So the well was built long way maybe 2000 year olds or more than that and the depth of the well it goes beyond 50 meters, 100 meters and the well is not serving just for a water, also the wells are used many of the times to have a social gathering, the programs also they conduct it. So how they have designed so beautiful well systems in western part of our country.

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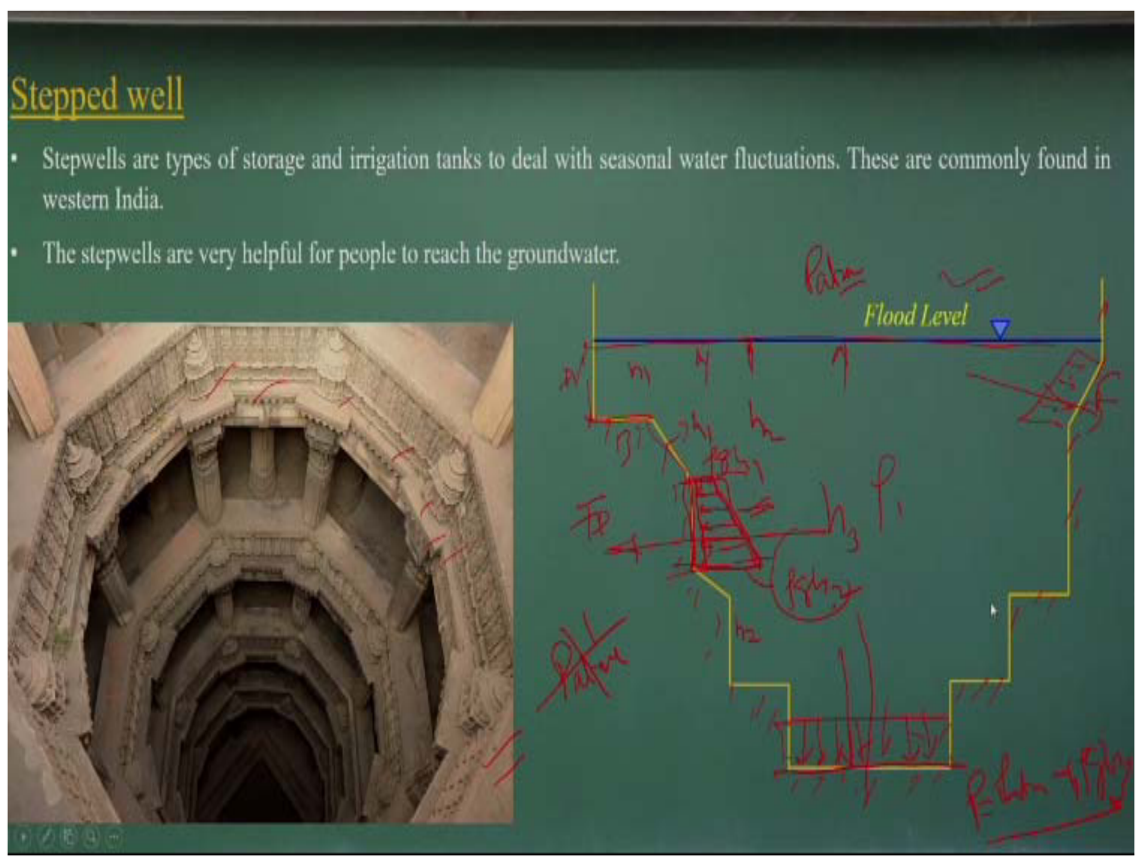


The one of the photographs, what I am showing it the stepwells if you can see it this is a plan view of the step view and there are lot of architecture part and there are the peripheral part. So that means in during these rainy seasons when you have a high rainfalls these well get totally filled up. As it dries off during the summer seasons it goes down and down and down.

So if you look at these the constructions how they have considered the hydrostatic pressure when you have a extreme flow conditions or when you have this well are at the full filled conditions. Like for examples this well is considered let be the flood level here. Now, I am not considering so complex geometry what is there.

If I consider very simplified geometry what I had sketching it here these are there are inclined surface, there are vertical surface, there are may be curved surface are there and there are horizontal surface and all. And these water levels if you can understand it fluctuates okay. During the summer seasons it goes down. During the rainy season it goes up. So it goes up and down with a seasonal variability.

