Experimental evaluation of the test methods EN 302-1 and ASTM D905 for wood-adhesive bonds

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Abstract

This work engages the topic of test methods for wood adhesives. Two test methods were evaluated, EN 302-1, a European standard, and ASTM D905, an American standard. The total amount of specimens manufactured and tested was more than 500. The adhesive bonds were tested in shear with an increasing load on the specimen until failure. The adhesives used were epoxy-resin, phenol-resorcinol-formaldehyde and a 2-K polyurethane.

The test programme included five different types of intentional errors per method, in order to investigate the sensitivity of the test methods. The different types of errors were double amount of adhesives applied, two types of errors in cutting of the specimens and two types of eccentric loading during testing.

The maximum shear stress of the adhesive was used in determining whether the test methods are stable or not. The main conclusion of this work is that both test methods are unstable for the tested errors.

1 Background

Wood is a material that has been used for thousands of years in constructions. Some of the advantages with wood are its strength to weight ratio, the price and its ability to maintain strength during fire.

In building processes, adhesive is an important component. To evaluate the strength of different adhesives, standard methods for testing have been developed. Today there are two frequently used standards for testing shear stress in adhesive bonds: ASTM D905, an American standard and EN 302-1, a European standard.

Numerical studies of these two test methods have been performed [1]. Few experimental studies have been done to evaluate the methods. The test methods have not been compared to each other.

2 Aim

The purpose of this work is to evaluate and experimentally compare two test methods, EN 302-1 and ASTM D905. The evaluation is based on five different types of intentional errors per method, in order to investigate the sensitivity of the test methods. The different types of errors were double amount of adhesives applied, two types of errors in cutting of the specimens and two types of eccentric loading during testing. The total amount of specimens manufactured and tested was more than 500. Difficulties during manufacturing of test specimens will also be taken into the evaluation.

3 EN 302-1 and ASTM D905

The European standard, EN 302-1, is a method for determining the strength in longitudinal shear of adhesive bonds [2]. The test specimen of two rectangular wooden adherends is strained to rupture by a force parallel to the grain of the wood. The area of the adhesive tested is 200 mm^2.

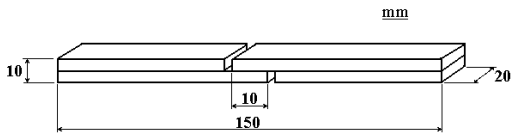

Figure 1. *EN 302-1 specimen.*

The American equivalence to EN 302-1 is ASTM D905 [3]. This standard also determines the shear strength of adhesive bonds, but in compression instead of tension. The area of the adhesive tested is 1900 mm^2, which is almost 10 times larger than EN 302-1. The load is applied parallel to the grain of the wood.

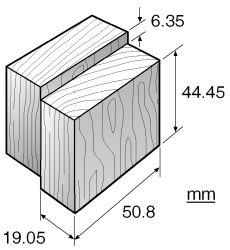

Figure 2. *ASTM D905 specimen.*

4 Description of adhesives

There are today many different types of wood adhesives on the market. The standard methods EN 302-1 and ASTM D905 test adhesives designed for load carrying constructions. There are among those adhesives different brands and types.

To make the result more general, adhesives with different properties are used. Testing different types of adhesives reduces the risk of drawing general conclusions based on a specific adhesive. The following types of adhesive are used in the comparison of the two test methods:

- Epoxy (EP)
- Phenol-Resorcinol-Formaldehyde (PRF)
- Polyurethane-Resin (PUR)

These are all two-component adhesives. Experience has shown that PRF is the most brittle and PUR is the least brittle of the three adhesives [1].

5 Test programme

In order to investigate the sensitivity of the test methods, five different types of intentional errors per method are created. The different types of errors were double amount of adhesives applied, two types of errors in cutting of the specimens and two types of eccentric loading during testing.

5.1 Reference

Before an evaluation of the five types of errors can be carried out a reference group must be created. This reference group is produced in accordance with each standard and instructions from the adhesive manufacturers. Results from test specimens with intentional errors will be compared to this reference.

5.2 Double amount of adhesive

During the preparation of specimens it is important to follow instructions given by the adhesive manufacturers. The error tested here is to apply double the amount of adhesive than normal usage.

5.3 Errors in cutting of the specimens

Manufacturing of identical test specimens can be hard to reproduce from one time to the next. Also different manufacturers accept different levels of imperfection in the specimens. The biggest defects that can arise during specimen production are cutting of grooves for EN 302-1, see figure 3 and cutting steps for ASTM D905, see figure 4. To test the sensitivity of the test methods the grooves in EN 302-1 and the steps in ASTM D905 specimens are cut with a ±0.5 mm margin.

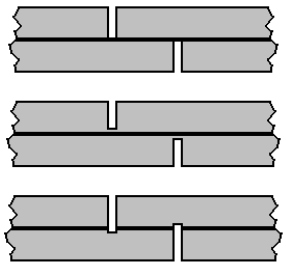

Figure 3. *Errors in cutting EN 302-1.*

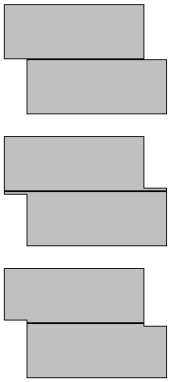

Figure 4. *Errors in cutting ASTM D905.*

5.4 Eccentric loading during testing

5.4.1 Horizontal displacement of EN 302-1

One type of eccentric loading for EN 302-1 is horizontal displacement. To create this error a piece of metal, 1 mm thick, is placed into the test apparatus. The test specimen will have an initial bending which can lead to lower measured strength of the adhesive bond.

5.4.2 Diagonal position of EN 302-1

The second type of eccentric loading for EN 302-1 means placing the specimen in a diagonal position during testing. Instead of testing a specimen placed vertically it is now tilted 3 degrees.

