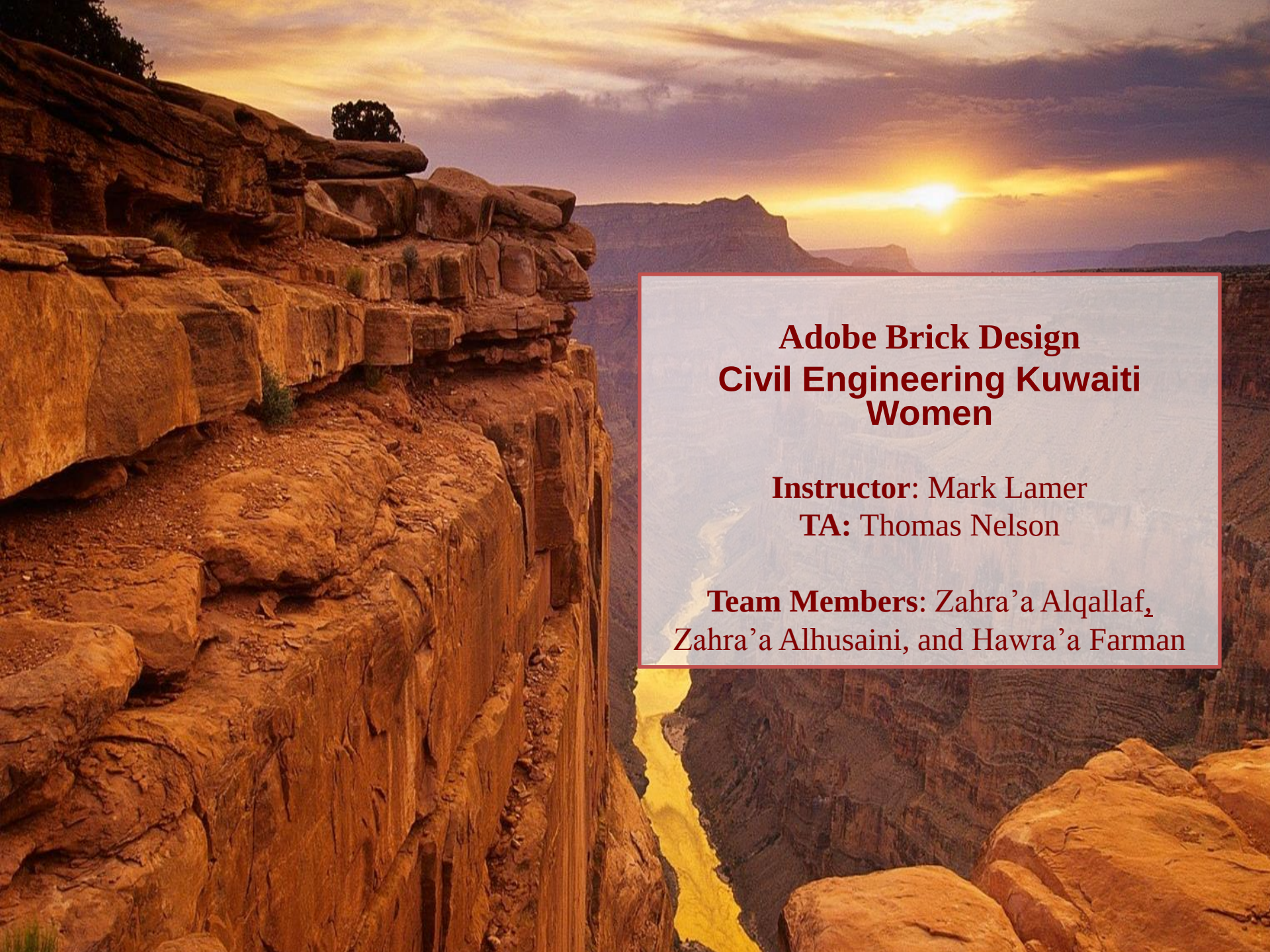

Adobe Brick Design
Civil Engineering Kuwaiti Women

Instructor: Mark Lamer
TA: Thomas Nelson

Team Members: Zahra'a Alqallaf, Zahra'a Alhusaini, and Hawra'a Farman

Introduction

Project Understanding:

- Adobe brick is defined as a brick that contains soil, cement, and water.
- Suitable adobe bricks will be developed for Coconino County through multiple soil soil and brick testing methods.
- The adobe brick's developed codes and qualifications will be compatible with Northern Arizona's environment.

The Adopted Codes:

Moister Content Test Modified ASTM (D2216)

Sieve Analysis Test Modified ASTM (D-421)

Liquid and Plastic Limit Test Modified ASTM (D-4318)

Water Absorption Test Modified ASTM (D-570)

Compressive Strength Test Modified ASTM (D-2166)

Main Stake Holders

- Coconino County
- Clients: Mark Lamer, Thomas Nelson

***Fig1**: Mr. Thomas Nelson*
www.nau.edu

***Fig 2**: Mr. Mark Lamer*
www.nau.edu

***Fig 3:** Coconino County*
www.CoconinoCounty.org

Soil Collection Process

- **Strategy:**
  - Obtain the soil after digging one feet deep

- **Locations:**
  - Ponderosa Park
  - Grass
  - Juniper Forest
  - Floodplain

***Fig 4**: Digging process*

***Fig 5**: Shovel*

***Fig 6**: Bucket*

Task 1. Soil Analysis

- The team performed multiple soil tests on the obtained soil samples. Theses tests include the Moisture Content test, Atterberge Limits test that includes the Liquid and Plastic Limit test, and finally Sieve Analysis test.

- The goal was to utilize the test results in classifying the soil and determining whether the obtained soil falls in the provided range of United States standard soil type for adobe brick design.

Fig 7: *Dry soil in the Moisture Can*

Task 1.1 Sieve Analysis

- The goal was to create one sieve analysis graph for all obtained soil samples, and utilize that graph to classify the soil using both USCS and USDA soil classification methods.
- Code: Modified ASTM (D-421)

