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Novel Approach to approximation-based Design of Gravity DAM on Staad Pro Software

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***Abstract*—** *This work present a review of the design and stability analysis of lower dam a concrete gravity dam situated. Through, the demanding years, it has been observed that failures of dams due to many factor are common. So it is the essential to analysis the dam against all its modes of failures, forces acting on it, uncontrollable disasters such as earthquake, etc. for this, the preliminary data of the dam required for design, such dimensions, base width, crest width, etc. was collected through the inspection engineer. On the basic collected data the elementary profile and practical profile of dam was estimated. Further all major and the minor force forces acting on dam were calculated, stability analysis of designed dam against all modes of failure and for various load combinations was carried out in STAAD PRO software and was checked permissible limits.*

I. 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.in order to prevent the structure from being collapse, it's very important to adopt earthquake resistant design philosophy while designing the structure. Waves which arises 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 be costly. Sometimes damages caused by earthquake vibrations very high that goes beyond repairs works.

Generally hydraulic structure like concrete gravity dam, canals and RCC multi-storeyed structures are sufficiently stiff and ductile. Concrete gravity dam is a 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 behaviour of concrete gravity dam with earthquake intensities as per U.S.B.R. recommendation. In order to study the precise behaviour of structures, finite element method 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.

II. RESEARCH MOTIVATION

Dams constructed out of masonry or concrete and which rely solely on its self weight for stability fall under the nomenclature of gravity dams. Masonary dams have been in use in the past quite often but after independence, the last major masonry dam structure that was built was the Nagarjunsagar Dam on river Krishna which was built. Normally, coursed rubble masonry was used which was bonded together by lime concrete or cement concrete. However masonry dam is no longer being designed in our country probably due to existence of alternate easily available dam construction material and need construction technology.

III. STAAD PROCEDURE

Open STAAD pro software and select the new project file. Now select the space option and give length units in meters and force units in kilonewtons. Now select the add new beam option and then click finish. Now add node points and give dimensions to draw the cross-section of the gravity dam. By giving the node numbers join the node points to one another. Now assign support at the ends of the gravity dam by selecting the support option in the general tab. Give the support as fixed on both ends supports. Now select load and definition and give dead load and live load for the gravity dam. Assign the self-weight of the dam in dead load and hydrostatic force on the upstream side and uplift pressure from the downward as live load. Also, assign the material of the gravity dam as masonry and give its density. Now select the translational repeat option give the global direction as Z--the axis and give step spacing. Now select the four-node plate option and join the nodes of the dam section by joining four nodes. Likewise, join all the remaining plates using the four-node plate option. Now select all the cross-sections and select the plate cursor. Now perform analysis to get the result of the gravity dam. After performing a run analysis go to the postprocessing tab to find the stresses and moments in the gravity dam.

RESEARCH SCOPE

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 the kind of dam that would be fit at a course of action site. Subsequently, conversations on the ground establishment points of view have been presented in this movement aswell.

IV. PROPOSED METHODOLOGY

STAAD or (STAAD. Pro) is a structural evaluation and layout pc software to begin with advanced via Research Engineers International in Yorba Linda, A. In past due 2005, Research Engineer International changed into provided via Bentley Systems. An older model known as STAAD-III for home domestic home windows is utilized by Iowa State University for educational capabilities for civil and structural engineers. The business model STAAD. Pro is one of the most importantly used structural evaluation and layout software. It also can hire numerous types of dynamic evaluation from modal extraction to time information and reaction spectrum evaluation. The dam frame is modeled in STAAD.pro the usage of the strong iso-parametric finite factors with 8 nodes. Each node has 3 translational stages of freedom. The stiffness matrix of the strong detail is evaluated via numerical integration with 8 Gauss – Legendre points. The dam is analyzed for numerous smooth masses and load mixtures possibly met with all through its service. These are enlisted in table 1 beneath. The stresses precipitated are checked for all of the mixtures and the size are so framed that the element of protection referred to above is maintained. The base of the dam is to relaxation on rock and the more excavation into be complete of concrete of same strength, the concept rock of about same to the height of dam is modeled round and beneath the concept level. The gift have a look at undertaken offers with time information approach of dynamic analysis. Time information is to be had first-rate for X direction, so as a way to observe forces in certainly considered one among a type angles, the shape desires to be have become spherical with prevalence mindset from zero to 90 stages, with an increment of 10 stages and column forces had been investigated in all cases. Further as a way to locate the suitable c language of one degree is used. The columns had been divided into 3 crucial categories, which includes corner, facet and internal columns and the effects are compared.

