CIGB ICOLD

The Dams Newsletter

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ICOLD: in Vietnam, for Sustainable Development

For the first time in the history of ICOLD, the 78th Annual Meeting of the International Commission of Large Dams (ICOLD), was held in Southeast Asia. Vietnam, one of the most recent member country of ICOLD hosted the meeting at the National Convention Centre, in Hanoi, from May 23rd to May 26th.

Over 800 delegates, leaders of national or technical committees, representatives of international organizations, scientists, experts or entrepreneurs participated in the meeting. For the first time, the meeting included a round-table discussion on Africa Hydropower, an initiative from the Secretary General and former Vice-President Adama Nombre which will be replicated for the next two meetings in Lucerne 2011 and Kyoto 2012.

Whether dam building goes with sustainable development is one of the most debated issues in international forums. The Vietnamese organizers decided to devote their international symposium to “Dams and Sustainable Development of Water Resources”. That symposium was a big success with more than 400 people having registered to deliver papers on 17 topics, among which 180 papers were selected to be presented at the Meeting.

Hanoï Press Conference

Deputy Prime Minister welcomes ICOLD

Vietnamese Deputy Prime Minister, Hoang Trung Hai, participated and spoke at the opening session. In his welcoming letter to the delegates, Mr. Hai stressed: "Vietnam has abundant water resources, but its rainfall is not equally distributed between months of the year, thus the country is prone to droughts and floods, human lives and the society's assets threatened. Vietnam is also vulnerable to sea level rise caused by climate change. Therefore, the country attaches great importance to the construction of a system of water resources management and hydropower works, with many large dykes and dams. (…) The contents of the meeting of the International Commission of Large Dams (ICOLD) will certainly be very useful to the cause of building dams and developing water resources in Vietnam as well as other countries in the world. I sincerely thank the ICOLD for selecting Hanoi, the capital of Vietnam to hold this important event in 2010, the year when we solemnly organize the 1000th anniversary of Thang Long – Ha Noi".

ICOLD welcomes two new members and plans new meetings

ICOLD continues to reach ever more countries as can be seen with the growing number of National committees joining the Commission. In Hanoi, Mozambique and Ukraine were officially elected as 91st and 92nd member countries. ICOLD President and Secretary General expressed the hope that the 100 members mark would be overcome by 2012.

It has been decided to invite non-member African countries to future ICOLD symposia and congresses through their ministries.

Another indication of ICOLD's vitality is the number of countries willing to welcome future meetings of the Commission: USA for 2013, three competing candidates for 2014 (Sri Lanka, India and Indonesia), already one candidate for the 2015 Congress (Oslo, Norway) and South Africa for 2016. Already decided by vote are the 2011 meeting and the 2012 Congress which will take place, respectively, in Lucerne (Switzerland) and Kyoto (Japan).

Questions for the 24th ICOLD Congress

For that 24th Congress in Kyoto, four questions were selected during the Executive Meeting by the assembled member countries. Those are:

Q92 – ENVIRONMENTAL FRIENDLY TECHNIQUES FOR DAMS AND RESERVOIRS

1. Environmental and social friendly planning, design and construction techniques for dams.
2. Mitigation and compensation measures.

3. Water quality and sediment issues.
4. Sustainable management of dams and reservoirs.

Q93 – SAFETY

1. Accidents and incidents in dams and reservoirs – Recent case studies.
2. Risks associated with human and organizational factors.
3. Legislation, regulatory concepts, guidelines and good practice.
4. Specific risks for small dams.
5. Risks specific to tailings dams, pump-storage schemes, flood control structures and other special purpose dams.

Q94 – FLOOD DISCHARGE

1. Evaluation, revision and selection of extreme and design floods.
2. Recent trends in spillway design and spillway upgrading.
3. Special risks from gates operation and floating debris.
4. Energy dissipation: stepped spillway, stilling basin and downstream erosion.

Q95 – AGEING AND UPGRADING

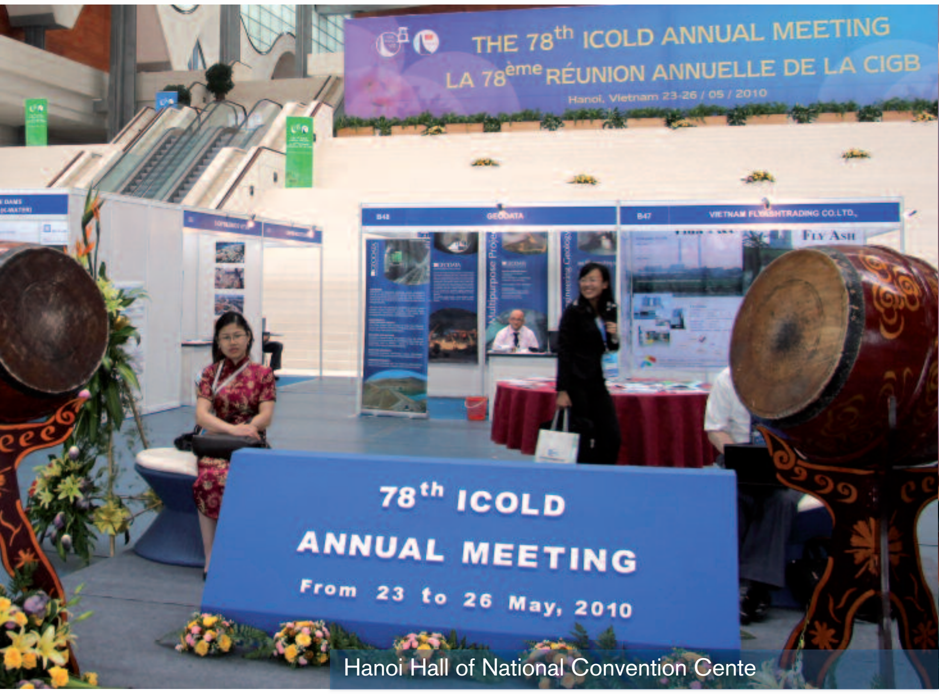
1. Risks associated with long-term behaviour of dam foundations.
2. Long-term behaviour of dam materials and structures.
3. Decommissioning or upgrading?
4. Upgrading for seismic safety.

For those willing to present papers to the Kyoto Congress, it is reminded that the papers have to be submitted first to the National Committees which are responsible for ensuring that they comply with the Guideline for the Preparation of Papers. Papers must be submitted by 5 September 2011 to the ICOLD Central Office.

Improved dissemination

An intense discussion during the Executive Meeting has beared upon how to best improve the dissemination of ICOLD publications, especially the technical bulletins, which are the heart of ICOLD's work. Speaking about dissemination, the success of the press conference must be underlined. Very well organized, the press conference drew a high attendance: 29 journalists from newspapers and magazine, 8 representatives of TV and 7 journalists from the online media participated. All those news media had the occasion to learn about ICOLD and its work for sustainable development of hydroelectricity and water resources.

