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Integrated Analysis of a Dam structure using analysis tool staad.pro

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ABSTRACT

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Dams are constructed to store water in large capacity for future use. Due to large storage the loads acting over the upstream side of the dam are heavy and, during earthquakes, in addition to these load a huge loads act on it because of ground motions. It may results in the failing of structure and thereby resulting in loss of life, social, economic and environmental crisis. The seismic vibration created at the time of earthquake must be minimized by proper application of engineering principles and so it is necessary to determine the behaviour of concrete gravity dam in the same basis. The dynamic analysis with Response spectrum method and time history method are the efficient ways to analyze the dam. In this paper, time history method is used to study the seismic behavior, the stability of gravity dam and considering hydrostatic pressure and soil interaction. To determine stresses induced due to medium type of soil condition with bearing capacity of 160 KN/m2. It is done by using STAAD-PRO. According to the Indian standard code of practice, comparative analysis is carried in between RCC dam and earthen dam have been analyzed on various parameters and the results obtained are compared, to determine the structural performance of concrete gravity dam. The effect of some parameters which influences the seismic performance and loading patterns are to be investigated.

Keywords : Gravity dam, Dynamic Analysis, water pressure, static condition, STAAD-PRO.

I. INTRODUCTION

Concrete gravity dam is coined as a structure designed in such a manner that it is capable to resists the external forces using its own weight. It is the weight of a gravity dam which encrypts it from being overturned when exposed to the thrush of appropriated water. Such kind of structure is solid and requires next to no support. Gravity dams normally comprise of a non-flood section(s) and a flood area or spillway. The two general solid development techniques for solid gravity dams are customarily positioned mass cement and RCC. Gravity dams, developed in stone brickwork, were assembled even decades back, frequently in Egypt, Greece, and the Roman Empire.

Concrete gravity dams are on the favoured end in a current period and for the most part, built. They can be developed effortlessly on any dam site, where there exists a characteristic establishment sufficiently able to tolerate the tremendous load of the dam. Such a dam is commonly square in plan, albeit at times, it might be somewhat bent. The line of the upstream substance of the dam or the line of the crown of the dam if the upstream face in inclining is taken as the reference line for design purposes, and so on and is known as the "Pattern of the Dam" or the "Pivot of the Dam". At the point when appropriate conditions are accessible, such dams can be developed up to extraordinary statures. The proportion of base width to the stature of high gravity dams is commonly under 1:1. Be that as it may, the previous dams are built with a proportion of 1.5 to 3. This is due to the low grade of concrete and low density of compaction achieved.

Engineers in India needs to pore cautious consideration towards the issue of seismic tremor stacking in the plan and assessment of practically all lasting structural building structures. The critical impacts brought about by tremors on dams are not just those straightforwardly identified with the seismic movements yet in addition those legitimately connected with the ground removal along the separation point. In the nation with 5,100 huge dams and 1,040 dynamic flaws covering 57% of landmass making inclined to tremors, there is consistently a likelihood that a serious quake in profoundly seismic zones may influence the exhibition of the dam. In any case, investigating the dam for seismic powers is anything but a straightforward issue. Like all other structure, solid gravity dam requires nonlinear, dynamic and probabilistic examination to assess the inner powers because of seismic stacking.

It isn't generally conceivable to acquire thorough scientific answers for the designing issue. A diagnostic arrangement can be acquired uniquely for certain disentangled circumstances. For the Problems including complex material properties, loading and limit conditions, the specialist presents suspicions and admiration esteemed important to make the issue scientifically sensible, yet at the same time fit for giving adequately inexact arrangements and the acceptable outcomes from perspective of security and economy. The connection between the genuine physical framework and the numerically possible arrangement is given by the scientific model which is the emblematic assignment for the substitute glorified framework including all the assumptions imposed on the physical problem.

Dynamic investigation of Buildings and Dams are extremely unpredictable phenomena. To comprehend this perplexing wonder, we utilize scientific modular including all the suspicions forced on the physical issue. In any case, in contrast to building and different structures, there is no improved standard methodology to investigate solid gravity dam for seismic stacking. This is the basic inspiration for the current investigation.

In this examination, we have contrasted a solid Dam and Gravity earthen dam for the equivalent hydraulic pressure with seismic load considering soil cooperation with medium kind soil utilizing investigation apparatus staad.pro.

Soil Structure Interaction

The examination of soil-structure communication (SSI) is related to the field of quake planning. It is basic to observe that the fundamental response is generally a result of the dirt structure association controls that speed up an impact of the structure. This is a type of seismic excitation.

The soil-structure interaction can be defined as the process in which the response from the soil influences the motion of the structure and the motion of the given structure affects the response from the soil. This is a phenomenon in which the structural displacements and the ground displacements are independent to each other.

Soil-structure force are mainly interaction forces that can occur for every structure. But these are not able to change the soil motion in all conditions.

Condition considered for soil-structure interaction effects are the soil flexibility. Softer is the soil, more is the chances for the occurrence of SSI effects. This is for a given structure and a site that have a free -field seismic excitation.

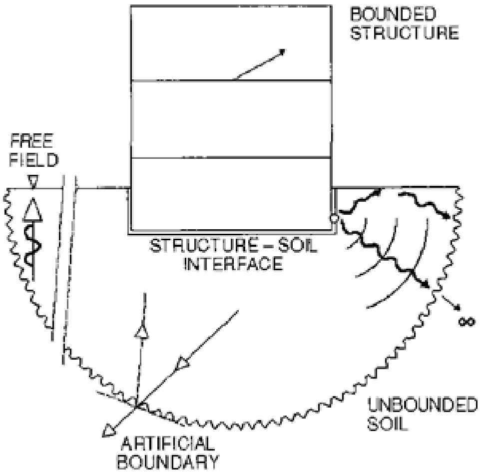


Fig 1: Soil Interaction

Objectives of the study

The primary objectives of this study is as follows:

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 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/m^2.

II. LITERATURE REVIEW

Deepika M et al (2017) This paper presented time history method for presenting the seismic behavior and firmness of a gravity dam. The designing and analysis of the model was done using the application Staad.Pro v8. As per the Indian standard code of training, the dynamic examination was done for a dam with various statures as 70m, 80m and 120m have been dissected and the outcomes acquired were analyzed, to decide the basic execution of solid gravity dam. The impact of certain parameters which impacts the seismic presentation, height of dam and loading designs were researched.

From the outcomes, it was inferred that the most extreme total pressure esteems (14.5N/mm2)for 120mdam was sensible in contrast with other considered dam models. Be that as it may, there was no huge gigantic contrast between 90mdam's qualities (14.2N/mm2). The creator considered most extreme and least chief burdens (6.97N/mm2, 0.893N/mm2)90m dam was productive when contrasted with the other two dams. The shear pressure values (0.259N/mm2, 0.372N/mm2) for 80m dam was better as look at 90m and 120m dams. At long last, the dynamic qualities for various statures of the dam the 90m dam recurrence, period, mass interest was sensible than another dam.

The principle advantage was pressure variety through the dam body and the inclines could be structured by the pressure design. Thusly, while contrasting these three distinct statures of the dam, the 90m dam was discovered more proficient than others.

