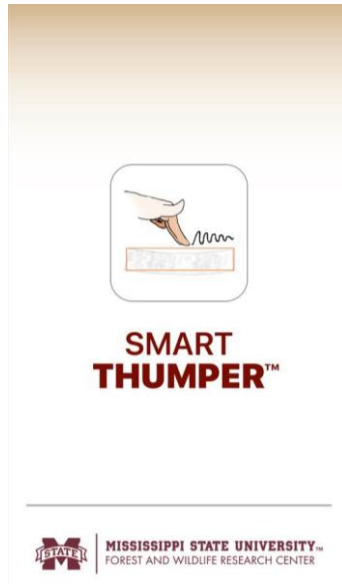# Smart Thumper Instructions

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Using lumber in wood frame construction requires the knowledge of its mechanical properties. Accurately sorting lumber into stiffness grades with known properties allows users construct project without exceeding strength values of lumber. Visual grading of lumber is the oldest and still the most used method for predicting mechanical properties of wood. **Smart Thumper** (Figure 1.1) provides an additional efficient way of evaluating the stiffness property of lumber and other custom size pieces based on the dynamic modulus of elasticity (dMOE).
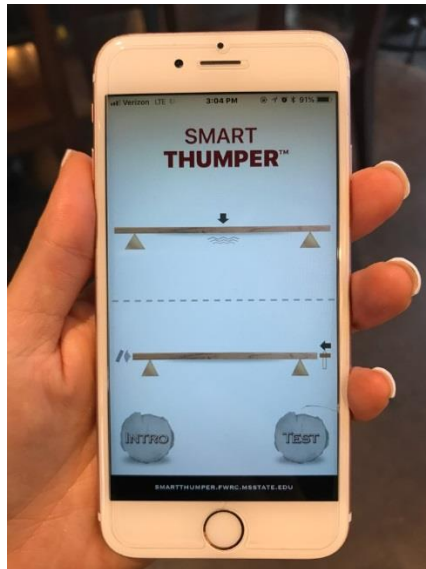
Figure 1.1   A Smartphone running the **Smart Thumper** application

Recent technological advancements in the smartphone industry transformed mobile phones into small, lightweight dynamic devices. These changes resulted in the smartphones' ability to run applications that create a new relationship between users and devices. **Smart Thumper** uses the built-in microphone or accelerometer to detect vibration and estimates the dMOE of lumber and other wood sizes.

Smart Thumper is the very first nondestructive tool that can read the soundwaves (longitudinal vibration) and vibration (transverse vibration). These two methods can predict dMOE allowing users to determine the best way to test (soundwaves or vibration) for their individual application.

Both testing methods can help users to make better decisions on how to use the available materials.

2. Installation

Smart Thumper is only available at the App Store (iOS). Search for and install the **Smart Thumper** application.

3. Instructions for use

3.1 Main page

On the main page or screen of your smartphone, select the **Smart Thumper** icon. It opens the main menu of the **Smart Thumper** (Figure 1.2). There are two options on the main menu: INTRO and TEST. Selecting INTRO will lead users to videos and an instruction guide that introduces testing procedures. Users should read all the instructions before using the application.
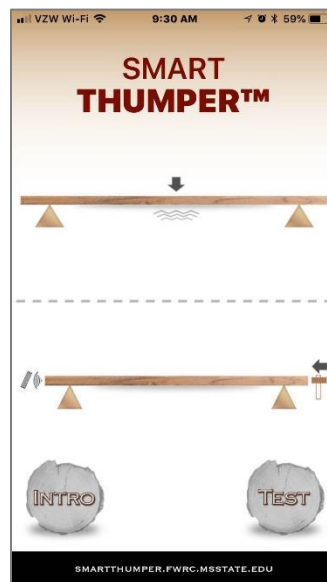
Figure 1.2   **Smart Thumper** main page

3.2 Introduction page

Smart Thumper INTRO section includes videos that demonstrate how to use the application and its grading functions. The first video introduces how to test in vibration mode while the second

video shows how to test in soundwave mode. An abbreviated instruction set is provided for quick reference. The complete instruction set of **Smart Thumper** is available on the website.

