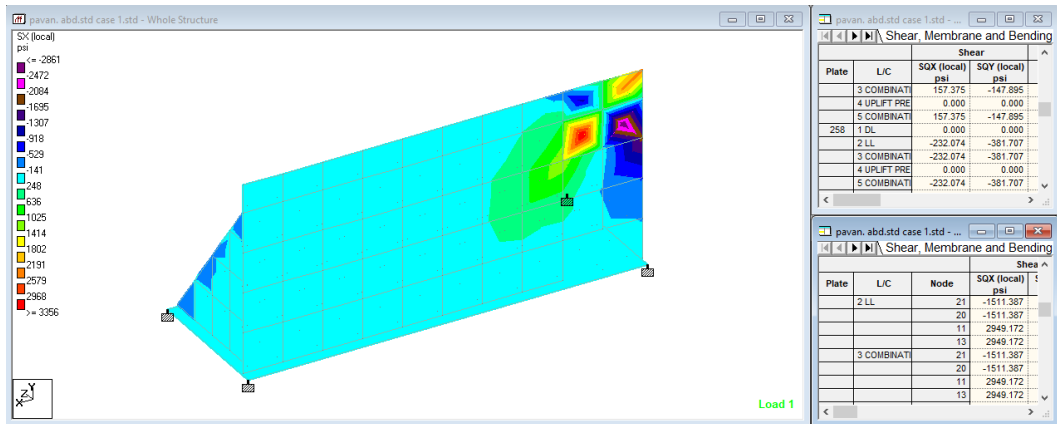M2=M1 + m2 = 45646683.41kNm
Opposing moments:- Mw1 = 784800x13.34 = 10469232 KN.m
Mup1=490506x20.26m =9937530kNm Mw1 +mup1 =10469232 + 9937530 KN.m
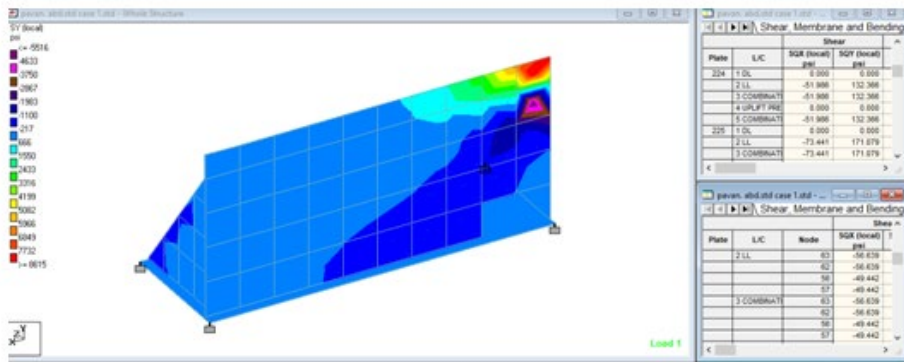Factor of safety = 45646683/20406762 = 2.24 >2 (safe against Sliding)
Friction (ff)=µ.N =0.7(509021.28 + 1431475.2)=1358347.536
Wp=784800
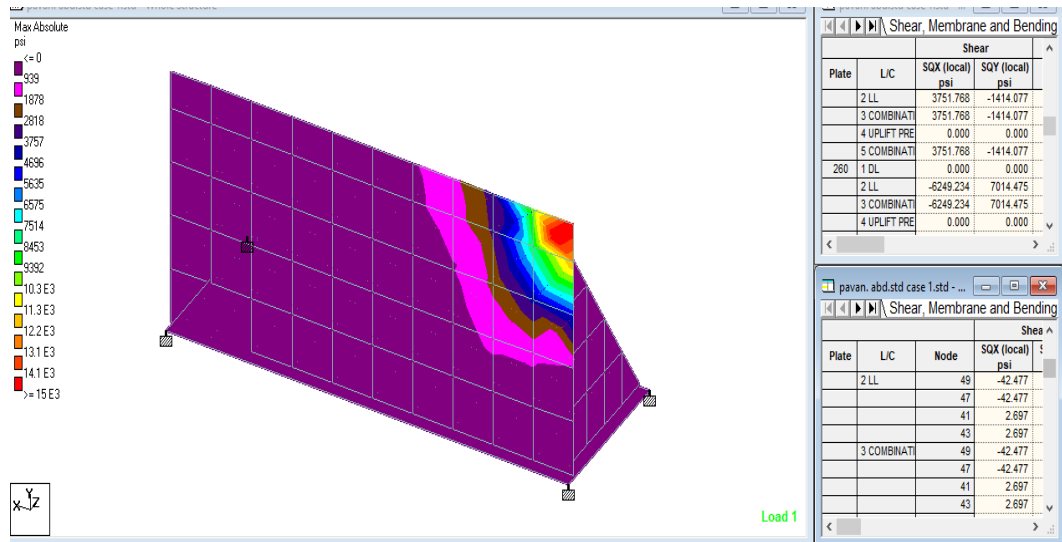F.o.s = 1358347.536/784800 = 1.73 >1.5 Safe

