COLD WEATHER CONCRETE-ROCK INTERFACE RESEARCH PROJECT

CENE 486C Presentation

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BACKGROUND

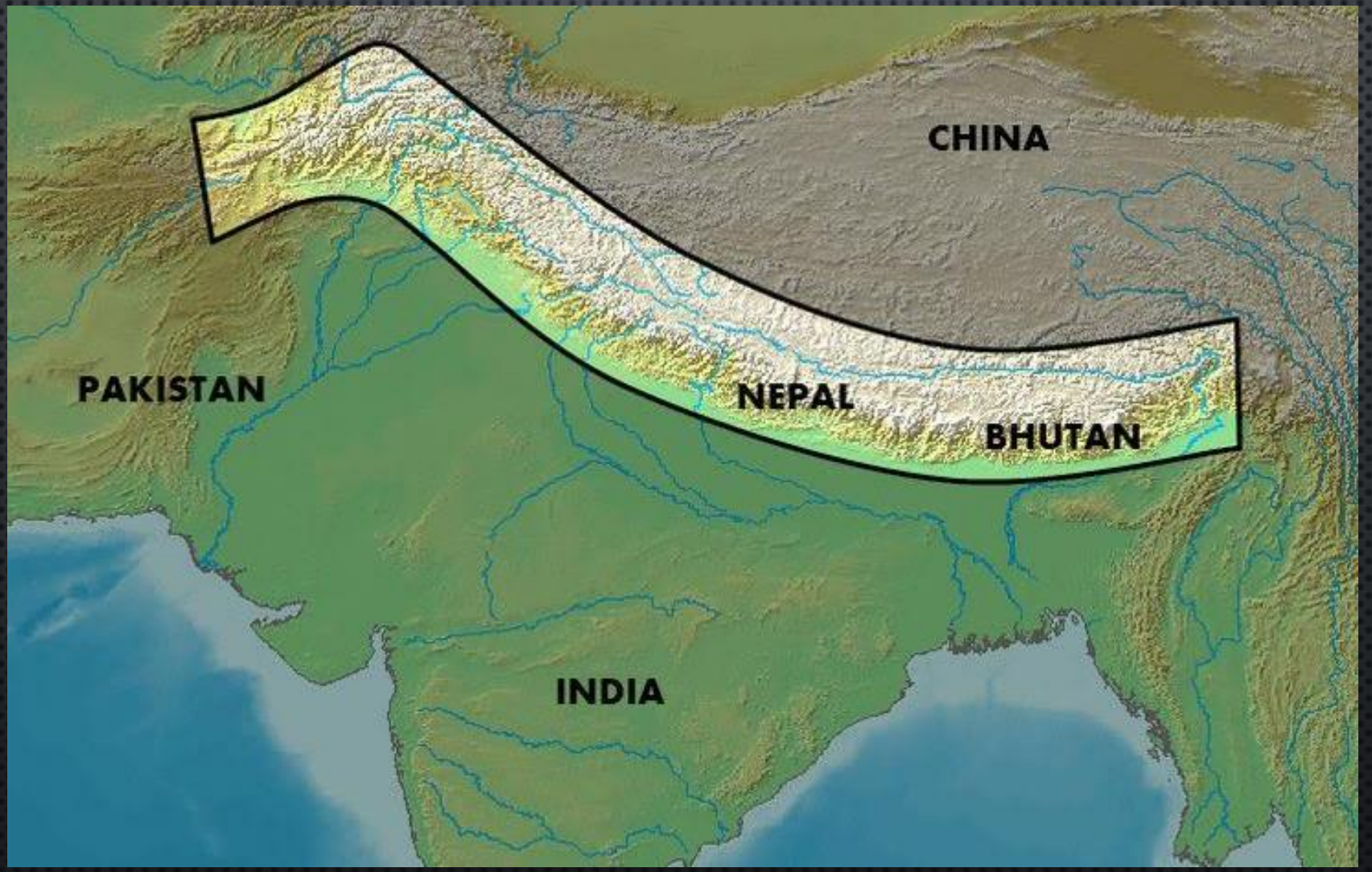

Figure 1: Concrete tunnel cross-section [1]

