1) Definitions:

Ship's (static) floatation results of a balance between its buoyancy and its weight:

- The buoyancy force corresponds to the product of the immersed volume by water density. Its application point is the geometric center of the immersed volume and its direction is always vertical, i.e. perpendicular to the floatation.

The weight and center of gravity of solid items is easy to calculate, but the weight of tanks need a special process:

- Tank's weight only depends on its filling and density, but its center of gravity depends on ships heel and trim and, therefore, must be recalculated for any step in the process.

- If tank's fluid was frozen, its geometric C.G. would be directly usable like a solid load for calculating the global (solid + fluid) C.G.. But in real cases, the tank's content is not frozen and an additional «Free Surface Effect» must be taken into account. Basically, this FSE means that tank's instantaneous CG to be used for stability calculations is not the geometric C.G. of the fluid, but a corrected one, located vertically above. The vertical distance between geometric and corrected G.G. is the metacentric radius (inertia of free surface / fluid volume). Therefore, in addition to the classical weight/CG management, a correction moment named «Free Surface Moment», must also be also be managed. Tank's FSM simply corresponds to the product of CG's vertical shift (metacentric radius) by fluid's weight. Dividing total FSM by ship's total weight allows to calculate calculate ship's corrected C.C., in order to take liquid effect into account for stability calculation.

- Depending on the inclining direction of its free surface, the metacentric corresponding radius varies according to the classical elliptic variation of moments of inertia. Therefore, 2 metacentric radii must be managed, depending on free surface's inertia axes. But fortunately (for the user), as ship's longitudinal stability is usually much greater than the transversal one, only the transversal FSMt has to be managed in practice.

- Ship's balance is a macroscopic one (total weight equals total buoyancy) but nothing insures that it is also microscopic: In any transversal slice of the ship, slice weight is generally not equal to the slice buoyancy (local weight not equal to local buoyancy). This difference therefore induces what is named «Longitudinal Strength», i.e. shear force and bending moments in the ship, according to beam's theory. Longitudinal strength are therefore calculated by comparing the weight curve (curve representing the weight of any transversal ship slice) and the Sectional Area Curve (representing the buoyuancy of any transversal ship slice).

2) MH+ Objects describing the virtual ship:

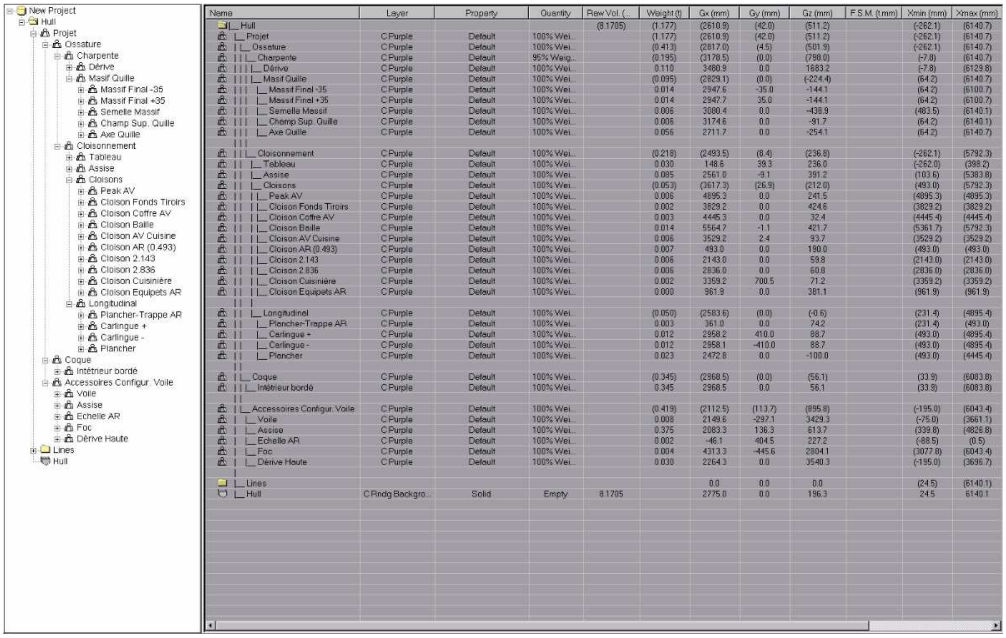
- **Compartments:** Ship's buoyancy results of a certain number of solids describing float's geometry: the « compartments». Moreover, a permeability is associated to each solid, allowing to specify its status: A zero permeability means that 100% of the theoretical buoyancy is available (the default «intact» state), 0.5 for 50%… and 1 for a total buoyancy loss. Although permeabilities can only represent large breaches (for small ones, an additional liquid effect must be taken into account), they are a convenient way to describe ship damadges: Intact ship => all permeabilities set to 0; damadged ship => damadged compartment permeabilities usually set to 0.85 to 1, depending on the internal space occupation.