Fig 1: Shear force in x direction (sx) for case-2
Maximum shear stress value =647.7 kN/m²(compression)
The highlighted area shows maximum shear force in x direction at the edge of dam

Fig 2 -Shear force in y direction (sy) for case-2
The variation of shear force in Y direction is shown in this figure
Maximum Shear stress value=124.5kN/m²

Fig -3: Maximum absolute shear force for case-2

Absolute shear force concept comes under picture when a point is subjected to 3D sate of stress i.e. there are three planes xy,yz,zx. On plane xy there will be one maximum value of shear stress and same for other two planes so we will get three values of maximum stress. Out of these three the maximum value is called absolute shear stress

The value of eccentricity for no tension condition in the dam is B/6
The resultant of all forces that is Hydrostatic pressure, uplift pressure and self weight of the dam should always lies within the middle third of the base for no tension when e>B/6 the value of stress intensity at top and heel are positive that is compression on both sides
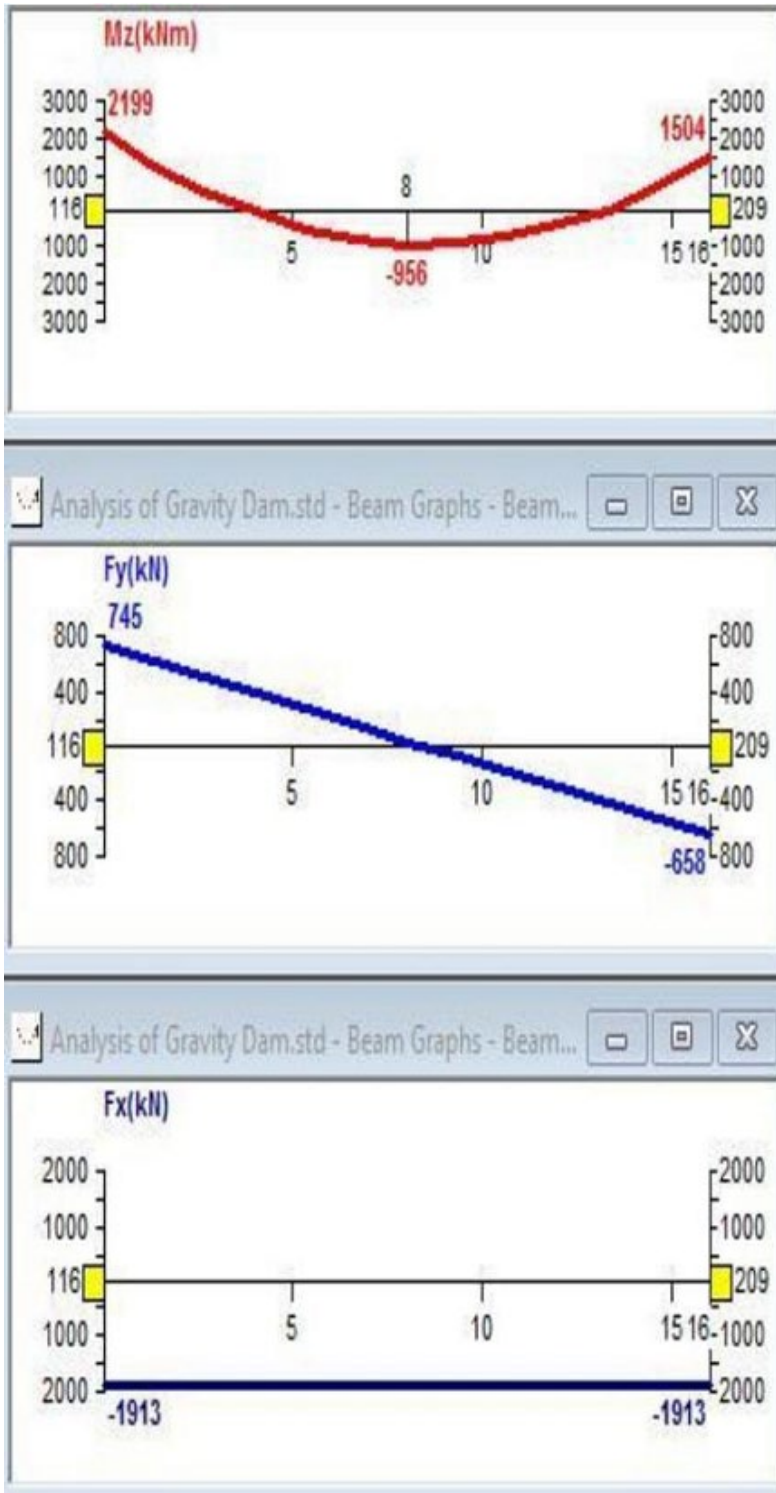
Fig-4: Bending moment diagrams with the respective values