Shou-yan JIANG and Cheng-bin DU (2015) the research paper examined considering parameters such as Geometric nonlinearity and large deformations along with the contact condition at the crack site. The area of infiltrated splits was first recognized utilizing the solid plastic-harm model dependent on the nonlinear limited component technique (FEM). At that point, the hard contact calculation was utilized to reproduce the break connection the typical way, and the Columb grinding model was utilized to recreate the split association in the distracting bearing. After evaluating numerical models through contextual analysis, the seismic soundness of the Koyna Dam with penetrated cracks was further described with different seismic peak accelerations, and the breakdown procedures of the broke dam were even displayed. The outcomes exhibited that the solidness of the dam with two kinds of entered splits can be guaranteed in a quake with a greatness of the first Koyna seismic tremor, and the broke dam has a huge seismic tremor safe edge. The disappointment procedures of the broke dam in solid seismic tremors could are isolated into two phases: the sliding stage and the toppling stage. The sliding stage finishes close to the pinnacle speeding up, and the top square slides a long separation along with the split before the breakdown happens. The most extreme sliding removal of the top square will diminish with an expanded grinding coefficient at the split site.

The outcomes showcased, the steadiness of the dam could be improved with an expanding interlayer erosion coefficient, since a higher grating coefficient can forestall the slide of the top square. The peak sliding removal of the conceivable slide square abatements with the expansion of the erosion coefficient at the split site. Because of seriously nonlinear properties at the crack site, the pinnacle joint opening increments with the split erosion coefficient just when the grinding coefficient was under 0.8. At the point when the grating coefficient was more noteworthy than or equivalent to 0.8, the opening marginally shifts.

Manoj Nallanathel et al (2018) 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 moment and negative moment, the summation of level and vertical forces were answerable for dam steadiness. The investigation further expressed that moment derived about because of self-weight go 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 sliding reductions if vertical 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. For same issue material shear quality, geometry grinding stays unaltered, consequently strength ought to rely on whole of every single vertical forces and every level forces.

Methodology

Step 1: To prepare a literature survey related to our study.

Literature Survey was prepared for the past study undertaken till date and shortcomings were identified on which further research needs to be executed. This step further dealt with presenting the application of concrete dam in various industries and its future prospects of general applications in various other industries.

Step 2: To prepare geometrical structure of the study using analysis tool STAAD.Foundation

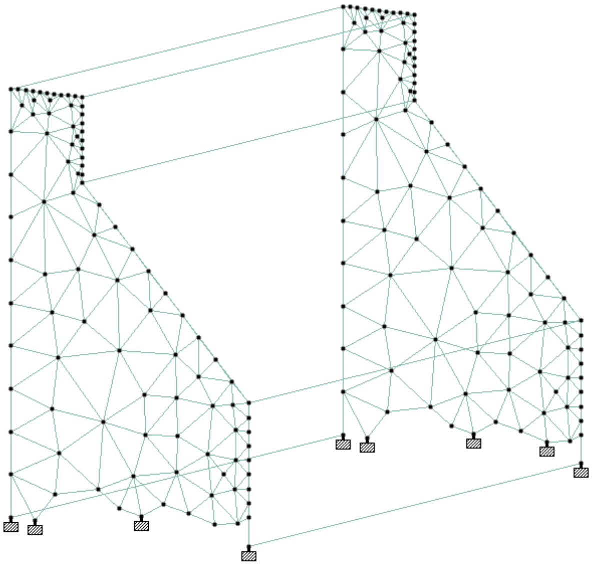


Fig 2 Modelling of Dam using Staad wizard

STAAD or (**STAAD.Pro**) is a structural analysis and design software application originally developed by Research Engineers

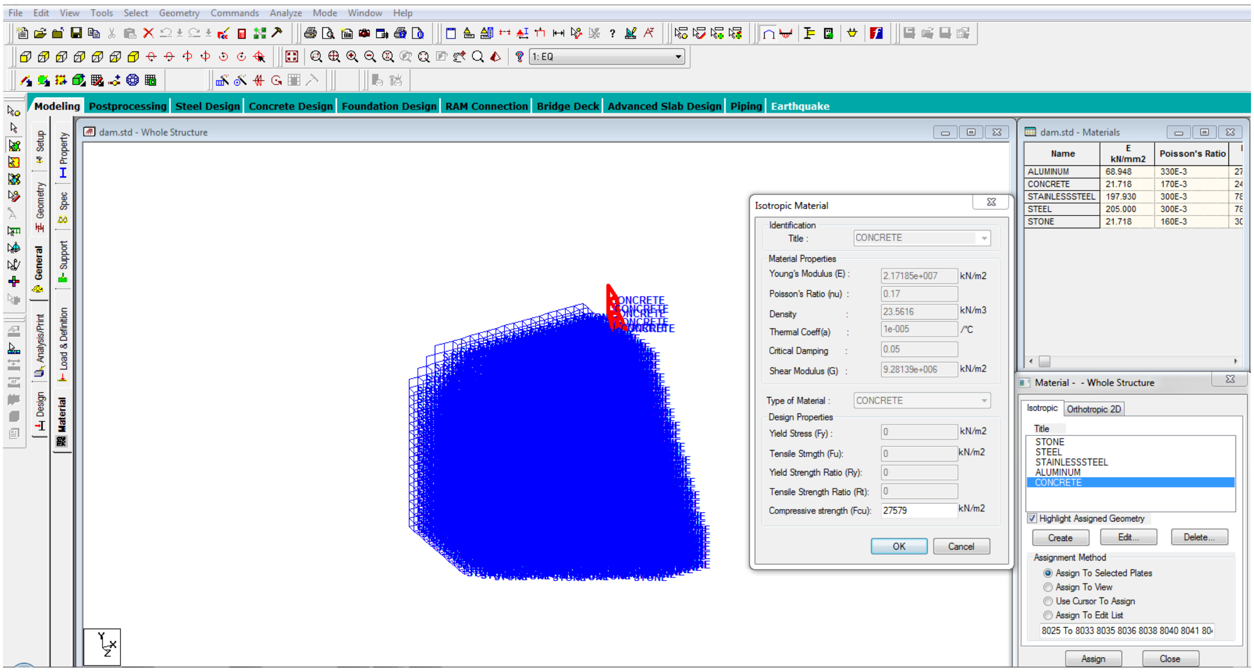
International in 1997. In late 2005, Research Engineers International was bought by Bentley Systems.

STAAD.Pro is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber & aluminium design codes.

It can make use of various forms of analysis from the traditional static analysis to more recent analysis methods like p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis methods from time history analysis to response spectrum analysis. The response spectrum analysis feature is supported for both user defined spectra as well as a number of international code specified spectra.

Additionally, STAAD.Pro is interoperable with applications such as RAM Connection, AutoPIPE, SACS and many more engineering design and analysis applications to further improve collaboration between the different disciplines involved in a project. STAAD can be used for analysis and design of all types of structural projects from plants, buildings, and bridges to towers, tunnels, metro stations, water/wastewater treatment plants and more. Here we have use the application for modelling and analysis of Cooling Tower.