3.3 Testing pages

By selecting the TEST option on the main page, **Smart Thumper** takes you to the specimen information page (Figure 1.3) where the dimensions and weight of the test sample are input for **Smart Thumper**. Please follow the instructions below:
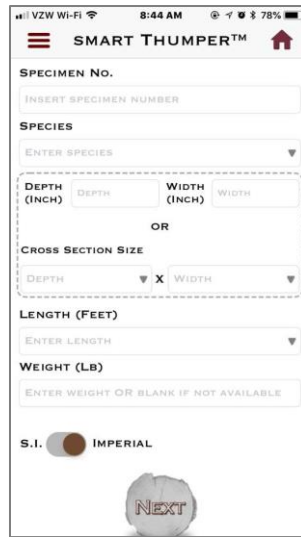
Figure 1.3   **Smart Thumper** specimen information page

1- Enter the specimen number.

2- Select the wood species and click "Done".

3- Enter the depth (thickness) and width OR Cross-Section Size of the specimen. (if testing US lumber it is preferred to enter, the Cross-Section Size and the actual size is automatically calculated)

5- Select the length from the menu and click "Done" OR select Others and click "Done" and then manually enter the length.

6- Enter the weight of the specimen if available (If left blank, **Smart Thumper** will use the species default).

7- **Smart Thumper** works in either International (S.I.) or Imperial units.

8- Click "Next".

9- Select the test method: Vibration or Soundwave (Figure 1.4) and the testing screen will open.
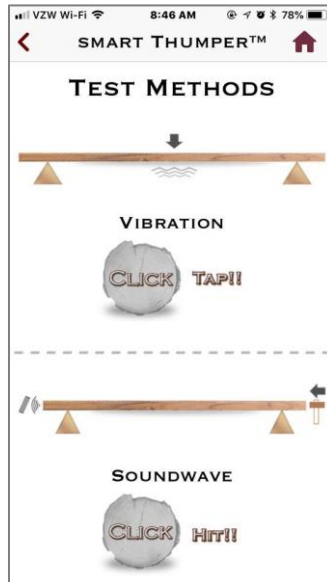
Figure 1.4   **Smart Thumper** testing methods screen

3.3.1 Vibration

Your choice will open the vibration test screen (Figure 1.5).
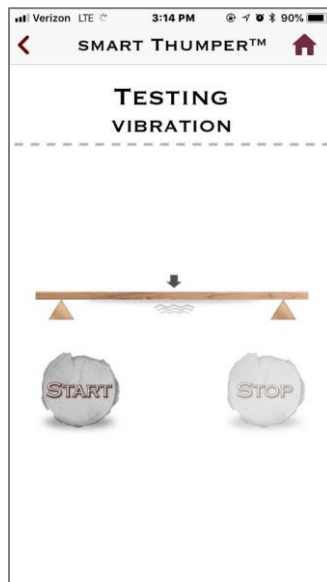
Figure 1.5   **Smart Thumper** vibration test screen

Using a pair of sawhorses, the sample that you intend to test needs to be simply supported flatwise as a beam spanning the entire length of the sample (Figure 1.6). Leave a one inch (2.54 cm) overhang on each end of the sample.
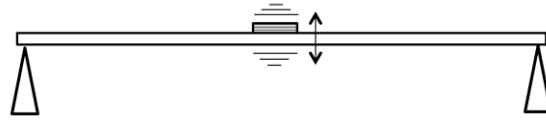
Figure 1.6   **Smart Thumper** vibration test setup

Place a smartphone in center of the sample. Press start on the **Smart Thumper** vibration screen. A 3 second count-down will start. Tap the sample gently to begin the vibration (Figure 1.7). While the sample is vibrating **Smart Thumper** collects the data and calculates the dMOE. For technical reference see ASTM D 6874 (2012).
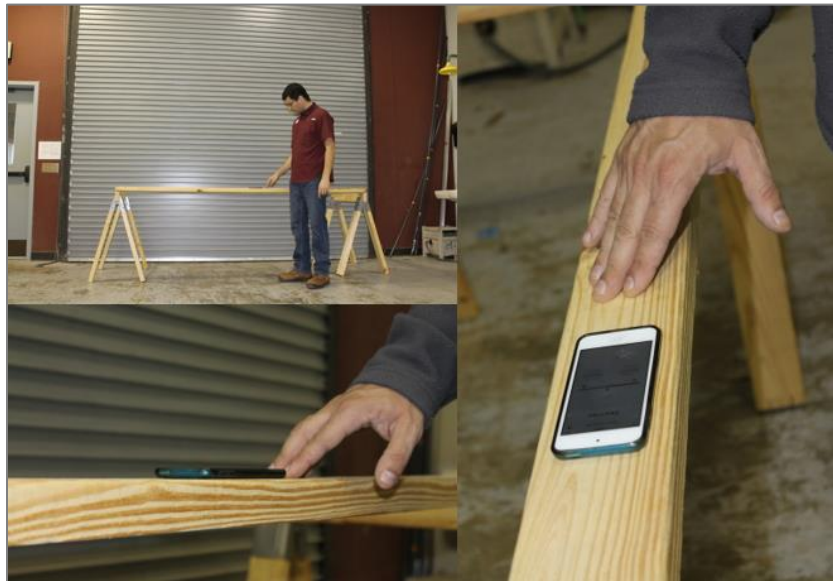
Figure 1.7   **Smart Thumper** vibration test