PROJECT UNDERSTANDING

- Create a Modified Representation of Tunnel Lining
  - Rock Type: Flagstone
  - Conventional Concrete
    - Modification: Admixture and Fiber Reinforcement
- Analyze the Effect of Cold Weather at the Interface
  - Modified Freeze-Thaw Cycles
  - Cause Fracture at the Seam
- Share Findings Based on Observations and Analytical Data

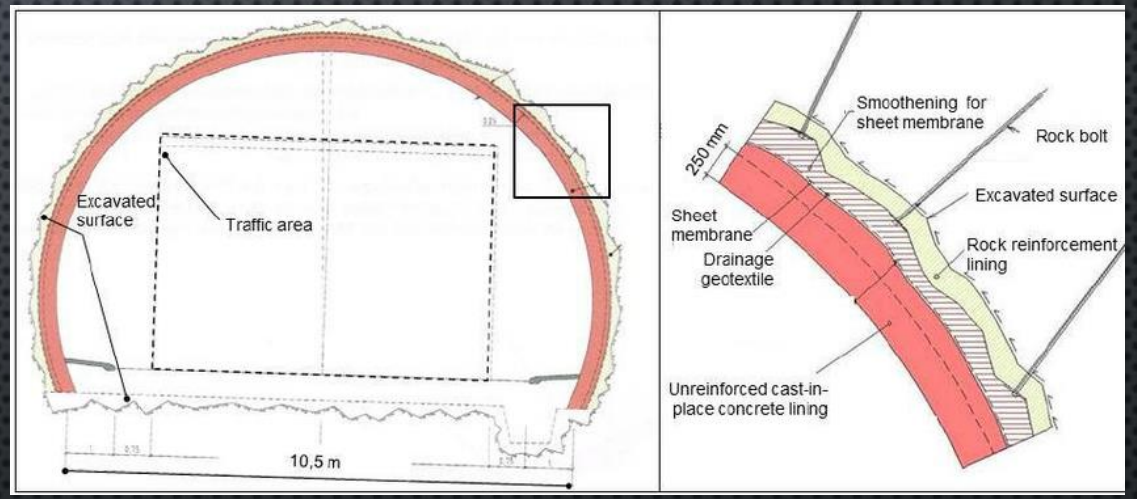

Figure 2: Concrete tunnel cross-section [2]

PAST FINDINGS

- Studies the Deterioration of Concrete Due to Moisture and Freezing Temperatures [3]
  - Freezing and Thawing is the Most Common Deteriorating Factor
- Research Shows That Admixtures Can Improve Resistance Concrete Subjected to Cold Weather [4]
- Most Common Point of Failure Occurs at Excavated Surface

Figure 3: Cracking due to freezing and thawing over time [5]

METHODS

- Creation of Concrete-Rock Block Specimens
  - Constants: Concrete Design Mix
  - Variable: Rock Surface
- Cold-Weather Simulation
  - 300 Modified Freeze-Thaw Cycles
- Strength Testing
  - Modified Direct Compression
  - Modified Splitting Tensile

Figure 4: Freeze-thaw machine at coldest point in cycle [6]

SPECIMEN DESIGN

- Rough - Saw cuts at ¼"
- Semi-rough - Saw cuts at ½"
- Smooth - No cuts

Figure 5: Flagstone surfaces: rough (left), semi-rough (middle), smooth (right) [7]

