Built-Up Members in Plastic Design

STRENGTH OF LONGITUDINALLY STIFFENED PLATE PANELS (SHIP BOTTOM PLATING)

PROGRESS REPORT ON TESTS WITH FIXED LOADING EDGES AND MEASUREMENT OF RESIDUAL STRESSES

A. Ostapenko
Jun Kondo

November 1962

Fritz Engineering Laboratory Report 246.11
1. INTRODUCTION

The objective of this project is to investigate the strength of longitudinally stiffened plate panels subjected to the conditions of loading and restraint as encountered in actual ship bottom plating.

Besides some theoretical and experimental work on component parts of stiffened panels (4)(5) ten tests have been conducted on whole panel specimens (1)(2) to explore the influence of some of the parameters, such as, the intensity of lateral pressure, subpanel-width-to-plate-thickness ratio and residual stresses. These tests, however, were conducted on specimens with simply supported ends. Since the bottom plating of ships of longitudinal construction is continuous over transverse frames, test specimens with loaded ends fixed would approximate its behavior more closely than specimens with simply supported ends. A new series of tests on specimens with fixed ends is currently under way at Fritz Engineering Laboratory.

This report presents a description of the new test series (Chapter 2) and of a simplified procedure for measuring welding residual stresses in wide plates (Chapter 3).

2. TESTS ON SPECIMENS WITH FIXED LOADING EDGES

2.1 Test Specimens

In the new test series on panel specimens with fixed ends the intensity of lateral loading is the variable parameter.

* Numbers in parentheses indicate references listed at the end of the report.
Four specimens have been fabricated. Three specimens will be tested, each under different lateral pressure-0, 6.5 and 13 psi. The fourth specimen will be kept as a spare to be tested if one of the preceding tests is unsuccessful.

The cross section for these specimens was chosen of T-7 type which is more typical for ship bottom plating than T-1 type. T-7 and T-1 refer to the cross sections of specimens tested in the past. The nominal dimensions of specimens are show in Fig. 1. The length is 57 in., the width 51 in. The plate slenderness ratio, \( b/t \) = 60 and the slenderness of the whole panel, \( \frac{L}{t} \) = 54. The ends of the specimens are welded to 3/4-in. plates (end plates in Fig. 3) which will be bolted to the end fixtures during testing.

In addition to four full-length specimens, a short specimen was used as a gage portion for measuring residual stresses. The results of residual stress measurements are given in Chapter 3.

### 2.2 Test Setup

The test setup, which has been adapted from the previous test series, (1)(3) consists mainly of end fixtures, an axial loading system, a lateral loading system, as shown in Fig. 2, and instrumentation.

Axial load is applied to the specimen through the end fixtures by means of 5,000,000-lb. universal testing machine. The uniform lateral loading is applied by means of a pressure box and compress air. With the specimen as a front wall, the pressure box forms a complete self balancing enclosure. Lateral forces between the specimen and the pressure box are transmitted through articulated links as indicated.
The end fixtures were designed to provide fixed end condition for test specimens. Each fixture is composed of an end block and a platen as shown in Fig. 3. All contact surfaces are flat and parallel to the surfaces of the pedestal and the cross head of the testing machine. The end plate of a specimen is bolted to the end block. The connection is made sufficiently strong to develop a full plastic moment in the specimen. The platen is needed to provide enough distance between the end block and the testing machine for the connection between the end block and the pressure box, and it is aligned with the end block by means of four pintles. The build-up of the end fixtures requires that sufficient axial force be applied before lateral loading to prevent any rotation of the specimen ends.

Instrumentation, consisting of a number of dial and electric resistance gages, is similar to that used in the previous tests.

2.3 Test Procedure

As mentioned earlier, three specimens will be tested, each under different lateral pressure, \( q = 0, 6.5 \) and \( 13.0 \) psi.

Before the application of lateral loading, however, a certain amount of axial load should be exerted in order to prevent rotation of the end fixtures which would be caused if lateral loading were applied first. Then, lateral loading is applied to the specimen and maintained at the required level during the further application of axial load. Axial load is
increased stepwise until the ultimate load is reached. After the ultimate load, a sufficient number of readings are taken to define the nature of the post-ultimate behavior. Then, the specimen is unloaded.

