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A REVIEW OF PREVIOUS WORK ON AN APPROACH TO DESIGN AND CONSTRUCTION OF LOW HEIGHT GRAVITY DAM

Anupam Kumar Pandey[1], Rohit Rai[2]

[1]Chartered Engineer & Scholar of M tech (Structure Engineering), Department of Civil Engineering, Maharishi University of Information Technology, Lucknow.
[2]Assistant Professor, Department of Civil Engineering, Maharishi University of Information Technology, Lucknow.

Abstract : -*This paper presents a comprehensive review of published literature on gravity dams especially earthen dams. The first tools to design earth dams to resist piping were developed during 1910–1935. Filter criteria for dispersive soils was refined in the 1970's. Piping phenomena are generally defined as: (1) heave, (2) internal erosion, (3) backwards erosion, although other modes are possible. Tim Stephens restrict to the construction of earth dams no higher than 5 m from streambed to finished crest level. Grishin, M. M. Gidrotekhnicheskie sooruzheniia. Moscow, suggest about the type of section of earthen dam and materials to be used for the construction of the dam. Murray Fredlund1 , Ph.D., P.Eng., HaiHua Lu1 , M.Sc., and Tiequn Feng2 , Ph.D., P.Eng. Shell Albian Sands, Ft. McMurray, Alberta, Canada had been given an important conclusion on topic 'Combined Seepage and Slope Stability Analysis of Rapid Drawdown Scenarios for Levee Design' in which They concluded that The strength of levees can be affected during fluctuations in the water table. The construction of dam at suitable site is needed on those rivers which carry huge amount of rain water. It is needed to review the work carried out by different researchers in context of the especial need arisen at Lucknow in river Gomti, where the construction of dam is to be carried out in flowing water without diverting it.*

Kew Words: **Geo Bags, R.B.M.(river bed material),Barrage, River front, Boulder.**

Introduction : -

A dam is a hydraulic structure constructed across a river or natural stream to store water on its upstream side. It is an impervious or semi impervious barrier put across a natural stream so that the reservoir is formed. It is very difficult to say as where and when the first man made dam was built. Archeological evidences helps in estimating that the very first man made dam is at least 3000 - 5000 years old.

The first Modern dam of the world was constructed on the Nile river in Egypt at Aswan. It was completed in 1902 and was as major engineering project. Material used in this dam construction was stone. The Second Modern dam of the world was Roosevelt Dam constructed on the salt River of Arizona (U.S.A.) completed in 1911. Material used in its construction was the solid blocks of concrete. Which was the type known as "Solid Masonry Gravity Dam.`` Hoover Dam (726'high) Bhakhra Dam (740'high) are some of example of "Solid concrete gravity dam type". The material of construction is generally earth, wooden planks, stone, bricks, sand, coarse aggregate, cement and steel which is used in most of the construction of dams. After proper designing, the site is vacated from the water by diverting the water through side channel spillway by constructing a coffer dam on upstream side. In conditions where if, river of water is stopped in downstream side away few kilometers from the construction site by structure like barrage, as it has to be done in Lucknow just to maintain level of water in river to feed a pump house for the purpose of supplying drinking water to nearby localities, Obviously it is impossible to vacate the construction site in this condition and construction of new gravity dam is to be done in water as already flows in river because the level of water in river could not be lowered otherwise water pumped by the said pumping station could be stopped and the people of the nearby, who are served by these pumps, could be agitated, the result of which would be as the problem of law and order in the city. This would be possible by various ways but here the requirement of a such type of dam which has to serve for three to five years. By intensive studying a large number of literature of dam construction. It is found to construct the dam by using E.C. Bags, Geo bags, Boulders, Bali Piling and earth.

Literature Review : --

Gravity dam is designed for various forces especially for the overturning moment and for the sliding forces. Proper design is also required to safeguard against piping which is a severe problem in the design of Earthen dam.

