# Concept of barge hull structure made of extruded aluminium panels

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ABSTRACT

*A design of the hotel barge of 52 m overall length and 9 m breadth , intended for inland waterway shipping on the route from Berlin to Kaliningrad, is presented. Hull of the barge is characterized by a unique structure consisted of densely stiffened aluminium panels of 4.5 mm plate thickness and 70 mm depth of stiffeners, supported by transverse walls or girders. The stiffeners of the panels are longitudinally directed. Also, are described problems associated with assurance of adequate strength and stiffness of such structure, resulting from a limited maximum depth of the barge.*

**Keywords** : inland waterways ships, ship hull strength, structures composed of aluminium panels.

## INTRODUCTION – PUSH TRAIN CONCEPT

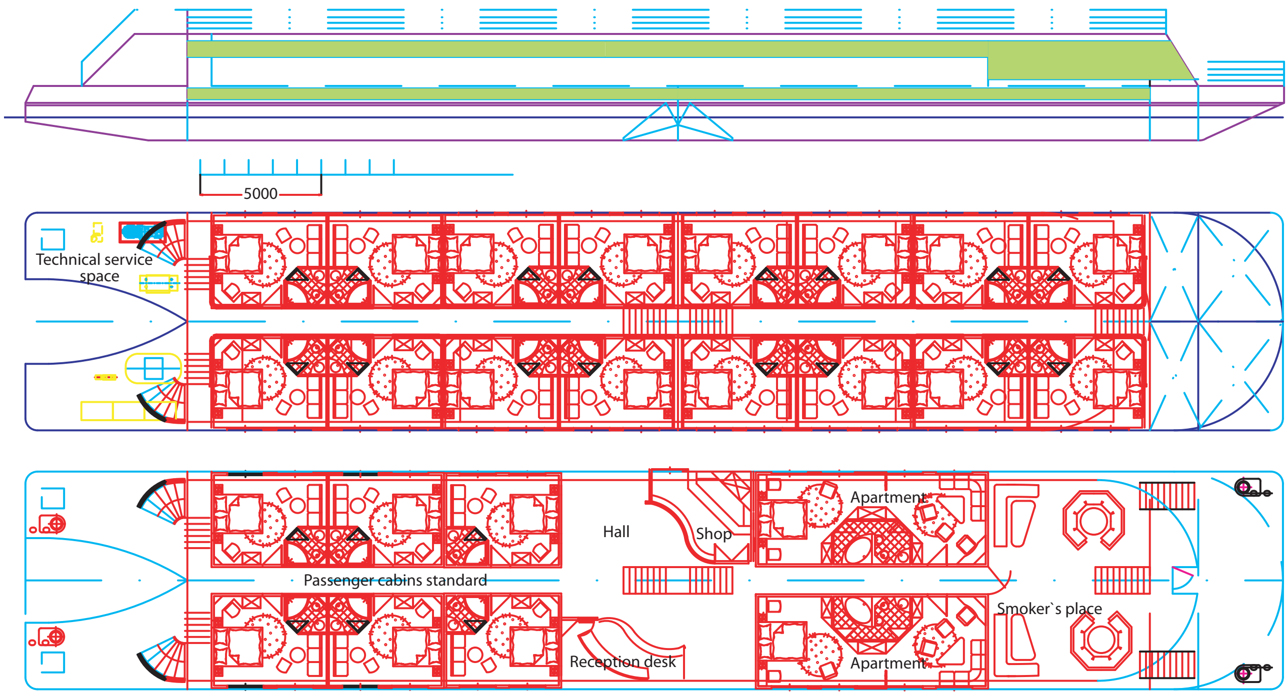
The push train shown in Fig. 1. is intended for operating on Berlin – Kaliningrad route. The train is composed of a hotel barge, restaurant barge and pusher. The lack of any protrusions on the upper decks characterizes the barges. The decks fitted only with folding bulwark rails serve as sun bath decks.

Such arrangement of the barges results from their limited depth associated with gabarites of bridges across the rivers and canals along the planned shipping route.

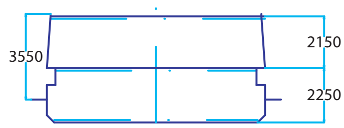
A unique construction of stern parts of the barges was proposed. The recesses provided there, are adjusted to the bow part of the pusher. As a result, an easily operated and strong connection between the two units is obtained.

The maximum depth limitation of the barges creates certain problems associated with assurance of appropriate strength of barge hull structure.

The problems are discussed in detail in Ch.3. And, in Ch.2 is described a unique structure of barge hulls composed of extruded aluminium panels.




| PRINCIPAL CHARACTERISTICS | | |
|---|---|---|
| Length overall | Loa | 52.00 m |
| Length between perpendicular | Lbp | 50.70 m |
| Breadth moulded | B | 9.00 m |
| Depth to main deck | H | 1.55 m |
| Design draught | T | 0.85 m |
| Scantling draught | Tmax | 1.20 m |




General arrangement

***Fig.1.** General arrangement of the push train .*

## BARGE HULL STRUCTURE

The limitations described in Ch.1 make that the sun bath deck (superstructure deck) cannot be located higher than 4.4 m above the base plane.

