UNDERGROUND WATER DIVERSION SYSTEM AS A FLOOD MITIGATION METHOD; A REVIEW

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Abstract - *In recent years, we have been aware of the damages caused by flooding around the world. Many states in India have already suffered the consequences of floods. In this situation, it is necessary to try something different from the remedies currently being applied. There are many flood mitigation measures such as modifying homes to withstand flood, constructing building above flood levels, protecting wetlands and introducing plant trees strategically etc. But none of this method seems to be efficient if a large flood occurs. Moreover, the seasonal changes nowadays are unpredictable. An underground water diversion system should be an excellent remedy to an extent. It has various advantages in areas of thickly populated and having buildings where no other remedies could be constructed above the ground.*

Key Words: **Underground Water diversion system, Flood control, Underground tanks, G-Cans**

1. INTRODUCTION

The need for underground water diversion systems and its studies are increasing in the present scenario. Every year, lots of people lose their life due to flooding. While some other regions are battling with shortage of water due to lack of rainfall. Earlier time, the rivers and the runoff runs through the nature and agricultural lands. But due to rapid urbanization, the chances of flooding began to increase as well.

The best possible solution in order to prevent flooding due to a heavy rainfall or storm floods is to build a reservoir. But it is not possible to built in a region which has higher population density and commercial buildings. There comes the utilisation of underground space which have higher seismic and fire resistance. Making use of the underground space for construction offers control over the effects of external environment too.

An underground water diversion system consists of intake facility, diversion channel and storage tank. The runoff can be collected through the intake facility thereby running through the channel and ultimately reaches the storage tank. The storage tank is designed to a capacity which can hold the runoff of a particular region. The water collected can be excellently stored, treated and can be used for various purposes in the time of scarcity of water if needed.

2. WATER DIVERSION SYSTEM

A water diversion is that the removal or transfer of water from one watershed to a different. The term consumptive use is employed to outline diversions and exports, as a result of the water is being consumed while not then returning to its supply. Water diversions are acceptable for analytic construction activities occurring at intervals or close to a water body like stream bank stabilization, or culvert, bridge, pier or abutment installation. They additionally could also be employed in combination with alternative ways, like water bypasses and/or pumps.

2.1 Water Pressure Management

Stavroula et al. [3] in their work mentioned water pressure management during a water distribution network (WDN) may be a key element applied to realize fascinating water quality further as an effortless operation of the network. Leaks manufacture negative effects each operationally and economically for firms. Systems with leaks want a lot of energy pumping to compensate pressure losses and increase the danger of intrusion of contaminants compromising the water distribution quality. These result in high capital investments for system rehabilitation or combat the deterioration of structures.

This paper presents a hybrid, two-stage approach, to supply optimum separation of a WDN into District Metered Areas (DMAs), up each water age and pressure. First stage aims to divide the WDN into smaller areas via the Geometric Partitioning methodology that is predicated on algorithmic Coordinate Bisection (RCB). Their boundaries, inlets and retailers (entrance and exit nodes) are being fashioned mistreatment differing types of valves and the flow meters, so as to enhance pressure management and assist the effective direction of the networks for leakages. The common goal is to optimize the formation of the DMAs so as to facilitate the efficient management of the system and cut back the typical operational pressure even while not putting in Pressure Reducing Valves (PRVs)

The identification and use of various PRVs sorts of behaviors' and influence on hydraulic systems (either for offer, distribution and irrigation) for the management pressures and reduction of leak will be a method for loss reduction program. Therefore, optimizations of a offer system mistreatment PRVs (oriented by management pressures) may end up in effectively cut back in loss within the system thereby improve the service. However, it's clear that the employment of PRVs is extraordinarily effective for dominant water losses and reduction of leak however, ought to be understood as an adjunct for specific things and their indiscriminate use isn't a suggested follow.

2.2 Valves in Water Distribution System

Wu et al. [9] had done a look within the long distance pressure water pipeline system, thanks to beginning or suddenly stopping pumps, gap and shutting of the valve and alternative reasons, flow rates in pipes and pressure can suddenly raise or low, that's severe eruption development. Positive pressure eruption might cause pipelines rupture, water interruption, and harm the equipment; Negative pressure eruption might causes pipelines recessed so water column separation and re-bridging development seems. So as to avoid the hazard of eruption, eruption protection devices ought to be put in pressurized water pipeline. The eruption protection devices are presently primarily air valve, pressure regulation tower, controlled check valves, air tanks, and eruption suppressors and then on.