Case 3:- **When the reservoir is half full**

W1 = 509021.28kN

W2 = 1431475.2kN

Water pressure:- (W1) = ρgh = 1000x 9.81 x 20m = 196200N/m = 196.2kN/m²

Total Pressure (Wp1) = 1/2 x 20 x 196.2 = 1962kN/m² Acts at 20/3 = 6.67m

Uplift pressure (Up):- At heel (Up1)=γxwxh =1000x9.81x20 =196.2kN/m²

At toe (Up2)=γwxh =1000x9.81x10 =98100N/m =98.1kN/m²

Over turning moment (Mw1) = 16644995.86kNm

Stabilizing moment (Mw2) = 29001687.55kNm

Mw1+Mw2=45646683.41

Opposing moment(Mw1')=196200x6.67=108654kNm

(Mup')=6525857.25

Factor of safety= 4564668.41/6525857.25 = 6.9972

Safe Sliding force/ Friction Ff=μn=0.7(509021.28+1431475.2) =1358347.536kN

Wp =196200kN

Factor of safety= 1358347.536/196200 = 6.9 > 1.5 Safe
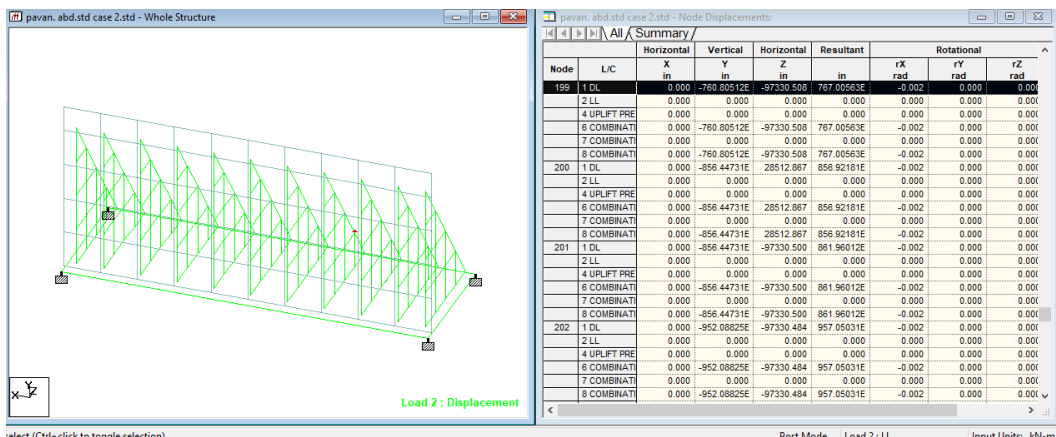
Fig 4: Deflection of dam in STAAD pro for case-3

