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EARTHQUAKE FORCE MODELING ON VERTICAL AND CRUMP WEIRS BY NEW MODELING APPROACH IN STABLITY ANALYSIS OF THE DESIGNED WEIRS AT THE GIVEN LOCAL HYDRAULICS

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ABSTRACT

By and large in geotechnical earthquake engineering the phenomena of earthquake and its effects are described as such as the site-specific amplification, soil liquefaction, and seismic slope stability are the important aspects of earthquake to be dealt on in earthquake engineering. And; these aspects must be adequately addressed in the development of sound earthquake-resistant designs when the effect of earthquake force on the structural stability of engineering works while concerned and hydraulic structures like diversion weirs and dams when required to be designed . Thus the study has actually focused on diversion weir designs and the modeling of earthquake force basically dealt on these specific structures for convenience . Although there are various methods for modeling of the magnitude of earthquake force on these structures in this articles consents however the result of this study has been required to introduce new modeling approach of earthquake force on vertical and crump weirs as compared with the known pseudo static method in science. Hence, in this study approach the effects of the vertical and horizontal inertial acceleration of seismic activity plus the peak ground motion generated inducing force when anticipated in the head work location to be occurred at various intensity of occurrence ideally the study has tried to quantify the magnitude based on computational fluid dynamic elite using new modeling scheme and formulae for earthquake force modeling in which have derived by the study while the stability of the structures analyzed . In this regard the methods has found possible to model the magnitude of earthquake force by this study regressively in correlation with the input data given for local hydraulic behavior of the flow system hypothetically when presupposed for particular sample design and then the required weir dimensions for stability analysis of the designed weirs . Ultimately, the results generated with respect for the observed samples deemed to be quite appropriate one have evaluated to have correlated with the local hydraulic input data used for modeling the weirs basically and the designed sample weirs geometries while operated optimally. In this case as the new notions by designating the flow behaviors on the weir and the energy profiles observed over the weir crest through dimensionless numerical model parameters known as alphas values consequently the magnitude of the required earthquake force have computed being optimized for each samples reggeressively and have compared each other . ultimately the study has found that the magnitude being linearly fitted with the models used for the computation as such having resulted coefficient of determination for the reduced linear models of 100% or $R^2 = 1$ signifying that there is the strongly and inverse correlation of the magnitude of earthquake force and slope of the downstream weir glacis when observed on vertical and crump weirs and in wide band analysis of the force system based on the defined input local hydraulics and geometry of the weirs as well as for the predictors and variables used for modeling . also in all cases the results has confirmed numerically that the determined magnitude for samples reggeressively coincides with or same as of the magnitudes when observed based on the pseudo static method for particular samples for justification .

Key words : Optimization, Peak ground motion and inertial acceleration, regressive modeling

1. INTRODUCTION

Off course, the field of earthquake engineering is quite complex, however, and there are many opportunities for future research. Among the many evidences have observed and revealed in earthquake engineering research activities basically the effect on dam on hydraulic structures deemed to be the relevant concern of the study context here even though that there are also numerous issues to be considered and dealt on by other studies w.r.t seismic activities in general . Hence, it is clear that the geotechnical factors often exert a major influence on damage patterns and loss of life in earthquake events. Thus to this end(Chen, W. F *et al*., 2003) has entailed that geotechnical considerations in design actually play an integral role in the development of sound earthquake-resistant designs. In deed the development and transmission of earthquake, and energy through the underlying geology is quite complex phenomenon.

Accordingly as far as magnitude of earthquake incident anticipated to be recorded and measured it is quite that earthquakes is produced in a particular geologic setting due to specific physical processes. A mid plate earthquake (e.g., New Madrid) will differ from a plate margin earthquake (e.g., San Andreas).

Therefore, in earthquake engineering the assessment of seismic waves and their effects in geotechnical investigations; seismic refraction, seismic reflection; electric resistivity and magnetic susceptibility the most common considerations and basically they are in use to understand the nature and phenomenon associated with earthquake force events and the worst incidents. Additionally the studies are quite focused on these conditions and studied the in coincidence with shear wave velocity, compression velocity and surface wave event often when dealing on earth quick incidents and applications in geotechnical investigation as (USBR, 1975) has hinted. Thus the potential seismic damages will typically will increase with earthquake events of greater magnitudes, seismic energies attenuate as far as it travel from the zone of energy release and spread out over a greater volume of materials. In addition, the local soil conditions may significantly amplified ground shaking and some soil deposits may undergo sever strength loss resulting in ground failure during earthquake shaking.

Hence three factors i.e. the magnitude, distance and local soil conditions are the most important factors and often in many cases seismic study has been focused on these factors Chow.W.F et al, (2006) and USBR (1976) has hinted.

In this respect when earthquake force magnitude measured, there is several earthquake magnitude scales know to date and it is important to use these scales consistently. The earliest magnitude scale known to be local magnitude scale, which had developed by Richter (1935). In addition, this is defined as the moment of the maximum amplitude on the wooden - Anderson torsion seismography located at a distance 100 km from the earthquake source (Richter, 1958). Other types of magnitudes are surface and body wave magnitudes. These magnitudes however are based on the amplitude of seismic waves at different periods.

Furthermore, among the forces causing damage in practices on structures at the given area the effect of ground motions and inertial acceleration, which are quite pertinent one and often has considered in hydraulic structures design. By and large the weight of the structures has required to assessed in design properly i.e. the static weight of the structure so as to quantify the magnitude of the induced earthquake force on the structure when it is anticipated in the given area at a specified intensity level of occurrence since the weight has significant impact on the magnitude.

Accordingly, in the existing trend of determining or modeling of the magnitude of earthquake force such as on hydraulic structures while revitalized, the pseudo static method is quite prominent one. In pseudo, static approach the magnitude of the induced earthquake force on the structure has often computed and deduced as by multiplying the static weight of the structure with intensity coefficient of earthquake force for the given locality has specified for.

However in this study modeling approach and evaluation of the magnitude of earthquake force components often they are resulted due to the inertial acceleration of seismic wave and pea ground motion when localized in the designed weir site ideally and anticipated to be induced on vertical and crump weirs different approach has followed being this study has developed new modeling equation which are potentially integrated the flow hydraulic with the weir geometry and dimensions using dimensionless model parameters in the equation.

Therefore, in this study context the results of the study have presented with basic finding through analyzing the feasibility and the reliability of the new modeling approach of earthquake force on vertical and crump weirs introduced by the study as a scientific findings in this article in the following manners.

2. Materials and Methods

Basically in designing vertical and crump weirs and for modeling the magnitude of the vertical and horizontal component of earthquake forces by this study an independent equations which are capable of predicting the magnitude of the induced earthquake force w.r.t slight variations in flow hydraulics over the weir crest and the input parameters in which used for designing the weirs have derived and employed for modeling by this study context .

The models used for the computation has designated the flow hydraulics and the magnitudes of the induced force in terms of dimensionless model parameters which have seen potential integrated the flow behavior with the weir dimension for the given local hydraulic input data. Indeed the model equations have derived consistently as well and having thoroughly analyzed the flow behavior or hydraulics often prevailed over the weir crest based on the phenomenon of computational fluid dynamics and flow hydraulics of diversion weir in open channel hydraulics under this study context indeed .

2.1. Description of the study area

Actually the secondary input data have used for the design of the sample weirs in general deemed to be the relevant elements or attributes which are potentially describing the sample designs local hydraulics and flow conditions in this study context and when the design of the sample weirs excited based on the modeling algorithm of the study. The same conditions have been dignifying the description of the study area in modeling of the magnitude of earthquake force on vertical and crump weirs for perusal .

2.1.1. Local Hydraulics Variables

The study has used variable local hydraulic input data which are actually secondary data acquired from design documents for modeling the magnitude of earthquake force likely to be induced on the sample weirs computationally .

Note that the local hydraulic input data has variables to be evaluated and tested through modeling the magnitudes of the required earthquake force components by using the models devised for this purpose. Therefore in the methodology the magnitude of earthquake force have modeled in wide band analysis and computational algorithms via a regression and correlation analysis of the magnitude with respect to the effect of the slope of the weir glacis and local hydraulic inputs used for modeling the weirs accordingly for each observed samples .

Although in the overall aspect of the design of the sample weirs and particularly while earthquake force magnitudes have been predicted note that optimization of the design parameters and the magnitudes have observed being possible by integrating the effects of earthquake force on the stability of the designed weirs in wide band computation and analysis. Indeed, the methodology of the study therefore enable to assess correlation of the input parameters with the predictors and variables of the force systems anticipated to be modeled smoothly by substitution and the step wise computations of each of each parameters embedded in the model equation for the given flow hydraulics of sample weirs .

Therefore for continence; on the methodology of modeling of the magnitude of earthquake force likely to be induced on vertical and crump weirs then the local hydraulics of samples data can be therefore defined as : (1) the design discharge and equations used for modeling the discharge i.e. $Q_{des.} = C\ L\ H_e^{\frac{3}{2}}$ where; $Q_{des.}$= design discharge in m^3/sec ; C = discharge coefficient, L = the crest length of the sample weir in meter and He = is the specific energy head over the weir crest (2) the approach velocity determined for specific head and water depth over the weir crest, slope of the river bed and manning's relation (3) the reach width which correspond to the crest length L of the sample design directly and defined at the location of the weir for the given discharge of each sample designs based on weir formula and also as determined by Lance's regime equation i.e. $P = 4.75\sqrt{Q}$ for large discharge values when used for designing of the sample weirs and where; P= the width of the river considered in meter Q= the design discharge used for designing the sample weirs in m^3/sec **(4)** a pre-defined upstream glacis slope as described 1:n, n value in meter and downstream glacis slope to be analyzed for the stability of the designed weir (5) a predefined weir height . **(**6) a pre-defined silt height which is considered at the head work location or when given for each sample design in meter (7) the determined or assigned value for the width of the weir crest for the sample design .

2.1.2. The derivations of the dimensionless model parameters

Accordingly, the aforementioned parameters being they are an input parameters for modeling they can vary from sample to sample . Indeed they have considered as a local hydraulics input variables for a particular sample designs in the methodology .Off course these parameters while given they used for proceeding the modeling algorithms of earthquake force magnitudes on the respective type of weirs and the overall design aspect of the weir based the equations have devised by the study for computing the magnitude of the required design parameters consistently once defined the numerical values of the dimensionless model parameters have deduced for these given parameters as such i.e .

$$Q_{des.} = C\ L\ H_e^{\frac{3}{2}} \tag{2.1a}$$

$$\alpha_1 = \frac{H_e}{H} \quad (2.1b)$$

$$\alpha_2 = \frac{H_d}{H} \quad (2.1c)$$

$$\alpha_3 = \frac{d_2}{H} \quad \text{(i.e. in case of vertical weir design option)} \quad (2.1d)$$

$$\alpha_2 = \frac{H}{d_2} \quad \text{(i.e. in case of crump weir design option)} \quad (2.1e)$$

$$\alpha_4 = \frac{H_d + H}{H} \quad (2.1f)$$

$$\alpha_0 = \frac{B}{H} \quad (2.1g)$$

Where; H= the designed weir height in meter (an input parameter decided); H_e = the specific energy head on the weir crest (m) which is dependent on the design discharge, Q_{design}; and discharge coefficient , C plus weir length , L ; H_d= water depth on the weir crest in meter. B= crest length in meter in the methodology.

2.1.3. The Model Equations used for modeling the Magnitudes of earthquake force on vertical and crump weirs

In fact as a methodology of the study the overall design activity of vertical and crump, weirs have integrated with earthquake force effect for wide band observation and analysis of the stability of the designed weir while the new modeling approach of the study revitalized. Perpetually, in this study the magnitude of the horizontal and vertical component of earthquake force has anticipated being to induced on the designed weirs correspondingly on vertical and crump weirs has intended to be predicted using eqn. 2.2a,b and 2.3a,b which follow for the given local hydraulic input data have used for modeling in sample designs of vertical and crump weirs respectively. These are actually as indicated hereunder.

$$\{H^2 \ \gamma_1 \ \sigma_h \ W_0 \ (\alpha_0 + 0.5\,m)\} \quad (2.2a)$$

$$\{0.5\,H^2 \ W_0 \ \gamma_1 \ \sigma_v \ (\alpha_0 + m)(\alpha_2 + 1 - \alpha_0 \ \alpha_2)\} \quad (2.2b)$$

$$\{H^2 \ \gamma_1 \ \sigma_h \ W_0 \ (n + 2\alpha_0 + m)\} \quad (2.3a)$$

$$0.5 \ H^2 W_0 \sigma_v \gamma_1 (n + \alpha_0 + m) \quad (2.3b)$$

Where; the parameters in these models has to be understood as described before and n= the slope parameter for the upstream weir glacis in case of crump weir design options and when the slope has expressed as 1:n m/m; m is the slope parameter for vertical and crump weir design options for the downstream glacis of sample designs and when the slope has expressed as 1:m , m in meter and α_h ; α_v is the intensity coefficient for the magnitude of the horizontal and vertical components of earthquake force anticipated to develop on the designed sample weirs as the result of the inertial acceleration i.e the horizontal and vertical inertial acceleration of seismic force and peak ground motion when predicted to be occur at the weir location in wide band analysis respectively.

Hence , in the study eqn.2.2a and eqn.2.2b have used for modeling the magnitude of the horizontal and vertical component of earthquake force on vertical weir and eqn.2.3a and 2.3b on the same way on crump weir design option respectively as the methodology of the study . Thus regressive modeling of the magnitude and in correlation with the slope of the designed weir glacis and the predictors of the force system for the given sample local hydraulic input has anticipated as such by the study meanwhile by optimizing the magnitude for stability analysis of the designed weir in general.