Step 3 To Assign and create sectional properties



dam.std - Materials

Name	E kN/mm2	Poisson's Ratio
ALUMINUM	68.948	330E-3
CONCRETE	21.718	170E-3
STAINLESSSTEEL	197.930	300E-3
STEEL	205.000	300E-3
STONE	21.718	160E-3

Isotropic Material

Identification
Title : CONCRETE

Material Properties
Young's Modulus (E) : 2.17185e+007 kN/m2
Poisson's Ratio (nu) : 0.17
Density : 23.5616 kN/m3
Thermal Coeff(a) : 1e-005 /°C
Critical Damping : 0.05
Shear Modulus (G) : 9.28139e+006 kN/m2

Type of Material : CONCRETE

Design Properties
Yield Stress (Fy) : 0 kN/m2
Tensile Strngth (Fu): 0 kN/m2
Yield Strength Ratio (Ry): 0
Tensile Strength Ratio (Rt): 0
Compressive strength (Fcu): 27579 kN/m2

OK Cancel

Material - - Whole Structure

Isotropic | Orthotropic 2D

Title
STONE
STEEL
STAINLESSSTEEL
ALUMINUM
CONCRETE

☑ Highlight Assigned Geometry

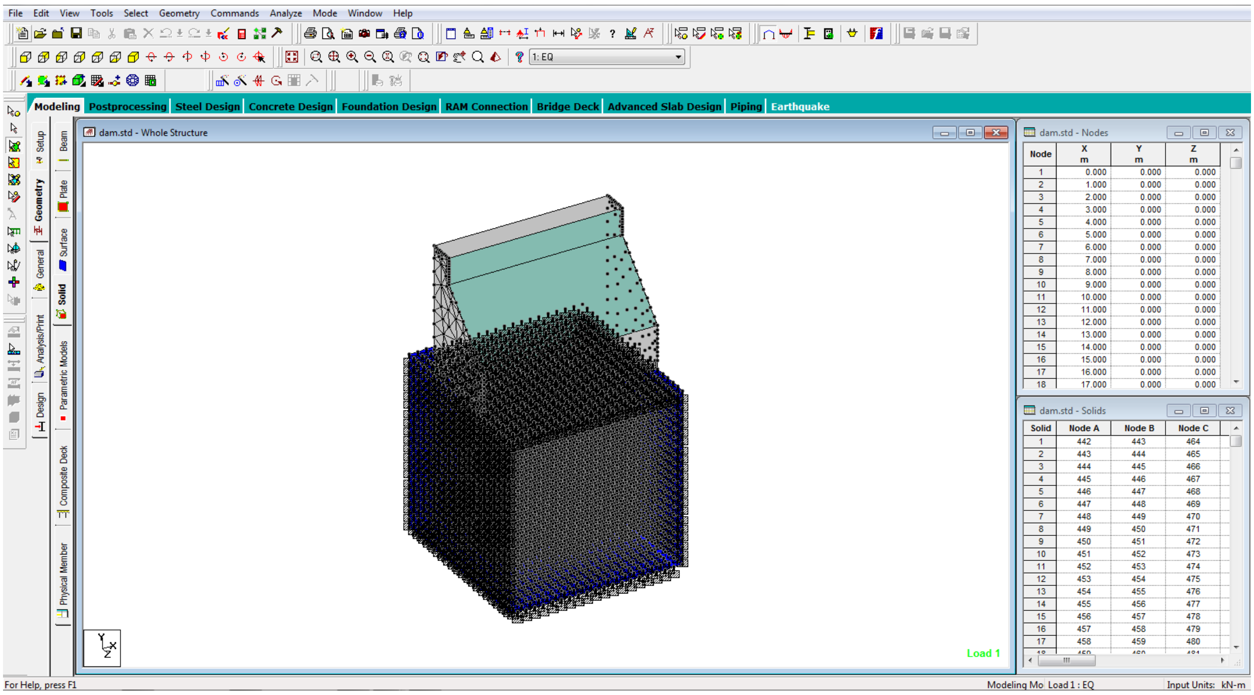
Create | Edit... | Delete...

Assignment Method
● Assign To Selected Plates
○ Assign To View
○ Use Cursor To Assign
○ Assign To Edit List
8025 To 8033 8035 8036 8038 8040 8041 80

Assign | Close

Fig 3 : Creating sectional properties

Step 4 To create soil mass of medium condition



dam.std - Nodes

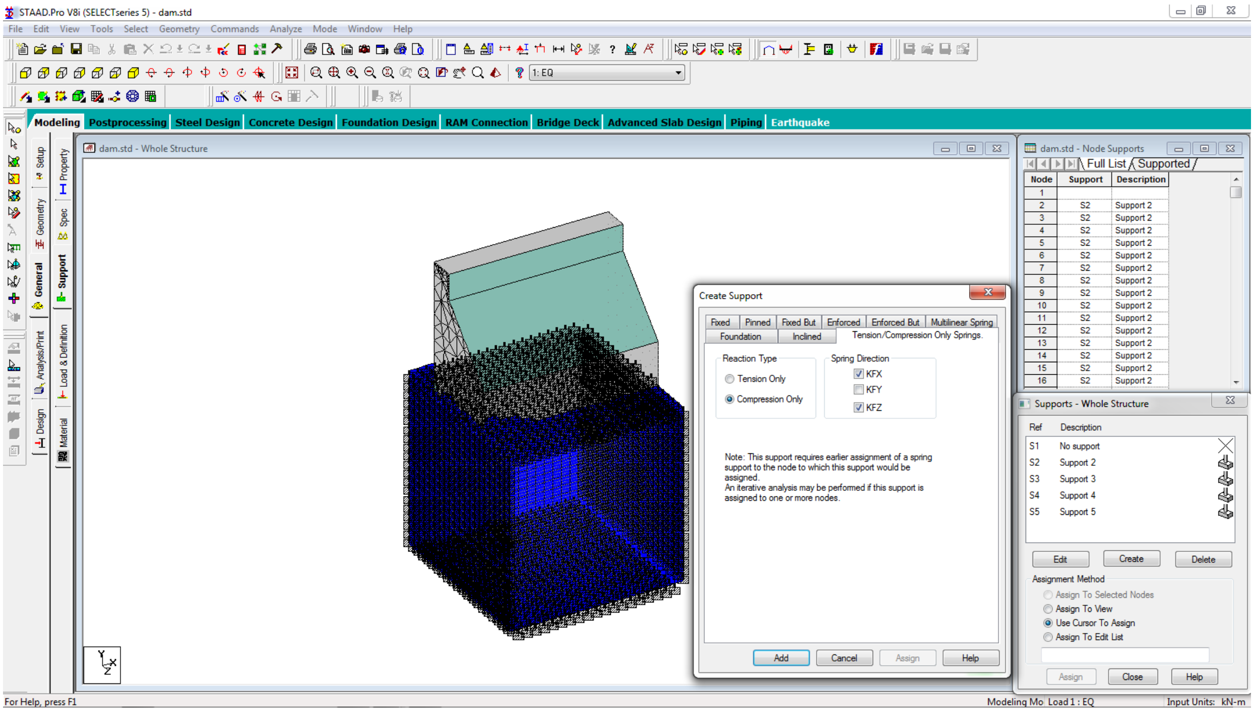
Node	X m	Y m	Z m
1	0.000	0.000	0.000
2	1.000	0.000	0.000
3	2.000	0.000	0.000
4	3.000	0.000	0.000
5	4.000	0.000	0.000
6	5.000	0.000	0.000
7	6.000	0.000	0.000
8	7.000	0.000	0.000
9	8.000	0.000	0.000
10	9.000	0.000	0.000
11	10.000	0.000	0.000
12	11.000	0.000	0.000
13	12.000	0.000	0.000
14	13.000	0.000	0.000
15	14.000	0.000	0.000
16	15.000	0.000	0.000
17	16.000	0.000	0.000
18	17.000	0.000	0.000