Among the new bulletins approved by the Executive Meeting, those bearing on the questions of Sedimentation, Seismic parameters, Planning of water resources, Role of dams in river basins, Cut-offs for embankments, Tropical residual soils and Dams safety and earth-



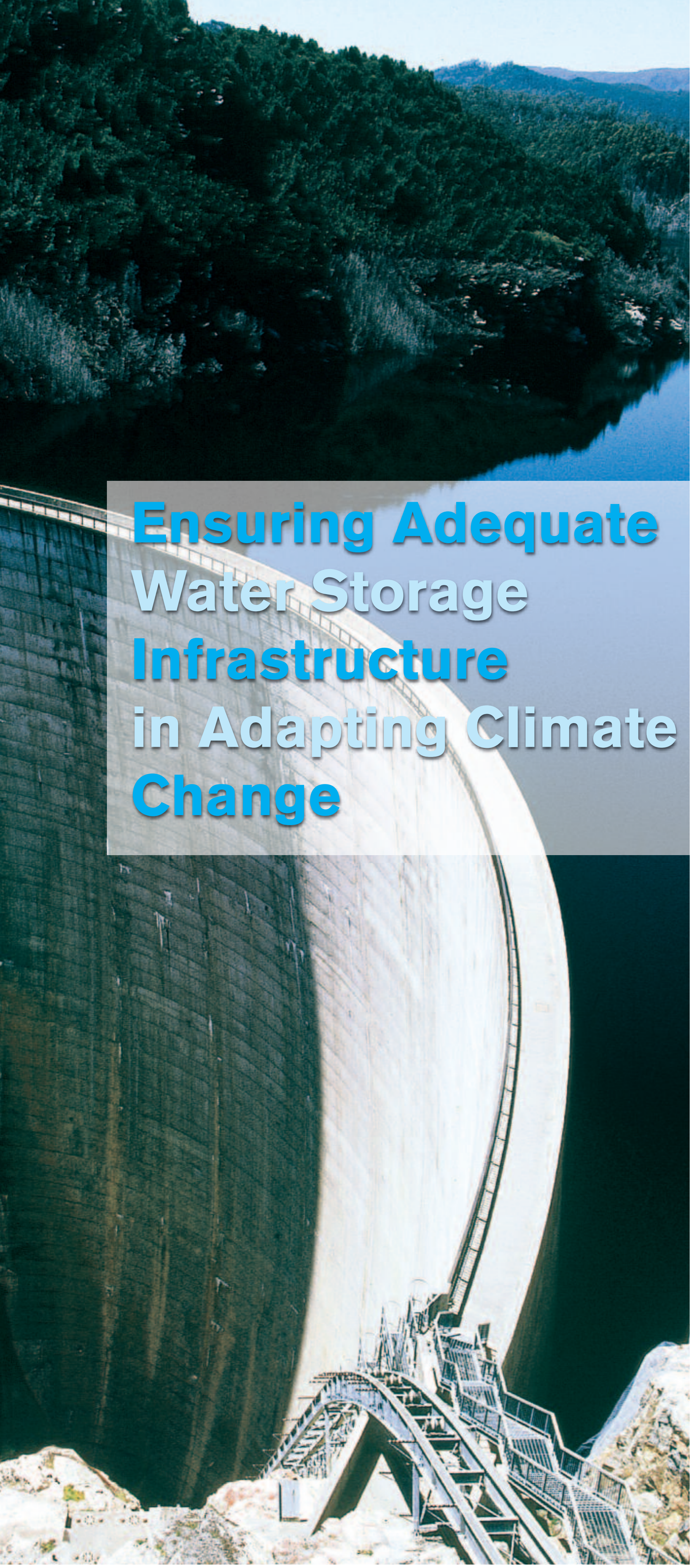
Hanoi Hall of National Convention Cente

quakes. This list gives an idea of the very wide scope of the works accomplished made inside ICOLD's Technical committees.

Also, two new Vice Presidents were elected: Werner Floegl (Austria) for Zone Europe and Pham Giang (Vietnam) for Zone Asia.

After the conference ended, delegates had the choice between five post-meeting technical study tours to dams across Vietnam, from the North to the South, such as the dams of Hoa Binh, Son La, Cua Dat, Phu Ninh, Dinh Binh, Ham Thuan – Da Mi, Tri An, etc. And before the conference started, the delegates could also take the occasion to visit the magnificent Ha Long Bay, one of the natural wonders of the world. Twice listes by UNESCO as a "World Heritage Site": in 1994 for its outstanding and universal aesthetic value, and in 2000 for its geological and geomorphological value.


Halong Bay



Ensuring Adequate Water Storage Infrastructure in Adapting Climate Change

Jinsheng JIA, Jing MA

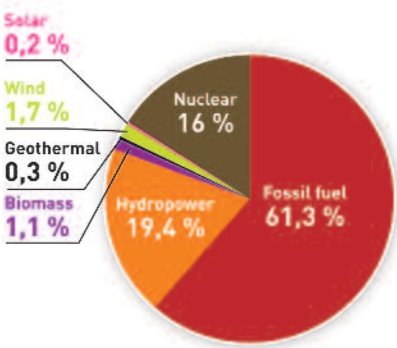
- International Commission on Large Dams (ICOLD), Paris
- China Institute of Water Resources and Hydropower Research, Beijing
- China National Committee on Large Dams (CHINCOLD), Beijing

Climate change is regarded as most sever challenge for us all. The view on ensuring adequate water storage infrastructure to adapt climate change has been widely accepted by international community. As for the water storage infrastructure, developed country has well conducted a complete network whereas developing country is facing tough work to be forehead. Based on the challenge induced by climate change, the need of development, the paper describes the importance and significance on ensuring adequate water storage facility for the sustainable development. And points out the path on developing water and energy in a reliable, cheap and environmental-friendly way.

1 Accelerating water storage infrastructure construction is the need on adapting climate change

The world is changing. Population growth and economic development turn to be the prime driving power that stimulates the ever-increasing demand for resources and energy. Water is a basic natural resource, but also a strategic economic resource, and it has an important influence on the environment. The world's population is growing by about 80 million people a year, implying increased freshwater demand of about 64 billion m^3 a year. In 2030, 47% of world population will be living in areas of

Figure 1:
Power generation by type



high water stress UNESCO, 2009 . In the meanwhile, the increasing on extreme climatic events including flood and drought induced by climate change further intensified the difficulties for water allocation and utilization.

As one of outstanding constraints we are facing now, climate change necessitates us to take actions. On the one hand, we need to actively push forward the strategic adjustment of the structure of energy supply, change the leading role of fossil fuel in the structure and reduce greenhouse gas emissions; on the other hand, we need security measures against the consequence of global climate change. Naturally, enlarging the storage and the regulating capacity are regarded as a core and key engineering measure. The consensus on the role of dam and reservoir in adaption of climate change has been conducted in a wide range by international community. More and more people are recognizing water infrastructure is essential to achieve sustainable development. Insufficient water storage facilities will delay our ability to respond to climate change and to meet the Millennium Development Goals.

The transition is causing a new era on dam and reservoirs construction. Many of the infrastructure investments and other steps taken as a result of the dam will help individual country deal with climate change and economic crisis such as in China and USA where billions of funds were invested in dam construction and rehabilitation. The supporter and opponent on constructing large water storage facility can back to sit together to discuss the issues on global development in a friendly manner, which reflects that development requirement is the foundation for forming consensus.

2 Multi-purpose dams and reservoirs have the comprehensive advantage on water and energy utilization

During the past century, multi-purpose dams and reservoirs have provided an opportunity for drought protection, flood mitigation, water provision for rural and urban need, navigation, recreation as well as energy. Moreover, its comprehensive advantage on water and energy utilization is popped out gradually with successive occurrence on energy crisis, water crisis, food crisis and climate change etc.

Water storage is energy storage. It has played an important role in modern power systems. Currently hydropower generation accounts for approximate 20% of world electricity (EIA, 2008), which is the second dominating power after the fossil fuel (**Figure 1**).

Among various types of energies hydropower has the highest energy pay back and lowest green house gas emission. The use of energy payback emerged with the oil crisis occurred in the early 1970s. After the oil crisis, the energy agenda began to change significantly, resulting in issues like energy independence, air quality, and later, climate change (Gagnon, 2008). Many countries started to explore oil substitutes. One of the key problems that became apparent was the selection of efficient energy options for growing future demand. To identify appropriate solutions, policy-makers need to consider life-cycle assessments before taking decisions. Such life-cycle assessments must include energy payback as a central component. Energy payback may be a somewhat indirect measure of overall impact, and it provides a useful perspective on the origins of the real-world impacts. Therefore, the concept of energy payback was used to evaluate energy options in the form of Net Energy Analysis (NEA) by comparing the "net energy" for different energy options on a life-cycle basis.

