13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 3055

STUDIES ON SEISMIC BEHAVIOR OF XIAOWAN ARCH DAM AND EARTHQUAKE RESISTANCE MEASURES

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SUMMARY

The Xiaowan arch dam on the Lancang River is a 292m high dam and is now under construction at a location in a seismically active region. The design peak ground acceleration (PGA) is designated as 0.308g. The seismic behavior of the dam is studied with a 3-D coupling model of finite elements, boundary elements and infinite elements (FE-BE-IBE) in time domain. The studies highlight the effects of some key factors on nonlinear seismic responses of the dam due to contraction joint opening, including the effects of different reservoir elevations, different earthquake input and that of radiation damping of infinite canyon. Furthermore, to enhance the integrity of the dam and to control the joint opening, several alternatives of strengthening measures are discussed. Conclusions drawn from the studies may be valuable to the design and construction of 300m level high arch dams.

INTRODUCTION

Presently, a series of 300m level high arch dams are being constructed or being designed for construction in regions of high seismicity in Southwest China. Among them is the Xiaowan arch dam, 292m high with a 935m chord length at the dam crest. The design PGA is designated as 0.308g, equivalent to a standard of 10% probability of exceedance, with a return period of 600 years. For arch dams of such record height and located in seismically active regions, their seismic behavior and safety guarantee are of great concern to the owners and designers. Usually, an arch dam is constructed with individual cantilever blocks separated by finally grouted construction joints that are likely to reopen during strong ground motions [Clough 1]. Such phenomena have been observed in the Pacoima arch dam after it encountered the 1971 San Fernando earthquake [Swanson 2] and the 1994 Northridge earthquake [Wieland 3]. The nonlinearity of joint opening will cause a significant redistribution of stresses between arch and cantilever components, thus raising concerns about the integrity and safety of the dam. [Fenves 4, Zenz 5, Zhang 6]. Therefore, it is necessary to thoroughly study some important factors related to earthquake effects. Herein, studies on nonlinear earthquake behavior of the dam due to contraction joint opening and assessment of different strengthening measures for earthquake resistance are conducted with a 3-D FE-BE-IBE coupling model,

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and the corresponding results are briefly summarized. First, for reducing the computational effort and obtaining a convergent response of the structure, different numbers of joints up to 47 are simulated; second, some influential factors are analyzed including effects of different reservoir elevations, different earthquake input, and that of radiation damping due to the infinite canyon on nonlinear behavior of the dam. To enhance the dam integrity and to control the joint opening to some extent, several alternatives of strengthening measures are analyzed and compared. These include discontinuous joint reinforcements, post-tensioned cables, continuous reinforcement belts and joint dampers. From the study, several important findings can be drawn: (1) the maximum joint opening occurs in the case of lowest reservoir elevation while the maximum total tensile and compressive stresses of the structure are still controlled by the full reservoir elevation; (2) remarkable effects of radiation damping of the infinite canyon on the nonlinear response of the dam are observed; and (3) since different strengthening measures have their own merits and disadvantages, a combination of different measures appears to be more applicable and efficient.

NUMERICAL MODEL

Coupling dam-canyon-reservoir system

The nonlinear response of Xiaowan arch dam due to contractions joint opening and reinforcement and the effects of arch dam-canyon interaction are performed using the FE-BE-IBE coupling procedure [Zhang 7] and a substructure technique [Fenves 4]. The substructure solution scheme is illustrated in Figure 1. For modeling of the reservoir, the Westergaard added mass is used herein.