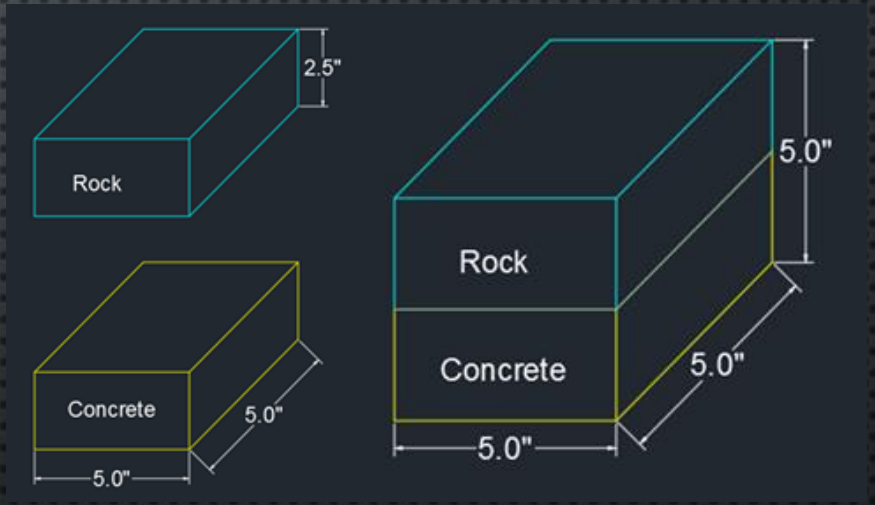

Figure 6: Model of Specimen Design [8]

PRELIMINARY TESTING

- Concrete Design Mix
- ASTM C116 – Direct Compression

Figure 7: Specimens for preliminary testing, original design mix (farthest left), modification improvements (left to right) [9]

SPECIMEN CONCRETE MIX DESIGN

- QUIKRETE
  - Commercial grade blend
  - ~ 20 -30% Cement [11]
- Water
  - Water/ Cement Ratio: 0.48
- AKKRO-7T
  - Liquid bonding admixture [12]
- FIBERMESH 150
  - Concrete reinforcement [13]

Figure 8: Design mix proportions [10]

25%	Cement
62%	Aggreggate and Sand
12%	Water
0.94%	Admixture
0.04%	Fiber

CONCRETE TESTING RESULTS

- 4 Day Curing Sample:
  - 3.6 KSI Failure
- 7 Day Curing Sample:
  - 4.4 KSI Failure

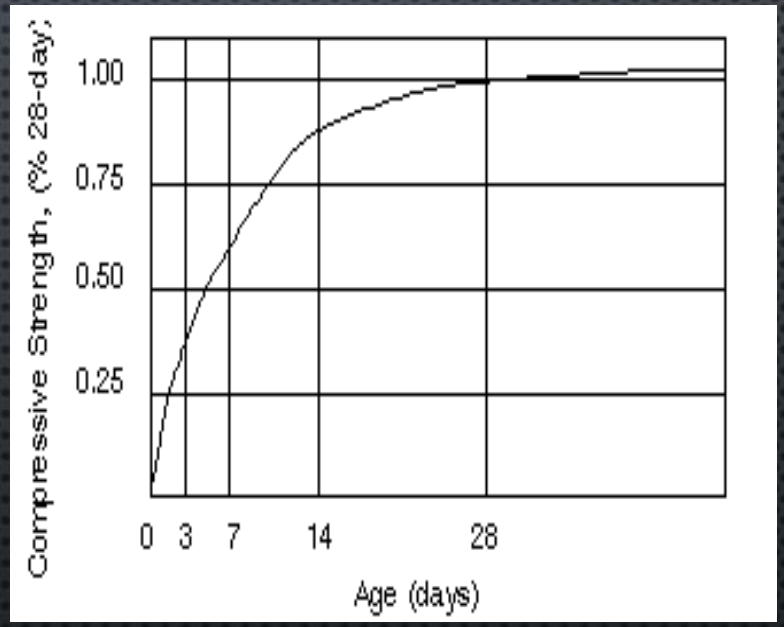

Figure 9: Compressive curing strength by percent [25]

Figure 10: 7 day cure compression failure [14]

COLD WEATHER SIMULATION

- Modified ASTM C666 Resistance of Concrete to Rapid Freezing and Thawing
  - Temperature 4 to -18ºC
  - Total of 300 Cycles

Figures 11: Specimens undergoing freeze - thaw cycles [15]

INTERFACE STRENGTH TESTING

- Modified ASTM C496 Splitting Tensile Strength of Cylindrical Concrete Specimens
  - Testing Performed at 50-Cycle Intervals