LOAD CONSIDERED

Dead Load

The Dead Load involves the heaviness of the solid design of the dam body not with-standing dock doors and extensions, if any ludicrous. Cement's thickness is assessed to be 2400 kg/m3.

Primary Load

Water Load: -

The dam's u/s and d/s faces are subjected to water pressure. The most overturning force acting on a gravity dam is the pressure of the water on the u/s face. Stability is aided by the tailwater pressure.

The tail water pressure is modest in comparison to the water pressure on the u/s fore-head. 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;

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 Load

The uplift is designed to affect the entire foundation width.

Wind Load

When the dam is full, wind acts simplest at the downstream facet accordingly contribute to stability.

Exceptional Loads

Under reservoir entire conditions, the most unfavourable seismic loading will then arise even as a ground wonder is associated with: – Horizontal foundation acceleration running upstream, an– Vertical foundation acceleration running downwards.

GENERAL

The STD input document is the manner by which the GUI (or Graphical User Interface) interfaces with the STAAD.pro research motor. The info documentis a book record that contains a bunch of orders that are run all together. The orders either give guidelines or information about examination and 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 office utilizing a vivid menu-driven designs arranged.

TYPE OF STRUCTURES

A plan can be divided into several sections. STAAD. Pro is ready to investigate and arrange structures made out of packing, plates/shells, and solid parts. Almost every arrangement can be found destitute someplace near STAAD. Professional programming. The most common way to go aboard an aircraft is by a space structure, which is a three-dimensionally drawn out plan with loads applied in any plane. Structures made of truss people can have lately critical part controls and no curvature in the people. A tale structure is a two dimensional development with no overall (X or Z) plan improvement [FX, FZ, and MY are controlled at each joint]. The overall XZ plane of a design's floor layout is an ideal illustration of a story structure. s longas the development does not have level stacking, portions can be displayed with the floor in narrati ve structure. If there is any even weight, it should be decomposed as a space structure.

GENERATION OF THE STRUCTURE

The layout is probably constituted of the information file or referencing the co-ordinates withinside the GUI. The determine under indicates the GUI age strategy.

SUPPORTS

Support is represented as Stuck, FIXED, or FIXED and has a variety of promotions (but called FIXED). Stack support has a limit on every translation turn of the event, not a limit on the rotation turn of the event. With everything in mind, the stubborn willingness to support a reaction to all forces is no less than a minute. Firm support has limits in all directions of ascent. In addition, it can represent translational and rotary springs. The spring is tensioned according to the spring constant. A translational spring support is described as the ability to remove a support joint by a unit length up to a given total distance. Torsion spring support is also expressed as the ability to rotate the support joint once around a given overall course.

LOADS

You can specify joint loads, beam loads, temperature loads, and loads to which the end bar of the structure is permanently attached. STAAD is an acronym for Standardized Transportation Authority. In addition, Pro calculates the weight of the structure and uses it in the analysis as a uniformly distributed element load. Any part of this weight can be directed in any direction.

Joint Loads

Each loose joint in the device can be exposed to hundreds of joints, including all forces and moments. Hundreds of these work according to the structure's global coordinate system. Nice coordinate defaults are afflicted by nice forces. Hundreds of joints can be associated with unmarried joints, and hundreds can be added to those joints.

Member load

3 Various partial loads can be applied directly to a person from a structure. These stacks are reliably acquired loads, concentrated weights, and moved straight weights (trapezoidal test). Uniform weights draw a circle with unlimited or inadequate section length. The collected issues work at a moderately determined point. Easily changing the weights makes the section length absurd. The trapezoidal straight alternating weights work at the full length of the section or the middle length. Trapezoidal weights are converted to unit weights and some concentrated weights. Many weights can be displayed back to any free-stacked section. Part loads can be viewed in part assembly structures or total work in the system. A stack of reliable ordered parts that has been proven to work over the full length or expected length of the parts in a global sort structure.