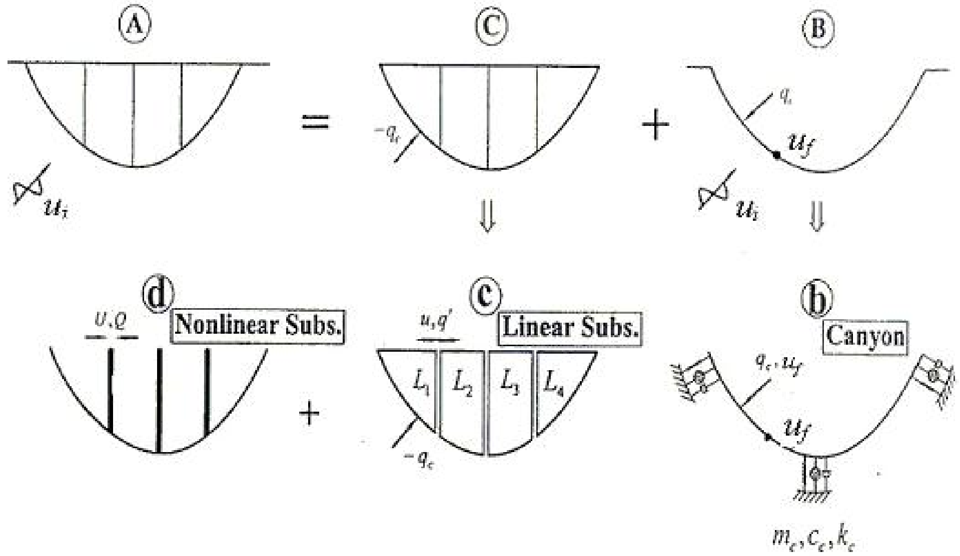


Fig.1 The substructure technique scheme of the coupling system

In order to simulate these nonlinearities together with radiation damping due to the infinite canyon, herein, finite elements are used for discretization of the dam and reservoir. Substructure of the canyon is discretized into boundary elements and infinite boundary elements for considering the radiation damping of the infinite foundation. Frequency-dependent impedance functions are first obtained for all degrees of freedom on the dam-canyon interface and then transformed into a mass-spring-dashpot system. Finally, these discrete parameters together with the linear substructure of cantilever bodies are condensed into the boundaries of nonlinear substructure -- a set of construction joint elements. The equilibrium iteration during a time step is conducted only for the degree-of-freedom for the nonlinear joint substructure. The free field earthquake input is used in the procedure. The dynamic equations of motion are as follows:

$$\begin{bmatrix} M_{dd} & M_{dc} \\ M_{cd} & M_{cc}+\overline{M}_{cc} \end{bmatrix} \begin{Bmatrix} \ddot{U}_d \\ \ddot{U}_c \end{Bmatrix} + \begin{bmatrix} C_{dd} & C_{dc} \\ C_{cd} & C_{cc}+\overline{C}_{cc} \end{bmatrix} \begin{Bmatrix} \dot{U}_d \\ \dot{U}_c \end{Bmatrix} + \begin{bmatrix} K_{dd} & K_{dc} \\ K_{cd} & K_{cc}+\overline{K}_{cc} \end{bmatrix} \begin{Bmatrix} U_d \\ U_c \end{Bmatrix} = \begin{Bmatrix} 0 \\ \overline{M}_{cc}\ddot{\overline{u}}_c + \overline{C}_{cc}\dot{\overline{u}}_c + \overline{K}_{cc}\overline{u}_c \end{Bmatrix} \tag{1}$$

where M , C and K letters denotes mass, damping and stiffness matrices, respectively, all u quantities denote time-dependent total-displacement vectors, subscript d denotes the number of DOF in the dam, excluding its c DOF located at the dam-canyon interface, and a bar placed above a letter, i.e. $\overline{M}$, $\overline{C}$ and $\overline{K}$ are the frequency independent mass, dashpot and spring matrices assembled from element parameters; $\overline{u}_c$, $\dot{\overline{u}}_c$ and $\ddot{\overline{u}}_c$ are earthquake free field motions acting on the dam-canyon interface.

Equation (1) has been expressed in the time domain. Thus, the nonlinearities of the dam due to contraction joint opening can be taken into account by changing the third term of the left hand side of the equation with restoring forces which are nonlinear functions of $\dot{U}$ and U of the nonlinear substructure.

Nonlinear joint element and joint reinforcement

A 3-D nonlinear joint element is used for modeling the contraction joints and reinforcements. The constitutive relations for joints and reinforcements are shown in Figure 2. The modelling of joint reinforcement and the effects on the response of the dam are considered by Zhang [6].

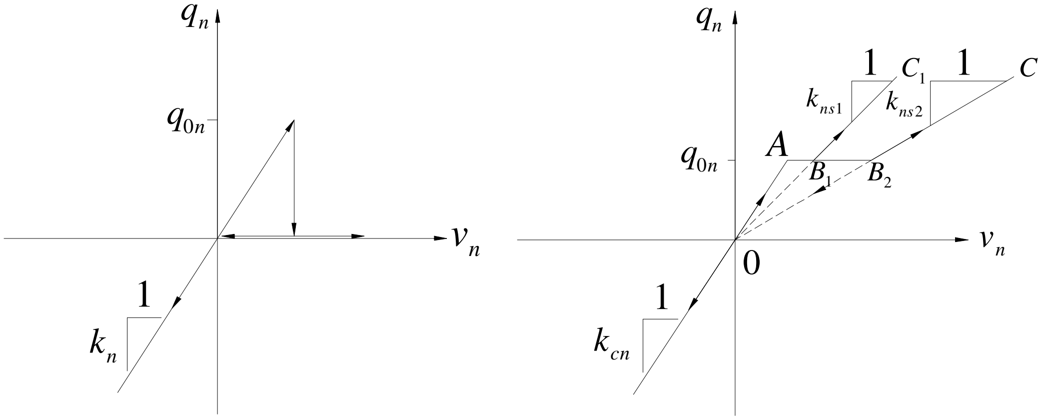


Fig.2 Constitutive relations for joints and reinforcements

ENGINEERING DESCRIPTION AND PROPERTIES OF THE PROJECT

Shown in Figure 3 is a general view (in design) of the Xiaowan arch dam. It is located on the upper reaches of the Lancang River, Yunnan province. The canyon is the V-shape type and the dam has a crest length of 935m. The maximum dam height is 292m. The thickness of the dam is 73m at the bottom and 12m at the crest. The rock formation of the dam foundation is composed of biotite granite-gneiss and hornblendite plagioclase-gneiss. Forty-seven contraction joints are to be grouted during the construction process. The PGA of the design basis earthquake is 0.308g in two horizontal directions and 2/3 PGA in the vertical direction. The material properties for the concrete are: unit weight=2400kg/m^3, modulus of elasticity=2.73×10^4 MPa, Poisson′s ratio=0.18; for the foundation rock: unit weight=0 for massless model, and 2400kg/m^3 for infinite canyon model, modulus of elasticity=2.73×10^4 MPa, Poisson′s ratio=0.25.

