MCEN 3047

Mechanical Engineering
University of Colorado Boulder

INVESTIGATON OF BUCKLING VERSUS AREA MOMENT OF INERTIA

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ABSTRACT / MOTIVATION

THE OBJECTIVE OF THIS EXPERIMENT IS TO INVESTIGATE THE THEORETICAL AND EXPERIMENTAL RESULTS OF BUCKLING BY USING A CUSTOM-DESIGNED COMPRESSIVE LOAD TESTING APPARATUS. THE EXPERIMENTAL RESULTS WILL BE OBTAINED USING THE NI-9219 DAQ WHICH WILL RECORD THE OUTPUT VOLTAGES FROM THE LOAD CELL. THE OBTAINED VOLTAGE VALUES CAN THEN BE TRANSLATED TO AN APPLIED FORCE BASED ON A DEFINED CALIBRATION CURVE, AND THE EXPERIMENTAL RESULTS CAN BE COMPARED TO THEORY

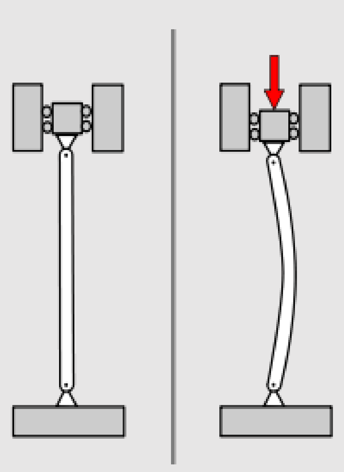
TO BETTER UNDERSTAND THE DATA ACQUISITION AND CALIBRATION PROCEDURES, THIS EXPERIMENT GIVES INSIGHT TO THE INTERNAL OPERATIONS OF MATERIAL SCIENCE TEST EQUIPMENT, SUCH AS THE INSTRON, AND REVEALS THE NATURE OF HOW THE RESULTS ARE OBTAINED.

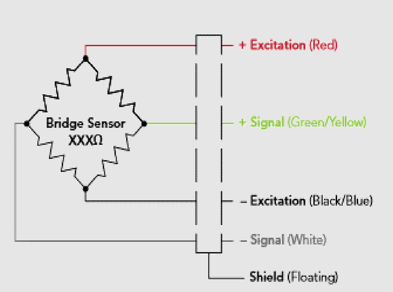
BACKGROUND

BUCKLING, THE FAILURE EXPERIENCED WHEN COLUMNS OF ANY SHAPE GIVE AWAY TO AXIALLY APPLIED FORCE, IS A PHENOMENA THAT CAN OCCUR IN STRUCTURAL ENGINEERING APPLICATIONS.

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

THE THEORETICAL MODEL FOR BUCKLING, AS SHOWN IN THE ABOVE EQUATION, FACTORS THE YOUNG'S MODULUS, AREA MOMENT OF INERTIA, AND LENGTH OF A COLUMN TO DETERMINE THE MAXIMUM LOAD IT CAN WITHSTAND BEFORE DEFLECTION IN THE X-AXIS CAUSES FAILURE WITHIN THE MATERIAL.





A FUTEK LCM300 LOAD CELL SENSOR, ALONG WITH A NI-9219 DAQ, IS USED DURING THIS EXPERIMENT. THE SENSOR MEASURES VOLTAGE VARIATIONS AMPLIFIED BY THE INTERNAL WHEATSTONE BRIDGE CIRCUIT. THE SENSOR HAS A LOAD LIMIT OF 100 LBF, WHICH IS NOT REACHED, AND AN OUTPUT RESOLUTION OF 2 mV/V NOM.

