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Life of Different Soil and Water Conservation Structures

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A B S T R A C T

The soil and water conservation hold the key position in agricultural position and watershed development. The expenditure incurred in construction is of high magnitude and hence structure need to last for longer duration in the field. The study was undertaken to study and compare the existing design procedures used in Department of Agriculture and reported in literature for various temporary and permanent soil and water conservation structures and to estimate the expected life of different soil and water conservation structures based on hydrological approach. It was revealed that the design return period considered in the design procedures adopted by Department of Agriculture are very less and hence the expected life of structure is less. This means that there is risk of failure of these structures due to unexpected high flows. The design return period for temporary, semi-permanent and permanent structures should be worked out by assigning certain risks of failure.

Introduction

Soil, water and plant resources are nature's gift to mankind. We have been using it for agricultural purposes since ages. The splendour and munificence of our natural resources are legendary. However, our land especially the predominately rainfed. draught prone and high population density areas is today in Over grazing deforestation, faculty cultivation, shifting cultivation and carelessly built roads in the catchment areas have laid to devastating effects in downstream areas. Tree cover has been depleted, soil erosion and damage have increased, water table has gone down the severity of draught has increased and ecological degradation of dry lands is greater than few decades ago. With a view to check soil and water erosion there is need to launch various soil and water conservation programs with basic objective of land and water resources management for sustainable production (Anderson and Bancroft, 1952; Benjamin and Cornell, 1970).

Proper conservation and management of soil and water are very important corollaries to increase the agricultural crop production to meet the demand of food for ever increasing human population. The basic source of water is the precipitation in the form of rainfall. In India, an average annual rainfall is estimated as 119.4 cm, which amounts to 393 M ha-m, when considered over geographical area of 328.05 M ha. Out of 393 M ha-m annual rainfall, 115 M ha-m flow as surface runoff, which is not useful for agricultural production. In Maharashtra, the total rainfed area is 89 % of the total land under agriculture. Hence, there is good scope in harnessing the surface and subsurface runoff from watershed to increase the land area under irrigation by constructing soil conservation and water conservation structures (Edward and Hann, 1989; Gurmel Singh, *et al.*, 1990).

If a design is based solely on the basis of a historical record of rainfall or stream flow, the stochastic model employed is simply the historical record itself. It should be kept in mind that any historical record is but one realization of a stochastic time series and that future realization will resemble the historical record only in a statistical sense even if the processes are stationary (Millete, and Sharma, 1986).

Designers of water resources systems have realized for years that evaluating their designs using past or historical records provided no guarantee that the design would perform satisfactorily in the future because future flow sequences will not be same as the past flow sequences. Typically, historical flow sequences are quite short generally less than 25 years in length (Snyder and Thomas, 1983). Even during the 100-year life of a project, an observed historical flow sequence of 10 to 25 years in length will not repeat itself. In all cases the designer would agree that the worst flood on record is not worst possible flood.

The use of historical records alone gives no idea of the risk involved. That is, if a design is made based on an historical record, chances are that the design would be adequate if the history repeated itself.

However, we know that the historical record will not repeat itself. There is thus a certain risk that the design will be inadequate for the unknown flow sequence that the system will actually experience. The work of determination of life was taken to study and compare the existing design procedures used in Department of Agriculture and reported in literature for various temporary and permanent soil and water conservation structures and to estimate the expected life of different soil and water conservation structures based on hydrological approach.

Materials and Methods

The chance of at least one occurrence of a T year event in n years is given by equation 3.1 (Haan, 1977).

$$R= 1 -\left(1- \frac{1}{T}\right)^{n}$$

Where, R = Risk T= Return period, year n=Expected life, year

If the expected life of structure and its design return period are the same the chances are very great that the capacity of the structure will be exceeded during its expected life.

The design return period must be much greater than the life of project to be reasonably sure that an exceedance will not occur. No matter what return period selected, there is still a chance that an exceedance will occur.

Fig. 3 shows the design return period that must be used to be a certain per cent confident that the design will not be exceeded during expected life of project. The parameters on the curves are the per cent chance (risk) of no exceedance during expected life. For example, to be 90 per cent sure that a design condition will not be exceeded during a project whose expected life is 100-years, the project would have to be designed on the basis of 900-year event.

Soil and water conservation structures

Different soil and water conservation structures can be broadly classified as temporary, semi-permanent and permanent structures. The expected life of these structures will differ and so the return period to be consider for design. Three important structures which come under above categories and widely used in field have been described below.

