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Effect of Nano Materials on increasing the Capacity of Spillways

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ABSTRACT: Due to modernization there is a drastic change in the atmospheric climate which leads to the natural disasters. Flood is one of the major natural disaster among that. Floods cause heavy loss to life and property. Due to urbanization, pervious soil is converted in impervious layers. Hence the runoff has become larger due to land use land cover changes. In order to avoid inundation on the upstream side of the dams due to the increase in runoff, the capacity of the spillways should be increased. An attempt has been made to use nano material for the increasing the capacity of spillways. Nano materials such as nano cement and nano flyash when used in cement mortar make the surface smooth. As a result friction can be reduced. This paper intends to study the effects of nano materials in increasing the capacity of spillways. In this study, 30% of cement in the cement mortar was replaced with nano cement and 40% of cement in cement mortar was replaced with nano flyash and the spillways were plastered with 1:3 cement mortar, cement mortar with 30% of nano cement and cement mortar with 40% of nano fly ash. The discharges over the spillways were found. The results reveal that the capacity of spillways can be increased by plastering the spillway with mortar containing nano materials. The results also indicate that the performance of spillway with flyash is better than that of the spillway with nano cement. This method of enhancing the capacity of the spillways is an economical and a simple method which will augment the capacity of spillway thus reduce the possibility of dams being overtopped during floods.

Keywords: Discharge, Flyash, Nano materials, Ogee spillway, Ordinary Portland Cement.

I. INTRODUCTION

Spillways are the hydraulic structures used to discharge the flood water from upstream to downstream side of reservoirs. The common types of spillway are drop spillway, ogee spillway, siphon spillway, chute or trough spillway, shaft spillway, side channel spillway etc. The ogee profile spillway is hydraulically efficient, structurally stable and more adequate to dispose the excess flood effectively to the downstream side of the dam. This spillway will be helpful to control the erosion, scouring and poundage if suitable energy dissipater is provided at end of the structure Maximum velocity at any section slightly decreases as the surface roughness and the length scale ratio increase. Normally water flows over spillways during the time of floods when the water level exceeds the permissible limit. Also exterior portion of the spillways gets eroded during the flow of water with high velocity. Cavitation occurs at the exterior portion of the spillways when the pressure falls below the vapour pressure. Cavitation can be prevented by reducing the flow velocity and by increasing the boundary pressure [1, 2]. The capacity of an existing spillway can be increased by lengthening the spillway crest, or increasing the discharge coefficient or operating head, or any combination of these approaches.Many studies are going on with the objective of increasing the capacity of spillways. Labyrinth weir is one of structures adopted to increase the capacity of spillways.Labyrinth weirs provide higher discharge capacity than the conventional weirs, with the ability to pass large flows at comparatively low heads. But Labyrinth weir is not suitable for rivers with high sedimentation flow. Piano key weir is also used to increase the capacity of the spillways [3-6]. Nano materials are having the capacity to increase the discharge by reducing the porosity in the exterior portion of the spillways. Also the friction between the flowing water and the surface get reduced.

Use of nano flyash will not only increase the spillway capacity but also reduce the disposal problem of flyash. Since fly ash is used to replace cement, the emission of CO_2 and other greenhouse gases (ie.NO_x,SO_2) can be reduced.

The main disadvantages of Ordinary Portland Cement (OPC) are liberation of CO_2during the time of production and the availability of raw materials. Mainly to avoid these difficulties, fly ash can be used to replace cement. Nano cement has few advantages over ordinary Portland cement. Use of nano cement results in greater workability, less permeability and high strength. Due to the fineness of the particles, the permeability of concrete will reduce and durability will improve. Most commonly used spillway is ogee spillway due to it is super hydraulic characteristics. Mainly ogee spillways are provided in gravity dams which pass the excess flow of water efficiently and safely. The main profile of ogee spillway is ogee or S-shape. Letting out the excess discharge through the spillway is one of the important tasks to be carried out during the times of flood. If the spillway capacity is inadequate, the water level in the dams may rise dangerously and may cause dam failure. Normally, discharge of spillway increases when increasing the length of the spillway. But in the case of existing spillways, it is not always possible to increase

the length. An innovative method of using nano materials in the Cement Mortar (CM) for plastering the spillways is explored with the objective of reducing the friction and increasing the capacity of the spillways.
In this study nano cement and nano flyash were used along with cement and sand for the plastering the exterior surface of the spillway with the objective of increasing the discharge.