dam.std - Solids

Solid	Node A	Node B	Node C
1	442	443	464
2	443	444	465
3	444	445	466
4	445	446	467
5	446	447	468
6	447	448	469
7	448	449	470
8	449	450	471
9	450	451	472
10	451	452	473
11	452	453	474
12	453	454	475
13	454	455	476
14	455	456	477
15	456	457	478
16	457	458	479
17	458	459	480

Fig 4 : Assigning soil mass below dam

Step 5 Assigning springs at soil mass and support condition



dam.std - Node Supports (Full List / Supported)

Node	Support	Description
1		
2	S2	Support 2
3	S2	Support 2
4	S2	Support 2
5	S2	Support 2
6	S2	Support 2
7	S2	Support 2
8	S2	Support 2
9	S2	Support 2
10	S2	Support 2
11	S2	Support 2
12	S2	Support 2
13	S2	Support 2
14	S2	Support 2
15	S2	Support 2
16	S2	Support 2

Create Support — Tension/Compression Only Springs.

Reaction Type: ○ Tension Only ● Compression Only

Spring Direction: ☑ KFX ☐ KFY ☑ KFZ

Note: This support requires earlier assignment of a spring support to the node to which this support would be assigned.
An iterative analysis may be performed if this support is assigned to one or more nodes.

Supports - Whole Structure

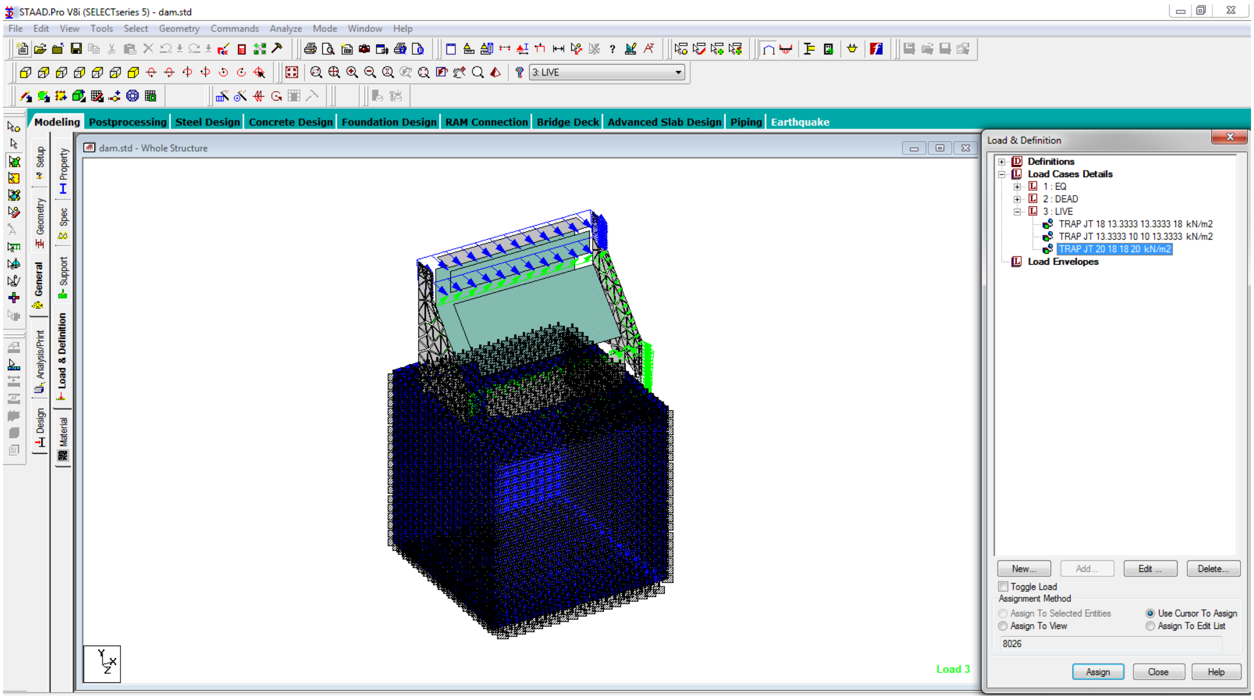
Ref	Description
S1	No support
S2	Support 2
S3	Support 3
S4	Support 4
S5	Support 5

Assignment Method: ○ Assign To Selected Nodes ○ Assign To View ● Use Cursor To Assign ○ Assign To Edit List

Fig 5 : Assigning springs and support

Step 6: Assigning hydraulic load condition on phase wall of Dam

Assigning hydraulic load calculated as per I.S. 3370 as hoop stresses and tension.

