Reservoir Sedimentation causes breakage of dams: A study of the Khodiyar reservoir in Gujarat

Abstract

Despite the benefits realized, dam reservoirs are not without their drawbacks. Any reduction in water storage caused by reservoir siltation and the associated loss of fertile soil are critical issues. The reduction of reservoir storage capacity decreases the attenuation of the flood and increases outflow. In addition to these, reservoir sedimentation can also affect the hydraulic and structural safety of reservoirs. Effects could be fatal, if capacity is moderated through heightening of embankment. These have been examined and established using data for the Khodiyar Reservoir in Gujarat state of India.

Medium and minor irrigation tanks in water scarce Saurashtra region of Gujarat, India, faces two extreme hydrological conditions. In lesser rainfall years, poor water storage in the reservoir remains a matter of concern, whereas in the years having slightly good rainfall, flash floods upsurge disaster. Reservoirs in such areas experience silting in much faster rate. Khodiar reservoir in Amreli district is one among them and is the study area for the present paper. Beside hydrological and water use impacts, effects of sedimentation on surface and subsurface water levels, seepage loss and water pressure have been checked. Study shows that the reservoir falls in the serious category as live storage capacity has reduced by 36.12% in 41 years. There are imbalances to be looked after, if hydrological, hydraulic and structural safety is desired.

On the basis of periodical silt survey data of 1975, 1987 and 2001, theoretical silt distribution and changes in area capacity scenarios of the reservoir have been evaluated for every fifth year from the year of first impounding water. For selecting the method of computing reservoir sediment distribution, both Empirical Area reduction method and Area increment method were employed initially for the year 1987. Computed results were compared with the survey data of 1987, are shown in table 1. Total cumulative sediment inflow with revised capacity for Khodiar reservoir in respective years is tabulated below in **Table- 2**. Computed new zero elevations at different years are also shown in the same table.

Table 1 Comparison between Empirical Area Reduction and Area Increment Method

R.L.	ORIGINAL SURVEY-1987	EMPIRICAL AREA REDUCTION	AREA INCREMENT METHOD
(m)	**capacity(Mcum)**	**capacity(Mcum)**	**capacity(Mcum)**
202.6821	29.93856	29.94422	29.93771
201.1582	22.29587	22.3222	22.48301
199.6343	16.29672	16.37571	16.69366
198.1103	11.59768	11.62344	12.07616

R.L.	ORIGINAL SURVEY-1987	EMPIRICAL AREA REDUCTION	AREA INCREMENT METHOD
196.5864	8.048414	8.028029	8.58239
195.0625	5.498867	5.382786	5.995753
193.5386	3.649207	3.566535	4.193092
192.0146	2.19932	2.052378	2.649773
190.4907	1.149773	0.997452	1.528879
188.9668	0.449887	0.323896	0.751133
187.0466	0.060023	0.056908	0.328426
185.9189	0	0	0.161382
179.8232	0	0	0

Table 2 Revised capacities, sediment inflows and new zero elevations in different years

year	Total cumulative sediment inflow (Mcum)	Capacity (Mcum)	New zero elevation (m)
1967	0	40.39	179.88
1975	8.13137	32.24	179.88
1980	9.128256	31.25	179.88
1985	10.12712	30.25	185.98
1990	11.12599	29.40	187.10
1995	12.12458	28.40	189.02
2000	13.12486	27.40	189.02
2005	14.12344	26.40	190.55
2008	14.72254	25.80	190.55

From **Table 2** it is evident that the reservoir capacity reduces at much faster rate than anticipated in the initial years of impoundments. The designed storage capacity of reservoir was 40.39 Mm^3 in the year of 1967, with the sediment deposition of 14.73 Mm^3 it reduces to 25.80 Mm^3 in 41 years. This reduction comes out to be 36.12%, shows the higher rate of siltation. From **Table 2** it is clear that the Zero elevation of reservoir changes R.L. of 179.88 m to R.L. of 190.55 m within 41 years span. It means that no storage would be available below 190.55m and structurally dam would loosen its stability.