Fig.3 General view of the Xiaowan arch dam (in design)

NONLINEAR BEHAVIOR DUE JOINT OPENING

In reality, forty-seven joints are designed for dam construction. For computational economy, fewer joints may need to be simulated in the analysis. Herein, six cases of joint number simulation, i.e. 5, 15, 25, 31, 37 and 47 joints, are assumed for comparison. For comparison with the linear response of the dam, an additional case is analyzed in which the dam is assumed to be linear elastic without considering joint opening. Figure 4 is the FE mesh sketch with the layout of 47 joints. The study is conducted under the lowest reservoir level with water depth of 228m that is proved to be the controlling case for joint opening. The design basis earthquake from the Chinese specification based spectrum (CSBS) for earthquake resistant design for arch dams is chosen as the input ground motion.

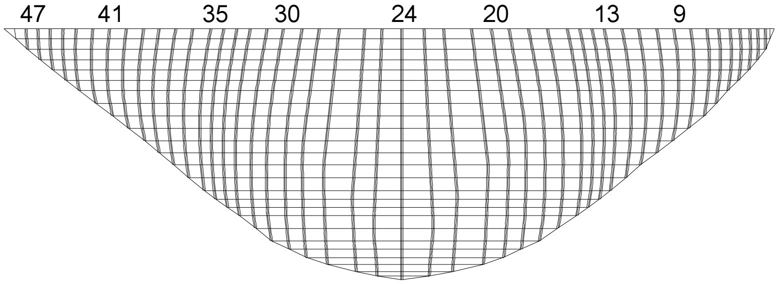


Fig.4 FE mesh sketch and layout of joints

Table 1 is the comparison of the maximum responses of 7 cases. The distributions of the maximum joint opening along the dam crest are plotted in Figure 5. It is interesting to note the following: (i) Figure 6 shows the maximum joint opening distribution on the upstream face of the dam. It should be noted from the results that the joints in the upper middle portion of the dam experience complete opening from the upstream to downstream faces. At least one third of the dam height from the crest is subject to significant opening. Comparing Figure 7 with Figure 8, a dramatic release of the arch stresses on the upper portion of the dam is evident, which coincides the joint opening distribution shown in Figure 6. However, the cantilever stresses only show a noticeable increase due to the joint opening. (ii) In order to get a convergent result of stresses, 5 joints (Case 2) may be acceptable with only a discrepancy that the arch tensile stresses are not sufficiently released in the upper portion of the dam. (iii) The convergent results of joint opening in Figure 5 show that at least 25 joints (Case 4) are necessary to be simulated. Even in this case, the opening of the side joints still possesses significant differences when compared with that of Case

7. (iv) Only a little difference of the arch and cantilever stresses is observed in Cases 2~7 meaning that the effects of the number of joint simulated on the maximum stresses are of minor influence.

Table 1 Comparison of maximum responses with different numbers of joint simulated

Case	Number of joints	Crest disp. (cm)	Max. stresses at Ups (MPa)				Max. stresses at Dns (MPa)				Max. joint opening (mm)
			Arch		Cantilever		Arch		Cantilever		
			Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	
1	0	21.9	8.4	-9.8	3.9	-15.7	7.0	-8.2	4.3	-9.7	/
2	5	23.0	3.4	-9.2	4.3	-15.4	3.0	-8.0	5.1	-9.7	69.4
3	15	23.4	2.4	-9.2	4.4	-15.4	2.3	-8.1	4.7	-9.8	30.2
4	25	23.2	2.3	-9.2	4.4	-15.2	1.9	-8.3	5.0	-10.2	15.4
5	31	22.0	3.0	-9.3	4.5	-15.1	2.2	-8.2	5.4	-10.0	15.4
6	37	20.5	3.1	-9.7	4.5	-14.9	2.1	-8.4	5.3	-9.6	14.1
7	47	23.2	2.8	-9.5	4.2	-15.5	2.2	-8.4	4.8	-9.9	14.5

Note: disp.- displacement; Ups – Upstream face; Dns – Downstream face; Tens – Tensile; Comp. – Compressive

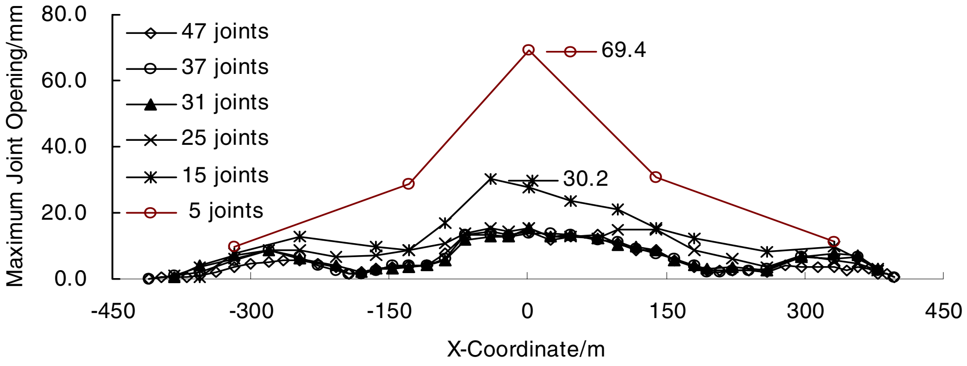


Fig.5 Distribution of maximum joint opening with different numbers of joint simulated