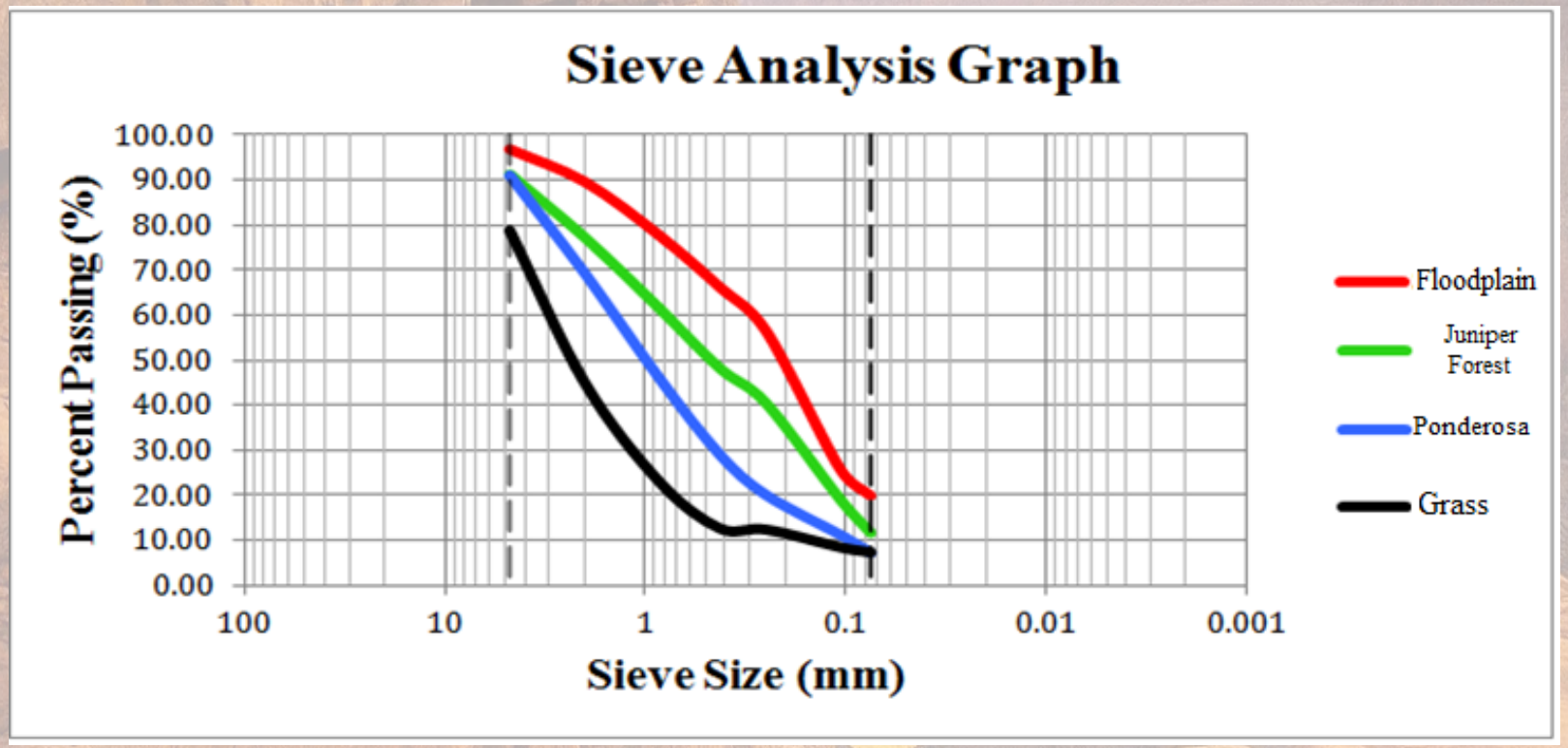

***Fig 8**: Sieve Analysis Graph*

Task 1.1 Sieve Analysis

USCS Soil Classification

Table 1. United Soil Classification System (USCS) Data

United Soil Classification System										
Soil Type	%Finer	%Gravel	%Sand	D10	D30	D60	Cc	Cu	USCS Symbol	USCS Classification
Floodplain	11.64	8.69	79.67	0	0.18	0.8	no value	no value	SW-SM	Well Graded Sand and Silt
Juniper Forest	7.19	8.966	83.842	0.1	0.46	1.5	1.41	15	SW-SM	Well Graded Sand and Silt
Ponderosa Park	7.33	21.21	71.46	0.2	1.2	3	2.4	15	SW-SM	Well Graded Sand and Silt
Grass	19.89	3.16	76.95	0	0.13	0.3	no value	no value	SM	Sand and Silt

Task 1.1 Sieve Analysis

Equations Required For The Sieve Analysis

- ***The uniformity coefficient (Cu):***

$$(\mathrm{Cu}) = (D_{60}/D_{10})$$

- ***The coefficient of gradation*** *(Cc):*

$$(\mathrm{Cc}) = (D_{30}{}^{2})/(D_{60} * D_{10})$$

Where,

D_{10} *= Diameter corresponding to 10% finer*

D_{30} *= Diameter corresponding to 30% finer*

D_{60} *= Diameter corresponding to 60% finer*

Task 1.1 Sieve Analysis

Soil Classification Data

Table 2. USCS and USDA Soil classification data for each sample.

