

The Three Gorges Project

By the Executive Office of the Three Gorges Project Construction Committee, State Council of the PRC



Figure 1. The completed Three Gorges Hydro Junction Project (2014, Zhengping Huang).

1 Overview

The Three Gorges Project is the largest hydro junction project in the world. A key backbone project for the harnessing and exploitation of the Yangtze River, the Three Gorges Project consists of the pivotal dam project, a power transmission and transformation project, and a resettlement project (see Figure 1).

The axis of the Three Gorges Dam is a total of 2309 m long, the dam crest level is 185 m, and the normal pool level is 175 m. Navigation structures include a permanent navigation lock and a ship lift. The permanent navigation lock is a double-line, five-level, multistage flight lock with a designed annual unidirectional tonnage capacity of 50 million tons. The ship lift is a single-line, one-level, steep-lifting type with a lifting height of 113 m, and a gross ship box weight of about 15 500 t—the largest lifting height and weight in the world.

The power transmission and transformation project involved the construction of 6519 km of 500 kV AC transmission line with a transformation capacity of 22 750 MVA and 2965 km of ± 500 kV DC transmission line with a DC converter station capacity of 18 000 MW.

After 40 years of planning, surveying, researching, designing, and testing from the early 1950s onwards, the 5th session of the 7th NPC finally approved the Resolution on the Construction of the Yangtze River in April 1992. Construction officially commenced in December 1994, and the diversion closure of the river was carried out in November 1997. In May 2006, the entire dam reached a height of 185 m. In December 2009, the project completed the scheduled preliminary design tasks. In December 2010, the target of trial water storage to 175 m was successfully completed. In 2011, the International Commission on Large Dams presented the “International Milestone Concrete Dam Project Award” to the Three Gorges Project. In 2013, the International Federation of Consulting Engineers granted the “FIDIC Centenary Award” to the Three Gorges Project.

2 Major technical challenges and solutions

The Three Gorges Dam is designed to withstand a 1000-year flood, and to survive a 10 000-year flood plus 10%; the corresponding flood discharges are $98\,800\text{ m}^3\text{ s}^{-1}$ and $124\,300\text{ m}^3\text{ s}^{-1}$, respectively. Flood discharge from the dam features a high

water head, a large volume of overflow discharge, and a large quantity of sediment outflow. To address both the removal of floating debris in the reservoir, and the diversion required by the construction, a three-layer large outlet layout was adopted after considerable debate, and after modeling with multiple programs. This three-layer outlet required a deep discharge outlet, a surface discharge outlet, and a bottom fluid-diversion outlet in the flood-discharge dam section. It overcame the challenge of dealing with a large volume of flood discharge, and also saved on the engineering work already invested in the project.

The concrete in the Three Gorges Dam occupies as much as 28 million m^3 , twice as much as the concrete in the Itaipu Hydroelectric Power Station, and with a shorter construction period. Rapid concrete construction is key to a scheduled performance. The adoption of a tower belt crane led to the new technique of continuous concreting from mixer plant to placement section, realizing the high-intensity feeding of concrete. In the year 2000, the project created a world record of an annual 5.48 million m^3 of concrete placement, with 553 500 m^3 per month, and 22 000 m^3 per day (Figure 2).

The greatest water depth of the diversion closure was 60 m, and the closure discharge volume was about $8480\text{--}11\,900\text{ m}^3\text{ s}^{-1}$, with both depth and volume ranking as world records. Pre-flow diversion by a constructed open-diversion channel and a pre-dumped bottom cushion reduced the difficulty of the closure, and created a world closure-construction record of $194\,000\text{ m}^3\text{ d}^{-1}$ of continuous landfill.

The turbogenerator unit of the project has one of the largest unit capacities in the world; the maximum water-head variation is 52 m, ranking top among units with similar capacity. The project also developed and adopted a generating unit with “fully air-cooling” and



Figure 2. Construction site of the Phase III Dam.

“evaporative-cooling” technologies, providing better operation reliability than “water-cooling” technology.

The ship lock of the Three Gorges Project has a designed total water head of 113 m; its delivery head is 45.2 m, and the peak height of the structure is 70 m, making it the highest liner-type ship lock in the world. A high-performance drainage system and a draw-cut type of high-strength bolt structure were adopted to form the world’s first “fully liner-type” ship lock; this new lock is a significant and innovative development from the traditional gravity-type lock.