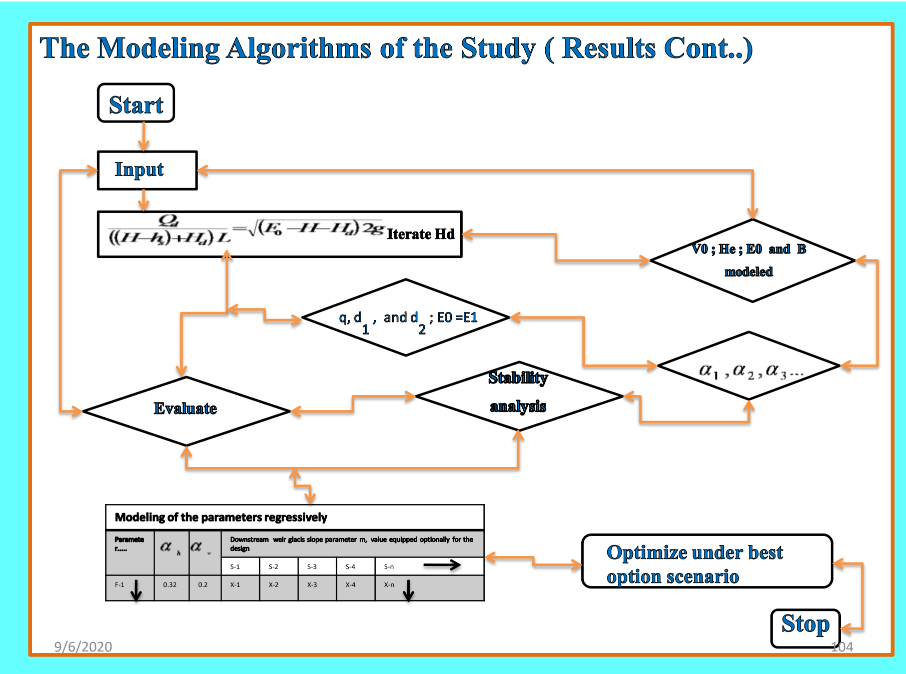

Fig .2. 1. The modeling algorithms of the study

2.2. The Modeling approach of earthquake force and other design parameters for the specific sample weirs

The scope of this study a Computational Research (i.e as an applied research) basically this study has no field experiment in testing the feasibility of the modeling approach of earthquake force and other components of the design parameters required in stability analysis of the weirs but it has considered as a Computational Experiment by using an abstracted computer modeling formats in excel program for data analysis and designing of the weir by the new modeling approach of the study for perusal .

Accordingly in the method and the modeling algorithms of the study in general (1) Prediction and simulation of the required design parameters magnitudes and the trend lines of the force system can be possible having integrating the results generated for the samples by using spread sheet format modeling scheme of the study (2) The overall design of the weirs based on earthquake force modeling when the stability of the sample weirs have been executed and optimization of the parameters therefore can be possible regressively by iterating the slope parameters in the reduced linear equations results as the predictor of the force in linear regression.

To this end Fig.2.1 has illustrated schematically the modeling approach of the study as the whole and while earthquake force have been required to be modeled when sample designs has been executed for the given local hydraulic input data used for modeling.

3. Results and Discussions

3.1. Earthquake force when concerned

Earthquake force is the worst scenario in the stability of diversion weir and hydraulic structures when it is not tolerated by the structure due to resisting moment. The earthquake force induced due to three causes i.e. the inertial force of acceleration, the effective vertical acceleration and hydrodynamic pressure (USBR, 1976) hinted.

The inertia force resulted due to the vertical force of acceleration acting up ward and down ward. When the vertical acceleration acting upward the foundation of the structure will be lifted up ward and become closer to the body of the structure, thus, the effective weight will increase and stress developed on the structure. In the contrary, if the vertical acceleration act down ward, the structure foundation will be move down ward and the effective weight of the structure reduced and its stability threatened. This is the worst scenario for design.

Additionally when giving brief account to the intensity and magnitude of earthquake force causing damages on the structures when occurred in localized areas; different studies were under taken by investigators on the phenomenon associated with earthquake force and Fig.3.1 has indicated below depicted the trends of hydrodynamic forces when acting on dam typically for convenience and its relation with the water depth pooled behind the dam (USBR, 1976).

$$P_e = C\ \lambda\ w\ h \tag{3.1}$$

Where;

P_e= hydrodynamic pressure effect due to the prevailing earthquake horizontal component (pound/foot-cube)

C= Coefficient giving the magnitude of distribution of pressure resulted due to horizontal component earthquake force (dimensionless)

λ = Earthquake intensity, which is equivalent to the ratio of earthquake acceleration to gravitational acceleration

W= unit weight of water in pound per cubic foot.

h =Total depth of reservoir at the section (feet)

Y= Vertical distance from the reservoir surface to a given section (feet)

C_m= Maximum value for a given constant slope and has relation with C value as such described by eqn. 3.2 follow.

$$C = \frac{C_m}{2}\left[\frac{y}{h}\left(2-\frac{y}{h}\right)+\left(\frac{y}{h}\left(2-\frac{y}{h}\right)\right)^{\frac{1}{2}}\right] \tag{3.2}$$

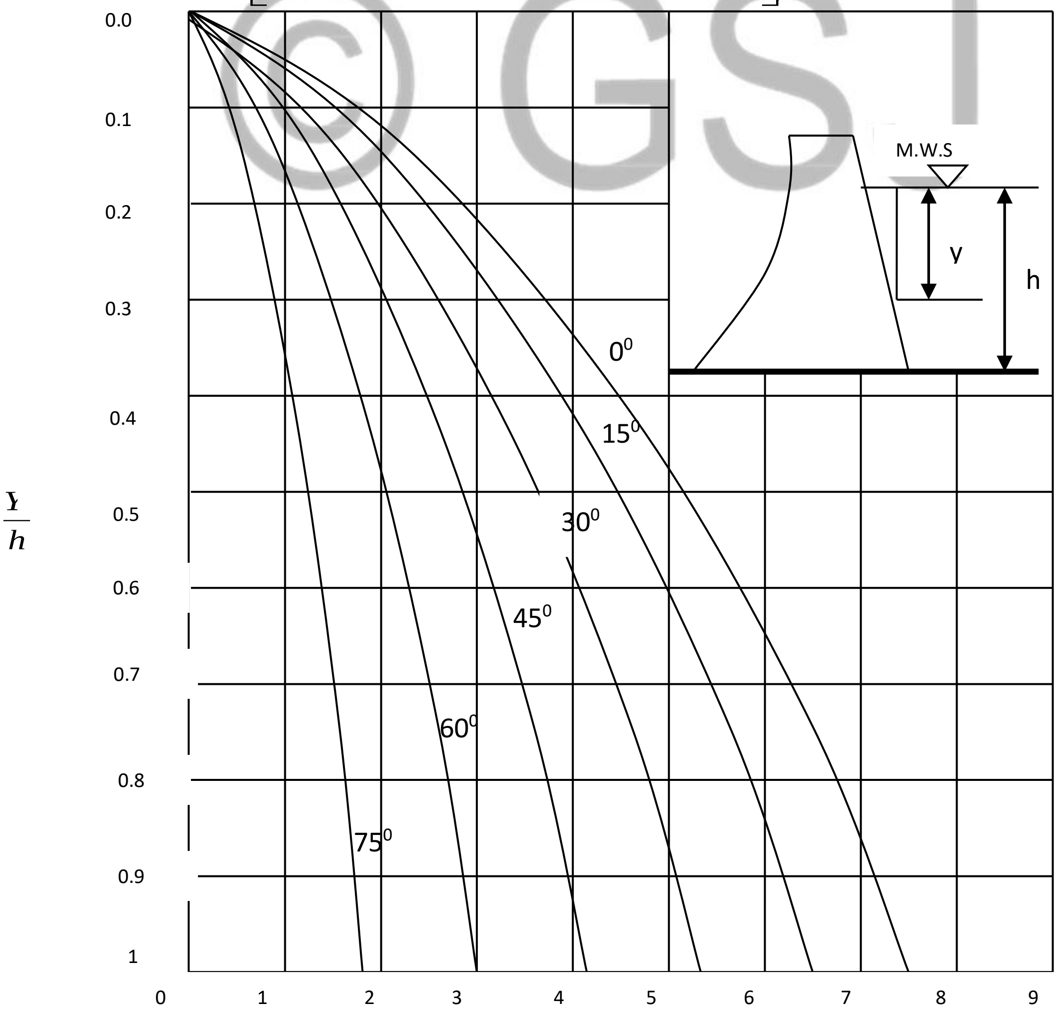

Fig. 3.1. Coefficient for pressure distribution for constant sloping force for hydrodynamic force effect as adopted from (USBR, Small dam design -288-D-2509, 19)

Although in practices when the effect of earthquake force on designed engineering structures have been dealt literatures have reviewed in this context has elicited that dealt the damages on structures often associated with the effect of ground motions and inertial acceleration which not be neglected when twined. Geotechnical factors often exert a major influence on damage patterns and loss of life in earthquake events.

In this case for instance , the localized patterns of heavy damage during the 1985 Mexico City and 1989 Loma Prieta, California, earthquakes provide grave illustrations of the importance of understanding the seismic response of deep clay deposits and loose, saturated sand deposits. The near failure of the Lower San Fernando dam in 1971 due to liquefaction of the upstream shell materials is another grave reminder that we must strive to understand the seismic response of critical earth structures (Chen, W. F et al., 2003).

To this end, geotechnical considerations therefore play an integral role in the development of sound earthquake-resistant designs. The development and transmission of earthquake energy through the underlying geology is quite complex. Earthquakes are produced in a particular geologic setting due to specific physical processes. A mid plate earthquake (e.g., New Madrid) will differ from a plate margin earthquake (e.g., San Andreas).

3.1.1. Strength of seismic events when measured and characterized

Furthermore note that in the assessment of seismic waves and effects in geotechnical investigations; seismic refraction, seismic reflection; electric resistivity and magnetic susceptibility have noted to be in use in geotechnical investigations to understand the nature and phenomenon associated in and worst incidents with respect to shear wave velocity, compression velocity and surface wave event due to earth quick incidents and applications in geotechnical investigation.

As (Chine W. F et al.,2003) hinted seismic refraction survey used to determine depth to bed rocks; and provides information on compression and shear velocity on surface deposits overlying bedrocks. Shear wave travels through the media at a lower velocity than compression wave therefore it is noted that shear wave arrival occurs after compression wave incident. Other type of wave also persists as a secondary arrival as a result of seismic reflection and a combination of reflection and refraction and surface wave. Furthermore; shear wave is distinguishable to provide information on emplaced dynamic properties of materials and there is a unique relation between compressions, shear wave velocity and unite weight of a materials.

In another citation; in practice the stability concern of dams and weirs are basically are operational with respect to the horizontal and vertical inertial acceleration in combination with the peak ground motion and loading system. The oscillatory horizontal and vertical inertial loadings are generated with respect to the dam and retained water in the reservoirs due to seismic disturbance. Hence for analysis the horizontal and vertical components can be computed as: $\sigma_h * static\ loading$ for the horizontal component and for the vertical component it is described by the equation $\sigma_v * static\ loading$ in general.

To this end and for clarity; these forces acting on the section centeroid and seismic forces incident associated with the complex oscillatory pattern and ground motions which generate a transit dynamic loads due to inertia of the dam and retained body of water dependent on the intensity and magnitudes of its occurrence.

The horizontal and vertical acceleration often not equal and (Cevital,1991) hinted that the horizontal component is greater than vertical in intensity and the intensity coefficient which is nothing but the ratio of the peak ground motion to gravitational acceleration i.e. g =9.81m/sec^2 is denoted as: $\alpha_h = (1.5-2)\ \alpha_v$ and this component operate normal to the dam axis. Consequently a worst scenario arises when the horizontal component act upstream side and the vertical component downward. The peak ground motion intern characterized with the acceleration, Velocity and displacement of the motion.

Conclusively, the horizontal acceleration has two components these are the hydrodynamic pressure often in case of dams and horizontal inertia force. The hydrodynamic force also needs to be considered, it may have a severe impact on the structure and an adverse condition may arise. . In fact this pressure has been computed based on the equations stated here i.e.$P_e = 0.55\gamma_m\, \sigma_h\, H^2$ normally when the pressure has been analyzed for the dam design and where the effect of the horizontal inertial acceleration and peak ground motion of earthquake on the retained water behind the dam in creating hydrodynamic pressure on the dame has been concerned

In computing the stability of the diversion weir by considering earthquake force, the coefficient of earth quick force is a design parameters which are in this case when needed to be considered in wide band for modeling of the loading systems and computing the magnitude with respect to slope parameters and existing local hydraulic condition prevail at the weir site by this and stated objectives.

However in conventional design procedures the magnitude is computed by multiplying the static loading by the coefficient not unique models are exist or formulas reviewed by this study so far which can quantify it w.r.t. the flow condition on the weir or energy profile, the weir geometry and slope parameters and conversely at the given local hydraulics . But in general depending on the localized earth quick situation and intensity observed the coefficients can be in the range (0.2 -0.5) for the vertical component of earthquake force (New Mark, 1965, Fell et al.; 1992 and seed, 1979) hinted then for the horizontal component the coefficient vary by a factor of 1.6 on average and it is in the range of (0.32- 0.8).