The flow condition of water pipelines are tormented by tract, buildings and alternative external factors, simple to supply the advanced development of hydraulic transient. A lot of seriously, it will cause the pipeline rupture, water interruption and instrumentation harm, leading to immense economic loss. It's necessary to equip the air valves in actual comes to stop the gas liquid transient flow. Air valve encompasses a straightforward structure, simple installation, low value and not subject to installation conditions constraints, it's been wide employed in long-distance water pipeline. The two stages closing air valve not solely reduces the negative pressure however additionally the positive pressure will increase smaller than the one stage closing air valve. Therefore the 2 stages closing air valve for the cautions in sensible engineering may well be effective. Therefore the programmed methodology may simulate the eruption with 2 stages closing air valve accurately

Gorev et al. [5] they studied a straightforward valve simulation methodology integrable into the world gradient algorithmic program (GGA), which is wide employed in hydraulic analysis of water distribution systems. Within the projected methodology, valves are treated as pipes whose resistance is adjusted within the course of the GGA iteration to satisfy the valve setting. This methodology options a unified approach to pressure management and flow management valves.

Three sorts of valves are considered: flow management valves (FCVs), pressure-reducing valves (PRVs), and pressure-sustaining valves (PSVs). FCVs stop the valve result surpassing its setting worth, PRVs stop the valve outlet pressure from surpassing its setting worth, and PSVs stop the valve body of water pressure from dropping below its setting worth. PRVs and PSVs head to a closed state if the pressure at the valve outlet exceeds that at the valve body of water (reverse flow through them isn't allowed). Check valves (CVs), that stop reverse flow, may be thought-about as FCVs with a zero setting wherever pressure management valves (PRVs and PSVs) and FCVs are sculptured by completely different algorithms, the projected methodology uses a unified approach to PRVs, PSVs, and FCVs: all valves are sculptured as pipes whose resistance is adjusted within the course of the GGA iteration to satisfy the valve setting.

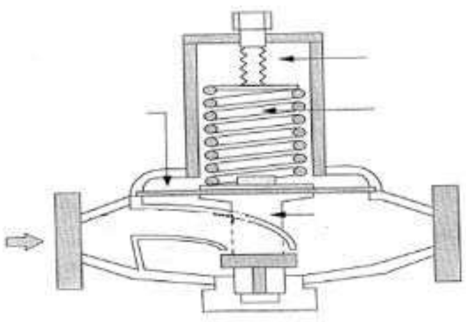

Fig.1 Pressure reducing valve controlled by spring

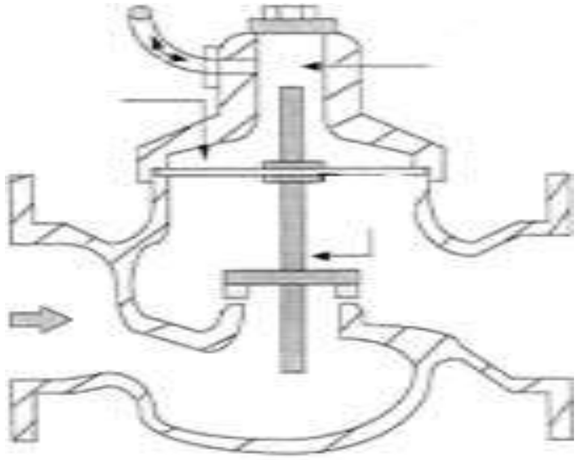

Fig.2 Pressure reducing valve controlled by diaphragm

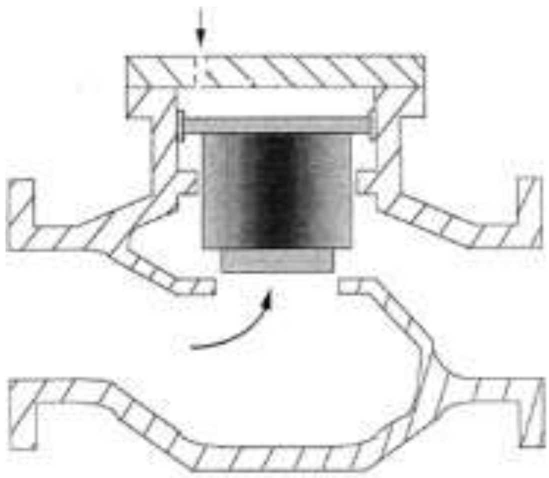

Fig.3 Pressure reducing valve controlled by piston

2.3 Assortment

Tu et al. [2] studied about underdrain. The use and study of underdrain pipes in soil infiltration beds have been extensive in the field of storm water management. Conventionally, underdrain pipes have been mainly used to collect water from the bottom systems or porous pavement System and deliver the collected water to a sewer system or to a river system or storage tank. The underdrain pipe is slightly sloped toward the entrance to facilitate debris removal utilizing gravity.