INDEPENDENT VARIABLE: LENGTH / DIAMETER

DEPENDENT VARIABLE: CRITICAL FORCE

CONSTANTS: MATERIAL (E)

MATERIAL PROPERTIES USED IN CALCULATIONS:

	1/8"	3/16"	1/4"
I [In^4]:	4.91E-06	6.07E-05	1.91E-3
E [Psi]:	2.3E6	2.3E6	2.3E6

EXPERIMENTAL METHOD

IN THE AXIALLY LOADED COMPRESSION TEST, LOAD WAS APPLIED TO THE CROSSHEAD, WHICH CONTAINED THE LOAD CELL. THE FORCE WAS TRANSLATED TO THE WOODEN ROD THROUGH THE JUNCTION PIN CONNECTION

DAQ: NATIONAL INSTRUMENTS 9219

SENSOR: FUTEK LCM300 LOAD CELL

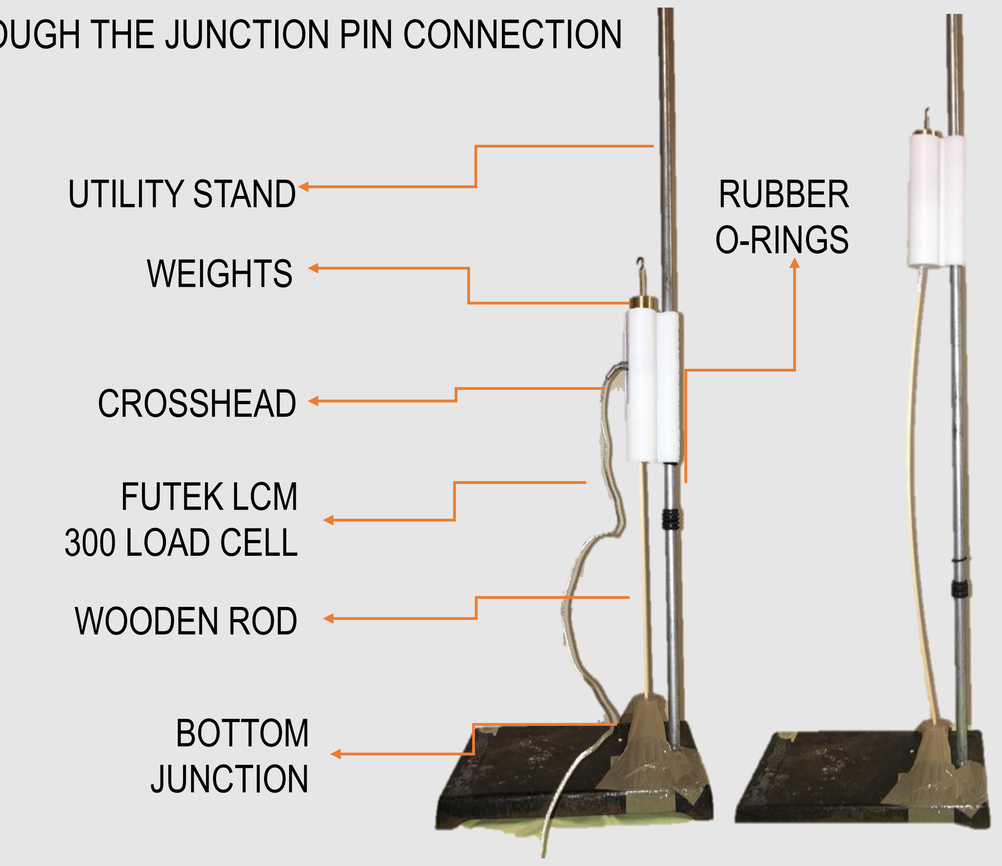
MATERIAL: OAK

5 LENGTHS [IN]:

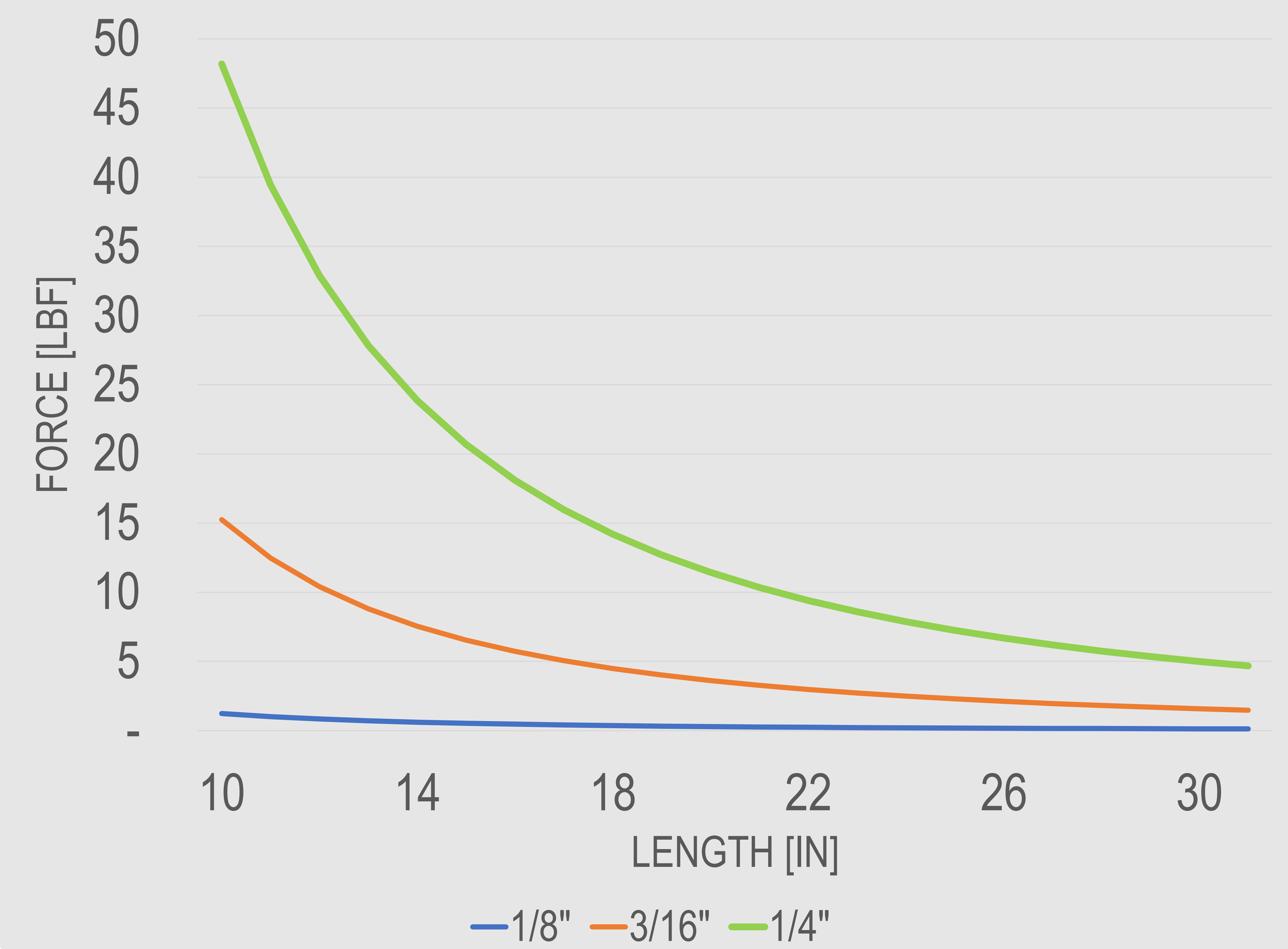
9.5, 13,18.5 ,23, 30

3 DIAMETER [IN]:

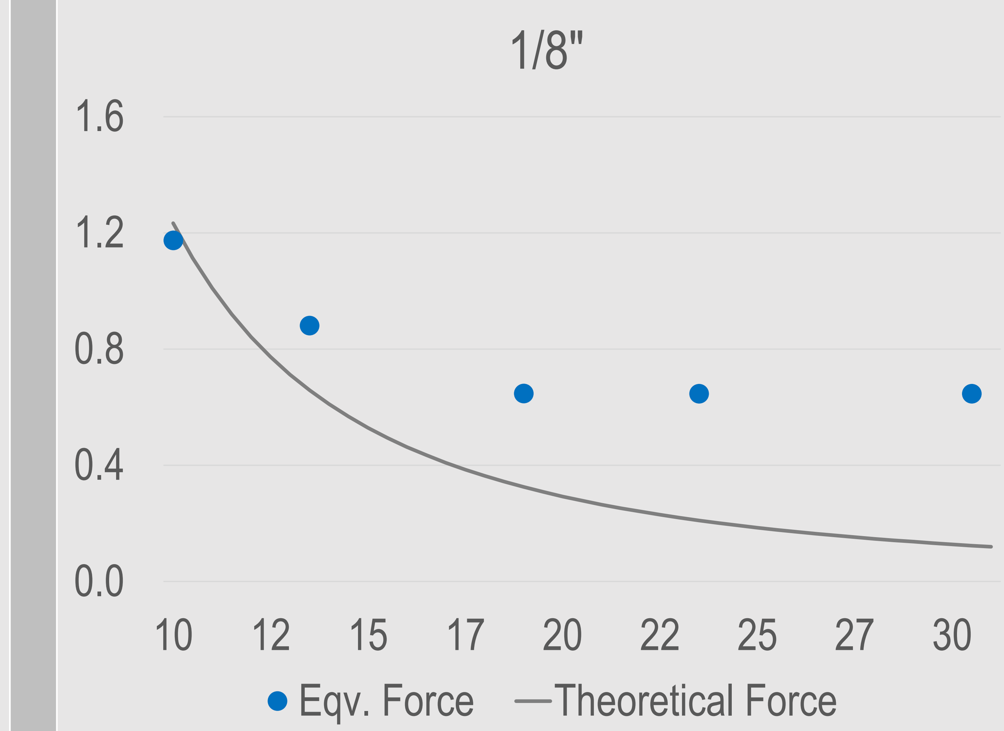
1/8", 3/16, 1/4

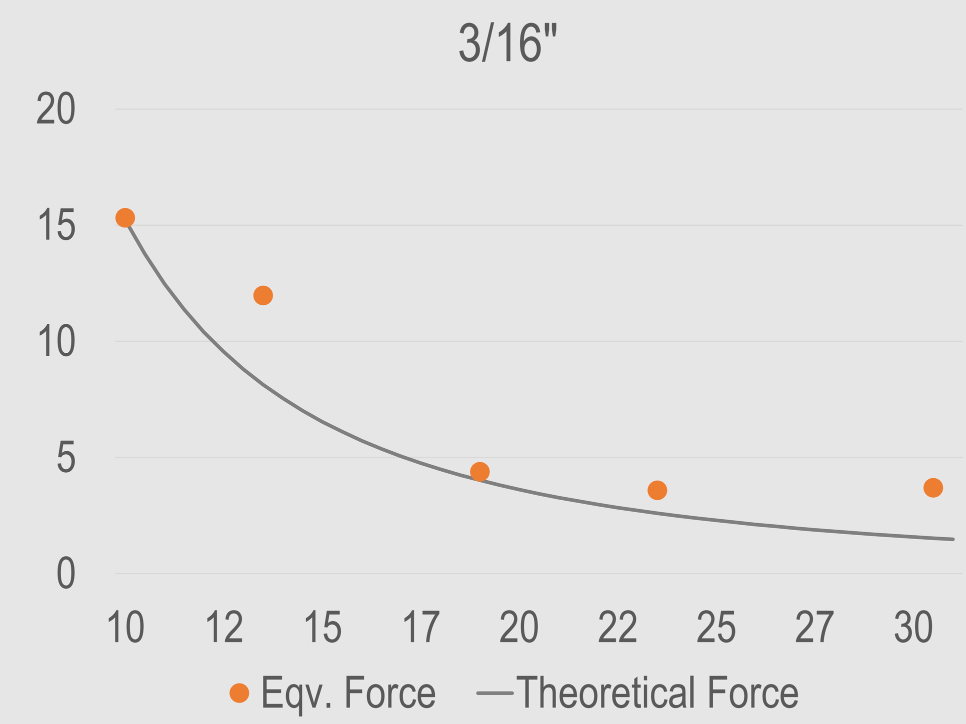


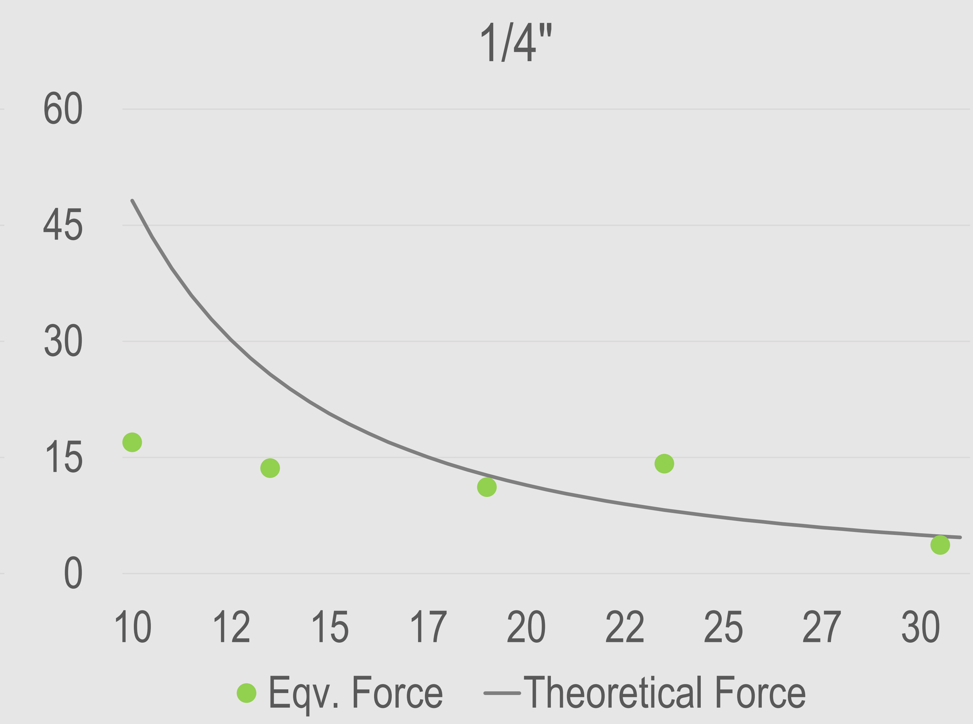
THEORETICAL MODEL



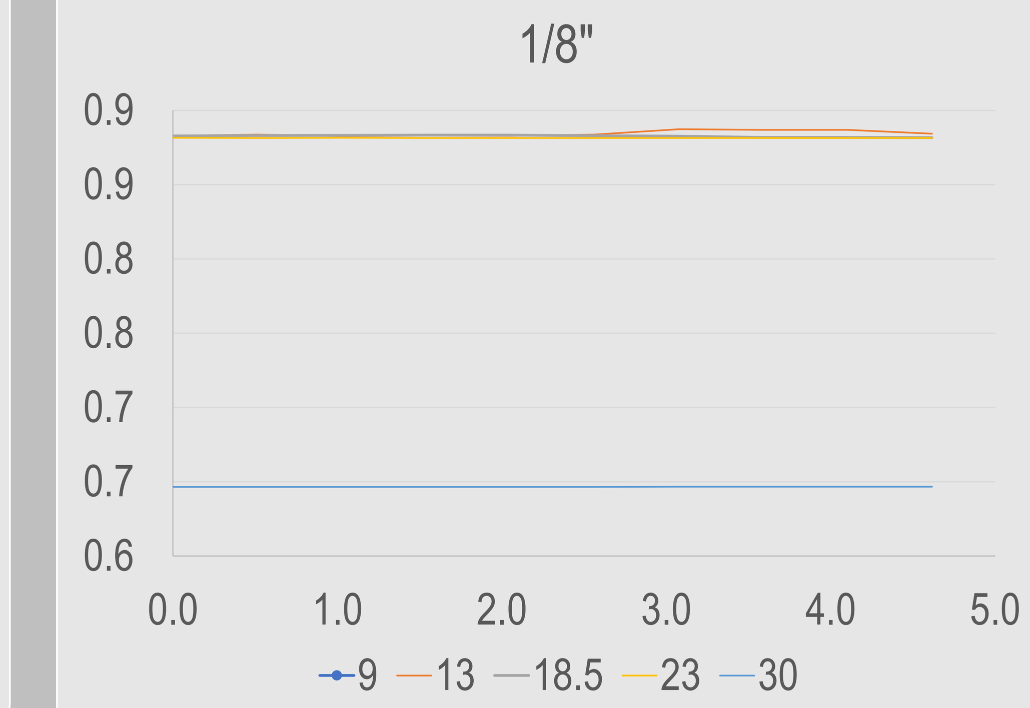
