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Saving the Blue Planet

(How membrane and spatial structures can preserve our precious water resources)

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Abstract

Water covers 70 % of our planet's surface and is vital to its survival, but water is becoming an increasingly rare resource. The conundrum is that the earth's population continues to expand, but the amount of potable water is becoming severely limited. Aggravated by the effects of global warming, fresh water is evaporating into the atmosphere at faster rates and is cycling back to earth where it is not necessarily needed; a small amount that dissipates into the atmosphere is lost forever.

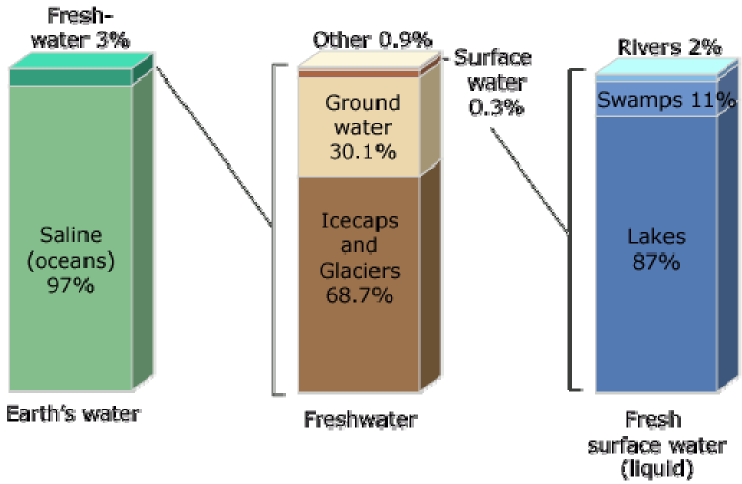
As engineers and designers, we are equipped to create structures that contain water efficiently and help prevent its evaporation. Spatial structures and tensioned membrane structures are ideally suited to this task. This paper explores both the problem of water scarcity and the potential solutions for protecting this most vital of resources.

Keywords: concrete shell, spatial structure, membrane structure, tension structure.

1. Introduction

Billions of years ago, icy comets passed through the inner solar system flying near the planet we now call earth. The heat from the young sun caused water to boil off these comets and become trapped by the earth's gravity. This unique event is widely believed to be the reason that 70 % of our planet's surface is covered with water and we are called the Blue Planet. When life first appeared on earth, it did so because of the presence of water. No other planet in our solar system was as lucky. In exploration of other planets, we have found only barren wastes or poisonous atmospheres. Water, then, is the key to our development and our survival. In the distant future, six billion years from now, our sun will become a giant star with a power output five thousand times greater than today. Our oceans will boil off, and earth will become a hot rocky planet no longer fit for human habitation. We don't really have to worry about that distant future, as we have more immediate concerns.

Of all the water on the planet, only 3% is fresh water; the balance is saline ocean water. Of the fresh water, two thirds is trapped in ice caps and glaciers leaving only one third available for our use. But even that is not the end of the story, because this small remainder is available both as ground water and surface water in lakes and rivers. The bottom line is that very little water is available for human use and of the available fresh water, 70% is used for agriculture (with cultivation of rice, cotton, and sugar being the most water intensive). There are more than six billion people in the world today. A billion of them lack access to fresh water and almost three billion lack adequate sanitation facilities. Considering that each of us needs about 30 liters of water per day to survive, where will we continue to obtain this required water, especially in light of the fact that by the end of the century our population is expected to grow to ten billion?



Distribution of Earth's Water

Looking at the world from space, those areas with the greatest population growth--Africa, Southeast Asia, and the Southwestern area of the United States--are in the greatest danger of suffering from water scarcity. "Water will be ***the*** defining issue of the century," according to Prof. Natasha Iskander of NYU. "While we have enough land to feed the world's growing population, we may not have enough water unless we discover new ways of using it much more efficiently." There is no question that the water crisis is partly the result of the current global warming trend, but that is too easy an answer. The reality is that we waste a great deal of water and do not treat it as the precious commodity it is. Consider the following:

- In the western United States, water is transported hundreds of miles from the lush north to the desert south to support wasteful water-intensive agriculture (spray or channel irrigation rather than more frugal drip irrigation). This water is also captured behind dams to feed cities in areas that would not otherwise support life. Lake Powell behind the Glen Canyon Dam took 17 years to fill after it was completed in 1966 and is now rapidly drying up as a result of a long-term drought (it is now at 60% of capacity). The city of Las Vegas depends for its very existence on the waters of Lake Powell and may soon find itself unable to supply its growing population with fresh water.

- "Most of the world's major waterways have been diverted or damned or otherwise manipulated - in the United States, only two percent of rivers run unimpeded - and people now use half the world's readily accessible freshwater runoff." This quote is from a recent article, *The Sixth Extinction,* by Elisabeth Kolbert, who suggests that man is responsible for the sudden die-off that will eliminate half of the world's current species and shortsighted water management is partially to blame.
- Silting of dams worldwide, such as at Egypt's Aswan dam and China's Three Gorges dam is expected to reduce their long-term capacity and effectiveness. Reversing the damage caused by the indiscriminate construction of thousands of dams worldwide over the past century will itself require a massive, costly effort. Also, as a result of global warming, the shrinking glaciers in the Alps, the Andes, the Himalayas and Africa's Mt Kilimanjaro will lead to a reduction of water runoff and cause drought in the populated lower plains.