II. MATERIALS

OPC is one of the globally known binding material and has several advantages over the other binding materials such as great resistance to cracking, shrinkage, faster initial setting time, higher durability and compressive strength. Nano cement and nano fly ash are the materials having the particle size less than few microns. These materials being small in size are very active and give additional strength to mortar and concrete. These particles also make the surface smooth and reduce the friction.
Nano cement was produced by grinding the OPC 53 grade cement available in the market. Ball mill grinder was used to grind the OPC into nano cement. Nano fly ash was also produced by grinding the flyash in ball mill grinder [8]. The nano cement and nano flyash particles had size below 500nm. River sand has become a scarce commodity. Hence M-sand is being used for the construction activities. M-sand is produced from hard granite stone by crushing. In this study M-Sand is used as a fine material for the construction of spillway.
Nano cement and nano flyash were used as partial replacement material in OPC in the cement mortar.

III. TEST PARAMETERS

The parameters considered in this experimental program are depth over spillway and the bed slope. The depth over spillway was varied from 0.5cm to 5cm with an increment of 0.5cm. Three slopes were considered. Three spillway models were built across a tilting flume. The first model was plastered with CM 1:3. The second one was plastered with CM in which 30% of the cement was replaced with nano cement. The third model was plastered with CM in which 40% of cement was replaced with fly ash.

IV. DESIGN OF OGEE SPILLWAY

Several standard ogee shapes have been developed by U.S. army corps of engineers at their Waterways Experimental Station (WES). Such shapes are known as 'WES standard spillway shapes'. The d/s profile can be represented by the equation [9].

$$X^n = K.H_d^{n-1}.Y$$

where,(X,Y) are the coordinates of the points on the ogee profile with the origin at the highest point of the crest, called the apex. H_d is the design head including the velocity head. K and n are constants depending upon the slope of the upstream face.
Thus, for a spillway having a vertical u/s face, the d/s crest is given by the equation

$$X^{1.85} = K.H_d^{0.85}.y$$

In this study the value of K is taken as 2 and the above equation becomes

$$X^{1.85} = 19.98.y$$

Coordinates were calculated using the above equation and the coordinates of the spillway are given in Table 1.

Table 1: Coordinates of the Ogee Spillway.

X(cm)	Y(cm)
0	0
12.04	5
17.56	10
21.87	15
25.55	20
28.83	25
31.82	30
34.59	35
37.18	40
39.63	45

The profile of the spillway adopted is shown in Fig. 1.

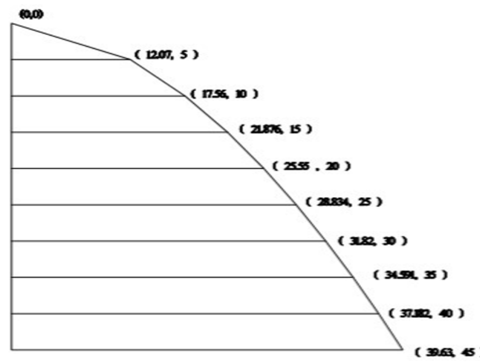

Fig. 1. Downstream profile.

V. FABRICATION OF OGEE SPILLWAY

Fabrication of Ogee Spillway consisted of three stages. In the first stage, the spillway is constructed using bricks in CM 1:6 and cured for 7 days. In the second stage, the mortar was prepared and the surface of the spillway was plastered with the mortar and cured for 7 days. In the third stage, experiments were conducted. The spillway was constructed in a tilting flume of size 10m × 0.55m × 0.6m. The view of the tilting flume is shown in Fig. 2.

Fig. 2. Tilting flume.

Three mortar mixes were used for the research. The first mortar mix used was CM 1:3. The second one was cement mortar 1:3 in which 30% of the cement was replaced with nano cement. The third mix was CM 1:3 in which 40% of the cement was replaced with nano fly ash. Fig. 3 shows the fabricated ogee spillway.

Fig. 3. Ogee spillway.

VI. TEST METHOD

Series of tests were conducted to determine effects of nano materials in increasing the discharge capacity of the spillway. Investigation was carried out using a tilting flume. The tilting flume setup consists of a tilting flume, collecting tank and a supply unit. Water was supplied into the flume by three pumps (2hp, 3hp&5hp). Water was let in a small compartment filled with broken stones so as to reduce the effects of impact. Water was then allowed to flow through a weld mesh so that flow will be uniform. Three slopes 0.0033, 0.0077 and 0.0122 were used for the study. The head over the spillway and the discharges are given in Table 2.