[1] **Rajendra Deshpande, Hindustan Construction Co. Ltd. Mumbai, India on the topic of ''Geo-Textile Sand Container Mattresses (GSCM) Lining For Temporary River Diversion Channels ''.**Traditionally, diversion channels are lined with (rip rap) boulders, 600 to 800 mm thick, in concrete ribs. Well graded sand filter of thickness varying from 300 to 600 mm is provided below the boulders. Collection of large quantity of boulders, its transportation to the site and stacking in a very short time frame involves unavoidable delays and higher costs. In some cases, like the one faced by HCC at Teesta hydro-electric project, the unavailability of the boulders itself was the bottleneck in lining constructing. Considering the constraints associated with this traditional design, a need was felt to develop an economical, speedy and reliable method of lining. **Geo-Textile Sand Container Mattresses (GSCM)** Lining was conceived, designed and installed for the Teesta IV Hydro electric project by HCC. Geo bags are used for construction of dam and also used to protect the open surfaces of dam to protect it against erosion.Sand filled Geo textile bag can be used for river revetments, Riverbank protection and River training works. Traditionally stone boulders are used for river revetments, bank protection and river training works, but it is costly country like Bangladesh. Geo textile bags found best in place of stone boulders.

[2] **Rajendra Deshpande, Hindustan Construction Co. Ltd. Mumbai, India on the topic of ''Geo-Textile Sand Container Mattresses (GSCM) Lining For Temporary River Diversion Channels ''.**1.Geo textile bags launch down the slope when the river erodes the bank under a launching heap or a falling apron. Slopes after launching are approximately 1V:2H, according to field observations and model tests. Diving investigations indicate that the gaps between adjacent launched bags are small, less than hand size. These observations make geo textile bags suitable for providing erosion protection on banks consisting of consolidated sandy soil. **2.** Geo textile bags of the dimensions used in providing stable elements for long parallel slope protection or revetments along riverbanks. Flow velocities along revetments are generally less than half those at exposed corners or spur heads, as indicated by physical model tests . **3.** Geo textile bags of 126 kg filled weight are stable against near bed velocities of up to 2.9 and 2.6 m/s on slopes of 1V:2H and 1V:1.5H respectively. This corresponds to depth-averaged velocities of more than 3 m/s. Bags of 90 kg are stable for slightly lower velocities. These values are well above observed at the sites. **4.** Geo textile bags provide high stability against currents. The main reason is the substantial difference in shape: flexible geo textile bags lying flat on the bank show high resistance to flow forces. Also, bags are flexible and over time form a smooth layer, so that they do not project into the flow and generate local turbulence.

[3] **Kevin S. Richards Æ Krishna R. Reddy 'Critical appraisal of piping phenomena in earth dams'** Excluding the advances in filter engineering, there have been few significant advances with respect to piping in non cohesive soils since Lane's weighted creep method was published in 1934. Other than Moffat and Fanning (2006) and A˚ berg (1993), very little recent work has been done with respect to piping in cohesion less soils. Although some headway is being made with the recent focus on related failures, dams are still failing by piping and more work remains to be done in this field. Even in spite of the number of advances in our understanding of piping phenomena, there are still a large number of incidents that occur due to concentrated leakage or formation of sinkholes in embankment dams. This re - flects a need for increased attention to the prevention of these potential failure modes **.**

[4] **Murray Fredlund1, Ph.D., P. Eng. Hay Hue Lu1, M.Sc., and Tiequn Feng2 , Ph.D., P. Eng. Shell Albion Sands, Ft. McMurray, Alberta, Canada 'Combined Seepage and Slope Stability Analysis of Rapid Drawdown Scenarios for Levee Design' .**The strength of levees can be affected during fluctuations in the water table. It is also possible for the climate to have an influence on the position of the water table in an earth levee. Traditional methods have resulted in approximate methods for dealing with the transient fluctuations of the water table in a levee. These approximations are generally accepted in engineering practice but the question can be rightfully raised as to how these approximations compare to a rigorous transient combined seepage and slope stability analysis. There are new questions that can be asked. Does an effective stress analysis diverge significantly from the 3-stage Duncan (1990) analysis? The primary difference is related to consideration of transient pore water pressures in the slope stability analysis. A secondary influence is the effect of geometry on the flow regime in an earth dam or levee. As a general note the total stress Duncan et al. (1990) 3-stage analysis seems to be conservative. There is an opportunity to more closely simulate soil behavior with respect to time and thereby optimize the design of levees with the result that there is a saving in costs by utilizing an effective stress analysis**.**