Loose boulder bund

Loose boulder structure is a structure in which stones are arranged in gully across the flow. Loose boulder structures are constructed in areas where stones are easily available. Typical loose boulder structure is shown in Fig. 3.2. It is used to dispose of flow at safe velocity and it is also used to minimize erosion. The height of those structures is usually kept as 1 m. Advantages of the loose boulder structures are that the stones are easily available and construction is very easy. The structures are cheap and do not require skilled labour. However, these structures can be constructed in small gullies where the flow is small and will not disturb the arranged stones.

Design procedure

The design procedure adopted by Department of Agriculture for loose boulder bunds is described below. The design flow is considered for 5-year return period. The upstream and downstream side slopes are considered to be 1:1 and 2:1.

Top width =Usually 0.5 m

Height = Usually 1 m

Bottom width = 2 (height x side slope) + top width.

Base = 0.3 m deep in gully bed

Volume above the base

$$= \frac{\text{Bottom width} + \text{Top width} \times \text{height} \times \text{length}}{2}$$

No. of bushes to be planted

$$= \frac{\text{length of bund}}{0.5} + 1$$

The procedure suggested by Kendall (1967) considers return period of design flow as 10 years. The upstream and downstream slopes are considered to be 1.5: 1.5 and 1.5: 1.5.

Earthen structure

Earthen structures are constructed in different gullies of watershed to reduce the soil erosion. It is constructed across, where immediate control of flow velocity is required. Typical earthen structure is shown in Fig. 3.3.

Earthen structure is used to collect sufficient amount of soil on their u/s side portion and is used for controlling runoff and to conduct the flow smoothly.

Earthen structure can be easily constructed and construction cost is less, as material of construction is readily available. However earthen structure may fail due to large runoff or improper compaction.

Design procedure

The design procedure adopted by Department of Agriculture is described below.…

The depth of base foundation is considered to be 0.3 m.

Top width = Usually 0.6 m

Height = Usually 1 m

The upstream and downstream slopes are considered to be 1.5:1.

Bottom width 2 (height x slope) + top width

Number of trees to planted

$$= \frac{\text{Length of bund}}{2.5} + 1$$

Stone pitching up to 0.6 m height from base on upstream side. The design flow is considered to be of 5-year return period.
The procedure suggested by Singh *et al.,* (1990) is as follows.

Top width =Usually 1.2 m

Height = Usually 2 m

Side slope=1:1.

Depth of foundation = 0.6 m.

The return period of 10 year is suggested for design flow.

Cement Nala Bunding

Cement nala bund is permanent structure. constructed in semi-arid and arid regions with low annual rainfall having relatively permeable soils. Bunds should be provided from ridge of the catchment valley at regular interval. Typical cement nala bunding is shown in Fig. 3.4

Cement nala bunding is used to collect water for percolation into deeper soil profile to enrich the soil by moisture. It reduces the soil erosion. It provides a means of ground water recharge and control of irrigation water.

It is very stable as compared to temporary and semi-permanent structures. It has less structural damage and there is no clogging. But the construction cost is more and it requires skilled labour. Stable grade below the structure is essential.

Design procedure

The design procedure adopted by Department of Agriculture is as follows.

Peak runoff rate is estimated by rational formula with return period of 10 year

$$\text{Height of water over crest} = \left(\frac{\text{Stream discharge}}{1.704 \times \text{spillway length}}\right)^{0.607}$$

Creep length = Creep length should be 6 to 10 times of water storage

Water cushion = 0.82 (Height of water over crest) x (Height of spillway

Length of apron = 2 x (Height of water over crest + height of spillway)

The design procedure suggested by Suresh, R. (1997)

Peak runoff rate to be estimated by rational formula with 50 year return period

Height of water over the crest to be decided using

$$Q\,p = \frac{1.711\, L\, H^{3/2}}{(1.1 + 0.01F)} \text{ with free board}$$

$$Q = 1.711\, LH^{3/2} \text{ with free board}$$

Where,

L = Crest length (m) F = Net drop (m) H = Crest height

Length of basin = F(2.28 h/f +0.52)

Head wall extension E = (3h+0.6)

Height of head wall = f+h+s

Apron thickness t = 22 to 30 cm for net fall ranging from 0.5 to 3 m.