Chahar et al. **[11]** had experienced infiltration trenches will management quality and amount of storm water from tiny urban structure. The run-off volume determines the scale of associate degree infiltration trench; whereas, whereas the hydraulic conduction of the formation governs the emptying time of the trenches. Solutions derived for the steady saturated ooze state will give a tenet for determinative the specified size of trenches and their spacing/numbers .It is vital to check the carrying capability of the diversion systems, considering the hydrologic uncertainties due to climate change phenomenon .So as to think about these uncertainties, the historical precipitation information of the nearest gauge stations are analyzed, then the precipitation variations within the future are predicted using GCM (general circulation model) information. The runoff of the basin is simulated using rainfall runoff modeling.

A standard diversion system is mistreatment associate degree upstream caisson accompanied with one or additional tunnels. The size of a diversion system ought to be created in an exceedingly method that may safely pass the attainable flood with regular come back periods, and if it fails to try to therefore, the flood damages ought to be reduced. Thus there's a exchange between construction prices and flood damages. The value of diversion works depends, among different factors, on: the tunnel dimension sand the meant tunneling support measures throughout and once excavation; quality and specifications of the rock through that the tunnel ought to be excavated. The size of the upstream (and downstream) cofferdams; the characteristics of the specified waste weir, ought to be designed to divert the floods. Handling pipes for a storm water system as massive as one, 524 mm (60 inches) in diameter will be a drag for each speed and safety. Ancient one, 220 mm (48 inches) diameter Ferro concrete pipe (RCP) is mostly two.44m (8ft) long and may weigh up to four metric tonnes (9,000 pounds).

3. PUMPS

Pumps are used to lift water from underground tanks. They can be motorized or manual pumps operated by hand or treadle. Pumps need better management for operation, maintenance and repair.

4. UNDERGROUND STORAGE TANKS

Tanks can be made in different shapes. Usually rectangular and circular shapes are preferred. Table.1 shows general classification of water tanks

Types of water tanks	
Based on water tank location	**Based on water tank shape**

Underground tanks	Rectangular tank
Tank resting on grounds	Circular tank
Overhead tanks	Spherical tank Intze tank Circular tank with conical bottom

Table.1 Types of tanks

According to **Ignatowicz et al .[1]** for the construction of underground storage tanks, cylindrical tank and rectangular tanks are preferred. Cylindrical shaped tanks with horizontal axis tanks are better than vertical axis tanks. In the case of vertical axis tanks, the load will be concentrated on a small surface area when compared to horizontal axis tanks and will result in settlement of sand or gravel foundation.

Fig.4 Construction of rectangular tank

Fig.5 Circular tank

Steel and RCC are mainly used for the construction. Brick masonry, Ferro cement, mild steel & stainless steel are also used for construction. However, the popularity of polyethylene, thermoplastic, and glass-reinforced plastic (fiberglass) is also increasing. Steel is susceptible to corrosion. Corrosion may be caused by the seepage of water, due to microbiological factors, a high pH and the presence of chlorides. Corrosion can be accelerated if cathode protection is not given. Fiberglass tanks can resist both external corrosion and internal corrosion.

4.1 Concrete Storage Tanks

Concrete water tanks are the oldest among the water tank types. They have a good longevity and are strong. The advantages of concrete water tanks are**;**

- Concrete water tanks have higher durability compared to plastic water tanks.
- They have a good longevity, if they are maintained well.
- They keep water clean and cold compared to plastic water tanks.