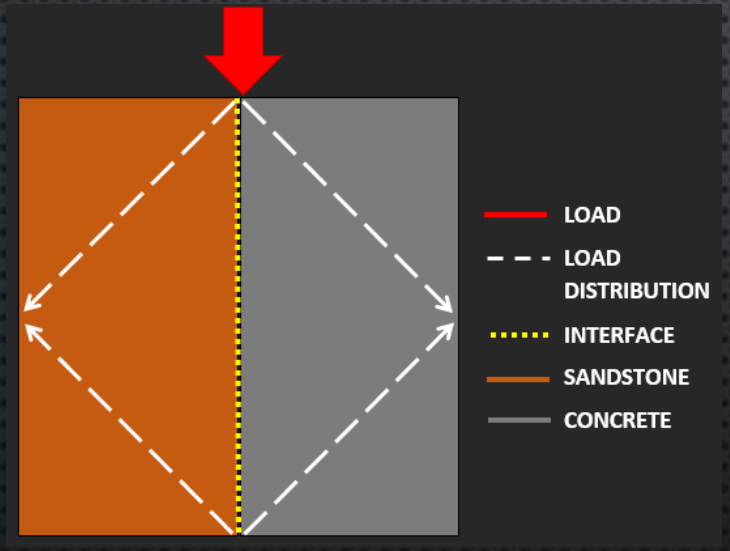

Figure 14: Illustration of the load distribution throughout the specimen [16]

Figure 15: Specimen, before test, with placed extensometers on each side [17]

TENSION SPLIT TESTING

Figure 16: Specimen tensile failure [18]