3.3.2 Soundwave

For soundwave testing, two sawhorses should be positioned to support the sample as shown in Figure 1/6. A simple piece of anti-fatigue flooring (e.g., sponge or foam) should be placed between the sample and sawhorses to reduce damping issues and to increase accuracy. Smartphone

microphones are very sensitive. Background noise (vehicles, loud voices, other artificial sounds) detected by the microphone can impact frequency determination, and hence, significantly impact the results. After a series of hits, if the captured frequency shows variation of more than 100 Hz, or many "try again" messages, the user should reduce the background noise and retest or switch to the vibration test.
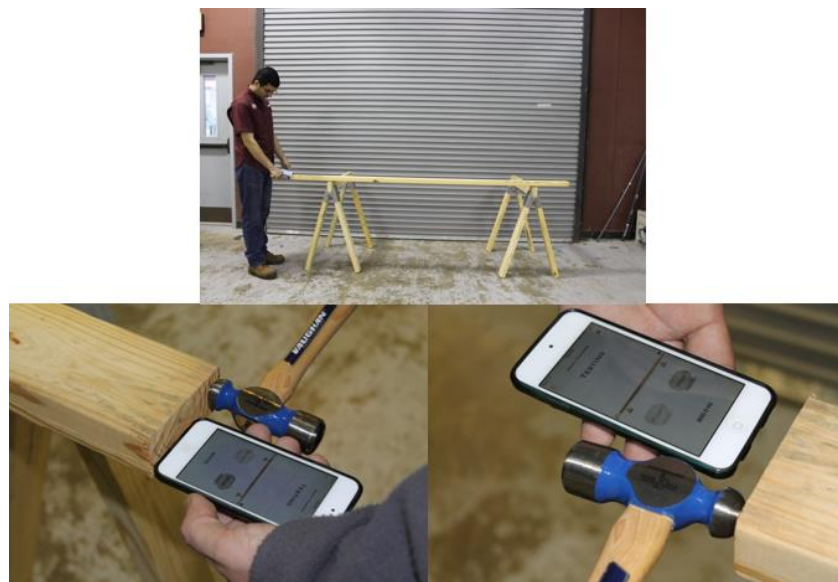
Figure 1.8   **Smart Thumper** soundwave test

Hold the smartphone (microphone end) at the either end of the sample. Press start on the **Smart Thumper** soundwave screen. A hammer tap at one end of the sample will produce a soundwave. **Smart Thumper** will capture the soundwave, determine the frequency and the dMOE, and the resulting stiffness grade. The soundwave can be captured at the tapping end where the hammer hits the sample as shown in (Figure 1.8) or at the opposite end (Figure 1.9). For technical reference see ASTM E 1876 (2015).
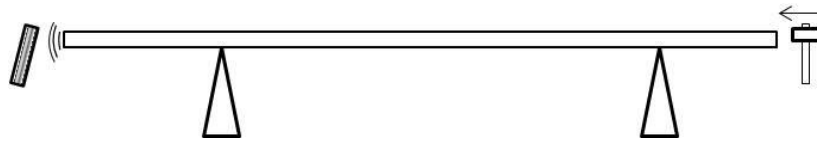
Figure 1.9   **Smart Thumper** soundwave test setup (opposite end)

4. Weighing the samples

Weighing the samples before testing (Figure 1.10) increases the accuracy by up to 30%. Any type of scale can be used. If the sample weight is omitted, **Smart Thumper** will estimate the weight based on the average density information of the sample species. Thumper_Calc (**STC**) is an Excel spreadsheet that can adjust weight and/or Moisture Content (MC) to obtain more accurate dMOE results. The spreadsheet can be downloaded from our website. **STC** allows users to email the data to themselves, to import the data, and change the weight and MC. The program has a final adjusted MC that is user specified on the menu tab. The dMOE values obtained during testing are for the sample MC at the time of testing. Updating weight and MC values increases accuracy. Please refer to Section 9.

Figure 1.10   Weighing a sample

5. Supports specification

5.1 Sawhorse types

Many types of sawhorses can be used as supports for **Smart Thumper** testing. There is no specific requirement for the support. The main purpose of having the sawhorses is to avoid damping issues during testing. Examples of sawhorses are shown in Figure 1.11.

