Chapter 51 –
Preparing Cargo Plans – Structural Limitations

51.1 Strength of Tank Tops, Tween Decks, Hatch Covers and Weather Decks

When preparing cargo loading plans, it is important that the ship is loaded as close as possible to its maximum deadweight or capacity, but it is equally important to consider the implications of loading any high density cargo. In the early stages of planning, it is essential to establish not only the physical dimensions of the cargo but also the maximum permissible weight that can be loaded into any compartment. In general terms, there is a common failure to fully understand the strength limits of tank tops, tween decks, hatch covers and even weather decks. The knowledge of many Masters in this matter is often superficial.

The strength limits that are to be applied to tank tops are calculated and approved by the Classification Societies. The maximum limits are expressed in tonnes per square metre and are included in the ship's technical manuals and capacity plans. To calculate the number of tonnes that can be loaded on the tank top without exceeding the limit, the area of the tank top in square metres is multiplied by the permissible number of tonnes per square metre. To ensure that the limits are not exceeded, the cargo must be spread evenly over the area of the tank top. The volume of the space above the lower hopper tanks should also then be calculated and the figure obtained included in the total quantity to be loaded. A typical calculation might be as follows:

Maximum tonnage to be loaded:

(L)ength × (B)readth × PL (permissible load) = 27 m × 21 m × 12 T/m^2 = 6,804 T

(where L and B represent the dimensions of the tank top excluding the hopper tanks)

Maximum volume to load:

6,804 T at 3 T/m^3 = 2,268 m^3

Height of stow:

2,268 m^3/567 m^2 = 4.0 m
(567 m^2 = 27 m × 21 m)

When discrete items are to be loaded, such as billets, steel coils, slabs, etc, it is recommended that the load should not exceed the equivalent tonnage shown above.

When other homogeneous cargoes are loaded, which may safely be stowed over the hopper tanks, additional weight may be carried, but always with the proviso that the overall height of stow should never exceed the original figure as arrived at in the example.

In such cases, the amount of weight that can be safely added can be calculated by using the formula:

0.5 (L × B × PL) T, where L = the length of hopper tank and B = the horizontal width of tank and PL = permissible load.

Thus, if L = 27 m and B = 4 m then 0.5 (27 m × 4 m × 12 T/m^2) = 648 T at each side. At 3 T/m^3, 648 T would occupy 648 T ÷ 3 T/m^2 = 216 m^3. Over a base area of 108 m^2 (27 m × 4 m), this would take the height to 2 m (216/108) or, allowing for the wedge of a 45° hopper tank, to 4 m height. Thus, the final result of the calculation would be that the total weight of cargo to load would be 8,100 T at an overall height of 4 m.

In any case, when making these calculations, Masters should consult the IMSBC Code (Reference 17) Section 2.1, Cargo Distribution.

Figure 51.1: Bulk cargo loaded in a heap in the centre of the hold.

When bulk cargo is poured into a ship's hold, it tends to form a heap, thereby increasing the load on the tank top towards the centre of the hold. The result is a tendency for the double bottom to sag and for the ship's sides to be drawn in, as indicated in Figure 51.2.

Total cargo: 8,100 T

Cargo of iron ore stowing at	3	T/m^2
Width of tank top	21	m
Length of hold	27	m
Peak of hopper tanks above tank top level	4	m
Base width of hopper tanks above tank top level	4	m
Classification Society permissible load	12	T/m^2

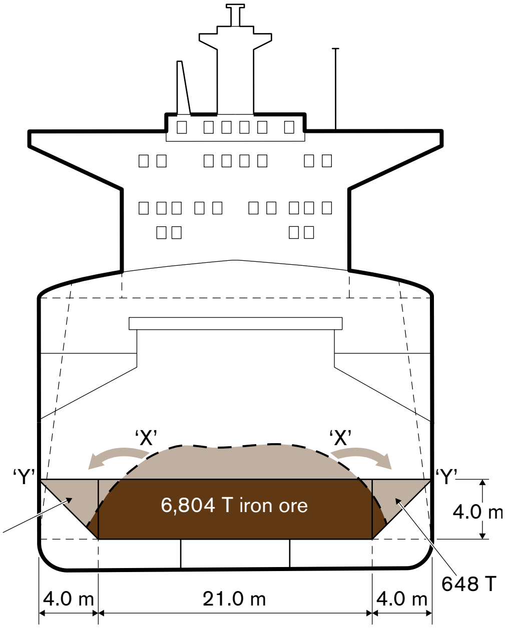

Figure 51.2: X = level of surface of stow before trimming, Y = level of surface of stow after trimming.

