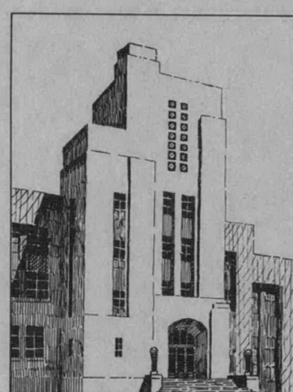
THE DAVID W. TAYLOR MODEL BASIN

UNITED STATES NAVY

RECENT TESTS OF THE TENSILE STRENGTH OF SHIP MEMBERS

BY PROF. DR.-ING G. SCHNADEL, BERLIN



DECEMBER 1941 TRANSLATION 92

RESTRICTED

RECENT TESTS OF THE TENSILE STRENGTH OF SHIP MEMBERS

(NEUE VERSUCHE ÜBER ZUGFESTIGKEIT VON SCHIFFSVERBÄNDEN)

by

Prof. Dr.-Ing G. Schnadel, Berlin

(Werft-Reederei-Hafen, No. 16, 15 August 1939)

Translated by M. C. Roemer

The David W. Taylor Model Basin
Bureau of Ships
Navy Department, Washington, D. C.

December 1941 Translation 92

RECENT TESTS OF THE TENSILE STRENGTH
OF SHIP MEMBERS

1. TEST SPECIMENS

The tests described were carried out with funds furnished by German Lloyds. Their purpose was to supply information regarding the tensile strength of welded ship members, although the Navy had previously authorized a series of tests at the National Bureau of Standards in Dahlem, in which welded and riveted joints were studied. The only completely riveted joint in that group was in a test specimen with a butt strap on one side. Such joints, however, are seldom used in merchant ship building, because of their comparatively low tensile strength. Therefore it seemed important to test welded members such as are preferred in highly stressed parts of merchant ships. This was considered necessary since empirical data for merchant ship building had been gathered chiefly from riveted structures, and exact knowledge of the relative strength of various members was required for the transition to welding.

Each of the two assemblies consisted of three strakes of plating in which the middle one only had a joint. The first assembly contained a lap joint with four rows of rivets, and the second a triple-riveted double-strapped joint. The strakes were double-riveted to each other along the seams. The assemblies were so dimensioned that they could be tested to rupture in the large testing machine at Dahlem. The length of the assemblies was 6000 mm (236.2 inches), the width 2360 mm (92.9 inches) and the nominal thickness 11.5 mm (0.453 inches). Assembly 1 is shown in Figure 1. A number of the Huggenberger tensometers which were used for measuring strains can be seen in this picture, as well as the bolts of the clamps with which the specimens were clamped into the testing machine.

In this test the relative strength of the individual elements of the specimens is particularly worthy of note. The cross-sectional area of the plate in the intact portion was 290 cm^2 (45 square inches), making allowance for the four rivet holes in the two double-riveted longitudinal seams. In the smallest cross-section in the region of the lap there was a net area of 270 cm^2 (41.8 square inches). The intact cross-sectional area of the middle strake was 102 cm^2 (15.8 square inches) and after deducting for the rivets in the outside row, 75.5 cm^2 (11.7 square inches). There was a total of 90 cm^2 (14 square inches) rivet cross-section available in the middle strake for the transmission of forces. The factor of safety, therefore, was disproportionately low, although it agrees with the riveting of thick plates in the specifications of German Lloyds. This method of riveting was selected in order to test the qualities of a joint having a relatively