And how they have designed it. What is the water pressure is acting on this surface, working on these surface it is surface A, surface B, one is a horizontal, another is vertical, another is inclined and it could you have the curve nature what is there? There are the curve, the projections and all. How much of water pressure acted when you have a totally the tank while well is in a filled condition.

Very interestingly when design it that means we need to determine what is the pressure force acting on vertical surface, horizontal surface, and the inclined surface. For a horizontal surface like what here it is a very easy. If I have the fluid $\rho_1$ okay and height is $h_3$ pressure at this point is P atmosphere you know it the pressure at this point will be the P P atmosphere plus rho g h 3.

And the pressure distributions will be the uniform as it is the horizontal surface. As it is a horizontal surface you will have a pressure distributions will be uniform and as the uniform pressure distributions. So it will be at the maximum force will be act at the centroid of these surface. As the pressure distribution is uniform the center pressure are where the pressure force is acting on that center the that what will be the match with the centroid of the these surface.

The surface can be a circular, can be elliptical shape, but that what will act on that. So you have the results of that. When you have these vertical surface let we consider this case okay. You can find out that as you know if it is $h_1$ and this is the $h_2$. So the pressure distributions will be the trapezoidal distributions. Because at this point the pressure will come it as $\rho g h_1$. At the point pressure will be $\rho g h_2$.

So this is the what pressure diagram. This is what the pressure diagram as the vertically the $\rho g h_1$ is a pressure at this point and this $h_2$ distance from the top will be $\rho g h_1$and I am neglecting the atmospheric pressure. That what we are neglecting as compared to the pressure what is getting from the water which is you know it much higher value of density as compared to the density of atmosphere, pressure at the atmosphere as compared to that.

So we can get the pressure diagram which will be trapezoidal forms and if I know this pressure diagram, I can compute what will be the total force acting due to this pressure diagram which is a very simplified thing to find out the area of these pressure diagrams, okay multiplied with the perpendicular distance or that what is many of the time we consider unit distance.

Then the area of these diagrams will tell me that what is the force is acting because of these pressures. Now another point is coming it where does this force act, the locations of this force acting is the center of pressure. That the center of pressures we can compute it very easily. That what I will be demonstrate it to you, but when you have an inclined surface also we can determine the pressure diagrams.

As you can find out the pressure will come it as a similar way trapezoidal part and the pressure will be normal to the surface, normal to this inclined surface and that pressure diagram again you can find out the area of the pressure diagrams or you do the integrations that is the same things that you are integrating the pressure diagrams to find out what will be the force acting due to the pressure distributions.

Or again you look it where is the center of pressure at which point this pressure force acts. That is what we look it as a central pressure and many of the times if you look at this beautiful the well, stepwells, our ancient people they well known about these hydrostatic pressures and all and they designed the structure which is existing still now without any damage. So that what indicate us the knowledge on hydrostatics, our knowledge on the fluids.

