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ECONOMICAL DESIGN OF FLOATING BRIDGES

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***Abstract*— Economy in construction is the ultimate need for today, so we go for suitable structures to fit the purpose. Pier-less bridges are not new to this world. During the Chola period for their invasion across rivers, they made use of trained elephants that swim on the surface, over which they transported all elements of battle by laying planks over elephants. Similarly in China, pontoons which float due to buoyancy similar to elephants used in chola period. This paper also includes floating bridges which are pierless and whose design has been modified to withstand more load and achieve more economy. These bridges are made of suitable concrete sections and are continuous in length so that they could connect island and mainland even over sea which eliminates the cost of pier and makes the bridges more economical.**

Keywords- pierless, buoyancy, floating bridges.

I. INTRODUCTION

Floating bridges were even built in olden ages with the help of boat like structures as supporting piers at regular intervals and decks were placed on it. Here the entire bridge transfers its load due to buoyancy.

As we propose to built a bridge across a natural drainage like rivers or some obstruction, we have to consider the height of piers constructed above the ground level as well as below the ground level as a part of foundation. When we lay piers for bridges crossing deeper rivers then the height of piers would be very large. Even if the river bed is of soft bed rock then the depth up to which the piers have to be laid under the ground level as foundation is also so high. So as a whole it leads to a large excavation cost for drilling piles under water as well as constructing piers for such great heights. Even if we construct like this we must increase the dimensions of piers drastically to avoid buckling or go for many piers at shorter intervals to reduce the load over the piers. So in order to reduce the cost and make the bridge more economical we go for floating bridges now, which is made of concrete and it floats based on the principle of buoyancy. In this paper more economical section has been designed which will reduce the stress on section.

II. BUOYANT FORCES

When an object is kept in a fluid, the fluid exerts a force in the upward direction called buoyant force. The buoyant force is due to pressure exerted by the fluid on the object. As the pressure increases with increase in depth, the pressure on the bottom surface of an object is always greater than the force at the top surface, which results in a net upward force called buoyant force. The buoyant force exists based on the object's condition whether it floats or sinks. Now consider a floating cube, but we can analyse the same for an object that is submerged.

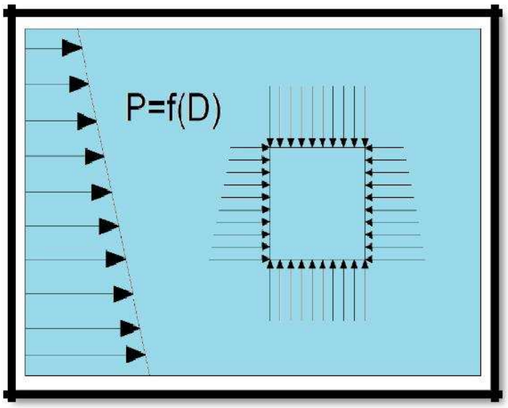


Figure 1

In a cube, although a similar analysis results the same for complicated objects, the object experiences forces on all of its six sides. On each side, force is obtained by multiplying pressure with area of the side and its direction is normal to the same side and acts towards inside of the object. The force on the left side is tricky to calculate because the pressure is different at different levels. Luckily we need not calculate it because this force is equal-and-opposite to the force on the right side. Similarly, the forces on the front and back cancel. The force varies vertically and it is function of depth. As the depth increases force also increases proportionately. Hence we get a larger force at the bottom surface than the upper surface.