Such stresses can seriously weaken the ship's structure. It is possible that the effects of such stowage procedures over a number of years may have contributed to the losses of loaded bulk carriers. During loading, the aim should be to maintain an even distribution of weight both transversely and longitudinally so that the specified tank top limits are not exceeded.

The procedures outlined above are simple, but more complicated situations may arise if breakbulk cargoes are to be loaded where large, heavy pieces of cargo may be offered for shipment.

A 200 T transformer with base dimensions of 5 × 3 m (15 m^2) is to be loaded into the hold illustrated in Figure 51.2. The spot load on the tank top would be 200 T ÷ 15 m^2 = 13.3 T/m^2. This load would be excessive if the limit were 12 T per square metre. To spread the load and reduce the pressure to within the specified limits, it is customary to build a grid-like timber frame on the tank top. The timber selected should have its grain running the length of the timber and be of uniform quality. The area over which to apply the timber can be calculated by dividing the weight of the transformer by the tank top limitation, ie 200 T ÷ 12 T/m^2 = 16.7 m^2. This would be the minimum area to be covered by the frame. 2 × 2 inches and 3 × 3 inches timber is commonly used with the loading of many cargoes, particularly steel. Square timber of greater cross-section is extensively used for supporting heavy lifts.

Ideally, a complete floor should be constructed, with baulks of timber placed next to the steel surface of the tank top and with no spaces between the timbers. In practice, this would be costly and uneconomical. Any procedure is likely to involve compromise, but it is in any case recommended that, with heavy lifts, the baulks used should be of substantial sized timber with cross-sectional areas of not less than 9 square inches (58 cm^2). The timber may compress under the applied weight and, as an alternative, a steel frame may be used. Before deciding the exact stowage position for a heavy lift, it is advisable to check the nature of the hull construction. A heavy lift should be placed with reference to the longitudinal reinforced structure (longitudinal girders). The placement of timber baulks should be considered with reference to the internal double-bottom structure, always bearing in mind that an important function of dunnage is to spread the load to the primary structure of the hull.

Other complications are likely to arise when loading steel cargoes. When loading steel coils, it is usual to load not more than three tiers high with individual coils weighing up to 10 T. If the unit weight is more than 10 T, only two tiers are loaded and, if more than 15 T, only one tier is loaded. Usually, two lines of double dunnage measuring 6 × 1 inches are laid athwartships between the coil and the tank top. Applying the formula above, the pressure exerted over the small bearing surface of the lowest coil is about 30 T. Without due care, the customary dunnage may not be sufficient to effectively spread this weight and there is a risk that the tank top will be overloaded beneath each unit.

Figure 51.3: Steel coils (loaded three high) in a cargo hold.

Every possible precaution should be taken to ensure that the spot load does not exceed the limit, bearing in mind that the load spread is improved if the pitch of dunnage is reduced and that the dunnage must be laid across primary structures and must not terminate in between members (ie between double-bottom longitudinal girders).

The stowage of steel slabs poses similar problems. A typical slab may measure 6 × 1.25 × 0.25 m and weigh 14.75 T. The area of such a slab is 7.5 m^2 and, when stacked 7 high, there would be 103 T bearing down on the tank top. Assuming the slabs were stowed flat, this would indicate a load of 13.74 T/m^2, ie 14.5% in excess of a 12 T permissible limit. However, the lowest slab is likely to be supported by three or four baulks of timber in order to facilitate handling by forklift truck. This means that the entire stack is supported on a maximum of four points, resulting in a tremendous concentration of weight on a small area. Unless larger dunnage is utilised, thereby spreading the load to within satisfactory limits, the tank top will be overloaded when such cargo is loaded in the manner described. Bearing in mind the manner in which steel billets and slabs are usually dunnaged and stowed, it should be clear that little or no weight of that stowage will be distributed to the sloping tank sides unless special dunnaging arrangements are constructed to do so. It is more likely that the flat tank top area alone will be supporting the entire cargo weight, even though billet/slab ends/sides may be touching the plating of the sloping tanks.

Masters are again encouraged to consult the IMSBC Code (Reference 17), referring particularly to Section 2.1.2 which states:

"A general cargo ship is normally constructed to carry cargoes in the range of 1.39 to 1.67 cubic metres per tonne when loaded to full bale and deadweight capacities.