4.2 Fiberglass Storage Tanks

Fiberglass storage tanks are one of the most popular media for underground as well as above ground storage for a number of substances from industrial chemicals, to water and fuel, and other liquids. They have a capacity upto 300 tones. The advantages of fiberglass storage tanks are:

- Fiberglass tanks are a more economic than concrete tanks, especially for large to medium capacity systems.
- Fiberglass tanks have extreme durability and tightness. In comparison with other materials, fiberglass provides several benefits, like it doesn't have any structural weakness, doesn't undergo any external or internal corrosion, and doesn't undergo any deterioration over time.
- Fiberglass tanks do not need any waterproofing coating or maintenance program due to its impermeable and mono hull nature.
- Fiberglass tanks are lighter than concrete tanks. This lightness simplifies relocation, installation, and transportation.

Fig.6 Fiberglass tank

Each material used to construct storage tanks comes with its unique set of merits and demerits. The storage needs decides which material is the best fit.

Mati [17] stated that the site of an underground tank should be chosen in terms of adequate catchment size, some gradient and positioning of the tank itself.

A good site has the following characteristics:

- Should be close to the collection point to reduce the length of pipes.
- Ground should be reasonably flat– otherwise it will have to be leveled before marking out.
- Away from places where surface water will gather.
- Away from trees – the roots of trees can be problematic.
- The ground should be suitable for digging, should not have hard rock etc.

Some of the techniques used for building surface tanks can also be used for underground tanks. Excavations is carried out and the soil is back filled around the outside of the tank on completion.

4.3 Materials used for construction of RCC underground tanks

Mati [17] mentioned that control over the quality of construction materials is necessary in the construction of successful water tanks. Cost and availability of materials are also to be considered.

- Cement: it is necessary to maintain the right proportion while mixing cement with other construction material.
- Water proofing cement: Water proof cement helps in sealing tanks, but it dries too quickly in hot and dry climates making fine cracks in the sealing coat.
- Sand: The main requirement on sand is that it should be free from organic or chemical impurities that would weaken the concrete.
- Aggregates: It should be very hard with rough surface for a good bonding with other material.
- Water: It may not have to be necessarily very clean for mixing with and curing cement but saline water should never be used for construction.
- Reinforcement: The main requirement is that they can be handled easily, and that they are flexible enough to be bent.

4.4 Cement Based Mixtures

The preparation of a high-quality mixture of mortar/concrete from cement, aggregate and water is one of the most important stages in building water tanks. The following the basic rules for mixing and applying mortar and concrete. The strength and water proof properties of tanks will be greatly reduced; leading to cracks and leaks if this is neglected

- Cement, sand, aggregate and water should be mixed well, without adding too much water.
- Mortar should be applied while fresh.
- The cement work should be cured properly by keeping it moist for at least three weeks.
- Mortar and concrete should be mixed in the right proportions, which vary depending upon the tank component.

Water should be added to the dry mix when everything else is ready for application. This helps in making use of the cement mixture while it is fresh. Water should be added just enough to make the mortar/concrete workable.

5. DESIGN ASPECTS

When it comes to the design of underground water diversion system emphasis is to be given to the design of the underground storage tank. A safe design is crucial for the long term stability and performance of any structure. It's very important to have an immense knowledge on its positioning, design methods, uplift prevention, ideal geometry etc. Designing of an underground water tank is different and more critical than the design of a tank resting on the ground as they are exposed to both hydraulic as well as earth pressure. Here depicts some aspects to be considered while the design of an underground water tank.

5.1 Geometry or shape of the tank

Alfanda et al. [6] carried out a comparative analysis of rectangular and circular reinforced concrete tanks based on economical design perspective. The analysis and design of circular as well as the rectangular tank were carried out in accordance with BS8007 code. A factor of safety of Uf=1.4 for liquid loads and concrete of grade C30 with a maximum water to cement ratio of 0.55 were used. A minimum cover of 25mm and a bar spacing of 300 mm were adopted. The results were presented in form of distribution charts. The fig.7 shows the concrete volume distribution of both tanks having same capacity.

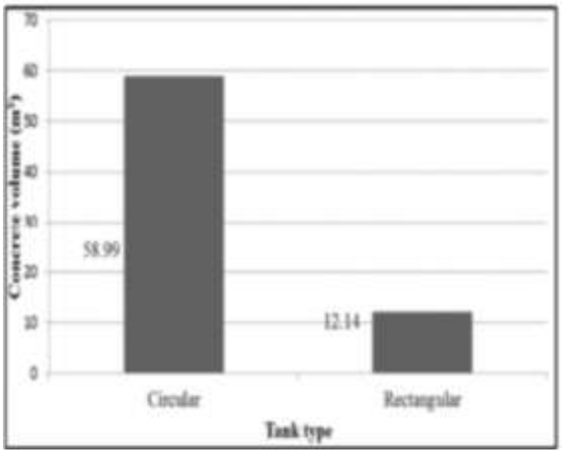

Fig.7 Concrete volume distribution

From the chart it is evident that the volume required for circular tank is higher when compared to the rectangular tank. Therefore it is advisable to use rectangular tank in terms of cost but in case of resistance to all pressure exerted circular is the better option.

