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Research Article

OPTIMIZATION OF VULNERABILITY IN CONCRETE DAMS IN TERMS OF USING LIGHT MATERIALS

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ABSTRACT
Today, several dams are being designed and built in our country because of its climate conditions that significant numbers of them are concrete ones. Most of concrete dams are built by concrete; thus, materials and foundation of these constructs are rusty due to several factors such as hydrostatic loads, dynamic and seismic loads, temperature changes, freezing and other items. Then, there are some ruptures made in them increasing with time and resonator effects available in the construct. In the condition that dams are under severe shakes of the ground, they need immediate repair and amplification. Using light materials has benefits of speed in installation, adaptation with any type of construction map, low weight, high resistance, and cost effectiveness. Sometimes dams are damaged because of hitting rocks and/or fluid forces. Putting buffer materials in front of concrete construct can be a suitable solution preventing these damages. On the other hand, non-used resources like volcanic ash, mineral cartridge and pumice can be used. The results showed that low weight concrete has capability of greater shock absorption than common concrete; also, increases in low weight pebbles of concrete causes decrease in density, elasticity module, and thermal expansion coefficient of concrete. Concrete with low weight pebbles delays creation of immediate cracks in constructs. Hence, use of low weight materials in concrete dams can decrease their significant vulnerability specifically in earthquake regions.

Keywords: *Vulnerability, Concrete Dams, Light Materials, Hydrostatic Loads*

INTRODUCTION
Water is one of the most important elements that human beings had tried for its maintenance from the beginning of creation. Water supplies development is one of the most items in developmental programs of countries that are considered as infrastructure principles for improving economic, social and welfare status. Thus, dam building projects have high importance in countries. Among human-made constructs, dams have a unique situation due to several items such as construction goals, severity and sensitivity of risks, and also damages caused by their possible failure. During recent decades, several reasons such as relatively high costs, variety and complexities included in design of dams, and also the need to increase their height caused rapid development in design and performance methods.
Recently, it is suggested to construct dams in terms of security, economically and also rapidly due to energy production incensement. Most high dams are constructed with concrete (weighted, back strapped and curved); thus, materials and foundation of these constructs are rusty due to several factors such as hydrostatic loads, dynamic and seismic loads, temperature changes, freezing and other items. Then, there are some ruptures made in them increasing with time and resonator effects available in the construct. Critical problem that we are going to face with in the future years is concrete dams getting old and ruptured. In the condition that dams are under severe earth shocks, they need immediate repair and amplification. When earthquake happens, we can find damaged parts using sensors, optical fibers, and other alarm devices to perform repair actions for them.
Earthquake can create huge loses to downstream parts of dams, thus it is tried to construct dams with optimum, economic and secured dimensions in light of improvement in dam Engineering of structural analysis.
Earthquake is the most destructive natural phenomenon that usually lasts just a few minutes but creates many damages, and cause of these failures refers to power, speed and sudden movements of earth. These

movements are usually caused by earth changes in margin of faults and thrusts; thus, earthquakes will have more density in regions with more structural fractions. Iran plateau is one of the very active regions in the world which had passed important and several tectonic movements and phases during earth evolution. These moves caused deep and lengthy faults and fractures in the crust of Iran which many of them are currently active with high seismicity power; so that Iran is considered as one of the seismic regions in the world regarding available statistics and information. It is always in danger of great and destructive earthquakes that are happened almost every year. With technology improvement, innovative methods in dam engineering and also the need to increase height of some dams and/or lack of adequate strength and stability against several powers such as earthquake, then the necessity of retrofitting these structures is inevitable. One of the usual issues of structural engineers is to find new and better ideas protecting constructs against destructive effects of environmental forces, and also to control their input energy. most structures have not enough stability against severe shocks of earth due to reasons such as lack of a stable system against lateral force, being located in regions with relatively high earthquake risk, weakness of design and performance, poor materials, lack of awareness when runtime, weak regulations and... Therefore, risk of property damage and loss of life is very high in these regions; it could be a serious alarm for everyone, particularly engineering society. Most repair operations are even more difficult and complex than constructing a structure; so it is better to do repairs when dam is full of water preventing physical and financial loses, and also disconnection of water and electricity services.

We can refer to concrete dams of Konya in India, Hesingfengkiang in china and Sefidrud in Iran due to damages caused by earthquake. Studies showed that the only reason of concrete dams’ destruction is thrust in their foundation; thus, this does not decrease the importance of safety issue of concrete dams against earthquake. The importance of dams’ resistance against earthquake is that floodwater and possible failure of a huge dam destroys all investment performed for structure and facilities related to it, besides it causes significant physical and financial losses in downstream of dams.

The current article studies optimization of vulnerability in concrete dams in terms of using light materials. First, types of earthquake, their effects, types of dams and possible factors of failure in dams are expressed briefly; then, it explains use of light materials in retrofitting of concrete dams and presents helpful information in order to decrease weaknesses of design and implementation of future dams.

Types of Earthquake

1. Tectonic Earthquake

Tectonic earthquakes are very high number of quakes that are registered throughout the world annually; the movements of sheets forming earth crust cause this type of earthquake.

2. Volcanic Earthquake

This type of earthquake happens just in volcanic areas; they are occurred due to explosions along boundary of sheets.

3. Crumble Earthquake

Crumble in underground caves and channels causes earthquakes known as crumble; these shocks are very little just having local importance.

4. Explosion-Caused Earthquake

Military and industrial explosions, also constructional activities also create earthquakes with predictable severity, time and location of occurrence.

5. Inductive Earthquake

There are some earthquakes happened because of dewatering or immediate changes in water level of lakes behind dams, water injection or other floodwaters to the earth and speed of their extraction, particularly in areas with active faults. In fact, main reason of these quakes is quick loading on the earth and/or immediate overloading from it. These are known as “inductive”; quakes caused by explosion of mines are also included here.

Effects of Earthquake

1. Dynamic Effects

When earthquake happens, earthy has a wavelike movement that is interpreted as "dynamic shake"; in fact, a point of earth moves three dimensionally and in form of a bewildered ram which naturally forces the structure on top of itself to similar movement. These moves are measured by seismograph or accelerometer and studied analytically. Dynamic factors of accelerate and movement are extracted as dynamic quantitative effects of earthquake.

2. Static Effects

Contrary to dynamic effects, these are fixed ones that are happened just once in a point and maintained persistent.

Types of Dam

Dams are usually classified based on their materials and formation, including:

1. homogeneous and nonhomogeneous earthy dams
2. gravel dams with soil core and concrete surface
3. concrete dams(weighted, strapped or curved)

Types and Possible Reasons of Dam Failure

The items that could lead to failure of dams are classified in the tables below:

Table 1: Possible reasons of dam failure

Failure features	**Failure reasons**
	Fluidity
	Landslides
Foundation instability	Subsidence
	Solids scour or solution of water-soluble materials
	Movement in adjacent faults or down the dam
	Obstruction
	Fracture
Overflow	Damage of crane and hoists
	Move of deltas
	Obstruction
Fault of evacuation facilities	Damage of cranes and hoists
	Coverage fracture

Table 2: Failure reason based on dam type

Failure features	**Failure reasons**
Concrete dam	The high uplift pressure
	Unforeseen uplift pressure distribution
	Non-uniform bending and motions
	Tension density causing concrete fracture
Earthy dam	Fluidity
	Slope instability
	Excessive water penetration
	Transmission and solution of solid/liquid materials
	Crack emergence due to earthquake activity
	Slope instability
Margin tank	Weakness of natural barriers
	Holes created by earthquake

Lightweight Materials to Lighten Structures

Despite improvements in design and construct methods during recent decades, but effects caused by earthquake are still one of the most important problems in seismic regions. One of the ways to decrease structural losses is use of lightweight materials and to lighten structures. Dams are of most important structures that require enough accuracy for their analysis, design and construct; according to volume of operations of such structures, the project will be non-economic and somehow impractical if just safety is under consideration.

In reinforced concrete structures, concrete contains main part of total load on the structure. Thus, decrease in concrete spatial weight leads to significant benefits such as more efficiency. On the other hand, there were several studies conducted in the recent years due to increase in efficiency, resistance and stability. Lightweight structure means decrease in structure's overall weight using new technique sand materials, and optimization methods. Besides saving time and energy, it also decreases losses caused by natural disasters like earthquake and minimizes damages caused by high weight of structure.

Since concrete is considered as the most widely used materials in most countries (water in first place), then lightening and proper execution of concrete structures is attractive in this period as one of retrofitting strategies against earthquake; in this regard, engineers could produce lightweight concrete using several techniques. From architects' point of view, it is more important to choose materials based on beauty and flexibility. Lightweight, plasticity, harmony, and proper compatibility with structural components are among the most important issues attractive for architects to choose materials. From contractors' point of view, it is more important to choose materials based on design performed by consultancy engineers with accuracy, quick and easy installation, less workforce and at last more profit.

From employers' viewpoint, choosing materials is based on safety, quick execution; easy changes with least waste and cost of materials, less destructive effects, beauty and providing their satisfaction. Nowadays, advanced materials are available in the market due to development of new technologies for cognition and production of new materials.

One of the important and effective materials in modern building industry is lightweight concrete with various applications. It is divided light concrete, sponge concrete, and concrete without fine grain. Light concrete has the advantages of having privilege of speed of installation, adaptation with any type of building map, low weight, high resistance and cost-effective. In the first level, its application is based on economic considerations. Lightweight concrete is produced using light and porous with apparent specific weight lower than 2.6. Spongy concrete is produced with creation of big holes inside the concrete; several types of this concrete are known as spongy, porous, volar or gaseous ones.

Dams' interaction with its surroundings (tank and foundation) caused their response to earthquake to be more complex than common issues of structure dynamics. Interaction of a dam with the water stored behind it causes incensement in period of its vibrations; it is because dam cannot operate without local changes of water tangent to it. The water which moves with dam causes total mass incensement due to earthquake. This added mass increases dam's natural vibrations period and affects inertial forces created by earthquake; it also can increase attenuation when absorbing pressure waves in tanks' boundaries and upward dispersion. In concrete dams, energy decline in tank boundaries usually affects hydrodynamics pressure. In most formulations, similar materials are considered indefinitely developed in depth without any obvious fixed boundary; such a model is usually big, though it might be decreased. Also we can consider simple non-mass foundation model with stone flexibility but without inertial and attenuation effects. It is not necessary for non-mass foundation model to be very large but it is enough to provide an acceptable estimation for flexibility of foundation. Sometimes dams are damaged due to hitting rocks and/or fluid forces; so putting buffer materials in front of concrete structure can be a suitable solution to prevent these damages. On the other hand, using resources in several mountain regions such as volcanic ash, mineral cartridge and pumice can be a good option.

Results of a study conducted by Vosughifar *et al.,* (2010) showed that application of light steel frame structural system and its role to lighten structures has a more appropriate seismic function than common systems of Iran. In a study conducted by Navaie *et al.,* (2013), issue of retrofitting weighted concrete dams was considered; here, post-tensioning technique was used as a retrofitting strategy to decrease sub pressure and to remove tensile stresses in dams. Thus, the results of linear dynamic analysis in weighted concrete dams and cable modeling were studied with Lagrangian and equivalent force methods, respectively considering interaction effect between dam-tank and dam-foundation in post-tensioned and non-post-tensioned moods. Results of linear dynamic analysis showed less response in post-tension mood than non-post-tensioned one. Onoue *et al.*, (2015) used capability of shock absorption by volcanic stones as buffer materials experimentally. Grain size, water to concrete ratio, thickness of buffer layer and velocity impact were considered as experimental factors, and test was designed by Taguchi method. Results of this study showed that lightweight concrete has capability of higher shock absorption than control one (crushed limestone as coarse). Also, statistical analysis showed lightweight concrete is 28 and 41% more effective than control concrete to decrease maximum effective load. In a research, Byard *et al.*, (2014) studied cracking tendency of deck concrete with lightweight aggregates. They found that increase in weight of soaked aggregates inside the concrete will decrease its density, elasticity module, and thermal expansion coefficient. When comparing this type of concrete with usual weight concrete, it is observed that the type with lighter aggregates delays occurrence of immediate cracks.

Conclusions and Suggestions

Generally, results showed that lightweight concrete has capability of higher shock absorption than usual one; also, increase in weight of soaked aggregates inside the concrete will decrease its density, elasticity module, and thermal expansion coefficient. Therefore, the type with lighter aggregates delays occurrence of immediate cracks.

Today, several technologies are used to provide more safety and comfort and cost saving, particularly to consume energy resources effectively. Results showed sever need to efficiency incensement in building sector. It reveals that use of traditional construction systems is not responsive to community needs; thus, use of technology in this sector is inevitable.

Implementation of this type of construction can be a strategy to industrialize building sector, and this has a high impact on decreasing material and energy consumption. The dam building industry of country should focus on this system specifically and use its various potentials to respond required technology.

REFERENCES

Abrishami M *et al.*, (2001). *Concrete Dams: Design and Performance* (publications of Ferdowsi University, Mashhad).

Alengaram U *et al.*, (2013). Utilization of oil palm kernel shell as lightweight aggregate in concrete: a review. *Construction and Building Materials* **38** 161-172.

Arici Y *et al.*, (2014). Comparison of the expected damage patterns from two and three dimensional linear dynamic analyses of a roller compact concrete dam. *Structure and Infrastructure Journal* **10** 305-315.

Byard B *et al.*, (2014). Cracking tendency of lightweight aggregate bridge deck concrete. *ACI Materials Journal* **111** 179-188.

Dabir E *et al.*, (2014). Study of concrete dams seismic behavior. *Construction Journal* **9** 13-18.

Khayat K *et al.*, (2014). Mixture design and testing of fiber-reinforced self-consolidating concrete. *ACI Materials Journal* **111** 143.

Kouroussis G *et al.*, (2011). Finite-dynamic model for infinite media: a solution of viscous boundary efficiency. *Journal of Engineering Mechanics* **137** 509-511.

Lin Gao *et al.*, (2012). An efficient approach for frequency domain and time-domain hydrodynamic analysis of dam reservoir systems. *Earthquake Engineering and Structural Dynamics* **41** 1725-1749.

Mirza Goltabar M (2012). Study of new retrofitting methods to control seismic response of structures. *2nd National Conference of Structure, Earthquake and Geotechnic*.

Moghadam H (2006). *Earthquake Engineering* (Farahang publications).

Morin B *et al.*, (2002). Seismic behavior of post-tensioned gravity dams: shake table experiments and numerical simulations. *Journal of Structural Engineering* **128** 140-152.

Navaie Nia B *et al.*, (2013). Retrofitting of weighted concrete dams. *6th Conference of Engineering Sciences, Tonekabon.*

Onoue K *et al.*, (2015). Shock absorbing capability of lightweight concrete using volcanic pumice. *Journal of Construction and Building Materials* **83** 261-274.

Pasbani *et al.*, (2010). Dynamic analysis of weighted concrete dam considering dam-tank- foundation interaction. *9th Conference of Iran Hydraulics, University of Tarbiat-e Modares, Tehran.*

Saberi A (2006). Increasing resistance of curved dams against earthquake. *National Conference of Repair and Retrofitting, Tehran.*

Siamardi K (2007). Methods of retrofitting concrete dams: case study of Sefidrud dam. *1st National Conference of Dam and Hydraulic Structures, Azad Islamic University of Karaj.*

Siamardi K (2007). Safety of concrete dams against earthquake and design parameters. *1st National Conference of Dam and Hydraulic Structures, Azad Islamic University of Karaj.*

Vermeulen B *et al.*, (2014). River scale model of a training dam using lightweight granulates. *Journal of Hydro-Environment Research* **8** 88-94.

Vosugjhifar H *et al.*, (2010). Comparison of LSF system with usual ones to lighten structures. *International Conference of Lightweight Structures and Earthquake, Kerman.*

Wang M *et al.*, (2012). Dynamic model rupture tests of concrete dams on shaking table. *Advanced Materials Research* **446-449** 2650-2655.

Yasar E *et al.*, (2003). Strength properties of lightweight concrete made with basaltic pumice and fly-ash. *Journal of Materials* **57** 2267-70.