When loading a high-density solid bulk cargo, particular attention shall be given to the distribution of weights to avoid excessive stresses, taking into account that the loading conditions may be different from those found normally and that improper distribution of such cargo may be capable of stressing either the structure under the load or the entire hull. To set out exact rules for the distribution of loading is not practicable for all ships because the structural arrangements of each vessel may vary greatly. The information on proper distribution of cargo may be provided in the ship's stability information booklet or may be obtained by the use of loading calculators, if available."

The data provided for iron ore in the individual cargo schedules of the IMSBC Code indicates that the very densest iron ore has a stowage factor of 0.29 m^3/T, which is considerably lower than that shown in the schedule at the upper limit of the range, ie 0.80 m^3/T. When compared with reported dimensions for billets, their stowage factor may be not greater than 0.25 m^3/T (allowing for dunnage, margin plate areas, interstitial spacing, etc), on the basis that a mild steel billet will have an inherent density of 7.86 T/m^3. If it were possible to stow billets without any interstitial spaces, the stowage factor would be 0.127 m^3/T, demonstrating that billets constitute a very heavy cargo which stows denser than the densest iron ore.

In purpose-built container ships, the tank tops and double-bottom structures are specially strengthened where container corner castings are to be positioned. Here, the guiding principle is the stack weight, where four, six or even nine units per stack are involved. When containers are carried in the holds of non-purpose-built vessels, such as general cargo ships and bulk carriers, great care must be taken to use adequate dunnage to spread the point loading, generated by the stack load, at the corner castings. For instance, a single stack of two units, 20 T each will exert a down loading of 40 T. Beneath each corner casting, the point loading will be about 345 T/m^2. Failure to appreciate the magnitude of such stresses has sometimes resulted in tank tops becoming pierced, followed by flooding of the hold by fuel oil or ballast water.

Figure 51.4: A collapsed tween deck.

When loading high density cargoes, there is a risk of overloading tank tops and proper precautions must be taken. Provided that the tank top is not overloaded, the pressure on the hopper tanks should be within acceptable limits, but in any case, if the density of the cargo is sufficiently high, the surface level of the stow will be below the upper limits of the sloping sides and no problems should arise. When high density bulk cargoes are loaded, the cargo should be levelled to ensure an even pressure over the tank top. Heavy lifts require plenty of strong, good quality dunnage, laying as much dunnage as feasible on the tank top in order to spread the load evenly. The tank top limitations are laid down when the ship is built and, provided that the structure remains within class specifications, remain unchanged throughout the life of the ship. If, through damage or wastage, the structure is reduced, reduced limitations may well have been imposed as a condition of class.

Masters should be aware that tween decks can collapse even when overloading is marginal. There are no safety margins and all cargo must be carefully trimmed. Where ships are fitted with twin hatchways (port and starboard), the cargo should be loaded in equal quantities on each side, unless there are specific instructions in shipyard plans that dictate otherwise.

51.2 Weather Decks and Hatch Covers

Similar caution should be exercised when loading heavy cargo and containers on weather decks and hatch covers.

Unless the weather deck has been specially strengthened, it is unlikely to have a loading limit in excess of 3 T/m^2. Similarly, unless hatch covers have been specially strengthened, it is unlikely that they would have a limit greater than 1.8 T/m^2, and maybe half that value in vessels less than 100 m in length. Hence, it is of great importance to consult and confirm the relevant data from the ship's documentation. When exceptionally heavy cargoes are to be carried, it may be necessary to shore up the weather deck from below, but in such cases care should be taken to ensure that the load on the tween deck plating is properly spread.

Ships should avoid loading to the maximum permissible limit on the weather deck. Heavy weather, and seas across the deck, can add additional weight, which may then exceed the weather deck limits.

It is good practice to add 5% to the weight to be loaded before calculating the dunnage area, to act as a safety margin.

Generally, containers should be stowed on deck two or more high only on those ships that have securing arrangements specially provided. At no time should the deck-loaded containers overstress the hatch cover or the hatchway structure. In cases of doubt, details of stress limitations should be obtained from the Classification Society. As mentioned above, where bulk carriers or dry cargo ships are used for the carriage of containers on the weather deck and/or the hatch covers, it should be borne in mind that it is the stack weight and the resultant point loading beneath the corner castings that must be taken into consideration. This aspect is relevant not only in terms of the structural capability of the ship, but also the ability of the lower tiers of containers to support the superincumbent weight.

Where containers are to be stacked two or more tiers high on the hatch covers or weather deck, the base tier should be provided with permanent footlocks for the lower corner castings. The containers should be secured one above the other by means of twistlocks and/or lockable inter-layer stackers and the upper corner castings of a block of units should be locked into each other transversely by means of screw-bridge fittings and/or tension clamps. Containers so carried must be treated as deck cargo and secured in accordance with the deck cargo rules and recommendations.

