U.S. Department of Transportation
United States Coast Guard

Marine Safety Center Technical Note

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Subj: SPECIAL CONSIDERATIONS REGARDING RACKING LOADS IN THE STRUCTURAL ANALYSIS OF LARGE MULTI-LEVEL SUPERSTRUCTURES ON PASSENGER VESSELS OPERATING ON PROTECTED OR PARTIALLY PROTECTED WATERS

Ref: (a) ABS, "Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways, 1980"
(b) ABS, "Proposed River Rules for Passenger Vessels, (Draft) 1993"

1. PURPOSE: This memorandum provides guidance regarding the structural adequacy of large multi-level superstructures on passenger vessels, with specific regard to the analysis of racking loads.

2. DISCUSSION:

a. Many high capacity passenger vessels built for service on protected and partially protected waters incorporate multi-level superstructures which extend nearly the entire length of the vessel. Due to the service nature of these vessels (casino, excursion, dinner, theater) and the high passenger densities, designers and owners strive to provide large, open public spaces within the superstructure. Such arrangements usually result in few, if any, interior transverse bulkheads within the superstructure. In addition, if brackets are fitted they are typically relatively small so that they can remain entirely above the finish ceiling and out of sight. This is a departure from traditional ship construction, which typically uses the interior transverse bulkheads in combination with brackets to provide transverse structural stability and rigidity to the superstructure. The lack of major transverse structure raises concerns about the ability of the superstructure to resist global side or racking loads.

b. The concern over transverse structural rigidity is further amplified when the superstructure is constructed with "floating channels." In floating channel construction the transverse deck girders are placed across the bottom face of the longitudinal deck stiffeners, rather than being welded directly to the deck plate as in more traditional construction (see Figure 1 attached or Figure 4.6 of reference (a)). This type of construction, which is quicker and cheaper to build, was developed and has been approved by ABS primarily for barges and tow boats, where it is used below the main deck only and the transverse rigidity of the hull is provided by large diagonals and required watertight bulkheads (see reference (a)). When floating channel construction is used for large, open, multi-level superstructures the resistance to racking loads is reduced even further.

c. ABS rules do not specifically address the design of multi-level superstructures for global side or racking loads, probably because the amount of transverse structure inherently associated with the traditional service and construction of vessels with large superstructures (such as ocean going cruise ships) provides sufficient rigidity. In those cases where the rigidity of the superstructure is in question, ABS has required specific analysis of the racking condition which falls outside of the scope of the published rules.
Unfortunately, this type of analysis usually involves extensive use of Finite Element Methods (FEM) and is both complicated and time consuming, and does not lend itself to routine plan review.

d. The MSC undertook a limited FEM study to qualitatively determine the effect of racking loads on large, open, multi-level superstructures such as those commonly found on river casino vessels, particularly those constructed with floating channels. The goal of the study was to assess how "big" of a problem racking loads are, and to develop some simple rules which can be used in everyday design and plan review in lieu of a full FEM study. The study concluded that the primary resistance to racking loads comes from the deck plate and the transverse bulkheads, not from the web frames in the superstructure. However, the superstructure frame and connection must be designed for the shear loads transferred from the deck plate. A superstructure designed for local loads in accordance with current ABS standards (reference (b)) typically has sufficient rigidity for the global side loads anticipated on protected or partially protected waters, provided that a few simple additional design calculations and structural modifications are made as outlined below. Where the guidelines below are not applied, detailed calculations and FEM studies may be required at the discretion of the plan reviewer to ensure that the structure is sufficient for all anticipated loads.

3. ACTION:

a. In the structural design and review of large multi-level superstructures, especially those with few transverse bulkheads, the following steps should be taken in addition to the requirements of reference (b):

i. The vertical members in the house sides which form the side of the truss (side frame) serve the dual role of supporting horizontal and vertical loads. Accordingly, they should be sized for both the lateral load (accounted for by the section modulus requirement in reference (b)) and the axial or bearing loads transmitted from above. Because there are few interior bulkheads in the superstructure the vertical loads are transmitted primarily through the vertical frames in the house sides and the stanchions. To account for the combined loading on the vertical side frames, the sectional area of a member which satisfies the section modulus requirement of reference (b) should be increased by 1 square inch for each 10 tons of axial load supported. The axial load on these vertical members should be calculated in a manner similar to the load on a stanchion which supports deck girders.