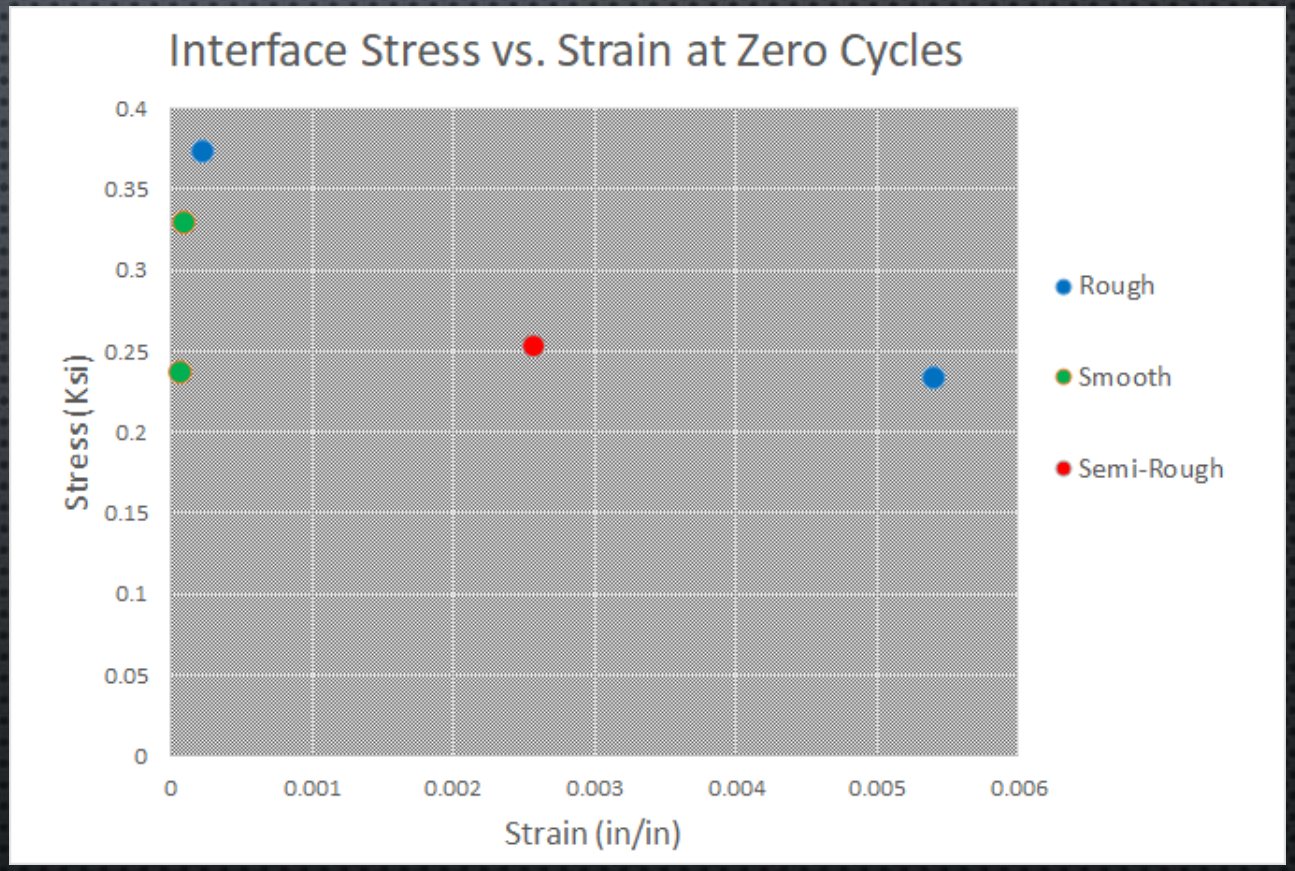

Figure 17: Stress vs strain data points of interface tension failure [19]

FAILURE ANALYSIS

Smooth
- **0.25 KSI**

Semi-rough
- **0.24 KSI**

Rough
- **0.18 KSI**

Figure 18: The failed interfaces of the smooth, semi-rough, and rough specimen interfaces [20]

MATERIAL COSTS

Table 1: Predicted material costs

Item	Quantity	Unit	Rate	Total
Labor	**843**	**hrs**	**$159.00**	**$43,419.50**
Project Manager (PM)	242.5	hrs	$75.00	$18,187.50
Research Specialist (RS)	297.5	hrs	$40.00	$11,900.00
Laboratory Technician (LT)	303	hrs	$44.00	$13,332.00
Material	**30**	**per item**	**$405.79**	**$876.82**
Cement Type III- Quikrete	3	bag	$23.09	$69.27
Fine Sand- Quikrete	7	bag	$3.72	$26.04
Aggregate	1	cyd	$15.00	$15.00
FiberMesh150	4	bag	$12.25	$49.00
Admixture- Hydro Max	1	bag	$97.95	$97.95
Admixture- Tammsweld	2	bottle	$122.09	$244.18
Admixture- HEY'DI SB	2	bag	$117.69	$235.38
Cold Rolled Steel	10	cyd	$14.00	$140.00
Others	**17**		**$1,625.00**	**$4,975.00**
400K Tinius Olsen	10	day	$300.00	$3,000.00
Hydrolic Press	3	day	$200.00	$600.00
Software	1	each	$1,000.00	$1,000.00
Resources	3	each	$125.00	$375.00
Overall Project Cost				**$49,271.32**

Table 2: Actual material costs

Item	Quantity	Unit	Rate	Total
Labor	**622**	**hrs**	**$159.00**	**$32,468.00**
Project Manager (PM)	192	hrs	$75.00	$14,400.00
Research Specialist (RS)	213	hrs	$40.00	$8,520.00
Laboratory Technician (LT)	217	hrs	$44.00	$9,548.00
Material	**18**	**per item**	**$232.01**	**$417.26**
Cement Type III- Quikrete	3	bag	$23.09	$69.27
Fine Sand- Quikrete	7	bag	$3.72	$26.04
Aggregate	1	cyd	$15.00	$15.00
FiberMesh150	4	bag	$12.25	$49.00
AKKRO-7T	1	bag	$97.95	$97.95
Tile Saw Rental	2	day	$80.00	$160.00
Others	**9**		**$1,580.00**	**$2,880.00**
400K Tinius Olsen	4	day	$300.00	$1,200.00
Hydrolic Press	3	day	$200.00	$600.00
Software	1	each	$1,000.00	$1,000.00
Resources	1	each	$80.00	$80.00
Overall Project Cost				**$35,765.26**

STAFFING COSTS

Table 3: Preliminary staffing costs

Task	Classification			Cummulative	Labor Total
	PM	RS	LT		
	$75/hr	$40/hr	$44/hr	(hrs)	($)
Project Start Up and Analysis	19	29	10	58	$ 3,025.00
Laboratory Work	139.5	179.5	197	516	$ 26,310.50
Data Collection	70	70	73	213	$ 11,262.00
Data Analysis	5	13	18	36	$ 1,337.00
Presentation of Deliverables	9	6	5	20	$ 1,135.00
Total Service Distribution	**242.5**	**297.5**	**303**	**843**	**$43,069.50**