[5] **Tim Stephen, Investment center division, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome .(Manual on small earth dams A guide to siting, design and construction.** In all dam construction, safety must be given priority and designer should follow the guidelines below: Designer should

restrict themselves to the construction of earth dams no higher than 5 m from streambed to finished crest level. Dams on catchment areas exceeding 25 km^2 or with reservoir areas storing more than 50 000 m^3 may require the advice of a hydrologist to assist in the design of spillways and other outlets and for the estimation of freeboard. No spillway should be less than 10 m wide and 1 m deep for catchments up to 5 km^2 and should be at least 15 m wide and 1.5 m deep for catchments exceeding this area. Any dam that involves out of the ordinary topography (i.e. steep slopes upstream, risks of landslips), hydrology (i.e. flash floods, droughts, snowmelt) or soils (i.e. poor quality soils, sodic soils, permeable layers in the soil, bare earth surfaces in the catchment) should only be designed and constructed under the supervision of a qualified engineer. Before any dam is constructed, an assessment of the hazard potential should be made.

[6] **Raghvendra Singh QIP Scholar, Department of Civil Engineering, Indian Institute of Technology, Kharagpur721302, WB. 'Investigation of Liquefaction Failure in Earthen Dams during Bhuj Earthquake'** Damaging effects of Bhuj Earthquake on embankment dams have been considered with particular reference to Chang Dam, Fatehgadh Dam and Kaswati Dam. Liquefaction to various extents of the foundation soils underneath these embankment dams during Bhuj Earthquake have been reported as one of the major causes of the distress within these dams. The data presented in this paper indicate that liquefaction within the shallow foundation soils would have been widespread underneath Chang Dam, while that underneath Fatehgadh Dam and Kaswati Dam were relatively localized. This assessment is in qualitative agreement with the facts that the damage to Chang Dam was near total, while those inflicted on the other two dams were relatively less pronounced. The sliding block method was then used to estimate the magnitude of observed deformations. This exercise indicates that the inferred failure pattern and magnitudes of deformation for the three dams are in reasonable agreement with observations.

[7]**Grishin, M. M. Gidrotekhnicheskie sooruzheniia. Mo scow, 1968. Stroitel'stvo, vol. 1. Moscow, 1964.(Entsikl opediiasovremennoi tekhniki.)**Adam built of soil materi als (sand, loam, clay, and so on), with a trapezoidal or nearl y trapezoidal cross section. Earthendams are usually of the fixed type (without the flow of water over the crown); the y are commonly used in many countriesbecause of their si mplicity of construction and maintenance.

[8] **New York State Department of Environmental Conservation Bureau of Flood Protection and Dam Safety.** When the Wachusett Reservoir was constructed at the turn of the last century, the **earthen dams** - or dikes - were intended to remain free of trees and shrubs to ensure their integrity. In addition to the new weir and spillway, the contract calls for raising the height of the existing **earthen dam** approximately three feet by constructing a 12,000-foot-long concrete parapet wall atop the existing dam. Regular monitoring is essential to detect seepage and prevent dam failure. Knowledge of the dam's history is important to determine whether the seepage condition is in a steady or changing state. It is important to keep written records of points of seepage exit, quantity and content of flow, size of wet area, and type of vegetation for later comparison. Photographs provide invaluable records of seepage.

[9] **GUIDELINES FOR THE CONSTRUCTION OF EARTH-FILL DAMS State of Tasmania 2008 .**Population at Risk (PAR) is defined in the ANCOLD Guidelines on Assessment of the Consequences of Dam Failure (May 2000): 'Includes all those persons who would be directly exposed to flood waters within the dam break affected zone if they took no action to evacuate'. and considers: 'Flood depths and velocities are relevant in estimating PAR (generally, an inundation depth of 0.3 metres or more can be used as an indication of the area where the population is at risk)'. When estimating the PAR the following issues should be taken into account: • Groupings of dwellings. • Roads and railway lines. • Camping areas and occupancy times. • Allowance for itinerants (fisherman, bushwalkers, birdwatchers, and picnickers). • River crossing and bridges. • Occupation of schools, factories, retirement homes, hospitals, institutions, commercial and retail areas.