III. EFFECT ON VOLUME BY INCREASE IN PRESSUR

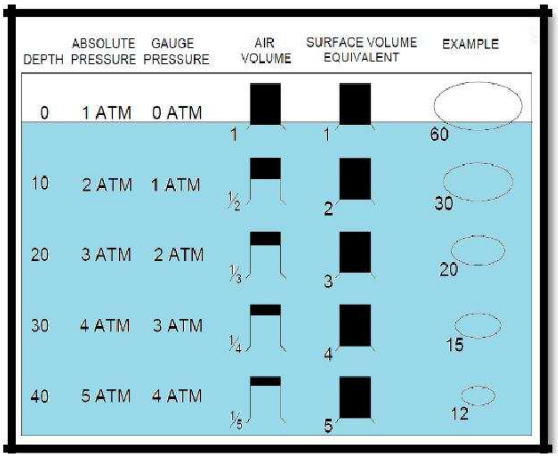


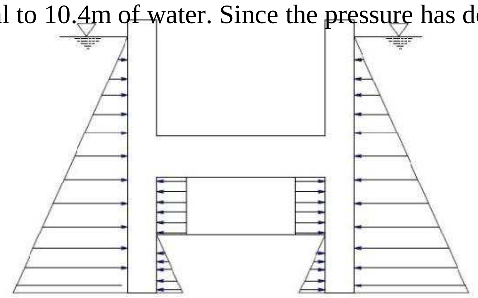
Figure 2

As we go deeper into water, the pressure due to water increases by the equation P=ρgh. So according to Boyle’s law, as pressure increases volume decreases, which is stated as PV=constant. If the air in a container of certain volume is exposed to atmosphere, it would experience a pressure of 1 atm. When the container is immersed to a depth of 10.4m the pressure due to water now is 2atm (since 1atm=10.4m of water). Now the pressure has doubled so that volume has become half so that PV remains still constant. But due to decrease in volume there is no loss of mass instead air in the container is compressed and density of air is also doubled.

IV.COFFER DAMS WITH ‘H’ SHAPED DESIGN:

Figure 3

Fig.3 shows the ‘H’ shaped structure of cofferdam in which the upper portion of ‘H’ makes use of law of buoyancy to float and lower part floats due to the property that air compresses when immersed in water. Coffer dam is a large hollow section which floats based on law of buoyancy. The lower part of cofferdam consists of air initially at 1atmospheric pressure. But when it is lowered into the water at a depth of 10m, the pressure acting on the air increases to almost 2atm which is equal to 10.4m of water. Since the pressure has doubled now



volume should decrease according to Boyle’s law. So now the volume decreases to half and this volume of air exerts a upward force equal to weight of water displaced by the halved volume of air.

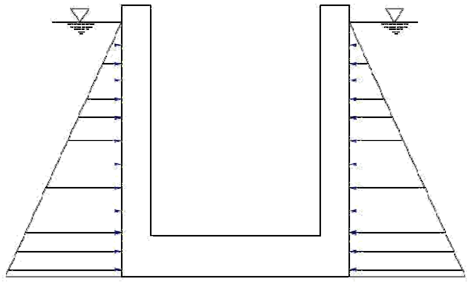


Figure 4(b)

While seeing through the pressure distribution on the walls of a ‘U’ shaped coffer dam (Figure 4(a)), it is just a triangular distribution with max at the base of coffer dam. But in the case of ‘H’ shaped structure the maximum occurs only at the mid half and not at the base. When we construct a ‘U’ shaped coffer dam of height X then the maximum pressure on the walls of coffer dam would be ρgX where ρ is the density of water and g is the acceleration due to gravity. But in case of ‘H’ section (Figure 4(b)), when the total height of the structure is X then the walls of coffer dam would experience a maximum pressure less than ρgX. This reduction in pressure is due to the air acting on the lower side of ‘H’ which would give a pressure in the direction away from the walls and this pressure would try to expand the lower part volume but water outside the lower part tries to compress the lower volume as a result of which stress acting at lower part is considerably reduced and economy is achieved.

Similarly the lower part contains some water upto a certain level which would oppose the force acting on the walls of dam due to water outside the lower part.

This changes in design would greatly reduce the pressure acting on walls of coffer dam as a result of which economy is achieved.

VI.PRESSURE DUE TO COMPRESSED AIR:

In order to calculate the pressure in the lower part volume and the height upto which the water has risen in the lower volume, we have to equate the total pressure at depth D upto which the structure has sunk.

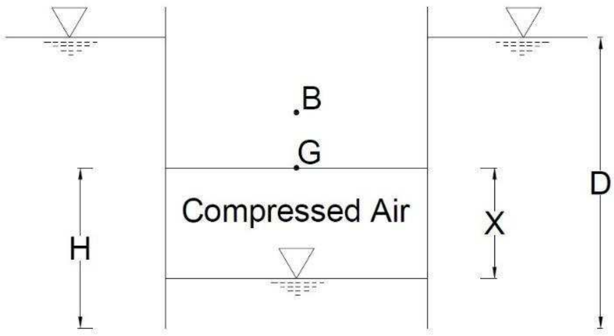


Figure 5

Considering an idealized H shaped section (Figure 5), let the height of air in the lower volume be 'X' and the height of lower volume be 'H'. By Boyle's Law PV=constant. Initial Pressure is 10.3m of water (Atmospheric pressure) and Initial volume is H×A m^3 where 'A' is plan area. Once the section has been immersed into the water, amount of air would have reduced to 'X x A' and let the pressure be 'h' m of water. Now equating according to Boyles's law, we get

$$10.3 \times H \times A = h \times X \times A$$

Therefore the pressure of compressed air in terms of water = ——

According to Pascal's law, the pressure at depth D metre is constant and equal to (D+10.3)m of water.This pressure is equal to pressure in the compressed air h (pressure in terms of head of water) plus (H-X)m of water. Thus equating we get

$$—— + H - X = D + 10.3$$

$$———— = D + 10.3$$

$$10H + HX - X^2 = DX + 10.3X$$

Rearranging, we get

$$X^2 + (D - H + 10.3)X - 10.3H = 0$$

Therefore solving this equation

Since the value of X can't be negative we take only the positive value.