Table 4: Actual staffing costs

Task	Classification			Cummulative Labor	Labor Total
	PM	RS	LT		
	$75/hr	$40/hr	$44/hr	(hrs)	($)
Project Start Up and Analysis	33	29	10	72	$ 4,075.00
Laboratory Work	125	125	139	389	$ 20,491.00
Data Collection	21	25	31	77	$ 3,939.00
Data Analysis	5	20	21	46	$ 1,749.00
Presentation of Deliverables	8	14	16	38	$ 1,864.00
Total Service Distribution	**192**	**213**	**217**	**622**	**$32,468.00**

4	**1.0**	**Project Start Up and Analysis**	**58 days**	**Tue 8/29/17**	**Thu 11/16/17**
5	1.1	Background Research	13 days	Tue 8/29/17	Thu 9/14/17
6	1.2	Material Consideration	6 days	Fri 9/15/17	Fri 9/22/17
7	1.3	Scheduling	14 days	Fri 9/15/17	Wed 10/4/17
8		Meeting 1	1 day	Fri 9/15/17	Fri 9/15/17
9		Meeting 2	1 day	Mon 9/18/17	Mon 9/18/17
:		Meeting 3	1 day	Wed 9/20/17	Wed 9/20/17
;		Meeting 4	1 day	Wed 9/27/17	Wed 9/27/17
<		Meeting 5	1 day	Wed 10/4/17	Wed 10/4/17
43	1.4	Cost Estimating	14 days	Fri 9/15/17	Wed 10/4/17
44	1.5	Code and Standards Research	14 days	Tue 9/5/17	Fri 9/22/17
45	**2.0**	**Laboratory Work**	**38 days**	**Fri 9/8/17**	**Tue 10/31/17**
46	2.1	Laboratory Safety Training	1 day	Fri 9/8/17	Fri 9/8/17
47	2.2	Equipment Training	1 day	Mon 9/11/17	Mon 9/11/17
48	2.3	Mixing	2 days	Tue 9/12/17	Wed 9/13/17
49	2.4	Sample Molding	2 days	Thu 9/14/17	Fri 9/15/17
4:	2.5	Curing	28 days	Mon 9/18/17	Wed 10/25/17
4;	2.6	Laboratory Maintenance	1 day	Mon 9/18/17	Mon 9/18/17
4<	**3.0**	**Data Collection**	**44 days**	**Mon 9/18/17**	**Thu 11/16/17**
53	3.1	Freeze-Thaw Cycles	39 days	Mon 9/18/17	Thu 11/9/17
54	3.2	Tensile and Compression Testing	23 days	Thu 9/28/17	Mon 10/30/17
55		50 Cycles	1 day	Mon 9/25/17	Mon 9/25/17
56		100 Cycles	1 day	Thu 10/5/17	Thu 10/5/17
57		150 Cycles	1 day	Mon 10/16/17	Mon 10/16/17
58		200 Cycles	1 day	Wed 10/25/17	Wed 10/25/17
59		250 Cycles	1 day	Mon 11/6/17	Mon 11/6/17
5:	**4.0**	**Data Analysis**	**58 days?**	**Tue 8/29/17**	**Thu 11/16/17**
5;	4.1	Result Assessment	2 days	Tue 11/7/17	Wed 11/8/17
5<	4.2	Statistical Analysis	3 days	Thu 11/9/17	Mon 11/13/17
63	**5.0**	**Project Management**	**58 days**	**Tue 8/29/17**	**Thu 11/16/17**
64	5.1	Supervising	54 days	Tue 8/29/17	Fri 11/10/17
65	**6.0**	**Presentation of Deliverables**	**3 days**	**Tue 11/14/17**	**Thu 11/16/17**
66	6.1	Assembly of Final Report	2 days	Tue 11/14/17	Wed 11/15/17
67	6.2	Assembly of Final Presentation	1 day	Thu 11/16/17	Thu 11/16/17
68	6.3	Website Development	1 day	Thu 11/16/17	Thu 11/16/17