One way to compare different energy options is to calculate the so-called life cycle Energy Payback Ratio. This is the ratio of total energy produced during that system's normal lifespan to the energy required to build, maintain and fuel the system. The Energy Payback Ratio of a power plant is defined as the total energy produced over the lifetime of the plant divided by the energy needed to build, operate, fuel, and decommission it. White and Kulcinski (1999) proposed a simple equation for

$$EPR = \frac{E_{nL}}{(E_{matL} + E_{conL} + E_{opL} + E_{decL})}$$

calculating the Energy Payback Ratio, EPR, in which, E_{nL} is the net electrical energy produced over a given plant lifetime L; E_{matL} is total energy invested in materials used over a plant lifetime L; E_{conL} is total energy invested in construction for a plant with lifetime L; E_{opL} is total energy invested in operating the plant over the lifetime L; E_{decL} is total energy invested in decommissioning a plant after it has operated for a lifetime L. A high ratio indicates a good performance.

According to Gagnon (2005), the energy payback ratio of different modes of energy development is about: 208-280 for hydropower with reservoir, 170-267 for hydropower run of river, 18-34 for wind power, 3-5 for biological energy, 3-6 for solar energy, 14-16 for nuclear energy, 2.5-5.1 for traditional thermal power and only 1.6-3.3 for thermal power in CO^2 capture or storage technology (Figure 2).

Hydropower is also a source of energy causing the least greenhouse gas emission (Figure 3). As World Energy Council (2004) calculation CO^2 emission per GWh is about 941-1022 t for traditional thermal power, 649-787 t for diesel, 220-300 t for thermal power in CO^2 capture or storage technology, 38-121 t for solar energy, 51-90 t for biological energy, 10-33 t for hydropower with reservoir, 9-20 for wind energy, 6-16 t for nuclear energy, and 3-4 t for hydropower run of river, the least emission.

Figure 2: Energy payback Ratio by type

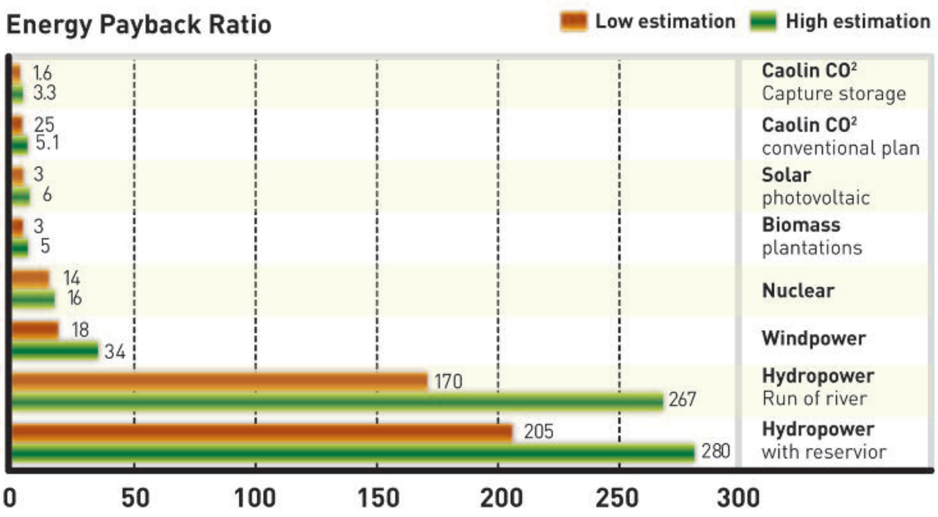
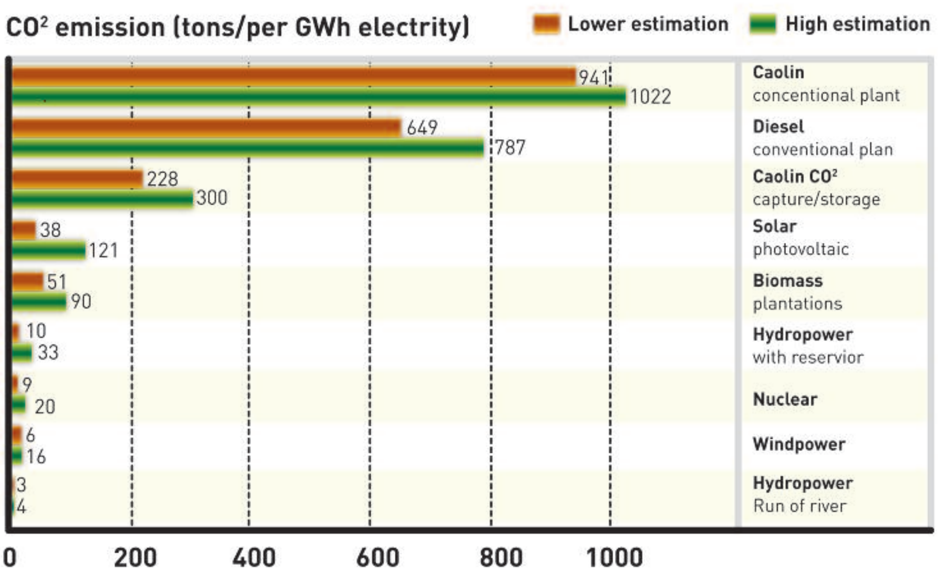


Figure 3: Greenhouse gas emission by type



3 Developing country is facing tough work to be forehead in adapting climate change

Not only the comprehensive advantages that the dam has, but also the tight relation it has with socio-economic development. This idea initiated from Berga (2008), the Former President of ICOLD. He thought the per capita storage capacity possessed by the country was closely related to the socioeconomic development. Follow this idea, we compare and analyze per capita storage capacity index and the human development index (HDI) about more than 50 countries. The result clearly indicates how dam/reservoir development is related to socioeconomic development **(Figure 4).**

HDI, the weighted average of the per capita GDP, health and education which reflect the quality of human development, is an overall index used to measure the level of socioeconomic development in the UN member countries. This index avoids the disadvantage that the per capita GDP is used as the sole index for measuring human development. HDI is a value ranging from 0 to 1, the closer it is to 1, the higher the human development level is. The countries with HDI higher than 0.9 are mostly developed countries, e.g. Australia (0.970), United States (0.956), UK (0.947), those with HDI in the range of 0.8 to 0.9 are relatively developed countries, e.g. Argentina (0.866), Russia (0.817), Brazil (0.813), while those with HDI below 0.5 are mostly less developed Asian and African countries, e.g. Rwanda (0.46), Burkina Faso (0.389) and Afghanistan (0.352).

As shown by the human development and dam/reservoir development data of over 50 countries in 2007(United Nation, 2009, Editorial Board, 2008), the countries with HDI above 0.9 had a per capita storage capacity of 3,184 m^3, those with HDI in the range of 0.8 to 0.9 had 2,948 m^3, those with HDI in the range from 0.7 to 0.8 had 541 m^3, those with HDI in the range of 0.6 to 0.7 had 208 m^3, and those with HDI in the range of 0.5 to 0.6 had 125 m^3 only **(Figure 4 and 5).** As seen from this fact, developed countries have a solid ground for securing water safety and coping with the changing water storage facilities, but developing countries still have a long way to go as limited by financial, technical and human resources. As for a given country, despite exceptions, e.g. Israel with HDI of 0.935 and a per capita storage capacity of 27 m^3, and Zambia with 0.481 and 1,072 m^3 respectively, the level of dam development in a country or region is directly proportional to the level of human development. It does coincide with result of United Nation (2006) that the global distribution of water infrastructure is inversely related to the global distribution of water insecurity risks.