DIAMETER GROUPS – FORCE VS LENGTH

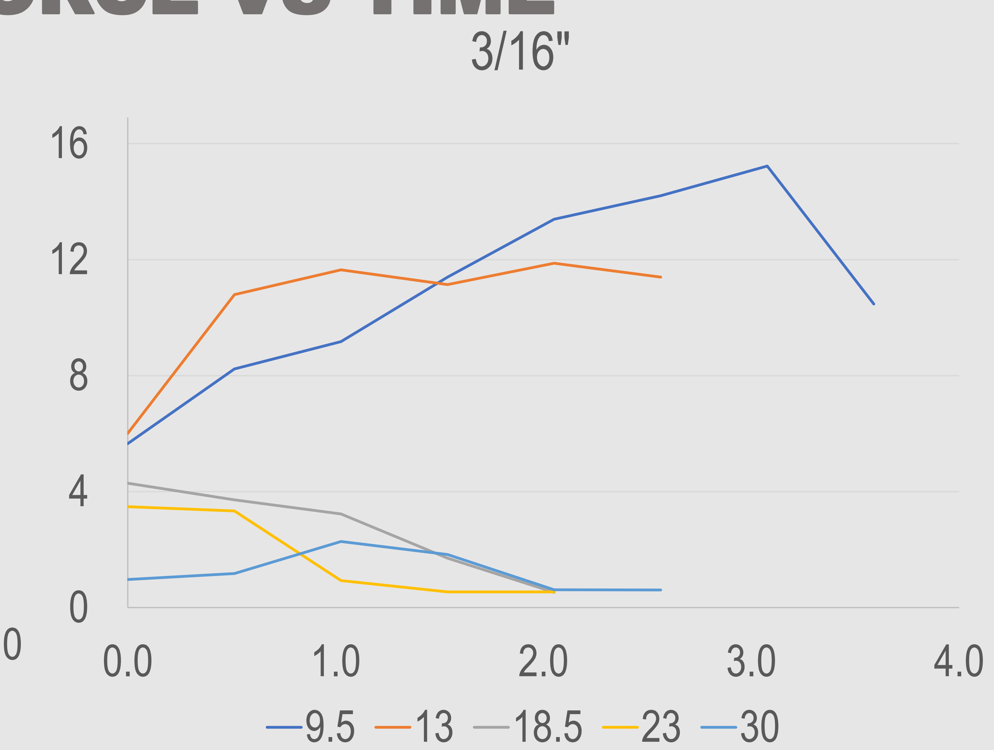


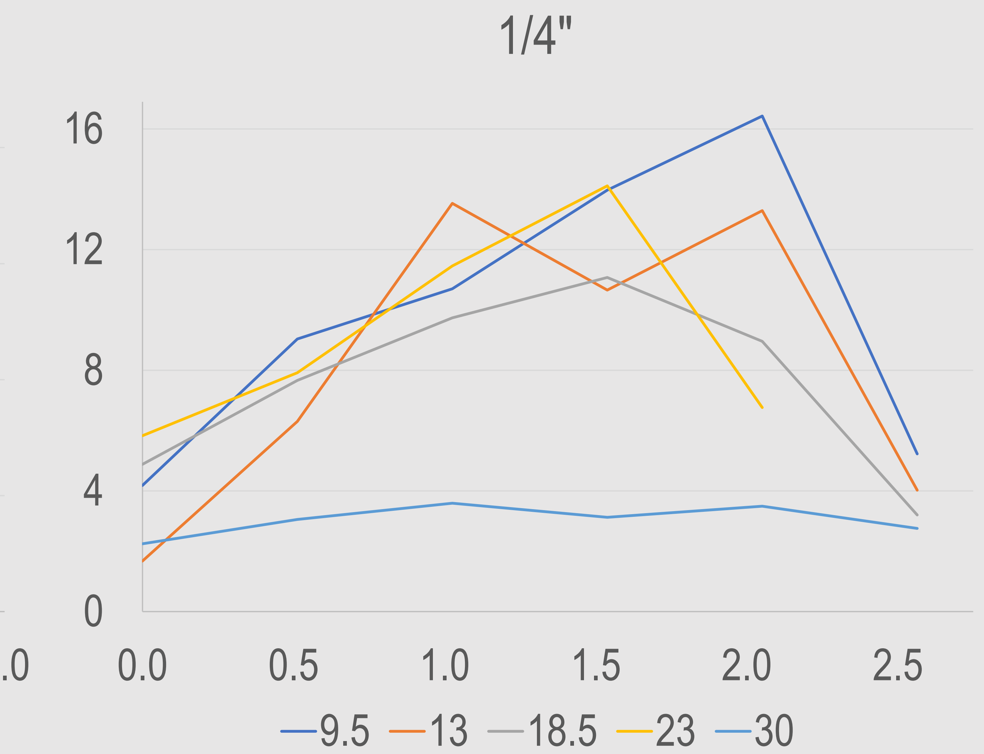




FAILURE PROFILES – FORCE VS TIME



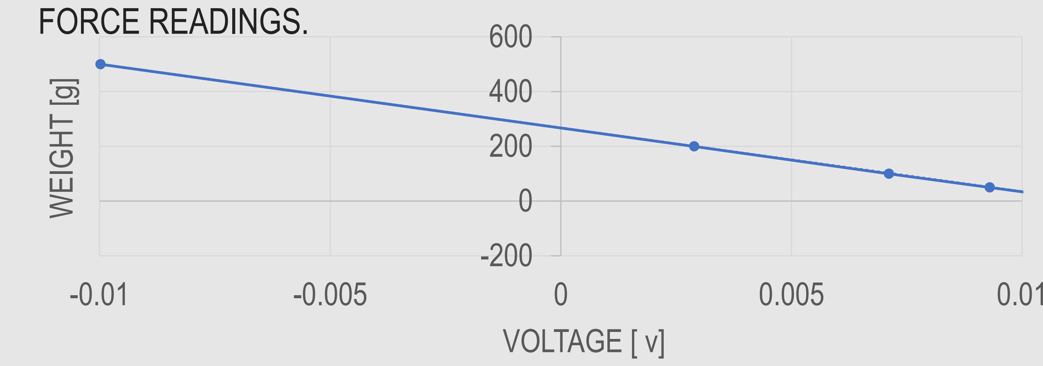




ANALYSIS / CALIBRATION

THE EXPERIMENTAL DATA FOLLOWS THEORY: AS DIAMETER DECREASES AND LENGTH INCREASES, CRITICAL FORCE DECREASES. HOWEVER, THERE ARE SOME ERRORS IN THE DATA BETWEEN TRIALS AND DISCREPANCIES BETWEEN THE THEORETICAL DATA.

