The Impact of Low Tech Research Experiences for Undergraduate Students

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The Suprenant Impact Factor

- Teaching: 4 schools over 16 years. Typical professor teaches 9 credit hours and has 20-30 students per course. 75 students per semester * 32 semesters = 2400 students

MONTANA STATE UNIVERSITY

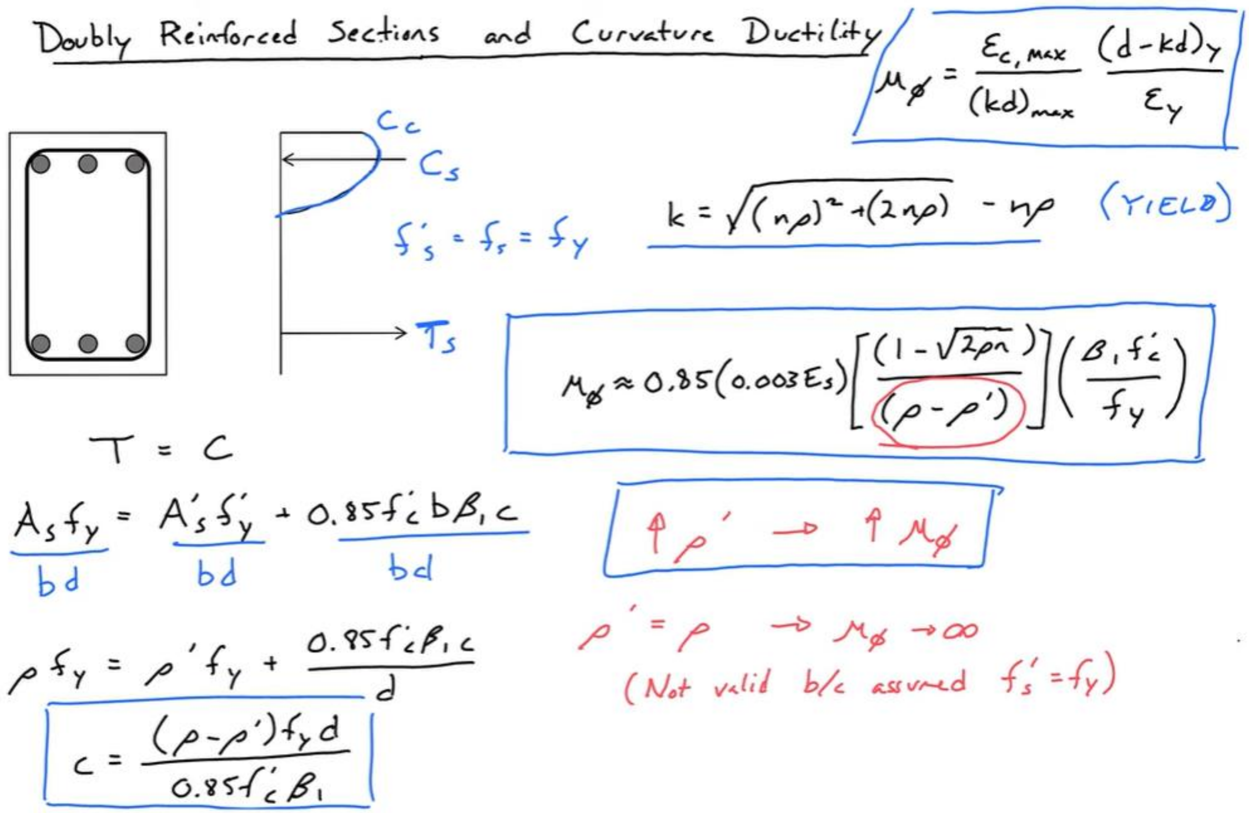
UNIVERSITY of WYOMING

UNIVERSITY of SOUTH FLORIDA

Boulder

1983 Dissertation: *Curvature ductility of reinforced and prestressed concrete columns*

Today: Multiple YouTube videos on Curvature Ductility



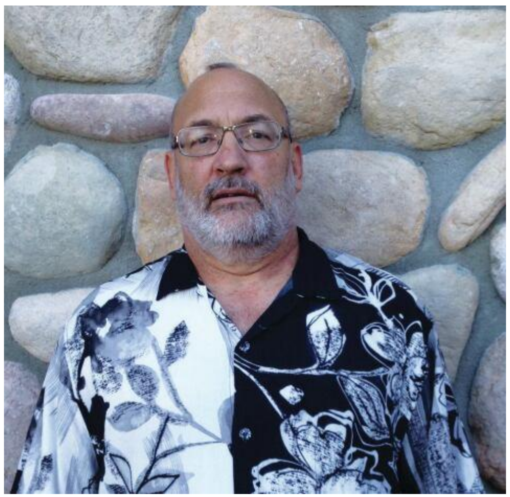
Industry Contribution – to name a few

- 84 Featured Articles in Concrete Construction
- 62 Abstract hits on www.concrete.org Publications
- Countless Technical Documents for ASCC
- Dozens of ACI Negative Votes (with Well Constructed Comments)

CIM Research Impact

- Industry Research: 10 semesters x 20 students = 200 undergraduate MTSU CIM students benefiting from practical, low tech research experiences; 40 students from NJIT, CSU-Chico and Texas State also participated in one project.

Hawaiian Shirts, Margaritas and Shop Talk



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Suprenant & Malisch

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Concentrated Efforts for Maximum ROI

- The methodology for effective undergraduate research takes planning due to the shortened schedule.
- Special Problems, Independent Studies, Capstone, Lab based courses are all built into curriculums that is the vehicle for success.
- Sending out a “Call to Action” research request each summer and winter to industry partners asking for bite sized data sets that they need to support their plant and field activities.
- Providing an industry mentor that can keep pace with the work and answer a lot of questions to ensure accuracy and integrity of the data collection.

Multi Semester projects

- Its not always possible to get valuable information in 10 - 14 weeks so being able to break the workload into multiple semesters has pros and cons.
- Pros: More students get to experience real world problems. The data set can be more comprehensive covering longer test cycles and more variables can be introduced.
