

# Dam Construction in China--2006

## Dam statistics, Progresses and concerned issues

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Abstract: Modern dam construction of more than 50 years has achieved great progresses in China. But there are still a lot of issues need to be paid much attentions in the way forward. In this paper, dam statistics results are introduced and main progresses and concerned issues in China are summarized.

### I. Dam statistics in China till 2005

China has a long history of dam construction. Anfengtang, located in Shouxian county, Anhui Province, 10m high, built in B.C. 598 ~591, has a history of 2600 years. According to dam statistics by ICOLD, there were only 15 dams higher than 30m in China up to 1950. Among them, 8 are earth or rockfill dams and 7 are gravity dams. Alternatives for dam type selection at that time are quite limited.

After the foundation of People's Republic of China, especially for the latest 20 years since the initiation of its reform and opening to the outside world, dam constructions and techniques for dams have achieved great progresses. According to dam statistics by ICOLD, average 335 dams were completed every year in the world except China from 1951 to 1977. In contrast, 420 dams were built in China during this period. According to incomplete statistics at the end of 2004, there were about 47500 large dams in the world of which 26278 dams are in China that take approximately 55%. Fig.1 shows the dam statistics of the world.

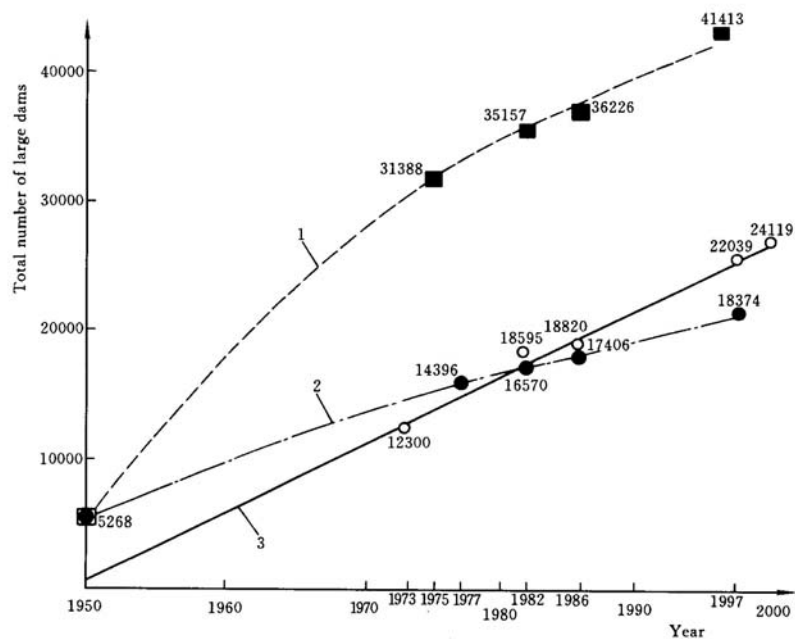


Figure1 Dam statistics of the world

By the end of 2005, there were 4860 large dams higher than 30m in China that takes about 37% of the dams in the world. Chinese dams are built mainly for irrigation, flood control and water supply. There are about 150 dams built only for power generation. Up to now, total installed capacity of China is 116,520 MW, with annual output of 395.2TWh, ranking the first in the world. By the end of 2005, there were 130 dams higher than 100m, 9 dams higher than 200m and 1 higher than 300m. The highest dam is Jinping-I arch dam, 305m high. There were 167 dams higher than 30m under construction. Among them, 45 are CFRDs, 27 are arch dams, and 22 are RCC dams.

## **II. Main Progresses of Dam construction in China**

Three Gorges Project, Ertan Arch Dam and Xiaolangdi multipurpose project are the typical projects of modern dam construction in China. Ertan and Xiaolangdi were completed in 1999 and 2001 respectively. The three projects indicates that dam construction techniques in China have been greatly improved from the state of catching up with the world level to keeping the same level with the world. Many large dams built in this period have five prominent features as follows.

- (1) High quality, safe and reliable with the adoption of modern construction and management methodologies.
- (2) Cost of most projects is lower than their budgets.
- (3) Construction periods of most projects are shorter than expected. Some of them have achieved the objectives of generating power ahead of the schedule.
- (4) Projects have achieved their economic and social benefits as expected. For example, the big floods in 1998 were mitigated by the integrated operations of dam clusters, which have played important roles in flood disaster reduction.
- (5) New dam types and new dam construction techniques have been developed, applied and further studied, such as CFRD, RCC and high arch dams.

In addition, under the auspices of national five-year plans for science and technology, studies related to dam construction have been carried out for many years and their results have greatly contributed the construction of Shuibuya CFRD, Longtan RCC dam and Xiaowan arch dam.

