old undamaged and new reinforcement, fresh concrete can be poured into place. Since concrete sets under water it is not necessary to retain the vessel in dry dock during the initial stages of hardening. The actual time required for weathering will depend on the structural importance and extent of the damaged portion, and unless this is considerable, the vessel can return to service after a much shorter lapse of time than was necessary between launching and delivery.

Methods of Waterproofing

Watertightness is one of the points which the naval architect will most critically examine when the question arises of replacing steel by reinforced concrete. Fortunately, experience of large tanks in land work is by no means limited, and it is possible to draw certain inferences from the behavior of these structures. Apart from the water-resisting ability of simple concrete there are various methods of treating the material which fall generally into two categories: (1) The addition to the concrete during mixing of a waterproofing compound; (2) The treatment of the finished surface with a suitable non-porous material. The first of these is generally believed to reduce the strength, and in the present position of the industry the naval architect will be chary of adopting it. The second comprises the treatment of the surface with a cement mortar well rubbed into the pores, coating with a special mixture, and painting as in a steel ship. It is interesting to note that, even in this early stage of development, reinforced concrete vessels are being built to carry fuel oil in bulk, experience with land storage tanks and experiments recently made indicating that mineral oil has little or no destructive effect on the material.

The ability of reinforced concrete to stand vibration, whether from propelling or deck machinery, may be called in question. The experience afforded by railway bridges and factory floors shows that little trouble need be feared from this cause, provided that the concrete is not allowed to fail progressively by unsuitable distribution of attachments.

Concrete when being worked in a plastic material; the processes of construction partake more of the foundry than of the shipyard, and the moulds required in a foundry equally have their place in the reinforced concrete shipyard. It is evident that the quantity of material required for the moulds is great, and the labor required for their erection will bear a considerable proportion to the total labor required for the ship. It is therefore an obvious economy to arrange that several vessels shall be cast from the same moulds. This has a marked effect on the standardization of type. Where wood is used for the moulds it will probably be found that from five to eight vessels can be built from one lot of shuttering, though considerable repairs and renewals to the woodwork will only be avoided by skilful design and care in erection and dismantling.

To Avoid Intricate Forms

It seems evident that if the usual ship form be adopted, in which there is curvature in two directions, the amount of work entailed in shaping the shuttering will be at its maximum. The minimum amount of shaping will be given by a rectangular box; but as such a form is usually inadmissible a compromise must be effected. The best result from the point of view both of the naval architect and the reinforced concrete engineer must be sought among the class of "straight frame" forms, which yields at once reasonable figures for resistance in association with curvature in one direction only. Two suggested compromises are shown in Figs. Nos. 1 and 2, the "batter" of the sides in Fig. No. 1 being given in order to reduce the chances of possible damage at the sharp bilge when lying alongside quay walls, and in the case of Fig. No. 2 to secure "flare" at the bows.

The inspection of a reinforced concrete vessel just prior to the commencement of pouring is apt to produce in the mind of the naval architect an impression other than favorable. The unfamiliar network of rods scarcely suggests serious shipbuilding, and the idea that these should be replaced by the more usual and substantial sectional material at once presents itself. In the case of the frames, for instance, two angle bars connected by light bracing would appear to possess the same strength as the rods, in combination with greater ease of erection and immobility during pouring. This system, however, would relegate the concrete to the inferior position of a mere cover for, and support to, a complete steel structure, and would be a return to a method long discarded by reinforced concrete engineers. It would seem a fundamental error to cling to methods of construction found suitable in one material when dealing with another material of a totally different character.

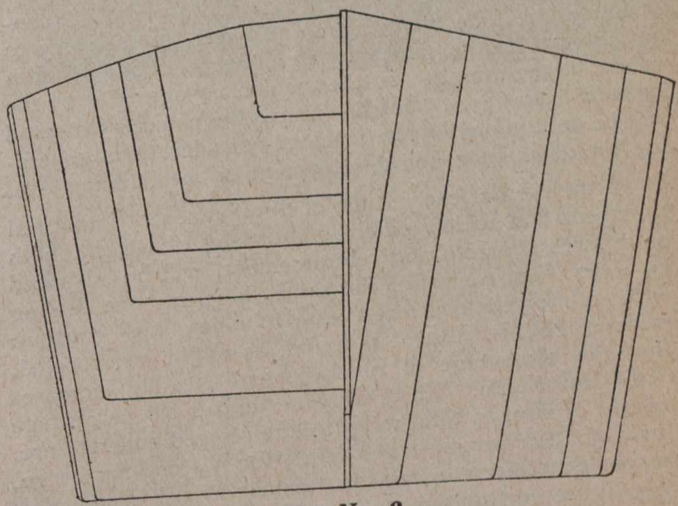

Fig. No. 2

The majority of present-day reinforced concrete designs are based on the production of a vessel which should be cast in one operation, the "monolithic" method, and the foregoing remarks on construction primarily have reference to a monolithic ship. The alternative method is to cast the integral parts separately and assemble them at the slip—the "sectional" method.

In the "sectional" method, portions of the structure more or less extensive are cast from moulds which should be capable of being used a large number of times. A vessel whose sides have irregular curvature, or one in which there is no great extent of parallel middle body, is evidently ill-suited to this form of construction. The sections are assembled in place, and in addition to grouting, steps must be taken to provide for continuity of the local reinforcing material. As it is impossible to allow the general longitudinal reinforcement to be broken abruptly, it is obvious that it cannot form part of the sections, and must therefore be placed in position separately from them. After the sections are assembled, the longitudinal reinforcement at gunwale, bilge, etc., would be placed and the concrete poured round it.

The launching of a vessel subjects the structure to local stresses which may be of considerable magnitude. By constructing the vessel in such a situation that she