- Cons: You’ve multiplied the hands touching the research which affects operator variability. More training and typically more space needed to keep samples around longer.

The Driving Force Behind the Work

Tolerances for building construction have sometimes been set without consideration for the builder's ability to meet them, or for the effect of an out-of-tolerance condition on the serviceability of the structure

Classifying Specification Traps

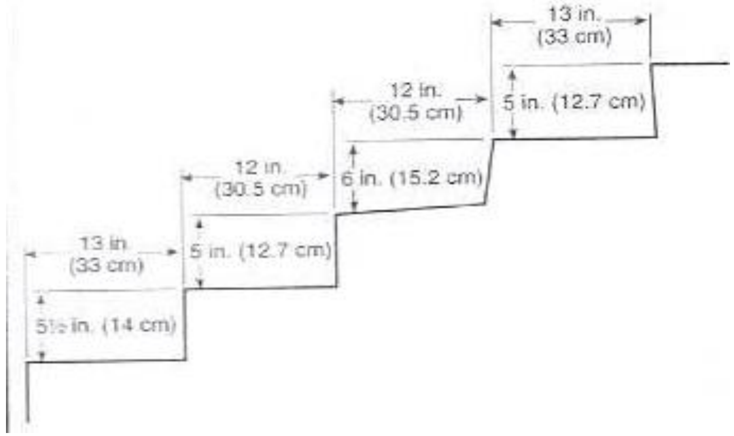
- Unreasonable construction requirements
- Irrational construction requirements
- Risk transfer
- Specification requirements for attributes that aren’t defined or are vaguely described

Project Example: Life Safety Code

- National Fire Protection Associations Life Safety Code, 2006 & 2009 Edition
  - Requires riser height to be measured as the vertical distance between tread nosings
  - Height can be measured using a carpenter's level and tape

Existing Standards

- Section 7.2.2.3.6 of the Life Safety Code
  - “There shall be no variation in excess of 3/16 in. in the depth of adjacent risers, and the tolerance between the largest and smallest riser shall not exceed 3/8 in. in any flight.”
- IBC 06 & ACI 117-06
  - Same 3/16 in. tolerance for depth but NO requirement for the difference between the maximum and minimum riser depth.



The Problem

- Regardless of cast-in-place, precast, or concrete-filled metal pans, these tolerances are hard to meet and corrective action is often expensive
- If an out-of-tolerance condition isn’t detected during initial construction and a trip-and-fall accident occurs later, as-built measurements may show that the stairs were out-of-tolerance.
- **The builder then becomes one of the defendants in a lawsuit**

Research Need

- This can happen despite the fact that there are no studies showing that a difference of 3/16 in. in the height of adjacent risers is less likely to cause a trip-and-fall accident than a difference of ¼ in. or more.
- 1992 - An in-depth review failed to establish a consistent, statistically valid link between stair safety and stair geometry.