Due to the varying extent effect, climate change represents different impacts and consequences to countries in different stages of development. As Blair (2008) pointed out in his report the change in climate is the same whether the emissions originate in New York or Shanghai. And of course, the most vulnerable to the impact of climate change live in the poorest area of the world. Likewise, the poor or undeveloped countries that have not caused, are not causing and will not cause significantly more greenhouse gas emissions are responsible for the cost of climate change. They are most easily subject to the effect of climate change and their adaptability is the most vulnerable. Countries in different stages of development have different objectives and priorities of water storage facilities, and also different concerns. For less developed countries, the consequence of global climate change is often catastrophic to the extent that, due to the inadequate storage capacity, subsequent extreme weather events occur frequently and bring about worse

Figure 4: Relationship between per capita storage capacity and HDI

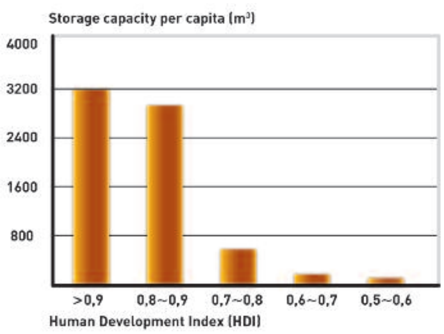
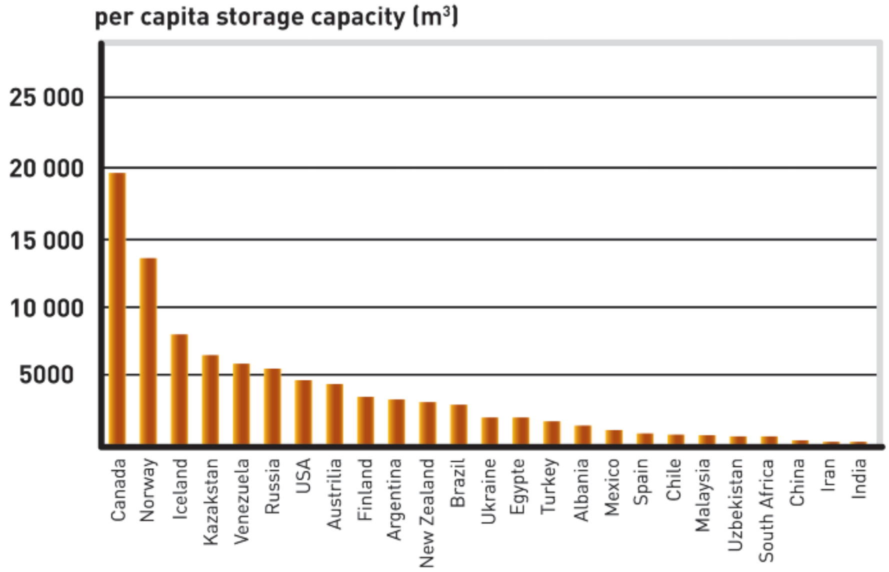


Figure 5: Per capita storage capacities by countries



disasters. The construction of water storage facilities is a crucial matter relating to their surviving and getting rid of poverty. Just as stated in the World Declaration on Hydropower Development (2008), a reliable electricity supply, taken for granted in many parts of the world, can be a life-saving commodity in the less developed African nations. In general, both energy and water needs are critical in these nations, so the obvious multiple benefits of hydro schemes (particularly when storage reservoirs are included) are of special significance in Africa. The effects of extreme climatic conditions (large-scale floods and regular droughts) that Africa suffers from can be vastly mitigated by dam/reservoir schemes. Naturally the supply of clean drinking water and irrigation water to enhance food security, are major additional benefits of hydro schemes. Thus the development of water and hydropower resources is of special significance for developing countries, especially the African countries, and one of the most urgent tasks to improve the livelihood.

4 Imperative transition and adjustment should be incorporated into dam field

Water storage infrastructure is a practice involving water security and energy security. In the past decade or so, however, water storage infrastructure development, especially the construction of large-scaled one was subject to incisive criticism from all walks of life, and the reply and response to such criticism remains insufficient. As the voice of striving for development and coping with climate change runs louder and louder in the world, the voice against dam construction is weakened to some extent. This change helps creating a good international opinion for the development of water and hydropower. Nevertheless, in the 21st century, the construction and operation of a dam and reservoir can no longer be considered as a purely scientific and technical matter. A wide range of other aspects are involved: economic, social and environmental. While it is clear today that water and energy schemes can be built to be safe, economic, and in harmony with the environment, mitigating environmental pacts remains a high priority for the profession, and must continue to be so. We must speed up water storage infrastructure construction in a sustainable way, and take joint actions to minimize the adverse impacts caused by the development, and base water development and management on new concepts, to make a greater progress in maintaining man harmonious with water and man harmonious with nature. In the light of this, the following four points are critical:

First of all, our attitude to nature should shift away from simply exploiting natural resources and adopting restoration measures, and should rather aim to protect the natural environment at an early stage of planning;

Second, decision making should not only be based on technical and economic feasibility, but also on social equity and environmental requirement;

Third, project operation and management should not only involve traditional techniques to ensure safety, but should also play a role in protecting the ecosystem. Examples are ensuring minimum flows, and appropriate operation of reservoirs;

Finally, benefit-sharing should be more inclusive, rather than just relating to a region or state. All stakeholders should be involved. One should remember that all members of society have the right to benefit from a project.

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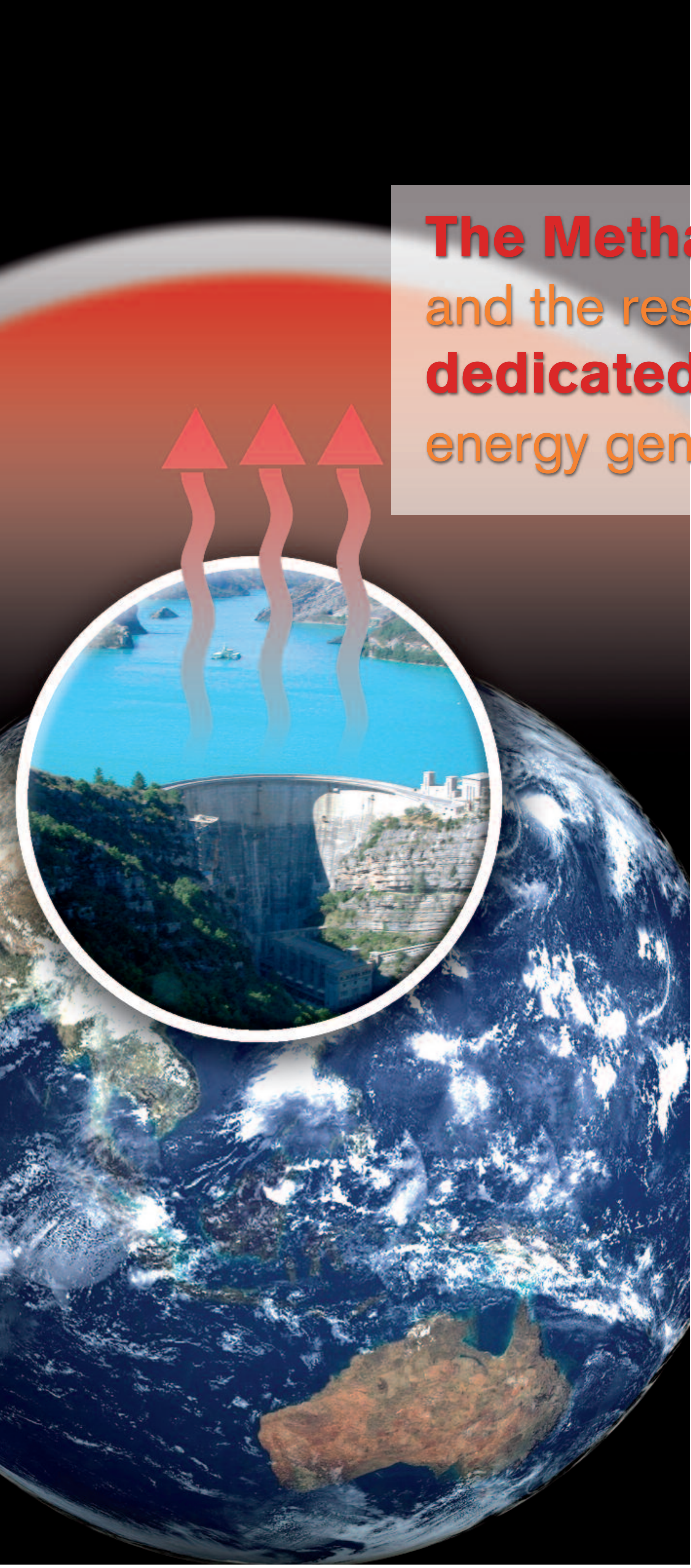