Unfortunately, once people are convinced that there is reason for concern, they are not always logical or scientific in coming up with solutions. Impressed by the fact that much of the available fresh water is locked up in Antarctic ice, an entrepreneur in one of the Gulf States suggested towing an iceberg to their country and parking it in a manmade basin, where it would provide an ample supply of water for a year. This folly of an idea reminded me of Ernest Hemingway's story of the *Old Man and the Sea.* In it, the old sailor, Santiago, hooks a marlin and after fighting for days to reel it in, ties it to the boat, but on the way home, the bleeding fish is devoured by sharks and only the skeleton remains when he finally arrives in port. Realistically speaking, I suggest that we forget about using icebergs to satisfy our thirst.

2. Innovation

Scientists have recognized for a long time that billions of people do not have access to fresh water for drinking and sanitation. Dean Kamen, the inventor of the gyroscopic controlled Segway scooter, is one scientist/inventor who is doing something about the problem.

Kamen realized that there were really two problems that needed to be solved: how to turn brackish water into potable water, and how to power the device when no electric power was available. His cleverly named solution, Slingshot, invokes the story of David and Goliath, but in this instance Sling is a Stirling engine power source and Shot is a vapor-compression water distiller. Each is housed in its own "black box". The generator provides 200 W @ 20% efficiency and can run on a variety of fuels, including cow dung, which makes it ideal for use in Third World villages where the need is greatest. Also it provides 800 W of waste heat, which can be used in the filter. The distiller makes 100 liters per day of clean water from waste water in a machine that doesn't need osmosis membranes or activated charcoal. In fact it requires no consumables whatsoever and is therefore ideally suited for use in isolated locations. Both components have been tested and work beautifully. They only need volume demand to make them economically feasible.

Water management has added a new word to our vocabulary: *hydropolitical.* It encompasses, for instance, development of the watershed of the Jordan River, which is vital to both Jordan and Israel and is perhaps one of the few issues that have led to cooperation between the two countries. This is by no means a unique instance of cross-border problems created by waterways that spill over national or regional boundaries as illustrated by the following list of similar challenges:

Hungarian Dam Controversy
San Diego Tijuana Water Problems
Ataturk Dam and Environment
Colorado River Dispute
Israel/Jordan Water Dispute
Lesotho Water Exports
Mekong River Dam
Baikal Wood Pulp Pollution

James Bay Project
Aral Sea Loss and Cotton
The Los Angeles Aqueduct and the Owens and Mono Lakes
Israel and Lebanon's Conflict over the Litani
Nile River and Conflict
Danube Pollution
Assyrian Water Warfare
Dead Sea Canal

All of these controversies relating to the use of precious water are either ongoing or only partly resolved.

3. Opportunities

How can we as engineers contribute to solving some of these water-related problems? Apart from doing whatever we can to alleviate the current global warming problem which, as we had mentioned above is partly responsible for the stress on our water resources, there are clearly areas of investigation that are worth pursuing. The most promising are:

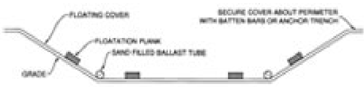
Cisterns
Reservoir covers
Water canals and piping
Desalinization
Filtration
Windmill pumps (tensegrity windmill?)

For this audience, the issue can be rephrased: how does the water crisis intersect with shell and spatial structures? Reservoir covers offer the best opportunities for innovation, as every town or city in the world has to minimize evaporation of its water supply and to prevent the introduction of contaminants into its water storage facilities. Birds treat reservoirs as their natural habitat and pollute the water with fecal matter and even disease-causing germs. New York City faced this issue a number of years ago when it was given the option by the health authorities of either providing filtration of the principal water reservoir for the city or providing a cover for it. As the cost of filtration was extremely high, the option of a reservoir cover appeared attractive.

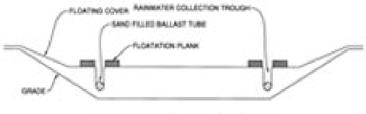
Many reservoirs in the past have relied on concrete covers, essentially placing the reservoir underground. This type of solution is very costly and introduces a forest of columns into the reservoir. An aluminum dome supported by a reticulated structure, is another possible design solution, but it can only be used to cover reservoirs that are circular or at least oval in plan.

As most reservoirs are not regularly shaped, another option is to use a floating cover, or flexible membrane, made of polypropylene, polyethylene, or a combination of materials. The membrane must be resistant to UV radiation and suitable to the unique environment where it is to be installed. In cold weather, when ice can form, the cover may be subject to bending and twisting caused by water-level fluctuations and ice movement. Reinforced membranes have been designed using Hypalon, high density polyethylene, or a number of composites with Dacron fibers and complex filler compounds, to solve some of these problems.

