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Assessment of Earthquake Analysis Method of Intake Tower

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ABSTRACT:

Seismic analysis of an intake tower may be carried out using one or more methods from themethods Seismic Coefficient (SCM), Equivalent Lateral Force (ELFM), Response Spectrum (RSM) and Modal-Time history (MTHM) Methods. SCM, ELFM or RSM may produce response quantities with magnitudes bigger or smaller than those of refined method (MTHM). How big or small are the magnitudes in comparison with those of the refined method? In other words, are the magnitudes of SCM, ELFM or RSM overestimated or underestimated when contrasted with those of the refined method (MTHM)? Answering these questions through detail investigation is the core objective of this study. In order to meet the core objective, an investigation of the seismic analysis methods of intake towers was conducted. The investigation was conducted by performing elastic seismic analysis of a squat free-standing intake tower, using the conventional and refined methods; and comparing the results of the analysis. The investigation started by selecting a suitable intake tower and its location for the study. In this regard, the squat free standing intake tower in kesem Dam irrigation project, in Afar Regional State, was found to be suitable. The project is located in East African Rift Valley which is largely prone to earthquake excitations. After selecting the intake tower and its location, the next step was structural, material and hydrodynamic modeling. Following the modeling, in put ground motions in form of response spectra and ground acceleration time-histories were developed. Next, seismic analysis of the intake tower was carried out using the models and the input ground motions; and applying each of the methods at a time. Finally, the results of the analysis were examined. From the examination, the study concluded that the magnitude of response quantities computed with SCM, ELFM or RSM were significantly different from those of the refined method. Moreover, the study concluded that the magnitudes of the response quantities computed with three methods were underestimated. So, SCM, ELFM or RSM, *especially SCM, are inappropriate for detail seismicanalysis of squat free-standing intake towers.As result, the study decided that MTHM shall be used for final and detail elastic seismic analysis of free-standing squat intake towers. However, further investigation are required in order to extendthe conclusion to other classes of intake tower such as free-standing slender intake towers and inclined intake towers. Similarly, other investigations are desirable in order to extend the conclusions of this study to inelastic analysis methods of intake tower.*

1.INTRODUCTOIN

Usually, reinforced concrete intake towers located in earth quake prone regions require seismic analysis. The seismic analysis may be carried out with the methods such as Equivalent lateral Force (ELFM), Seismic Coefficient (SCM) and Response Spectrum (RSM) or/and the more refined, Modal-Time History (MTHM)method(s). The four methods mentioned here above, have special features peculiar to each as well as features common to all. For example, Equivalent lateral Force Method is unique in that it idealizes earth quake loads as static ones; however, the rest are devoted to representation of the earthquake loads as dynamic loads. Moreover, Response Spectrum Method, on its part, is unique such that it can be used to calculate maximum earthquake responses regardless of their time of occurrences. On the contrary, Unlike the Response-Spectrum Method, Time-History Method may be employed to calculate the maximum responses along with their time of occurrences. These and other unique and common features, owned by the methods, may be the reasons why the methods often considered being different. Are they really different? If the answer is yes, then what is the extent of their difference? These are questions that this study going to answer after making quantitative and qualitative comparisons among response quantities computed with the respective methods. Answering these questions requires detail and careful investigations. Accordingly, an investigation was carried out by conducting seismic analysis of an intake tower with two methods that represents the conventional methods and the more refined method (ModalTimeHistory Method) by applying each of them at a time. The investigation started by selecting an intake tower from two broad categories of intake towers. The two broad categories of intake tower are inclined intake tower and free standing intake tower. The class of inclined intake towers includes intake towers that totally leaned against abutment for purpose of support, while the class of the free standing ones consists of intake towers that stand straight upward and primarily supported on foundation beneath it. Free-standing intake towers may further be classified as slender or squat based on theirgeometric configurations. If an Intake towers has width to height ratio less than 1/10, thenit is slender, otherwise it is squat. Because most of in take towers constructed so far are from the free-standing class (U.S Army of Corps of Engineers, (2003a)), a squat intake tower from this class has been chosen for purpose of assessing the three methods. The four methods will be employed, separately, to run the seismic analysis of the squat free standing intake tower. After the analysis, the results will be compared quantitatively as well as qualitatively to decide whether the conventional methods produce response quantities whose magnitudes are significantly different from those of the refined method. Seismic Coefficient Method is still being used in Ethiopia for detail analysis of intake towers (WWDSE et al, 2010a; WWDSE et al, 2010b; and WWDSE et al, 2010c).This method has been identified as being obsolete (Novak et al (2007)).So, the study has purpose of examine the extent of obsolescence of the method by comparing the magnitude of response quantities computed using the method with those of refined method, there by concluding appropriateness of the method for practical applications. Therefore, generally, purpose of carrying out the investigation, in this study, was to establish the extent of magnitude difference among the respective response quantities computed with the four methods, thereby comparing the output of the conventional methods with the output of the refined method. The desire for carrying out the investigation has been inspired by the need for having in depth knowledge regarding the seismic analysis methods of intake tower. Prior to this study, there had been no literature which discussed in detail about the magnitude difference among the methods when applied for seismic analysis of intake tower.

