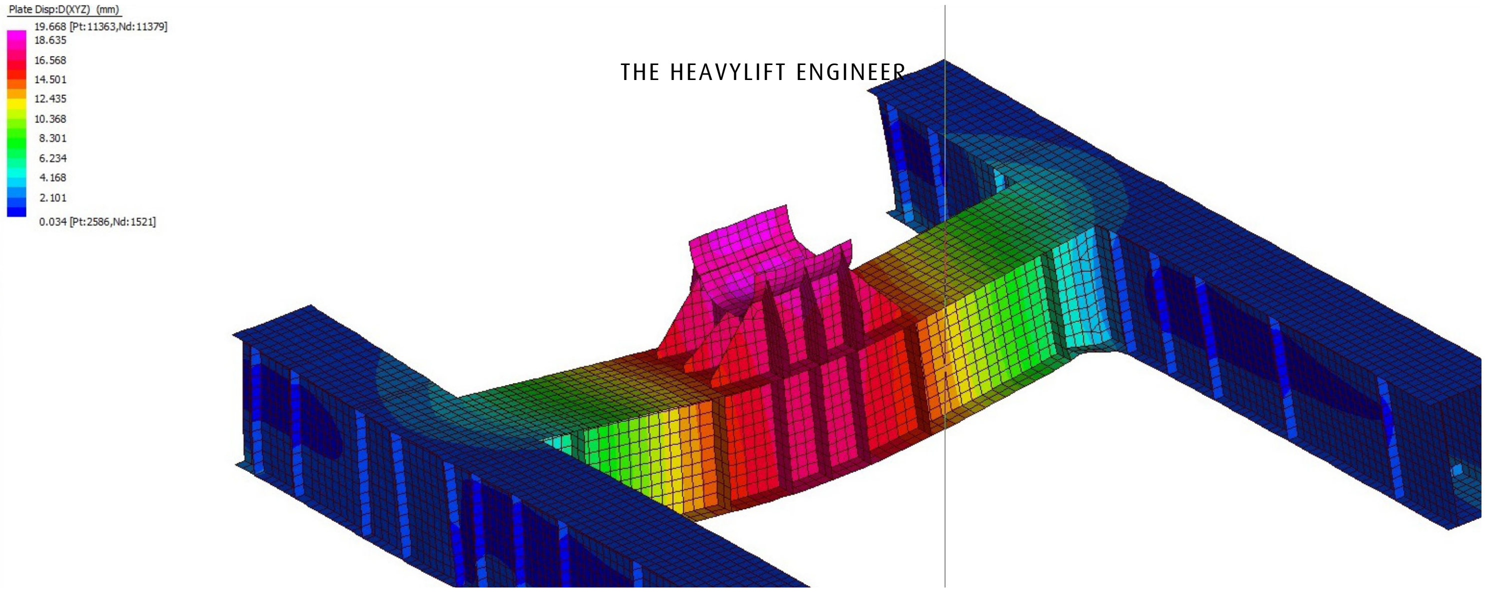

fig. 09/ transport frame showing exaggerated displacement

FINITE ELEMENT ANALYSIS (FEA):
AN INFINITELY BETTER APPROACH TO LOAD ANALYSIS?

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Finite Element Analysis (FEA) is a powerful tool that enables engineers to gain a deep understanding of how any given structure responds to external loads, combined with an appreciation of how these loads flow through a structure. This understanding helps them to then identify areas of local, high stress.

Despite this value, outside structural engineering circles, it is also one of the least understood areas of engineering analysis. This misunderstanding is two fold:
• how does FEA do what it does?; and
• how can it add value to a project?

Addressing the first question, FEA works by building a representative numerical model of a structure. In every case, this model is an approximation of the real thing, often thought of in terms of how it is portrayed on screen.