Therefore it was proposed that the barge accommodations should have the following gross height (i.e. that determined without taking into account plate stiffening system or girders which make the net height even smaller) :

- from the base plane to the main deck : 2.25 m
- from the main deck to the sun bath deck : 2.15 m.

The so small gross heights of accommodations make it necessary to apply a specific structural arrangement in order to obtain the minimum permissible net height of living and servicing accommodations. Hence it was decided to use the unique structural arrangement composed of the extruded panels made of 6082 aluminium alloy (acc. OIN) having the tensile strength $R_m$ = 290 MPa. The cross-section of the panels is shown in Fig. 2.

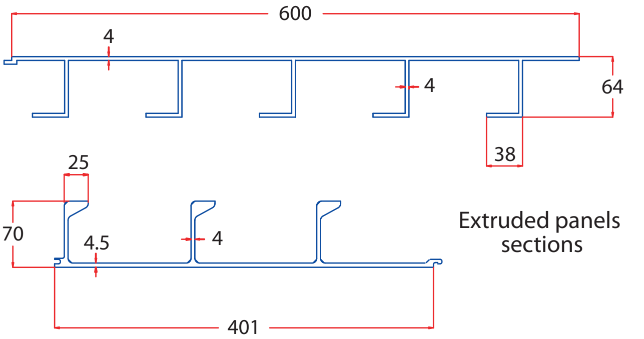



***Fig. 2.*** *The extruded panels to be applied .*

Such panels are densely stiffened. At 70 mm depth, they ensure relatively high bending strength of the stiffeners as well as local bending strength of the plates of 4.5 mm thickness. This way it is possible to eliminate transverse frames from the space below the main deck, which would support the panels, as the panels, longitudinally stiffened, can be supported directly by the transverse walls which are also intended to be made from extruded aluminium panels of stiffeners directed vertically.

The walls are placed with spacing not greater than 4.5 m, which results from the barge space subdivision because on the lower tier of each of the barges is designed a row of passenger cabins (hotel barge), crew cabins or various servicing accommodations (restaurant barge). The panels are so strong that at the barge draught T = 0.85 m they can transfer the load resulting from water pressure over so large span as that (i.e. up to 4.5 m).

The midship section of the barge hull composed of the stiffened panels is shown in Fig.3.

The specific construction of the joint of the stiffened panels and transverse walls is presented in Fig.4.

In the corridor between cabins the panels are to be supported by transverse girders just in the planes of transverse walls.

Short spans of the girders allow for making them of aluminium profiles of a relatively low depth. As a result, a sufficient net height of the corridor is obtained.

On higher tiers of both barges (under sun bath deck), relatively large accommodations are located, where the distance between transverse walls exceeds 4.5 m substantially, and in consequence the girders supporting both the deck and side panels cannot be avoided. In order to obtain a sufficiently large

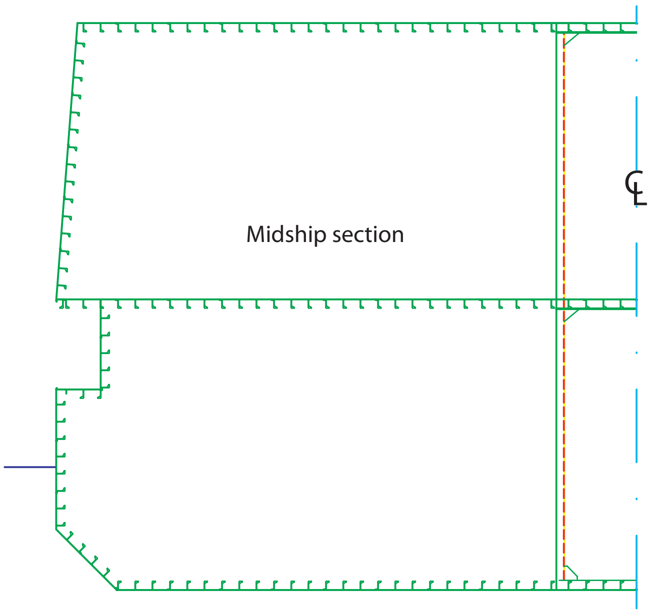



***Fig. 3.*** *Midship section of the barge hull .*

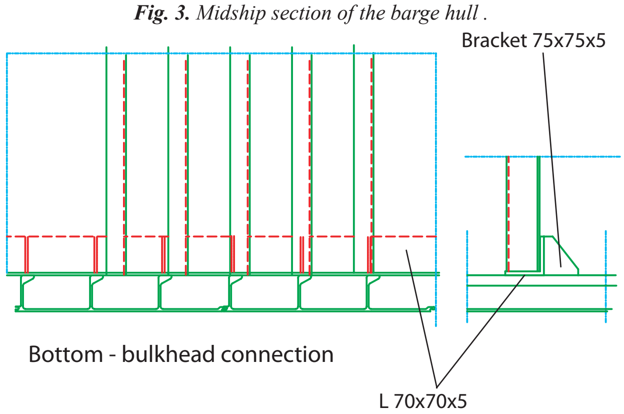



***Fig. 4.*** *The joint between the stiffened panels and transverse walls .*

net height of the accommodations it is necessary to apply such joints between the panels and transverse girders as shown in Fig.5. It is also necessary to provide additional support of the transverse girders by means of pillars, to reduce the girder depth as much as possible. The pillars are placed just at the transverse walls separating the cabins.