[10] **G S R Murthy1, Katta G Murty2 and G Raghupathy3 1 Indian Statistical Institute, Hyderabad. Designing Earth Dams Optimally** Engineering design of an earth dam is a crucial issue from the view point of safety and economy of construction cost. In this paper we have looked the problem of designing earth dams as an optimization problem. Majority of the dams constructed are earth dams as they are most economical. Factor of safety is an important and mandatory aspect of designing earth dams. The factor of safety is evaluated using slip circle method. This method is most widely used and recommended method for evaluating the factor of safety. As per the mandatory recommendations, the factors of safety should be evaluated under different conditions.

[11] **Wikipedia, the free encyclopedia** Ilding of a dam and the filling of the reservoir behind it places a new weight on the floor and sides of a valley. The stress of the water increases linearly with its depth. Water also pushes against the upstream face of the dam, a nonrigid structure that under stress behaves semi plastically, and causes

greater need for adjustment (flexibility) near the base of the dam than at shallower water levels. Thus the stress level of the dam must be calculated in advance of building to ensure that its break level threshold is not exceeded.[4]Overtopping or overflow of an embankment dam beyond its spillway capacity will cause its eventual failure. The erosion of the dam's material by overtopping runoff will remove masses of material whose weight holds the dam in place and against the hydraulic forces acting to move the dam.

[12] **ACGI Department of Civil & Environmental Engineering Imperial College of Science, Technology & Medicine London, United Kingdom September 2013** Many earth dams around the world are located in zones characterized by moderate to high seismicity. Their seismic stability can be particularly critical for the safety of the areas in the downstream side and therefore an in depth understanding of their response during earthquakes is required.

[13] **Bhyravamurth, Panthragadi, "Design and construction of earth dams." (1949).**The dam is to be constructed as per the design and the specifications. The compaction is attained by the mechanical effort at the optimum moisture content. The mechanical effort is influenced by the type of roller, its weight and the number of passes. Field control is affected by vigilant supervision, needle penetration, ring test and sand test. The construction is to be carried out according to a plan of seven stages.

[14] **E. Yıldız & A.F. Gürdil Temelsu International Engineering Services Inc., Ankara, Turkey. Review on Seismic Design of Concrete Gravity or RCC Dams** It is not economical to increase the strength requirements because of the stress concentrations at areas where abrupt geometry changes are inevitable. There may be considerable permanent displacements along the assumed cracking surface in case of MDE loading. However, these deformations and the relevant damage may be considered as acceptable where the inelastic behavior is evaluated in a realistic way by advanced analysis methods, and the stability of the dam or critical blocks are satisfied during and after the earthquake considering the post-earthquake material and load conditions and possible aftershocks.
[15] I found very helpful the book '' Irrigation Engineering and Hydraulic Structures '' written **By Santosh Kumar Garg** .In this book writer has given very comprehensive analysis and design methods and in evaluation of various forces encountered by a dam in its service periods.

[16] The book '' Irrigation and Water Power Engineering '' written By **Dr. B. C. Punamia** is found very useful the detailed discussion about the design of filter materials which is helpful in controlling the failure due to seepage .

[17] I also found helpful the book '' Fluid Mechanics and Hydraulic Structures '' written By **P.N. Modi and Seth.** The writer has given very elaborate materials about the various liquid forces enacting on the various surfaces**.**

Results and discussions : --- By Reviewing of the findings and conclusions of the various reputed researchers, it could be understand the importance of site selection, structural designing, selection of appropriate materials and various aspects related to gravity dams construction specially earthen dams .

The guidelines laid down by Tim Stephens about the design and construction of earthen dam is found very useful. He restrict to the construction of earth dams no higher than 5 m from streambed to finished crest level. Dams on catchment areas exceeding 25 km^2 or with reservoir areas storing more than 50 000 m^3 may require the advice of a hydrologist to assist in the design of spillways and other outlets and for the estimation of freeboard.

It is also found useful the suggestions of Grishin, M. M. Gidrotekhnicheskie sooruzheniia. Moscow**,**a bout the type of section of earthen dam and materials to be used for the construction of the dam.Adam built of soil materials (sand, loam, clay, and so o n), with a trapezoidal or nearly trapezoidal cross section. E arthendams are usually of the fixed type (without the flow of water over the crown). It is relevant to collect the data required for calculating the PAR value as suggested in Guidelines for the Construction of earth-fill dams state of tasmania 2008 **.**While estimating the PAR the following issues should be taken into account: • Groupings of dwellings. • Roads and railway lines. • Camping areas and occupancy times. • Allowance for itinerants (fisherman, bushwalkers, birdwatchers, and picnickers). • River crossing and bridges. • Occupation of schools, factories, retirement homes, hospitals, institutions, commercial and retail areas.