2 LITRATURE REVIEW

Several studies have been conducted to examine the factors that affect seismic responses of intake towers. The factors often under investigations are the following: water-structure interaction, soil-structure interaction, and multiple support excitation effects. The responses of intake towers to seismic excitation are affected by water-structure interactions; Vidot et al, (2004b) quoted Daniel and Taylor (1975) to state that the response of intake tower under dynamic loading can be strongly influenced by its interaction with reservoir water outside and inside it. The influence may manifest it self by elongating natural period of intake tower which in turn changes the corresponding response spectrum ordinate ,as result altering seismic forces (spyrakos and ChaojinXu (1997)) . In addition, the study of spyrakos and ChaojinXu (1997) revealed that there existedinteraction between the reservoir's hydrodynamic load and flexible foundation soil beneath the intake tower. The Hydrodynamic load and the flexible soil foundation interact in such away that deflections, shear and moment of the intake tower are more than they are under rigid foundation assumption. Spyrakos and ChaojinXu (1997) also investigated effects of intake tower configurations and water-structure interaction on soil-structure interaction. The investigation concluded that water-structure interaction negates the soil-structure interactions given the intake tower is squat; however, soil-structure interaction gets magnified by water-structure for slender tower. Now days, after several researches, the belief that intake towers' seismic response are magnified by hydrodynamic load has become an established fact. Consequently, when evaluating the three seismic analysis methods of intake towers, the hydrodynamic effect on seismic response will be taken into consideration. The water-structure interaction effects may be taken into consideration by converting hydrodynamic loads into equivalent masses (U.S Army Corps of Engineers, 1999). The equivalent masses will be placed at nodes of models of intake tower as if they were added masses of the structure Soil-structure interaction is the other factor that significantly influences response of intake tower to seismic excitation (Vidot et al, 2004a). Furthermore, Vidot et al, (2004C) citing Goyal and Chopra (1989b) commented that the interaction increases the fundamental period of intake towers and effective damping because of flexibility and energy dissipation of the soil foundation. The effect will be worse if the fundamental period of foundation soil is approximately equal to the fundamental period of intake tower. However, the fact that a structure has been constructed on soil foundation alone does not necessarily imply substantial soil structure interaction. Soil-structure interaction is substantial at times when stiff intake towers, with large height to footing radius ratios, are founded on flexible soil strata (Vidot et al, 2004a). One of the way of accounting for soil-structure interaction effect is by attaching springs and dash-pots to base of the structure or to different levels of non-homogenous soil strata under the structure, during seismic analysis of an intake tower , (Dowrick, 1978).In this way, the intake tower can be modeled as beam-column system. On their part, the springs and dash-pots may be placed at contact point between the model and foundation for homogenous soil stratum .on other hand, for non-homogenous soil strata, the springs and the dash-pots will be interconnected in series ,beneath the foundation. Alternatively, Finite element modeling may be used to account for the soil-structure interaction. In this alternative approach, certain depth of soil foundation along with the superstructure will be idealized as a unit during seismic analysis of the intake tower (U.SArmy Corps of Engineers, 2007a). The other factor that possibly affects the seismic response of intake tower is the bridge–intake tower interaction .It is the factor that needs attention especially during modeling of an intake towers connected to access bridge. If the connected bridge is light, then the intake towers may be modeled as independent entity without the bridges. In the case of massive access bridge connection, the bridge and intake tower will be modeled as a single composite structure (U.S Army Corps of Engineers, (2003b)). Once it is decided that modeling of the intake tower and the access bridge as a single composite structure is important, the next issue requiring similar decision would be regarding the design ground motions. Generally, in single composite models, intake tower base level may be different from the bridge supports' levels, or piers' bases level; hence, the geology at the base of the intake tower may be different from the geology at the base of the bridge supports. The difference in geology may result in different ground accelerations during earth quake excitations. In situations like this, one may opt to use different input ground motions at intake tower and pier base levels so as to account for multiple support excitations. Regarding effect of multiple support excitations on response of intake, a study has been conducted by U.S. Army Corps of Engineers (Vidot et al, 2004). The out come of the study implied that multiple support excitation effect on seismic response of composite bridge-intake tower system is negligible. Hence, defining identical design ground motions for all of the support of the composite model suffice. Based on the conclusion of the study, for the composite bridge-intake tower system the multiple support excitation effect may be disregarded during defining the design ground motions.

