Concrete high dam seismic research in 60 years

Foreword

This book mainly describes the progress in concrete high dam seismic design and research of China Institute of Water Resources and Hydropower Research. Especially in recent 10 years, with the establishment of a serial of 300m high dams in macroseism region in west China, some innovative research achievements and their engineering application following discipline development leading edge and breaking through the tradition haven been gained in close combination with China national conditions and engineering practices so as to promote the communication of international science and engineering field and further joint cooperation. It will be used as reference for professionals, college teachers and students of design research related to high dam anti-earthquake.

This book briefly but symmetrically describes the independent innovative achievements with Chinese characteristics in concrete high dam seismic safety design and research and their applications in China high dam engineering practices so as to enable a overall concept and systematic understanding. So the general conceptual description and detailed methods are omitted. If required, the reader can refer to the attached reference documents and related articles and reports published by the author.

The contents in book manly come from the representative research achievements of high concrete dam anti-earthquake of China Institute of Water Resources and Hydropower Research in the industry. It emphasizes the reflection of concept, thoughts, exploration and experiences of high dam seismic safety which are accumulated in high dam project service practices in more than 50 years research of high dam seismic research of the author. The quantitative contents are mainly of the representative achievements in the topics researched by the author himself or joint accomplished by leading the team and postgraduate students or in major chief by himself, which are noted with the referential document.

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There may have some misgivings and oversight in the book due to the limitation of author capability, it is very kind for the fellows and scholars at home and abroad for point out the mistakes and grant the instructions.

1 China national conditions and anti-seismic of dam

Although the water conservancy construction has a long history, the large dam construction in modern times began from 1949. The preliminary anti-seismic design of large dam adopted the pseudo-static method in America and former Soviet Union. After the frequent earthquake after

water conservation of Guangdong Xinfengjiang dam in 1959, which demands anti-seismic reinforcement, the integral and systematic dam anti-seismic research including dynamic analysis, dynamic model test, field prototype seismic measurement are then initiated. With the development of water conservancy and hydropower construction in china in past 60 years, a number of major dam projects have been established in succession which effectively promotes the anti-seismic design and research of large dams.

The fundamental national conditions related to social and engineering background of large dam anti-seismic can be summarized as follows:

As is known to us all, the water and energy source are essential material basis for development of human society, and in directly relation to the sustainable development of social and national economy and improvement of material and mental lives of people, and it is also one of important confinement factors for development of social and economic development of china. China is facing the huge challenges of population, resource and environment in process of realization of modernization and universally comfortable lives.

The water has become a global focus in 21 century. The water problems puzzling human society has been intensified into water crisis in some regions. The water resources as basic natural resource and strategic economic resources is an integral part of overall national strength. The per capita water resource in china is in severe shortage, which is only 1/4 of that of the world and ranks 88^{th} in 153 countries in the world. It is forecasted that the per capita water resource will be $1760m^3$ when the population in china reaches 1.6 billion in 2030, which is less than the standard for water stressed country internationally accepted. Moreover, due to the influence of monsoon climate conditions, the rate of flow is uneven in time distribution, in which the flood runoff amount in flood period of one year approximates 2/3. The sharp changes in years and frequent flood-drought disasters considerably limited the social and economic development and impacted the ecological environment. The spatial distribution of water source in china is extremely disproportional, which decreases from southeast to northwest, and do not match the land resources. Thus, China faces the threats including shortage of water source, severe water disaster, water environment deterioration and intensification of water and soil loss. The dealing with challenges of water crisis becomes important strategic problems for sustainable development of China economic society. This is the first of the fundamental national conditions.

To this end, the intensification of construction of water reservoir dam to control and utilize the flood during flood period is the strategic demand for reasonable allocation and utilization of water resource, drought and flood control to minimize the disaster, harnessing of great rivers, and protection of water environment and recovery of water ecology.