Results and Discussion

Loose Boulder Bund

The expected life of loose boulder is estimated to be 0.5 year considering the design return period of 5 years and risk of 10 per cent in case of design procedure adopted by Department of Agriculture. Whereas the expected life comes to be 1 year in case of design return period of 10 year with 10 per cent risk as suggested by Singh (1990). As the structure is temporary more risk can be taken then considered which may increase the expected life slightly.

Earthen Structure

The expected life of earthen structure is estimated to be 0.5 year considering the design return period of 5 years and risk of 10 per cent in case of design procedure adopted by Department of Agriculture. Whereas the expected life comes to be 1 year in case of design return period of 10 year with 10 per cent risk as suggested by Singh (1990). Though the structure is semi-permanent the same criteria of return period is used and hence the expected life is less. This necessitates increase in design return period.

Cement Nala Bunding

The design procedure adopted by Department of Agriculture suggests 10 year design return period and hence the expected life is 1 year at 10 per cent risk.

However, by the design return period of 50 year as suggested by Suresh (1997), the expected life is 5.2 year at 10 per cent risk. Since the structure is permanent structure, it should last longer and should have less risk.

Relation between expected Life and Return Period

In order to have a better estimate of expected life, design return period and the risk involved from hydrological point of view following table will serve a guideline

Study was made on life of three different soil and water conservation structure and it was found that for Loose boulder structure constructed by Department of Agriculture (M.S.) when risk was taken as 10 per cent and return period as 5 years. The expected life was calculated as 0.5 year. Theoretically when risk and return period was taken as 10 per cent and 10 years respectively the expected life of structure is calculated as one year.

Earthen structure constructed by Department of Agriculture (M.S.) when risk was taken as 10 per cent and return period as 5 year the expected life was calculated as 0.5 year. Theoretically when risk was 10 per cent and return period was taken as 10 per cent and 10 years respectively the expected life was calculated as one year.

Table.1 Relation between Expected Life and Return Period

Sr No	Temporary structures n=2		Semi-permanent structures n=10		Permanent structures n=25	
	R	T	R	T	R	T
1	1	1	0.89	5	0.630	25
2	0.75	2	0.65	10	0.396	50
3	0.55	3	0.498	15	0.285	75
4	0.4375	4	0.40	20	0.222	120
5	0.36	5	0.35	25	0.181	125
6	0.305	6	0.28	30	0.153	150
7	0.265	7			0.330	175
8	0.234	8			0.117	200
9	0.209	9				
10	0.190	10				

Fig.1 Can also be used to evaluate the risk of an event in excess of the design event during expected life. For example, if a project is designed on the basis of a 50-year event and expected life of project is 10 years, the designer is taking a 19 per cent chance (Risk) that the design condition will be exceeded.