Soil Type	USCS Classification	USDA Classification	Comments
Floodplain	Well Graded Sand and Silt (SW-SM)	Loamy Sand	It fits the range of standard soil type for adobe brick design.
Juniper Forest	Well Graded Sand and Silt (SW-SM)	Loamy Sand	It fits the range of standard soil type for adobe brick design.
Ponderosa Park	Well Graded Sand and Silt (SW-SM)	Sandy Clay Loam	It doesn't fit the range of standard soil type for adobe brick design.
Grass	Sand and Silt (SM)	Loamy Sand	It fits the range of standard soil type for adobe brick design.

Table 3. United States Standard Soil Type for Adobe Brick Design.

Standard Soil Type For Adobe Brick			
Soil type	Sand	Clay	Silt
Loamy sand	70% - 85%	0% - 15%	0% - 30%
Sandy loam	50% - 70%	15% - 20%	0% - 30%
Sandy clay loam	50% - 70%	20% - 30%	0% - 30%

Task 2. Brick Development Process

Task 2.1 Designing Wood Form

Equipment:

- Three 8ft. long, (2” X 4”) wood
- Wood glue
- 1 lb. (2.5”) Nail box
- Drill
- Wood cutting Device

Brick Samples’ Dimensions:

- Brick sample were 4”x4”x4”
- 4”x4”x4” dimensions were chosen to have multiple samples for testing and for cost efficiency.

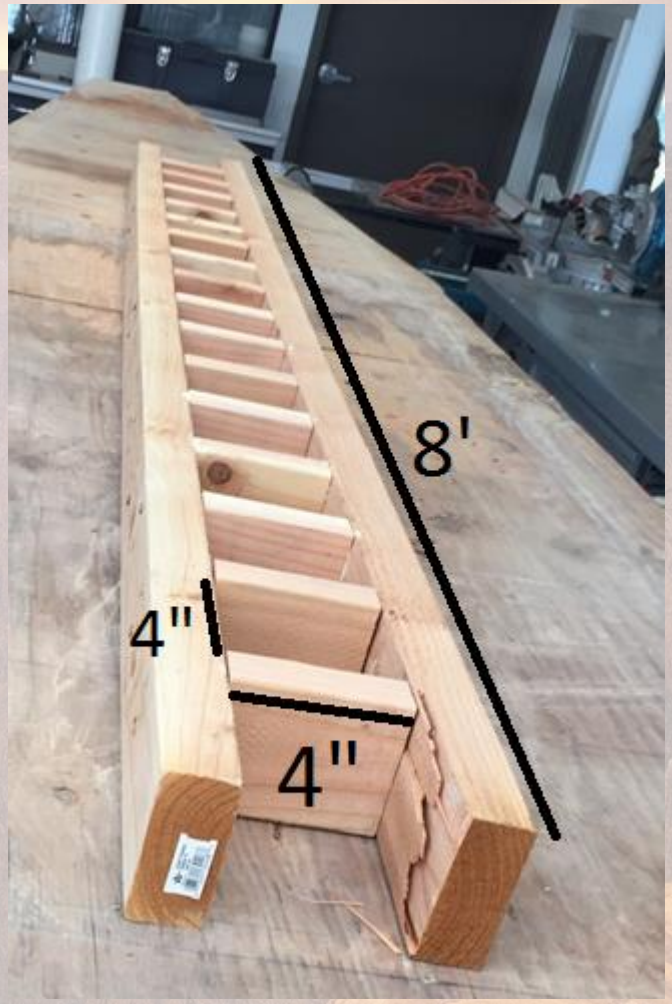

Fig 9: *Wood Form*

Task 2.2 Cement Analysis

- The team used Portland cement only.
- The team used varying percentages of cement when designing the adobe brick samples as seen in **Table 4**.

Table 4. The Percentage of Materials used to Design the Brick Samples

	Cement	Water	Soil
Trial 1	12%	18%	70%
Trial 2	9%	24%	67%
Trial 3	18%	24%	58%

- Adobe brick sample's strength was tested to determine the suitable amount of cement, water, and soil that will guarantee maximum strength in the final adobe brick design.