Energy is one of important strategic resources for economic and social development, while the energy safety is generally concerned by all countries and plays a critical role for the medium and long term strategic objective for building a well-off society in an all-round way and realization of basic modernization, especially for the electric secondary energy source as the anteceding and basic industry of national economy. China features large gross economic scale and relative shortage of energy resources. The per capita procession is only equivalent to half of average level in the world. Especially the secondary energy structure with 76% ratio for coal power is increasingly constrained by the capacity of environment and water resource and hard to sustain. Although the energy structure mainly of coal electricity in medium and long term still will not change, but it is no time to delay to decrease its proportion. There is a broad prospection for

development of renewable energies such as wind power, solar energy and biomass energy and nuclear energy, but it is predicted that the weights of wind power, solar energy, biomass and nuclear energy can not be large in power installation at least before 2030 due to the limitations of quality characteristic, economic, technical and resource reasons. The water energy resource of China ranks first in the world. The development capacity of water power in continental part of China is up to 540 million kW (Pan Jiazheng, 2007). Calculated with utilization in 100 years, the water energy resources can approximate 40% of demonstrated conventional energy resources. In medium and long term, the water power energy including pumped storage will account for 22.3% and it will still be the main force to deal with the climate change, reduction of coal power emission and improvement of secondary energy structure. This is the second of fundamental national conditions.

Vigorous development of renewable water power clean resource is a sustainable project to integrate the territorial management, river development, flood and drought control, dealing with climate change, regional economic revival, poverty alleviation and ecology improvement. Due to the features of high control performance, large installation capacity and high comprehensive benefit, high dam reservoir plays a nonreplicable role in construction of water power projects.

With the increasing buildup of global environment awareness and sustainable development requirement, the consideration for functions of high dam water reservoir by international society is deepening. Under the conditions of fully considering influences by resettlement of migrated residents, ecology and environment, active and orderly constructions of water reservoir high dams are more suitable for China national conditions and can meet the emergent demand for development of society and economy, so it becomes one of essential components for current infrastructure construction in China. The water energy as the basic natural resources and strategic economic resource is the component of overall national strength.

The China continent is among several large crustal blocks and located at the interjection positions of two seismic belts in the world, the east is close to Pacific seismic belt west branch and the west and southwest part is the part passing by Eurasia belt, so China is one of earthquake-prone countries. The China continent belongs to east part of Eurasian plate and the earthquake has the intraplate features happened in continent. The intraplate earthquake has large intensity due to thick crust, long rock age, high strength and high accumulated energy, and most of the seismic focuses are at of 10 to 30km deep. The earthquake damage of continental shallow earthquake is severe. Therefore, not only the earthquake zones are wide and scattered, but also the earthquake happens frequently with large strength. Only in 20th century, the number of earthquakes with the amplitude of equal to or more than degree 8 is up to 10. According to data of Chinese Seismic Bureau, the earthquake of at least amplitude of degree 5 has happened in each province in China continent, the earthquake of amplitude of over degree 6 has happed in 29 province except Zhejiang and Guizhou and earthquake of over 7 degree in 20 provinces. Figure 1-1 shows the block plan for ground motion peak ground acceleration in china. It indicates most of national land areas are of seismic zones. There are two clear seismic belts in China continent, one crosses the land middle part from north to south and the other spans the north China region from east to west. According to data of Chinese Seismic Bureau, the earthquake of at least amplitude of degree 5 has happened in each province in China continent, the earthquake of amplitude of over degree 6 has happed in 29 province except Zhejiang and Guizhou and earthquake of over 7 degree in 20 provinces. The seismic hazard not only threatens the people lift and property safety, it also

one of important factors limiting economic structure and social development. China is the country suffered from the seismic hazard the most in the world. In record in human history, there are 6 earthquakes caused death of more than 200,000 peoples, in which China accounts for 4 times. Since 20th century, the Haiyuan earthquake in Ningxia in 1920 causes more than 200,000 people death and much more injured. In Tangshan earthquake in 1976, the death was up to more than 240,000 with tragic loss. According to statistics of Chinese Seismic Bureau, since 20^{th} century, the total death number in globe due to earthquake reaches about 1.5 million, in which that in China is up to 600,000 accounting for 40%. In 1949 to 2000, the number of death due to various natural disaster is up to 550,000, more than half of which is from earthquake hazard for 280,000 (Hu Yuxian, 2006). In 21st century, for the MS 8.0 Wenchuan earthquake at east of Sichuan province of china in 2008, the maximum intensity at epicenter reaches scale 11. The seismic zone underwent catastrophic damage with wide calamity area. The number of fatalities is more than 70,000. It is the most destructive earthquake with the widest suffering area in past 60 years. Sichuan province is a major water resource province in China with the first ranking water resource in the country, so there are a large amount of water dams and water power plants, which are damaged to certain extents in this earthquake. The grim seismic regime and severe seismic hazard is the third fundamental national conditions.