Cleaning the surface of debris and standing water is another problem with such covers. The introduction of troughs for water collection and wash down, as shown below, is one possibility.



COVER SECTION WHILE RESERVOIR IS EMPTY



COVER SECTION AFTER RESERVOIR IS FILLED

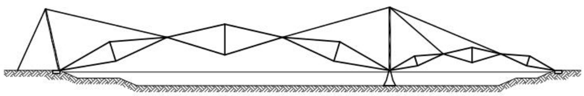
Air-supported tension-fabric roof.

In a study for a cover for New York's Hillview Reservoir, a number of alternative configurations were considered. The reservoir covers 365,000 m^2 and is divided with a concrete wall into two sections, so that one section may be cleaned while the other remains operative. The irregularly shaped plan results in maximum spans on each side of the dividing wall of 290m and 114m. Objectives of the study were to design a cover that:

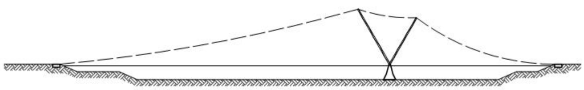
- Presented minimum maintenance requirements
- Was self-cleaning, vermin-resistant, easily repaired, and durable
- Was aesthetically pleasing and contextual to its urban environment
- Had minimal impact on air and water quality and on fish and wildlife
- Was economical and provided the least impact from construction

Several alternatives were considered:

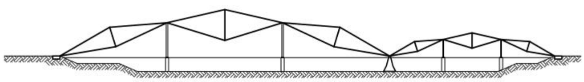
- Tower-supported Tenstar cover
- Cable net cover
- Posted Tenstar® cover
- Air Supported Cover



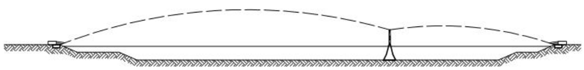
TENSTAR



CABLE NET

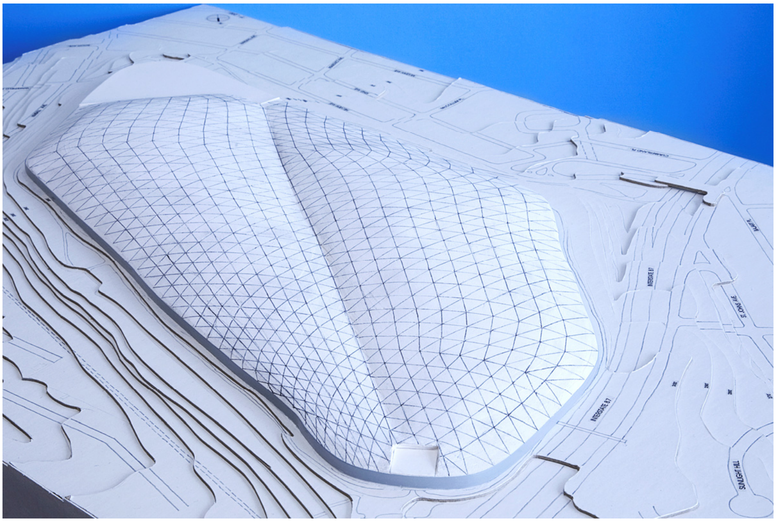


POSTED TENSTAR



AIR SUPPORTED

The results of the study showed that an air-supported fabric cover best satisfied the objectives. This scheme required the development of anchorages on the east and west sides of the ring beam circling the reservoir and the construction of a series of posts on top of the dividing wall. Also included were a series of ten inflation units designed to maintain pressure under the roof in normal conditions as well as in high wind or high snow situations. Normal seam and joint leaks were assumed, as well as leakage due to accidental damage or loss of a fabric panel. For efficient construction, it was contemplated that barges on the reservoir could be used to assemble the cable net.



4. Conclusion

In the distant past, Greek, Indian and Chinese philosophers independently recognized the existence of our planet's four classical elements: earth, air, water and fire. Today, mankind is well on its way to destroying three of these. We abuse the earth with litter and indiscriminate mining, pollute the water with chemicals and waste, and poison the air with greenhouse gases. The fourth, fire, escapes our wrath but, even though it provides us with light and heat, it is itself a destroyer; burning down our forests and homes and using precious oxygen in the process. Clearly, our planet is out of balance, and the first problems that we must address are political and psychological--apathy, obsolete government policies, and ingrained habits and attitudes—before we can redirect mankind and forge a new environmental consciousness. Some of these issues have penetrated our consciousness and made us aware of problems and solutions. In the past few years, we have focused our attention on the issue of global warming. For instance, we are aware of the destruction of the earth and have initiated recycling to reuse materials torn from the earth and rehabilitation to repair the damage caused by mining and deforestation. Moreover, there is now general consensus that a problem exists, that we are the cause of the problem, and that we must take action to change the way we use and dispose of carbon products to return the planet's atmosphere to a balance that existed a century and a half ago. The issue of water conservation is only now coming into focus and this paper is meant to sound the alarm for water conservation and get out the message that there is much work to be done by motivated scientists beyond forecasting our doom.