The total holding power of the lashing arrangements, properly disposed and attached to appropriate terminal points, should be not less than three times the static gross weight of the containers and contents.

If circumstances demand a twin tier stack in the absence of footlocks or welded restraints, properly rigged foot lashings should be used. The units must be twist locked together and lashed as discussed above. In such instances, the correct use of dunnage, both as to size and application, beneath the base corner castings is of paramount importance, as illustrated in Figure 51.5 (see also Section 53.2).

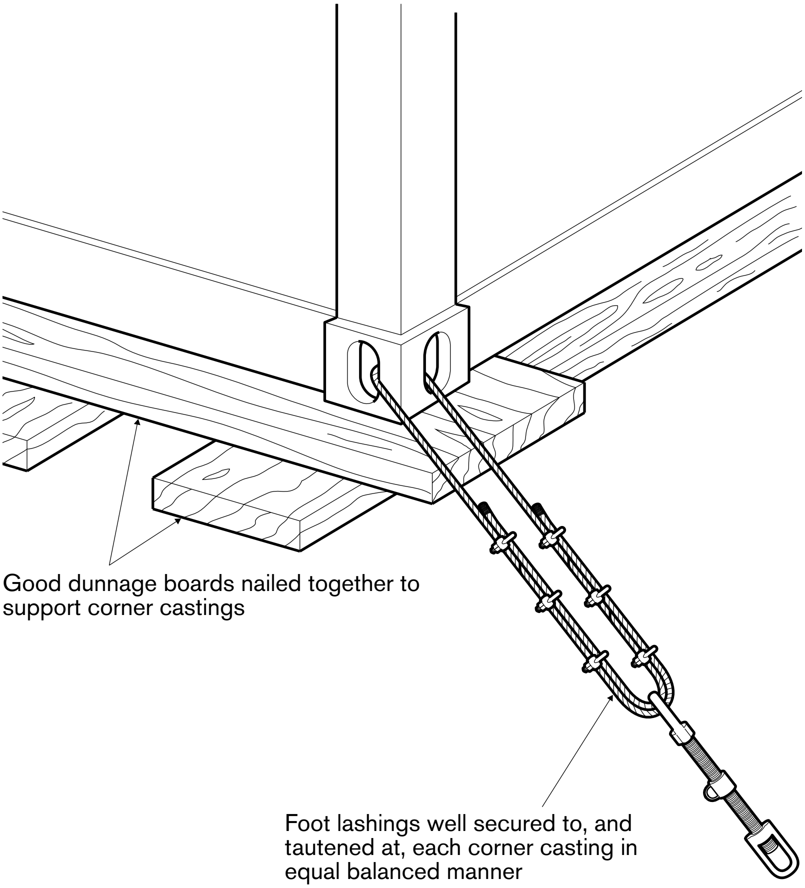

Figure 51.5: Dunnaging and lashing at base corner casting.

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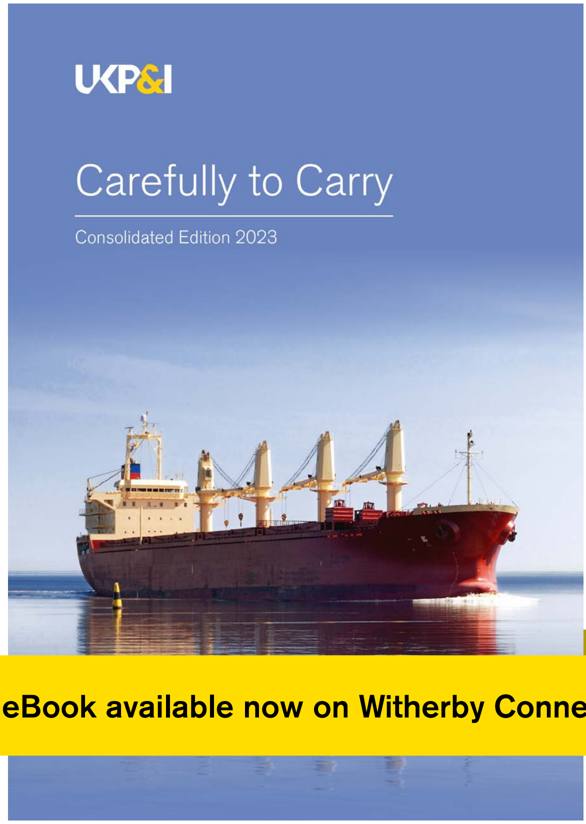

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