As (Tencev. . *et al.*, 1991) has further the notions he noted that the horizontal and vertical acceleration of earthquake force often are not equal and the horizontal component is greater than the vertical component in terms of the intensity in turn in magnitude hence the intensity coefficient for the horizontal component can be ranges from (0.32- 0.8) and for the vertical component (0.2-0.5) .in this respect note that the intensity coefficient is nothing but the ratio of the peak ground motion to gravitational force of acceleration i.e. $g = 9.81 m/sec^2$ and in the computation the coefficients actually it is quite clear that the intensity coefficient for the horizontal inertial acceleration has computed as: $\alpha_h = (1.5 - 2)\alpha_v$ where; σ_v is the intensity coefficient for the vertical inertial acceleration of earthquake force and the horizontal and vertical components of earthquake forces are anticipated to be operated normal to the designed weirs in this case as of often operated in dam design.

As (Novak.P,2007) hinted The strength of a seismic event can be characterized by its *magnitude* and its *intensity*, defined thus:
Magnitude: a measure of the energy released; it therefore has the single value for a specific seismic event. And this can categorized on the Richter scale, ranging upwards from M-1.0 to M-9.0.
Intensity: a measure of the violence of seismic shaking attaching to an event, and hence of its destructiveness, at a specific location. Intensity thus varies with position and distance from the epicenter, and is commonly expressed on the modified Mercalli scale of MM- I to MM-XII.

The terminology associated with seismic safety evaluation includes a range of definitions, some of which especially significant in the context of dams, thus:

i. *Maximum Credible Earthquake (MCE):* the event predicted to produce the most severe level of ground motion possible for the geological circumstances of a specific site

ii. Safety Evaluation Earthquake (SEE): the event predicted to produce the most severe level of ground motion against which the safety of the dam from catastrophic failure must be assured.

iii. The Pseudo static Analysis normally used for computing the magnitude of the horizontal and vertical component of earthquake force as the product of the intensity coefficient of the inertial acceleration with the static weight of the structure.

- Several earthquake magnitude scales know to date and it is important to use these scales consistently. The earliest magnitude scale known to be local magnitude scale was developed by Richter (1935).And this defined as the moment of the maximum amplitude on the wooden - Anderson torsion seismography located at a distance 100km from the earthquake source (Richter,1958).
- Other types of magnitudes are surface and body wave magnitudes. This magnitude however is based on the amplitude of seismic waves at different periods. In this case the moment magnitudes different from other magnitude scales because it is directly related with the dimension and characteristics of fault raptures in which expressed as:$M = \log m - 10.7$

  Where; m is seismic moment in dyne-centimeter and computed as ; is shear modulus of materials along the fault plain; A_f is area of the fault in cm^2 and D is average slip in fault raptures.

  a. The magnitude of an earthquake event when occurred in a localized areas the amount of energy released during the difference between earthquake of different magnitude is significant (Chow, W.F.,et al ,2006) .

  b. Seven earthquake event release nearly a thousand times more energy than a magnitude of five events.

  c. Thus the potential seismic damages will typically will increase with earthquake events of greater magnitudes, seismic energies attenuate as far as it travel from the zone of energy release and spread out over a greater volume of materials.

3.2. The Magnitude of Earthquake force while modeled in this study modeling approaches

Normally in this study context of modeling of the magnitude earthquake force the model equations described under eqn.2.2a,b and eqn.2.3a,b were used for predicting the magnitude of the horizontal and vertical component on the designed weirs in the case of vertical and crump weir design options respectively as the main finding.

Actually depending on the input parameters the magnitudes have predicted on the designed weirs likely to be varied consistently being linearly fitted with the models as of the pseudo static methods for the existing variations in input parameters which are generated for the samples depending on the numerical values of the dimensionless modeling parameters inscribed in the equations 2.2a,b and 2.3a,b and then on the predictors of the forces and do also for the variables in the reduced linear models which are generated as indicated under tab. 3. 3a.b and tab.3.4a.b subsequently for sample designs and modeling.

Therefore the input data used for designing the respective type of sample weirs and meanwhile for modeling the magnitude of earthquake force components in this study context are described hereunder tab.3.1 below.

Table.3.1. The Local hydraulic input data in which they are used for the computational algorithms when modeling of the required parameters for the designed sample weirs by the study

Local hydraulics input variables	The type of weirs designed	Observed samples 01	02	03	04	05	06	07	08	09	10
Designed discharge (m3/sec)	VWD	300	1800	120	165	205	450	368.02	500	300	294
	CWD	300	1800	120	165	205	450	368.02	500	300	294
Weir height (m)	VWD	2.2	2.95	1.6	1.89	2.2	2.3	2.25	2.25	2.35	1.9
	CWD	1.85	2.8	1.5	1.67	2.2	2.2	2.25	2.8	1.85	1.9
Tail water depth(m)	VWD	4.2	3.84	2.43	3.08	3.489	5.25	4.477	5.22	3.94	3.84
	CWD	4.1	3.8	2.405	3.01	3.485	5.23	4.77	5.49	4.102	3.72
Silt height behind the weir(m)	VWD	0.6	0.8	0.35	0.5	0.5	0.35	0.500	0.65	0.5	0.45
	CWD	0.5	0.8	0.5	0.5	0.65	0.65	0.750	0.5	0.5	0.45
Water depth on the crest (m)	VWD	3.382	2.888	1.87	2.40	2.7	4.35	3.603	4.3	3.08	3.09
	CWD	3.34	2.85	1.85	2.37	2.68	4.275	3.560	4.45	3.342	3.342
Specific energy head (m)	VWD	3.67	3.02	1.996	2.54	2.885	4.745	3.910	4.74	3.295	3.37
	CWD	3.67	3.024	1.996	2.571	2.883	4.73	3.904	4.788	3.408	3.47
weir length in(m)	VWD	25	201	25	23.5	24.6-	25.6	28.00	28.50	29.5	28.0
	CWD	25	201	25	23.5	24.6	25.6	28	28.5	29.5	28.0
Upstream side weir body slope parameter i.e. 1:n, n in (decimal)	VWD	0	0	0	0	0	0	0	0	0	0.00
	CWD	1.43	1.3	1.4	1.26	1.17	1.45	1.5	1.63	1.65	2.00

Remark:
i.VWD = vertical weir designed sample
ii. CWD= crump weir designed sample
iii. The crest width of the weirs have determined based on Bligh's equations hence not given by option for the samples
iv. The corresponding designed samples of vertical and crump weirs in this respect have designed based on same discharge component

Note that the reduced linear models therefore are quite useful tools to predicate the magnitude of earthquake force upon iterating the specified slope parametric values has equipped for the sample designs in the linear equations and for reggeressively modeling of the magnitude by the study methodology in general. In this case the predictors of the magnitudes have deduced based on these input data procedurally in using the equations developed for modeling and by determining the numerical values of the dimensionless modeling parameters of this study in which have incorporated in the models in the methodology as the results .

3.2. 1.The modeling parameters of the study

Actually, the overall computation of the magnitudes of the forces anticipated to be induced on the designed weirs in this study modeling methodology relay on the numerical values of the dimensionless modeling parameters in which they are determined w.r.t the observed energy profile over the weir crest, weir height and weir geometry as described under eqn.2.1a-eqn.2.1g in general as the methodology of the study .

These parameters therefore are capable of integrating the required force system with the flow hydraulics dimensions consistently when the design of the weirs in general and modeling of the magnitudes of earthquake force components on the designed weir by prediction when accomplished in particular by the study.

Accordingly the results observed for sample test therefore in this regard has elucidated under table 3.2a and the variance ratio test for the observed numerical values of these parameters for the designed samples of vertical and crump weirs while evaluated further it show that the ANOVA resulted the computed statistics for the parameters of measure being it is : 1.26, 1.25, 8.236, 2.936 and 1.236 having a mean value of the (1.513, 1.404, 1.767, 2.488, 1.327) and (1.579, 1.451, 0.576, 2.349 and 1.385) for the observed vertical and crump weir samples evaluated in the test w.r.t to these model parameters in i.e alpha one, alpha two , alpha three, alpha four and alpha zero or prime values as order of importance's accordingly.

Table 3.2a The results obtained w.r.t the numerical value of the dimensionless model parameters of the study for the observed sample weirs for design

Descriptions	Type	Observed samples									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
α_1	**vwd**	**1.684**	**1.032**	**1.253**	**1.368**	**1.322**	**1.847**	**1.75**	**1.678**	**1.41**	**1.783**
	crwd	**1.986**	**1.08**	**1.331**	**1.54**	**1.314**	**1.917**	**1.735**	**1.338**	**1.779**	**1.77**
α_2	**vwd**	**1.55**	**0.977**	**1.178**	**1.276**	**1.24**	**1.708**	**1.615**	**1.544**	**1.314**	**1.641**
	crwd	**1.806**	**0.977**	**1.245**	**1.42**	**1.224**	**1.743**	**1.582**	**1.256**	**1.63**	**1.626**
α_3	**vwd**	**1.93**	**1.305**	**1.524**	**1.635**	**1.589**	**2.08**	**1.99**	**1.923**	**1.674**	**2.022**
	crwd	**0.451**	**0.736**	**0.624**	**0.554**	**0.632**	**0.644**	**0.504**	**0.621**	**0.494**	**0.496**
α_4	**vwd**	**2.55**	**2.806**	**2.178**	**2.277**	**2.24**	**2.708**	**2.615**	**2.544**	**2.319**	**2.641**
	crwd	**2.806**	**2.018**	**2.245**	**2.42**	**2.224**	**2.743**	**2.582**	**2.256**	**2.629**	**2.626**
α_0	**vwd**	**1.476**	**0.905**	**1.099**	**1.2**	**1.16**	**1.62**	**1.535**	**1.472**	**1.237**	**1.563**
	crwd	**1.74**	**0.947**	**1.167**	**1.351**	**1.152**	**1.681**	**1.522**	**1.173**	**1.56**	**1.552**

*:

Table 3.2b. The results describing the statistical test has conducted w.r.t. the numerical values of the model parameters observed for the sample designs an

Descriptions	Type	mean	St.dev	Var.	F-cal	Table values 5% L.S	Table values 1% L.S	Mean Difference	t-cal	Table values 5% L.S	Table values 1% L.S
α_1	vwd	1.513	0.272	0.074	1.236	3.18	5.35	0.066	0.341	1.83	2.82
	crwd	1.579	0.302	0.091							
α_2	vwd	1.404	0.24	0.058	1.25	3.18	5.35	0.047	0.261	1.83	2.82
	crwd	1.451	0.268	0.072							
α_3	vwd	1.767	0.257	0.066	8.236	3.18	5.35	1.192	6.951	1.83	2.82
	crwd	0.576	0.09	0.008							
α_4	vwd	2.488	0.218	0.047	2.963	3.18	5.35	0.139	0.448	1.83	2.82
	crwd	2.349	0.375	0.14							
α_0	vwd	1.327	0.238	0.057	1.236	3.18	5.35	0.058	0.339	1.83	2.82
	crwd	1.385	0.265	0.07							

*: The alpha parameters are the modeling parameters of the study in which used for integrating the flow hydraulics with the required design parameters and earthquake force magnitudes deliberately in the derivation and for modeling

To this end, in the results the variance ratio test have confirmed that the computed statistical parameters corresponding to alpha one , two and alpha prime has found being less than the table value at 0.05 probability as described under tab.3.2b and with these it has inferred that these parameters not indicated significant variations among samples observed.

It is presumably sure that these parameters have denoted the designation of the flow hydraulics consistently for the observed and compared samples even though there are variations in input data.

But for alpha three and alpha four actually the computed statistics has found as being it is 8.236 and 2.936 respectively having indicated significant variations at 0.05 percent probability among the observed sample designs in terms of upstream and downstream water level when the flow system simulated and have modeled for the given discharge values has used for sample designs and other input variables in modeling of the respective type of weirs . The variations in weir geometry and tail water depth on vertical and crump weirs have consequence these results and plus in the designation of the flow system and modeling by the study the numerical values for alpha three as the parameter of modeling while computed for vertical and crump weirs the due have inverse relations. That is why the variations accounted for the test

As far as the student t-test has conducted in this regard and the results have observed when concerned the computed statistics for the student t- test w.r.t the parameters evaluated i.e alpha one, alpha two , alpha three, alpha four and alpha zero or prime values of sample data has found being it is : 0.341, 0.261,6.951,0.448, and 0.339 respectively . indeed in the result the mean difference for these parameters while observed on vertical and crump weirs has found as it is 0.066, 0.0487,1.192,0.139 and 0.058 accordingly and only alpha three among the parameters tested has shown significant variations among the corresponding samples of vertical and crump weirs observed in the test at 0.05 percent probability level as indicated in

Table 3.3a. Results describing the reduced linear models for the prediction of the magnitude of the horizontal component of earthquake force on vertical weir samples in KN i.e where X, being considered as slope parameter for the downstream glacis in terms of m and the slope being 1:m , m in meter.