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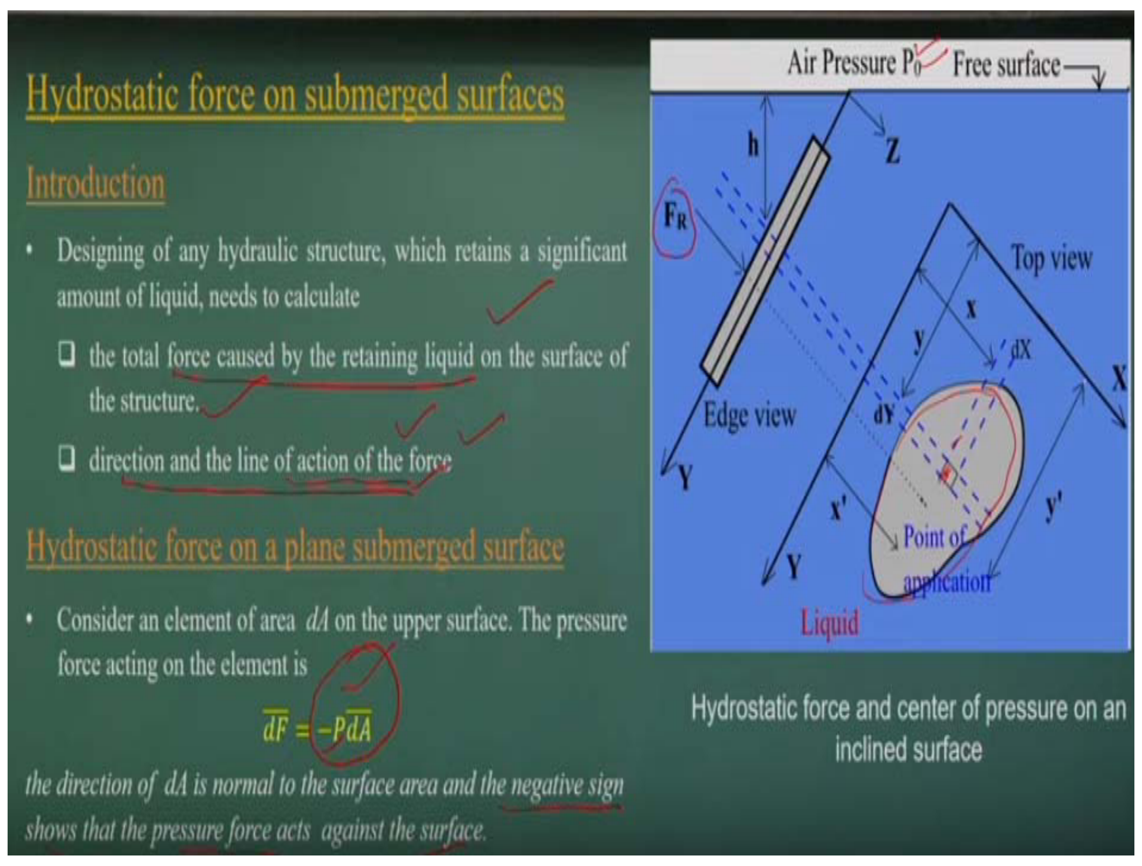


Now if you look it that, let us coming to the derivations of the hydrostatic pressures on a submerged surface. That means surface is submerged in a liquid. So we have the atmospheric pressure acting on that. We have the free surface and I am just putting a surface which is the x and y projections in these directions is it look it from this point you will have an inclined surface which is having this x and y.

This is what very complex shape we have considered it okay. And that is what inclined and is having the h height and we are looking it what could be the force due to this pressure distribution and where does it act. That is what we are looking it. If these two things we know it then we can design these things that what type of material to be used, what type of lifting arrangements will be there, if this is as equal to a get conditions. The submerged plane can be considered as a get conditions.

So total force caused by retaining liquid that what we are looking and directions and lineup for actions as the directions will be always perpendicular to the surface that what the directions and the line of actions what of the force is the center of pressure. Now to derive this part let me consider a small element okay, let me consider a small element. In this small element of the dA if the pressure is P Then P into dA will be the force, pressure into area will be force.

$$\overline{dF} = -P\overline{dA}$$

The negative sign we have considered because considering the normal vectors. If I considering the area that normal vectors and the pressure they have opposite directions. That is the reasons we use the negative sign. The pressure force acts against the surface because surface normal vectors and pressures they are in opposite direction. Because of that we use the negative signs.

Otherwise the pressure acting on this small area of dA will be the force P into dA is a small elementary area what we have considered to derive what could be the total force x acting on this as well as the center of pressure.