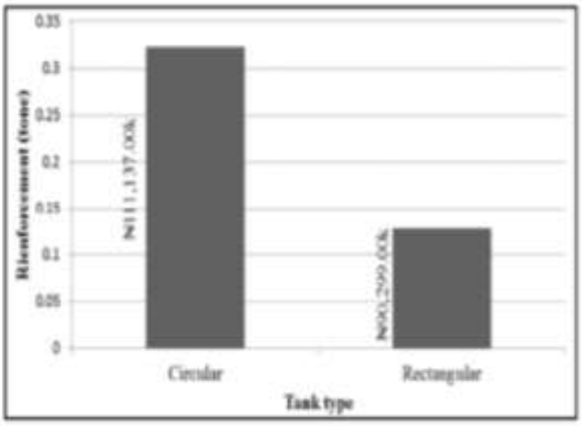

Fig.8 Reinforcement distribution

Fig 8 shows the reinforcement distribution chart, it reveals that amount of reinforcement tonnage for circular tank is higher.

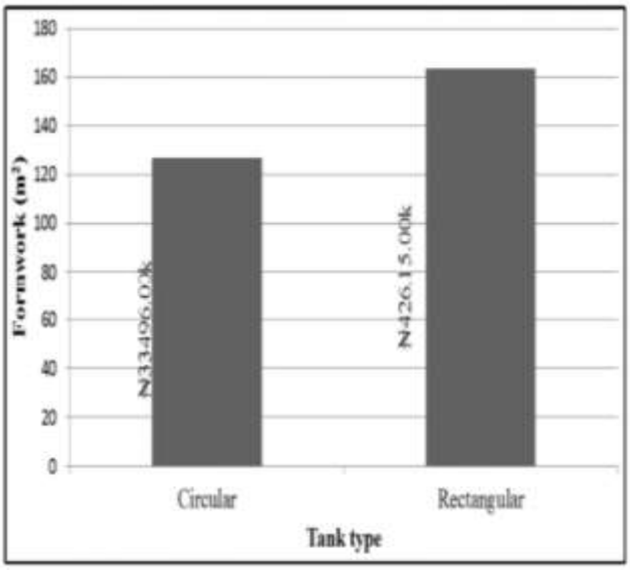

Fig. 9 Formwork distribution chart

Fig.9 which is the formwork distribution chart shows that the amount of formwork in meter square is higher for rectangular tank. In conclusion circular tank possess greater amount of concrete and reinforcement where rectangular tank possess greater amount of formwork.

Generally the construction material output for all water tanks will be based on the choice of the design consideration, with the size of their structural elements. Hence there exists possibility of having an equal capacity and similar geometrical shaped water tank but with some measurable difference in the material requirement. It can be clearly seen that the material needed for the construction of rectangular tank is comparatively more than that required for a circular one but the ease of construction is difficult in circular than rectangular.

5.2 Design philosophy

Jindal et al. [12] carried out a comparative study of design of water retaining structures using Working stress and Limit state method. The study was carried out mainly on two types of tanks, that are; i) Tank resting on ground ii) Elevated tank. For the purpose of study three tanks were selected. First one was an Intz type of tank having about 1 million liters capacities, then a rectangular tank designed to store 2500 kiloliters of water and finally a square tank having an inner dimension of 7.5 x 7.5 x 2.65. The design of the tank was carried out in accordance with IS 3370 (1965) and IS 3370 (2009) for working stress method and

in accordance with IS 3370 (2009) for both Limit state of collapse and Limit state of serviceability. The results of the study showed that the size of members as well as the requirement of steel reduced for Limit state design method by IS 3370 (2009) when compared to working stress design method of both IS 3370 (1965) and IS 3370 (2009). Hence it was found that the provision of reinforcement through the surface zone in IS 3370 (2009) provides economical and more effective reinforcement.

