Bijlage 5

Interview Mark Hayward (Head of advanced engineering & consulting DNV GL Londen)

At what time does you company get involved with a project?

So we are acting as consultants and providing advisory services. That is our main staple of work. That work might lead on to a roll in a marine warranty aspect. They are both a part of the side assessment. So in an advisory role, as consultants, we will really look at and analyse at anything that our client wants us to look at. So that can be involved as early as supporting the costumers in trying to build the projects. They require some proof that the asset is capable of working at that site. And that proof of the asset being capable of working at that site is a site specific assessment and that can be quite high level with some approximate conditions or it can be very detailed looking, in case of wind farm, at every individual location across that entire wind farm. So we might get involved at the feasibility level in supporting somebody like DEME in tendering for that work, so if they are tendering their asset for a developer, then they might look at us to support that. That's not done on every project so normally the jack-up operator has enough information to be able to tender their assets. 90 percent of our work comes in at that stage, they won a contract and they are looking to operate their asset at this entire wind farm in which there are a lot of positions, anything from 20 up to 200 because of the current size of the exciting wind farms. They need to do enough to satisfy both the developer whom they are contracted too and their insurance, their underwriters, that their assets are capable of meeting the requirements at these sites. So that's where we step in and we will look at the wind farms soil conditions, if they are uniform across that entire site then that makes life quite easy because now we only have to look at one soil profile, those layers within that soil profile and assess the structure (jack-up) for a loading condition. If the soil conditions wary across the wind farm, we try not to do 200 individual load versus penetration response plots, you can generally categorize them into groups of locations whit the same soil conditions.

What are the steps chronologically that are taken when designing a SSA?

If we are starting with a blank piece of paper, if we know nothing, then the first thing we do is information gathering. So for the wind farm site we will need a site investigation survey, so that is somebody going out there and doing the ground condition tests and checks for us. They

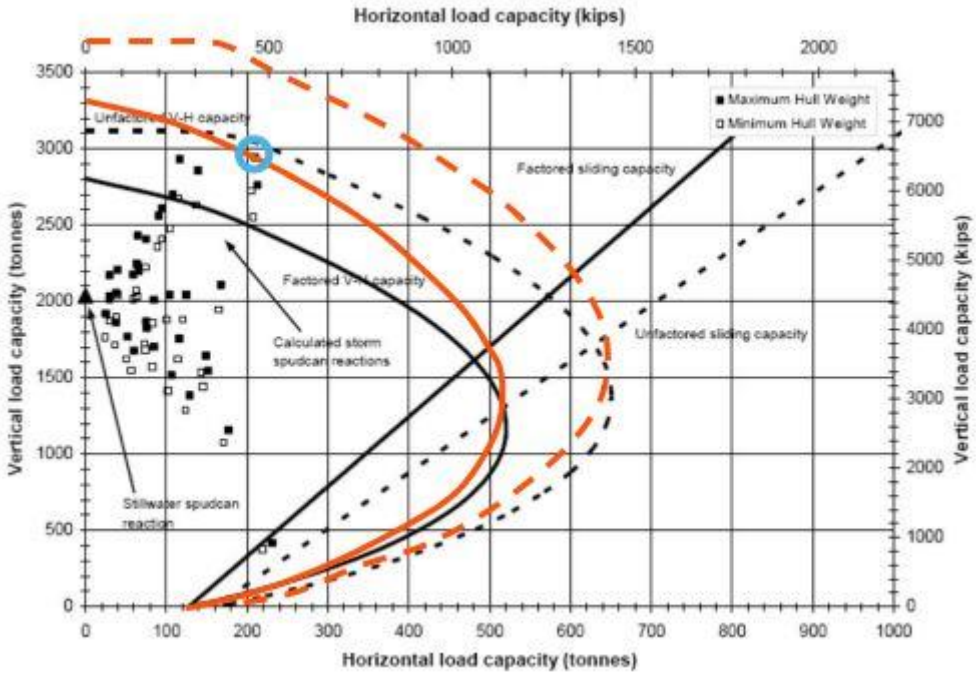
will take boreholes on the site and actually bring up the soil layers or take cone penetration tests (CPT's). That is a report that we will need, it tells us about the raw ground conditions that we will feed into our model. We need to understand about the jack-up structure itself and the loading conditions or what that jack-up is going to be doing on the location.