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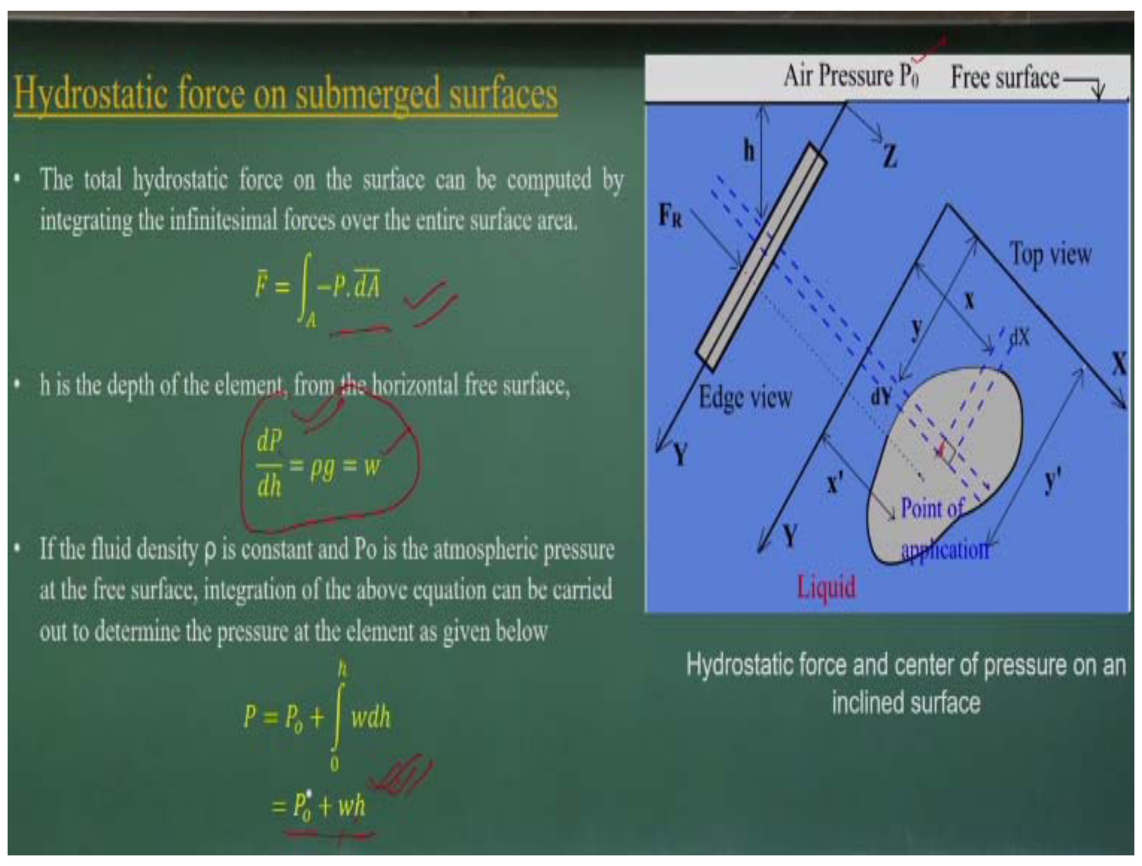


If you look it that, that means to get a total hydrostatic pressure we have to do integrations, the area integration, surface integrations of this quantity okay.

$$\bar{F} = \int_A -P.\overline{dA}$$

So if h is the depth, we know it. The depth is a functions with the unit weight $\frac{dP}{dh}$. Substituting that any point the pressure will come it as we discuss in manometric case the pressure at this point will come as pressure atmospheric pressure plus unit weight of the waters or any liquid what we are considering.

$$\frac{dP}{dh} = \rho g = w$$

Then the h is the height is the vertical height what we are considering. That is what the pressure. If you just integrate these equations you will get it this part, that is what is there and which is we are integrating from zero to h to get it what is the pressure at this element and elemental area of dA.