The Methane and the reservoirs dedicated to energy generation

Bernard Tardieu
Former ICOLD Vice-President

One of the arguments presented against dams is the potential emission of methane associated with the impounding and the operation of the reservoir. This argument has been recently put forward by anti dam activists to try to prevent hydropower to obtain registration as credit carbon project, which is necessary to obtain Certificate Emission Reduction (CER) on the carbon market. These CER triggered small or medium size Hydropower projects which are hard to finance without them Soit is important to settle as surely as possible what is the true participation of hydroelectric reservoirs in methane emissions.

The Methane is abundant in the atmosphere and is more effective than Carbon Dioxyde (CO^2) to absorb the infra red radiation emitted by our system planet-atmosphere, it is a more potent greenhouse gaz that CO^2.

A decrease in the global accumulation of atmospheric CH_4 has been measured in 1991-1992. Stabilization is measured since 2000 but it is not clear whether this trend will continue.

Five processes explain the methane emissions:

- Biogenic anaerobic process by bacteria
- Thermogenic formation in the sub-soil
- Incomplete combustion for example in forest fire or agricultural slash and burn
- Certain kind of plants in anaerobic condition
- Oceans though submarines volcanoes, sediments and geothermal sources

The main emissions of methane in TG/year are distributed as follow:

METHANE emission Tg/year

WETLAND	tropic	104	
	boreal and temperate	43	
RICE		31	
LANDFILL		60	
TOTAL BIOGENIC ANAEROBIC			238
RUMINANT ANIMALS		90	
TERMITS		23	
TOTAL ANIMALS Anaerobic			113
BIOMASS BURNING		38	
BIOFUEL		12	
TOTAL BIOMASS INCOMPLETE BURNING			50
COAL FOSSIL INDUSTRY			110
OCEAN			19
TOTAL			525

Other figures are proposed, almost in the same range.

The life duration of methane in atmosphere is short, almost 8 years and as a consequence, the present emission has limited impact of atmosphere in 2020 and a fortiori in 2050.

The reason of the short residence period in the atmosphere is the reaction of CH_4 with radical OH° whose life duration is extremely short (one second), which is abundant and variable in time and space. It gives CO then CO^2. Other reactions produce Ozone.

The transformation of the atmospheric methane by OH° is 90 %of the total methane sink: 450 Millions of tons per year.

The second methane sink is the soil. The methane is reabsorbed by soil. The methanotrope bacteria absorb from 0,08 to 1,3 g CH_4/m^2/year.The soil of the equatorial or tropical forest is a methane sink when it is dry: 0,08 to 0,8 g CH_4/m^2:year.The soil absorbs 15 to 45 Millions tons of methane per year.

As a consequence, the life duration of methane in atmosphere is variable and depends on climate, on available OH° and of the behavior of the soils.

It should be mentioned that the main stock of methane is in the sub-soil: The methane hydrates (clathrates) constitutes a huge stock of:
0,5 1012 tons in permafrost sub-soil
0,2 to 2,5 10 12 tons in oceanic sediments.

The emissions of Methane are difficult to measure and they are very variable in time and location. There is a large uncertainty in methane emission process and in methane presence in atmosphere. The following figure shows the uncertainties in annual average.

The dominating process of methane emission is the biogenic anaerobic fermentation. Among the whole anaerobic emission, the wet zones play the major role.

Wetlands are arbitrarily defined as water bodies with a depth of 1 metre or less: they are the interface between terrestrial and aquatic ecosystem. The wetlands include inundated or saturated areas with fresh, brackish or sea water.

The estimated wetland global area 5.3 10^6 Km^2 with a large uncertainty. For example the Amazon inundates 140 000 Km^2 every year during the rainy season.

The wetland covers almost 4% of emerged areas. They are protected by RAMSAR Convention (February 2 1971, entered into force December 21 1975). 1 610 000 Km^2 are declared of remarkable interest.

There are three wetland systems with distinct behaviour:

- The tropical/ subtropical or low latitude wet zones governed by large scale precipitation and flood cycle
- The boreal and
- The temperate or high latitude wet zones governed by seasonal interaction temperature/water cycle.

The areas of each of these systems are:

Tropical wetland area	2 .10^{12} m^2
Temperate	0.6 .10^{12} m^2
Boreal	2.7 .10^{12} m^2
Total	5.3 .10^{12} m^2
	or 5.3 .10^6 Km^2

The wetlands are classified as follow:

- Bog
- Fen
- Swamp
- Marsh
- Floodplain
- Shallow lakes (since 1989).

Artificial or natural lakes are never listed as methane emitter. Shallow lakes are not precisely defined. Frequently shallow they are lakes less than 5 metres (15 feet) deep.

The parameters controlling the methane emission are:

- Net primary production
- Temperature (maximal emission for the temperature range 30°-40°)
- Water table and hydrology
- Transport of organic sediments
- Vegetation type and morphology
- Chemical characteristics of organic material
- Salinity
- Soil nutrient status
- Topography Geomorphology

Episodic ebullition in very shallow water participates for 20 to 90% of the seasonal emission;

Ebullient fractions increase from open water to grass mats and flood forests;

Ebullition is strongly anticorrelated with water depth and triggered by wind and water currents.

Deep lakes are methane or carbon sinks because they partially transform organic material into deep sediments. As a result, the mass of organic material in lacustrian sediment is greater than the mass of the organic material in worldwide forests. A large part of the fossil carbon and fossil hydrocarbon have been generated by this way.

The majority of the methane emissions of the wet zones or shallow lakes are located in tropical zones. The boreal emission is not significant for open water.

The tropical emission is noticeable in various wet zones and shallow lakes in tropical zones.

The total emission is largely concentrated in the tropics 90 Tg/year for 2. 1012 m^2. The average emission of tropical wetlands is almost 45 g/m^2/year.

The total surface area of open lakes is estimated at 1.106 Km^2 in fresh water and 1.5 1012 Km^2 in brackish or salty water.