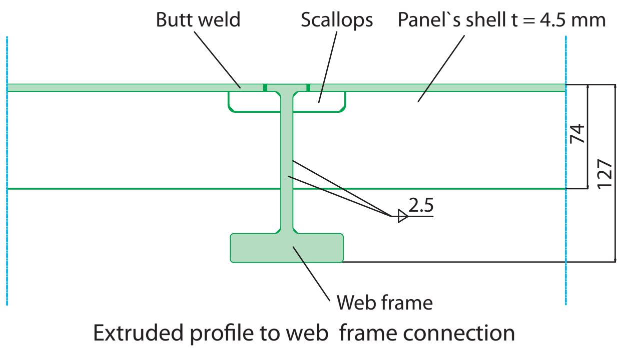



***Fig. 5.*** *The joint between the panels and transverse girders .*

## STRENGTH OF BARGE HULLS

The above described barge hull structures composed of extruded aluminium panels greatly differ from equivalent classical steel structures. Hence specific strength problems arise.

The assumed large span of the panels (up to 4.5 m) results in a high level of stresses due to local bending of stiffeners of the panels supported by transverse walls or girders.

At the pressure acting on the barge bottom, p = 12.0 kPa (resulting from the draught T = 0.85 m and wave load), and the span l = 4.5 m, the bending stresses are equal to :

$$\sigma = \frac{psl^2}{12W} = 165 \text{ [MPa]}$$

where :

p, l – as given above,
s = 0.133 m – spacing of stiffeners (see Fig. 20)
W = 16.28 $cm^3$ – strength modulus of stiffener with plate strip of effective width.

The σ value is relatively large, not exceeding however the permissible one acc. [1], where the following is assumed :

$$\sigma_{dop} = 0.8\ \sigma_y = 200 \text{ MPa}$$

($\sigma_y$ = 250 MPa – proof strength of the aluminium alloy).

Another consequence of the relatively large span l are also the relatively large deflections of the panels. At the pressure p = 12.0 kPa the maximum deflection amounts to about 37 mm (at the Young modulus of the aluminum alloy, E = 70 000 MPa).

A relatively massive structure of the panels results in that there are no problems with the assuring of sufficient strength to the barges under overall bending.

It was assessed that the maximum stresses σ resulting from the minimum bending moment [1] applied to the barge hull :

$$M_{min} = 0.07\ BHL^2 = 2510 \text{ kNm}$$

where :

B – barge breadth (9.0 m)
H – barge depth (1.55 m)
L – barge length (50.7 m)

enlarged by the wave bending moment $M_w$ = 851 kNm (for the navigation zone „3” of the wave height up to 0.6 m, acc. [1]), are equal to σ = 9.0 MPa only (in the barge bottom plate, assuming that the superstructure deck is the strength one).

The so small value of compressive stresses are not imminent as regards the buckling either of panel stiffeners in compression or their plating.

The Euler stresses for the stiffeners of bending mode of instability at the span l = 4.5m, are equal to about 24 MPa.

The Euler stresses for the stiffeners of torsional mode of instability and those for panel plate buckling are many times greater than the above given stresses for stiffeners of bending mode of instability.

During designing the barge hull structures, emerged a serious problem dealing with assuring a sufficient bending stiffness to the deck transverse girders. It was revealed that the deck transverse girders, though they satisfy the strength requirements of the Rules [1] at their span of 4.5 m and the calculation pressure p = 4.5 kPa for passenger decks, have their bending stiffness smaller than the critical one. Thus they do not prevent the decks against overall buckling. In order to obtain their stiffness greater than the critical it was necessary to apply pillars to support the transverse girders in the spacing not exceeding ¼ B (where B – barge breadth).

## FINAL REMARKS

- Limitation of the overall depth of the barges forced to apply a specific construction to their hulls. To this end, the extruded aluminium panels of stiffeners directed along the ship axis, were used. The panels were supported by walls or transverse girders placed relatively sparsely – even as much as about 4.5 m apart.

- On the upper tier of the barges where spacious accommodations were designed it was necessary to apply many pillars in order to ensure sufficient structural strength and stability of the transverse girders of the superstructure deck. The pillars -without a doubt – affect negatively functionality of the accommodations.

- The expected deflections of the bottom panels between transverse walls reach significant values (up to 37 mm). Hence some difficulties may appear in using the accommodations of the first tier of the barges.

**BIBLIOGRAPHY**

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*Photo : Arkadiusz Łabuć*