ii. Both vertical frames in the superstructure sides and stanchions, which support deck girders in the superstructure, must have a ratio of length to least radius of gyration less than 150. This ensures that these members can resist the bending moments caused by the global side loads on the superstructure.

iii. An effective means of transmitting the load from the deck stiffeners to the superstructure frame at the house ends (fore and aft) must be provided. Typically this is accomplished with vertical stiffeners in the house ends which are connected to each longitudinal stiffener on the deck where they terminate. When the house end is horizontally stiffened, vertical members must be fitted from the termination of the longitudinal deck stiffener down to the first horizontal stiffener on the house (see Figure 2). The load on longitudinal deck girders in the superstructure must be effectively transmitted to the main deck through vertical frames in the house ends, as shown in Figure 2.

iv. Where floating channel construction is used, a plate of thickness at least equal to the thickness of the transverse girder must be inserted in the gap between the deck plate, the transverse girder, the farthest outboard longitudinal stiffener, and the vertical truss member in the superstructure side, at every frame (see Figure 3). This plate greatly reduces the shear stress at these connections by increasing the area available to transmit the loads.

v. Where floating channel construction is used the transverse deck girders should be channel sections. Where "L" or other sections are used, tripping brackets must be fitted at least every 10 feet of transverse span.

vi. Where the decks in the superstructure are transversely stiffened with the deck girders running longitudinally, the same general guidelines above apply. Each transverse deck stiffener must connect to a vertical stiffener in the longitudinal superstructure side shell. Floating longitudinal girders must be fitted with filler plates as described above, and vertical members which form the truss ends in the transverse superstructure bulkheads should be sized for axial and side loads.

b. Special consideration will be given to designs which do not meet the above guidelines provided that calculations are made which specifically address the following:

i. Analysis of the superstructure side frame under combined loading of both axial and lateral loads.

ii. Adequacy of the design for the resistance of racking loads, including buckling analysis of the deck plate.

iii. Detailed analysis of the stress at the connection of the deck plate to the transverse bulkheads under racking loads.

iv. Detailed analysis of the shear loads at each connection of a floating transverse girder with a vertical side frame or longitudinal deck girder.

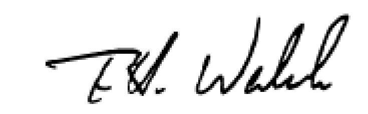
Typically a FEM study will be required to demonstrate the adequacy of the superstructure. Any such study must contain the following as a minimum:

i. A 3D model extending at least one web frame spacing longitudinally and from side shell to side shell transversely. Symmetry in structure or loading can not be assumed.

ii. A statement of boundary conditions used and how they were derived from global forces.

iii. List of maximum permissible stress for each type of element used.

iv. An explanation of the loading conditions investigated.



