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Analysis and Design of Gravity Dam in Finite Element Method by Using STAAD Pro

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Abstract

Gravity dams are solid concrete structures that maintain their stability against design loads from the geometric shape, mass and strength of the concrete. The purposes of dam construction may include navigation, flood damage reduction, hydroelectric power generation, fish and wildlife enhancement, water quality, water supply. The design and evaluation of concrete gravity dam for earthquake loading must be based on appropriate criteria that reflect both the desired level of safety and the choice of the design and evaluation procedures. The Dam discussed in this paper is of the height 110m for which Equivalent static analysis and dynamic analysis by using time history method is carried out. Most of the organizations analyze the dams by elastic method which gives very rough results. Here Finite Element Approach is used to analyze the dam which is proved to be the realistic for such structures. Comparison is done between the equivalent static approaches of seismic analysis with dynamic analysis by using time history.

Keywords: ***Gravity Dam, Finite element analysis, Dynamic analysis, Stress Contours, Staad-pro***

INTRODUCTION

Any structure that is constructed will undergo many forces such as wind, seismic, self-weight or forces like ice/snow etc. Among these, seismic forces are natural and as we know earthquake is a natural calamity and is so unpredictable.inorder to prevent the structure from being collapse, it's very important to adopt earthquake resistant design philosophy while designing the structure. Waves which arise during Seismic event carries very massive speed and when it struck with any structure it travels through foundation to the top roof resulting In-elastic deformation. there may be the possibility of collapse of whole structure or probably it will survive depending upon the design adopted but surely the structure will have some major repairing and strengthening works which will be costly. Sometimes damages caused by earthquake vibrations are very high that goes beyond repair works. Generally hydraulic structures like concrete gravity dam, canals and RCC multi-storied structures are sufficiently stiff and ductile. These structures undergo large Deformations in its inelastic region. Concrete gravity dam is massive structure having many forces acting on it. It's very important for the dam to survive against seismic vibrations. This Paper is mainly focused on behavior of concrete gravity dam with nonlinear characteristics using seismic time history analysis. In order to study the precise behavior of structures, seismic time History or response spectrum plays an important role. These analyses methods can be adopted to study the structures having single degree of system or multi degree of freedom system possessing non-linear characteristics. Time history performs analysis which is based on Time-acceleration as an input data which is basically an already experienced acceleration w.r.t time by the ground during seismic event. Time history analysis provides the most probable shapes and directions of structure which is its dynamic structural response under loading which varies as according to specified time-acceleration function. One can predict either the structure will survive or not against these seismic vibrations by using time history analysis results. Mainly structures consist of stiffness and damping as a nonlinear parameter. Damping mostly

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encountered in dynamic problems related with structural control, aerodynamics and offshore hydraulic structures. Most hydraulic structures undergo yielding under seismic vibrations. Damping orinertia, displacement and acceleration are non-linear parameters which provide the non-linear characteristics to the structure. The design lateral force shall be considered in each of two orthogonal horizontal directions of the structure. For structures which have the lateral force resisting elements in the two orthogonal directions, the design lateral force shall be considered along one direction at a time, and not in both directions simultaneously. It is known that for most world tectonic regions the ground motion can act along any horizontal direction, therefore, this implies the existence of a possible different direction of seismic incidence that would lead to an increase of structural response. Critical angles are earthquake incidence angles, producing critical responses.

In this study, a four storey reinforced concrete building with moment resisting frame, of different shapes i.e., L shaped and Shaped are analyzed by Time history method of Dynamic analysis of Earthquake. A set of values from 0 to 90 degrees, with an increment of 10 degrees has been used of excitation of seismic force. The details of the study and its result are described briefly in the following section of the paper.