Figure 1.11   Types of sawhorses that are commercially available

5.2 Damping

Damping may reduce the energy of the sample during testing which may in turn impact the accuracy of the **Smart Thumper** results. For more information about damping, refer to the damping theory described in http://farside.ph.utexas.edu/teaching/315/Waves/node10.html.

5.2.1 Vibration test damping solution

Smart Thumper recommends reducing damping for the vibration test by inserting screws or nails as supports on the top the sawhorses to increase accuracy. The sample should be positioned over the supports to minimize contact with the sawhorses as shown in Figure 1.12.

Figure 1.12   Vibration test damping solution

5.2.2 Soundwave damping solution

Smart Thumper recommends to reduce damping for the soundwave test by placing a piece of anti-fatigue flooring (e.g., sponge, foam or rubber) between sawhorses and the sample to increase accuracy as shown in Figure 1.13.
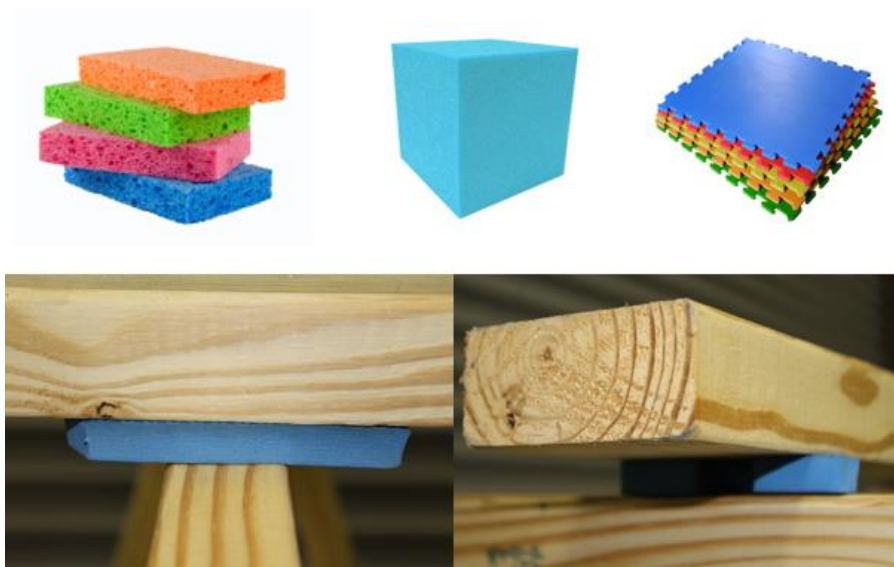

Figure 1.13   Soundwave test damping solution

6. Hammer

Many types of hammers can be used for soundwave testing (Figure 1.14). The recommendation is to hit (or tap) the samples in a consistent way. The tapping force applied to all test samples of the same size should be equal. A consistent tapping force is the key to accuracy. The force applied to the sample should be proportional to the sample size. Larger samples require more "energy" or "force" during testing. However, the force applied during the tap should be less than a nail driving force.

Figure 1.14   Example hammers

7. Understanding the results

7.1 The stiffness results

The stiffness results of **Smart Thumper** are demonstrated in different colors on the testing result screen as shown in Figure 1.15 and are unrelated and are independent from strength assignments resulting from visual and other grading systems. Examples of results in vibration tests and soundwave tests are demonstrated in Figure 1.16 and Figure 1.17.

- Green: the sample's MOE is equivalent to a Smart Thumper #1
- Yellow: the sample's MOE is equivalent to a Smart Thumper #2
- Red: the sample's MOE is equivalent to a Smart Thumper #3
- Grey: the sample needs to be tested again