Goal

- Present a methodology along with data for measuring stairs that can be useful in better defining reasonable stair tolerances

Questions to answer…

- Variability in riser height from one set of stairs to another
  - Are there differences in stairs constructed using different systems?
- Variability of riser height in a given set of stairs
  - Is the top or bottom step more likely to be out of tolerance than other steps?
- Variability in riser height for any single step in a set of stairs
  - Does the location of the measurement affect the probability of being in or out-of-tolerance?

Sampling Sites

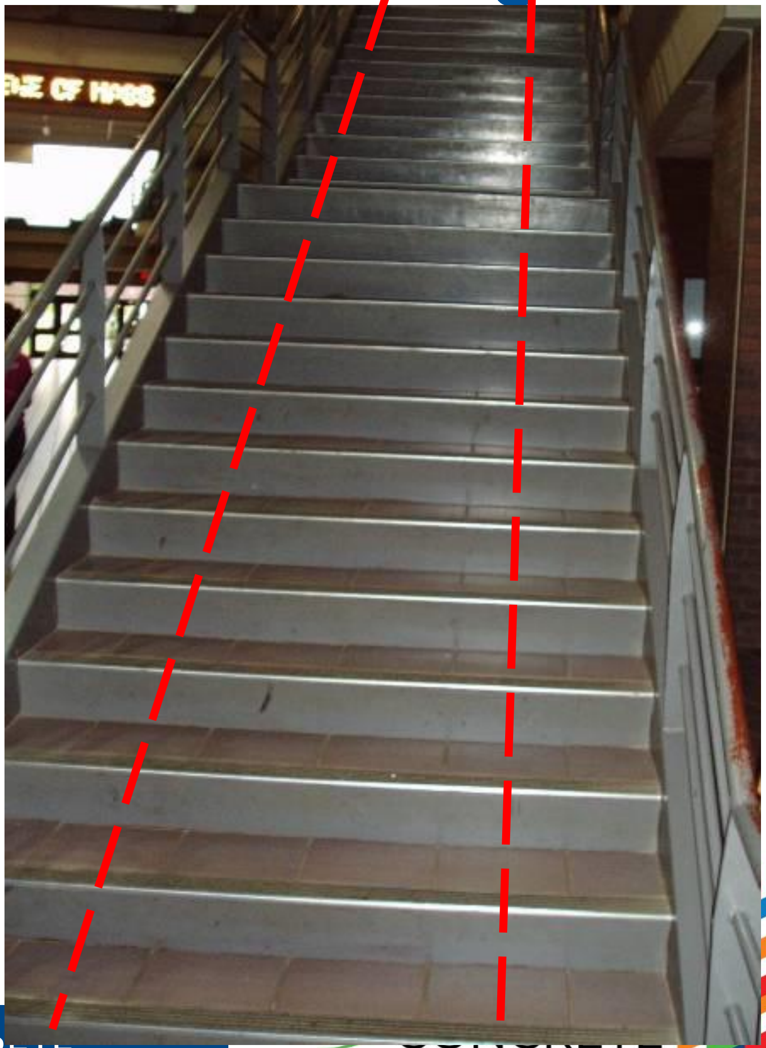
- Residential Construction was excluded
- Ten sets of stair measurements in three types of buildings:
  - Government Buildings
  - Schools
  - Offices/Medical

Developing a Measurement Protocol

- The Life Safety Code has a method for measuring riser height however does not specify tread location.
- Using standards from handrail requirements, it was determined that the area where foot traffic was most likely to occur was about 18 in. from the wall.

Mass Communications Building

- Middle Tennessee State
  - Built in 1991
  - Cast-in-place concrete
  - Six operators
  - Measured
    - 2 flights
    - 13 steps on each flight
    - 18 inch from left
    - 18 inch from right