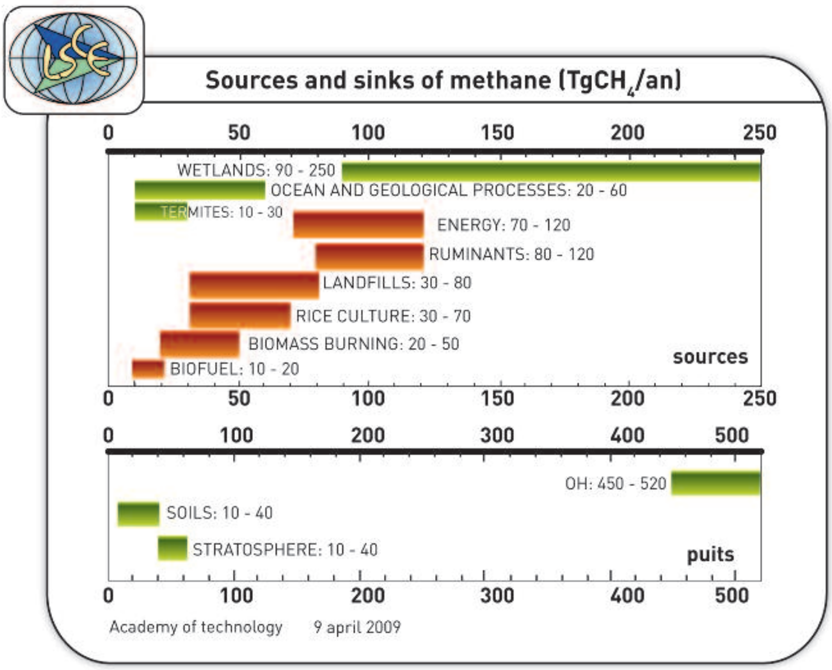
The average depth of natural lakes is extremely variable. For examples:

- Victoria lake 68 800 Km^2 av depth 20 m (maxi 83 m) volume 2750 Km^3
- Baikal lake 31 722 Km^2 av depth 744 m (maxi 1642 m) volume 23 615 Km^3
- Chad lake 1 350 Km^2 in 2000, 26 000 Km^2 in 1950, 300 000 Km^2 in 1000 BC, today av depth 1,5 m, (maxi 10,5 m), the water disappears completely from time to time during the dry season and is totally transformed into a wet zone.

The artificial lakes are listed in the International Commission on large dams Register:

273 000 Km^2 among them almost 25% (ICOLD sources) are dedicated to energy generation 70 000 Km^2 (7% of natural fresh water lakes).

The average depth of artificial lakes is extremely variable. Assuming that the



average maximum depth for the lakes dedicated to energy generation is almost 100 meters and that the shallow part of the lake is the part of the lake where the depth is less than 5 metres (5%), we could roughly say that dS/S=2 dH/H, and the order of magnitude of the area of the shallow part of the artificial lakes is 10% of the total area.

So the shallow portion of the artificial lakes dedicated to energy generation is almost 10% of 70 000 Km^2 which mean 7000 Km^2, which is negligible compare to the variation of the areas of the natural wet zones.

The next template summarizes the relative areas of the different bodies:

The shallow portion of artificial lakes is extremely low compared to the total surface area of the wet zones (5.3 10^6 Km^2), almost 0,1%.

Only the shallow portion of the lakes may emit CH_4. The deep portion of the lakes is a carbon sink as explained here above. The area of the shallow portion of the artificial lakes dedicated to energy generation is negligible compared to the size of the area of the natural wet zones, and also negligible compare to the seasonal and interannual variation of there areas. So, their methane emission is extremely low compare to the methane emission of the natural wetlands and to their variations in time and space.

The methane emissions of artificial lakes should be compared with natural methane emission without artificial lake. This is the net emission which is the difference between the emission fro the biotope with the artificial lake and the emission from the biotope without the lake.

The net emission from tropical artificial lakes depends on the morphology of the lake (bathymetry)-surface below 1 metre (and 5 metres for instance) and average depth-, the temperature, the wind, the water currents, the organic content, and the residence duration of the water in the lake.

The net emission of a reservoir may be positive or negative

It remains two points highly depending on location of the reservoir:

- The initial period just after impounding,
- The emission in the turbines themselves due to the fast drop in the water pressure in the turbine.

The emission of methane during the first after impounding is proportional to the quantity of immerged biomass, to the temperature of the water and to the residence time of the water in the reservoir. Even in tropical zones, the diffusive fluxes disappeared after 3 years due to the development of colonies of methanotrop bacteria which oxidize the methane. Emission by bubbling could continue, progressively decreasing.

The methane emissions could be generated from deep water by the water released downstream where the released water is reoxidized.

They could be also be generated in the turbines themselves due to the fast drop in the water pressure in the turbine. This methane may be collected in the draft tube and used locally as biogas.

Conclusion

Methane emission by artificial lakes is not a sustainable argument against hydroelectricity generation.

Wetlands	+- 5 300 000 Km^2
Tropical Wetlands	2 000 000 Km^2
Open lakes (fresh water)	1 000 000 Km^2
Tropical lakes (artificial and natural)	256 000 Km^2
Artificial lakes (any latitudes)	273 000 Km^2
Id dedicated to energy generation	70 000 Km^2
Shallow portion (<5m) of artificial lakes dedicated to energy generation	7 000 Km^2

Recognizing Milestone achievements in rock fill dam engineering

Jia Jinsheng

It was recently decided to identify and recognize “international milestone” rockfill dam projects. Typical features of international milestone rockfill dams were defined during discussions and presentations at the First International Symposium on rockfill dams in Oct. 2009. The main technical achievements of 13 projects including Shuibuya CFRD, Xiaolangdi rockfill dam with inclined core and Zipingpu CFRD in China are summarized here.

1 International milestone Rockfill dams and their typical features

Looking to the coming years of the 21st century, which will be characterized by further development of urbanization and modernization, as well as increasing concerns about the impacts of climate change, the role of dams and reservoirs is fundamental. These structures support economic and social development based on flood control, water supply and energy and food security.

It is necessary to continue to develop new technology, paying more attention to environmental protection, so as to make a greater contribution to the benefit of mankind. In recent years, rock-fill dam projects, a more popular and competitive dam type, have gained vigorous development with advantages in economy and security. The Zipingpu Concrete Faced Rock-fill Dam (156m), 17 km from the epicenter of the M 8 Wenchuan Earthquake on May 12, 2008 survived the event. Nurek rockfill dam with clay core in Tajikistan, at 300m, is the highest dam in the world and has operated well since 1980. Shuibuya CFRD in China, at 233m, is the highest CFRD and has performed well since impounding in Oct., 2006. These dams have demonstrated the good performance of rockfill dam for both normal and exceptional loading cases, such as during earthquake events, and they are very important for further development of Rockfill dams.

To recognize major achievements of rock-fill dam technology and define milestones in this field, with the support of various National Committee of ICOLD, Chinese National Committee on Large Dams (CHINCOLD) and Brazilian Committee on Dams (CBDB) proposed the presentation of Milestone Award for International rock-fill dams, during the First International Symposium on Rockfill Dams in Chengdu, China (October 18~20, 2009).

Nomination were put forward by international experts in the field of dam engineering throughout the world. In total, 36 rockfill dams candidates were recommended by various experts. These projects are located in Australia, Austria, Belgium,Brazil, Canada, Chile, China, France, Germany, Greek, Iceland, India, Italy, Japan, Mexico, Norway, Philippines, Russia, South Africa, Spain, Switzerland, Tajikistan, USA, and etc. Hon. President Berga of Spain, C.B. Viotti of Brazil, C.V.J. Varma of India, H. Hoeg of Norway, W. Pircher of Austria have contributed a lot on this issue. The event also received favorable responses from world famous experts, for example, the vice presidents of ICOLD, Mr. Matsumoto of Japan, Mr. Ekpo of Nigeria, and chairmen of ICOLD technical committees, M. Wieland, A. Zielinski, R. Charlwood and others.

Their support and participation play an important role in recommending and determining the milestone projects. After recommendations, evaluations and re-evaluation, the milestone projects of rock-fill dam have been finalized. The selected milestone projects have common features as:

(2) Santa Juana Dam in Chile

(3) Shuibuya Dam in China

(1) Technical innovation in design, construction, operation or other aspects;
(2) Good performance after completion;
(3) Much attention has been paid during construction and operation stages to environmental protection and social aspects;
(4) Attention paid to raising awareness of technical achievements and advanced experience.