So if we don't know about the asset already we need to understand about those key details to be able to build a model. We typically ask for a comprehensive set of design drawings for these assets. So DEME has the Innovation and we are currently looking at that asset for one of their sites so for the Innovation for example we asked for extensive leg drawings, these are the designer drawings for that asset. The hull drawings, the weight conditions, the crane conditions, what they will be offloading at that position. So in the example of a windfarm, how heavy the mono-piles are, how high the cell needs to go on that wind turbine. So we can then built an analytical of that asset. For example for the Innovation we have all the leg properties modelled, we have the hull properties modelled, we have the support system modelled, so the pinions in that case and the gearwheels with their strength and their stiffness properties. We give that model some hydrodynamic properties for the leg in the water, how much drag that leg would attract, we give the hull some wind properties**,** some wind area. To calculate how much wind loading the hull will attract. It's got stiffness properties of the leg and that leg to hull connection and everything has a mass. Not only for loading but also the dynamic effects. So we got information on the seabed condition and we interpret that into how deep our spudcans are expected to penetrate whilst preloading or proof testing the soils. We got our analytical model of our jack up, our computer simulation of what that model is, within our properties to capture how it will respond to the loadings that we are going to apply to it. And then we need the environment that it is sitting in. So we need to understand the water depth at every location, we need to understand the wind, wave and current which built up our storm loading condition. We need to understand that the weight that I have already talked about and importunately the airgap. So how far above the water the asset is going to be sitting. These are your building blocks for the assessment, you have got your soil conditions and we put them into our software and interpretation of them so we give it some stiffness parameters at the seabed. We can ran a pinned scenario where there is no seabed restraint condition. If we are a single pile leg on a hard sand that would typically just be a pinned or we can provide a fixity in the seabed where the seabed is trying to hold on to our spudcan and stop our jack up from moving around as much. So we have modelled our seabed conditions and what they are doing for us, we have our jack up properties where we are now applying some loading to it. Our current and wind loading are just going to try and

push our asset over. We know that are storm loading is not going to be a continuous nice set of simultaneous waves going through. Our storm condition is going to be a whole hodgepodge of waves conditions, small waves, big waves. So we run that storm simulation with a random sea state and that's explained in the ISO aspects which regards to some of the parameters you would look to include, including matching your maximum wave height and things like statistical parameters of that storm condition. So we will run a random storm through our model for 8 hours. And we pick out the worst dynamic response of our jack up during that time. So our jack up is going to be moving around and we are looking to make sure that we are capturing the inertia loads properly. So that's the actual analysis and I also talked about doing a one-step or a two-step approach. Where your one step is you get everything together and try to understand your seabed restraint condition as you apply your load and the 2 step approach is understand your dynamics first and make a representation of that and put it back into your model to understand whether your seabed stiffness's are going to degrade so as you apply higher load you might reach the elastic limits of your soil conditions for your fixity. And you are going to move through that elastic, plastic threshold so you won't have fixed stiffness's at the seabed. Some of that stiffness is going to degrade or give up on you as your spudcans exceed the soil limits. It might move or rotate a little. So that is the analysis and we do a whole bunch of post processing. So we look up the loads at the seabed and we see if it is stable, we look to the loads in our legs so our leg chords and our leg braces and make sure that the leg strength is sufficient at the seabed and all the way up to the top where our jack up is. We look up the loads from that leg going into the jacking system, so our pinion strength checks. We look at how much the jack up actually moves, so displacement, if it is going to collide with anything. In the case of oil and gas structures, if it is going to hit the platform. And that is really it, those are the key aspects we report. If it is stable and it is big enough and strong enough to withstand your storm condition with factors of safety build into that assessment. So we apply load factors on our loads on our loads, we apply resistance factors on our capacities so we scale up our loads and we knock down our capacities and that gap in between is your safety factor on you assessment. If we are meeting those requirements then we are good to go. The asset meets the industry requirements and they can go and operate on that location. For DEME in particular we will probably be issuing that certificate for approval. What that certificate of approval does is it validates it's insurance. So the underwriters, the insurers underwriters or brokers require somebody to do an independent check and put their name to a piece of paper saying: 'we believe that asset is big