Bagath et al. [4] in their work carried out a comparative study of design of a rectangular tank using the old and new provision of IS 3370. The studies emphasis that the working stress method incorporated limited cracking width whereas the limit state method considers the materials according to their properties treats load according to their nature etc. The results of the work shows that the design of water tank as per IS 3370 (2009) by limit state method is more economical when compared to design as per IS 3370 (1965) by working stress method. Area of steel for reinforcement reduces in limit state method. The thickness of wall and the size of member of ring beam also decrease in limit state method. Hence limit state method proves to be more economical.

5.3 Uplift prevention

Kapadia et al. [7] carried out a study on design analysis and comparison of an underground rectangular water tank using STAAD Provid8 software. The study mainly included the design of the underground tank and also commented on the mechanisms to be adopted if the design criteria are not satisfied properly. The design was carried out in STAAD Provid8 software and the user defined data like span, load and grade cement and steel were the inputs. The design was carried out for two tanks having different dimensions. The first tank was designed to have a wall thickness of 450mm and a floor thickness of about 750mm, whereas the second tank was designed with a wall thickness and floor thickness of 200mm and 400mm respectively. All other dimensions remained the same.

Fig.10 indicates the comparison of two tanks. The result showed that there would be failure due to uplift for the tank having smaller dimensions in terms of thickness of slab and walls. The paper points out that this failure due to uplift cab be prevented by adopting measures like increasing floor thickness, use of plain concrete inside tank above and below the RC floor, use of toe to increase soil weight and the use of tension pile.

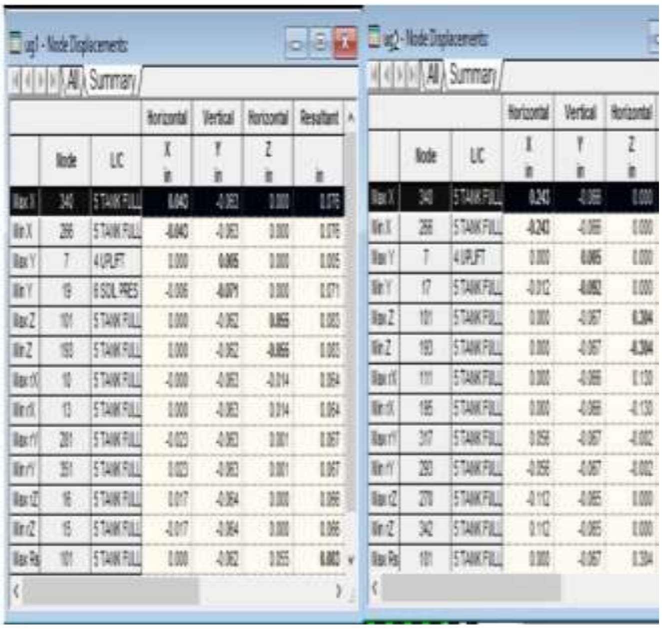

Fig.10 comparison between two tanks

Darwish[13] studied the use of arched cables for the fixation of underground tank against uplift which might be developed by the rise of water table. Conventionally the uplift is prevented by increasing the self weight of the tank or by providing a raft foundation supported by several piles. But both this solutions are not applicable for large size tanks due to increasing amount of uplift pressure and the corrosion tendency of pile. Hence Darwish presents an arched cable system provided to a rectangular tank to prevent the uplift. As uplift pressure acts as a uniformly distributed load on the tank floor in order to prevent the uplift the two long walls have to be kept in position. In order to provide the curved cable parabolic duct is provided inside the long walls. Then a high tensile steel cable was passed through this duct. Each ends of the cables need to be well anchored to a soil anchorage.Fig.11 shows the typical arrangements of the curved cable system.

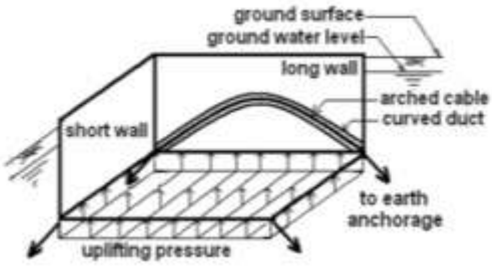

Fig.11 Arrangement of curved cable system

The results of the study showed that the use of two earth anchored curved profile cables in a system known as the arched cable system would prevent the uplift of the tank. The parabolic shape of each cable can exert a uniform downward force on the two long walls of the tank. The amount of the linear downward force exerted can be well calculated to counter the uniform uplifting pressure which would cause the failure of the design. Suggested system can also eliminate the use of the current disputed pile foundations.