$$P = P_o + \int_0^h wdh$$

$$= P_o + wh$$

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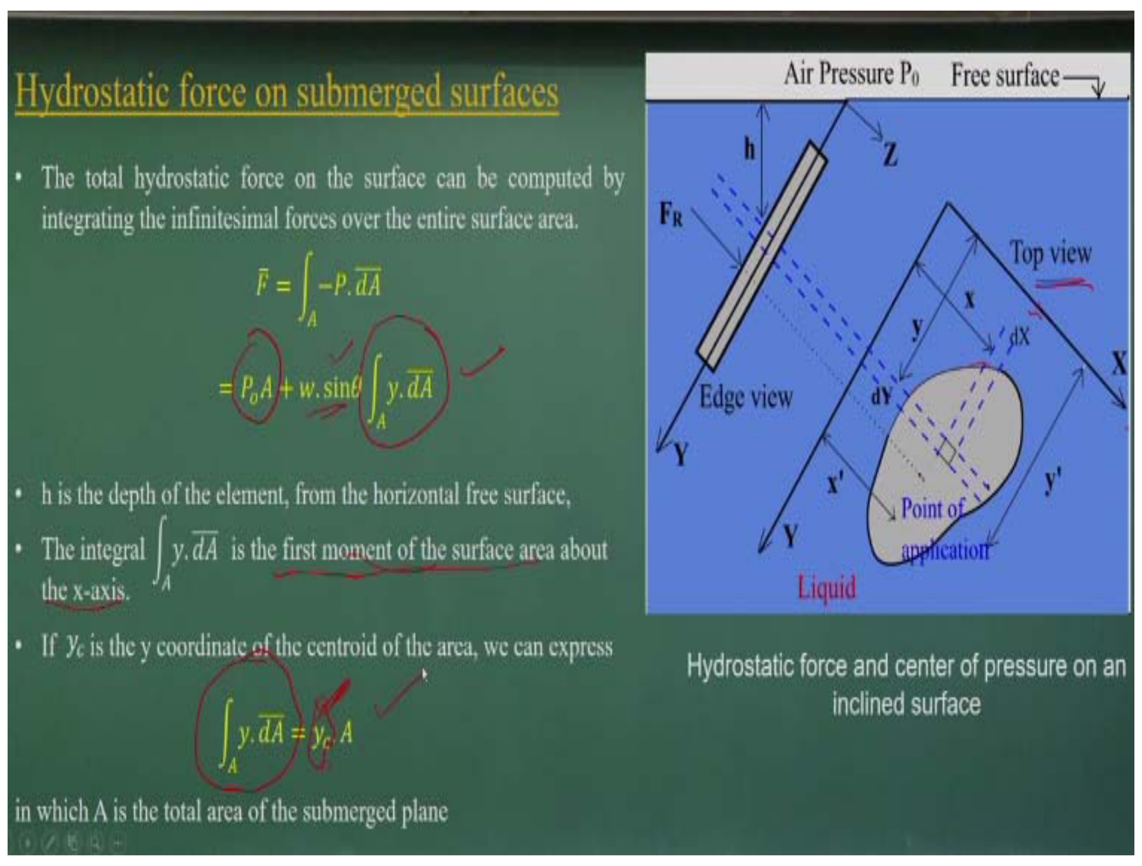


Now if I integrate this part if you know it one component will come it with atmospheric with a another component will be

$$\bar{F} = \int_A -P.\overline{dA}$$

$$= P_oA + w.\sin\theta \int_A y.\overline{dA}$$

What is the y dA? Very simple things is a first moment of the surface area about the x axis. If I have this x axis, if you look it this top view, you have the x axis this is the y axis.

If $y_c$ is the y coordinate of the centroid of the area, we can express

$$\int_A y.\overline{dA} = y_c.A$$

in which A is the total area of the submerged plane. So that means if you integrate this first moment, that means it will become a centroid of $y_c$ that $y_c$ distance from x axis. That is the distance along the y directions. That is the centroid point what will be there if this surface have a centroid this $y_c$ will come it.

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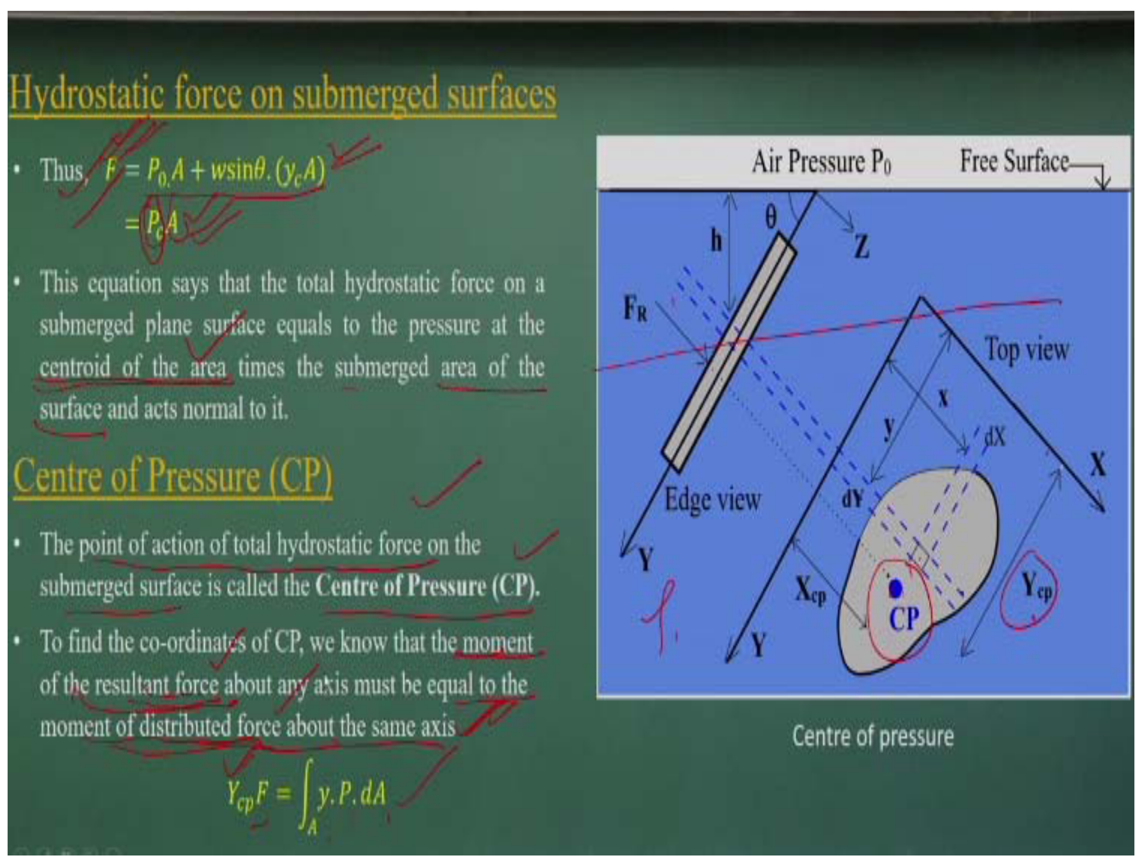