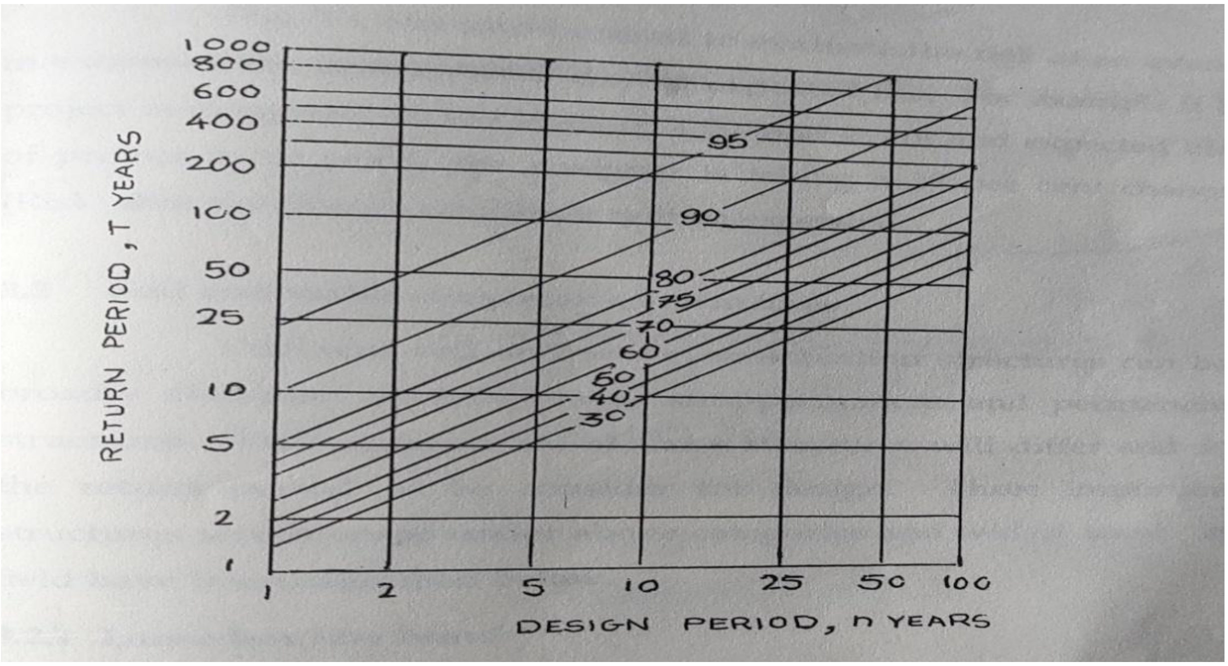


Fig.2 Loose Boulder nund

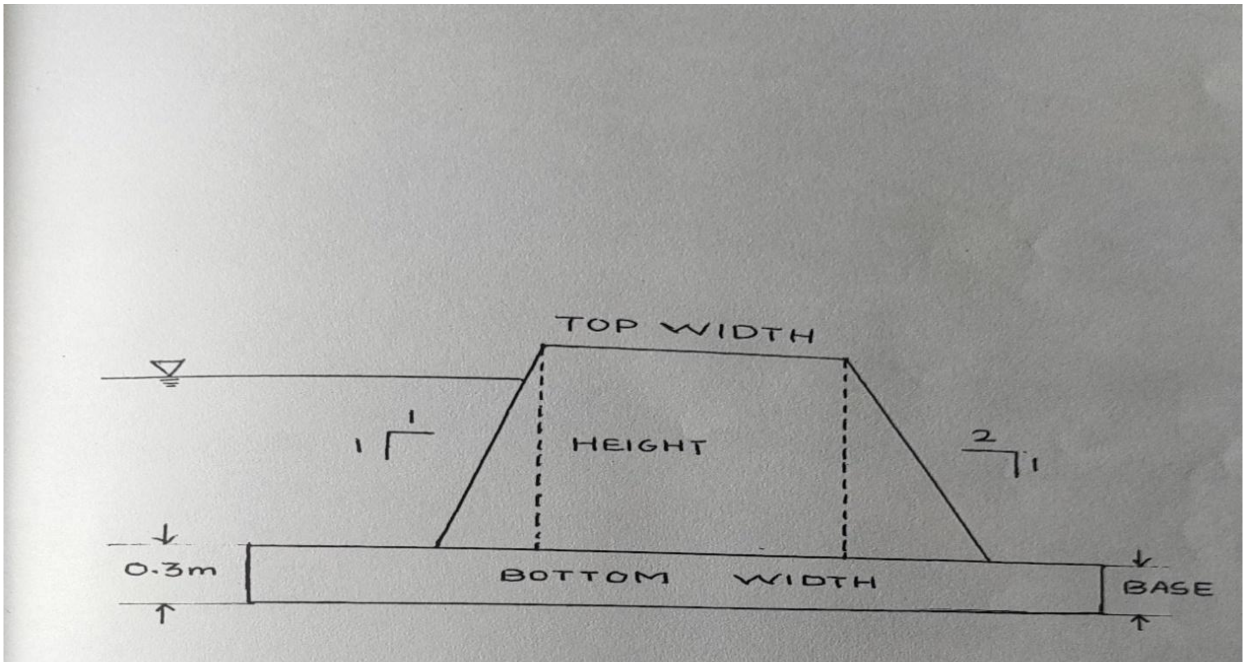


Fig.3 Earthen Structure

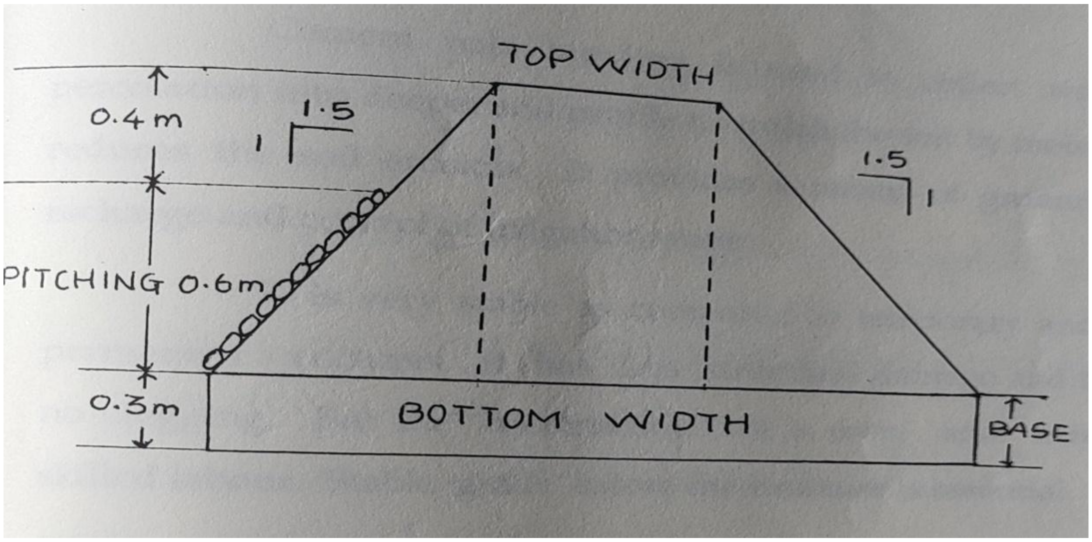
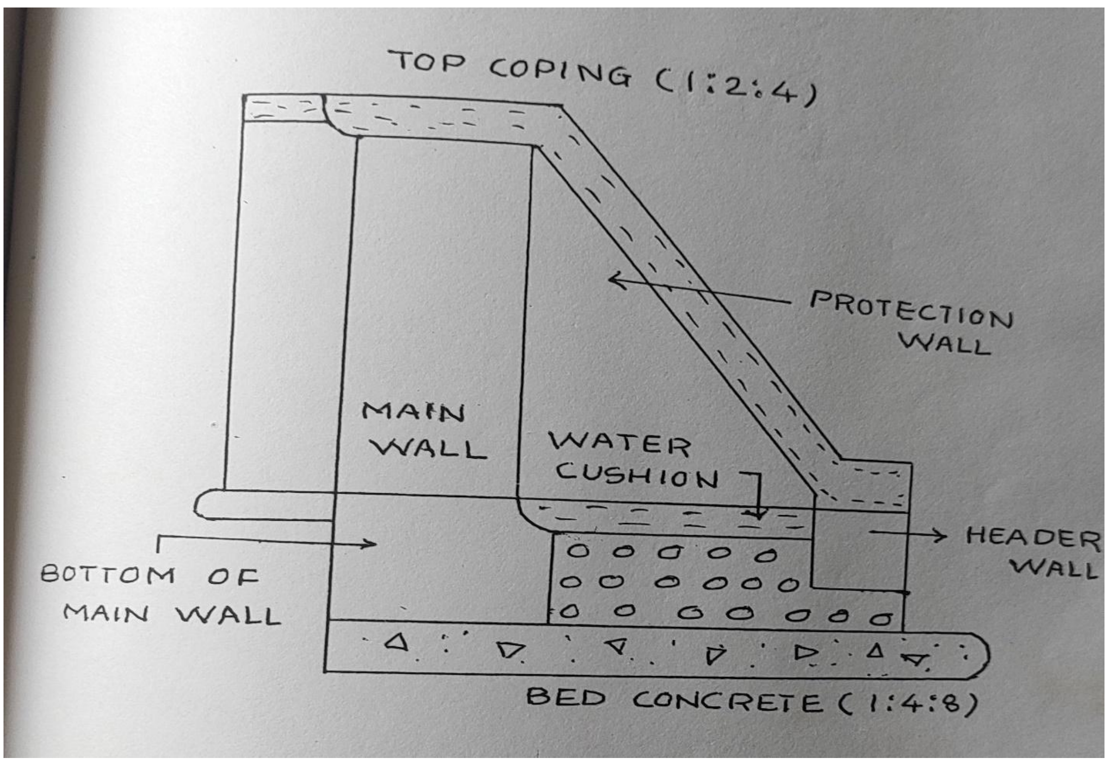


Fig.4 Cement Nala Bunding



Cement nala bunding constructed by Department of Agriculture (M.S.) when risk was taken as 10 per cent and return period as 5 year the expected life was calculated as one year. Theoretically, when risk was 10 per cent and return period 50 year the expected life of structure is 5.2 years.

The design return period considered in design of various structures by Department of Agriculture is very less and leads to very high risks of failure.

Further, it can also be concluded that for different types of structures the risks of failures should be assigned and accordingly the design return periods can be worked out.

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