Figure 1.15   Stiffness level colors
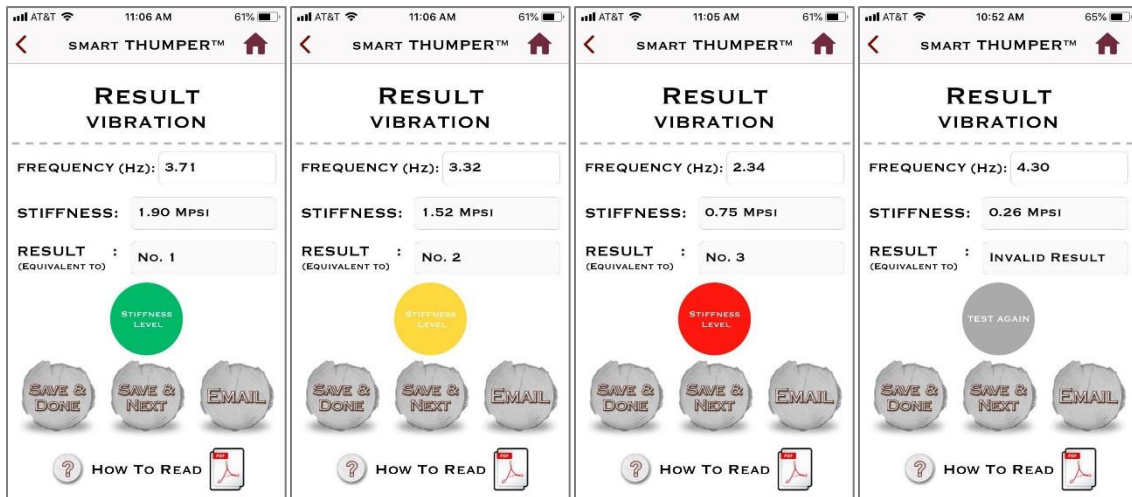
Figure 1.16   Examples of vibration test results
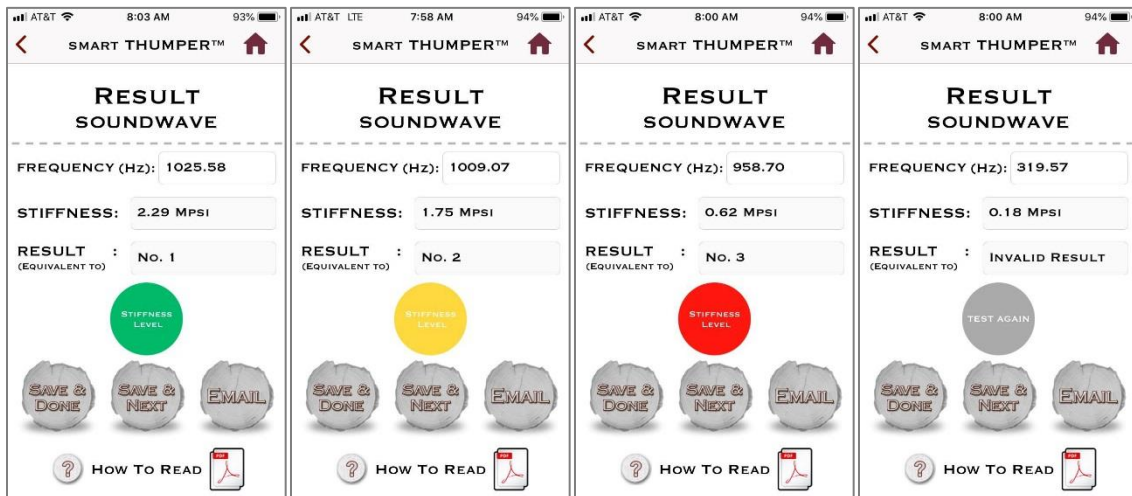
Figure 1.17   Examples of soundwave test results

7.2 Smart Thumper Stiffness result criteria

Figure 1.18 demonstrates the stiffness scales used for **Smart Thumper.** Each species has its own stiffness scale. The stiffness scales are unrelated and are independent from strength assignments resulting from visual and other grading systems.

7.2.1 Smart Thumper Species stiffness (only) scales

Southern Yellow Pine (SYP)

Spruce-Pine-Fir (SPF)