Samples designed	Descriptions	Intensity coefficient	Linear trend line equation for the regression analysis of the magnitude	Coefficient of determination for the series
1	VWD-S-01	0.32	y = 1.781x + 5.259	$R^2 = 1$
		0.48	y = 2.671x + 7.889	$R^2 = 1$
		0.64	y = 3.562x + 10.52	$R^2 = 1$
		0.8	y = 4.452x + 13.15	$R^2 = 1$
2	VWD-S-02	0.32	y = 3.202x + 5.797	$R^2 = 1$
		0.48	y = 4.803x + 8.695	$R^2 = 1$
		0.64	y = 6.405x + 11.59	$R^2 = 1$
		0.8	y = 8.006x + 14.49	$R^2 = 1$
3	VWD-S-03	0.32	y = 0.942x + 2.070	$R^2 = 1$
		0.48	y = 1.413x + 3.105	$R^2 = 1$
		0.64	y = 1.884x + 4.140	$R^2 = 1$
		0.8	y = 2.355x + 5.176	$R^2 = 1$
4	VWD-S-04	0.32	y = 1.314x + 3.155	$R^2 = 1$
		0.48	y = 1.971x + 4.733	$R^2 = 1$
		0.64	y = 2.629x + 6.311	$R^2 = 1$
		0.8	y = 3.286x + 7.888	$R^2 = 1$
5	VWD-S-05	0.32	y = 1.781x + 4.131	$R^2 = 1$
		0.48	y = 2.671x + 6.196	$R^2 = 1$
		0.64	y = 3.562x + 8.262	$R^2 = 1$
		0.8	y = 4.452x + 10.32	$R^2 = 1$
6	VWD-S-06	0.32	y = 1.946x + 6.307	$R^2 = 1$
		0.48	y = 2.920x + 9.460	$R^2 = 1$
		0.64	y = 3.893x + 12.61	$R^2 = 1$
		0.8	y = 4.866x + 15.76	$R^2 = 1$
7	VWD-S-07	0.32	y = 1.863x + 5.717	$R^2 = 1$
		0.48	y = 2.794x + 8.576	$R^2 = 1$
		0.64	y = 3.726x + 11.43	$R^2 = 1$
		0.8	y = 4.657x + 14.29	$R^2 = 1$
8	VWD-S-08	0.32	y = 1.863x + 5.482	$R^2 = 1$
		0.48	y = 2.794x + 8.224	$R^2 = 1$
		0.64	y = 3.726x + 10.96	$R^2 = 1$
		0.8	y = 4.657x + 13.70	$R^2 = 1$
9	VWD-S-09	0.32	y = 2.032x + 5.028	$R^2 = 1$
		0.48	y = 3.048x + 7.543	$R^2 = 1$
		0.64	y = 4.064x + 10.05	$R^2 = 1$
		0.8	y = 5.080x + 12.57	$R^2 = 1$
10	VWD-S-10	0.32	y = 1.328x + 4.153	$R^2 = 1$
		0.48	y = 1.992x + 6.230	$R^2 = 1$
		0.64	y = 2.657x + 8.307	$R^2 = 1$
		0.8	y = 3.321x + 10.38	$R^2 = 1$

tab.4.3 due to the fact that there is inverse relation in designation of the flow hydraulics on the respective type of weirs for this parameters as a justification on this result. Therefore as the methodology of modeling once the numerical values of the dimensionless modele parameters have determined and tested meanwhile incorporating these values in the derived equations and by integrating the effect on the magnitude of the force components in correlation with the slope of the weir glacis ample alternative results automatically have observed being generated and the following subsequent tables i.e tab.3.4; tab.3.5 and tab.3.6 has indicated the critical values determined for magnitude of earthquake forces components in

compromise with the pseudo static approach for the samples have tested and evaluated . When the magnitude of earthquake force predicted tab.3.3a-d has indicated that the results

*: The magnitude of the induced earthquake force computed using the equations stated for each samples corresponding to the intensity level by iterating the value of X as X= m and m is slope parameter for the downstream weir glacis i.e 1:m, m in meter .

Table.3.3b.. Results describing the reduced linear models for the prediction of the magnitude of the vertical component of earthquake force on vertical weir samples in KN i.e. Where X, being considered as slope parameter for the downstream glacis in terms of m and the slope being 1:m , m in meter.

Samples designed	Descriptions	Intensity coefficient	Linear trend line equation for the regression analysis of the magnitude	Coefficient of determination for the series
1	VWD-S-01	0.2	y = 1.113x + 3.287	$R^2 = 1$
		0.3	y = 1.669x + 4.931	$R^2 = 1$
		0.4	y = 2.226x + 6.574	$R^2 = 1$
		0.5	y = 2.783x + 8.218	$R^2 = 1$
2	VWD-S-02	0.2	y = 2.001x + 3.623	$R^2 = 1$
		0.3	y = 3.002x + 5.434	$R^2 = 1$
		0.4	y = 4.003x + 7.246	$R^2 = 1$
		0.5	y = 5.003x + 9.058	$R^2 = 1$
3	VWD-S-03	0.2	y = 0.588x + 1.294	$R^2 = 1$
		0.3	y = 0.883x + 1.941	$R^2 = 1$
		0.4	y = 1.177x + 2.588	$R^2 = 1$
		0.5	y = 1.472x + 3.235	$R^2 = 1$
4	VWD-S-04	0.2	y = 0.821x + 1.972	$R^2 = 1$
		0.3	y = 1.232x + 2.958	$R^2 = 1$
		0.4	y = 1.643x + 3.944	$R^2 = 1$
		0.5	y = 2.054x + 4.930	$R^2 = 1$
5	VWD-S-05	0.2	y = 1.113x + 2.581	$R^2 = 1$
		0.3	y = 1.669x + 3.872	$R^2 = 1$
		0.4	y = 1.669x + 3.872	$R^2 = 1$
		0.5	y = 2.783x + 6.454	$R^2 = 1$
6	VWD-S-06	0.2	y = 1.216x + 3.942	$R^2 = 1$
		0.3	y = 1.825x + 5.912	$R^2 = 1$
		0.4	y = 2.433x + 7.883	$R^2 = 1$
		0.5	y = 3.041x + 9.854	$R^2 = 1$
7	VWD-S-07	0.2	y = 1.164x + 3.573	$R^2 = 1$
		0.3	y = 1.746x + 5.360	$R^2 = 1$
		0.4	= 2.328x + 7.147	$R^2 = 1$
		0.5	y = 2.910x + 8.934	$R^2 = 1$
8	VWD-S-08	0.2	y = 1.164x + 3.426	$R^2 = 1$
		0.3	y = 1.746x + 5.140	$R^2 = 1$
		0.4	y = 2.328x + 6.853	$R^2 = 1$
		0.5	y = 2.910x + 8.566	$R^2 = 1$
9	VWD-S-09	0.2	y = 1.270x + 3.143	$R^2 = 1$
		0.3	y = 1.905x + 4.714	$R^2 = 1$
		0.4	y = 2.540x + 6.286	$R^2 = 1$
		0.5	y = 3.175x + 7.857	$R^2 = 1$
10	VWD-S-10	0.2	y = 0.830x + 2.596	$R^2 = 1$
		0.3	y = 1.245x + 3.894	$R^2 = 1$
		0.4	y = 1.660x + 5.192	$R^2 = 1$
		0.5	y = 2.075x + 6.490	$R^2 = 1$

*: The magnitude of the induced earthquake force computed using the equations stated for each samples corresponding to the intensity level by iterating the value of X as X= m and m is slope parameter for the downstream weir glacis i.e 1:m, m in meter .

Table 3.3c. Results describing the reduced linear models for the prediction of the magnitude of the horizontal component of earthquake force on crump weir samples i.e. Where X, being considered as slope parameter for the downstream glacis in terms of m and the slope being 1:m , m in meter.

Samples designed	Descriptions	Intensity coefficient	Linear trend line equation for the regression analysis of the magnitude	Coefficient of determination for the series
1	CrWD-S-01	0.32	y = 1.259x + 6.189	$R^2 = 1$
		0.48	y = 1.889x + 9.284	$R^2 = 1$
		0.64	y = 2.519x + 12.37	$R^2 = 1$
		0.8	y = 3.148x + 15.47	$R^2 = 1$
2	CrWD-S-02	0.32	y = 2.885x + 9.216	$R^2 = 1$
		0.48	y = 4.327x + 13.82	$R^2 = 1$
		0.64	y = 5.770x + 18.43	$R^2 = 1$
		0.8	y = 7.212x + 23.04	$R^2 = 1$
3	CrWD-S-03	0.32	y = 0.828x + 3.092	$R^2 = 1$
		0.48	y = 1.242x + 4.638	$R^2 = 1$
		0.64	y = 1.656x + 6.184	$R^2 = 1$
		0.8	y = 2.07x + 7.730	$R^2 = 1$
4	CrWD-S-04	0.32	y = 1.026x + 4.065	$R^2 = 1$
		0.48	y = 1.539x + 6.098	$R^2 = 1$
		0.64	y = 2.052x + 8.131	$R^2 = 1$
		0.8	y = 2.565x + 10.16	$R^2 = 1$
5	CrWD-S-05	0.32	y = 1.781x + 6.188	$R^2 = 1$
		0.48	y = 2.671x + 9.283	$R^2 = 1$
		0.64	y = 3.562x + 12.37	$R^2 = 1$
		0.8	y = 4.452x + 15.47	$R^2 = 1$
6	CrWD-S-06	0.32	y = 1.781x + 8.571	$R^2 = 1$
		0.48	y = 2.671x + 12.85	$R^2 = 1$
		0.64	y = 3.562x + 17.14	$R^2 = 1$
		0.8	y = 4.452x + 21.42	$R^2 = 1$
7	CrWD-S-07	0.32	y = 1.863x + 8.465	$R^2 = 1$
		0.48	y = 2.794x + 12.69	$R^2 = 1$
		0.64	y = 3.726x + 16.93	$R^2 = 1$
		0.8	y = 4.657x + 21.16	$R^2 = 1$
8	CrWD-S-08	0.32	y = 2.885x + 11.47	$R^2 = 1$
		0.48	y = 4.327x + 17.20	$R^2 = 1$
		0.64	y = 5.770x + 22.94	$R^2 = 1$
		0.8	y = 7.212x + 28.68	$R^2 = 1$
9	CrWD-S-09	0.32	y = 1.259x + 6.008	$R^2 = 1$
		0.48	y = 1.889x + 9.013	$R^2 = 1$
		0.64	y = 2.519x + 12.01	$R^2 = 1$
		0.8	y = 3.148x + 15.02	$R^2 = 1$
10	CrWD-S-10	0.32	y = 1.328x + 6.780	$R^2 = 1$
		0.48	y = 1.992x + 10.17	$R^2 = 1$
		0.64	y = 1.992x + 10.17	$R^2 = 1$
		0.8	y = 3.321x + 16.95	$R^2 = 1$

*: The magnitude of the induced earthquake force computed using the equations stated for each samples corresponding to the intensity level by iterating the value of X as X= m and m is slope parameter for the downstream weir glacis i.e 1:m, m in meter .

Table3.3d. Results describing the reduced linear models for the prediction of the magnitude of the vertical component of earthquake force on crump weir samples i.e. where X, being considered as slope parameter for the downstream glacis in terms of m and the slope being 1:m , m in meter.

Samples designed	Descriptions	Intensity coefficient	Linear trend line equation for the regression analysis of the magnitude	Coefficient of determination for the series
1	CrWD-S-01	0.2	y = 0.787x + 3.868	$R^2 = 1$
		0.3	y = 1.180x + 5.802	$R^2 = 1$
		0.4	y = 1.574x + 7.737	$R^2 = 1$
		0.5	y = 1.967x + 9.671	$R^2 = 1$
2	CrWD-S-02	0.2	y = 1.803x + 5.760	$R^2 = 1$
		0.3	y = 2.704x + 8.640	$R^2 = 1$
		0.4	y = 3.606x + 11.52	$R^2 = 1$
		0.5	y = 4.508x + 14.40	$R^2 = 1$
3	CrWD-S-03	0.2	y = 0.517x + 1.932	$R^2 = 1$
		0.3	y = 0.776x + 2.898	$R^2 = 1$
		0.4	y = 1.035x + 3.865	$R^2 = 1$
		0.5	y = 1.293x + 4.831	$R^2 = 1$
4	CrWD-S-04	0.2	y = 0.641x + 2.541	$R^2 = 1$
		0.3	y = 0.962x + 3.811	$R^2 = 1$
		0.4	y = 1.282x + 5.082	$R^2 = 1$
		0.5	y = 1.603x + 6.352	$R^2 = 1$
5	CrWD-S-05	0.2	y = 1.113x + 3.868	$R^2 = 1$
		0.3	y = 1.669x + 5.801	$R^2 = 1$
		0.4	y = 2.226x + 7.735	$R^2 = 1$
		0.5	y = 2.783x + 9.669	$R^2 = 1$
6	CrWD-S-06	0.2	y = 1.113x + 5.357	$R^2 = 1$
		0.3	y = 1.669x + 8.035	$R^2 = 1$
		0.4	y = 2.226x + 10.71	$R^2 = 1$
		0.5	y = 2.783x + 13.39	$R^2 = 1$
7	CrWD-S-07	0.2	y = 1.164x + 5.291	$R^2 = 1$
		0.3	y = 1.746x + 7.936	$R^2 = 1$
		0.4	y = 2.328x + 10.58	$R^2 = 1$
		0.5	y = 2.910x + 13.22	$R^2 = 1$
8	CrWD-S-08	0.2	y = 1.803x + 7.169	$R^2 = 1$
		0.3	y = 2.704x + 10.75	$R^2 = 1$
		0.4	y = 3.606x + 14.34	$R^2 = 1$
		0.5	y = 4.508x + 17.92	$R^2 = 1$
9	CrWD-S-09	0.2	y = 0.787x + 3.755	$R^2 = 1$
		0.3	y = 1.180x + 5.633	$R^2 = 1$
		0.4	y = 1.574x + 7.510	$R^2 = 1$
		0.5	y = 1.967x + 9.388	$R^2 = 1$
10	CrWD-S-10	0.2	y = 0.830x + 4.237	$R^2 = 1$
		0.3	y = 1.245x + 6.356	$R^2 = 1$
		0.4	= 1.660x + 8.475	$R^2 = 1$
		0.5	y = 2.075x + 10.59	$R^2 = 1$

*: The magnitude of the induced earthquake force computed using the equations stated for each samples corresponding to the intensity level by iterating the value of X as X= m and m is slope parameter for the downstream weir glacis i.e 1:m, m in meter .