6. CAUSES OF UST FAILURE

According to **Nadimet al**. **[15]** main causes of failures are poor installation, loose fitting, corrosion in tank and their pumping system, movement of tank due to land subsidence etc. The common cause of cracks in structures and linings is the errors in mixing and applying the cement. It is important that only pure ingredients are used like clean water, clean sand, clean rocks. The materials have to be mixed very thoroughly. The amount of water added during mixing needs to minimal, the concrete or cement needs to be just workable. It is essential that the cement or concrete is kept moist at all times during curing for at least a week. It should be covered with plastic, large leaves or other materials during the curing period, and kept wet regularly.

7. REGULATOR CUM BRIDGE

Praveena et al. [10] studied the development of Regulator Cum Bridge (RCB) may be a utile project. The most objective is to evolve enough storage for irrigating the gross space and for meeting the drinkable provide. Also for the effective management of saline water intrusion into the upstream facet of regulator. Besides, the watercourse once bridged connecting the 2 banks, can improve the communication facilities and also the employment opportunities therein space. Barrage or RCB uses radial or sluice gates to manage and lift water levels in their upstream reaches of streams and irrigation canals with delicate slopes. Water analysis and field survey were conducted for evaluating the result of RCB on soil characteristic and water quality. Though RCB has range of positive impacts in terms of bar of saline water intrusion, increase in spring water table, increase in space of production, improved transportation and communication facilities, has range of negative effects conjointly on the upstream facet of it. The results of this study reveals that a radical Environmental Impact Assessment (EIA) of the regulator cum bridges are to be conducted to assess the negative impacts on the upstream facet of it and applicable corrective / remedial measures are to be taken to beat these negative impacts.

Fig.12 Chamravattam bridge

8. G-CANS PROJECT: A Case Study

G-Cans Project or the Metropolitan Area Outer Underground Discharge Channel is the world's largest underground water diversion system made by man. In order to hold off the increasing amount of rain that falls on Tokyo every year, this massive underground system was designed to channel inundating waters. The project's aim was to protect the city of Tokyo from floods during typhoons and heavy rainfall. The components of the system include five huge silos, a 6.5 km connecting tunnel, a storage tank and pumps. The five containment silos which made up of concrete are 65 m deep and 32 m in diameter. The silos are connected to a 10.6 m diameter tunnel which is constructed 50 m underground. The tunnel sends the water when the silos are fully occupied to the storage tank. The water storage tank is 25.4 m high and 177 m long. It is supported by 59 pillars which are 20m tall. The storage tank is connected to 14,000hp turbines and 78 pumps. These turbines have an ability to pump 200t of water a second and draining into the Edogawa River.

Fig.13 Metropolitan Area Outer Underground Discharge Channel

8.1 Necessity and Objectives

Around 30 percent of Tokyo's population was living below sea level and are affected by the flooding. It became the national priority of Japan to protect the economy and inhabitants of the capital city. As reservoirs cannot be built due to the population density of Tokyo, the best possible solution was to build an underground water diversion system.

The objective was to take all the flooding waters before it causes damage using its containment silos, diversion tunnel and huge storage tank. It can also pump water at a speed of nearly 200 cubic meters per second.

8.2 Working of the G-Cans Project

There are a series of 5 giant silos built into the ground which are designed to collect the runoff and overflow from nearby rivers. When the water entering the silos are beyond the capacity, it flow through the 6.3 km tunnel and reaches the underground storage tank. The water is stored here and when needed, it pumps the water out into river at a rate of 200 meter cubes per second using its turbines.

9. CONCLUSIONS

Underground water diversion system proves to be an ideal solution for the flooding due to excess precipitation.

- Underground space is characterized by excellent sound insulation, seismic as well as fire resistance.
- It involves less utilization of valuable land.
- Huge storage reservoirs can be constructed underground.
- Such flood prevention methods also offer the possibility of reuse of water after proper treatments.

Meanwhile it also possesses some difficulties in their establishment;

- Renovations of the underground facilities that have been previously built present a major issue.
- If a variety of underground facilities are constructed in a complex manner and a large number of people use such facility, comprehensive measures for disaster prevention are essential.

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