These milestone projects are representatives of the main achievement in rockfill dam construction until now, and this is also the basis for the construction of new dams. The experiences of these international milestone projects can be used as a valuable reference for future development of rockfill dams.

2 International Milestone Rockfill Dams

2.1 CFRD Projects

(1) Foz do Areia Dam in Brazil

Foz do Areia Dam in Brazil was the highest dam (160 m) and the largest in rockfill volume (14 000 000 m^3) by the time of construction. It was also the first CFRD with a big reservoir, about 6 billion m^3 of total volume, without outlets provision for emptying the reservoir.

Techniques of compacting rockfill and designing the joints were improved and had a great step forward. Productions of rockfill placing were higher than 500 000 m^3/month during two consecutive years.

Treatment of the downstream slope was executed in such a way as to ensure a face in accordance with the project's theoretical requirements, with minimal deviations. This gives an exceptional pleasing appearance.

The reservoir filling started in 1980 and has operated in good performance. The maximum leakage discharge recorded reached 236 l/s after reservoir filling and decreased to a steady rate of 80 l/s later on. Both the percolation values and their evolution confirm the excellent performance of the waterstop system. The good performance of Foz do Areia Dam enhanced the confidence in CFRD and was greatly responsible for its international acceptance.The project is owned by Companhia Paranaense de Energia COPEL.

(2) Santa Juana Dam in Chile

Santa Juana Dam with the height of 103 m in Chile was constructed with alluvial materials on the sandy gravel layer and first adopted an integrated anti-seepage system among the dams higher than 100 m. In the system, a linkage plate was used to connect the underground concrete wall and the plinth. The good anti-seepage performance of the project proved the effectiveness of the integrated anti-seepage system, which set a good example for the following dam construction. Santa Juana Dam was completed in Dec. 1995 and has been in good performance up to now.
The project is owned by Chile Public Works Ministry.

(3) Shuibuya Dam in China

Shuibuya CFRD is the highest one of its type among those built or under construction in the world with a maximum height of 233 m. The rockfill volume of the dam is 15.7 million m^3.
The design and construction of the dam have applied the state of the art of modern CFRD and it also represents the highest level of present CFRD construction. The technical innovation and progress include: optimized rockfill construction steps, dynamic compaction of riverbed foundation, new type waterstop structure and materials, permanent horizontal joint, treatment of extrude curb, GPS recorded compaction tracks, fast check of compaction density, advanced instrumentation, etc. Dam construction was completed in 2008. After reservoir impoundment, the dam's operation is normal and presents good performance.
The project is owned by Hubei Qingjiang Hydroelectric Development Co., Ltd.

(4) Kárahnjúkar Dam in Iceland

Kárahnjúkar Dam is a 198 m high CFRD dam, the highest of this type in Europe and one of the highest CFRD dams in the world. The dam is built at the upstream end of the Hafrahvammar canyon with up to 90 m high vertical sidewalls within the dam area. The central portion of the Dam was designed to support high stresses and avoid spalling of the concrete face slab. Elastic joints in the slab were introduced at the first time. Several other new design features were also introduced. The diversion works were even more smartly designed, which deserves to be published. The fill volume of the dam is about 9 million m^3. In spite of the very slim

crest and high FS-Water level, the dam behaves excellently after reservoir filling.
The project is owned by Landsvirkjun, the National Power Company in Iceland.

(5) El Cajón Dam in Mexico

El Cajon Dam, located at a distance of 250 km to the Northwest of Guadalajara City, the second in importance of Mexico, is the highest CFRD built in México with maximum dam height of 188 m and crest length of 550 m. Rockfill volume was about 10.3 million m^3. The covered area by the concrete face slab reached 107 000 m^2. The design of the concrete face was carried out using fillers between joints to minimize spalling for the first time. Performance after reservoir filling is excellent.
Based on instrumental data and periodic inspections, no evidence of excessive movement occurred in the joints and slabs of the concrete face. The main deformations are located in the central zone of the concrete face, without compromising the integrity of the slabs and joints. The highest leakage recorded was 247 l/s during first impounding in January, 2007. Currently, the flow is approximately 40 l/s.
The project is owned by Comisión Federal de Electricidad.

2.2 Earth Core Rockfill Dam Projects

(1) Irape Dam in Brazil

Irape Dam is a rockfill dam with clay and gravel core. The maximum dam height is 208 m and the total volume is 10.3 million m^3. It is located in a place of very rugged topography, the type canyon with difficulties constructive associated with topographical aspects and local geochemical conditions. The tight 40-month construction schedule and the strict economic limitations of the job, made obligatory the use of the excavated materials in the dam embankment, including large amounts of weathered sulfide-rich rocks based on study results. The dam core was built with sandy-clay with the precaution to use a mixture of gravel and clay in the deep channels, to get higher rigidity modulus in this zone. A layer of more plastic, self-healing soil was placed along the clay/rock contact on the valley walls to help the redistribution of stresses. Natural sand was used in the fine filters, and crushed rock in the coarse filters and transitions. Consequently, with the exception of protection and covering rockfills, which were made of non-sulfide or sulfide-poor rocks, all the other embankment materials came from the required excavations. In addition, to reduce the amount of rain water seeping into the downstream zone, and prevent the production of acid effluents, a sort of "umbrella" was provided in the downstream slope, made up of 6 m wide sheets of HDPE (high density polyethylene).
The project is owned by Cemig Geração e Transmissão S.A..

(2) Xiaolangdi Dam in China

Xiaolangdi inclined core rockfill dam is the highest earth core rockfill dam constructed in China, with the dam height of 160 m. The project is located at the main stream of Yellow River and it has multiple functions. As its unique position in regulating Yellow River, specific high sediment flow, complex geological conditions, rigor requirements of reservoir operation and the huge engineering scale, it is considered as the most complicated and challenging project in the world. The construction of the project has applied a series of new technologies, which include: the construction of concrete diaphragm wall in deep foundation (81.9 m), prevent sediment block at intakes of high sediment flow, large span underground structure excavation, stabilization of the intake and outlet of the left bank large scale tunnels and caverns, etc. Incorporation of new technologies and materials culminated in completion ahead of schedule, excellent quality and cost saving. After being put into operation, Xiaolangdi project has played an important role of restoring the ecological function of the river channel. Up to now, the project has been in stable and normal operation, resulting in remarkable social, ecological and economic benefits.
The project is owned by Xiaolangdi Dam Project Construction and Management Bureau.

(3) Tehri Dam in India

Tehri Dam with maximum height of 260.5 m is one of the highest rockfill dams in the world. Total quantity of various fill materials placed in the dam is about 27.98 million m^3, including the quantity of fill in coffer dam which is a part of the main dam.
A number of innovations have been made at Tehri project in respect of the slope stabilization for the reason that the area had very soft quartzite rocks and were found to

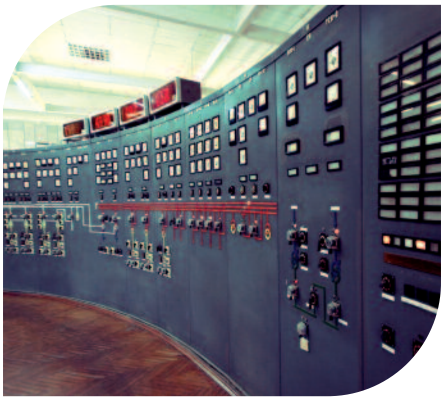
(5) El Cajón Dam in Mexico

be unstable. These measures included deep pile shafts of 3 m diameter, long cable anchors of 30-40 m length and bundled anchors consisting of 7 strands. An abrasion resistant coating called 'Polyurea Coating' was applied on the lining of low-level outlet of the project. Further, use of high performance concrete of M-60 grade consisting of silica fume was extensively made at various wearing surfaces exposed to the velocity of more than 25 m/s.
The project was put to operation in Oct. 2005. The dam has not yet shown any sign of abnormal pore pressure build up inside the dam body. The seepage through the dam body and abutments is well within the limits even after 4 years of operation. The settlement in the dam body has also been observed to be much below the prescribed limits.
The project is owned by Tehri Hydro Development Corporation Ltd., India.