The Three Gorges Project uses a patented double air-cooling technology to realize the stable maintenance of low-temperature concrete at 7 °C at the outlet. The project adopts an individualized dynamic water-cooling technique, and uses a new type of surface insulation material to control the mass concrete temperature and to prevent cracking. More than 4 million m³ of concrete has been placed for the Phase III dam and, through site inspection, no temperature cracking has been found—a miracle in the history of concrete gravity dams.

3 Major project benefits

After 20 years of hard work, the construction task of the Three Gorges Project is basically complete; the dam is now beginning to produce huge and comprehensive benefits such as flood control, power generation, waterway transport, and water-resource utilization.

3.1 Flood control

The Three Gorges Reservoir has a water area of 1084 km² and a storage capacity of 39.3 billion m³, with a flood-storage capacity of 22.1 billion m³. On its completion, the Three Gorges Project will improve the flood-control criteria for the Jingjiang river reach from once in a decade to once in a century. During the flood seasons in 2010 and 2012, the Three Gorges Project underwent inflow peak floods of 70 000 m³·s⁻¹ and 71 200 m³·s⁻¹, respectively, which effectively mitigated the flood-control pressure along the middle and lower reaches of the Yangtze River and protected the lives and property of over 15 million people and 23 million mu of land.

3.2 Power generation

The Three Gorges power station has 34 power sets (32 units with a unit capacity of 700 000 kW and 2 units with a unit capacity of 50 000 kW) with an installed gross capacity of 22.5 million kW. Its annual power generation is 100 billion kWh, which is equivalent to a yearly reduction of 50 million tons of raw coal consumption and a yearly reduction of 100 million tons in carbon dioxide emissions. In 2014, the Three Gorges power station generated a total of 98.8 billion kWh of electricity, exceeding the world record for annual power generation from a single hydroelectric power station, a record that had previously been created by the Itaipu Binacional. With a total electricity generation exceeding 800 billion kWh by the end of 2014, the Three Gorges power station has effectively relieved the shortage of electricity in East China, Central China, and Guangdong, and has become a valuable large production base of clean energy in China.

3.3 Navigation

The Three Gorges Project improves the navigation conditions from Yichang to Chongqing, a distance of about 660 km, and along the middle and lower reaches of the Yangtze River in the low-flow season. As a result, a 10 000 tonner fleet can travel all the way from Hankou to Chongqing, reducing transportation costs significantly. In 2011, the freight volume through the Three Gorges navigation lock reached 100.3 million tons, achieving its planned target 19 years in advance. Over the lock’s 10 years of navigation, the accumulated freight in transit has reached 700 million tons. Thus, the Yangtze River has become an extremely profitable watercourse.

3.4 Comprehensive water resource utilization

The abundant fresh water stored in the Three Gorges Reservoir is a valuable strategic fresh-water resource in China, and could provide a guaranteed water source for water-deficient areas in northern China. The Three Gorges Reservoir could supplement the middle and lower reaches of the Yangtze River with more than 20 billion m³ in the low-flow season every year, adding an average depth of about 0.8 m to the main channel. This supplementary water could effectively mitigate shortages in water for production, living, and ecological needs along the middle and lower reaches of the Yangtze River.

In spite of the stunning benefits brought by the Three Gorges Project, it will also cause certain impacts on peripheral areas and the downstream eco-environment. In particular, the reservoir shore reconstruction might give rise to geological hazards and have impacts on the water quality and aquatic life in the reservoir, as well as in the downstream rivers and lakes. Therefore, we must pay close attention to these matters.

4 Future work

To fit in with the new strategic positioning of the Three Gorges Project and the reservoir region in coming years, the Chinese government has made a significant deployment of resources toward subsequent work in the Three Gorges region. With the wellbeing and enrichment of millions of migrants as the intent and purpose of subsequent work, we should ac-

celerate the development of a generally affluent society in the reservoir region. We should give priority to the re-establishment and protection of the ecological environment; ensure the effective protection of this national strategic fresh-water resource pool; and strengthen our observation and treatment of impounding influences, making use of advantages while striving to avoid disadvantages. We should also enhance our integrated management, optimize our regulation, and

improve our ability in and level of scientific management for the Three Gorges Project. In this way, we can ensure the long and safe running of the dam and sustain its comprehensive benefits; drive economic and social development in the Three Gorges region, enabling the development of a harmonious society; improve the ability of the Three Gorges Project to serve the national economy and nation-wide social development; and thus provide improved benefits to the people.