3.SEISMIC RESPONSE ANALYSES OF AN INTAKE TOWER

In this study, the seismic responses analyses of an irregular intake tower have been conducted using Seismic Coefficient, Equivalent Lateral

Force, Response Spectrum, and Modal-Time History analysis methods. The seismic analyses were conducted based on two general approaches. In the first approach, initially, the seismic analysis of the intake tower was performed, as if it were regular. later the effect of irregularity, torsional moment of the intake tower, was incorporated by multiplying the lateral inertia forces, for a given vertical portion of the intake tower, by their eccentricities from center of rigidity of the intake tower (U.S Army Corps of Engineers, 2003b).This approach was followed when conducting seismic analysis of the intake tower with Equivalent lateral force and Response Spectrum Methods for which theintake tower was discretize as beam-column system. In the second approach, using software, the intake tower was modeled by three dimensional shell elements to take its irregularity into account directly. Since the software program automatically caters for the eccentricity effects, there is no need of worryingabout the irregularity of the intake tower. Following the modeling, the seismic analysis of the three dimensional model was performed using the Modal-Time history method. Before conducting the seismic response analysis, determination of design ground motions, hydrodynamic loads have been carried out as preliminary steps. In order to execute the preliminary steps, first suitable project and its intake tower have been be chosen in such a way that they provide input data good enough to generate big seismic response. Data of the intake tower, which is chosen as suitable, will be used to derive inputs for its seismic analysis.

3.1 SELECTION OF SUITABLE PROJECT SITE AND AN INTAKE TOWER

Kesem Dam irrigation project site and its intake tower, in Afar Regional State, were selected as suitable site for conducting the study on the seismic analysis methods of intake towers. The project and its intake tower were chosen for the study because of the expectation that the seismic response quantities of the intake tower would be significant. The response quantities would be significant since the project and its intake tower are located in a region of high seismicity. The seismicity high is due to the fact that the project is expected to be exposed to earthquakes whose magnitude could be as high as 7.1, on Richter scale (Geophysical Observatory, 2005). As result of the location of the project in high seismic region, the input ground motion will be so large as to cause sensible and comparable magnitudes of the response quantities. Moreover, the seismic responses of an intake tower may be large provided that they are analyzed for maximum credible earthquake

(MCE). MCE is the greatest design ground motion that a source of earth quakes can produce (U.S Army of Corps of Engineers, 1995). MCE are usually specified for seismic analysis of critical intake towers as per recommendations of manual ER 1110-2-1806. The manual categorizes an intake tower as critical one when the intake tower is in a project with high seismic hazard potential rating. In addition, the manual rates seismic hazard potential of a project as being high when the failure of, at least, one of its component structure entails loses of life, demolition of properties destruction of the environment. For that matter ,The Kesem dam and irrigation project seismic hazard potentials may be designated as being high since the seismic failure of the its main dam or intake tower,ensues lose of life ,demolition of properties and destruction of the environments.

3.2 GEOMERY OF THE INTAKE TOWER

Kesem intake tower is free-standing intake tower with total height of 41m and with rectangular cross section with over all dimensions of 15.38m by 12.03m.Out of the total height only 27.45m is effectively freestanding while rest is embedded in concrete backfill. The elevated view of the intake tower is depict the actual horizontal cross-sections. At top of the intake tower, a control-room has been constructed to monitor the amount of water release through the intake tower. A foot bridge with 2.5m width and 95m length spans from the top of the main dam the control-room of rectangular cross-section. The rectangular cross section has some openings positioned unsymmetrical. The unsymmetrical positioning of opening is largely responsible for in plan irregularity of the intake tower. In addition, added masses from the access bridge and crane did contribute to the in plan irregularity of the intake tower. They form the irregularity by causing the non – uniform mass distributions in plan. Based on the actual cross-section, shear center location of the intake tower may be determined manually. However, the manual calculation of the shear centers based on this actual section was so involved because of irregularity of the actual cross-section; therefore, a modification was introduced to the actual section so as to create simple section for easy estimation of the shear center

CONCLUSION:

In this study, generally, after the evaluation of the seismic analysis methods of the intake tower, it was concluded that the extent of the magnitude differences between the seismic response quantities computed with the refined methods (MTHM) and the other three methods were appreciable. In other words, SCM, ELFM and RSM underestimated magnitudes of seismic response quantities of squat free-standing intake towers. Especially, SCM underestimated the magnitudes adversely than ELFM and RSM did, but; the underestimation of RSM was not as intense as it was for ELFM or SCM. Therefore, detail seismic analysis of free-standing squat intake tower shall preferably and satisfactorily be carried out with the refined method (MTHM). The Usage of the method is emphasized for final seismic analysis and subsequent detail design of the intake tower.Nevertheless, using SCM, ELFM or/and RSM for detail seismic analysis of the structure is not acceptable, so design offices shall refrain from using them for practical applications. Particularly, the design offices, in Ethiopia, should abandon their current practice of applying SCM for detail seismic analysis of squat free-standing intake towers. However, the three methods (SCM, ELFM and RSM) are recommendable for seismic analysis of intake tower in preliminary study stages. Even, during the detail seismic analysis stage, SCM can still be used for stability analysis of the intake tower Alternatively, the approach towards seismic analysis of the intake tower may be performed progressively. The progressive analysis starts from SCM or EFLM, proceeds to RSM, and finalizes with MTHM. The progressive analysis will be observed at least for detail and final seismic analysis of the intake tower. Moreover, the study found out that the magnitudes of response quantities computed using SCM, ELFM, RSM and MTHM do not depend on the type of models used to idealize the squat free-standing intake tower. Rather, the magnitudes rely on the type of method used to perform the seismic analysis.

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