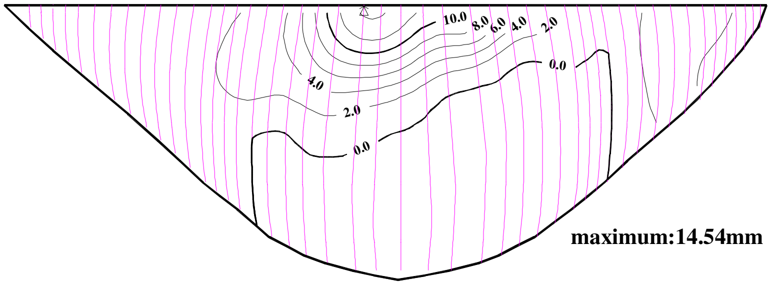
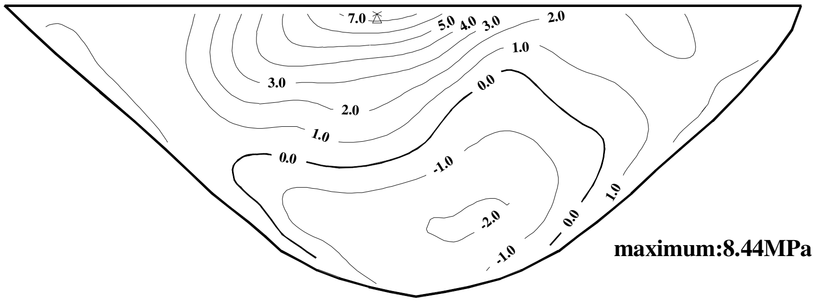
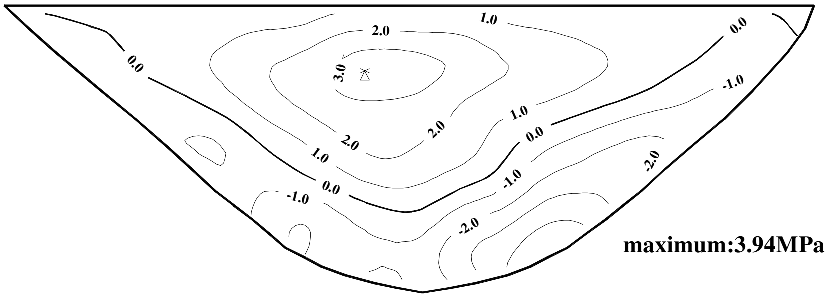


Fig.6 Isolines of maximum joint opening with 47 joints simulated (on upstream face)

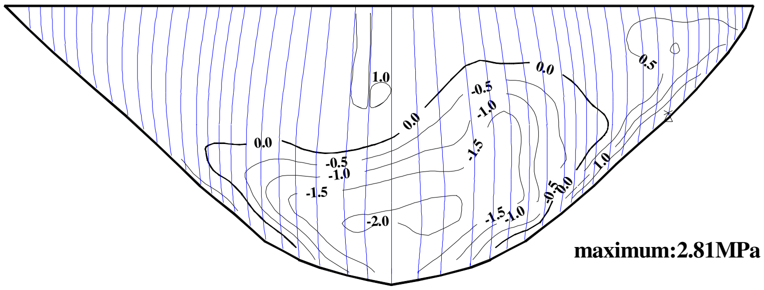


(a) Arch stresses at upstream face

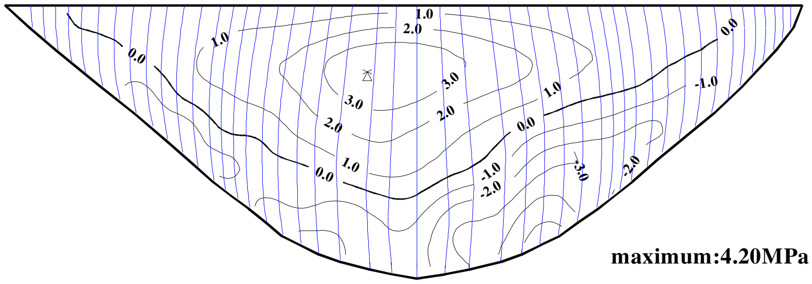


(b) Cantilever stresses at upstream face

Fig.7 Isolines of maximum stresses without considering joint opening (Case 1)



(a) Arch stresses at upstream face



(b) Cantilever stresses at upstream face

Fig.8 Isolines of maximum stresses with considering joint opening (Case 7)

EFFECTS OF KEY FACTORS ON NONLINEAR SEISMIC RESPONSES

For safety evaluation of the Xiaowan arch dam to resist the design earthquake, it is important to study the effects of different input loadings and reservoir conditions on the nonlinear response of the dam. The main findings from the study are summarized as follows. In this section, the above case with 31 joints simulated is chosen as the analysis model and all material parameters are kept the same.

Effects of different reservoir elevations

The reservoir elevation will periodically change during the operation of the Xiaowan hydropower plant, which will subsequently change both the static and dynamic loading conditions and frequency components of the system. To assess these effects on nonlinear seismic response of the dam, five cases of water levels are examined with reservoir depth of 287m, 270m, 261m, 239m and 228m, respectively.

The maximum responses are listed and compared in Table 2. Figure 9 shows the corresponding distribution of maximum joint opening along the dam crest. The following remarks can be made from the comparison. (i) As shown in Table 2 and Figure 9, both maximum values and distributions along the dam crest of joint openings decrease gradually with the reservoir level rising, which is obviously caused by the higher level of compression in the arch components. Thus, the case of the lowest reservoir proves to be the controlling condition in evaluating the maximum joint opening of the dam. Under the design basis earthquake, the maximum joint opening of Xiaowan arch dam is 15.4mm. (ii) The stresses represent a rather complicated distribution in the arch and cantilever components with the variation of reservoir elevations. The maximum tensile stress of 5.0MPa occurs at the upper region of the central cantilever beam and that of 6.3MPa occurs at the downstream face, both of which happen at the maximum full reservoir condition. The maximum compressions of 14-15MPa, however, may either occur at the full or the lowest reservoir elevation as shown in Table 2. From the point of cracking prevention, it appears that the full reservoir is still the controlling case in safety evaluation.

Table 2 Comparison of maximum responses with different reservoir elevations

Reservoir depth (m)	Crest disp. (cm)	Max. stresses at Ups (MPa)				Max. stresses at Dns (MPa)				Max. joint opening (mm)
		Arch		Cantilever		Arch		Cantilever		
		Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	
228	22.0	3.0	-9.3	4.5	-15.1	2.2	-8.2	5.4	-10.0	15.4
239	22.1	3.1	-10.0	4.3	-14.6	2.1	-8.6	5.5	-10.7	13.7
261	19.4	3.4	-12.3	3.6	-12.5	2.2	-10.0	6.1	-12.0	9.5
270	23.0	3.4	-13.4	3.6	-11.7	1.8	-10.5	6.2	-12.5	8.3
287	22.6	4.0	-15.0	4.9	-10.1	1.6	-13.2	6.3	-13.7	3.6

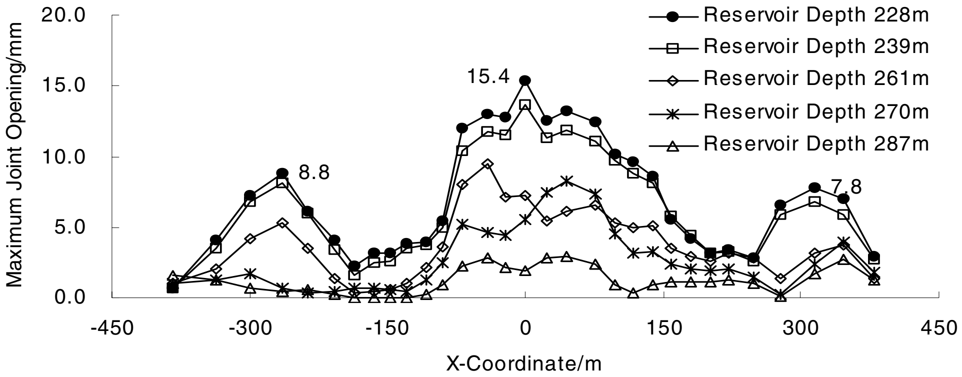


Fig.9 Distribution of maximum joint opening with different reservoir depth

Effects of different earthquake input

Among the important elements for consideration in safety evaluation of earthquake resistance for an arch dam, the most influential but uncertain factor would be the seismic input including the design PGA and the corresponding spectrum. It is desirable to perform a sensitivity study relating to different input time histories and different PGA.

As shown in Table 3, five cases of earthquake input are applied for comparison. Cases 1, 2 and 3 are the design basis earthquakes, i.e. CSBS time histories with PGA of 0.4g, 0.308g and 0.2g in the two horizontal directions, respectively, and 2/3PGA correspondingly in the vertical direction. In each of these 3 cases the same time history without phase difference is applied in all directions, which results in peak accelerations in three directions occurring at the same time instance. The Koyna earthquake is used in Case 4 with PGA of 0.308g. Case 5 is a modified one based on Case 2, in which the time history in stream-direction is made a reversal of signs and those in the other two directions are adjusted by a time lag and forward shift of 0.2s, respectively. The lowest reservoir elevation is used here.

The maximum responses are compared in Table 3. Figure 10 shows the corresponding distributions of maximum joint opening along the dam crest. The following findings from the test can be drawn. (i) From comparison among results of Cases 1, 2 and 3, the maximum displacements and joint opening distributions of the dam increase non-uniformly along the crest with the increase of the input PGA. It is interesting that the maximum values of displacements and joint opening increase almost linearly with the increase of PGA. In addition, all 3 cases show similar response patterns, including that of joint opening, dynamic displacements and stresses (not shown due to space limitation). (ii) Although the same PGA is used, maximum responses in Cases 2 and 4 show significant differences due to different earthquake applied, indicating that the effects of different response spectrum are important. Furthermore, compared with Case 2, the ground motion of Case 5 makes the responses of the dam remarkably decreased by shifting the occurring instance of PGA asynchronously in three directions. (iii) From the above discussion, it is shown that Case 2 (design case) is appropriate for evaluating the seismic resistant ability of Xiaowan arch dam. For consideration of earthquake′s uncertainty, Case 1 with PGA of 0.4g may serve as a further check for safety. In this case, the maximum responses will be within the dimension of 20mm for joint opening, 6.4MPa and 17.1MPa for tensile and compressive stresses, respectively.