That means, if I just put all these values what I am getting this part, which is

$$F = P_{0.}A + w\sin\theta.(y_cA)$$
$$= P_cA$$

If you look at this component and take the A out from these come on to this that is what at the center point, at the center gravity points CG point. At that point, we have what is the pressure that is the Pc multiply the area that what will come is the force. That means if you do integration it is okay.

But if you do not do the integrations for any surface, you can find out the total hydrostatic force on a submerged plane that equal to pressure at the centroid of the area that is what we have derived okay. Centroid of area multiply it with the area of the surface and as we have discussed earlier, it acts normal to the surface okay. One is that you can do an integrations and find out these things or if you know the CG the center of gravity of that submerged plane surface, at that CG point you get what is the pressure.

That is why easy to find out what is the pressure. And once you know that pressure, multiply with the area of the submerged space that what will give you the force component. Is that what you have just to remember it if you want to solve the problems at faster rate okay as compared to do a integrations and solve the problems. But be remember that when you have not a single liquids case like for this case we have a single liquid system.

That means I have the single liquid systems which is easy to do it, but let you have the plate which is having somewhat in a two liquid interfaces. In that case you have to do the integrations to find out where does it act it okay. So the like in this case what we have consider is a single liquid having the rho 1 constant that but if you have a multiple liquid the liquid 1 and liquid 2 they will have a different densities and find out what is pressure force is acting on this.

Then you need to do the integrations, find out the element area, integrate it from one liquid, another liquid, find the total force acting on that as the pressure diagram changes it when you have a two different densities, two different fluids of the different density. So you will have a different pressure diagrams and that what you have to consider and in that case you have to do integration.

But if you have a simple one fluid systems then the density is a constant. Then you can find out the CG. At that CG point you find out what is the pressure. That what you can just equate it atmospheric pressure then height, how what is the point below the from the free surface. Then you if you know that the pressure at this point multiply this area then what will you get it the force component.

So force component due to the hydrostatic pressure distribution on a inclined submerged plane can easily obtain following these simple equations. Now let us compute to that we need to compute center of pressure. That means, the point of action of total hydrostatic force on this submerged surface. That what I tried to explain it that it is not that where his force acting.

That is what is also the plays a major role to design a structures okay, design a gate, design a any wall we need to know it where this force, the location of the force also matter it and that is what the center of pressures. That was the center of pressures. Now if you look it how to compute it.

This is a very simple case as you have done it in case of solid mechanics you take a moments of resultant forces the total pressure and the pressure distribution and take it from one point here we consider from a axis of axis point to compute it what will be the point where it acts it. So there is a simple problem like as you have done cantilever with different loading to find out where the point you have the force is acting it.

The same concept we use it to find out the moment of resultant forces about any axis you can x axis and y axis equal to the moment of distributed force about the same axis. As we do in a solid mechanic, same concept we are using. We know the pressure distributions. There you know the load distributions and you know it what is the total force acting in.