Comparison of various losses due to sediment accumulation over the years is shown in Table 3 for different return period floods. Though the storage loss due to decrease in capacity is maximum, however, losses due to evaporation and seepage cannot be neglected. Evaporation

loss is more as compared to seepage loss and the difference between the two respective values narrowing down as the return period of the floods increases.

Table 3 Percent increase of water losses due to Khodiyar reservoir sedimentation for different return period floods

YEAR	2 Year Return Period			5 Year Return Period			7 Year Return Period			10 Year Return Period		
	Storage loss (%)	Evapo loss (%)	Seepage loss (%)	Storage loss (%)	Evapo loss (%)	Seepage loss (%)	Storage loss (%)	Evapo loss (%)	Seepage loss (%)	Storage loss (%)	Evapo loss (%)	Seepage loss (%)
1975	25.54	1.66	5.71	16.3	0.73	1.28	13.94	0.673	2.11	8.60	2.87	1.13
1980	28.64	11.11	8.57	18.28	2.94	2.56	15.64	6.04	3.10	9.65	4.02	3.40
1985	31.77	14.81	9.28	20.28	6.61	5.12	17.35	8.72	4.34	10.71	4.02	3.69
1990	34.44	15.74	10	21.98	8.52	6.41	18.80	11.14	6.83	11.60	4.02	3.69
1995	37.57	20.37	11.42	23.98	10.29	7.69	20.52	12.75	7.45	12.66	4.02	3.69
2000	40.70	22.22	12.14	25.98	11.76	8.71	22.23	14.76	8.07	13.72	4.02	3.69
2005	43.84	23.14	12.85	27.98	12.49	10	23.94	15.43	8.69	14.77	4.02	3.69
2008	45.72	25.92	14.28	29.18	14.70	10.25	24.97	16.77	9.31	15.41	4.02	3.69

Percent increase in water pressure on the earthen dam section due to sedimentation is shown in figure 1. It is evident that water pressure on the dam section increases with the increase in reservoir sedimentation. These computations are carried out considering reservoir and pour water heads. Considering only the water thrust from reservoir water head and with new zero elevation moving upward with the age of the reservoir, overturning moment around the toe of the dam may increase gradually with sedimentation. Computations to these effects are carried out for Khodiyar reservoir dam section considering toe elevation at R.L. 179.88 m. Results of the analysis are tabulated in Table 4. For the present dam section, these moments are overall decreasing ('-'ve sign) as the sedimentation occurring in progressing years. For the years 1975 and 1980 results are indicative of the fact that new zero elevation remained same as that of the year 1967.

Table 4 Percent Increase in the toe-moment for different return period flood (RP)

YEAR	2 yr RP	5 yr RP	7 yr RP	10 yr RP
1975	18.14288	3.896011	6.470652	3.448224
1980	27.98413	7.89191	9.609883	10.58068
1985	8.408238	-1.19048	-2.65006	-2.23758
1990	3.072918	-3.34107	-0.7171	-7.13838
1995	-7.25381	-11.4762	-10.313	-16.7047
2000	-4.96892	-8.32793	-8.40737	-16.7047
2005	-15.8982	-15.2737	-16.7819	-25.1314
2008	-11.4412	-14.4955	-14.9198	-25.1314

Conclusions

1) Increase in Evaporation Losses- It is concluded from the results that with the increase in sediment accumulation in the reservoir, water spread area increases and resulting in to more evaporation loss.

2) Effect on Seepage losses and Structural Safety- As the water levels in the dam reservoir rises, differential head causing seepage through earthen dam section increases. Water pressure on

the dam section may increases, which may lead to seepage and piping failure of dam. Increase in the downstream well water level fluctuations is indicative of such effects. However, toe-moment calculation for a section showed overall reduction in moment due to sedimentation.

Reference:

Kande S., 2009, "Reservoir Sedimentation and its Hydrological Impacts: A case Study of Khodiar Reservoir ", Unpublished ME Dissertation, LD College of Engineering, Ahmedabad, Gujarat, India.