Fig-5: Max absolute shear force for case-3
Value for absolute shear force for case-3= 202×10^3N
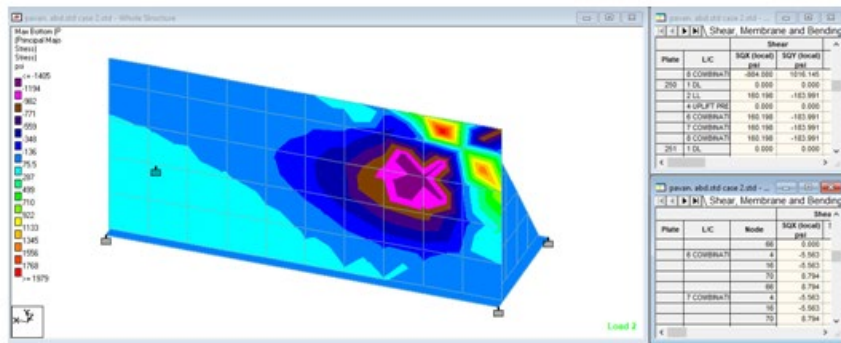
Fig 6: Major principle stress for case-3
Value of major principle stress for case 3 = 939.139 kN/m²

Tables and results

Table 1: Self weight and water pressures values

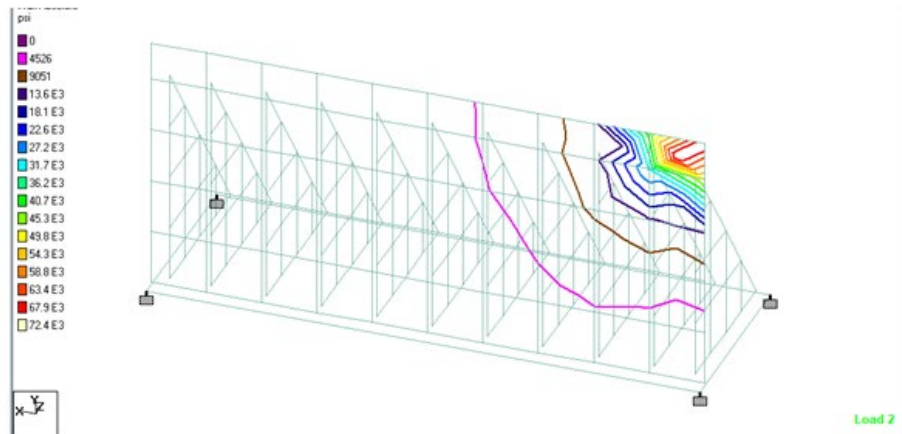| Sl.no	force	Horizontal force	Vertical force
1	Self-weight M1		509021.28
	M2		1431475.2
2	Water pressure W	748400	
3	Uplift pressure, at heel		-396.2
	At toe		-98.1
4	Silt pressure	-180	

Table 1

Sl.no	force	Horizontal force	Vertical force
1	Self-weight M1		509021.28
	M2		1431475.2
2	Water pressure W	196200	

3	Uplift pressure, at heel		-196.2	4	Silt pressure	-180	
	At toe		-98.1		Table 2		

Section Properties

Prop	Section	Area (cm²)	I_{yy} (cm⁴)	I_{zz} (cm⁴)	J (cm⁴)	Material
2	Rect 0.30x0.20	600.000	20E 3	45E 3	47E 3	CONCRETE

Plate Thickness

Prop	Node A (cm)	Node B (cm)	Node C (cm)	Node D (cm)	Material
1	25.000	25.000	25.000	25.000	CONCRETE

Materials

Mat	Name	E (kN/mm²)	Density (kg/m³)	(1/°K)
3	STEEL	205.000	7.83E 3	12E -6
4	ALUMINUM	68.948	2.71E 3	23E -6
5	CONCRETE	21.718	2.4E 3	10E -6

Supports

Node	X (kN/mm)	Y (kN/mm)	Z (kN/mm)	rX (kN m/deg)	rY (kN m/deg)	rZ (kN m/deg)
6	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
9	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
18	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

Plate Loads : 2 LOAD CASE 2

Plate	Type	Direction	Fa	Fb	X1 (m)	Y1 (m)	X2 (m)	Y2 (m)
75	TRAP N/mm2	Z	0.015	0.004	-	-	-	-
79	TRAP N/mm2	Z	0.004	0.004	-	-	-	-