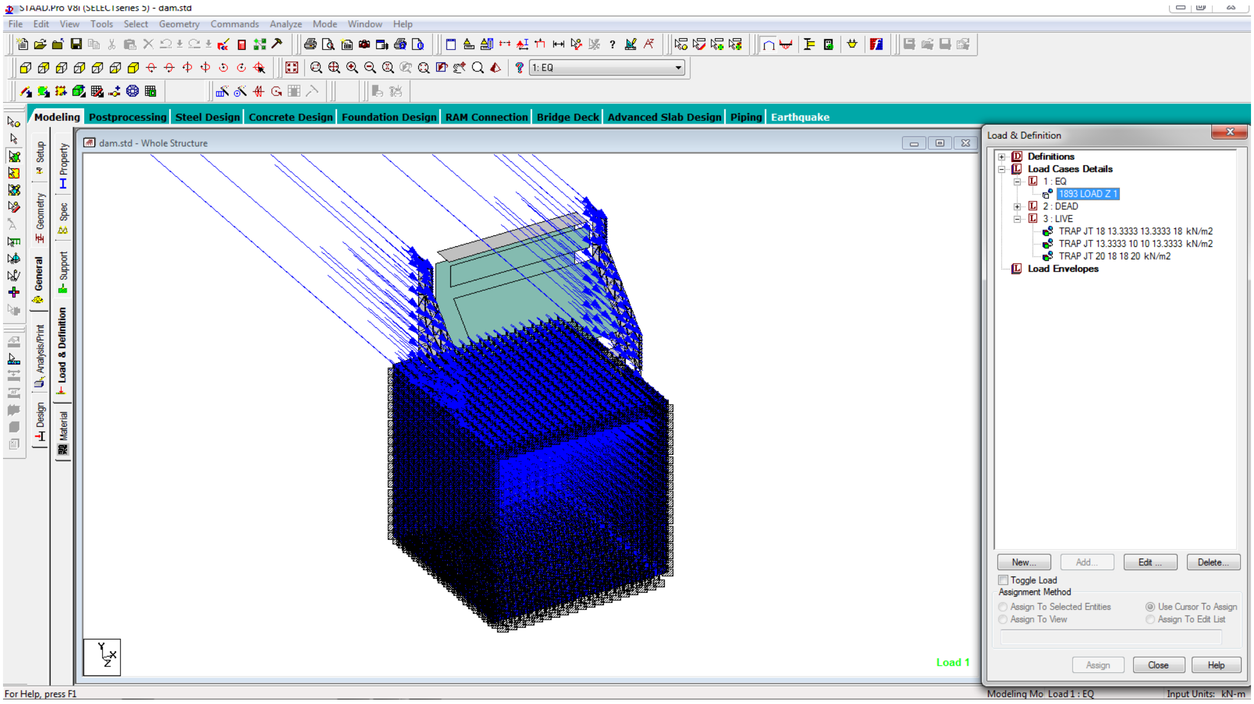

STAAD.Pro V8i (SELECTseries 5) - dam.std

Load & Definition

- Definitions
- Load Cases Details
  - 1 : EQ
  - 2 : DEAD
  - 3 : LIVE
    - TRAP JT 18 13.3333 13.3333 18 kN/m2
    - TRAP JT 13.3333 10 10 13.3333 kN/m2
    - TRAP JT 20 18 18 20 kN/m2
- Load Envelopes

Fig 6: Assigning hydraulic load on phase wall

Step 7: Assigning Seismic load as per I.S. 1893:1:2016


STAAD.Pro V8i (SELECTseries 5) - dam.std

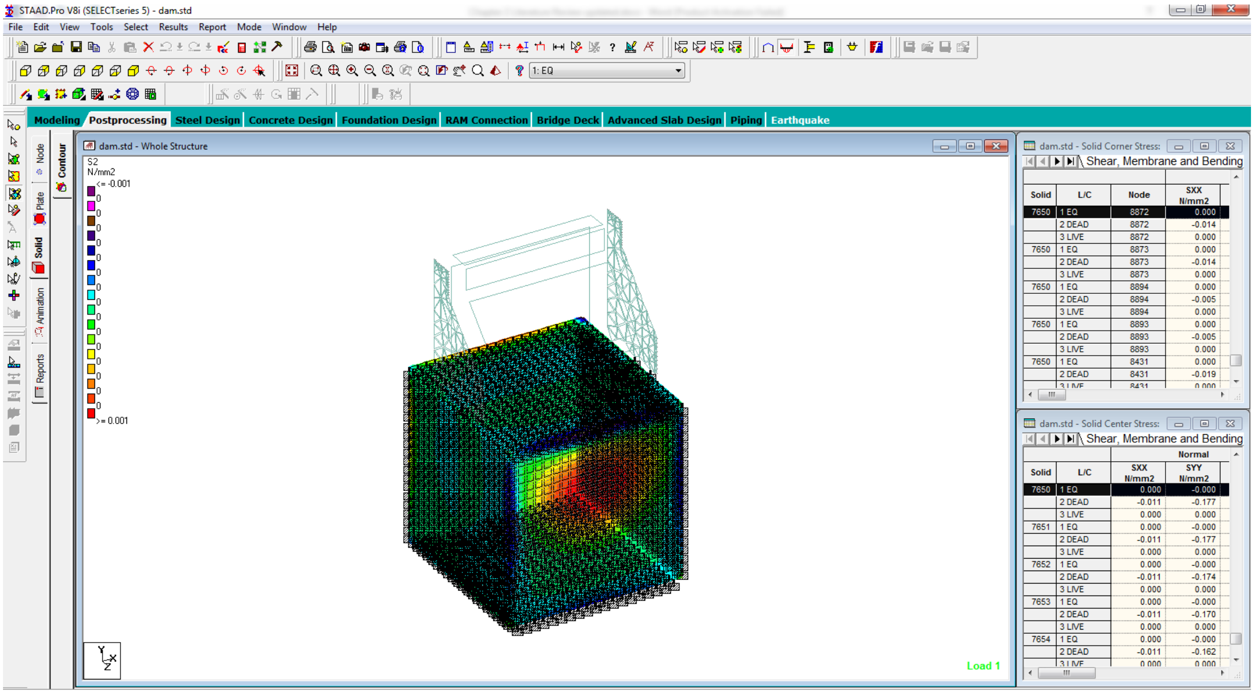
Load & Definition

- Definitions
- Load Cases Details
  - 1 : EQ
    - 1893 LOAD Z 1
  - 2 : DEAD
  - 3 : LIVE
    - TRAP JT 18 13.3333 13.3333 18 kN/m2
    - TRAP JT 13.3333 10 10 13.3333 kN/m2
    - TRAP JT 20 18 18 20 kN/m2
- Load Envelopes

Fig 7 : Assigning Seismic load

Step 8: Analysis for soil structure Interaction

Assigning soil mass at the bottom of dam structure shows the distribution of support reaction at the bottom of the structure and at soil mass results in development of stresses on the soil mass