LITERATURE REVIEW

Review by the workers of analyses performed by licensees, or their consultants, ought to think about the assumptions employed in the analysis. the premise for vital assumptions appreciate allowable stresses, shear strengths, drain effectiveness, and loading conditions ought to be rigorously examined. The consultant's reports, exhibits, and supplemental data should offer justification for these assumptions appreciate foundation exploration and testing, concrete testing, instrumentation knowledge, and records maintained throughout the particular construction of the project. Also, the workers engineer's freelance information of the dam gained through website scrutinys or review of operations inspection report similarly as familiarity with previous reports and analyses, ought to be accustomed verify that the exhibits bestowed area unit representative of actual conditions. Ways of study ought to change to the standard procedures employed in the engineering profession.

Conservative assumptions will scale back the number of exploration and testing needed. to Illustrate, if no cohesion or drain effectiveness is assumed in associate analysis, there would be no ought to justify those assumptions with exploration and testing. For this reason, it should generally be a lot of useful to investigate the dam with conservative assumptions instead of to undertake to justify less conservative assumptions. there's but a minimum information of the inspiration that has got to be obtained. The potential for slippy on the dam foundation is usually investigated. However, the potential for failure on a plane of weakness deep within the foundation ought to be investigated. expertise has shown that the best danger to dam stability results once vital attributes of the inspiration aren't proverbial. to Illustrate, within the case of Morris Sheep arduous Dam, 26/ P-1494, a horizontal seam beneath set the dam, providing a plane of weakness that wasn't thought-about. This oversight was solely discovered once the dam had practiced vital downstream movement

Concrete gravity dam and apparent structures

The basic form of a concrete gravity dam is triangular in section (Figure 1a), with the highest crest usually widened to produce a road (Figure 1b).

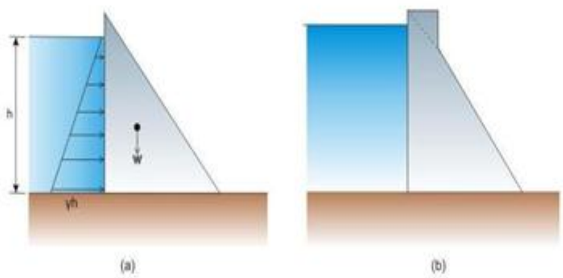

FIGURE 1 : Concrete gravity dam section (a) Basic triangular shape (b) Modified shape

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The increasing breadth of the section towards the bottom is logical since the water pressure additionally will increase linearly with depth as shown in Figure 1a. within the figure, h is assumed because the depth of water and γh is that the pressure at base, wherever γ is that the unit weight of water (9810 N/m³), W is that the weight of the dam body. the highest portion of the dam (Figure 1b) is widened to produce area for vehicle movement. A gravity dam ought to even have associate acceptable conduit for emotional excess flood water of the watercourse throughout monsoon months. This section appearance slightly completely different from the opposite non-overflowing sections. A typical section of a conduit is shown in Figure a pair of.

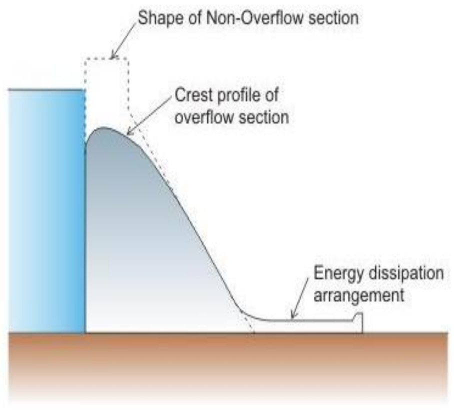

FIGURE 2: Typical overflow section of a gravity dam

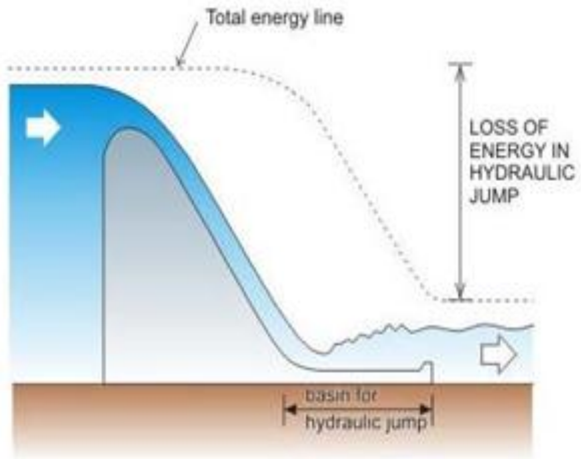

FIGURE 3: Water flowing over a spillway

FIGURE 2:Typical overflow section of a gravity dam

The flood water glides over the crest associated downstream face of the conduit and meets an energy dissipating structure that helps to kill the energy of the flowing water, that otherwise would have caused erosion of the watercourse bed on the downstream.