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Table 3.4a . The magnitude of the induced earthquake force components have modeled on the designed samples of vertical weirs based on the given local hydraulic input data by the study methodology

No	Description	E.q.f.i.c		Horizontal component in KN					Vertical component in KN				
				Slope of the downstream weir glacis					Slope of the downstream weir glacis				
		α_h	α_v	1:1.2	1:1.5	1:1.75	1:2.5	1:4.5	1:1.2	1:1.5	1:1.75	1:2.5	1:4.5
1	SDVW-01	0.32	0.2	7.397	7.932	8.377	9.713	13.27	4.623	4.957	5.236	6.07	8.297
		0.48	0.3	11.1	11.9	12.57	14.57	19.91	6.935	7.436	7.853	9.106	12.45
		0.64	0.4	14.79	15.86	16.75	19.43	26.55	9.247	9.915	10.47	12.14	16.59
		0.8	0.5	18.49	19.83	20.94	24.28	33.19	11.56	12.39	13.09	15.18	20.74
2	SDVW-02	0.32	0.2	9.64	10.6	11.4	13.8	20.21	6.025	6.626	7.126	8.627	12.63
		0.48	0.3	14.46	15.9	17.1	20.71	30.31	9.038	9.938	10.69	12.94	18.95
		0.64	0.4	19.28	21.2	22.8	27.61	40.42	12.05	13.25	14.25	17.25	25.26
		0.8	0.5	24.1	26.5	28.5	34.51	50.52	15.06	16.56	17.82	21.57	31.58
3	SDVW-03	0.32	0.2	3.201	3.484	3.719	4.426	6.31	2.001	2.177	2.324	2.766	3.944
		0.48	0.3	4.801	5.225	5.579	6.638	9.465	3.001	3.266	3.487	4.149	5.915
		0.64	0.4	6.402	6.967	7.438	8.851	12.62	4.001	4.354	4.649	5.532	7.887
		0.8	0.5	8.002	8.709	9.298	11.06	15.77	5.001	5.443	5.811	6.915	9.859
4	SDVW-04	0.32	0.2	4.733	5.127	5.456	6.442	9.071	2.958	3.205	3.41	4.026	5.669
		0.48	0.3	7.099	7.691	8.184	9.663	13.61	4.437	4.807	5.115	6.039	8.504
		0.64	0.4	9.466	10.25	10.91	12.88	18.14	5.916	6.409	6.82	8.052	11.34
		0.8	0.5	11.83	12.82	13.64	16.1	22.68	7.395	8.011	8.525	10.07	14.17
5	SDVW-05	0.32	0.2	6.268	6.803	7.248	8.584	12.15	3.918	4.252	4.53	5.365	7.591
		0.48	0.3	9.403	10.2	10.87	12.88	18.22	5.877	6.378	6.795	8.047	11.39
		0.64	0.4	12.54	13.61	14.5	17.17	24.29	7.836	8.503	9.06	10.73	15.18
		0.8	0.5	15.67	17.01	18.12	21.46	30.37	9.794	10.63	11.33	13.41	18.98
6	SDVW-06	0.32	0.2	8.643	9.227	9.714	11.17	15.07	5.402	5.767	6.071	6.984	9.417
		0.48	0.3	12.96	13.84	14.57	16.76	22.6	8.103	8.651	9.107	10.48	14.13
		0.64	0.4	17.29	18.45	19.43	22.35	30.13	10.8	11.53	12.14	13.97	18.83
		0.8	0.5	21.61	23.07	24.28	27.93	37.67	13.51	14.42	15.18	17.46	23.54
7	SDVW-07	0.32	0.2	7.953	8.512	8.978	10.38	14.1	4.971	5.32	5.611	6.485	8.813
		0.48	0.3	11.93	12.77	13.47	15.56	21.15	7.456	7.98	8.417	9.727	13.22
		0.64	0.4	15.91	17.02	17.96	20.75	28.2	9.942	10.64	11.22	12.97	17.63
		0.8	0.5	19.88	21.28	22.45	25.94	35.25	12.43	13.3	14.03	16.21	22.03
8	SDVW-08	0.32	0.2	7.718	8.277	8.743	10.14	13.87	4.824	5.173	5.464	6.338	8.666
		0.48	0.3	11.58	12.42	13.11	15.21	20.8	7.236	7.76	8.197	9.507	13
		0.64	0.4	15.44	16.55	17.49	20.28	27.73	9.648	10.35	10.93	12.68	17.33
		0.8	0.5	19.3	20.69	21.86	25.35	34.67	12.06	12.93	13.66	15.84	21.67
9	SDVW-09	0.32	0.2	7.468	8.077	8.585	10.11	14.17	4.667	5.048	5.366	6.318	8.859
		0.48	0.3	11.2	12.12	12.88	15.16	21.26	7.001	7.572	8.049	9.478	13.29
		0.64	0.4	14.94	16.15	17.17	20.22	28.35	9.334	10.1	10.73	12.64	17.72
		0.8	0.5	18.67	20.19	21.46	25.27	35.44	11.67	12.62	13.41	15.8	22.15
10	SDVW-10	0.32	0.2	5.748	6.147	6.479	7.475	10.13	3.593	3.842	4.049	4.672	6.333
		0.48	0.3	8.622	9.22	9.718	11.21	15.2	5.389	5.762	6.074	7.008	9.499
		0.64	0.4	11.5	12.29	12.96	14.95	20.26	7.185	7.683	8.098	9.344	12.67
		0.8	0.5	14.37	15.37	16.2	18.69	25.33	8.981	9.604	10.12	11.68	15.83

RM: i..E.Q.I,C = earthquake force intensity coefficient ii. α_h = intensity coefficient for the magnitude of the horizontal component iii.α_v = intensity coefficient for the magnitude of the vertical component iv. SDVW= sample design vertical weir

Table3.4b . The magnitude of the induced earthquake force components have modeled on the designed sample crump weirs based on the given local hydraulic input data by the study methodology

No	Description	E.q.f.i.c		Horizontal component in KN					Vertical component in KN				
		α_h	α_v	1:1.2	1:1.5	1:1.75	1:2.5	1:3	1:1.2	1:1.5	1:1.75	1:2.5	1:3
1	SDCW-01	**0.32**	**0.2**	7.701	8.079	8.394	9.338	9.968	4.813	5.049	5.246	5.837	6.23
		0.48	**0.3**	11.55	12.12	12.59	14.01	14.95	7.22	7.574	7.869	8.755	9.345
		0.64	**0.4**	15.4	16.16	16.79	18.68	19.94	9.626	10.1	10.49	11.67	12.46
		0.8	**0.5**	19.25	20.2	20.98	23.35	24.92	12.03	12.62	13.12	14.59	15.58
2	SDCW-02	**0.32**	**0.2**	12.68	13.54	14.27	16.43	17.87	7.924	8.465	8.916	10.27	11.17
		0.48	**0.3**	19.02	20.32	21.4	24.64	26.81	11.89	12.7	13.37	15.4	16.75
		0.64	**0.4**	25.36	27.09	28.53	32.86	35.74	15.85	16.93	17.83	20.54	22.34
		0.8	**0.5**	31.7	33.86	35.66	41.07	44.68	19.81	21.16	22.29	25.67	27.92
3	SDVW-03	**0.32**	**0.2**	4.086	4.334	4.541	5.162	5.576	2.554	2.709	2.838	3.226	3.485
		0.48	**0.3**	6.129	6.501	6.812	7.743	8.364	3.83	4.063	4.257	4.84	5.228
		0.64	**0.4**	8.172	8.668	9.082	10.32	11.15	5.107	5.418	5.676	6.453	6.97
		0.8	**0.5**	10.21	10.84	11.35	12.91	13.94	6.384	6.772	7.096	8.066	8.713
4	SDCW-04	**0.32**	**0.2**	5.297	5.605	5.862	6.631	7.145	3.311	3.503	3.664	4.145	4.465
		0.48	**0.3**	7.946	8.408	8.792	9.947	10.72	4.966	5.255	5.495	6.217	6.698
		0.64	**0.4**	10.59	11.21	11.72	13.26	14.29	6.621	7.006	7.327	8.289	8.931
		0.8	**0.5**	13.24	14.01	14.65	16.58	17.86	8.277	8.758	9.159	10.36	11.16
5	SDCW-05	**0.32**	**0.2**	8.326	8.86	9.306	10.64	11.53	5.204	5.538	5.816	6.651	7.208
		0.48	**0.3**	12.49	13.29	13.96	15.96	17.3	7.806	8.307	8.724	9.976	10.81
		0.64	**0.4**	16.65	17.72	18.61	21.28	23.06	10.41	11.08	11.63	13.3	14.42
		0.8	**0.5**	20.82	22.15	23.26	26.6	28.83	13.01	13.84	14.54	16.63	18.02
6	SDCW-06	**0.32**	**0.2**	10.71	11.24	11.69	13.02	13.91	6.693	7.027	7.305	8.14	8.697
		0.48	**0.3**	16.06	16.86	17.53	19.54	20.87	10.04	10.54	10.96	12.21	13.05
		0.64	**0.4**	21.42	22.49	23.38	26.05	27.83	13.39	14.05	14.61	16.28	17.39
		0.8	**0.5**	26.77	28.11	29.22	32.56	34.79	16.73	17.57	18.26	20.35	21.74
7	SDCW-07	**0.32**	**0.2**	10.7	11.26	11.73	13.12	14.05	6.688	7.038	7.329	8.202	8.784
		0.48	**0.3**	16.05	16.89	17.59	19.68	21.08	10.03	10.56	10.99	12.3	13.18
		0.64	**0.4**	21.4	22.52	23.45	26.25	28.11	13.38	14.08	14.66	16.4	17.57
		0.8	**0.5**	26.75	28.15	29.31	32.81	35.14	16.72	17.59	18.32	20.5	21.96
8	SDCW-08	**0.32**	**0.2**	14.93	15.8	16.52	18.68	20.13	9.334	9.875	10.33	11.68	12.58
		0.48	**0.3**	22.4	23.7	24.78	28.03	30.19	14	14.81	15.49	17.52	18.87
		0.64	**0.4**	29.87	31.6	33.04	37.37	40.25	18.67	19.75	20.65	23.36	25.16
		0.8	**0.5**	37.34	39.5	41.3	46.71	50.32	23.33	24.69	25.81	29.19	31.45
9	SDCW-09	**0.32**	**0.2**	7.52	7.898	8.213	9.157	9.787	4.7	4.936	5.133	5.723	6.117
		0.48	**0.3**	11.28	11.85	12.32	13.74	14.68	7.05	7.404	7.7	8.585	9.175
		0.64	**0.4**	15.04	15.8	16.43	18.31	19.57	9.4	9.872	10.27	11.45	12.23
		0.8	**0.5**	18.8	19.74	20.53	22.89	24.47	11.75	12.34	12.83	14.31	15.29
10	SDCW-10	**0.32**	**0.2**	8.375	8.773	9.106	10.1	10.77	5.234	5.483	5.691	6.314	6.729
		0.48	**0.3**	12.56	13.16	13.66	15.15	16.15	7.851	8.225	8.536	9.471	10.09
		0.64	**0.4**	16.75	17.55	18.21	20.2	21.53	10.47	10.97	11.38	12.63	13.46
		0.8	**0.5**	20.94	21.93	22.76	25.25	26.92	13.09	13.71	14.23	15.78	16.82

RM: i..E.Q.I,C = earthquake force intensity coefficient ii. α_h = intensity coefficient for the magnitude of the horizontal component iii.α_v = intensity coefficient for the magnitude of the vertical component iv. SDCW= sample design crump weirs generated for the reduced liner models based on the predictors and variables of the force system that have correlated with the input data used for modeling the sample weirs in the analysis . Ultimately, under tables 3.4a and 3.4b the magnitude of the induced horizontal and vertical components of earthquake forces have predicted for the samples by the methodology illustrated giving clear insight on the method for perusal.

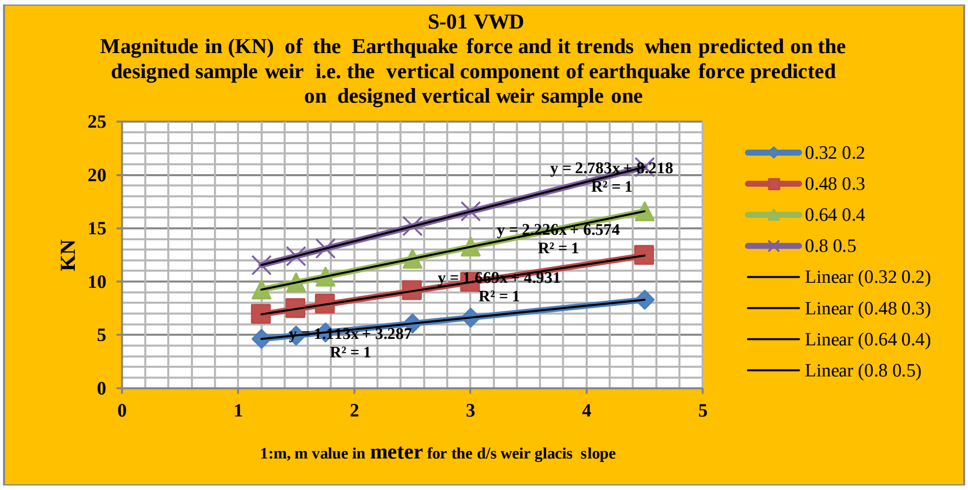
When modeling of earthquake force magnitude horizontal and vertical inertial accelerations of seismic events are not equal, the former being of greater intensity. For design purposes both should be considered operative in the sense least favorable to stability of the structure.