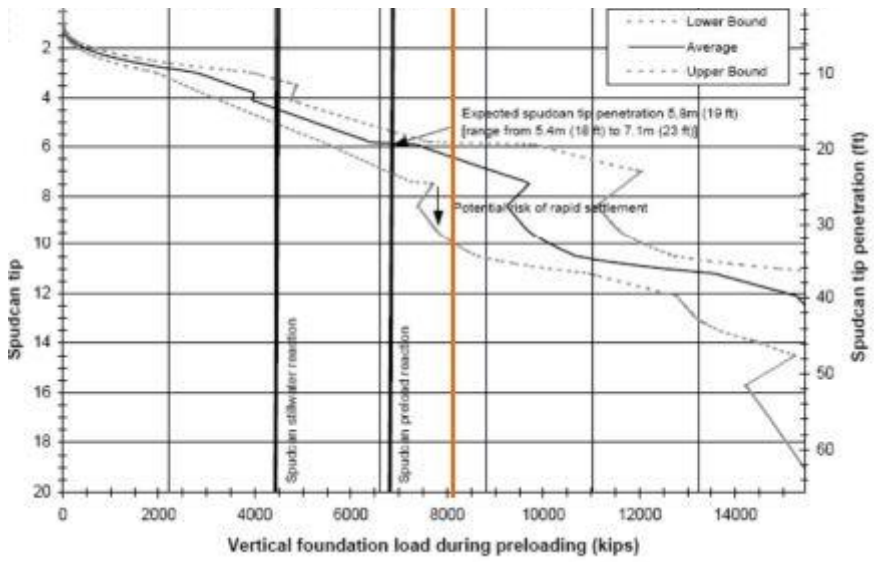
enough, strong enough, safe to operate at this location.' When we are comfortable we will issue that certificate of approval and that validates their insurance.

Can you elaborate this curve please?



Figuur 1: Foundation envelop

Bron: Mike White (2016)



Figuur 2: Penetration curve

Bron: Mike White (2016)

This curve in particular is one of the most difficult aspects to try and explain and visualize. If we actually start with the plot on the right hand site because that is easier. So our load versus penetration plot. We are preloading or proof testing our foundation up to just over 3000 tons in this case. Our self-weight per leg is about 2000 tons and we're preloading the load at the seabed up to 3000 tons. So we are buying ourselves just over a 1000 ton margin to withstand storm loads. So you can imagine that with anything, you know your operating load is going to be 2000 tons but you have proof tested it up to more than 3000 tons and that is your margin that you afforded yourself for your storm load to sit within. So how that translates to that bow curve. So now just take a look at that plot to the left. So hopefully you have understood the vertical axis so far. So that the 3000 tons preload is our black dotted curve. So that's the unfactored foundation capacity. That's what we think the soil is good for with regards to talking load without any further displacement or settlement. The reason it is a bow curve is that we can take 3000 tons vertical load but as we then begin to increase horizontal load as well. So we are pushing it purely vertically but then if we try and start imposing a horizontal load as well, then we have to reduce that vertical capacity. So we begin to build our combined capacity envelope. So by the time we are talking let's say 400 tons horizontal capacity then we are only good for in the order of 2500 tons vertical load. Because that combined capacity is the equivalent to a pure vertical load of just over 3000 tons. And then when we go further up to 600 tons then we are reducing our vertical capacity down to something around the order of 2000 tons. So that is how the top half of the curve works. It's a representation of the combined capacity of the soil for a combination of vertical and horizontal loads. There are moment loads hidden in here as well but let's just keep it simple with those 2 plains. The bottom half of the curve when it kicks back into towards 200 tons in this case. It is a sand foundation, we know that sand is friction dependent so the bottom part half of the curve is analogist to that friction dependency. So a combined capacity as we reduce vertical load, we know that we can no longer sustain as much horizontal load. So in principle it is a lot more complicated than that and that's why the shape of the bow curve is slightly different to our sliding capacities, our purely horizontal load capacities. But that is probably enough for your thesis. So what we want to do is we want to apply a factor of safety to that, so we have proof tested our soils up to just over 3000 tons. We don't want our storm load to get right up to that load that we have proof tested it. We want a factor of safety on that . So the way we apply that is that we apply a resistance factor so we reduce our capacity that we are allowed to use in our assessment. So that is our factored envelope. So actually want our storm footing load not to exceed that black capacity envelop. Because we still want a margin of safety on these foundation checks. Then