Here also you have a total force acting because of this pressure distribution. Then you try to find where it works it. That what to find out the moment of resultant force and moment of the distribution force. That what we do it. That means $Y_{cp}F$.

$$Y_{cp}F = \int_A y.P.dA$$

This is the point of CP, center of pressure will y into P into dA pressure into area force y dA we just integrate it to equate this part. So y multiplication is there. That what is the any point if you consider that what the moment about the distributed force what we compute it. This is simple from as you did in solid mechanics.

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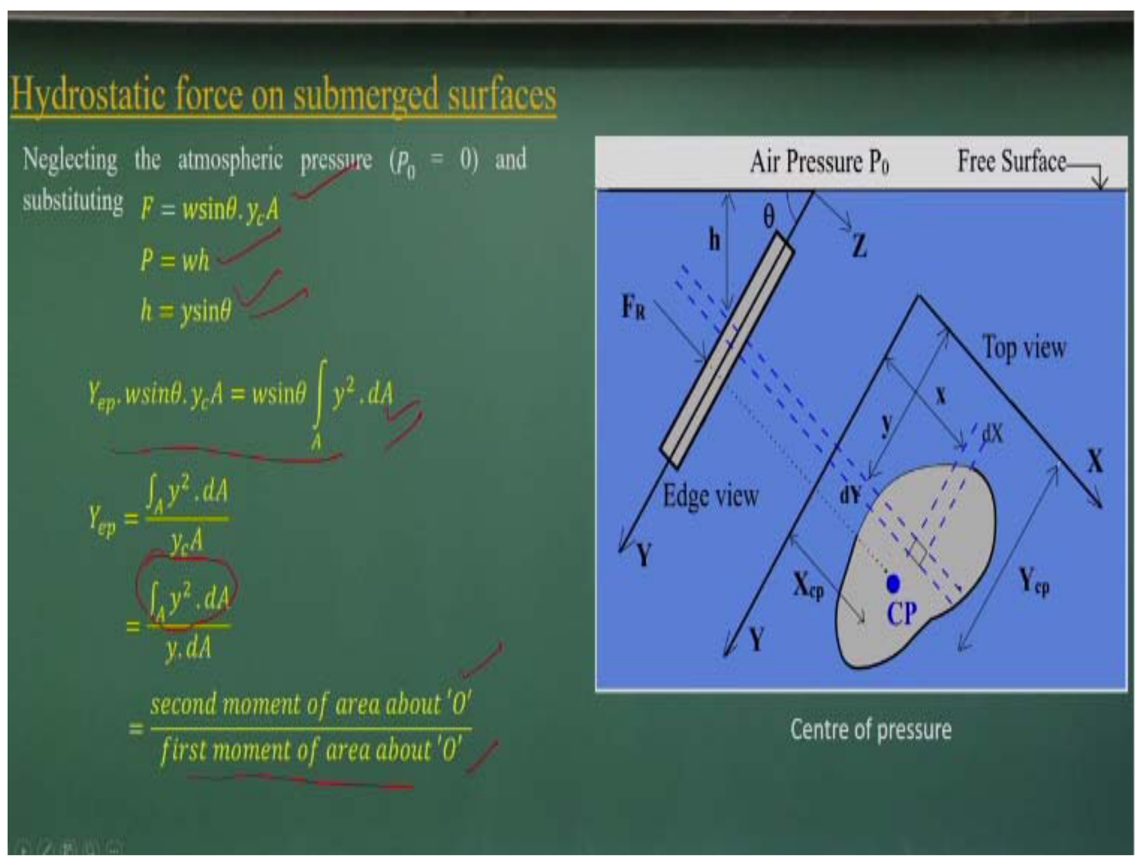


If I do that first, do the integrations and all what I will get it like this force F will be this component as we have derived it. Pressure will be unit weight and h;

$$F = w\sin\theta . y_c A$$

$$P = wh$$

$$h = y\sin\theta$$

Equating all then what we are getting it that,

$$Y_{ep}.wsin\theta.y_c A = w\sin\theta \int_A y^2 . dA$$

$$Y_{ep} = \frac{\int_A y^2 . dA}{y_c A}$$

$$= \frac{\int_A y^2 . dA}{y. dA}$$

$$= \frac{second\ moment\ of\ area\ about\ 'O'}{first\ moment\ of\ area\ about\ 'O'}$$

That means second moment of area about zero okay. The first moment of area about O which is the y dA part.