Node Displacements

Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
2	1:LOAD	9.736	3.598	-0.360	10.386	0.000	0.017	-0.005
	2:LOAD	1.135	0.302	0.055	1.176	-0.000	0.003	-0.001
3	1:LOAD	117.273	1.943	-1.380	117.297	-0.000	-0.003	-0.002
	2:LOAD	23.175	0.211	-0.324	23.178	-0.000	-0.001	-0.000
4	1:LOAD	116.193	2.379	3.698	116.276	0.001	-0.003	-0.010
	2:LOAD	22.799	0.237	0.728	22.812	0.000	-0.001	-0.002
5	1:LOAD	9.912	1.855	-1.300	10.168	0.001	-0.002	-0.005
	2:LOAD	1.105	0.096	-0.180	1.124	0.000	-0.000	-0.001
6	1:LOAD	0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000
	2:LOAD	0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000
9	1:LOAD	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
	2:LOAD	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000

Results-:
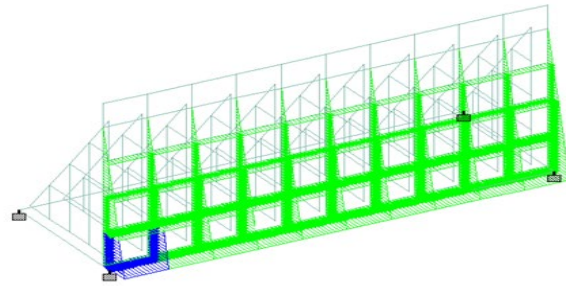
Fig1: Design of Loads case 2
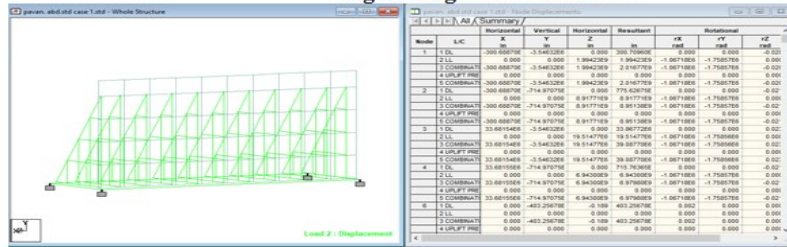
Plate Loads : 2 LOAD CASE 2

Plate	Type	Direction	Fa	Fb	X1 (m)	Y1 (m)	X2 (m)	Y2 (m)
75	TRAP N/mm2	Z	0.015	0.004	-	-	-	-
79	TRAP N/mm2	Z	0.004	0.004	-	-	-	-