Table 3 Comparison of maximum responses with different earthquake input

Case	Earthquake input	Crest disp. (cm)	Max. stresses at Ups (MPa)				Max. stresses at Dns (MPa)				Max. joint opening (mm)
			Arch		Cantilever		Arch		Cantilever		
			Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	Tens.	Comp.	
1	CSBS-0.4g	29.6	3.5	-11.4	5.4	-17.1	2.7	-9.8	6.4	-11.5	19.7
2	CSBS-0.308g	22.0	3.0	-9.3	4.5	-15.1	2.2	-8.2	5.4	-10.0	15.4
3	CSBS-0.2g	15.8	1.7	-7.6	2.7	-13.1	1.5	-6.6	3.1	-8.1	10.0
4	Koyna-0.308g	11.5	2.3	-7.1	3.2	-12.5	1.6	-6.3	4.3	-7.8	8.0
5	Modified CSBS-0.308g	18.2	3.6	-10.1	3.1	-14.7	1.9	-8.3	4.4	-8.6	11.6

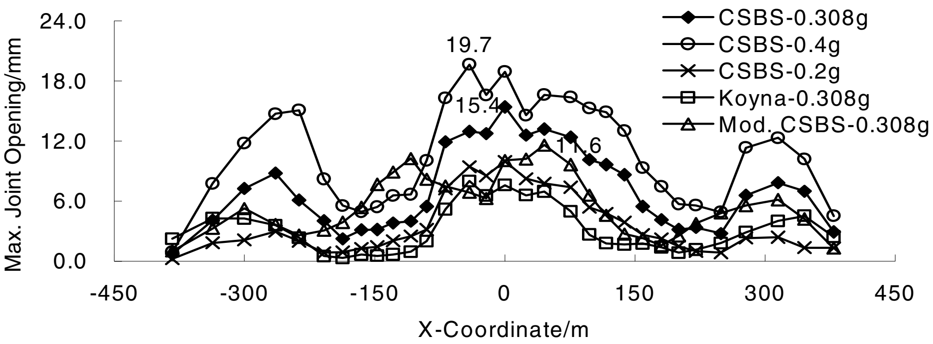
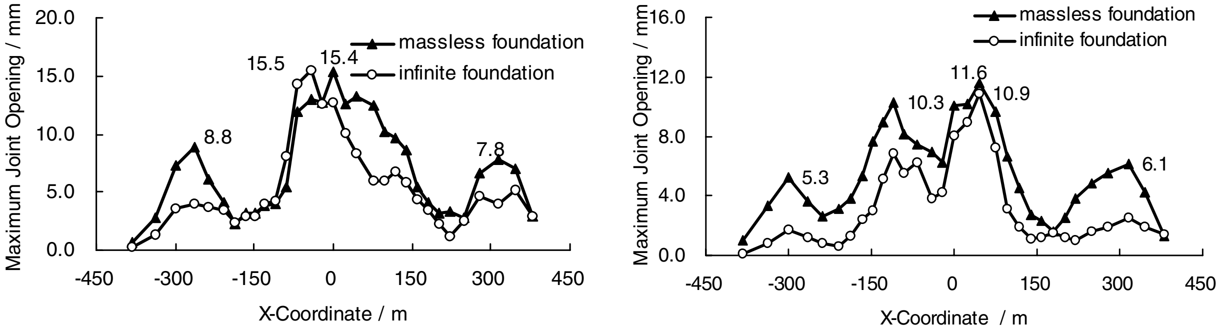


Fig.10 Distribution of maximum joint opening with different earthquake input

Effects of radiation damping due to infinite canyon

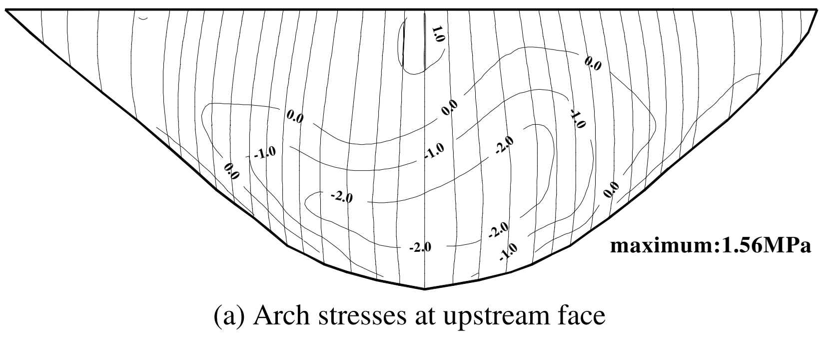
Radiation damping of infinite canyon has significant effects on linear seismic responses of arch dams [Chopra 8, Dominguez 9, Zhang 7]. Herein, the effects on seismic response with nonlinearites due to joint opening are further investigated. The analysis is comparatively conducted between the interaction model and the traditional massless model under the lowest reservoir level. The design basis earthquake is again used as the uniform input for both cases.