The horizontal l inertial accelerations is therefore, it is assumed to operate normal to the axis of the dam. Under reservoir full conditions the most adverse seismic loading will then occur when a ground shock is associated with: (1) horizontal foundation acceleration operating upstream, and (2) vertical foundation acceleration operating downwards in case of dam design .

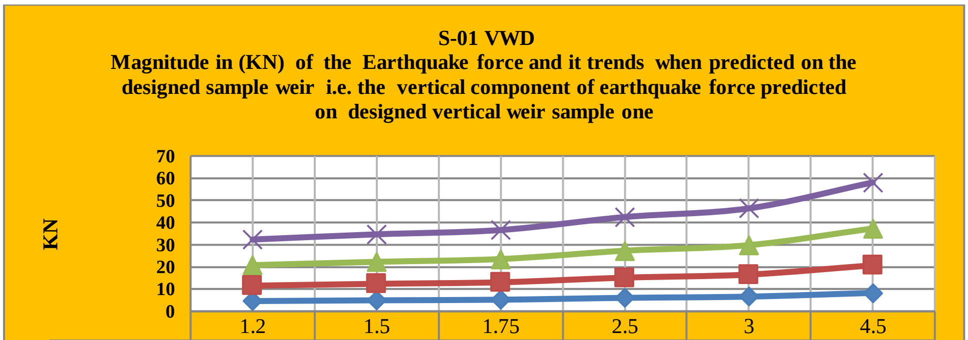
Accordingly, the existing correlation of the magnitude of each of each earthquake force components with respect to the predictors and the variables of the forces have determined based on the input local hydraulics data of the sample weirs in the design of vertical and crump weirs and as investigated notably , it is quite and has proofed that the magnitudes has seen positive correlation with the slope parameters i.e 1:m , m values have equipped for the sample design for the downstream weir glacis meanwhile resulting the reduced linear models that can attributes the modeling approach of the magnitudes of earthquake force on the designed weirs to be computed reggeressively using the linear models described under tab.3.3a-d and the value of m, i.e when the slope of the downstream glacis expressed as 1:m for the design having verified that the magnitude id linearly fitted one with these models generated for the computation at various intensity level for the observed vertical and crump weir samples perpetually as the results of the study.

off course the regressive observation of the magnitude under variable slope options when provided for of the downstream weir glacis slope parameters and by iterating this value in the reduced linear models subsequently will give out the magnitude up on modeling at various slope conditions . Finally the study has identified that the coefficient of determination of the magnitude of the vertical and horizontal component of earthquake force when modeled based on this study modeling on vertical and crump weirs at variable local hydraulic input conditions it has inferred that in all instant being it is 100% or $R^2 = 1$.

The following consecutive figures illustrate that trend lines of the magnitude of earthquake force components when predicted on the designed vertical and crump weirs as an illustrations once the magnitudes has observed regressively for the designed weirs as indicated in tab.3.4a,b described above for convenience .

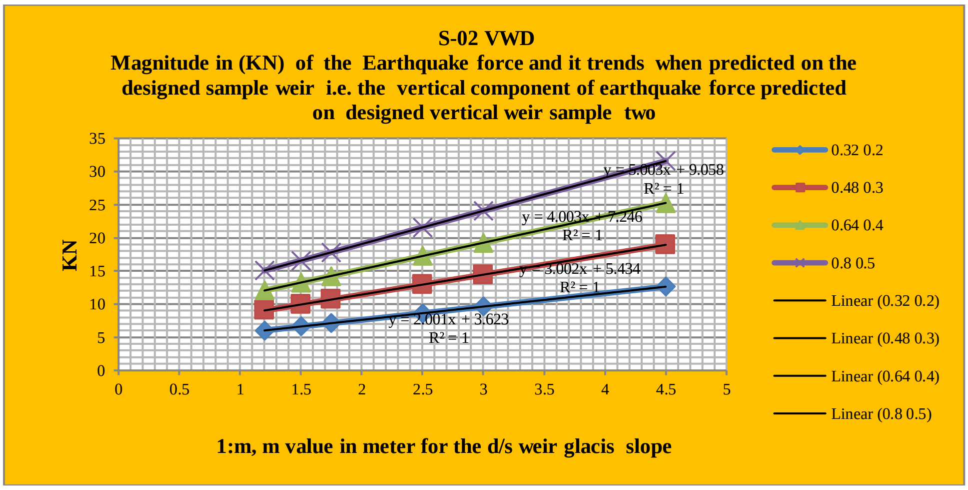


(a-1)

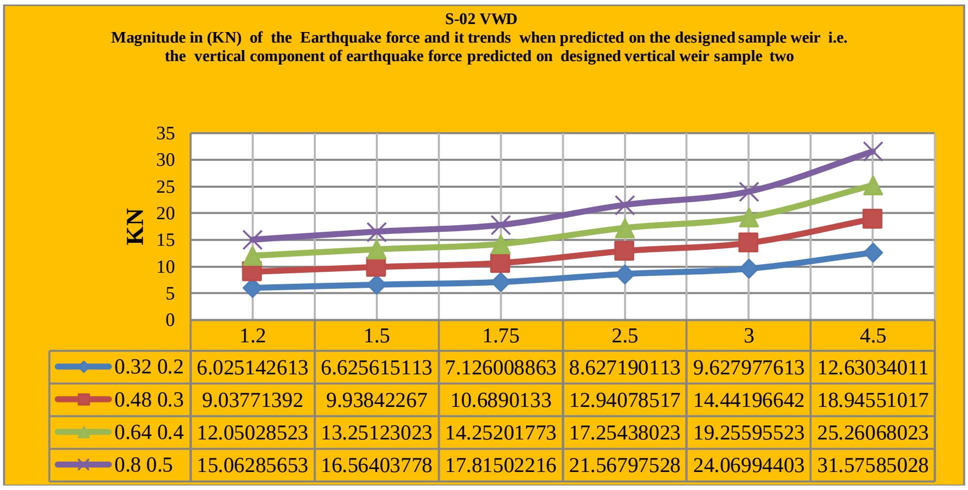


	1.2	1.5	1.75	2.5	3	4.5
0.8 0.5	11.55823139	12.39313139	13.08888139	15.17613139	16.56763139	20.74213139
0.64 0.4	9.246585112	9.914505112	10.47110511	12.14090511	13.25410511	16.59370511
0.48 0.3	6.934938834	7.435878834	7.853328834	9.105678834	9.940578834	12.44527883
0.32 0.2	4.623292556	4.957252556	5.235552556	6.070452556	6.627052556	8.296852556

(a-2)



(b-1)

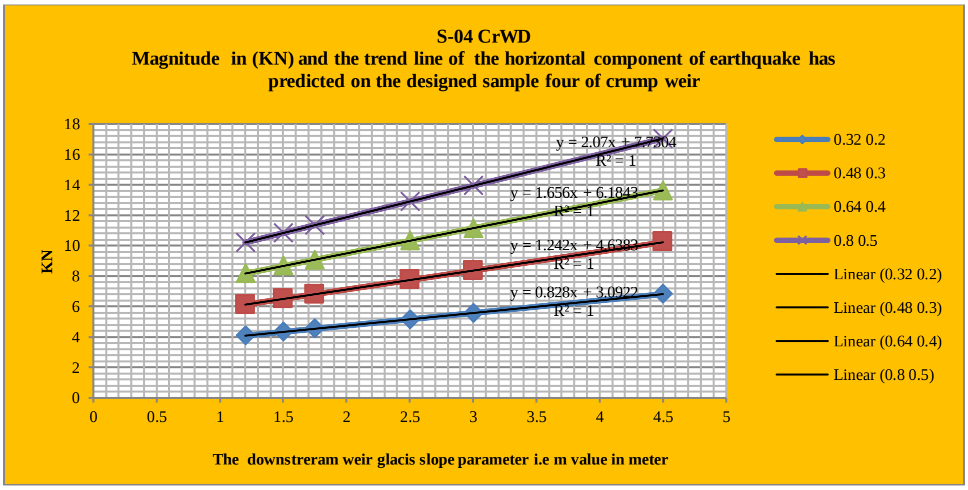


	1.2	1.5	1.75	2.5	3	4.5
0.32 0.2	6.025142613	6.625615113	7.126008863	8.627190113	9.627977613	12.63034011
0.48 0.3	9.03771392	9.93842267	10.6890133	12.94078517	14.44196642	18.94551017
0.64 0.4	12.05028523	13.25123023	14.25201773	17.25438023	19.25595523	25.26068023
0.8 0.5	15.06285653	16.56403778	17.81502216	21.56797528	24.06994403	31.57585028

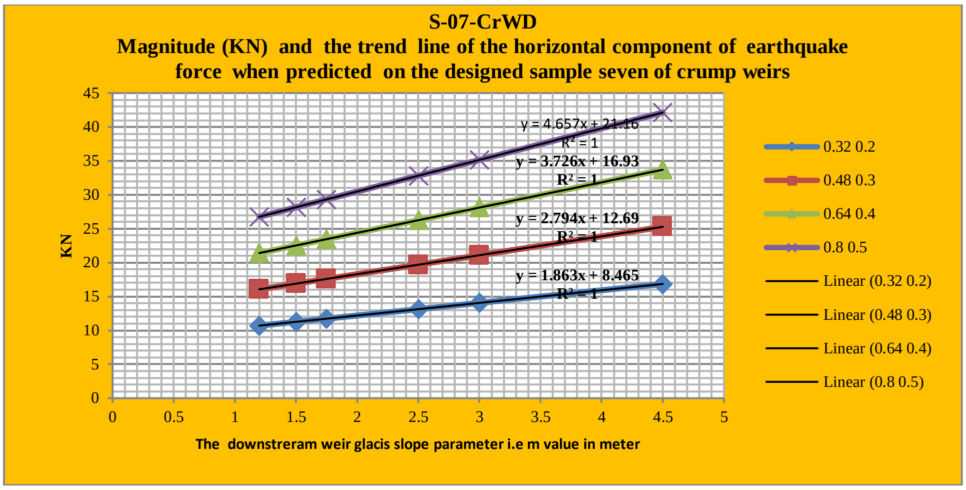
(b-2)

Fig. 3.1a and b. Which are typically illustrating typical the trend line of the magnitude of the vertical component of earthquake forces likely to be induced on the designed vertical when the magnitude computed using the reduced linear models given for the prediction on the sample weirs in KN.

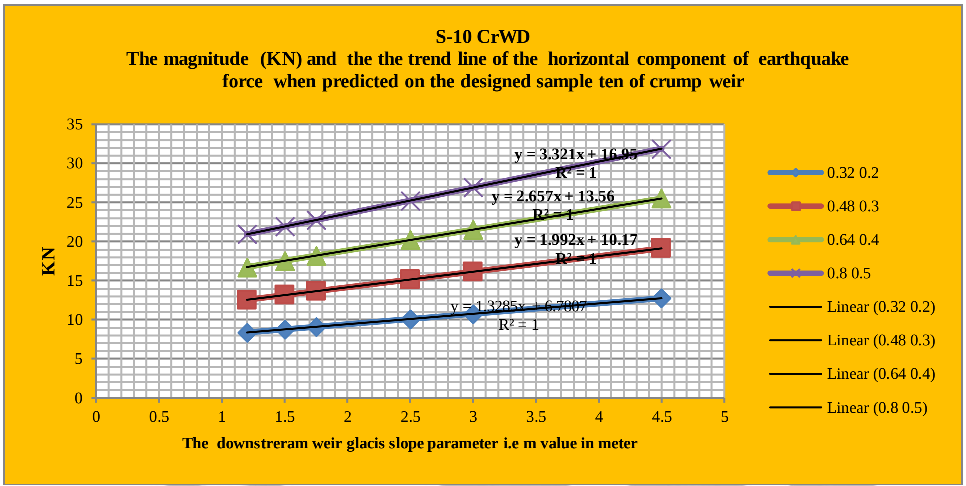
Similarly, Fig. 3.2a and b. are also typical demonstrated the trend line of the magnitude of the horizontal and vertical components of earthquake force in which likely to be induced on the sample design four; seven and ten of crump weirs for illustration in KN .