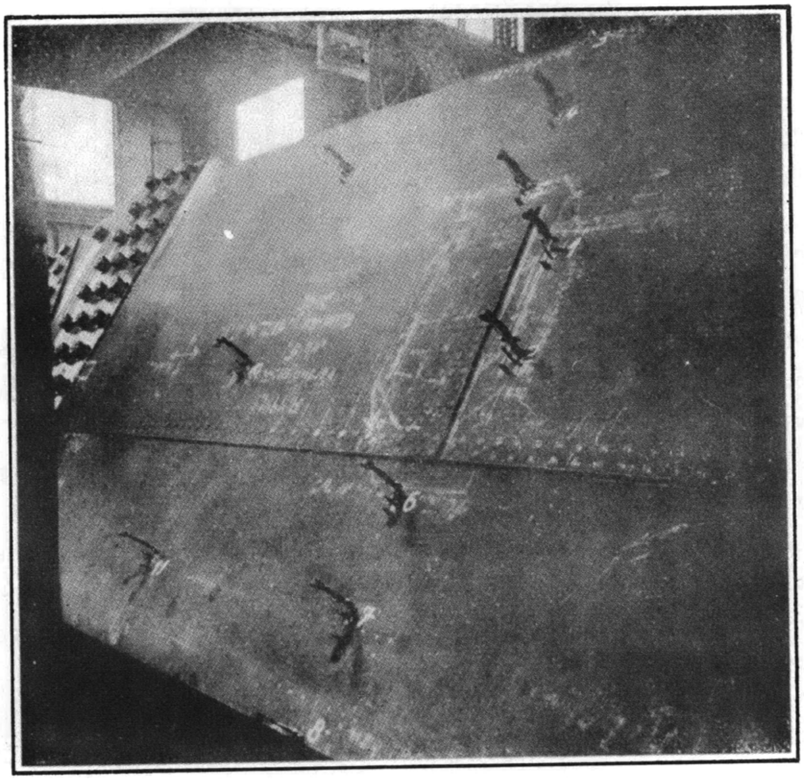


Figure 1 - Plate with lapped joint

small rivet area. The rivet diameter in the specimen was 13 mm (0.51 inches). As there was no testing machine available for full-scale tests, all the dimensions of the plates were reduced in a given ratio to those in a ship structure.

Assembly 2, as stated, had a double-strapped joint with a total cross-section of 281 cm² (43.5 square inches) to the left of the joint, allowing for the four rivet holes in the intact cross-section. The smallest cross-section in the first row of rivets of the joint was 262 cm² (40.6 square inches). The jointed strake itself had a gross cross-section of 101.3 cm² (15.7 square inches), and a net cross-section of 78 cm² (12 square inches) through the outer row of rivets. The joint was made up with 48 rivets in double shear, having a total cross-section of 127 cm² (19.7 square inches) and a rivet diameter of 13 mm (0.51 square inches). The riveting of this joint, therefore, was unusually heavy. Consequently it was thought that the two specimens would behave very differently from each other.

The specimens were made of Siemens-Martin shipbuilding steel as prescribed by German Lloyds. Samples were cut from various parts of the test specimens to ascertain the properties of the material. The strength qualities of the individual parts of the first assembly are in good agreement.

Elastic limit, yield point, and ultimate strength are approximately equal. In Assembly 2, on the other hand, the middle strake was made of material having a higher elastic limit and a higher yield point than the two outside strakes. This will be referred to subsequently.

2. THE LAPPED JOINT

As already stated, the strains were measured with Huggenberger gages in this test. In addition, the displacements of the butt and the displacements of the middle strakes with respect to the two outside strakes along the seams were determined. At several important points the strains were measured, beginning with the first load increment, so that for these points all the permanent and elastic deformations are known. Moreover, the overall extension of the assembly was measured over a length of 4 m (157.5 inches).

One of the results of these investigations is shown in Figure 2, where the measured strain over a length of 4 m (157.5 inches) is plotted

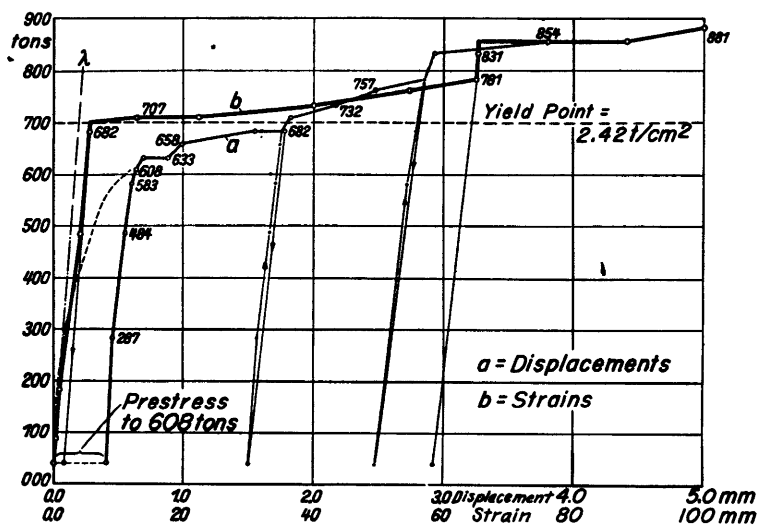


Figure 2 - Results of displacement and strain measurements of the plate with a lapped joint