Douglas-fir
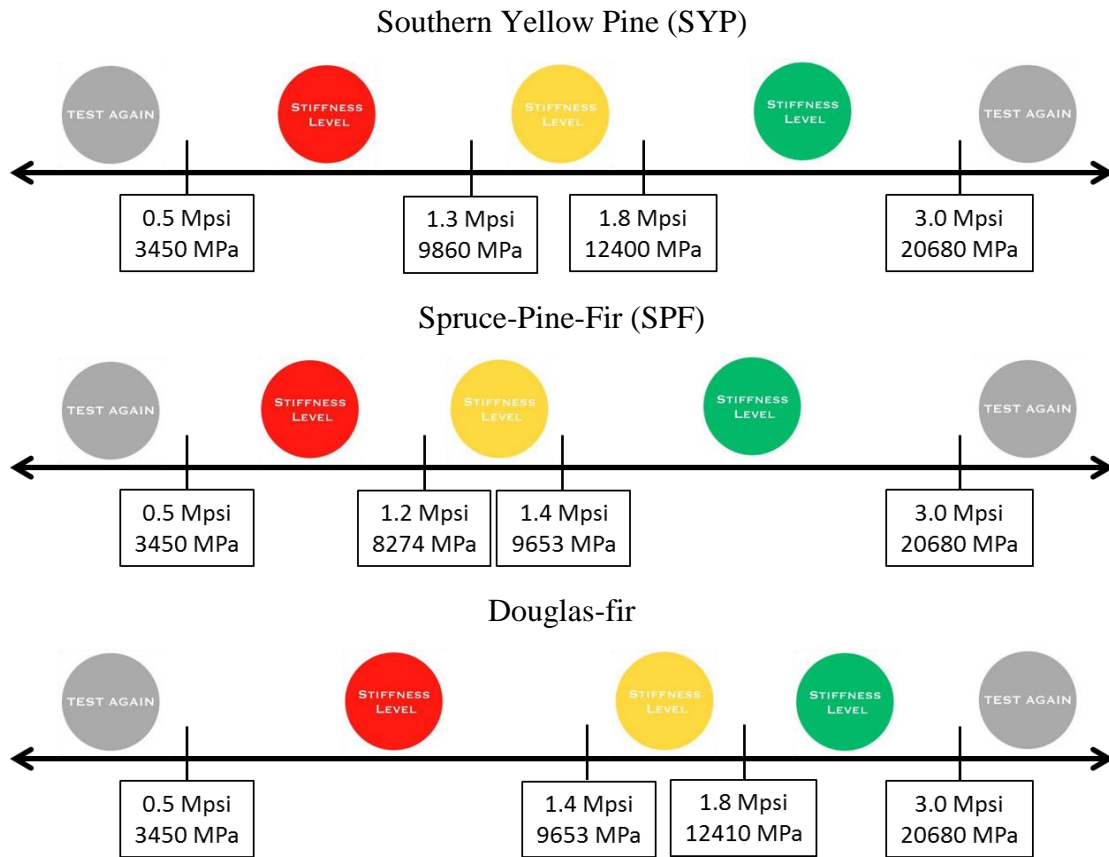
Figure 1.18   Species stiffness scales

7.3 Examples of each test

As demonstrated in the INTRO Videos, vibration and soundwave are two different measuring systems. Consequently, each one will yield slightly different frequency results. However, the results from both methods are closely correlated. Both (vibration and soundwave) tests use frequency to calculate dMOE.

7.3.1 Vibration

Measure the sample according to section 3.3.1 and prepare the sample for testing shown in Figure 1.6. This example (Table 1.1) is for an 8 ft. long, 2x4 sample that weighs 12 lbs. and 2 oz. Before entering the data in the specimen information page, choose the appropriate units in the bottom of the screen.

Table 1.1   Example data entry for both tests

Category	Imperial	S.I.
Specimen No.	01	01
Species	Southern Yellow Pine	Southern Yellow Pine
Depth	1.5 inches	3.81 cm
Width	3.5 inches	8.89 cm
Cross Section Size	2x4	3.81x8.89 cm
Length	8 feet	Approx. 2.44 meter
Weight	12 lbs. 2 oz.	5.50 kg

After data input, choose vibration on testing methods page. Press start on the vibration screen, and tap the sample gently as shown in INTRO Video 1 and Figure 1.7. **Smart Thumper** will then show the result based on the frequency, dimensions, and weight (Figure 1.16).

As an example from Table 1.1, a 2x4x8 with frequency of 8.98 Hz represents a dMOE of 0.93 Mpsi. **Smart Thumper** shows the red color as shown in Figure 1.19, and classifies the sample as stiffness #3.
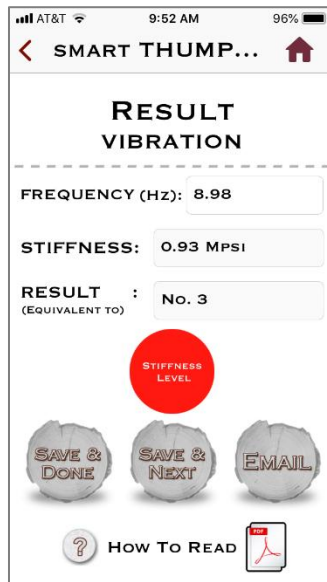
Figure 1.19   Result of the vibration testing sample