(a-1)

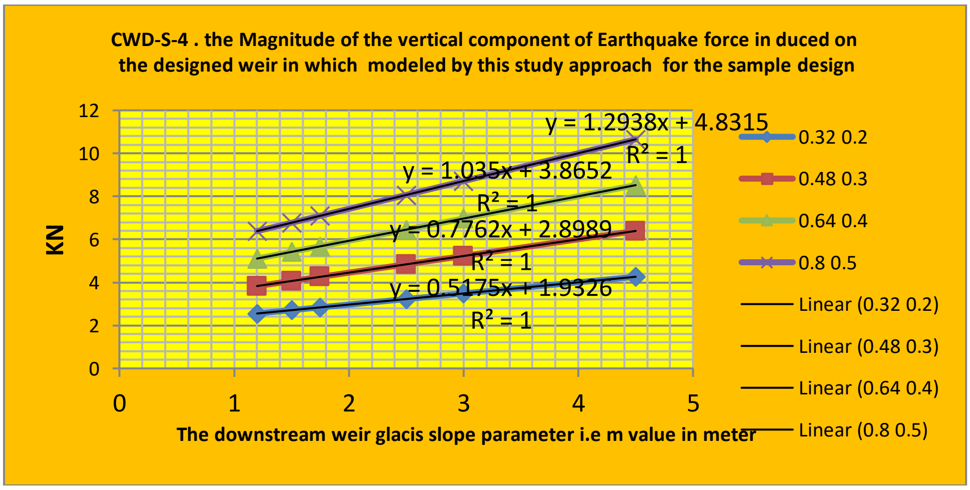


(a-2)

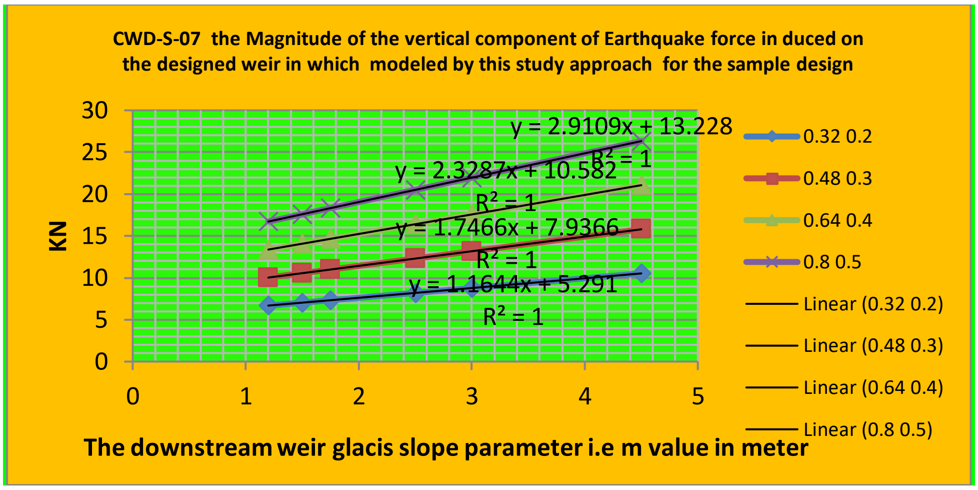


(a-3)

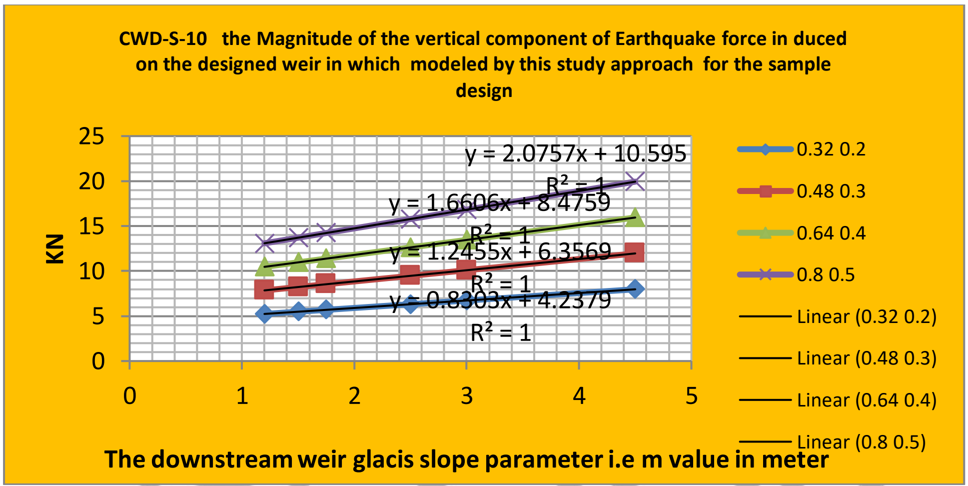
Fig. 3.2a. Which are typically demonstrating the trend line of the magnitude of the horizontal component of earthquake forces likely to be induced on the designed sample four , seven and ten of crump weirs as an illustrations in KN.



(b-1)



(b-2)



(f)

Fig. 3.2b . Which are typically demonstrating the trend line of the magnitude of the vertical component of earthquake forces likely to be induced on the designed samples of crump weirs i.e sample four , seven and ten respectively when the magnitude have modeled using the reduced linear models have generated for the samples in KN .

3.2.1.The mean magnitudes of earthquake force components has optimized for the stability of the designed sample weirs

In the methodology once the magnitude of earthquake force components have predicted as indicated in table 3.4a,b described above for the observed sample designs of vertical and crump weirs it is obvious that the effect of the magnitude on the structural stability of the designed weirs has interactively assessed by the study so as to optimize the stability of the weirs at the given local hydraulic conditions optimally.

Therefore the methodology aim at optimizing the magnitude at the data point where the stability of the designed weir assured being satisfied quite and design limits for the eccentricity of the resultant force has fulfilled the requirements as indicated in table 3.5c which follow . Meanwhile as a results at the specified slope values when $e \leq \frac{L}{6}$ i.e when the eccentricity of the resultant forces opt to be less than one sixth of the base length of the designed weir the magnitude of earthquake force components have modeled and generated at that specified slope condition of the downstream weir glacis perceived to be the optimum values optimized for the sample design being satisfied adequately the stability of the weir in correlation with other components of the induced forces.

Hence , tab.3.5a has described the mean magnitude of the induced earthquake force components for the observed designed sample weir as the result of the study by large and when these values have been compared with the results likely ro be end with the pseudo static method by computing the magnitude as the product of the mean weight of the stricture measured at that specified slope and earthquake force intensity coefficient almost all the results have found same .

Obviously, the results of the study while evaluated the modeling of earthquake force magnitudes on diversion weir under this study examination have assured that when the magnitudes of earthquake force components anticipated and predicted on the designed weirs under the existing local hydraulics condition of the weir site and weir geometry it has confirmed that the magnitude is linearly fitted with the model equations described in the methodology of the study irrespective of variations among samples in terms of design discharges and other input parameters have observed .

Because in the methodology the predictors and the variables of the magnitude of the force system have computed based on the input data consistently via modeling parameters of the study and weir dimension . Hence dimensionless modeling parameters has offered to provide significant clues for the existing variations in input data implicitly for the samples evaluated having these parameters are consistently designated in the equations for vertical and crump weirs without any biases or ambiguity among samples tested. Indeed the earthquake force intensity coefficient and slope of the weir glacis used for the computations for the samples being consistent and same corresponding to the designed vertical and crump weirs accordingly in the methodology .

Moreover , the study has found virtually that the magnitude of earthquake force components computed based on the modeling approach of this study have found being same while compared with the pseudo static method as well and typically for justification the mean static weight of the weir at optimized stability condition of the designed and observed sample weirs have found being the one described under tab.3.5b. When these weight multiplied by intensity coefficient of earthquake force components consequently will result the same magnitudes as described under tab.3.5a of the optimized mean values for the designed and observed samples indeed .

Table.3.5a . Results describing the mean magnitude of earthquake force components have modeled for the designed sample weirs in KN **.**

No	Components	Type	Observed designed samples									
			1	2	3	4	5	6	7	8	9	10
1	f_1	vwd	13.88	24.16	7.745	9.548	15.02	15.13	14.9	14.49	15.02	10.76
		crwd	14.69	24.96	7.947	11.6	18.62	20.45	24.6	28.91	17.13	18.84
2	f_2	vwd	8.675	15.1	4.841	5.967	9.389	9.454	9.31	9.053	9.39	6.723
		crwd	13.12	22.29	7.096	10.36	16.63	18.26	21.96	25.81	15.29	16.82

*: f_1= mean magnitude of the horizontal component of earthquake force ; f_2= mean magnitude of the horizontal component of earthquake force ; vwd= designed vertical weir ; crwd= designed crump weir

Table 3.5b.. The results in which describing the static weight of the designed sample weirs in which have used for pseudo static methods of modeling the magnitudes of earthquake force components on the observed sample designs for the comparisons in KN .

Description	Observed samples designed										
	Type	1	2	3	4	5	6	7	8	9	10
Static weight of the weirs	vw	24.79	43.14	20.3	17.05	26.825	27.010	26.601	25.867	26.829	19.208
	cw	26.23	44.58	14.19	20.72	33.255	36.526	43.921	51.628	30.585	28.455

Note: The static weight of the structure when employed for computing the magnitude of earthquake force components and meanwhile compared with the results have obtained for the samples it has no variation for the samples with respect to the results described under tab. 3.5a

Table 3.5c Results describing the mean magnitude of earthquake force components and slope parameters which ensured the stability of the weirs for the observed and tested samples

No	Description	unit	type	observed designed samples									
				1	2	3	4	5	6	7	8	9	10
1	f_1	KN	vwd	13.88	24.16	7.745	9.548	15.02	15.13	14.9	14.49	15.02	10.76
			crwd	14.69	24.96	7.947	11.6	18.62	20.45	24.6	28.91	17.13	18.84
2	f_2	KN	vwd	8.675	15.1	4.841	5.967	9.389	9.454	9.31	9.053	9.39	6.723
			crwd	13.12	22.29	7.096	10.36	16.63	18.26	21.96	25.81	15.29	16.82
3	1:n, n value	m	vwd	0	0	0	0	0	0	0	0	0	0
			crwd	1.43	1.3	1.4	1.26	1.17	1.45	1.5	1.63	1.65	2
4	1:m, m value	m	vwd	1.5	2.5	2.5	1.75	2.5	1.2	1.5	1.5	1.75	1.5
			crwd	1.75	1.75	1.75	2.5	2.5	1.75	3	1.75	3	1.75
5	e	m	vwd	0.384	0.612	0.682	0.032	1.183	0.129	0.759	0.367	0.133	0.827
			crwd	0.55	0.749	0.381	0.629	0.847	0.636	0.939	0.672	0.703	0.628
6	L/6	m	vwd	1.091	1.674	0.96	0.929	1.342	1.081	1.138	1.114	1.17	0.97
			crwd	1.518	1.865	1.079	1.422	1.768	1.79	2.258	2.125	1.915	1.679

Remarks: (i) f_1 = The mean magnitude of the horizontal component of earthquake force optimized for stability analysis of the designed weir at optimum stability condition and has expressed in KN (ii) f_2 = The mean magnitude of the vertical component of earthquake force optimized for stability analysis of the designed weir at optimum stability condition and has expressed in KN (iii) e = eccentricity of the resultant force has ensured as optimal for the weir in meter (iv) L/6 the required design limit for the eccentricity of the resultant force at the specified slope of the weir glacis and base length (L) of the designed sample weir in meter (v) 1:n; 1:m, are the upstream and downstream glacis slope has considered to be optimal for ensuring the designed weir stability for the given weir height and input parameters used for the design and where n and m has been expressed in meter

Meanwhile, as the result (1) the magnitude of earthquake force components (2) The magnitudes of the vertical reaction force , the horizontal reaction forces and the resultant forces (3) the magnitudes of the sum of toppling moment, sum of the stabilizing moment and the resulting net moment (4) the magnitude of the eccentricity of the resultant force (5) the magnitude of the vertical stresses (6) the magnitude of the foundation pressures and the bearing capacity of the foundation (7) the overall factor of safety , the sliding and shear friction factor of safeties in which required to be often modeled in structural stability analysis of diversion weir has enabled to be mode regressively in due effect of earthquake force and slope of the weir glacis in the modeling approach of the study while vertical and crump weirs designed .

3.3. Validation of the modeling approach of earthquake force used by the study

Additionally , tab. 3.6 has clearly indicated that results of the statistical test in which have conducted for validation w.r.t the mean magnitude of the predicted of earthquake force component likely to be developed on the designed vertical and crump weirs accordingly with the input data and design parameters have determined based on the existing conditions anticipated at the weir site.

Consequently as the result when the mean magnitude of the modeled and optimized value of the horizontal component of earthquake force on the observed vertical and crump weir have evaluated the study has found that the variance ratio test among samples compared in this regard has revealed that the magnitude has the mean value of 14.06 and 18.78 KN with variance of 19.67 and 40.65 on the observed vertical and crump weir designed samples respectively.

In this case the magnitude of the horizontal component of earthquake forces predicted on the respective type of designed weirs have not shown significant variations among samples have compared sine the computed paramour for the statstics is 2.067 and it has found as being less than the table value at 0.05 percent probability level.

Whereas when the student paired comparisons of the magnitude on the corresponding samples have evaluate the magnitude of the horizontal component of earthquake force in which modeled on vertical and crump weirs has shown the mean difference of 4.712 KN force with computed value of the student t- test statstics of 2.481 at the specified degree of freedoms and 0.05 percent of probability level .

Indeed the results in this regard has indicated that the magnitude has significant variations on the corresponding designed vertical and crump weirs even though that the weirs have had designed based on same design discharge and almost all similar local hydraulic input variables. To this the justification for this deemed to be that the weir geometry has significantly attributes for this variations when the corresponding samples of vertical and crump weirs have designed and the magnitude of earthquake forces components likely to be developed on the designed weirs have evaluated by the study objectives.