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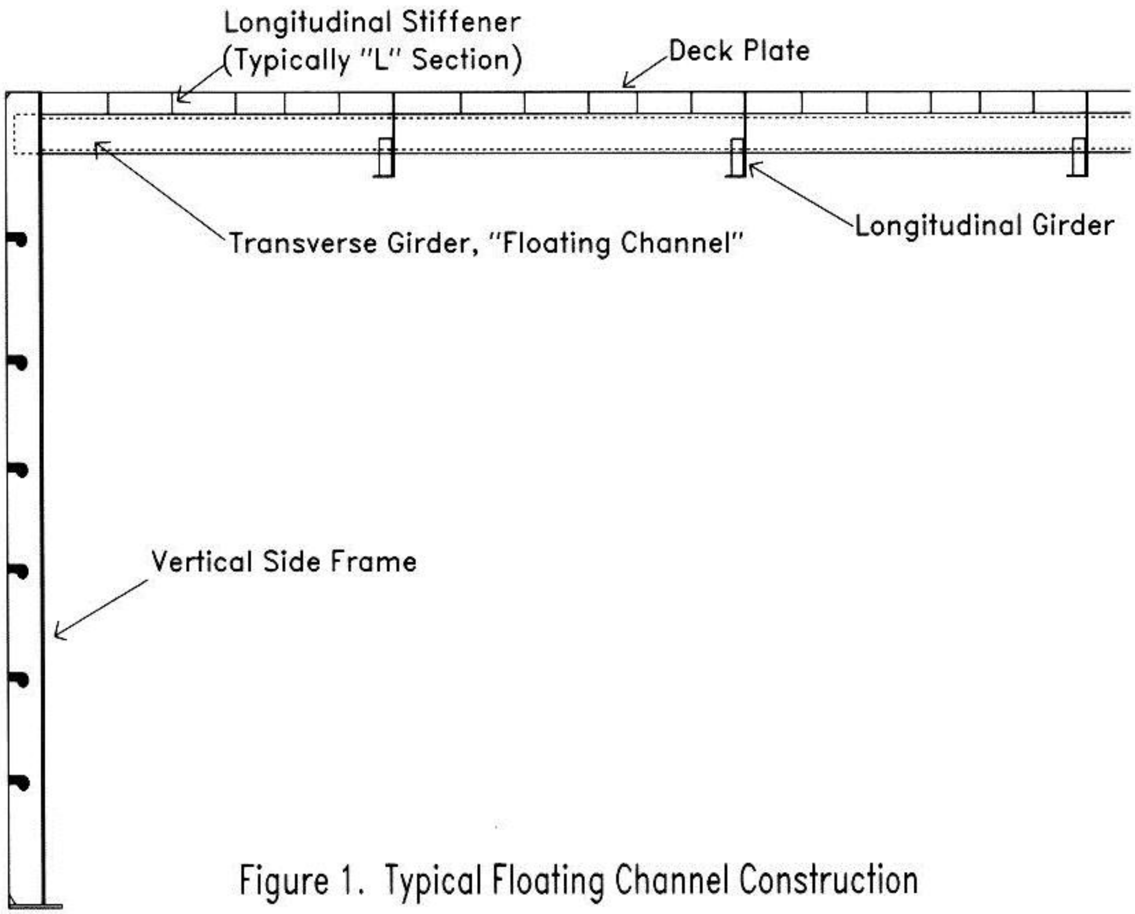