Therefore

and water would have risen in the lower part upto X from the flange of the section. Hence, the compressed air produces pressure to expand the lower part while water outside will compress the lower part, thus compressed air inside reduces the compressive stress acting from outside resulting in economy. In addition to this water which has risen into the lower part would reduce the compressive stress from outside by applying pressure on the inner sides of wall.

Pressure in compressed air =

VII.STABILITY ANALYSIS:

For an H shaped section the condition of stable equilibrium is that, Centre of buoyancy B should lie above the Centre of gravity G. Centre of gravity of the whole section lies at a distance of (D-H) from the water surface. Centre of buoyancy B which is the Centre of gravity of displaced water lies at a distance of ——— from the water surface. The condition of stable equilibrium is that, Centre of buoyancy B should lie above the Centre of gravity G. Hence for stable equilibrium

(D-H) > ——— (refer Figure 5)

But at the time of erection it needs some lateral supports to avoid toppling till its weight and upthrust has been balanced.

VIII.MATERIALS USED:

Steel of grade used in ships which are resistant to corrosion due to water and have good compressive strength can be used here.

The deck of the bridges can be of any type depending upon the strength and life time of bridge.

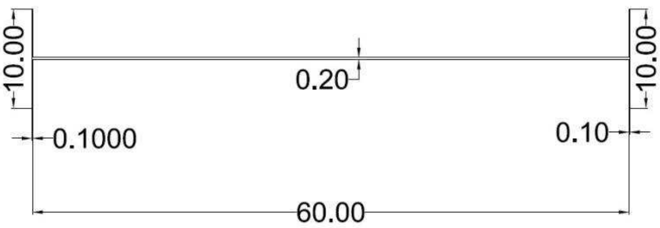
These coffer dams and deck are precast and brought to erection point using heavy ships.

IX.ERECTION:

Coffer dam has to be carried using heavy ships to the place where small piers have to be placed at regular intervals across the coffer dam. Over these piers deck of the bridge has to be placed and the traffic load over the bridge transfers to the coffer dam through the deck and small piers.

Like this we place many coffer dams at regular intervals and decks are placed over it. These decks are connected by tension cables to make it stand still and coffer dams are connected to the river bed by means of tie rods in four directions to avoid toppling of the 'H' shaped structure. The decks are made of pre stressed concrete using these tension cables to provide pre stress and these tension cables are also used connect the decks.

X. NUMERICAL CALCULATION:



Consider a section of unit length: The downward force

due to H section= (60□0.2m)+(10 □ 0.1)(2) = 14m3=14x7850=109.9ton

Volume of compressed air =

D=10m (fully immersed case)

H= (5-0.1) m=4.9m

Therefore X=2.77m

Consider the upward force

due to buoyancy = (5-0.1) ×60m = 294m3 of water

= 294x1000kg of water force = 294 ton force

Consider upward force

due to compressed air = 2.77×60m3 of air

= 166.2m3 of compressed air = 166.2x1000kg of water = 166.2 ton force

Total upward force =294+166.2=460.2ton force Total downward force= 109.9 ton force

Therefore the section can be acted upon by a load of (460.2-109.9) =350.3 ton per metre of section

XI. PERFECTIONS:

Since the stress would be more concentrated at the corners of coffer dam the corners have been filleted to avoid stress concentration. In addition to these perfections, sensors have to be provided to ensure that the volume of air inside the lower part is above a particular level, so that the force exerted by the air in the lower part remains potential.

XII.CONCLUSION

Thus an attempt has been made for design of economical section which could withstand more compressive stress compared to normal boat like structures of Chinese and U shaped coffer dams which float on lakes. This design reduces the stress acting on the structure by opposing the compressive stress and reducing the total stress acting on it, making it to be economical. Hence the capacity of sections to withstand load has improved considerably and it can be used to control the traffic these days. These bridges could be built across large lakes which would avoid a long ride around the river and reaching the other side of lake. Hence it again proves to be economical.

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