It is important to realise that this is just a visualisation of the underlying numerical model made up, in the simplest sense, of four main sections, namely:

1. Element list
2. Nodal co-ordinates list
3. Connectivity section
4. Load cases section

The element list consists of a library of standard elements (nodes, beams, plates, 3D brick elements etc). These standard elements are typically referred to repeatedly and are stored in a "lookup table" of one form or another. This lookup table, in its simplest form, assigns each element a unique number, alongside various properties such as thickness, section properties, material assignment etc.

The nodal co-ordinates list details all the points in space that represent a position where one element connects to another or to a point that represents the model boundary (foundation, anchor point on a ship, interface with a large structure etc).

The connectivity section assigns how nodes are connected to each other and which element is to be assigned to that connection, for example node 1 is connected to node 3 via a beam 2 from the element list. It also allows the restraints on nodes to be specified, for example node 2 is rigidly connected to a foundation and so cannot translate in x, y or z directions and is also not free to rotate about any of these same 3 axis.

The final section, load cases, specifies how the loads are to be applied and where. So, for example, load case 1 has a force of 10kN applied in y direction to node 4 and load case 2 has a force of 10kN applied in the z direction to node 5 etc.

The number of elements used to describe any one given structure is driven by the mesh size which drives cost of building the model (modelling) and analysing the output (post processing) measured in man hours. Once all this has been specified either in a text file (if you are old enough to remember doing it this way) or via a more modern graphical user interface, the connections and element properties are arranged into a stiffness matrix. The power (or magic) of matrix algebra is then harnessed to solve thousands and thousands of simultaneous equations to ultimately tell us how the structure reacts to the applied load. It is a common misconception that the key output is structural stress. It is in fact structural deflection, and this is then turned into a stress plot and visualised on the screen. See fig. 10.

By understanding the key fact that the analysis is centred on stiffness rather than stress, the power of FEA becomes apparent, suggesting, as it does, how it may be practically used in a heavy lift project where timeliness and applicability of any engineering is key.

We can first set aside the obvious questions such as whether or not a deck structure can accept a particular load or if a lifting beam is overloaded or not - answers which 9 times out of 10 can be gained using quicker, traditional hand calculations. Instead, we may consider more complex, interesting questions, for example, where should sea-fastenings be placed on a structure, or what is the expected load path for a given layout of weightors under a structure. It is from questions such as these that we can see how the FEA approach, focused as it is on how the structure deflects, displays its real potential.

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the structure deflects, displays its real potential.

By addressing these questions, you are afforded the opportunity to make real savings. The approach is however also of great practical use in the execution of a heavy lift project by dramatically reducing not only the amount of steel for sea fastenings, but also the cost of installing, removing and making good deck and cargo after. In the weighing case, the position of weighing points can be ruthlessly economised allowing a more efficient weighing pattern, reducing cost to the end client both financially and in terms of down time and site disruption around the installation and removal of equipment.

It is also worth considering what the model is to be used for, to ensure that the mesh size is appropriate. FEA is often dismissed as a potential tool as the perception is that it will take too long and be too expensive to build a representative model. But if we bear in mind that all models no matter their complexity, are approximations of the real thing, then the question reduces to one of ensuring that the detail used is appropriate to the task in hand.

When I was a student, our professor who took the structures lab was an incredibly well-respected offshore engineer, who literally wrote "the" book on offshore structural analysis. He was a major advocate of the use of FEA, albeit sparingly, to the extent required by the situation in question. Simple models that were representative of what was going on to feed and inform early stage design decisions were an invaluable tool. A well thought out model consisting of only 20 or 30 elements rather than one containing 2-3 million, of an offshore jacket and its foundation piles could give quick useful answers that led the early stage FEED in a well-informed manner.

This same approach can be applied to heavy lift projects. An understanding of load paths through hatch covers and decks to inform cargo stowage options can be invaluable during tendering and early stage design phases - even for warranty approval.

Similarly, when looking at the distribution of loads through a complex structural cargo, such as in the case of dry transportation of a ship hull, both fully meshed and simpler part models have a place.