dam.std - Solid Corner Stress: Shear, Membrane and Bending

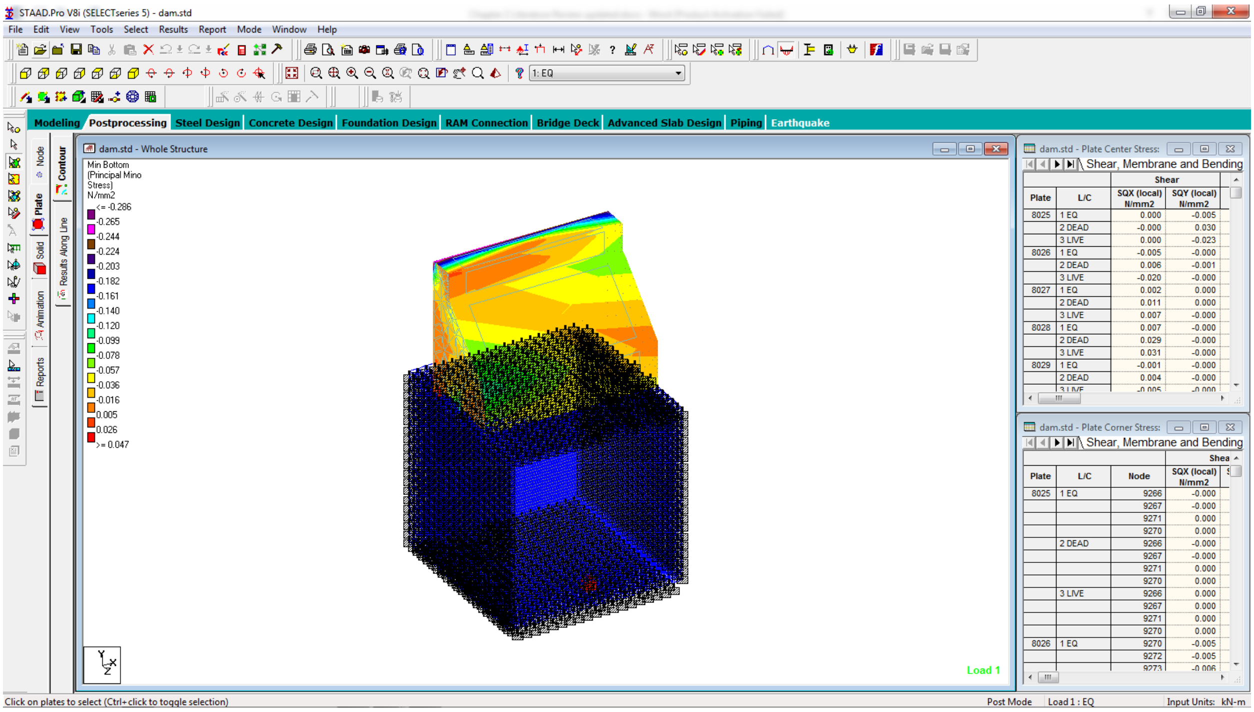
Solid	L/C	Node	SXX N/mm2
7650	1 EQ	8872	0.000
	2 DEAD	8872	-0.014
	3 LIVE	8872	0.000
7650	1 EQ	8873	0.000
	2 DEAD	8873	-0.014
	3 LIVE	8873	0.000
7650	1 EQ	8894	0.000
	2 DEAD	8894	-0.005
	3 LIVE	8894	0.000
7650	1 EQ	8893	0.000
	2 DEAD	8893	-0.005
	3 LIVE	8893	0.000
7650	1 EQ	8431	0.000
	2 DEAD	8431	-0.019
	3 LIVE	8431	0.000

dam.std - Solid Center Stress: Shear, Membrane and Bending

		Normal	
Solid	L/C	SXX N/mm2	SYY N/mm2
7650	1 EQ	0.000	-0.000
	2 DEAD	-0.011	-0.177
	3 LIVE	0.000	0.000
7651	1 EQ	0.000	-0.000
	2 DEAD	-0.011	-0.177
	3 LIVE	0.000	0.000
7652	1 EQ	0.000	-0.000
	2 DEAD	-0.011	-0.174
	3 LIVE	0.000	0.000
7653	1 EQ	0.000	-0.000
	2 DEAD	-0.011	-0.170
	3 LIVE	0.000	0.000
7654	1 EQ	0.000	-0.000
	2 DEAD	-0.011	-0.162
	3 LIVE	0.000	0.000

Fig 8 : Soil Interaction

Step 9: Analysis of structure



dam.std - Plate Center Stress: Shear, Membrane and Bending

		Shear	
Plate	L/C	SQX (local) N/mm2	SQY (local) N/mm2
8025	1 EQ	0.000	-0.005
	2 DEAD	-0.000	0.030
	3 LIVE	0.000	-0.023
8026	1 EQ	-0.005	-0.000
	2 DEAD	0.006	-0.001
	3 LIVE	-0.020	-0.000
8027	1 EQ	0.002	0.000
	2 DEAD	0.011	0.000
	3 LIVE	0.007	-0.000
8028	1 EQ	0.007	-0.000
	2 DEAD	0.029	-0.000
	3 LIVE	0.031	-0.000
8029	1 EQ	-0.001	-0.000
	2 DEAD	0.004	-0.000
	3 LIVE	-0.005	-0.000

dam.std - Plate Corner Stress: Shear, Membrane and Bending

			Shea
Plate	L/C	Node	SQX (local) N/mm2
8025	1 EQ	9266	-0.000
		9267	-0.000
		9271	0.000
		9270	0.000
	2 DEAD	9266	-0.000
		9267	-0.000
		9271	0.000
		9270	0.000
	3 LIVE	9266	0.000
		9267	0.000
		9271	0.000
		9270	0.000
8026	1 EQ	9270	-0.005
		9272	-0.005
		9273	-0.006

Fig 9 : Analysis of the structure with soil mass

Geometrical Data

Table 1 Details of Parameter

SR .NO.	PARAMETER	SIZES
1	Height of the dam	15 m
2	Length at the Bottom	20 m
3	Length at the Top	20 m
4	Width at the Bottom	10 m
5	Width at the Top	2 m (Stem)
6	Soil Mass	50 x 50 x 50 m

Table 2 Details of Material Used in the Project

SR.NO.	PARAMETER	DESCRIPTION
1	CONCRETE	M20
2	REBAR	FE 500
3	Modulus of Elasticity	1.95xE5 MPa
4	Ultimate Tensile Strength	1860 MPa
5	Soil type	Medium
6	Soil bearing capacity	160 kN/m^2
7	Soil Density	18.5 KN/m^2