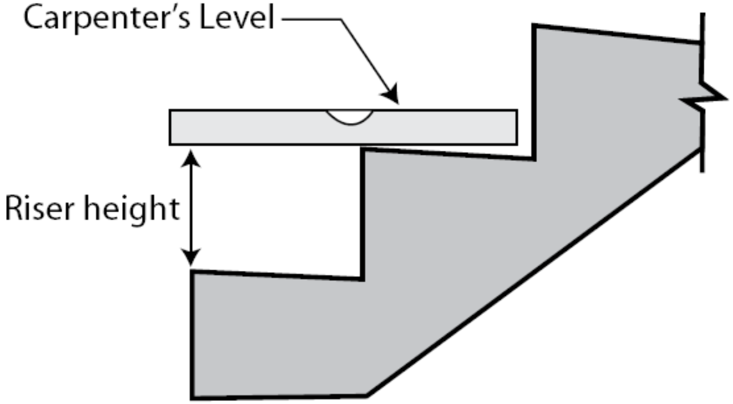


Floyd Stadium

- Middle Tennessee State
  - Built in 1998
  - Cast-in-place concrete
  - Six operators
  - Measured
    - 2 flights
    - 21 steps on each flight
    - 18 inch from left
    - 18 inch from right

Precision Statement

- Operator
- Equipment (ruler and level)
- Calibration of equipment
- Setting out survey line (18 inch from wall)
- Measuring procedure
  - – Nose to nose
  - – Level



Stair	Corbin	Nadeau	Nickell	Mertens	Masteller	Hamm	Range
1	7	6 1/16	6 3/16	6 15/16	7	7	15/16
2	7	6 1/8	6 ¼	6 3/8	6 ½	7 1/16	15/16
3	7 1/8	6 ¼	6 3/8	6 7/8	6 15/16	7 ¼	1
4	7 1/8	6 3/8	6 ½	6 7/8	6 15/16	7 ¼	15/16
5	6 7/8	6 1/8	6 1/8	6 5/8	6 11/16	7 1/8	1
6	7	6 3/8	6 ½	6 13/16	6 ¾	7 3/16	13/16
7	7 ¼	6 1/8	6 ¼	6 15/16	7	7 5/16	1 3/16
8	6 7/8	6 ½	6 3/8	6 ½	6 9/16	7	5/8
9	7	6 1/8	6 ¼	6 11/16	6 ¾	7	7/8
10	6 15/16	6 1/8	6 ¼	6 7/16	6 7/16	7	7/8
11	6 13/16	6 3/16	6 5/16	6 11/16	6 ¾	7	13/16
12	7 1/8	6 ½	6 5/8	6 13/16	6 13/16	7 1/16	5/8
13	7 1/4	6 11/16	6 13/16	6 7/8	6 13/16	7 1/4	9/16

ASTM E691 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

• 6 operators	(ASTM min = 6)
• 4 flights of stairs	(ASTM min = 4)
• 13 steps per flight	(ASTM min = NR)
• 2 measurements per stair	(ASTM min = 2)

Interlaboratory Data Analysis Software from ASTM

Precision Statement

- Repeatability
  - Within lab (same operator; same lab)
  - Sr = repeatability standard deviation
  - r = 95% repeatability = 2.8 x Sr
- Reproducibility
  - Between lab (different operator & lab)
  - SR = reproducibility standard deviation
  - R = 95% reproducibility = 2.8 x SR

Precision Statement for Stairs

Precision, characterized by repeatability , Sr, r, and reproducibility, SR, R has been determined for the materials to be:

Stairs	Average	Sr	SR	r	R
Mass flight 1	6.8125	0.2366	0.5862	0.6625	1.6413
Mass flight 2	6.5938	0.2552	0.4954	0.7144	1.3872
Floyd flight 1	6.9271	0.1712	0.1712	0.4793	0.4793
Floyd flight 2	6.9896	0.3238	0.3253	0.9065	0.9107

Repeatability

95% of the time, the same operator should be able to measure the riser height twice *anywhere on the stair* and be within 7/16 inch

Min = 1/16 in

Max = 15/16 in

Avg = 7/16 in

Reproducibility

- 95% of the time the results between two operators that measure the riser height *anywhere on the stair* should be within 1 in.

Min = 3/8 in

Max = 1 ¾ in

Avg = 1 in

Initial Indications

- Based on data from the first ten sets of stairs:
  - about 30% of the differences in adjacent riser heights are greater than 3/16 in
  - about 82% of the maximum-minus-minimum riser height differences in a stair flight are greater than 3/8 in.
- This indicates that a very high percentage of the stairs measured were not within the tolerances required by either the 2000 or 2006 Editions of the Life Safety Code
- We suggest using the preconstruction meeting to discuss locations of stair riser measurements that will be used either to check for compliance with tolerance requirements or effectiveness of corrective measures.

Thank you!