- **Tanks:** Basically, a «tank» is a special compartment whose permeability is forced to 0 (it must be watertight), in order to allow it to contain a certain amount of fluid. As a physical tank usually includes an internal structure, tank's ideal geometric volume is not totally available in practice and a «tank permeability» appears as a convenient way to specify the percentage of tank's space really available. Therefore, a value of 0.95 (95%, the most common value) means that 95% of tank volume is available.

- **Masses:** Ship's weight estimate contains all the items to be taken into account for C.G. calculation, except fluids, which need a separate process. MH+ masses are used to represent all

these items, the resulting C.G. being calculated in real time. But, in order to allow a more synthetic work, MH+ masses can include submasses, and so on.. Moreover, each mass can be instantly set from 0% to 100%, in order to allow easy weight configuration (for example, among the present masses shown below, just set «Crew Guest Luggages» mass quantity from 100% to 50% and the resulting total load will be updated in real time, allowing to calculate the new ship balance directly). Moreover, in order to allow Longitudinal Strength calculation, the longitudinal extension of masses can be specified.

If necessary, this recursive mass management allows to encapsulate the complete mass distribution into a single mass object:

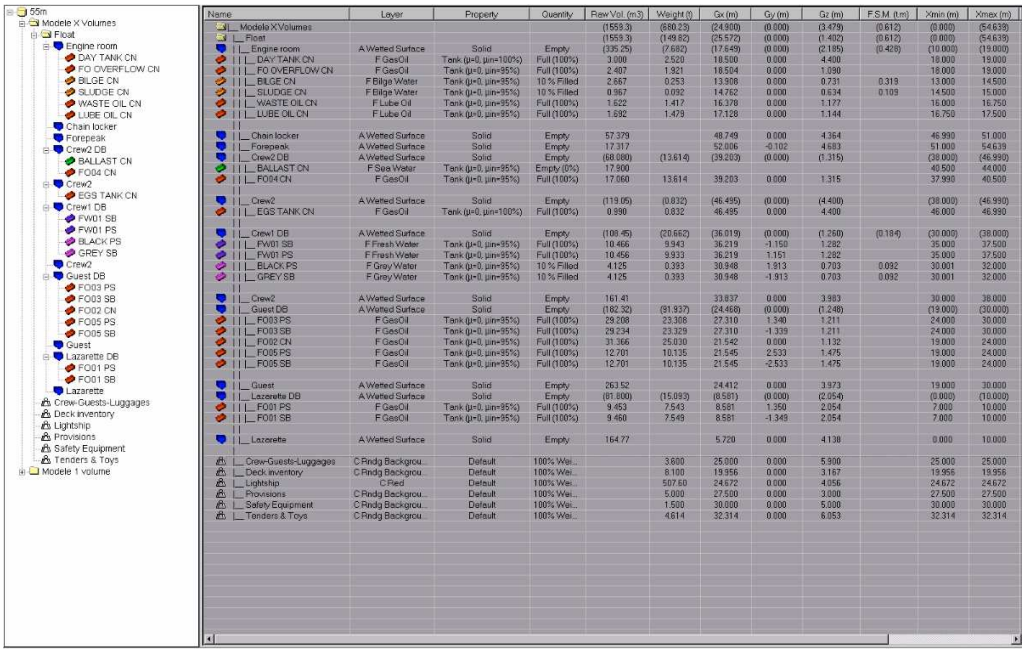


Two important properties also result from the recursive management of MH+ objects:

- When a compartment has child compartment(s), child(ren)'s volume is subtracted. This is very convenient for representing any kind of hole and cavity.

- When a compartment has child tank(s), tank's buoyancy is ignored as long as compartment's permeability is 0. In other cases, a part of tank's buoyancy is taken into account, depending on compartment's permeability. For example, for an 80% permeability, 80% of tank's buoyancy will be taken into account.