Area / Floor Load

A uniformly allotted load is likewise carried out to a floor (bounded with the aid of using the X-Z plane). Calculating

the member load for every floor's person contributors may take a long time. Using the AREA or FLOOR LOAD commands, the person may also outline the area loads (unit load in keeping with unit rectangular area) for contributors. For those participants, the software program willdegree the tributary place and calculate the right person loads. One-manner.

SECTION TYPES OF CONCRETE

Dam Concrete members may be constructed for there are various precise varieties of cross sections. Prismatic Beams for (Rectangular) Prismatic Columns (Rectangular)

DESIGN PARAMETERS

A variety of parameters are covered withinside the software program which might be wanted for IS 13920 architecture. It accepts all the parameters required for IS: 456 architecture. It additionally has a few extra standards which might be best to be had when the layout is finished in line with IS: 13920. The default parameter values had been selected to be numbers which might be frequently discovered in conventional architecture specifications. This guide consists of a complete listing of the to be had parameters in addition to their default values, which may be changed to accommodate the particular layout being done. Before starting the concrete plan, the duration and pressure devices have to be declared in milli-meters and Newtons

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 in elastic miss-happenings 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 further more 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 player layout and code testing. Pro are primarily based totally at the IS:800 allowable anxiety layout process (1984). It's a way for proportioning structural contributors below obligation situations with the aid of using the use of production masses and pressures, permissible stresses, and layout limits for the desired material. In this textbook, it is going to be not possible to cowl any a part of IS: 800. However, the main functions of the permissible stresses described with the aid of using IS: 800 and carried out in STAAD will be mentioned on this section. Advantageous During the attention of different kinds of permissible pressures, suitable components of IS: 800 might be cited.

MULTIPLE ANALYSIS

Multiple studies in a single run can be wanted for structural analysis/format. To allow several analyses withinside the equal run, STAAD. Pro lets in the customer to modify input which incorporates member properties, help requirements, and so on in an input file. For format purposes, the effects of numerous analyses may be integrated. It may be possible to render those contributors disabled for one load case and then allow them for each different 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.

Stability Requirements The human beings' thinness proportions are expected and contrasted with the maximum noteworthy qualities. The commonly talking slenderness ratios for different classifications of human beings are summed up withinside the IS: 800. An appropriate maximal thinness percent for each element may be given withinside the STAAD execution of IS: 800. Pressure human beings might be checked closer to a maximum intense genuinely well sincerely properly really well worth of 180, at the same time as pressure human beings might be checked closer to a awesome genuinely well sincerely properly really well worth of four hundred if no awesome thinness percent is determined.

Deflection

Check In this office, customers can include what they dislike as a model in their code review and parts backup efforts. Avoidance control can be controlled by three limits. Redirects are used, despite other strength and robustness-related principles. The Nahaversion rating is based on the latest rating results.

Code Checking

The purpose of the Code Check is to determine if a particular section meets the requirements of the relevant specification code. Code validation is based on IS: 800 Requirement (1984). Code-check equations use forces and moments on specific parts of a participant. You can specify the section using the BEAM parameter or the SECTION command. If the part is not listed, the code will be checked using power.

GEOMETRY IMPORTANCE

Concrete dams are solid structures which are built of mass concrete. The geometry, strength of concrete and shape of the dams help to resist the imposed forces acting on the dam. Spillways are hydraulic works made of concrete inserted in dams, in which the main goal is the discharge of water in order to ensure the safety of the dam. The structure should be safe against the forces such as water pressure, tail water pressure, uplift pressure, silt pressure, earthquake forces. These forces make the dam unstable and cause overturning, sliding, and tension effects on the dam. Analysis of the stability is conducted at the base of the dam and at selected planes within the dam. Analysis of the 3D Finite element dam model is performed by using STAAD.Pro. During earthquake due to ground motion an additional seismic force will act on the structure of the dam. This additional force lead to collapse of structure and affects the dynamic nature of structure it may cause the cleavage/cracks in the gravity dam. Dynamic analysis can be performed to determine the design seismic force and its distribution to difference levels along the height of the structure. The main objective of using F.E.M in this study is to evaluate the stability of the dam against various forces.

For solving large problems, many FE software are available such as STAAD.PRO, etc. In this study a 3 dimensional finite element model is created using solid elements in STAAD.Pro software. One of the main advantages of FE modelling is the possibility to set up complex models with geometry close to reality. Discretization of the elements is important for the analysis.

Solid elements enable the solution of structural problems which involve three dimensional stresses. Finite element analysis provides a powerful tool when using solid elements to determine the stress distributions. It consists of 8 nodes with 3 translational degrees of freedom at each node. The boundary conditions control how the construction is supported. Here hinged support is provided at the base. The gates are modeled using plate elements having thickness of 400mm. After all the loads and load combinations are provided, the model is analyzed. Stability analysis includes safety of the dam against uplift, overturning and sliding.

Fundamentally a gravity dam should satisfy the following criteria:

1. It shall be safe against overturning at any horizontal position within the dam at the contact with the foundation or within the foundation.

2. It should be safe against sliding at any horizontal plane within the dam, at the contact with the foundation or along any geological feature within the foundation.

3. The section should be so proportional that the allowable stresses in both the concrete and the foundation should not exceed.

Safety of the dam structure is to be checked against possible loadings, which may be classified as primary, secondary or exceptional. The classification is made in terms of the applicability and/or for the relative importance of the load.

1. Primary loads are identified as universally applicable and of prime importance of the load.

2. Secondary loads are generally discretionary and of lesser magnitude like sediment load or thermal stresses due to mass concreting.

3. Exceptional loads are designed on the basis of limited general applicability or having low probability of occurrence like inertial loads associated with seismic activity.

Technically a concrete gravity dam derives its stability from the force of gravity of the materials in the section and hence the name. The gravity dam has sufficient weight so as to withstand the forces and the overturning moment caused by the water impounded in the reservoir behind it.

It transfers the loads to the foundations by cantilever action and hence good foundations are pre requisite for the gravity dam. The forces that give stability to the dam include:

1. Weight of the dam

2. Thrust of the tail water

V. RESULT AND ANALYSIS

The analysis of the **Gravity Dam using an approximation-based design approach in STAAD Pro software** provides an efficient and reliable way to evaluate structural performance under varying load conditions. The model incorporates self-weight, hydrostatic water pressure, uplift forces, and seismic effects as primary loads. By approximating the dam cross-section with simplified geometric assumptions, the design reduces computational complexity while still capturing essential stress and stability characteristics. The STAAD Pro analysis ensures that stresses remain within permissible

limits, sliding and overturning safety factors are maintained, and displacement is minimal under critical loading. The results confirm that the approximation-based design approach can significantly reduce modeling time without compromising accuracy, making it suitable for preliminary design and optimization of gravity dams before proceeding to detailed design phases. This highlights the capability of STAAD Pro to integrate practical engineering assumptions with advanced structural analysis for achieving safe, economical, and time-efficient dam design solutions.

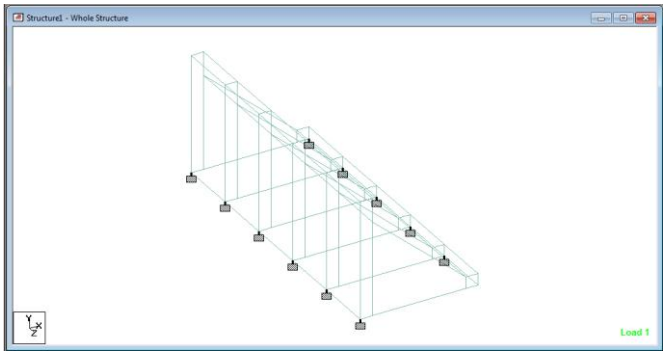

Fig.1. Proposed Design.