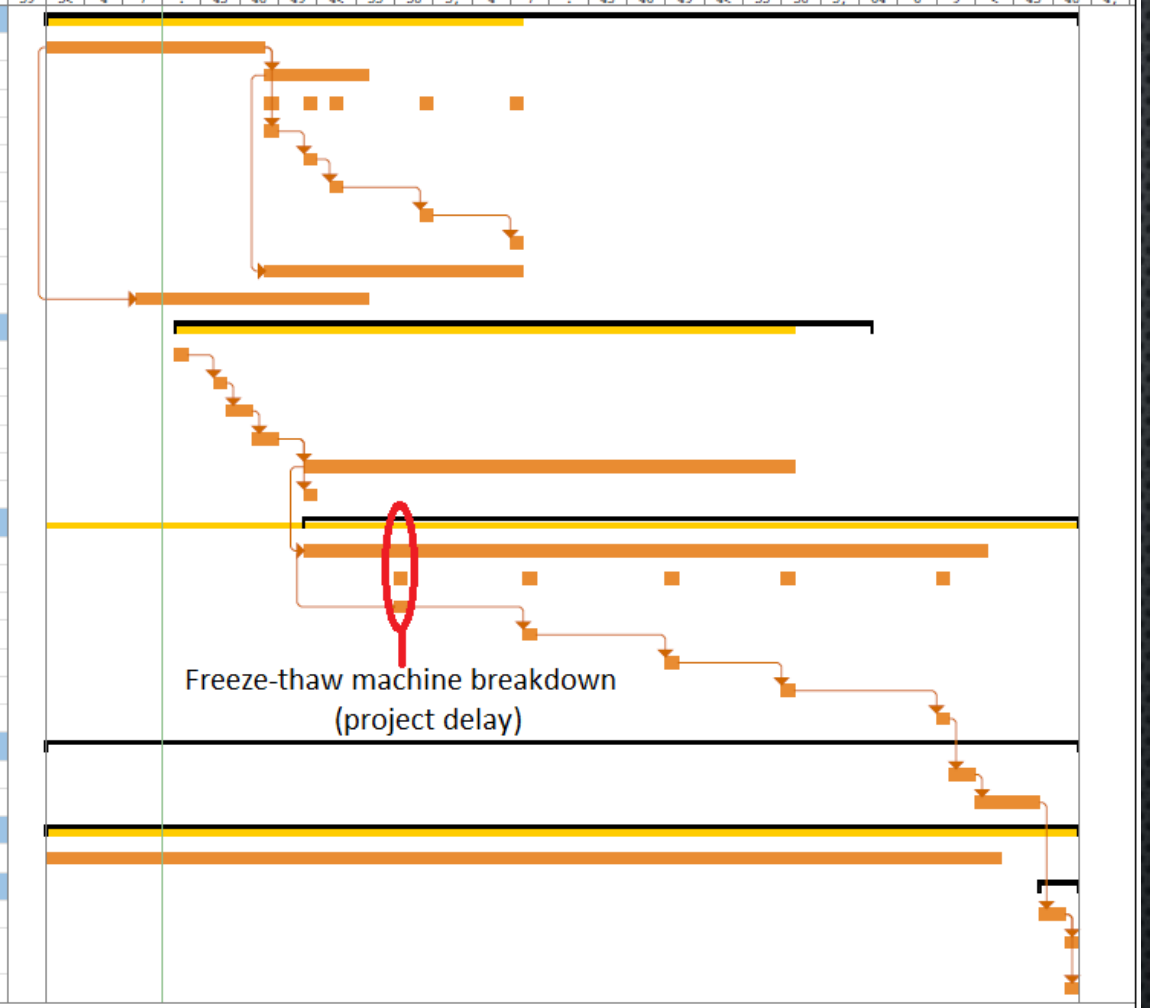

Figure 19: Gantt chart schedule with delays [21]

PROJECT CONTINUATION

- Continued by Dr. Ho & a Volunteer Grad Student
- Goals:
  - 300 cycles (one year) Tests
  - Publish Findings in an Academic Paper

Figure 22: Cold Region magazine cover [15]

Figure 23: Freeze-thaw machine cycling [16]

IMPACTS: SOCIAL & ENVIRONMENTAL

- Economics
  - Reduction Cost in repairs
  - Transportation of goods
- Social
  - Share analytical data for future research
  - Accessibility of Nearby Cities
    - Linking two cultures
- Environmental
  - Less carbon emissions
  - Reduces fuel usage

Figure 20: Chenani-Nashri tunnel connecting between Jammu and Srinagar [24]

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