The results are shown in Figures 11 and 12 and the observations are summarized as follows: (i) Consideration of radiation damping of infinite canyon receives a remarkable overall reduction in the nonlinear seismic responses of the dam, including joint opening, dynamic displacements and stresses in arch and cantilever components. This reduction varies from 10 to 20%, less than that of effects on linear responses [Zhang 7]. (ii) Examining Figure 11 and comparing Figure 12 with Figure 8, it is shown that the response patterns are quite similar for the two foundation models, indicating that the radiation damping only has minor influence on the structural dynamic characteristics although a portion of wave energy dissipates through the infinite foundation.

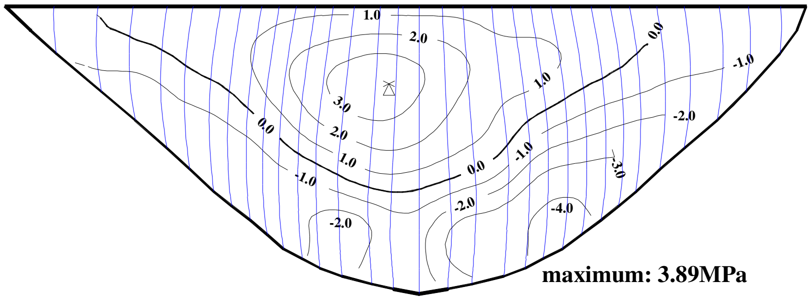


(a) Under CSBS input (b) Under Modified CSBS input

Fig.11 Distribution of maximum joint opening with different dam foundation models



(a) Arch stresses at upstream face



(b) Cantilever stresses at upstream face

Fig.12 Isolines of maximum stresses with infinite canyon (CSBS input) (for comparison with Fig.8)

STRENGTHENING MEASURES

The necessity and alternatives for adopting anti-seismic measures for the Xiaowan arch dam have been investigated and widely discussed for years. Xiaowan is the highest arch dam to be built in the world as well as having the longest crest length of 935m and it is located in a region of high seismic risk. As stated previously, the contraction joint opening of the dam during strong earthquakes is inevitable and significant, which will be an important factor in safety evaluation of the dam. Owing to this non-linear behavior, weakening of dam integrity and possible damage of waterstops between joints will be of great concern to engineers. Therefore, a proper and applicable strengthening solution is definitely necessary to improve the earthquake resistance of the dam.

The common understanding has to be recognized that the principal purpose of anti-seismic measures is to enhance the dam integrity. During strong earthquakes, the central upper portion of the dam is significantly weakened due to joint opening and possible cracks in cantilevers are dangerous if they form discrete concrete wedges between some monoliths. Significant deflection and slippage or even rocking of these wedges during strong earthquakes will have severe consequences on the dam′s safety

In view of this, several alternatives of strengthening measures have been considered and compared, including post-tensioned cables, discontinuous joint reinforcements, continuous reinforcement belts, joint dampers, etc. Shown in Figure 13 is the sketch of different strengthening measure alternatives. For evaluating the strengthening efficiency of these measures, some procedures have been developed, either numerically or by experiments, to assess their feasibility and effectiveness. Some conclusions made from the thorough study are summarized as follows.

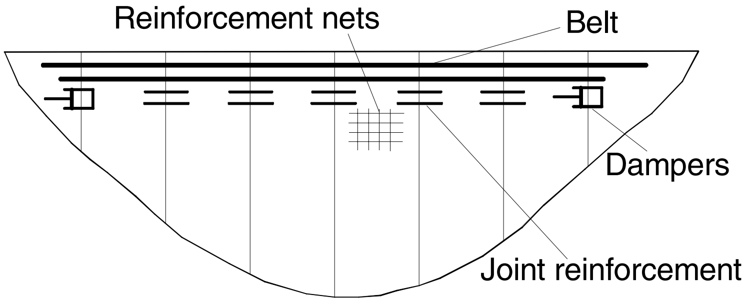


Fig.13 Sketch of strengthening measure alternatives

Post-tensioned cables

In this measure, post-tensioned cables are designed to be placed horizontally and continuously from the left to the right abutment along the galleries located at higher elevations near the crest. The cables have to be anchored into both abutments to a certain depth to generate the required thrust. As the post-tensioning procedure can be carried out after the construction of the dam, this measure has little disruption to the concrete pouring. However, since the dam crest is too long, it is very difficult to produce sufficient thrust for reducing the joint opening.