The kind of energy dissipating structure shown in Figure a pair of is named the stilling basin that dissipates energy of the quick flowing water by formation of hydraulic jump at basin location. This and different sorts of conduit and energy dissipators area unit mentioned in an exceedingly future section. Figure three shows the functioning of this kind of conduit

Usually, a conduit is supplied with a gate, and a typical conduit section could have a radial gate as shown in Figure four. The axis or trunnion of the gate is command to anchorages that area unit mounted to piers.

Design of concrete gravity Dam sections

4.1 Design of gravity dam

Fundamentally a gravity dam ought to satisfy the subsequent criteria:

1. It shall be safe against overturning at any horizontal position among the dam at the contact with the inspiration or among the inspiration.
2. It ought to be safe against slippy at any horizontal plane among the dam, at the contact with the inspiration or on any earth science feature among the inspiration.
3. The section ought to be therefore proportional that the allowable stresses in each the concrete and therefore the foundation shouldn't exceed. Safety of the dam structure is to be checked against doable loadings, which can be classified as primary, secondary or exceptional.

The classification is created in terms of the pertinence and/or for the relative importance of the load.

1. Primary hundreds area unit known as universally applicable and of prime importance of the load.

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2. Secondary hundreds area unit typically discretionary and of lesser magnitude like sediment load or thermal stresses thanks to mass concreting.
3. Exceptional hundreds area unit designed on the premise of restricted general pertinence or having low likelihood of incidence like mechanical phenomenon hundreds related to unstable activity.

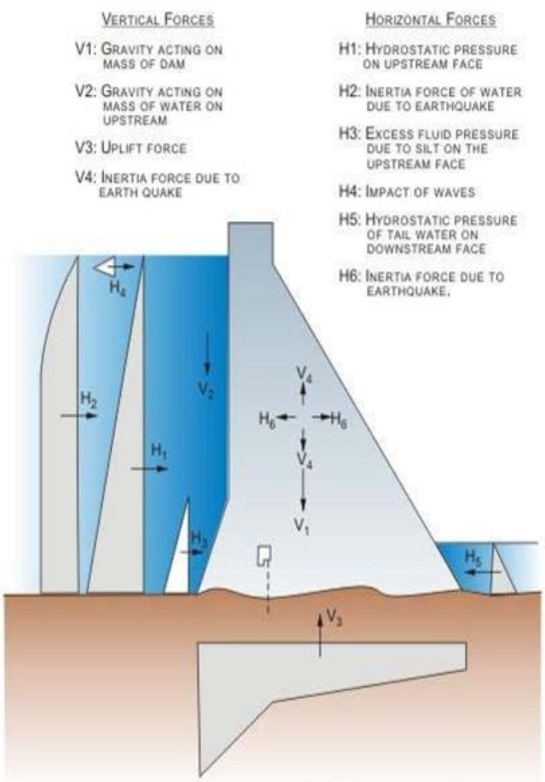

FIGURE 23: Different forces acting on a concrete gravity dam

Technically a concrete gravity dam derives its stability from the force of gravity of the materials within the section and thus the name. The gravity dam has ample weight therefore on withstand the forces and therefore the overturning moment caused by the water impounded within the reservoir behind it. It transfers the hundreds to the foundations by cantilever action and thus sensible foundations area unit pre requisite for the gravity dam.