It is relevant here to mention the work carried out by Murray Fredlund1 , Ph.D., P.Eng., HaiHua Lu1 , M.Sc., and Tiequn Feng2 , Ph.D., P.Eng. Shell Albian Sands, Ft. McMurray, Alberta, Canada on topic 'Combined Seepage and Slope Stability Analysis of Rapid Drawdown Scenarios for Levee Design' in which They concluded that The strength of levees can be affected during fluctuations in the water table. It is also possible for the climate to have an influence on the position of the water table in an earth levee. Traditional methods have resulted in approximate methods for dealing with the transient fluctuations of the

water table in a levee. These approximations are generally accepted in engineering practice but the question can be rightfully raised as to how these approximations compare to a rigorous transient combined seepage and slope stability analysis. There are new questions that can be asked. Does an effective stress analysis diverge significantly from the 3-stage Duncan (1990) analysis? The primary difference is related to consideration of transient pore water pressures in the slope stability analysis. A secondary influence is the effect of geometry on the flow regime in an earth dam or levee. As a general note the total stress Duncan et al. (1990) 3-stage analysis seems to be conservative. There is an opportunity to more closely simulate soil behavior with respect to time and thereby optimize the design of levees with the result that there is a saving in costs by utilizing an effective stress analysis**.**

It will also be useful here to quote the study carried out by Raghvendra Singh QIP Scholar, Department of Civil Engineering, Indian Institute of Technology, Kharagpur 721302, WB. On topic 'Investigation of Liquefaction Failure in Earthen Dams during Bhuj Earthquake' and arrived at the conclusions as Damaging effects of Bhuj Earthquake on embankment dams have been considered with particular reference to Chang Dam, Fatehgadh Dam and Kaswati Dam. Liquefaction to various extents of the foundation soils underneath these embankment dams during Bhuj Earthquake have been reported as one of the major causes of the distress within these dams. The data presented in this paper indicate that liquefaction within the shallow foundation soils would have been widespread underneath Chang Dam, while that underneath Fatehgadh Dam and Kaswati Dam were relatively localized. This assessment is in qualitative agreement with the facts that the damage to Chang Dam was near total, while those inflicted on the other two dams were relatively less pronounced. The sliding block method was then used to estimate the magnitude of observed deformations. This exercise indicates that the inferred failure pattern and magnitudes of deformation for the three dams are in reasonable agreement with observations.

By studying a no of researches carried out by the learned researchers we found that they are all concerned to dam design and construction on such a site where there are no water present at work site or the construction site is first vacated by the construction of coffer dam or through sheet piling.

As concern to the dam construction without diverting the water from the river as if specific conditions compel is yet to be explored. I would find perhaps useful the geo textile bags discussed by Rajendra Deshpande, Hindustan Construction Co. Ltd. Mumbai, India on the topic of ''Geo-Textile Sand Container Mattresses (GSCM) Lining For Temporary River Diversion Channels. As A challenge was arisen before us to construct a dam in river Gomti at Lucknow without diverting the water from the river as the specific conditions compel and we found a way to design the same and construct it by using geo bags along with clay and materials required to lay down the filter at the toe of the dam.

Conclusion : -

By studying a no of researches carried out by the learned researchers we found that they are all concerned to dam design and construction on such a site where there are no water present at work site or the construction site is first vacated by the construction of coffer dam or through sheet piling.

A challenge was arisen to construct a dam in river Gomti at Lucknow to fulfill two objectives –

First, to maintain the level of water in river which was already maintained by the gates of barrage to fulfill the need of pumping station situated 9.50 km.on upstream side of barrage. It was decided to construct the dam in somewhere between pumping station and barrage. Obiviously, there was no chance to remove water from the site where the construction of dam was proposed. So the construction had to be executed in somewhat still water and somewhat flowing with little velocity.

Second, to clean the river by Drezing and to execute the work related to river front development downstream from the construction site and it is also required to run the dam at least the time till the development work is to be completed about four to five years.

Obviously a specific condition arises where construction of a dam in river Gomti at Lucknow without diverting the water from the river is required and the construction of a dam without diverting the water from the river is needed to be explored .

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