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The Cemented Material Dam: A New, Environmentally Friendly Type of Dam

Jinsheng Jia [a,*], Michel Lino [b], Feng Jin [c], Cuiying Zheng [a]

[a] China Institute of Water Resources and Hydropower Research, Beijing 100038, China
[b] ISL Ingénierie, Saint-Jean-de-Luz 64500, France
[c] Tsinghua University, Beijing 100084, China

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ABSTRACT

The first author proposed the concept of the cemented material dam (CMD) in 2009. This concept was aimed at building an environmentally friendly dam in a safer and more economical way for both the dam and the area downstream. The concept covers the cemented sand, gravel, and rock dam (CSGRD), the rockfill concrete (RFC) dam (or the cemented rockfill dam, CRD), and the cemented soil dam (CSD). This paper summarizes the concept and principles of the CMD based on studies and practices in projects around the world. It also introduces new developments in the CSGRD, CRD, and CSD.

1. The concept of the cemented material dam

Reservoirs are important infrastructures with functions such as flood control, irrigation, power generation, and water supply. Dams were being built to store water before 1000 AD. Early dams were constructed out of local materials, but most of these dams failed and brought unmitigated disaster to the people living downstream. The development of dam construction theories laid a foundation for dam safety, allowing higher and higher dams to be built. Dam safety has been improved significantly, especially since the 1990s. However, dam engineers continue to seek new technologies to build dams in a safer, more economical, and more environmentally friendly way.

The concrete gravity dam has a high degree of safety [1]. A serious secondary disaster will not occur in this type of dam, even if a dam block breaks or if overtopping occurs due to an earthquake or to unexpected flood events (e.g., Shigang Dam [2] in Taiwan had no serious secondary disaster, even when it was broken during an earthquake). This characteristic makes the concrete gravity dam stand out from other dam types. However, concrete gravity dams are much more costly, so that there is less than 5% of these dams in dams higher than 15 m. An idea for a new type of dam—partway between a concrete dam and an earth-rockfill dam—was first proposed in 1941 by an American engineer, Homer M. Hadley, but the idea was not taken into practice. The symmetric gravity dam (optimal gravity dam) was proposed by Jérôme Raphaël in 1970 [3], but no dams were constructed based on this concept. In 1992, Pierre Londe and Michel Lino [4] proposed the concept of the symmetric concrete-faced hardfill dam; this concept was reported in the International Commission on Large Dams (ICOLD) Bulletin No. 117 under the title "The gravity dam: a dam for the future" [5]. Marathia Dam, completed in 1993 (Fig. 1), was the first hardfill dam. From that point on, several dams of this type were built in Greece, the Dominican Republic, Peru, Turkey (Fig. 2), the Philippines, and Algeria [6–8].

Based on the concept of the symmetric hardfill dam, Japan proposed the trapezoid cemented sand and gravel (CSG) dam, with new progress in material preparation, mix proportion de-

* Corresponding author.
E-mail address: jiajsh@iwhr.com

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sign, and the utilization of a "trapezoid" section [9]. The cofferdams of Nagashima, Tokuyama, and Takizawa, some slope treatment projects, and some sediment control dams were built using this method, as were Okukubi Dam (H = 39 m) and Tobetsu Dam (H = 52 m) (Fig. 3), which were completed in 2012 [10,11].

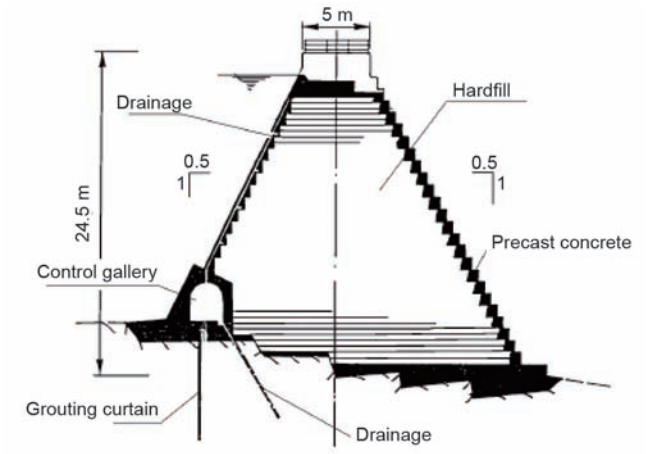

Fig. 1. Marathia Dam in Greece.

Based on the concept and practice of the hardfill dam and the trapezoid CSG dam, Jia et al. [12] put forward the concept of the cemented sand, gravel, and rock dam (CSGR dam, or CSGRD) in 2004. The Jiemian and Hongkou CSGR cofferdams were completed in 2004 and 2005, respectively. The CSGRD further broadens the scope of local material utilization, with the maximum particle diameter increased from 80 mm to 150 mm, and with similar way of mixing sand, gravel, and excavated rock as aggregates. It can be built with artificial sand and rock when no sand and gravel is available for a steep river. The dam structure can be designed according to the material properties of the CSGR in order to make full use of local materials. For a CSGRD, a "symmetric" or "trapezoid" structure is not always necessary based on research and project practice; especially for some low dams, a traditional gravity dam section can be used when the dam stress level is very low. At present, the Shunjiangyan CSGRD with a gravity dam section (H = 11.6 m) has been built, and the Shoukoubu CSGRD with a symmetrical section (H = 61.4 m) is under construction (Fig. 4). Several CSGRDs in China that use artificial sand and rock material are under design.

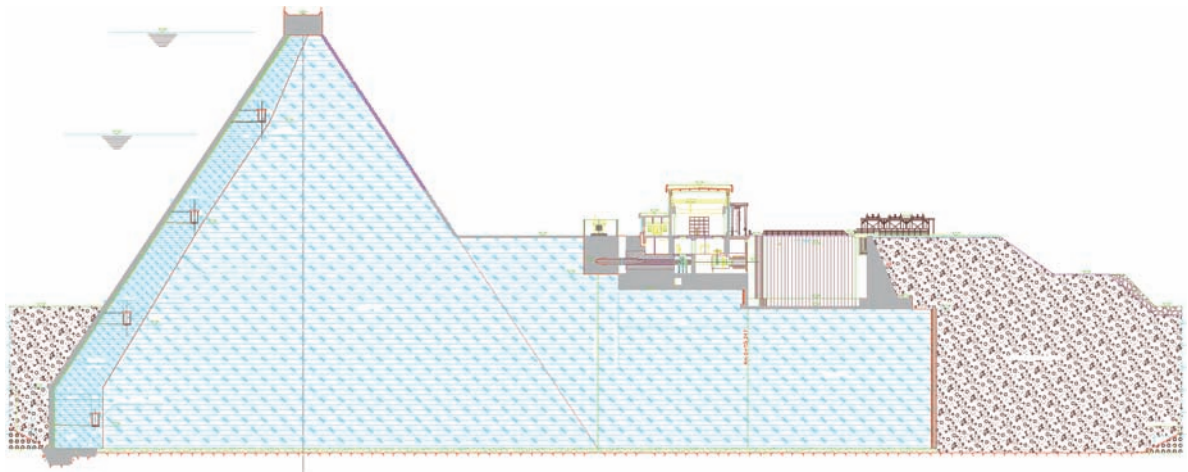

Fig. 2. Cindere Dam in Turkey (H = 107 m).

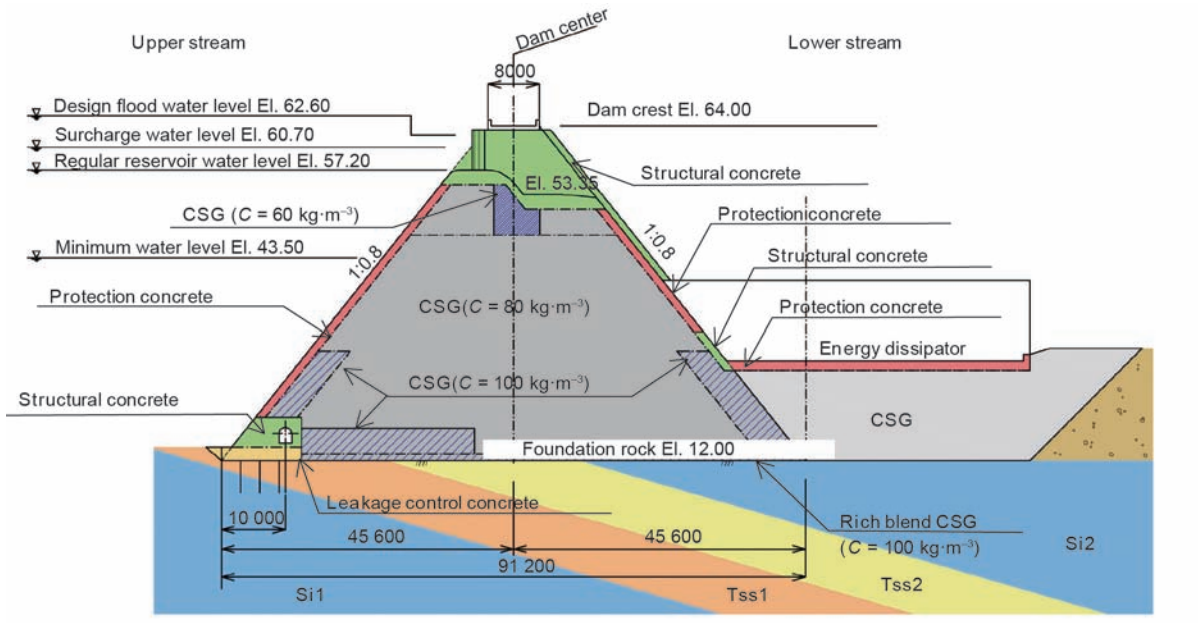

Fig. 3. Tobetsu Dam in Japan (H = 52 m).