against the displacement of the joint. With respect to the strains it should be noted first that they are little affected by the size of the assembly and the arrangement of the joint. Although the strain in the elastic range was somewhat higher than that corresponding to the Hooke parameter λ for the mean elastic modulus of the material, this difference is not to be attributed to the stress condition of the plate but to a small curvature present in the assembly from the start. The strain at the yield point under a load of 700 tons* corresponding to a stress of 2420 kg/cm² (34,420 pounds per square inch) is only slightly lower than that at the normal yield point, which in the tensile tests was determined with small samples. This shows that the flow phenomena and the displacements are confined to a narrow (short)** zone near the joint. Under repeated loading the strengthening of the assembly is particularly noticeable under a load of 780 tons. Displacements in the joint occur under loads as small as about 400 tons without any noticeable effect on the (overall)** strain. The shear limit is reached at a load of about 633 tons, the mean stress amounting to about 2170 kg/cm² (30,865 pounds per square inch).

The subsequent tests plainly showed a slipping of the rivets on the longitudinal seams also, even though these displacements are considerably smaller than those in the middle of the joints. The local strains were not evenly distributed among the three strakes of plating. Local yielding occurred in the two outer strakes under a load of about 600 tons, in immediate proximity to the joint, while the middle strake reached the local yield point at certain places only at about 670 tons. Analysis of the measured strains, displacements, and permanent deformations gave the change in load distribution in the three strakes of plating under the various loadings.

In this connection it is worthy of note that at the lower load stages, up to about 1200 kg/cm² (17,068 pounds per square inch) mean stress, the riveted strake was subjected to a greater load than the two adjacent strakes. Above this load, the yield (Nachgiebigkeit) of the joint had the effect of increasing the displacement, which resulted in relieving the jointed strake, so that the load on this strake with respect to the mean gradually decreased by about 7 to 8 per cent. Above the slip limit the two outer strakes bear less of the load because of local plasticity near the joint, which caused the load once more to be evenly distributed over the three strakes.

Rupture occurred under a load of 999 tons. This load can be taken as highly reliable, since it was measured not only on the testing machine but was also checked by strain measurements on the tension shaft (Zugspindel) of the machine. The ruptured plate is shown in Figure 3. The rupture started in the outside row of rivets in the joint in the middle strake. After the load began to decrease, it was once more raised to 710 tons, when complete

---

* Translator's note: Tons referred to herein are metric tons.

** Added by translator.

rupture occurred in the upper (outer) strake. This indicates a retarding effect of the riveted longitudinal seam, which was sufficient to prevent complete rupture at first.

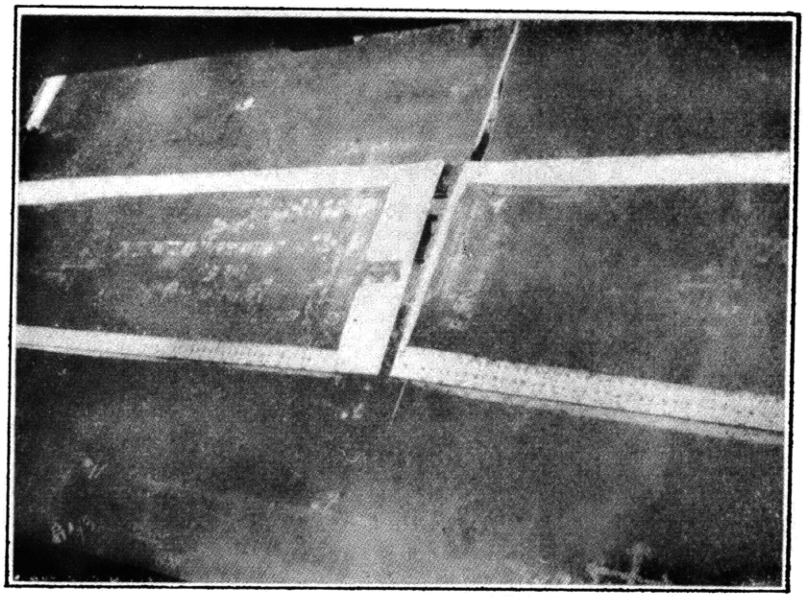


Figure 3 - Rupture in plate with lapped joint

The mean stress over the entire cross-section at the moment of rupture was 3440 kg/cm² (48,928 pounds per square inch), not considering the rivet holes. In the cross-section of the joint the stress over all three strakes was 3700 kg/cm² (52,626 pounds per square inch). Since at the maximum load all the strakes carried equal loads, according to the strain data, the stress in the zone of the first row of rivets was found to be about 4400 kg/cm² (62,582 pounds per square inch); this is somewhat higher than the strength of the material under uni-axial load. The shear stress in the rivets at the moment of rupture was 3700 kg/cm² (52,626 pounds per square inch) under the same conditions.