5.4.3 Horizontal displacement of ASTM D905

The two types of eccentric loading of ASTM D905 are very similar to each other. The specimen is tested while horizontally displaced 1 mm and 2 mm from its original position. This error is created by placing a piece of metal into the test apparatus. The result of such displacement is that the applied load will be moved away from the adhesive bond.

6 Results

The test results with EN 302-1 and ASTM D905 are sorted into their different test groups. In figure 5 the reference group using the adhesive EP is presented. From each test group an average of the maximal shear strength, τ, is calculated. The coefficient of variation, which is a measure of the spread in the group, is also calculated. The number of test specimens is at least 20 for the reference groups and at least 10 for each of the other test groups.

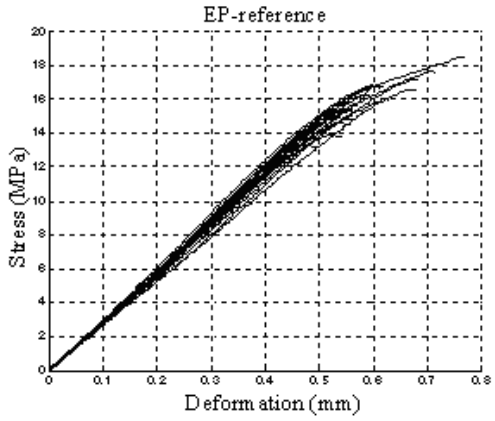

Figure 5. *Collected data from the reference group using epoxy.*

Where possible, the test specimens are taken from different glued planks. The reference and the two groups with eccentric load are picked from three different glued planks. All specimens with double amount of adhesive come from one glued plank and specimens with either to shallow or to deep cuts come from the same glued plank.

The figures 6 and 7 display the average of the shear strength for each group and adhesive.

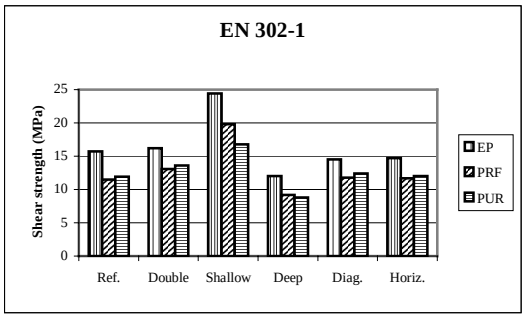

Figure 6. *Cluster diagram for EN 302-1.*

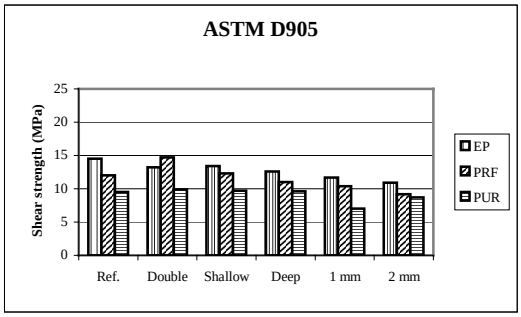

Figure 7. *Cluster diagram for ASTM D905.*

6.1 Hypothesis test

In order to compare the test results, a hypothesis test is used. With a hypothesis test it is possible to decide if the tested group has different average shear strength compared to its reference group. The test accounts for the test groups having different variance between the groups. It is assumed that each group comes from a normal distribution. The tested hypothesis is as follows: The averages of the shear strengths of two groups are different. The computer function that tests the hypothesis returns the level of significance at which the hypothesis should be rejected. From the hypothesis tests conclusions can be drawn.

The comparison of the two standards is done by evaluating the results from the hypothesis test. The only comparable groups are the reference group and the group with the double amount of adhesive.

The hypothesis test requires a level of significance. A typical level is 5% significance. There is a 5% chance of rejecting the hypothesis even though it is true.

7 Conclusions

Most of the conclusions below are a result from the hypothesis test. The level of significance is 5% if noting else is stated.

7.1 EN 302-1

- EN is very sensitive to errors in cutting. If the cut is 0.5 mm too shallow or too deep the results will not be comparable to a correctly cut specimen.
- The EN specimens show higher shear strength when double amount of adhesive is added. This is based on a lower level of significance (12%).
- The diagonal position does not affect the result.
- There is a risk that EN specimens distort during the manufacturing. Initial stresses will be introduced in a distorted specimen during insertion into the test machine. With initial stresses the specimen can give lower maximal shear strength.

7.2 ASTM D905

- The test results with the adhesive PUR are not reliable. Too many results with surprisingly low shear strength appeared during the test.
- ASTM is significantly affected by almost every tested variation.
- Comparing double amount of adhesive to the reference gave lower shear strength for EP and higher shear strength for PRF.

7.3 Comparison between EN 302-1 and ASTM D905

- A comparison between the reference groups of the two test methods gave different results for the EP adhesive but not for PRF.
- By applying double amount of adhesive the results obtained are different between the two test methods.
- The adhesives react differently to the intentional errors.
- Without access to numerically controlled machines, there is a higher risk of imperfections in manufacturing of the specimens. Experiments show that errors in cutting EN 302-1 specimen affect more than errors in cutting ASTM D905. Though it must be said that both test methods are very sensitive to the errors in cutting.
- The process of manufacturing the test specimens for both test methods are about the same. Where none is more difficult than the other.
- The test methods are both sensitive to errors, since many of the intentional errors affected the results.

Acknowledgements

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References

[1] Serrano, E. (2002) *On the Mechanical Behaviour of Test Specimens for Wood-Adhesive Bonds. Report TVSM-3063.* Div. of Structural Mechanics, Lund University, Lund, Sweden.

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