7.3.2 Soundwave

Measure the sample according to section 3.3.2. Prepare the sample for testing shown in Figure 1.8 and Figure 1.9. This example is for an 8 ft. long 2x4 sample that weighs 12 lbs. and 2 oz. Before entering the data in the specimen information screen, choose the appropriate units in the bottom of the screen. After data input (Table 1.1), choose soundwave on the testing methods page. Press start on the soundwave screen, and hit the sample as shown in Figure 1.8. You can also watch the INTRO Video 2.
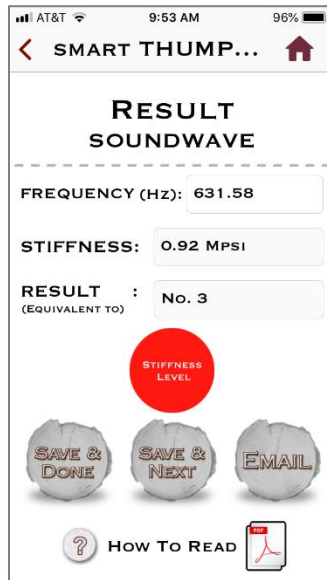
Figure 1.20   Result of the soundwave testing sample

Smart Thumper will then show the results. Figure 1.17 shows examples of each stiffness grade by species. **Smart Thumper** results will be shown as only one of these grades based on the frequency. As an example from Table 1.1, a 2x4x8 with frequency of 631.58 Hz represents a dMOE of 0.92 Mpsi. **Smart Thumper** shows the red color as shown in Figure 1.20, and classifies the sample as #3.

8. My Wood

Results can be reviewed in the My Wood page (Figure 1.21).

Figure 1.21   Examples of both test results in My Wood page

All testing results can be saved in the app. When each test either vibration or soundwave is complete, there are three options to select from: Save & done, Save & next, and E-mail.

- Save & done: this button can be used when a series of test is completed that will lead to a specimen information page to start new test series.
- Save & next: this button allows users to continue testing with the same specimen information (except for weight). This function eliminates repetitive need to insert the same specimen information for multiple tests. Each test result can also be emailed with the Email button.
- Email: Users can email a single data

On My wood page, users can manage single data as well as entire data. Three buttons on the top of My wood page enable users to manage the entire data tested.

- Test more: test more button is to move to the specimen information page to begin a new series of test.
- Email all: all of the test results can be emailed in csv format.
- Delete all: Delete all button enables users to delete all data at once. when the data is deleted from **Smart Thumper**, it can't be restored.

When a user selects a result using drop down bar on My wood page, there are three buttons in the bottom of the page that enables the user to Share(via message, mail, add to notes, Facebook, etc.), Email, Delete the selected single data.

9. Thumper_Calc for Weight and MC updates

After testing, users may desire to update results to improve accuracy of NDT measurements with weight and/or MC values for each sample. Download Thumper_Calc.xlsm (**STC**) from the website (Smartthumper.fwrc.msstate.edu).

Figure 1.22   Menu Tab-Thumper_Calc Module

1- Open up the Thumper_Calc Microsoft Excel worksheet.

2- Import **Smart Thumper** data by 1st exporting data from the application via email and, 2nd save to your computer disk, and 3rd selecting Import Smart Thumper Data and directing to the file.

3- Find the Input tab where users can insert actual weight and MC as shown in Figure 1.23.

M	N	O
Weight lbs	Weight Kg	Current MC%
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

Figure 1.23   Input Tab-Weight and MC input by Specimen

When testing using **Smart Thumper**, the initial dMOE shown by the application is for the specimen at the specimen's current MC and weight. The weight is either assumed or entered by the user at test time. After testing and importing the test results into **STC**, the weight and MC adjustments may be applied to each test specimen. If a weight is entered in either the yellow or red column, **STC** will update the dMOE based on the new weight. If the weight is zero in the yellow and red columns of figure 1.23, then **STC** does not adjust the dMOE for weight. If the MC is entered in the green column of Figure 1.23 for any specimen, then **STC** will adjust the final dMOE using the equations presented by Evans et.al. The MC entered in the green column on Input Tab of **STC** is the MC of the specimen at test time. **STC** will adjust dMOE to the desired final adjusted moisture for all specimens. The final adjusted MC is user specified as shown in Figure 1.24. The desired final adjusted moisture is user changeable on the Menu Tab of **STC**. The order of the calculations in **STC** is to start with the dMOE from the original test performed by the application, adjust for weight if adjustments are indicated, then adjust for MC if adjustments are indicated.
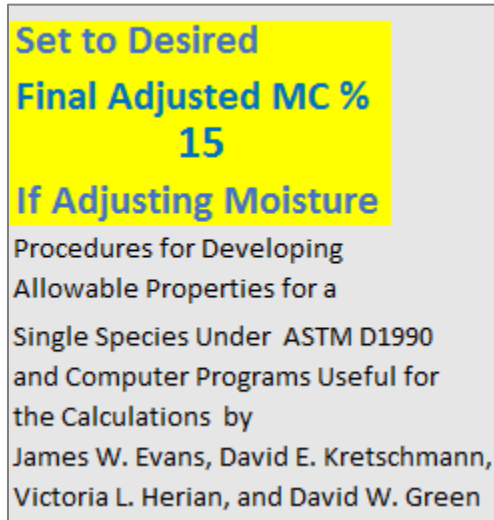
Figure 1.24   Menu Tab-Desired final adjusted MC