Fig. 4 shows the stage discharge graph for spillways with nano materials when the channel slope was 0.0033. Fig. 5 shows the stage discharge graph for spillways with nano materials when the channel slope was 0.0077. Fig. 6 shows the stage discharge graph for spillways with nano materials when the channel slope was 0.0122.

Table 2: Discharges over the Spillway for various Heads.

S.No.	Depth (cm)	Discharge (m^3/s)								
		CM 1:3			CM with 30% nano cement			CM with 40% nano flyash		
		Slope 1 (0.0033)	Slope 2 (0.0077)	Slope 3 (0.0122)	Slope 1 (0.0033)	Slope 2 (0.0077)	Slope 3 (0.0122)	Slope 1 (0.0033)	Slope 2 (0.0077)	Slope 3 (0.0122)
1.	0.5	0.0003	0.0003	0.0003	0.0005	0.0006	0.0007	0.0011	0.0010	0.0009
2.	1	0.0009	0.0009	0.0009	0.0016	0.0016	0.0015	0.0024	0.0031	0.0027
3.	1.5	0.002	0.0016	0.0016	0.0031	0.0038	0.0039	0.0037	0.0037	0.0041
4.	2	0.0035	0.0033	0.0034	0.0046	0.0049	0.0049	0.0057	0.0065	0.0055
5.	2.5	0.0049	0.0048	0.0052	0.0061	0.0067	0.0072	0.0076	0.0073	0.0073
6.	3	0.0065	0.0069	0.0076	0.0083	0.0087	0.0087	0.0102	0.0098	0.0100
7.	3.5	0.0091	0.0088	0.0088	0.0104	0.0109	0.0104	0.0131	0.0127	0.0118
8.	4	0.0106	0.0109	0.0114	0.0135	0.0131	0.0143	0.0143	0.0153	0.0153
9.	4.5	0.0123	0.0147	0.0147	0.0164	0.0170	0.0176	0.0183	0.0191	0.0183
10.	5	0.0163	0.0163	0.0169	0.0208	0.0199	0.0208	0.0218	0.0218	0.0218

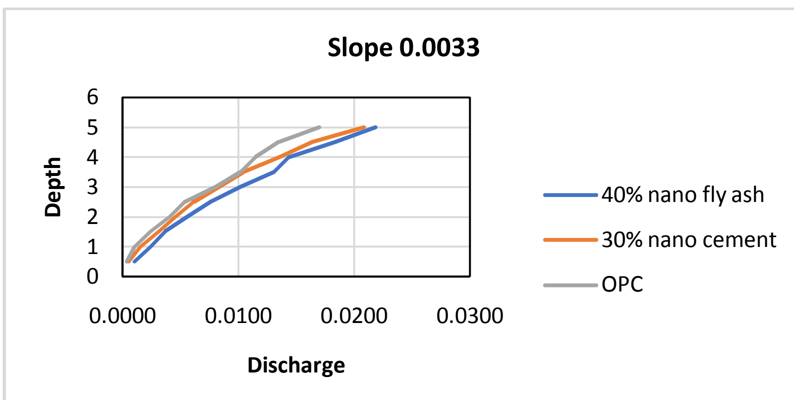

Fig. 4. Stage discharge graph for channel with a slope of 0.0033.

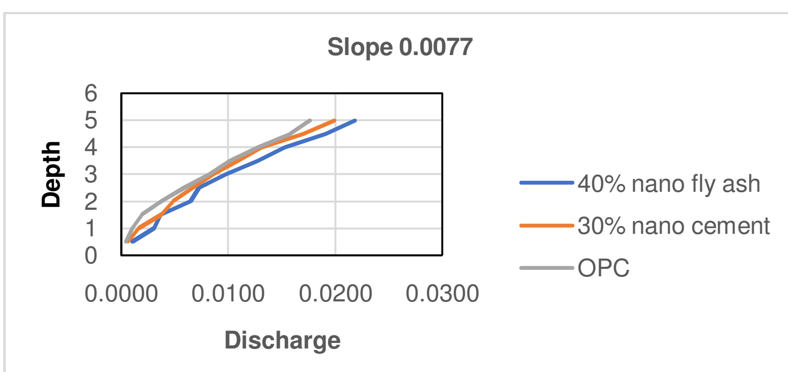

Fig. 5. Stage discharge graph for channel with a slope of 0.0077.