all of the solid black dots are footing reactions from our asset in that storm condition. So we have applied storm loads in different directions around our asset because it won't be uniform. So we apply storm loads bow on and then typically 30 degrees all the way around that asset. So our storm footing loads, our footing reactions at the seabed will vary as we try and tilt our unit. What we see here is that the storm load exceeds our factored capacity envelop. So we report utilization test how much of our allowable capacity are we using. If we are using all of it, that would be a utilization check of 1. That would be if we are using a 100% of our allowable capacity. So in this case our utilization checks will be bigger than one. Something in the order of 1,3 perhaps. So what does that actually mean, it means that our storm footing load is bigger than we would like and it is not achieving the required factor of safety that is built into our assessment check. But that doesn't necessarily mean this is a show stopper, because sometimes foundation conditions are okay to support much higher loads. A good analogy here is probably the table you are working at where you got a normal operating load, just with all your kit on it and you can proof test your table. You can physically push down on your table to tents of kilo's but actually your table is good for probably 100-150 kilos perhaps. So your table is much stronger then you have proof tested it. And that will be analogist to a hard sand seabed. So we now jump back to the plot on the right hand side and go: 'okay, if we were targeting a load in the order of 3700 tons what is actually going to happen to our seabed. Would this be acceptable to withstand that storm load and build back in to that load our required factors of safety. So we know that the storm load is exceeding our target, or our ideal allowable but if we build back into that load our required factors of safety which is what the solid orange and the dotted orange envelops are doing. We know what our storm load is, we build in back in top of that storm load our required factors of safety. Where will that sit on our foundation load versus penetration response plot and could that be acceptable?

So if we were to just take the midbound or the average line on our load versus penetration response plot then the difference between that second black line and that orange line, what's our additional displacement between those 2 and that's in the order of maybe a third to half a meter. So that could be okay but then if we look at the lower bound response, the line just below that, where our soil conditions could go from something in the order of 7 metres at full preload all the way down to 10 metres under that equivalent load then that wouldn't be acceptable because that would be too much additional settlement to withstand the storm loading. So certainly a meter and a half extra penetration on 1 or more legs, will mean a decrease in your air gap and in this storm condition that is far from ideal and that wouldn't meet the assessment checks.

ISO uses the 50 year independent extremes and the 100 year joint probability, can you explain a bit more what is meant by these values?