For testing without lateral loading (q = 0), the loading sequence is correspondingly simpler.

The ultimate axial load on the specimens is expected to be limited by the buckling strength of the plate at the mid-height. The behavior of the fixed end specimens, compared to simply supported specimens, is considerably complicated by the redistribution of moments resulting from the plastification of the stiffener flanges at the ends.
3. SIMPLIFIED PROCEDURE FOR MEASURING WELDING RESIDUAL STRESSES
IN WIDE PLATES

3.1 Introduction

In conventional methods of determining residual stresses, the following steps are performed:

1) Measurement of gage distances pre-marked on the surface of a fabricated member in one or several directions.

2) Release of residual stresses in the measured portion of the material by its complete or partial severance from the member under investigation.

3) Measurement of the gage distances after the release of stresses.

The difference in the two measurements is used to compute residual strains. Residual stresses are then evaluated from the strains.

This procedure gives the final residual stresses in the plane of the surface whatever their cause—cooling, rolling, heat treatment or welding. The greatest inconvenience of the method is that the gage portion must be completely (in some techniques, partially) separated from the parent member. In structural members measurements are usually made only in the longitudinal direction and the gage portion is sliced.

When residual stresses are primarily due to welding and the distance between individual weld lines is considerable, such as in welded built-up members and stiffened plating, the procedure can be greatly simplified. The residual strains
are computed from the measurements on the plate surface BEFORE and AFTER welding, and no slicing or other means of releasing residual stresses is necessary. This procedure allows making residual stress measurements directly on a test specimen or on an actual structure. However, only compressive residual stresses between welds can be reliably determined, but these are usually the stresses of primary importance in strength analysis.

3.2 Application of the Simplified Procedure to Stiffened Plate Panels

In stiffened plate panels, compressive residual stresses in the longitudinal direction between stiffeners are of primary importance for the buckling strength of the plate and thus for the strength of the whole panel. The procedure of determining these stresses is as follows:

1) The gage distances are laid out on the plate in the longitudinal direction.

2) Small holes for the gage points are drilled and the first set of measurements is taken on both sides of the plate. The popular Whittemore gage with a ten-inch gage length can be effectively used here.

3) The stiffeners are welded to the plate. To protect the gage point holes during welding, they can be covered with adhesive tape.

4) The second set of measurements is taken, and residual stresses are computed.

The gage point holes are so small that they would have no influence on the buckling strength of the plate or the
ultimate strength of a panel.

This procedure can be effectively used on steel or other metals such as aluminum alloys; the bar for reference readings should then be made of the corresponding material.

3.3 Experimental Justification

Justification of this method must consist of the proof of two premises: that initial residual stresses in a plate are negligible and that inelastic deformations due to weld take place only in the immediate vicinity of the weld. Some experimental data to verify these points were obtained in this project.

Specimen T-7 had a combination of initial and welding residual stresses. Its average compressive residual stress was, however, essentially the same as in specimen T-9 which had residual stresses only due to welding. This can be seen in Fig. 4. The difference in pattern is due to different welding sequences. It may be concluded, then, that initial residual stresses were of negligible magnitude. It is reasonable to assume that such a condition will also exist in other wide plates.

In the specimens fabricated for the fixed end tests residual stresses were first determined by using the simplified procedure. The average compressive stress in the middle subpanel was 4.5 ksi. Then the gage portion was sliced and a somewhat higher average residual stress of 4.8 ksi measured. The stress plots are shown in Fig. 5. The band of inelastic strains at the weld is seen to be about 2 in. wide,
that is, about 8 times the plate thickness.

The test results thus indicate that the simplified procedure of measuring residual stresses gives sufficiently reliable values.

4. REFERENCES

(1) A. Ostapenko and T. Lee: TESTS ON LONGITUDINALLY STIFFENED PLATE PANELS SUBJECTED TO LATERAL AND AXIAL LOADING, F. L. Report No. 248.4, August 1960


Fig. 1 TEST SPECIMEN
Fig. 2 TEST SETUP

Fig. 3 END FIXTURE
Fig. 4  RESIDUAL STRESSES IN PLATE OF T-7 AND T-9

Fig. 5  RESIDUAL STRESSES IN PLATE BY SIMPLIFIED PROCEDURE AND BY SLICING (T-12)