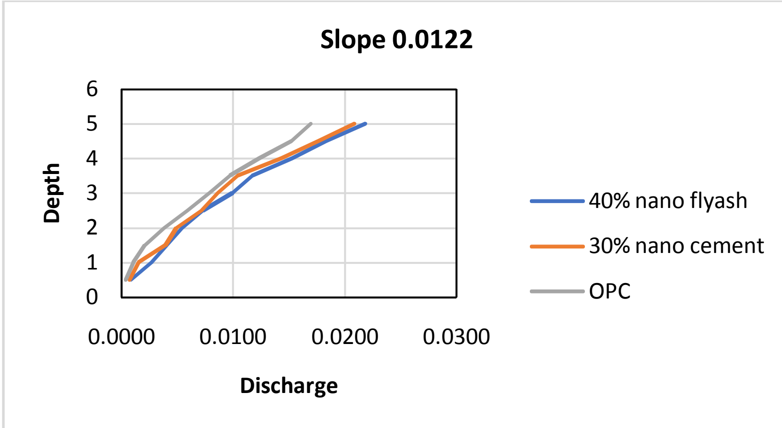

Fig. 6. Stage discharge graph for channel with a slope of 0.0122.

Table 3: Percentage increase in discharge of spillway with nano materials.

S.No.	Depth (cm)	Discharge(m^3/s)					
		% increase in 30 % of Nano cement			% increase in 40% of nano fly ash		
		Slope 1 (0.0033)	Slope 2 (0.0077)	Slope 3 (0.0122)	Slope 1 (0.0033)	Slope 2 (0.0077)	Slope 3 (0.0122)
1.	0.5	49.2	39.3	87.6	191.1	132.0	125.7
2.	1	53.6	58.3	42.3	139.4	200.7	150.9
3.	1.5	29.5	91.0	88.0	52.4	86.4	96.4
4.	2	13.0	27.7	29.0	39.5	69.0	42.9
5.	2.5	14.7	14.7	21.9	43.3	23.8	23.8
6.	3	3.6	5.7	9.4	26.7	19.1	26.1
7	3.5	2.3	7.1	6.8	28.6	25.0	20.5
8	4	17.6	2.9	15.6	25.0	20.0	23.3
9	4.5	21.4	7.4	15.4	36.0	20.8	20.0
10	5	22.7	13.0	22.7	28.6	23.8	28.6

The percentage increase in the discharge values for the spillways with nano materials are given in Table 3.

From Fig 4, 5, 6 and Table 3, it can be seen that the discharge over the spillway increases enormously for the spillways with nano materials. The percentage increase varies between 2.3 to 53.6 for the spillway with 30% nano cement for the slope 0.0033. The percentage increase varies between 2.9 to 91.0 for the spillway with 30% nano cement for the slope 0.0077. The percentage increase varies between 6.8 to 88.0 for the spillway with 30% nano cement for the slope 0.0122. The percentage increase varies between 25.0 to 191.1for the spillway with 40% nano flyash for the slope 0.0033. The percentage increase varies between 19.1 to 200.7 for the spillway with 40% nano flyash for the slope 0.0077. The percentage increase varies between 20.0 to 150.9 for the spillway with 40% nano flyash for the slope 0.0122. Muthu, & Prince [11] carried out an investigation to determine the conveyance of channels lined with cement mortar tiles and tiles with nano materials. It was reported that nano materials increased the conveyance of channels in the range between 50% to 400%.

The discharges over the spillway were much higher for the spillway with 40% nano flyash than that of spillway with 30% of nano cement. The reasons for the increase in the discharge are smoother surface and reduced porosity of the surface when nano materials were used.

VII. CONCLUSIONS

The following conclusions arederived based on this experimental work.

– Nano materials make the exterior surface of the spillway smoother and hence porosity and friction were reduced.

– The increase in discharge of spillway with 30% Nano cement was found to vary from 2.3% to 91.0%.

– The increase in discharge of spillway with 40% Nano flyash was found to vary from 19.1% to 200.7%

– Nano flyash was found to be more effective in increasing the discharge of spillway than nano flyash.

– When appropriate nano materials are used for plastering the surface of the spillway, the capacity of spillways can be increased without constructing additional spillways.

VIII. FUTURE SCOPE

We believe that the results of this study will help the reservoir managers to use nano materials for plastering the surface of the spillways to increase the capacity of spillways.

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Conflict of Interest. There is no conflict of interest.

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