Development of Super Hybrid Rice for Food Security in China

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The current population in China is over 1.3 billion and will reach 1.4 billion soon. Meanwhile, China's arable land is decreasing year by year. Facing such a severe situation of population-growth pressure plus cropland reduction, it is obvious that the only way to solve the food shortage problem is to greatly enhance the yield level of food crops per unit of land area through advances in science and technology. Thus, we are currently carrying out three yield-increasing projects.

1 Project No. 1: Developing a super high-yielding hybrid rice variety ($16 \text{ t}\cdot\text{hm}^{-2}$)

The development of higher and higher crop yields is an eternal pursuit. Rice is the number one grain crop in both China and the world. In order to substantially increase rice yield, Japan took the lead in initiating a super high-yielding rice breeding program that was targeted to raise rice yield to $12 \text{ t}\cdot\text{hm}^{-2}$ within 15 years. However, this target has not yet been realized, after 34 years. Next, the International Rice Research Institute (IRRI) launched a program to develop super rice in 1989, which was later altered into a new plant-type breeding program, with the target of developing a super rice yielding $12\text{--}12.5 \text{ t}\cdot\text{hm}^{-2}$ by 2000. However, this target was not reached either. Evidently, it is extremely difficult to develop a super rice yielding $12 \text{ t}\cdot\text{hm}^{-2}$.

In order to meet the food demand required by the Chinese people in the 21st century, a super rice breeding program was set up by the Ministry of Agriculture and the Ministry of Science and Technology in 1996 and 1997, respectively. This program was divided into four phases. The yield targets are listed below (based on an average yield at a location with 6.7 hm^2 or 100 mu, where $1 \text{ mu} = 1/15 \text{ hm}^2$):

Phase I: 1996–2000 $10.5 \text{ t}\cdot\text{hm}^{-2}$ or $700 \text{ kg}\cdot\text{mu}^{-1}$

Phase II: 2001–2005 $12 \text{ t}\cdot\text{hm}^{-2}$ or $800 \text{ kg}\cdot\text{mu}^{-1}$

Phase III: 2006–2015 $13.5 \text{ t}\cdot\text{hm}^{-2}$ or $900 \text{ kg}\cdot\text{mu}^{-1}$

Phase IV: 2016–2020 $15 \text{ t}\cdot\text{hm}^{-2}$ or $1000 \text{ kg}\cdot\text{mu}^{-1}$

Through morphological improvement plus the utilization



Figure 1. The Super 1000 variety in the trial field in Sanya, Hainan.

of inter-subspecific heterosis, as well as the unceasing efforts and collaborative work of our research team, all of the yield targets to date have been fulfilled one by one, either on schedule or ahead of schedule. The representative variety of Phase I, named *Liang-you-pei-jiu*, was co-developed by the Jiangsu Academy of Agriculture Sciences and the Hunan Hybrid Rice Research Center. This variety was released to large-scale commercial production in the first few years of the 21st century, with a highest annual planting area of nearly 10 million mu and an average yield of $550 \text{ kg}\cdot\text{mu}^{-1}$. The representative variety of Phase II, *Y Liangyou 1*, was planted over 8 million mu in 2014, with an average yield of around $600 \text{ kg}\cdot\text{mu}^{-1}$; and the representative variety of Phase III, *Y Liangyou 2*, yielded $926.6 \text{ kg}\cdot\text{mu}^{-1}$ at a 100 mu demonstration location in Longhui County, Hunan Province, in 2012. The latter variety began to be commercialized in 2013, and the planting area reached 1 million mu in 2014, with a higher yield of $650 \text{ kg}\cdot\text{mu}^{-1}$. The representative variety of Phase IV, *Y Liangyou 900*, yielded over $1000 \text{ kg}\cdot\text{mu}^{-1}$ at four locations covering 100 mu each, and yielded $1026.7 \text{ kg}\cdot\text{mu}^{-1}$ ($15.4 \text{ t}\cdot\text{hm}^{-2}$) in Xupu County, the highest yield of rice in the world to date. It is predicted that