4- Return to the Menu tab, and select the Refresh results button. **STC** will automatically recalculate the stiffness results for Imperial and SI.

5- Export results to save it to your computer. **STC** will ask for an export location and then **STC** will name each export of your data to the location as either an Imperial export or SI export as shown in Figure 1.25. The file names are composed of date & time & SI or Imperial_Smart_Thumper_Results.xlsx.

2018-07-25_01_34_40_PM_SI_Smart_Thumper_Results.xlsx	7/25/2018 1:34 PM	Microsoft Excel Wor…	11 KB
2018-07-25_11_28_59_AM_Imperial_Smart_Thumper_Results.xlsx	7/25/2018 11:29 AM	Microsoft Excel Wor…	39 KB
2018-07-25_11_29_07_AM_SI_Smart_Thumper_Results.xlsx	7/25/2018 11:29 AM	Microsoft Excel Wor…	11 KB
2018-07-25_11_32_35_AM_Imperial_Smart_Thumper_Results.xlsx	7/25/2018 11:32 AM	Microsoft Excel Wor…	40 KB
2018-07-25_11_32_44_AM_SI_Smart_Thumper_Results.xlsx	7/25/2018 11:32 AM	Microsoft Excel Wor…	11 KB

Figure 1.25   Thumper_Calc Export File Names

6- When all calculations are complete, close the program by selecting the Quit button.

If users do not have MC information, then the MC should remain at zero. **STC** will use the updated numbers that are greater than zero. If users are using KG for weight information, make sure the LB column is left at zero.

24

10. Limitations of Smart Thumper

Both methods use frequency, dimensions, and weight to evaluate the dMOE of each sample. The basics of vibration and soundwave are different. **Smart Thumper** in vibration test mode can capture frequencies between 1 Hz and 26 Hz, whereas, **Smart Thumper** in soundwave test mode captures frequencies between 20 Hz and 4,190 Hz. These ranges permit testing of a large range of wood sample sizes. The limits of sample sizes are shown in Table 1.2 for each test method.

Table 1.2   Minimum sample length for vibration and soundwave test

Cross-section size in inches (meters)	Minimum sample length in feet		
	Vibration		Sound wave
	Flatwise	Edgewise	
0.5 x 0.5 (0.013 x 0.013)*	3.0 (0.914)	3.0 (0.914)	1.5 (0.457)
1.0 x 1.0 (0.025 x 0.025)	3.5 (1.067)	3.5 (1.067)	
1.5 x 1.5 (0.038 x 0.038)	4.5 (1.372)	4.5 (1.372)	
1.5 x 3.5 (0.038 x 0.089)	4.5 (1.372)	7 (2.134)	
1.5 x 5.5 (0.038 x 0.140)	4.5 (1.372)	8.5 (2.591)	
1.5 x 7.25 (0.038 x 0.184)	4.5 (1.372)	10 (3.048)	
1.5 x 9.25 (0.038 x 0.235)	4.5 (1.372)	11 (3.353)	
1.5 x 11.25 (0.038 x 0.286)	4.5 (1.372)	12 (3.658)	
3.5 x 3.5 (0.089 x 0.089)	7 (2.134)	7 (2.134)	

* Minimum length calculated based on default density

11. References

American Society of Testing and Material. 2009. ASTM D 6874-09: Standard Test Methods for Nondestructive Evaluation of Wood-Based Flexural Members using Transversal Vibration. West Conshohocken, Pennsylvania, USA.

American Society of Testing and Material (2009) ASTM E 1876: Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impulse Excitation of Vibration. West Conshohocken, Pennsylvania, USA.

Evans, James W., David E. Kretschmann, Vicotoria L. Herian, and David W. Green, "Procedures for Developing Allowable Properties for a Single Species Under ASTM D1990 and Computer Programs Useful for the Calculation", FPL-GTR-126, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory Madison, WI, 2001.