Independent extremes are exactly what they suggest. What is the biggest wind speed you might see in a 50 year period, a 50 year storm. Separately what is your biggest wave height that you might see in a 50 year period, typically a 50 years storm and what is your biggest current speed you might see in a 50 year period. Which might not be during your 50 year storm. So you are talking your biggest ever wave with your biggest ever wind and your biggest ever current for that 50 year period. What we see, is that in reality you might not get your biggest wave at the same time as your biggest wind speed, at the same time as you biggest current. So if we go for a 50 year independent extremes where we take the maximums, biggest wind, biggest wave and biggest current, together. In a joint probability case we now look at a higher return period, but I am coming back to that, but we take our biggest wave that we might see in a 100 year period and then look at what is the wind speed that we expect to see at the same time as that wave and what is the current speed that we expect to see at the same time as that wave. And then separately, so that is our wave dominated case, together with wind and current that you expect to see at the same time. Separately we have to see, what is our biggest wind speed and then what is our wind and current that we would expect to see at the same time as that wind speed. And the third one is obviously current, what is our biggest ever current and what is our wave and wind that you would expect to see at the same time as your current. And we would actually have to look at certainly 2 of those cases. The current case normally isn't used. Look at those 2 cases separately to see whether it is wind speed covened or wave height covened. The purpose of both approaches together with the load factors is to try and get to that 1 in 10.000 year probability of failing which is the benchmark for offshore structures. In the North sea we have to make sure that our structure has sufficient air gap to avoid that 10.000 year wave. That's come about from a number of cases in the North sea, in the offshore sector where conditions in storm conditions have been taller than people had expected and the air gap, that clearance between your flat water line and your bottom side of your keel hasn't been big enough. So within the last 10 years there is been this additional requirement for a larger air gap. Because when a wave hots a structure and with a jack up that will be the wave hitting the hull. That was never something the unit has been designed for. The purpose of a jack up with its relatively skinny legs is to sit way above the water line and never we exposed to any wave loading other then it's relatively skinny legs. So the legs aren't attracting much wave load. So the 10.000 year air gap requirement is your bottom line in series of 10.000 year data. So the

minimum air gap requirement in a 10.000 year case is that the keel should be 20 metres above the water line in this case. Historically we would have taken your 50 year maximum wave height and added 1,5 metres to it to calculate your minimum requirement for the air gap. In this location that is not enough to meet your 10.000 year equivalent wave. So we take our 50 years extreme and derive our loading from those 50 year extremes and our partial action factor is our safety factor. This is where I talked about, we scale up our load. So we scale up our loads and reduce our capacities. We scale up our loads with load the factor, so by 15 percent in this case for 50 year data and we reduce our capacities. And then that is our combined factor of safety on our assessment.

How is the meteocean data gathered?

We subscribe to various databases of just this sort of parameter. So we can buy into some, what are called high end cast data sets where people have published and continuously updated datasets for, let's say the North sea because that is our playground, so there are extensive datasets already for that area which is a combination of satellite data more so these days, wave buoy data, wind speed measurements from the jack ups, jackets and now windfarms that are populated in the North sea alongside extensive modelling. So all of this data comes together for, in some cases, up to 30 years. And then put into big computer models and extrapolate that out to other values. So we buy that high end cast data and we run our own statistical analysis on that to come to the 1 in 50 year return period event. So we have 3 meteoceanographers sitting within our group who do this for us. It is important to know that those wave buoys or wind speed measurements might not be at our location. So they could be somewhere else on the North Sea and then the big computer models will map how those wind speeds and those wave conditions vary as we change water depths and as we change position around the North Sea. So you have large flow models looking at the weather forecasting where they predict how that weather is going to move and change. It's exactly that but we use high end cast data because it has already occurred. So we are mapping data that we know has previously occurred and we are building that into computer simulations or models.

In the ISO there is only talk about the lower bound penetration calculation, how is the upper bound calculated?

We have a range of strengths conditions from that side investigation data. So in our site investigation data for clays we will have a range of strength parameters. It won't be a fixed value which would be nice but there is always a range of tolerance to that clay strength so we might be looking at a range of clay strengths so thinking back to our load versus penetration response graph, we were looking on how deep our spudcans were going to go. Then we try and map that lower bound response which typically takes our weaker clay boundary. So if it's 50-100 kilo pascals then our lower bound response will be based on our 50 and our upper bound response, our shallower penetration, will be based on the 100 Kpa. And then the average is just that, we might make some recommendations to understand the coast but this solutions give a theoretical lower bound to soil resistance. So that lower bound response plot gives a boundary and actually if you are asking for our opinion, if you are betting on a response, we would generally suggest that we would not expect that spudcan to go down to that 8-10 metres on that plot that we were just looking at (lower bound) because that is the lower bound simple response strength plot but it can't be ruled out. We are not expecting it, we are following the assessment methodology, we have followed a theoretical lower bound response to that soil combination but actually we wouldn't expect it but it can't be rules out, it might happen.