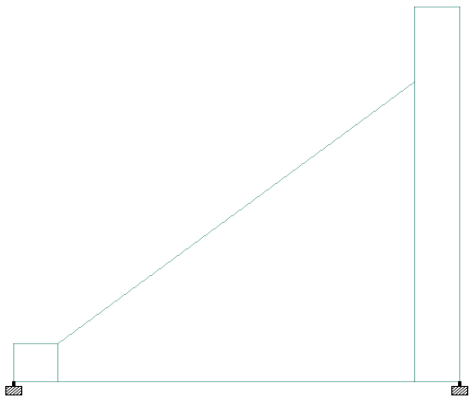

Fig.2. Side view

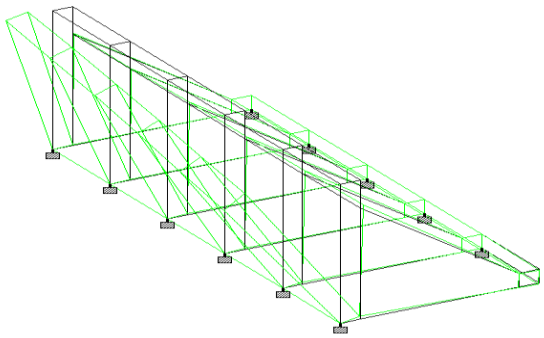

Fig.3. Displacement.

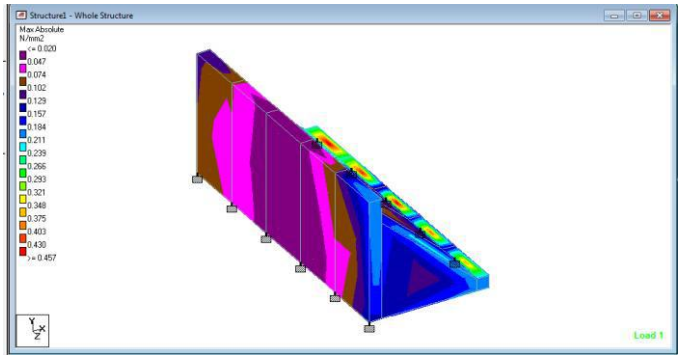

Fig.4. Stress Level

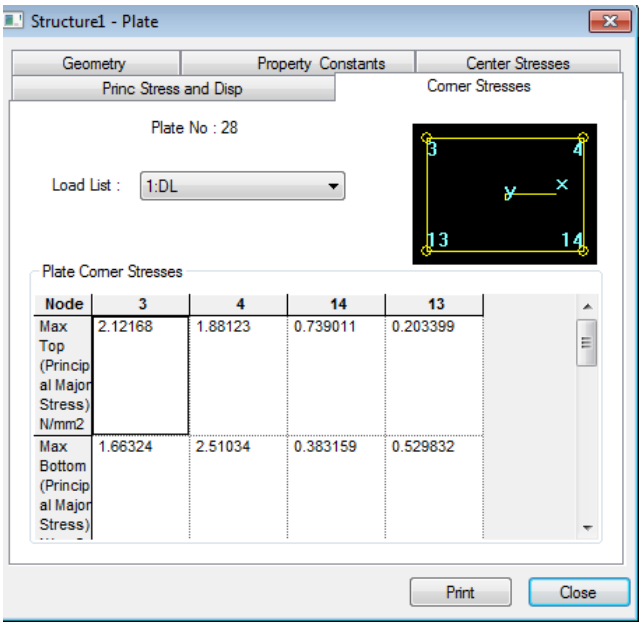

Fig.5. Corner stress

VI. CONCLUSION

The study concludes that the approximation-based design of a gravity dam in STAAD Pro offers a practical balance between computational efficiency and structural reliability. By applying simplified geometric assumptions along with rigorous load analysis, the method ensures stability against sliding, overturning, and excessive stresses while reducing design time. The results highlight that such an approach is highly effective for preliminary design stages, where rapid assessment and optimization are crucial. Furthermore, the STAAD Pro simulation validates the structural integrity of the dam under multiple loading conditions, confirming its suitability for safe and economical construction. Hence, this approach can serve as a valuable tool for engineers in conceptual design and decision-making before moving to more detailed and resource-intensive modeling.

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