Discontinuous joint reinforcements combined with reinforcement nets in the upper dam body

This measure has been used in Inguri arch dam (272m high) in Georgia. Steel bars are placed discontinuously across contraction joints in the upper portion of the dam. A certain length of steel bars on both sides of the joints need to be treated cohesion-free from the surrounding concrete to give required deformation for the expected joint opening. An additional length of steel also needs to be embedded into the dam concrete to prevent the steel bars from pulling out from the concrete. Joint reinforcements contribute a significant effect on controlling joint opening. A numerical test is conducted on the Xiaowan dam with a model with 35 joints simulated, in which about 20,000 tons of steel is placed in the upper one-third portion of the dam. Figure 14 shows the comparison of the joint opening distribution between two cases respectively with and without joint reinforcement. The overall redection in joint opening is observed and the maximum value is reduced from 14.8mm to 9.7mm. However these reinforcements do not help to prevent concrete cracking in cantilevers and arches. To improve the structural integrity and decrease the risk of dam cracking, it is suggested that reinforcement nets be placed in the upper portion of the dam both nearing the up and the down-stream faces.

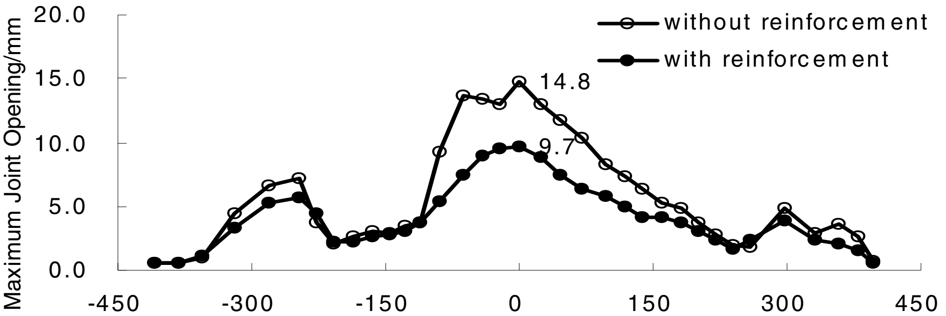


Fig.14 Distribution of maximum joint opening with and without joint reinforcements

Continuous reinforcement belts

Compared with the discontinuous joint reinforcements, the only difference is that in this strengthening measure, steel reinforcements are set continuously along the arch direction, spanning through all joints that need to be controlled. There are two existing dams installed with such belts, i.e. Rapel arch dam in Chile (110m high) and Sir arch dam in Turkey (120m high). During the March 1985 earthquake (7.7 on the Richter scale) Rapel dam appeared to have performed well without obvious damages under the excitation with maximum acceleration of 0.31g in horizontal direction and 0.11g in vertical [Wieland 3].

In spite of the satisfactory strengthening effects, the continuous anti-seismic belts have a vital disadvantage. They may cause a severe disruption to the concrete pouring schedule that may result in an unpredictable delay in the construction period.

Joint dampers

Joint dampers can be installed in contraction joints to provide a viscous damping force to resist seismic action. The damping force F is proportioned to the relative velocity v of joint opening, but acts in a contrary phase. The following equation is used to obtain the viscous force.

$$F = Cv^{\zeta} \quad (2)$$

where C and ζ are parameters chosen depending on the type of damper. The products of damper are available in the world markets.

The installation of joint dampers is relatively simple and has little disruption to the concrete pouring. However, a limited number of joint dampers appear to have insufficient absorption effect on the whole dam structure. So the joint damper may only be functioning locally to reduce the joint opening and may serve as a supplemental alternative.

Combined strengthening solution

From the above discussion on several strengthening measures, different solutions have their own merits and disadvantages. For considering improving of the structural integrity, joint opening control as well as construction feasibility, the combination of discontinuous joint reinforcement with reinforcement nets is preliminarily suggested. First, both horizontal and vertical steel bars are placed in the upper portion of individual monoliths to form reinforcement nets, which limits the cracking of the dam concrete and improves the integrity. Secondly, joint reinforcements are used to control the joint opening and further enhance the integrity of the whole structure by cooperating with the strengthening nets in the monoliths. As an additional measure mainly for experimental purposes, a number of joint dampers are also suggested to be installed at the dam crest. Further investigations need to be performed.

CONCLUSIONS

(1) The safety evaluation and design of the world′s highest (292m) and longest (935m) arch dam, Xiaowan, to resist strong earthquakes (0.308g) present great challenges to Chinese engineers and scientists in hydropower and high dam engineering. Extraordinary care must be taken and strengthening measures are necessary to ensure the dam′s safety.

(2) From analysis, the lowest reservoir is the controlling case in evaluating the maximum joint opening of the dam. On the other hand, from the point of cracking prevention the full reservoir proves to be the critical condition in safety assessment. The design of strengthening measures required consideration of different reservoir elevations.

(3) For 300m high arch dams, due to the uncertainty of the seismic environment in safety evaluation of dams, a sensitivity study relating to variations of PGA, different response spectra and the corresponding input time histories is recommended in the design.

(4) Effects of radiation damping of infinite mass canyon on arch dam response are remarkable when compared with the massless foundation. A reduction of 10-20% in nonlinear response is observed. This reduction may be used as a safety margin in the anti-seismic design.

(5) Different strengthening measures have their own merits and disadvantages. A combined solution of joint reinforcements and reinforcement nets as well as joint dampers is preliminarily suggested at this stage. Further investigations are being carried out.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support for this study work from National Natural Science Foundation of China (50209004) and National Key Basic Research and Development Program (2002CB412709). Appreciation is also extended to Dr. Liu Xinjia and Mr. Long Yuchuang for their assistance in the numerical calculation.

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