III. Analysis Result

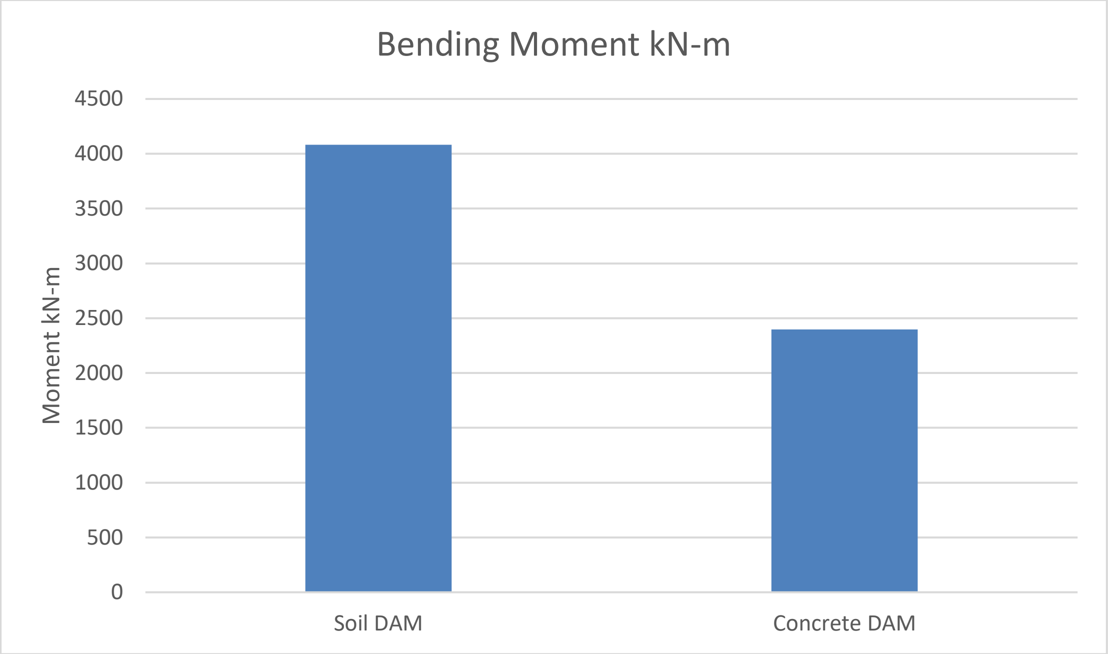


Fig 10: Bending Moment

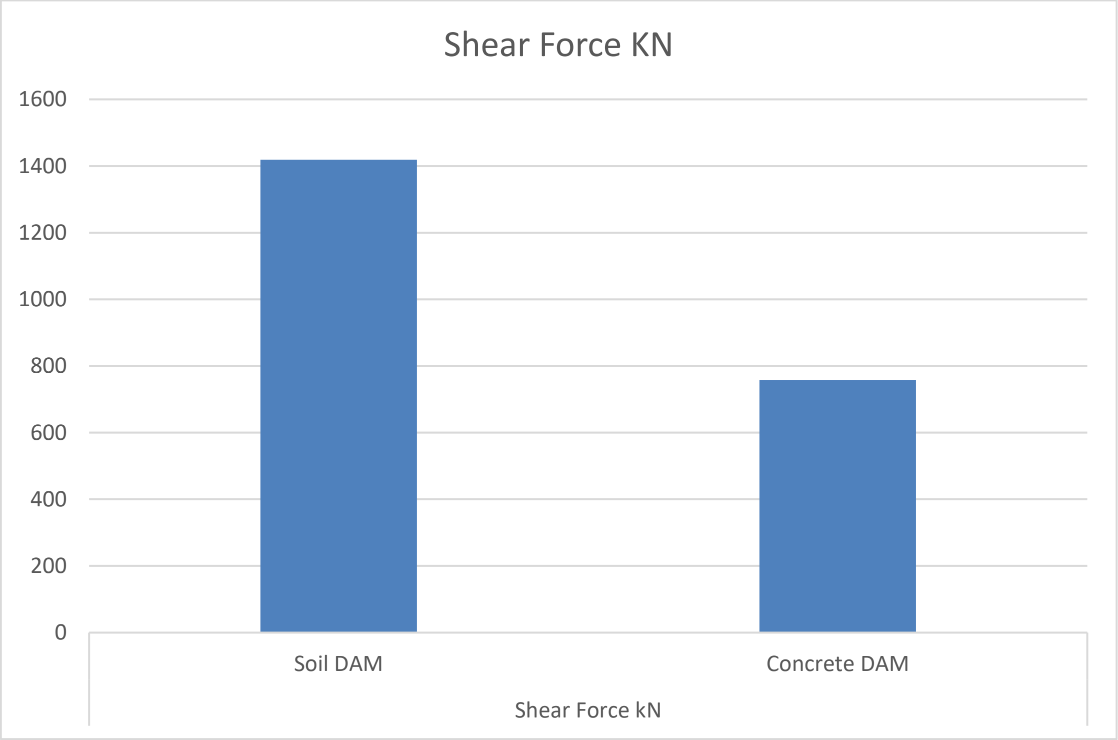


Fig 11: Shear Force

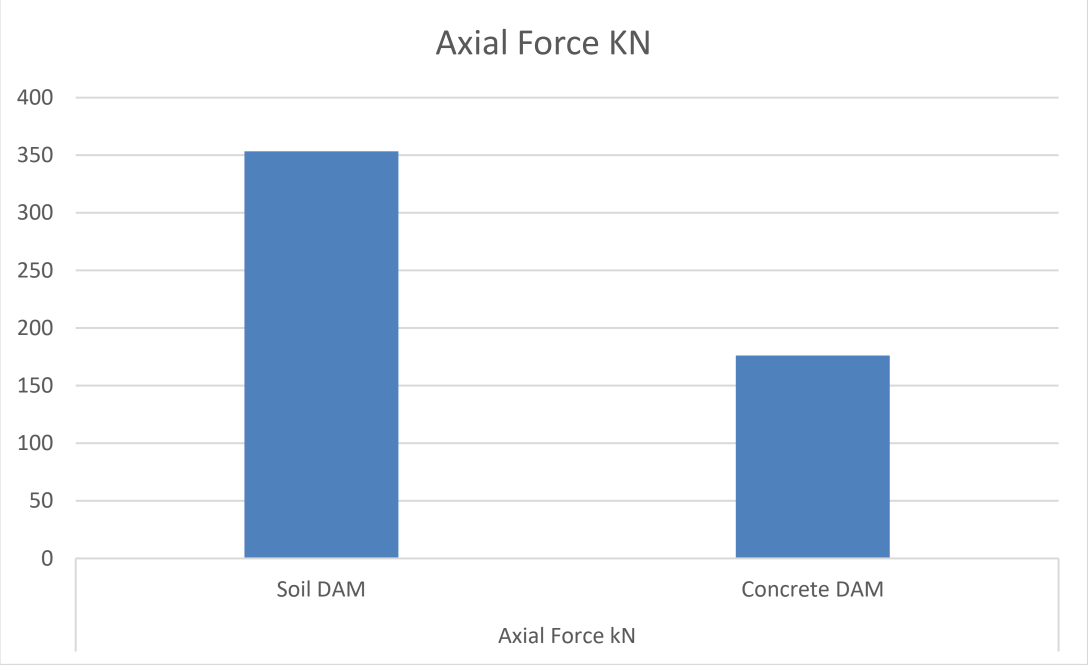


Fig 12: Axial Force

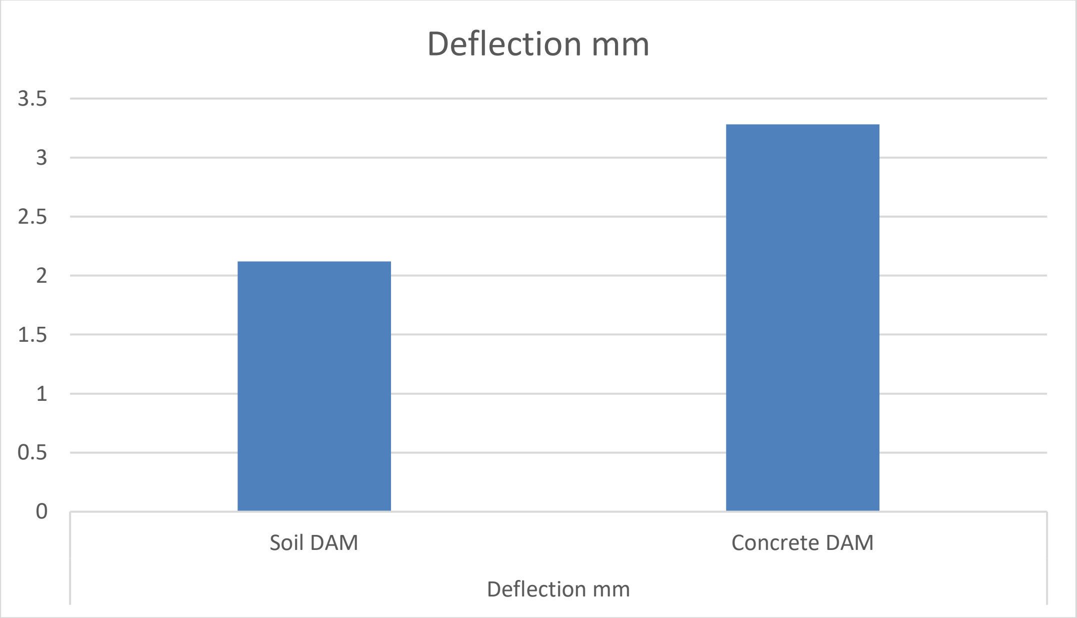


Fig 13: Deflection

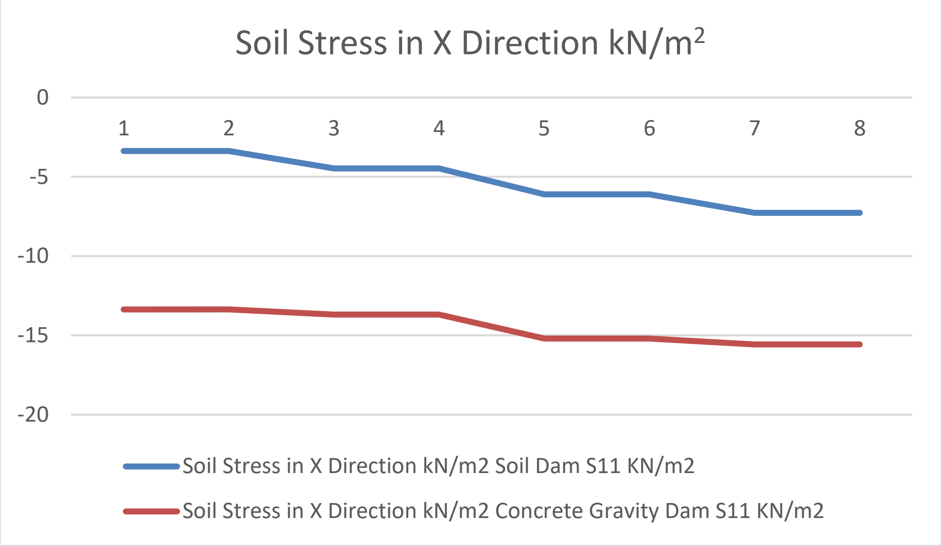


Fig 14: Soil Stress in X Direction

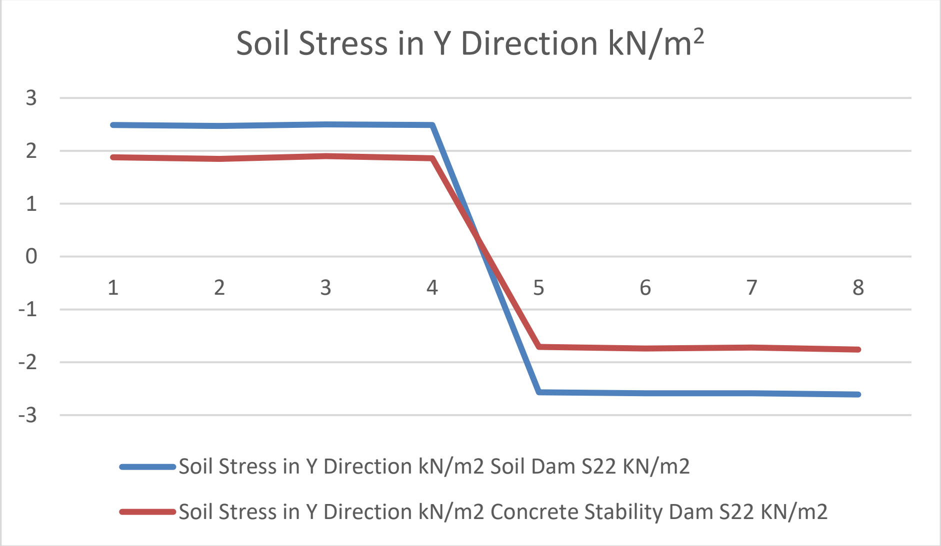


Fig 15: Soil Stress in Y Direction

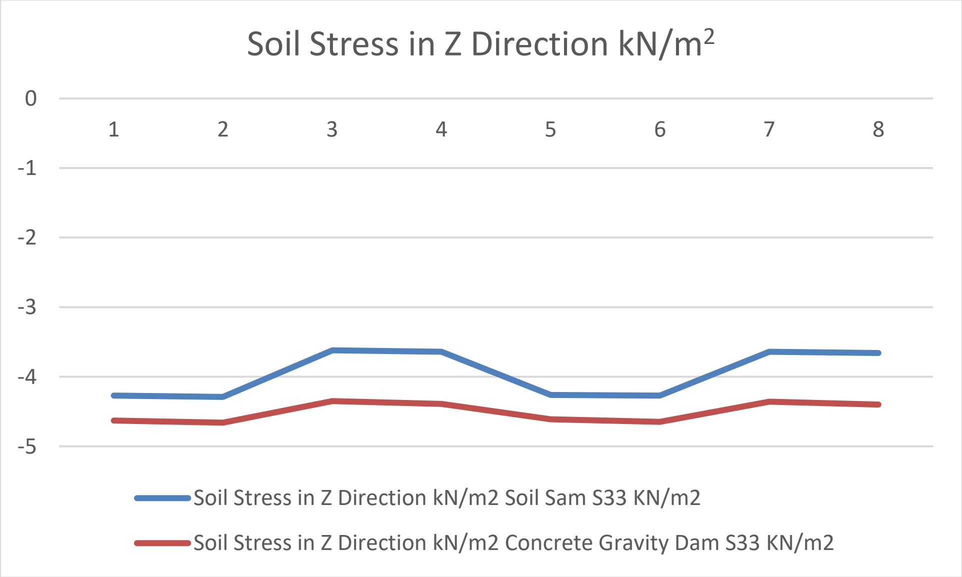


Fig 16: Soil Stress in Z Direction

CONCLUSION

Shear Force

Shear force in known as the unbalance force observed due to interaction of hydrostatic pressure at wall continuously, in our study it is observed that with concrete dam it can be minimized in all the cases considered for study.

Axial Force

Axial force is known as the vertical force observe in bottom, this force is meant to distribute load from structure to earth. It is observed in the results that with concrete dam Distribution of vertical forces can be processed easily.

Bending Moment

In terms of bending moment it is observed that minimum bending is in concrete dam, which is resulting in comparatively most economical in comparison, as bending moment is directly proportional to reinforcement requirement.

Deflection

In case of deflection we observed that maximum deflection is obtained in Soil dam as compared to concrete dam due to stability of concrete mass.

Base Analysis

With problem consideration, the stability analysis of gravity dam is done in absence of seismic forces initially. Thus analysis highlighted that in presence of various loads like dead load, water/ hydrostatic pressure, uplift pressure, total cumulative values of +ve moment and -ve moment, summation of horizontal and vertical forces are overall responsible for dam stability. Further with analysis it is clear that moment resulting due to self-weight act as resistive moment against moment produced due to water, uplift pressure etc. Which means that stability against overturning is achieved when +ve moment is greater than -ve moments. Whereas stability against sliding depends upon coefficient of friction, sum of all vertical forces and all horizontal forces.

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