Figure 1. Typical Floating Channel Construction

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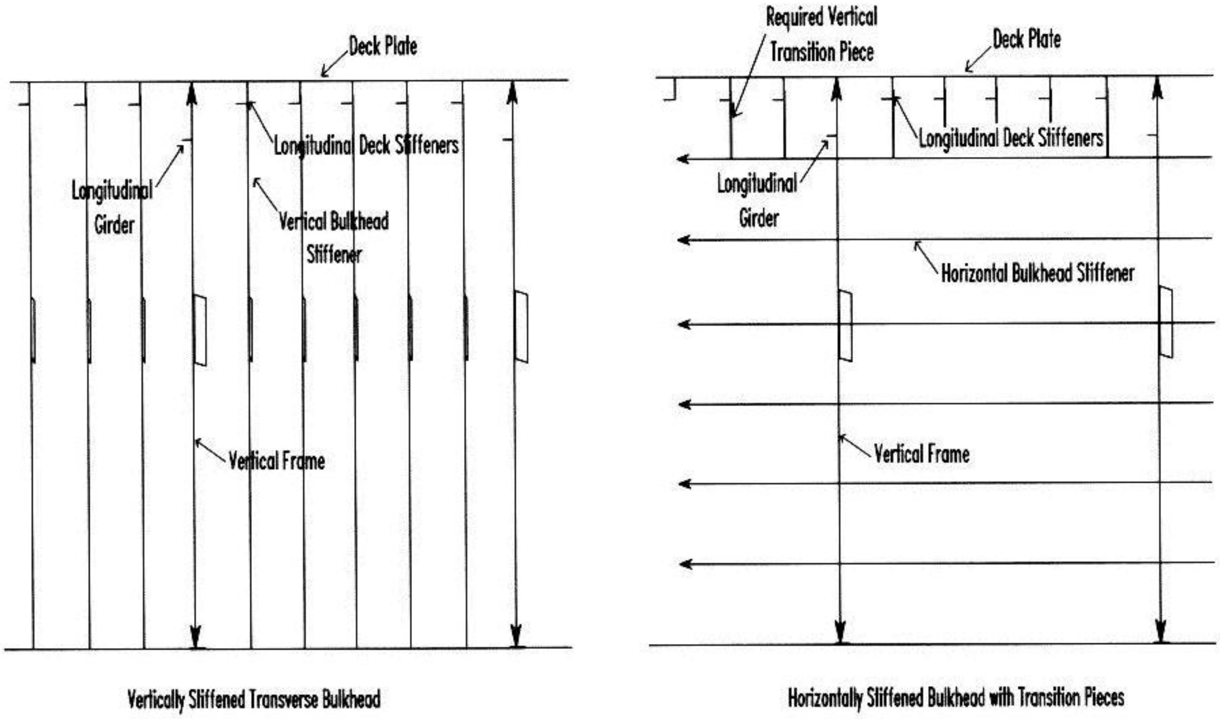
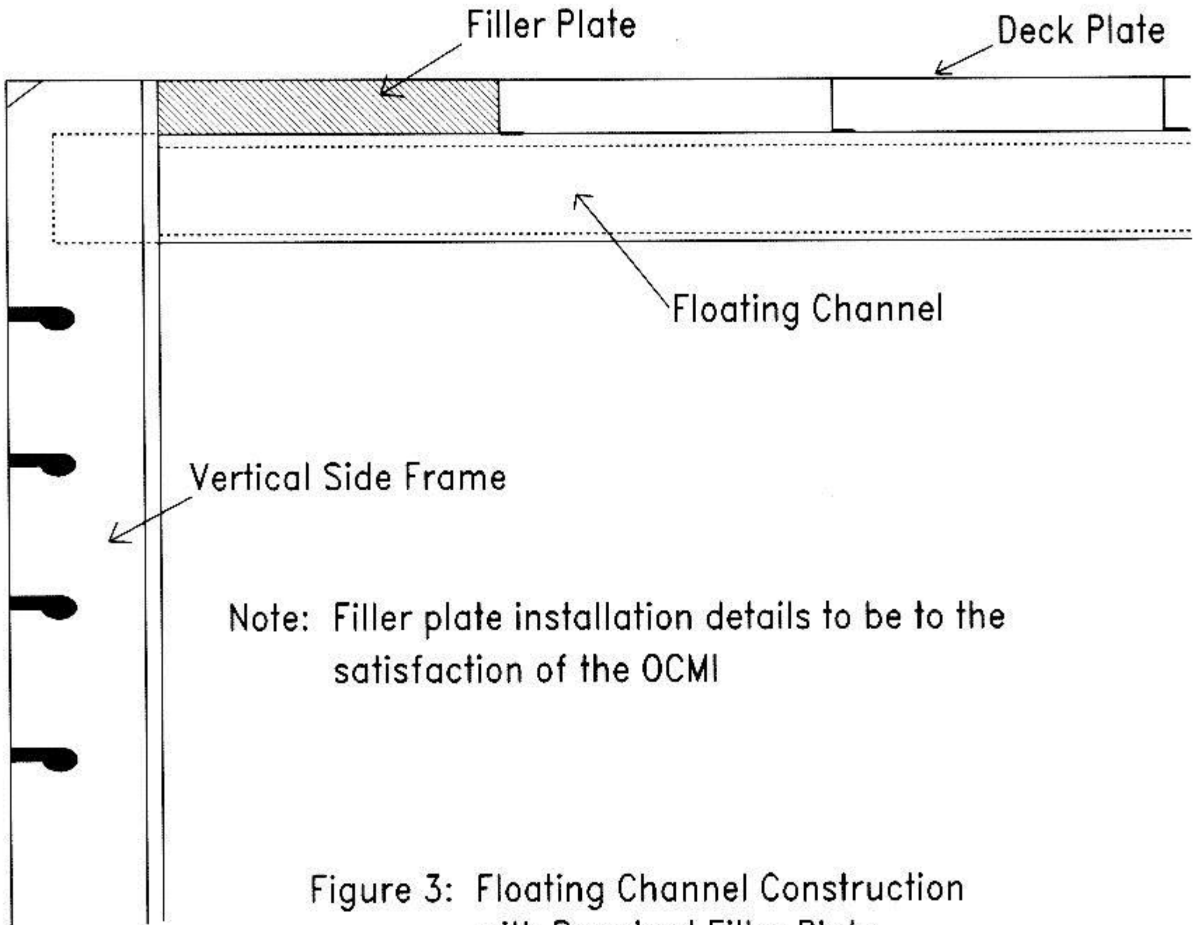


Figure 2. Sectional View of Transverse Bulkheads



Note: Filler plate installation details to be to the satisfaction of the OCMI

Figure 3: Floating Channel Construction with Required Filler Plate