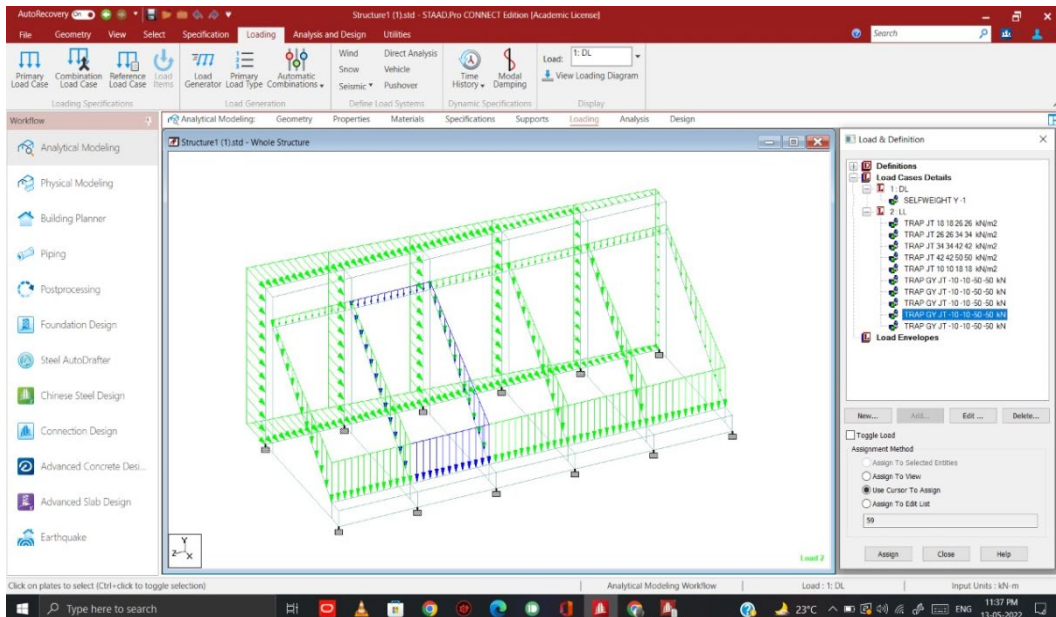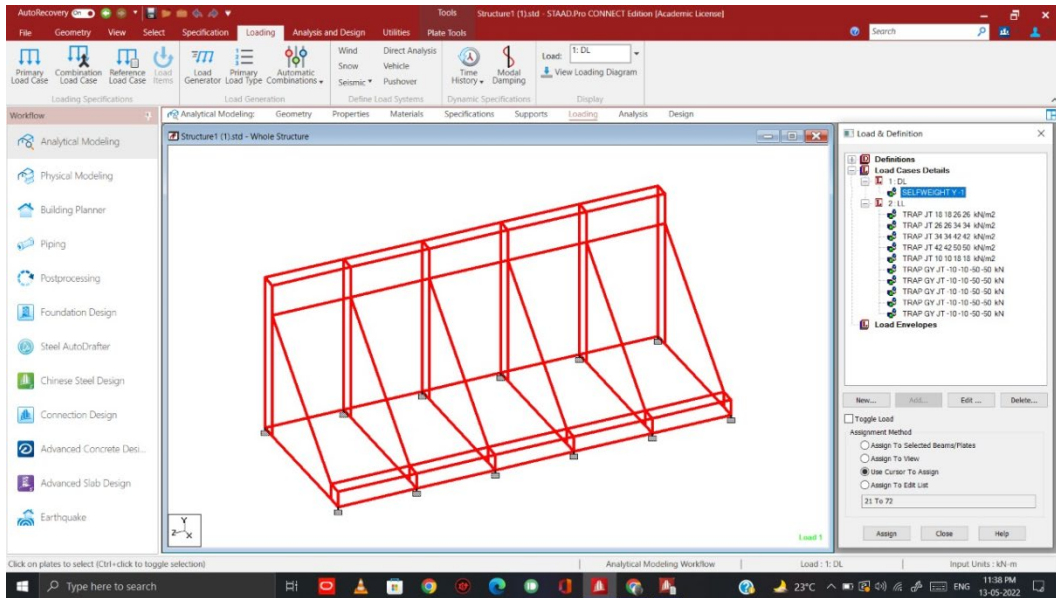**Fig:** Section Properties, Material, plate thickness

Fig2: Deflection of dam in STAAD pro for case-2

44

Fig 3: Load Combination on Dam

CHAPTER 6
CONCLUSION

- Stress distribution revels maximum normal vertical stress pf 2414 KN/m² (compression), 65.8 KN/m² Tension and maximum shear stress value of 674.7 KN/m2 (compression), 124,5 KN/m² tension these values are less than the permissible stress values

- Total number of 930 elements and 2929 nodes are used

- Shear friction factor, safety against overturning and sliding are 1.78,1.1 and 3.78 which are safe

- Maximum horizontal and vertical crest displacement are 2.74mm and 3.8 mm

- Gravity dam behavior for stability and response to seismic forces is read in this paper. By considering the problem, analyzing the stability of the gravitational dam is done without the seismic force initially. The analysis therefore highlighted that where there are various loads such as dead load, water / hydrostatic pressure, height pressure, accumulated values of good and bad times

- The reduction of horizontal force and standing contributes to the stability of the dams. Continuing with the analysis it is clear that the resulting moment of survival acts as an opposing moment against the moment produced due to water, high pressure etc. This means that stability against the coup is achieved when a good moment is greater than a bad moment. Although stability against slipperiness depends on the coefficient of friction

- The sum of all direct and indirect forces is horizontal. Therefore, the slide is dominated by high pressure. However, when the horizontal force increases the stability against the slide it decreases when the vertical force remains approximately the same. Thirdly the stability of the dam is based on the shear friction factor, this depends on the coefficient of friction, the sum of all vertical forces, the sum of all the horizontal forces, the geometry of the dam and the shear strength. In the same shear strength problem, the geometric collision remains unchanged, so stability must depend on the value of all direct and indirect forces. With the problem considered in the study, the dam gains stability.

Future Scope

In addition to the current analysis conducted using Staad Pro V8i there are some other developmental features that can be considered for further research:

(i) The degradation of concrete strength over the years may lead to the formation of cracks. Research into the formation and distribution of cracks may be performed to predict the indirect behavior of the dam. The inclusion of non-linear compounds in both isotropic and anisotropic compounds may be the subject of further research.

(ii) The current model does not take into account the thermal pressure caused by hydration concrete which may affect the aging of the dam. (iii) The current problem may be extended to a 3-dimensional form by the proper installation of the radiation boundary condition in place of the infinite dam.

(iii) (iv) The current problem may be extended to study the impact of the dam base fluctuations taking into account soil structure interactions in order to obtain a more accurate conduct of the integrated system. More accurate behavior can be achieved if the combined effect of the foundation-dam-reservoir interaction is considered.

References

[1] Badanapuri .V.R - 2018 - Seismic Forces and Stability Analysis of Gravity Dam - International Journal of Science and Research (IJSR) -Analysis and Design Practice of Hydraulic Concrete Structure - ISSN: 2319-7064 Research Gate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

[2] Naidu. G.G , Sree Sai .S- 2019- Stability Analysis of Gravity Dam by Using STAAD Pro in Time History Method- International Journal and Magazine of Engineering ,Technology ,Management and research ISSN:2348-4845 volume no:4(2019),Issue 3(march)

[3] Mettal .D - 2017 - Integrated Analysis of a Dam structure using analysis tool staad.pro- International Journal of Scientific Research in Civil Engineering
 2017 IJSRCE | Volume 4 | Issue 5 | ISSN: 2456-6667

[4] Mathur .N.M- 2020 - Integrated Analysis of a Dam structure using analysis tool staad.pro- International Journal of Scientific Research in Civil Engineering - e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 2 Ver. VIII (Mar. - Apr. 2020), PP 35-39

[5] BIS IS12966 -1990 (Part 1), "Practice for Galleries and different Openings in Dam, New Delhi, Bureau of Indian Standards, New Delhi

[6] BIS IS6512-1984,"Criteria for style of Solid Gravity Dam, Bureau of Indian Standards , New Delhi, UDC 627.824.7.04

[7]Dowd,RichardM. "Leaking undergroundstoragetanks." *Environmental Science & Technology* 18, no. 10 (1984): 309A-309A.

[8]S. Pollock, Accelerated corrosion of UST equipment (an ethanol hangover), in: 23rd National TankConference,StLouis,19-21March,2012.

[9]J.W. Sowards, E. Mansfield, Corrosion of copper and steel alloys in a simulated underground storage-tanksumpenvironmentcontainingacid-producingbacteria,CorrosionScience,2014.doi:http://dx.doi.org/10.1016/j.corsci.2014.07.009

[10]J.S.Kim,D.H.An,S.Y.Lee,B.Y.Lee,Afailureanalysisoffilletjointcrackinginanoilstoragetank,
J.LossPreventProc,vol.22-6,p.845,2009.

[11]V.P.McConnell,Globalunderground:thestateofcompositestoragetanks,in:ReinforcedPlastics,vol.51(6),p.26-31,2007.·

[12]F.Trebuiia,F. Simcak, J.Bocko,Failure analysisof storagetank,Eng Fail Anal, vol.16, p. 26-38,2009.

[13]B.M.Das,Seepageforceperunitvolumeofsoilmass,in:AdvancedSoilMechanics, 2ndEd.,TaylorandFrancis,1997.

[14]T.W. Lambe, R.V. Whitman,Soil with water,no flow orsteady flow, one-dimensional fluid flow, SoilMechanics,1stEd.,John Wiley&SonsInc.,1969.

[15]Sowards, Jeffrey W., and Elisabeth Mansfield. "Corrosion of copper and steel alloys in a simulated underground storage-tank sump environment containing acid-producing bacteria." *Corrosion science* 87 (2014): 460-471.

[16]Sheng, Ooi Ching, Wai KengNgui, Hui Kar Hoou, Lim Meng Hee, and Mohd Salman Leong. "Review of underground storage tank condition monitoring techniques."

In *MATEC Web of Conferences*, vol. 255, p. 02009. EDP Sciences, 2019.
[17]Chang, James I., and Cheng-Chung Lin. "A study of storage tank accidents." *Journal of loss prevention in the process industries* 19, no. 1 (2006): 51-59.

[18]Sacile, Roberto. "Remote real-time monitoring and control of contamination in underground storage tank systems of petrol products." *Journal of Cleaner Production* 15, no. 13-14 (2007): 1295-1301.