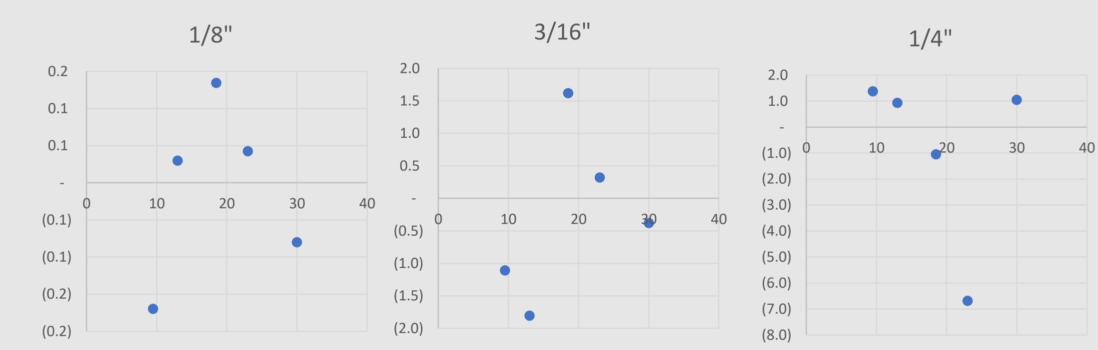
THE FOLLOWING CALIBRATION EQUATION WAS USED TO CORRELATE THE MEASURED VOLTAGE OUTPUTS FROM THE DAQ INTO EQUIVALENT FORCE READINGS.



$$P_{CR} = (-51.3*V) + 0.59$$

THE CALIBRATION WAS DONE WITH FIVE VARIOUS WEIGHTS. A LINE OF BEST FIT WAS DERIVED FROM THE DATA TO CREATE THE CALIBRATION CURVE.

RESIDUAL PLOTS



CONCLUSION

THE EXPERIMENTAL DATA AGREES WITH THE TRENDS OF THE THEORETICAL DATA: AS THE DIAMETER INCREASES AND/OR THE LENGTH DECREASES, THE CRITICAL VALUE INCREASES, ADDING MORE STRENGTH TO THE COLUMN.

THE RESIDUAL PLOTS SHOW NO TREND, THEREFORE THE DATA AGREES WITH THE THEORETICAL CURVE.

SOURCES OF ERROR INCLUDE THE HUMIDITY DISTRIBUTION OF THE WOOD, BOUNDARY CONDITIONS OF THE COLUMN (I.E. THE COLUMNS SLIPPING IN UNDESIRED DEGREES OF FREEDOM), AND ANISOTROPY OF THE WOOD.

THE CHANGE IN HUMIDITY DURING DISTRIBUTION LIKELY AFFECTED THE MATERIALS LEADING TO A DISCREPANCY IN CRITICAL FORCES. TO MINIMIZE THESE ERRORS, AN ISOTROPIC MATERIAL, AND ONE THAT IS UNAFFECTED BY HUMIDITY, COULD BE USED (SUCH AS STEEL OR ALUMINUM). THE EXPERIMENT WAS ABLE TO MODEL THE INNER WORKINGS OF AN AUTOMATED MATERIAL TESTING MACHINE BY USING A MECHANICAL-LOADING SYSTEM AND PERFORMING POST PROCESSING CALIBRATION.

REFERENCES

1.1 Green, David W. "Mechanical Properties of Wood." Mechanical Properties of Wood, Forest Products Laboratory, 1999, www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch04.pdf.

2 "MODEL LCM300 Miniature Threaded In Line Load Cell." FUTEK Advanced Sensor Tech- nology, Inc., FUTEK, www.futek.com/files/pdf/Product%20Drawings/lcm300.pdf.

3 K. Regner, MCEN 3047 LAB 5: Determining the pressure inside a soda can, CU Boulder, 2018