(3) Tehri Dam in India

(4) Chicoasén Dam in Mexico

Chicoasén Dam (H= 261 m) in Mexico was constructed in extremely harsh environments, including complex topography and geology. Its design in early 1970's and construction between 1974 and 1980 were achieved satisfactorily and it has been reference for the design and construction of many large dams worldwide. The project first successfully adopted highly plastic clay at the contact zone between corewall and abutment, which gave a good instruction for the following similar projects in the world. Another specific feature associated with this project is that the flood releasing is completely accomplished by the three tunnels with no spillways. The performance of the dam has been adequate up to date.
The project is owned by Comisión Federal de Electricidad


(5) Nurek Dam in Tajikistan

(5) Nurek Dam in Tajikistan

The Nurek Dam is a large earth fill dam located on the Vakhsh River in the central Asian nation of Tajikistan. The Nurek Dam was constructed by the Soviet Union between the years of 1961 and 1980. At 300 m (984 ft) it is currently the tallest dam in the world. It is uniquely constructed, with a central core of cement forming an impermeable barrier within a 300-meter-high rock and earth fill construction. Length of the dam top is 714 m, width at foundation level is 1420 m and at the dam top is 20 m. The volume of the mound is 54 million m³. Antiseismic belts were provided at the upper dam shell due to increase dam seismicity starting from 855 m and for the full slope length and width that accept and smoothly disburse shear stress that develops in the dam during earthquake. Reinforce concrete elements and flexible steel connections limit and adjust the operation of antiseismic belt. Rock fill between belt blocks provide solid drain lay that ensures dynamic pore pressure decrease in the material of the upper dam shell.
Concrete saddle locates under dam core and appears to be core extension. Concrete saddle at the upper side is built up as V-shaped unit for the good contact with the core and to protect concrete against piping under high water heads (up to 30 atmospheres). Concrete surface is covered with epoxy waterproof by 4 mm thickness and reinforced by two layers of glass fabric. Concrete saddle divided by two expansion joints into three sections.
Analyses of monitoring data showed that it is in satisfied condition for the last 35 years operation. Due to that the experience of Nurek Dam can be applied for the other high dams' construction in the areas of high seismicity where the earth fill dam appeals to be more reliable rather than CFRDs.
The project is owned by Nurek Hydropower Plant, Ministry of Energy and Industry of the Republic of Tajikistan,OJSHC "BARKI TOJIK"

2.3 Asphalt Concrete Core (Asphalt Concrete Face) Rockfill Dam Projects

(1) Finstertal Dam in Austria

The Finstertal Dam in Austria is a 150 m high rockfill dam with an asphaltic concrete core of 96 m, located at an altitude of 2325 m above sea-level. The special topography of the dam site made it sit above the deepest foundation of the downstream shoulder. The dam was built in the years of 1977 to 1980. Difficult climatic conditions, at an altitude of over 2300 m, meant that construction work was only possible on around 100 days in the year. It is an early representative in the development of this type of dam, featuring an inclined thin core (surface of 37 000 m², thickness decreasing with height from 70 to 50 cm); a generous monitoring system with several innovations, justified by the pioneering role of this dam;

it covers the deformation behaviour of the entire dam body with particular focus on the core and the adjacent central zone, and is complemented by precise sectional seepage control.

The Finstertal Dam has operated without a hitch over 28 years. Surface deformations, with maximum settlements of 38 cm and maximum horizontal deflections of 19 cm, are of a magnitude that would hardly have been considered possible with earlier rockfill dams of such a height. Total seepage water losses through the 37 000 m^2 core membrane surface were only 9 l/s on first filling, and declined to 1.5 l/s by the end of 2008.The project is owned by Tiroler Wasserkraft AG (TIWAG), Tyrolean Hydro-Electric Power Company

(1) Finstertal Dam in Austria

(2) Yashio Dam in Japan

Yashio Dam completed in 1992 is a 90.5 m high asphalt faced rockfill dam. It is one of the highest dams among its type. The covered area by the asphalt concrete face slab reached 370 000 m^2.

The facing of this dam was designed as a double-deck structure having an impermeable layer in each upper and lower portion. An intermediate drainage layer is placed to detect clearly the water leakage. There are a total of seven layers, and the thickness of the facing is 37 cm. The surface of the facing is covered with thin layer of asphalt mastic so as to protect it from damage. The maximum length of the facing of the Yashio Dam is approximately 200 meters. A special portal winch with an extra-long reach was developed specifically for this paving job to allow the entire 200-meter length of slope to be paved in one stage. To improve antiseismic performance of the facing, 8.5% asphalt and 0.8% fibre were added in asphalt concrete.

The dam has been in good performance after impounding.

The project is owned by Tokyo Electric Power Co., Inc. (TEPCO)

2.4 Special Award: Zipingpu Dam in China

156 m high Zipingpu Dam was completed and put into operation in 2006. The Project with a storage capacity of 1.112 billion m^3 is mainly for flood control, water supply and power generation. The Wenchuan Strong Earthquake on May 12th, 2008 with a magnitude of 8 in Richter scales shocked the whole world. Zipingpu project at only 17 km away from the epicenter suffered great damages. However, the dam had withstood the serious test of strong earthquake, becoming the first higher than 100 m CFRD experiencing Magnitude-8 strong earthquake and maintaining safety in the world.

After the earthquake, a series of emergency measures were adopted to ensure the safe operation of the project. About 10 minutes after the earthquake, idling units have been opened to provide emergency water supply to the lower reaches. The bottom outlets and sediment flushing holes were emergently repaired and began to release water in 28 hours after the earthquake to decrease reservoir water level to ensure the safety of the dam. The power station was repaired and started generation in 5 days to supply electricity to the earthquake disastrous areas.

Zipingpu

The safety of Zipingpu Dam assured the confidence of more than 10 million people living downstream and guaranteed the water and electricity supply during the post-disaster period. A rescue transportation route on the reservoir has been formed, which had played an irreplaceable role in timely shipping rescue team and materials into and evacuating people from the earthquake-stricken areas.

The survival of Zipingpu Dam means the design, the construction and the maintenance at all levels were correctly organized. The lessons and experience from this project will provide an excellent reference for dam engineers in seismic areas of the world.The project is owned by Sichuan Zipingpu Development Co., Ltd.

3 Conclusion

Reviewing the past and looking ahead to the future, multipurpose dam projects have played, and will continue to play, very important role in the socio-economic development, especially considering global climate change concerns and urbanization.

Recognizing International Milestone Projects is an effective way to focus on, and raise awareness about, achievements in worldwide dam technology. This also plays a role in increasing technical exchanges and advancing of knowledge and the state-of-the-art of engineering practice.

79th ICOLD annual Meeting Lucerne 2011 May 29 - June 3

Lucerne is the historical birthplace of the Swiss Confederation, which was founded here more than seven hundred years ago. Switzerland was in 1928 a founding member of ICOLD: being without fossil fuel resources the country has relied on hydroelectricity for its industrial development. Still today, almost 60% of the electricity consumed in the country is produced by hydropower and many schemes are being built or planned: pumping-storage projects, heightening of old dams and building of new ones.
The symposium on June 1st will be devoted to the theme: “Dams and reservoirs under changing challenge”. Three technical visits are proposed to the delegates and the accompanying persons on June 2nd.

Come to Lucerne !
Visit our website to prepare your meeting: http://www.icold2011.ch/en

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