The forces that provide stability to the dam include:
1. Weight of the dam
2. Thrust of the tail water

The forces that attempt to destabilize the dam include:

1. Reservoir water pressure
2. Uplift
3. Forces thanks0 to waves within the reservoir
4. Ice pressure
5. Temperature stresses
6. Silt pressure
7. unstable forces
8. Wind pressure

The forces to be resisted by a gravity dam represent 2 classes as given below:
1. Forces, appreciate weight of the dam and water pressure that area unit directly calculated from the unit weight of materials and properties of fluid pressure and
2. Forces appreciate uplift, earthquake hundreds, silt pressure and ice pressure that area unit assumed solely on the premise of assumptions of variable degree of responsibility. of course to judge this class of forces, special care needs to be taken and reliance placed on the market knowledge, expertise and judgement.

Figure twenty three shows the position and direction of the assorted forces expected in an exceedingly concrete gravity dam. Forces like temperature stresses and wind pressure haven't been shown. Ice pressures being uncommon in Indian context are omitted.

For thought of stability of a concrete dam, the subsequent assumptions area unit made:
1. That the dam consists of individual crosswise vertical parts every of that carries its load to the inspiration while not transfer of load from or to adjacent parts. but for convenience, the steadiness analysis is often applied for the complete block.
2. That the vertical stress varies linearly from upstream face to the downstream face on any mechanical drawing.

The Bureau of Indian Standards code IS 6512-1984 “Criteria for style of solid gravity dams” recommends

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that a gravity dam ought to be designed for the foremost adverse load condition of the seven given kind mistreatment the security factors prescribed.

Depending upon the scope and details of the assorted project parts, website conditions and construction programme one or a lot of the subsequent loading conditions could also be applicable and will would like appropriate modifications. The seven sorts of load mixtures area unit as follows:

1. Load combination A (construction condition): Dam completed however no water in reservoir or tailwater
2. Load combination B (normal in operation conditions): Full reservoir elevation, traditional dry weather tail water, traditional uplift, ice and silt (if applicable)
3. Load combination C: (Flood discharge condition) - Reservoir at most flood pool elevation ,all gates open, tailwater at flood elevation, traditional uplift, and silt (if applicable)
4. Load combination D: Combination of A and earthquake
5. Load combination E: Combination B, with earthquake however no ice
6. Load combination F: Combination C, however with extreme uplift, assumptive the emptying holes to be defunct
7. Load combination G: Combination E however with extreme uplift (drains inoperative)

It would be helpful to elucidate in an exceedingly bit a lot of detail the various loadings and therefore the ways needed to calculate them. These area unit explained within the following sections.

4.2 Loadings for concrete Gravity Dams

The significant loadings on a concrete gravity dam embrace the self-weight or load of the dam, the water pressure from the reservoir, and therefore the uplift pressure from the inspiration. There area unit different loadings, that either occur intermittently, like earthquake forces, or area unit smaller in magnitude, just like the pressure exerted by the waves generated within the reservoir that his the upstream of the dam face. These loadings area unit explained within the following section

4.3 load

The load contains of the load of the concrete structure of the dam body additionally to pier gates and bridges, if any over the piers. The density of concrete could also be thought-about as 2400 kg/m³. Since the cross section of a dam typically wouldn't be easy, the analysis could also be applied by dividing the section into many triangles and rectangles and therefore the load (self weight) of every of those sections (considering unit breadth or the block width) computed singly so superimposed up.

For locating out the instant of the load (required for calculative stresses), the moments thanks to the separate sub–parts could also be calculated singly so summed up.

4.4 Water pressure on dam

The pressure thanks to water within the reservoir which of the tailwater working on vertical planes on the upstream and downstream facet of the dam severally could also be calculated by the law of hydraulics. Thus, the pressure at any depth h is given by γhkN/m² acting traditional to the surface. Once the dam contains a sloping upstream face, the water pressure will be resolved into its horizontal and vertical componenets, the vertical part being given by the load of the water prism on the upstream face and acts vertically downward through the centre of gravity of the water space supported on the dam face.