The result of the test shows that the lap joint with its relatively small rivet cross-section possesses high strength. More than 80 per cent of the tensile strength of a full cross-section is attained, so that at the present state of welding technique a joint of this type must be considered as equivalent to a welded joint. Referring the strength values to the yield point, the riveted joint is found to have a strength of 88 per cent with respect to the intact plate. It is important to point out that the overlaps in the joint were included in the investigation, i.e., the overlaps must be taken into account in comparing riveted and welded joints.

3. THE DOUBLE-STRAPPED JOINT

As previously noted, a double-strapped joint is distinguished from a lapped joint primarily by the fact that the riveting is much stronger in the former.

In this assembly the total strains were also measured over a base length of 4 m (13.12 feet) and the displacement of the straps was measured with respect to the middle strake. The result of the strain and displacement measurements is given in Figure 4. Here too the stress-strain curve is affected only slightly by the arrangement of the joint. The Hooke parameter, designated by λ in the figure, differs only slightly from the measured curve below the yield point. The yield point itself is reached at about 767 tons, corresponding to a mean stress of about 2730 kg/cm² (38,830 pounds per square inch), and lies only slightly below the mean yield point, which was determined with the tensile specimens. In this plate too, strengthening is noted under repeated loadings.

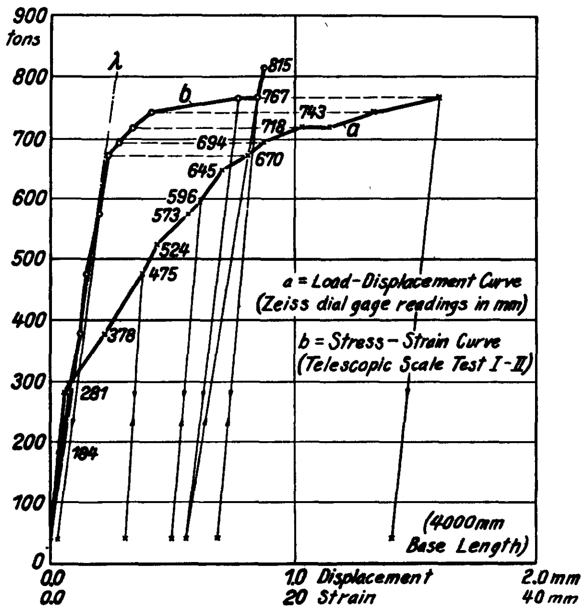


Figure 4 - Data of displacement and strain measurements on the double-strap-jointed plate

The displacement picture of the joint is much more conspicuous than that of the first assembly. Up to a load of about 300 tons the displacement of the joint is very slight, which is an indication that the rigidity of the double-strapped joint is extraordinarily high. At about 300 tons the riveting begins to slip, but the actual slip limit is reached at about 718 tons. The local strain readings corresponded to the displacement data. Local yielding of the outer strakes started under loads of 600 to 700 tons, while the middle strake showed signs of yielding at about 750 tons.

Analysis of all the data showed that the jointed strake was greatly overloaded at the lower load stages, up to about 18 per cent of the mean stress. At the inception of sliding or slipping in the joint, a relieving effect set in, amounting to more than 20 per cent at a mean stress of 2000 kg/cm² (28,446 pounds per square inch). After the local elastic limit was reached in the outer strakes, the load was once more evenly distributed among all three strakes.

In Assembly 2, rupture began at a considerable distance from the joint in the intact portion. The stress amounted to about 2900 kg/cm^2 (41,247 pounds per square inch), referred to the full cross-section of the plate. It is attributed in part to the use of materials of various strengths in the three strakes, and in part to a lack of impact resistance in the jointed strake. This second test was unable to develop the full resistance of a double-strapped joint, because rupture occurred under a load which was less than the rupture strength of the joint. However, based on the test data and the resistance to slipping of the rivets it may be assumed that the strength of a double-strapped joint in suitable material is even higher than 80 per cent of the strength of the intact material.