The progresses of Chinese dam construction can be summarized as the following 10 aspects.

1. Three Gorges Project (mass concrete gravity dam with a height of 181m)

Three Gorges Project is a multipurpose project for flood control, power generation and navigation, etc. Its installed capacity is 18200 MW with an annual power generation of 84.7TWh. It began to be built in 1993 following its approval by the People's Congress. The first-phase river closure was completed in 1997. The reservoir began its impoundment in 2003 while the first generator began its power generation and the ship lock to be in service. The total predetermined investment of this project can be reduced by 20 billion RMB. Three Gorges Dams was constructed to its crest elevation in May 2006. It is one the typical huge projects with high quality, safety and reliability. Its planed benefits are achieved in a shorted period of construction and a lot of investments are saved.

## 2. Ertan arch dam (240m high)

Ertan is the first project completed among the 21 cascaded hydropower stations planned on the main stream of Yalongjiang River. It is the second largest hydropower project constructed in the 20th century in China following the Three Gorges Project. The main purpose of Ertan project is power generation. Its installed capacity is 3300MW and its annual output is 17TWh. Ertan arch dam is the highest dam in Asia and the third highest dam in the world in last century.

Ertan Hydropower Project is financed by the central and local governments. It is also financed by a loan of 930 million US\$ from the World Bank. In construction, international competition bidding is adopted to select the best contractors and supplies. Advanced construction techniques and management experiences were introduced into the construction.

## 3. Xiaolangdi Multipurpose Dam (160m inclined clay core dam)

Xiaolangdi Multipurpose Dam is a dominated project located on the main stream of Yellow River. It can not only control the flood of Yellow River, but also trap sediments using its dead storage to prevent downstream riverbed rising. The integrated multi-reservoir operations of Xiaolangdi, Sanmenxia, Luhun and Guxian can increase the flood control standard of the Yellow River from 1 in 100 years to 1 in 1000 years.

Xiaolangdi Project was started in September 1991. Its main structure was started in 1994. The river was closed in October 1997 and its first generator was put into operation in January 2000. The whole project lasted for 11 years before its completion in 2001. 200 thousand resettlements were relocated. Many achievements have been obtained in the aspects of shortened construction period, saved investment and high project quality. It is praised all over the world as a good example of the cooperation between the World Bank and a developing country.

The prominent technical features of Xiaolangdi Project include the following

aspects.

- The combination of horizontal and vertical seepage control measures.
- Siltation prevention in the intake
- The largest tunnel spillway with orifices in the world
- Underground caverns in complicated foundation

#### 4. Concrete faced rockfill dams

Shuibuya is the highest CFRD under construction in the world. CFRD construction in China started in 1985. The earliest CFRD is Xibeikou dam, 95m high. It is completed in 1990. Based on the research achievements and practices in construction techniques, seismic safety analysis, dam materials using soft rock, as well as in cold areas and high-altitude areas, CFRDs have been developed very quickly in China. There are 312 CFRDs higher than 30m in the world by 2005, of which 169 CFRDs are in China including Shuibuya (233m), Jiangpinghe (221m), Sanbanxi (186m), Hongjiadu (179.5m), Tankeng (162m) and Zipingpu (158m).

#### 5. RCC Dams

Longtan RCC gravity dam (216.5m) and Shapai RCC arch dam (132m) are the highest ones in the world up to now. Kengkou RCC gravity dam is the first RCC dam in China, completed in 1986 in Fujian Province. There are 275 RCC dams higher than 30m in the world up to now and 90 of them are in China. Typical RCC dams under construction at present in China are Guangzhao (195.5m), Jin'anqiao (156m), Dahuashui (134m), etc.

#### 6. High Arch Dams (Concrete or masonry materials)

Arch dam has become one of the main dam types. Following the operation of Ertan arch dam in 1998, many experiences for super high arch dam construction are obtained. There are 707 arch dams higher than 30m, including Jinping-I (305m), Xiaowan (292m), Xiluodu (278m), Laxiwa (250m) and etc at present. State Research Programs related to arch dams have been carried out for many years, especially studies on seismic safety, structural analysis, materials and design of key structures. Abundant research results have been achieved.

#### 7. Asphalt lining, asphalt core and clay core projects

By international cooperation and self-development, asphalt projects have been developed very quickly in China in recent years. There are 31 dams higher than 30 m that have been completed or under construction. Tianhuangping, Yele, Nierji, Maopingxi projects have been completed. Zhanghewan, Xilongchi, Baoquan projects are under construction.

Most Chinese dams are earth or rockfill dams. The typical clay core dam under

design is Nuozhadu with a height of 261.5 m.