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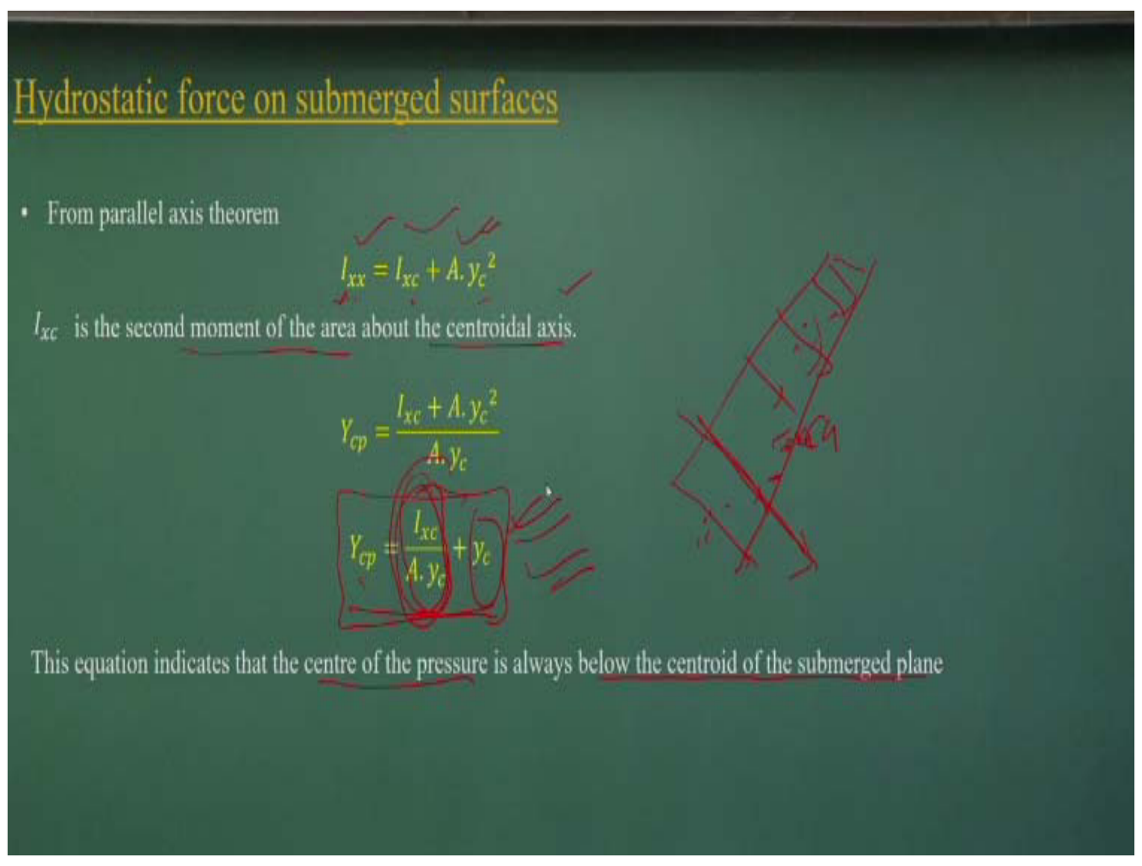


Now if you use the parallel axis theorems, then you can find out what could be the second moment of area about the centroidal axis.

$$I_{xx} = I_{xc} + A.{y_c}^2$$

Now if you look at these equations that any distributions you will have this component which is additional component and this is the centroid locations y value. This is Y cp.

$$Y_{cp} = \frac{I_{xc} + A.y_c 2}{A.y_c}$$

$$Y_{cp} = \frac{I_{xc}}{A.y_c} + y_c$$

That means the center of pressure is always below the center of a submerged plane. So if you consider a submerged plane, if you have a CG at this point, your CP is always be lesser than that because of this component mathematically.

And if you look at the pressure distributions you can find out if you have a linearly increasing the pressure distributions definitely it will not be the force, the resultant force will not act on the CG. It will act below that to make it the equal portion of the area, equal proportion of the area in both the sides. That what will happen it just below on that.

So that what the graphically you can understand it. Mathematically also we can see that with the integrations and all we can compute the $Y_{cp}$ will be this component plus the $y_c$.