Similarly for the magnitude of the mean vertical component of earthquake force in which have observed being predicted by this study modeling method on the respective type of vertical and crump weir sample designs have observe the results then elicited that the computed statstics being it has found as 4.215 with the mean value of 8.79 and 16.76 KN on vertical and crump weir observed samples respectively.

Hence, the mean difference being it is 7.973 KN while compared the size of the designed weir and the weir geometry has contributed such significant variations in the magnitude as compared to the horizontal component which has found as 4.712 KN force . Although , the student t-test has resulted significant variations for the vertical component of earthquake force modeled on the respective type of weirs in paired comparisons' of the corresponding samples .Hence the mean difference has found that being equivalent with the variances ratio test i.e 7.973 KN and the computed statstics in this respect has found as it is 7.79 . Therefore the results has shown hugely significant variations in magnitude of the vertical component of earthquake force have observed on the corresponding vertical and crump weir sample designs in the test.

Largely the results obtained for the samples are directly correlated with the magnitude of the reaction forces and the resultant force since the whole computations of the force components on the designed sample weirs embed the earthquake force effect as an additive values in structural stability analysis. However , even though that the magnitude of the vertical component of earthquake force has observed to have variations among samples of vertical and rump weirs tested in the evaluation the reaction forces and the resultant force however tested have not indicated variations when the variances ratio test have conducted for the observed vertical and crump weir samples have been evaluated .Because this is due to the fact that the reaction forces are depend on many factors and force components beside earthquake force and when these forces evaluated while modeled they are linearly fitted with the models used for computation and in effect the stability of the designed weirs since assured optimally the magnitude modeled for the weirs has not been out of the limit to cause adverse conditions on the designed weirs as evaluated and proofed under table 3.5c in general .

Finally the feasibility of earthquake modeling approach of this study in this regard has validated and verified to be quite appropriate and exact one to be used alternatively with pseudo static method when the design of diversion weirs have been executed in open channel hydraulics by considering earthquake force magnitudes equally with other components of external force anticipated to induced on the weirs when analyzing the structural and hydraulic stability of the respective type of weirs and for more and in-depth analysis of the effect of the flow hydraulics on the magnitude of earthquake force and in turn on the designed weirs while revitalized carefully by considering extreme loading events .

At the end , tab. 3.6 which follow therefore has indicated the details about the result of the test statstics performed for the observed sample weirs and with respect to the magnitude of earthquake force components, the reaction forces and the resultant force in reassurance of the stability of the weirs and the feasibility of the modeling approach of the study for designing the respective type of weirs virtually from statistical evaluation point of views having the results of the longitudinal section and plan views of the designed weirs in other portion of the study manuscript for perusal .

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Table 3.6 . Describing the statistical test tests results conducted with respect the mean magnitudes of earthquake force Components and the reactive and resultant forces observed on the designed sample weirs at optimum stability conditions of the weirs

												ANOVA of the model parameters				F-table value		Student t- test		Table value	
Description	Weir type	Numerical values of the model parameters of the study observed for the sample designs										Mean	St.dev	var.	F-cal	5%	1%	mean diff.	t-cal	5%	1%
		1	2	3	4	5	6	7	8	9	10										
f_1	VWD	13.88	24.16	7.745	9.548	15.02	15.13	14.9	14.49	15.02	10.76	14.06	4.435	19.67	2.067	3.18	5.35	4.712	2.481	1.83	2.82
	CWD	14.69	24.96	7.947	11.6	18.62	20.45	24.6	28.91	17.13	18.84	18.78	6.376	40.65							
f_2	VWD	8.675	15.1	4.841	5.967	9.389	9.454	9.31	9.053	9.39	6.723	8.79	2.772	7.685	4.215	3.18	5.35	7.973	7.79	1.83	2.82
	CWD	13.12	22.29	7.096	10.36	16.63	18.26	21.96	25.81	15.29	16.82	16.76	5.692	32.4							
R_H	VWD	22.86	37.47	11.93	15.61	23.11	25.32	24.43	23.87	24.49	17.62	22.67	6.87	47.2	2.038	3.18	5.35	6.604	2.211	1.83	2.82
	CWD	23.88	38.26	12.42	17.8	28.15	33.11	36.89	44.53	32.93	24.82	29.28	9.807	96.19							
R_v	VWD	10.4	29.84	8.06	9.743	14.61	9.575	10.01	10.96	14.7	6.837	12.47	6.59	43.42	1.458	3.18	5.35	4.733	1.629	1.83	2.82
	CWD	13.83	24.5	8.03	7.775	12.63	19.7	17.59	33.48	12.81	21.73	17.21	7.956	63.3							
R_F	VWD	25.13	49.91	14.4	18.4	27.34	27.1	26.42	26.28	28.56	18.92	26.25	9.569	91.57	1.614	3.18	5.35	7.24	1.829	1.83	2.82
	CWD	27.59	45.43	14.79	19.43	30.87	38.53	40.88	55.72	28.62	33	33.49	12.16	147.8							

Remark:

i. VWD= vertical weir designed sample

ii. CWD = crump weir designed samples

iii. f_1 = the mean magnitude of the horizontal component of earthquake force determined for the designed weirs at optimum stability condition of the weirs in KN

iv. f_2= the mean magnitude of the vertical component of earthquake force determined for the designed weirs at optimum stability condition of the weirs in KN

v. R_H = the mean magnitude of the horizontal reaction force determined for the designed weirs at optimum stability condition of the weirs in KN

vi. R_v= the mean magnitude of the vertical reaction force determined for the designed weirs at optimum stability condition of the weirs in KN

vii. R_F = the mean magnitude of the resultant force determined for the designed weirs at optimum stability condition of the weirs in KN

3.4. Earthquake forces Evaluations when Regarded

To conclude on the discussion and analysis of the results of this study the following notions are quite important to be mentioned here again and again when modeling of earthquake forces revitalized by any methods on hydraulic structures like diversion weirs and dams for consciousness .

Therefore, as far as earthquake force modeling concerned on such structures literatures have hinted that often evaluation of the risks adversely affecting the stability of the designed structures in engineering it is quite pertinent always . Indeed s (Novak. P etal., 2007) has hinted that the evaluation task basically need to focus on identification of the regional geological structure, with particular attention being paid to fault complexes. Activity or inactivity within recent geological history will require to be established from study of historical records and field reconnaissance.

In this case the reviewed items has elicited further that if historical records of apparent epicenters can be matched to key geological structures, then it is possible to make a probabilistic assessment of seismic risk in terms of specific intensities of seismic event.

However , in case if reliable historical information not available in the region monitoring of micro seismic activity could be an essential approach and a basis for the probabilistic prediction of major seismic events. Process either is imprecise or will at best provide only an estimate of the order of seismic risk.

As a measure of reassurance over seismicity it has been suggested that most well-engineered dams for instance on a competent foundation can accept a moderate seismic event, with peak accelerations in excess of $0.2g$, without fatal damage. Dams constructed with or on low-density saturated cohesion less soils, i.e. silts or sands, are, however, at some risk of failure in the event of seismic disturbance due to pore water pressure buildup and liquefaction with consequent loss of stability.

Actually the major concern of this study being design of diversion weir the views and ideas in which inherently pertinent one have extracted from literatures ameliorated with the discussions of the results of the study in sound manners .

More or less therefore most of the notions included here are convicting one and they are virtually helpful for understanding of the basic phenomenon and modeling of earthquake force on hydraulic structures like dams and weirs in focus before have introducing the new method of the study for casual readers. That is why the discussion consist as such in-depth views and notions along side with the main findings of this study and focuses.

To this end , although, in design the dynamic loads generated by seismic disturbances must be considered in the design of all major dams situated in recognized seismic ‘high-risk ‘regions. The possibility of seismic activity should also be considered for dams located outside those regions, particularly where sited in close proximity to potentially active geological fault complexes.

Actually, the strength of a seismic event can be characterized by its magnitude and its intensity, defined thus: magnitude is a measure of the energy released; it therefore has the single value for a specific seismic event. It is categorized on the Richter scale, ranging upwards from M–1.0 to M–9.0. Intensity is measure of the violence of seismic shaking attaching to an event, and hence of its destructiveness, at a specific location. Intensity thus varies with position and distance from the epicenter, and it is commonly expressed on the modified Mercalli scale of MM–I to MM–XII (Novak.P et al. 2007).

(Novak .p et al., 2007) further added that the terminology associated with seismic safety evaluation includes a range of definitions, some of which are especially significant in the context of dams, thus: Maximum Credible Earthquake (MCE): the event predicted to produce the most severe level of ground motion possible for the geological circumstances of a specific site. Safety Evaluation Earthquake (SEE): the event predicted to produce the most severe level of ground motion against which the safety of the dam from catastrophic failure must be assured. SEE may be defined as a proportion of the MCE or equal to it; an alternative is to specify SEE on the basis of a notional return period (cf. flood categorization in the case of spillway design.

In recommended UK practice (Charles et al., 1991) SEE takes the place of MCE as employed in US practice, e.g. USBR (1987). Other terms employed in seismic design include Controlling Maximum Earthquake (CME), Maximum Design Earthquake (DBE) and Operating Basis Earthquake (OBE).

Ground motions associated with earthquakes can be characterized in terms of acceleration, velocity or displacement. Only peak ground acceleration, PGA, generally expressed as a proportion of gravitational acceleration, g, is considered here. PGA can be rather imprecisely correlated with intensity, and in general terms seismic events with a high PGA of short duration are less destructive than events of lower PGA and greater duration as the reviewed literatures has entailed .

Moreover when the existing trends of modeling of seismic loads on structures literatures entailed that the magnitude can b approximated in the first instance by using the simplistic approach of pseudo static, or seismic coefficient, and response spectrum methods or by dynamic analysis in case of dam designs. The simplifications inherent in pseudo static analysis are considerable. Complex problems of dam-foundation and dam-reservoir interaction are not addressed, and the load response of the dam itself is neglected. The interactions referred to be of great importance, as they collectively modify the dynamic properties of the dam and consequently may significantly affect its load response. They are accounted for in dynamic response analysis.

By and large (Arora, 2012) has hinted that earthquake acceleration is usually expressed as the function of acceleration due to gravity i.e. g where g is taken as 9.81 m^2/sec and often earthquake acceleration given as: α g . In this case, in the design of gravity dam when concerned this expression is it is quite applicable in dam design. Hence the coefficient α is known to be seismic coefficient and it is often determined by either of (1) seismic coefficient method (2) Response spectrum method in general.

Therefore in seismic coefficients method the parameter α is normally determined as: $\beta I \alpha_o$ where; β is the soil foundation system factor, the value which for gravity dam is one; I is the importance factor; the value for gravity dam is taken as to be two and α_o is the basic seismic coefficient whose value differs for different seismic zones and it ranges normally from 0.01 to 0.08.

Consequently upon substituting the value of β and I in the above expression then for the earthquake acceleration it is give another notation for alpha value as $\alpha = 2\alpha_o$ when the earthquake acceleration determined by seismic coefficient methods.

Conversely in using response spectrum approach however the expression for alpha is bit different than seismic coefficient method .In this case for response spectrum method (Arora, 2012) hinted that the coefficient can be determined as : $\alpha = \beta I F_0 \left(\frac{S_0}{g}\right)$ where; $\beta$and I are a parameters which are described above for seismic coefficient method moreover, the parameter F_o in this expression is basically denoted as seismic zone factor for the average acceleration of the spectra and the value of it is normally obtained from table by knowing average acceleration coefficient i.e. $\left(\frac{S_0}{g}\right)$.

In this regard , the average acceleration coefficient is depend upon the natural period of T and the parameter T then computed as : $T = 5.55 \left(\frac{H^2}{B}\right)\sqrt{\frac{W_0}{gE_0}}$; where; H is the height of the dam in meter; B is base width of the dam in meter ; W_0 is unit weight of materials of the dam in (KN/m^3) ; E_c is modulus of elasticity of material of the dam in KN/m^2.

4. Conclusions

In general , the study have given a brief account on the effect of earthquake force on the stability of vertical and crump weirs while performing the design of the respective type of weir using the new modeling approach and design equations for computation of the magnitude of all induced forces and earthquake force components at the given local hydraulic input data used for modeling the sample weirs.

In this case, actually the study has devised new computational equation for modeling the magnitudes of earthquake force and have analyzed mean while the results in its effect on the stability of the designed weirs in wide band analysis computationally.

The predictors and the variables of the horizontal and vertical component of earthquake force in the methodology of modeling the magnitude have predicted based on the given data and by the equations meanwhile to deduce on the effect on the stability of the designed weir in correlation with the given slope of the downstream weir glacis and other force components have modeled similarly using the respective equations for computations in which have developed by the study accordingly in the methodology.

In these regard; note that the results of the study observed w.r.t. the magnitude of earthquake force modeling have accomplished based on this study philosophy have shown that when the magnitude modeled on the respective type of weirs i.e on optimum designed samples of vertical and crump weirs it is quite sure that it is linearly fitted with the model equations signifying the predictors and variables of the force system in accordance with the variations in local hydraulic variables and weir geometry being the models have integrated all these factors with the weir dimensions or size of the structure inherently via the dimensionless modeling parameters of the study has introduced as an advent.

Moreover the magnitude of earthquake force while modeled on the respective type of weirs it has observed for the designed sample weirs at various range of intensities and occurrences in which anticipated and the study then finally has confirmed that the results have obtained for the sample designs and evaluations as it is numerically equivalent with the magnitude when determined by the known pseudo static method.

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TR-20 computer program (new windows beta version):
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