In conduit section, once the gates area unit closed, the water pressure will be puzzled out within the same manner as for non–overflow sections apart from vertical load of water on the dam itself. throughout overflow, the highest portion of the pressure triangle gets truncated and a trapezium of pressure acts below fig

PREPARATION OF FOUNDATION FOR DAM CONSTRUCTION

A concrete gravity dam meant to be made across a watercourse natural depression would typically be set on the arduous rock foundation below the traditional watercourse overburden that consists of sand, loose rocks and boulders. but at any foundation level the arduous rock foundation, again, might not perpetually be fully satisfactory right along the projected foundation and abutment space, since domestically there could also be cracks and joints, a number of these (called seams) being filed with poor quality rock.

Thus before the concreting takes place the complete foundation space is checked and in most cases reinforced unnaturally such it's ready to sustain the hundreds that may be obligatory by the dam and therefore the reservoir water, and therefore the impact of water oozy into the foundations besieged from the reservoir.

Generally the standard of foundations for a gravity dam can improve with depth of excavation. often the course of the watercourse has been determined by earth science faults or weaknesses.

A plug of concrete of depth double the breadth of the seam would typically be adequate for structural support of the dam, in order that depth of excavation can, on most occasions rely upon the character of infilling material, the form of the excavated zone and therefore the depth of cutoff necessary to confirm a acceptable hydraulic gradient once the reservoir is crammed. Associate example of this kind of treatment for Bhakra dam is shown in Figure forty two.

RESULTS AND DISSCUSTIONS

Fig. 1: Gravity Dam

II. Computer files TAKEN FOR ANALYSIS

Table- 1

Input Data Taken For Analysis

Max. Water Level	MWL	799.1	m
Full Reservoir Level	FRL	797	m
Crest Level	CL	802	m
Silt Level	SL	681	m
Deepest Foundation Level	DFL	650	m
Unit WT. Of Concrete	WC	2.5	t/m³
Design Seismic coefficient	DSC	0.125	g
U S Slope Change Level	USCL	792	m
D S Slope 0.9H:1V	DSS	0.9:0.1V	
U S Slope 0.1H:1V	USS	0.1:1V	
Top Width	TW	10	m
Size of Gallery	B	1.5	m
	D	2.3	m
PHI	PHI	37	
Width of Dam	BW	100	m
D S Slope Change Level	DSCL	793	m
Tail Water Level(MWL)	TWL	747.45	m
Tail Water Level(FRL)	TWL_1	652	m
Density of Water	DW	1	t/m³
Total Base Width	TBL	172.9	m
Dist. Of Gallery From U/S	DISTGAL	20.4	m

A. Static Load:

1) The weight of the dam: The unit weight is set from materials investigation.

2) Hydrostatic pressure of the water within the reservoir.

3) The uplift forces caused by hydrostatic pressure on the inspiration at the interface of the dam and therefore the foundation. Uplift forces area unit typically thought-about in stability and stress analysis to confirm structural adequacy and area unit assumed to be unchanged by earthquake forces.

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CONCLUSION

For Corner Column C1: The shear force in X direction i.e. Fx is decreasing throughout from zero to ninety degrees, it's most worth at zero degree for L structure whereas T structure additionally shows parabolic decreasing curve for Fx and attains most worth at twenty degrees. Moment concerning Y axis for corner column C1 of L structure attains most worth at eighty degrees and Moment concerning Z axis attains most at zero degrees whereas T structure attains most worth at ninety degrees for My and for Mz at twenty degrees.

For aspect Column C2: Shear force Fx is constant from zero to thirty degrees so it decreases until ninety degrees for L structure whereas for T structure the curve is ceaselessly increasing i.e. minimum worth at zero degree and most at ninety degrees. L and T structure each attains most My at ninety degrees and Mz at zero degrees. For Middle Column C3: For L structure the shear force Fx at begin will increase slowly and shows a steep slope and from twenty degrees forward constant throughout. T structure shows a distinct nature as shown in figure No. 8a. Value of My i.e Moment concerning Y axis is most at ninety degrees for L structure and eighty degrees for T formed structure. Value of Mzi.e Moment concerning Z axis is most at zero degrees for L and T formed structure. From then on top of graphs and conclusions it will be ended that T formed structure needs to resist additional shear force than L formed structure**.**

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