The former, as in figure 12 overleaf, is a major undertaking but can be used to understand the complex interaction between transport vessel and cargo, as well as being used for the verification of internal structure around hull and bulkhead openings.

For "simpler" ships, the cross section at paired frames in way of transport cradles can be represented by beams only, with stiffeners and associated plates simplified to the point that modelling becomes easier but also allows for an accurate understanding of how loads are transferred and shared among decks and pillars.

Lastly, there is the situation where the whole ship, or cargo, can be modelled as a single series of beams with each being the full section modulas of the ship at a particular location along its length. These models are simple to generate but like those mentioned earlier, are good for understanding the interaction between cargo and vessel under global load cases and can be used to guide early operational decisions prior to detailed design taking place.

So when faced with a challenge, tools like FEA should not be dismissed as a hammer too big for the nut in question. Like all engineering tools, their usefulness can be tailored to the job at hand and simple models built in a day or two can deliver insights that otherwise would be difficult or impossible to glean by hand.

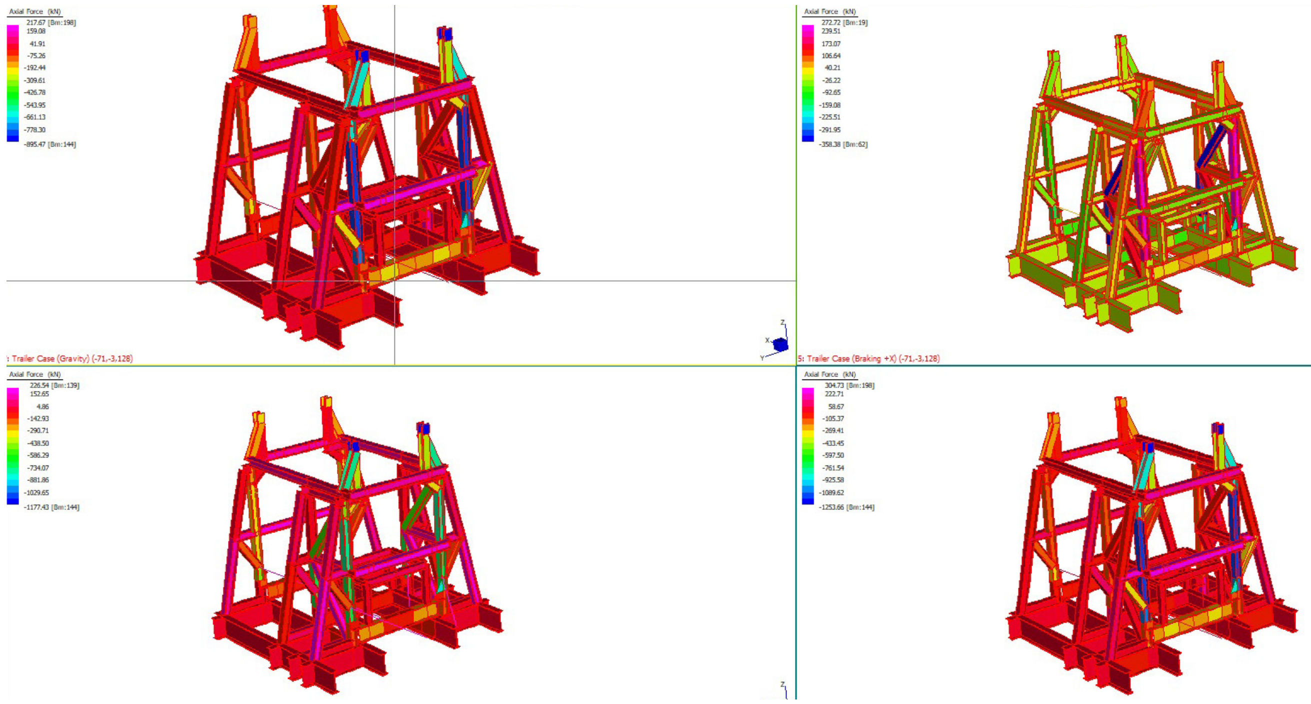

fig. 10/ multi view of transport jig model showing different load cases

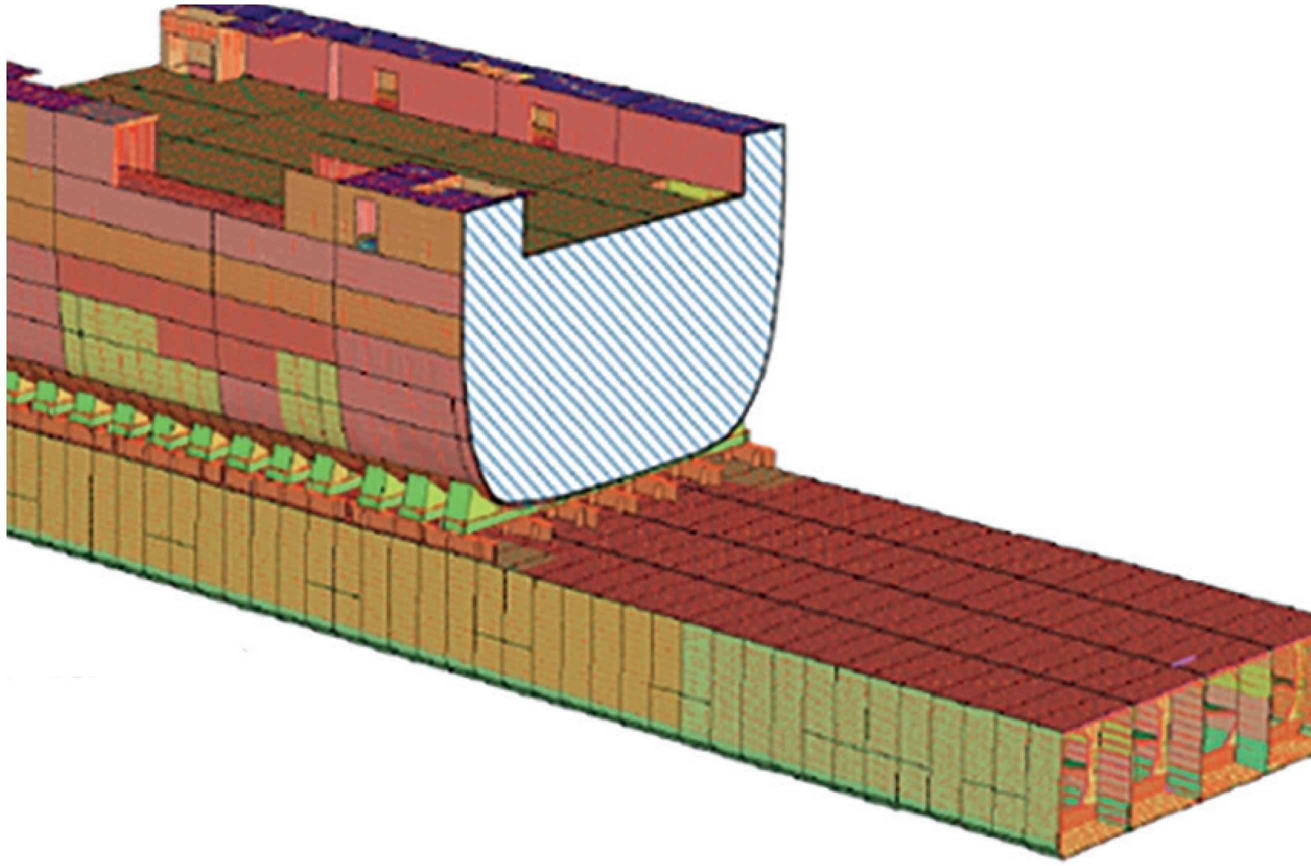

fig. 11/ FEA model of cargo, barge and connecting steelwork