This MH+ display will sum up these explainations :



- The blue items are the ship compartments.

- These compartments are parents of differently colored tanks (depending on their content). This means that no tank floatability will be taken into account as long as compartments are intact.

- Different masses (black icons) also appear, representing the main items that the designer wants to set (from 0% to 150%) for defining the different Loading Conditions used for stability calculations.

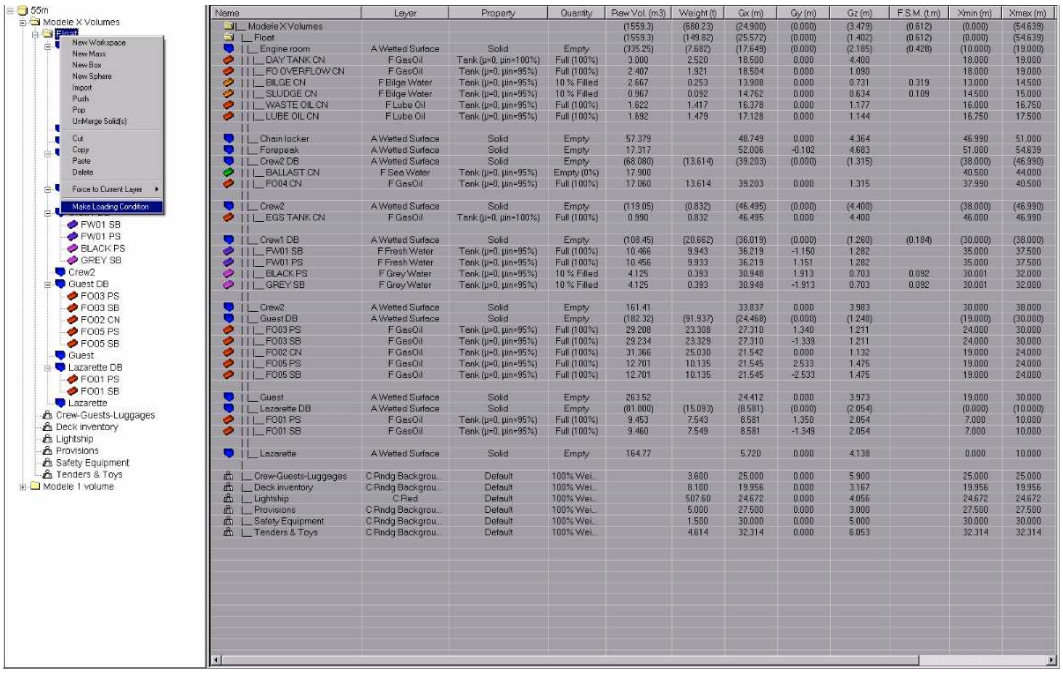
At this stage, we can see how the designer can set the ship status in order to calculate the corresponding behaviour at see:

- Setting the compartment permeabilities, in the « Property » column, according to the damadge case.
- Setting the fluid contained by tanks, in the «Layer» column, as well as the tank permeability, in the «Property» column or the tank filling in the «Quantity» column.
- Setting the percentage of masses to take into account (such masses can also be added or removed).

This ship's status setting is named its «Loading Case». Managing ship's Loading Cases is therefore extremely important, as ship's behaviour totally depends of these settings (i.e. Stability criteria can be fulfilled for certain cases, but not for others).

In order to provide a maximum flexibility for managing these Loading Cases, and therefore avoiding to redefine ship's status item by item for calculating different Loading Cases, MH+ is able to create «Loading Case» objects, encapsulating all the current settings of the active model in a single object (with a «tap» icon) : Double clicking on such objects allow to return instantly to these settings whenever necessary (provided that compartment and tanks have not been renamed, moved or deleted).

To create a Loading Case object containing the current settings of the active set, select its parent in the browser (usually the active set itself), right click and select « Make Loading Condition » in the popup menu :



A « Loading Case » object is then created. It is a good habit to name it according to the corresponding ship status, as the active set will be automatically renamed according to the selected Loading Condition. You can therefore modify the ship settings as you want, retain these settings

by creating as many «Loading Cases» as you want: Double clicking on such objects will intantly restore ship's status to the corresponding settings, the active set being renamed accordingly:

