Dams Made of Steel !!

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Many may feel strange to know that dams were constructed across the rivers with steel in place of masonry / concrete material. At the end of nineteenth century, engineers felt that dams constructed with steel have following advantages over other dam building material.

1. Perfect water tight joints can be achieved with steel,
2. Easier accessibility for inspection, maintenance and repairs,
3. Faster construction,
4. Greater ability to handle thermal expansion and contraction,
5. Flexibility to uneven settling and
6. Economical in cost

The water pressure acting perpendicular to the inclined steel dam surface provides the thrust against the uplift forces acting on the dam structure. The lateral thrust of impounded water is taken care by the structural steel of the dam. These steel dams are called fixed steel dams or structural steel dams. The fixed steel dams are different from giant movable / rotating steel gates provided on the modern dams for passing the floodwater. Three fixed steel dams (see Table 1) were built between 1895 and 1910 in USA with following details.

Ashfork Dam: Built in 1898, this dam is located in an inaccessible area in the arid North Arizona desert. Taking advantage of the igneous rock presence at the dam site, the steel bents and the toe of the dam are anchored directly to the bedrock although some concrete is used as sealant. This dam is a buttress dam with 45º inclined upstream face with overflow provision. This dam is still in active service for more than 100 years.

Table 1: Details of Fixed Steel Dams

Dam name	Steel portion length (ft)	Maximum height (ft)	Angle (from horizontal)	Steel plate thickness (inches)	Type
Ashfork	184	46	45º	3/8	Over flow
Redridge	464	74	55º	3/8	Non over flow
Hauser Lake	630	81	35º	?	Over flow

Redridge Dam: Built in 1901, this dam is located on the Lake Superior River in Upper Peninsula of Michigan. Steel is selected as dam construction material due to non-availability of stone, topsoil, etc. The maximum height of the dam is 74'. Since the bedrock at the site is weak sand stone, the dam is designed as a hybrid of gravity and structural steel dam. A large concrete base is made over the weak sand stone bedrock as substructure for the steel super structure. The steel dam is provided with higher inclination of 55º since the weight of the dam substructure is also contributing to the dam stability.

Though the dam is not designed as an overflow structure, in the year 1941 this dam endured the overtopping and the battering that has taken place when an upstream dam collapsed due to heavy rains and excessive snow melt. This dam was decommissioned in 1979 by creating large openings in the steel plates just above its concrete foundation. This dam structure is still extant as a souvenir of fixed steel dams for the structural steel engineers.

Hauser Lake Dam: Built in 1907, this dam steel work is rested on longitudinal footings placed in a bed of water bearing gravel because the bed rock is deep at 40' to 60' below the water level. To prevent undermining of footings by water seepage, steel sheet piling is driven up to 35' to 40' along the length of the dam. This seepage preventing technique (refer: www.sia-web.org/iajournal/IAVol15/Vol15no1pages1to20.pdf) is followed in all types of dams whenever required.

In 1908 after a year of service, the Hauser Lake dam failed due to excessive seepage from the sheet piling which washed off the gravel from beneath the dam foundation footings. This dam failed due to inadequate foundation design but not of deficiency in steel structure. Conventional dam replaced the dam later.

Like Hauser Lake steel dam, all other type dams failed occasionally for various reasons in the history of dam construction. But these dam failures have not precipitated the abrupt end to further construction of fixed steel dams. The main reason for not taking up new steel dams is declining cost advantage of steel with respect to cement. When these steel dams were built between 1890 and 1914, the cement prices were high compared to steel. After 1914, the steel prices galloped by nearly two times during first world war which made cement as economical material for dam construction.

Utility of steel dams: The present day steel manufacturing technology is far superior in terms of strength, durability and workability, which can make steel as prime contender as dam building material. The following factors would also weigh in favor of steel dams.

1. Fixed steel dams take lesser construction time to build compared to masonry dams. Complete structural steel portion could be built in one monsoon year. Early commissioning of a project reduces construction cost by saving expenditure on interest during construction and profits starts accruing earlier by generating sales.

2. Transportation cost of bulk items such as cement, gravel and sand reduces drastically due to use of steel. Steel dams are more economical where dams are located in hilly and remote area due to higher cost of bulk material transportation.

3. There is no need of large capacity river diversion for constructing the steel dam. The river diversion / cofferdam may be required during the construction of foundation / substructure of the steel dam only. Though the steel structure of the steel dam is completed earlier, the cover plates are fixed to the structure when reservoir is required for filling. The flood of the river is passed over the

substructure of the steel dam. The number of available workable days in a year is more for fixed steel dam compared to masonry dam

4. Most of the land acquisition can be done in phases after construction of the dam. Thus major land acquisition cost is borne out of the project revenues. This aspect reduces the capital investment on the project. Non-settlement of legal issues would not hinder the project construction activity.

5. It is possible to increase the dam height in future by strengthening the steel structure and additional stiffening of the steel plates. The maintenance and repair works of the fixed steel dam is also easier. The contraction or expansion of steel dams are better taken care unlike in masonry / concrete dams. This is achieved by providing curvature to steel plates.

6. Generally flood water is passed by providing flood conduits with gates / valves located at the base level of the dam when the level difference between maximum reservoir level and the maximum tail water level is substantial. Otherwise overflow spill way is provided for passing the design floodwater. Since the flood passing provision is made at riverbed level, the silt accumulation is reduced drastically and the useful life of the dam increases. This factor is very important in run off river hydroelectric projects in Himalayan region where the silt load is excessive.

7. Whenever a powerhouse or pumping station is planned at the toe of the dam, the powerhouse could be located on the base of the dam itself. Incase road or rail bridge is required, it can be built with separate structure located on the dam base itself.

Steel dam is generally economical in case the steel prices are less than seven times the cost of cement (rupees per ton of cement). The steel dams have all the features, which would take care of the construction difficulties associated with masonry or concrete dams. Whenever a dam is to be built at a particular location, it would be prudent to check techno economics of fixed steel dam considering the CIF prices of steel and cement at site.

References:

www.sia-web.org/iajournal/IAVol15/Vol15no1pages1to20.pdf - A Narrow Window of Opportunity: The Rise and Fall of the Fixed Steel Dams by Terry S. Reynolds.

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