#### 8. Pumped Storage Power Stations

Construction of pumped storage power station began in 1960s. By the end of 2005, there were 24 pumped storage power stations completed and the installed capacity amounts to 15950 MW. Guangzhou, Shisanling, Tianhuangping PSP are projects completed. Zhanghewan (1000 MW), Xilongchi (1200 MW) and Tongbai (1200 MW) are projects under construction. Along with electricity development in China, pumped storage power stations will go forward rapidly.

#### 9. Small hydropower development

China has rich small hydropower resources in rural areas that have storages of 128 GW widely distributed in more than 1600 counties, especially in mountain areas. Small hydropower projects are comparatively simple with small inundation areas and a few resettlements. Their construction period is rather short and as a result their benefits can be produced quickly. Small hydropower has also the advantages of separated development, power supply for nearby areas, as well as short-distance and high-voltage transmission.

By the end of 2002, there were 42.2 thousand small hydropower plants in China and the installed capacity is 31150 MW, about 30% of the total national hydropower installation. The annual power generation is 104.1TWh, occupying about 30% of the national hydropower production.

#### 10. CSG dams

CSG dam construction has just begun in China. It is now in the stage of learning experiences from foreign countries and carrying out experimental studies. Two CSG coffer dams have just been constructed. It can save 50% of materials in comparison with CFRD. It can be built on weak foundation that is not possible for conventional gravity dams. It also has the prominent advantages in cost, construction period and adaptability to different foundation conditions.

### **III. Main technical issues in future dam construction**

Although modern dam construction in China has been witnessed for more than 50 years and has achieved great progresses, there are still many challenging issues to be investigated in the future. Following 10 concerned aspects are summarized with consideration of technical issues. Tasks related to environment protection are very complicated and not listed here.

#### 1. New dam type

CFRD, RCC dam technique has played important roles in shortening construction period and decreasing dam investments, etc. They represent the main progresses made in recent 20 years. For the way forward, efforts should be made on

new types of dams and their applications.

## 2. Research and construction of higher CFRD

Research and construction of Shuibuya CFRD has made great contribution on the development and application of CFRD in China. For the requirement of future hydropower development, it is necessary to investigate the techniques to construct super high CFRD in China in economic and reliable ways, such as CFRD of above 300 m.

## 3. Research and practice of higher RCC dam

Longtan RCC dam and several other RCC dams with height around 200m are under construction or under design in China. It is very important to investigate effective measures to guarantee the safety of this kind of dams. Great attention should also be paid on the construction technique of high RCC dams.

## 4. Construction of higher RCC arch dams

Several thin RCC arch dams have been built in China. There are many successful projects and at the same time there are lessons and issues to be treated carefully, such as leakage and surface cracks problems, etc. Much attention shall be paid to determine the construction principles of high RCC arch dams (thin or thick) and to investigate the possibility to build super high RCC arch dams.

## 5. The safety of high arch dams around 300m

There are several high arch dams around 300m under construction or under design in China after the successful completion of Ertan 240m arch dam. It is very important to guarantee the safety of high arch dam for the reasons that only a little experience has been obtained and the huge reservoir storages will have potential threats.

## 6. Dam rehabilitations

A lot of dams have been built for many years and need to be rehabilitated. It is really needed in China to develop new techniques for detecting hidden defects with safety risks within dams and new technique for their rehabilitations.

## 7. Life span of aged dams, dam retirement and risk management

It is a complicated to determine the financially reasonable life spans of dams and establish a framework for the evaluation of dam retirement, especially for very high dams. It is also a complicated issue faced by the society to manage dams based on risk management theories that are not yet perfect to be practically used.

## 8. Structure analysis for dams and simulation techniques

It is necessary for high dams to be constructed based on experiences. It is also necessary to carry out accurate structure analysis and to adopt advanced techniques of simulations. Reliability of structure analyses need to be improved based on construction experiences for high CFRD, RCC, and other kinds of dams.

#### 9. Research on materials for dam construction

Dam type selection is usually affected by available local material. Continual investigations on dam materials will not only help to improve dam performances but decrease dam construction cost also.

#### 10. Technical standards for environment friendly dam construction

Societies have been paying more and more attentions on dam construction nowadays. It is necessary for dam engineers to cooperate with ecological and social experts to investigate effective ways to protect environment in the mean time to study dam construction technologies. Studies on technical standards for environment friendly dam construction will be one of the main tasks in the near future.

### **IV Conclusive remarks**

It is fairly difficult to summarize the progress and key issues in dam construction comprehensively. It is expected that this paper can help foreign friends to know the dam construction situations in China. It is also hoped that this paper be a primary foundation for further discussions among Chinese colleagues.