Task 2.3 Brick Sample design

Task 2.3.1 United States Standard Adobe brick Building Code Requirements:

- The clay content of the soil used in producing adobe bricks must be greater than 25% and less than 45%.
- Bricks shall not have more than three shrinkage cracks. No shrinkage crack shall exceed 3 inches in length.
- The minimum compressive strength acceptable for a 4”x8”x16” brick that weighs 28 pounds should be 300 psi.

Task 2.3 Brick Sample design

Task 2.3.2 preparing the soil for designing the adobe brick samples

- Obtain more soil
- Leaved it to dry
- Pass (3/8) sieve
- The process was done in the geotechnical Engineering lab
- The process was conducted on three different soil samples (Floodplain, Juniper, Grass)

Brick Molding Consideration:

- Start small—until you learn the right blend
- Use soils with high sand and low clay content
- The bricks will erode easily in wet weather

***Fig 10**: Cleaning the obtained soil*

Task 2.3 Brick Sample design

Task 2.3.3 Developing brick samples containing water and soil only

- Measured the appropriate percentage of soil or water
- Place the soil with the water in a bucket and start mixing
- Wash the form then fill it with the mixture
- Compress the mixture in the form and strike the edge.
- This procedure shall be repeated several times to have a good amount of brick samples for testing.
- Remove the samples after 24 hours and place in clean dry location.

Fig 11: *Mixing soil and water*

Fig 12: *filling the form with the mixture*

Fig 13: *place brick samples in dry location*

Task 2.3: Brick Sample design

Task 2.3.4 Developing brick samples containing water, soil, and Portland cement

- Measured the appropriate percentage of soil, water, and cement based on **Table 4**
- Mixing the soil, cement, and water in a bucket
- Wash the form then fill it with the mixture
- Compress the mixture in the form and strike the edge
- This procedure shall be repeated several times to have a good amount of bricks samples for testing.
- Wait for approximately 30 min then remove the bricks from the form
- Place the bricks on a dry surface and leave it to dry for three weeks.

Fig 14: *Mixing soil, water, and cement*

Fig 15: *filling the form with the mixture*

Fig 16: *Creating multiple samples*

Task 3 Brick Testing

- Brick Testing
  - Water Absorption
  - Compressive Strength Test
  - Structure Test
  - Size, Shape, and Color
  - Hardness and Soundness

Fig 17: *Compressive Strength Test*

Fig 18: *Structure Test*

Task 3.1 Hardness and Soundness Test

Hardness Test:

- This test is conducted by scratching the brick's surface using a nail and observing the results.
- If the scratch leaves a significant mark that means it's a poor quality bricks and it's not hard enough.

Table 5. Hardness Test Results

Hardness Test			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	Good Quality	Good Quality	Good Quality
Juniper Forest Soil	Good Quality	Bad Quality	Good Quality
Grass	Good Quality	Good Quality	Good Quality

- From the Hardness test, **Juniper forest** had the worst soil quality.

Task 3.1 Hardness and Soundness Test

Soundness Test:

- This test is conducted by beating two bricks with one another.
- If the bricks give a strong metallic sound without shattering then those are good quality bricks.

Table 6. Soundness Test Results

Soundness Test			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	Bad Quality	Good Quality	Bad Quality
Juniper Forest	Good Quality	Bad Quality	Bad Quality
Grass	Good Quality	Good Quality	Bad Quality

- From the Soundness test, **Grass** had the best soil quality.

Task 3.2 Size, Shape, and Color Test

- The purpose of this test is to verify the uniformity of the brick samples per trial
- This test is conducted by staking the bricks along lengthwise, widthwise and height wise at the end of each trial to :
  - Measures the variation of brick sizes per trial.
  - Verify that all brick edges are sharp.
  - Verify that the colors of the bricks are uniform per trial.

Table 7. Size, Shape, and Color Test Results

Size, Shape, and Color Test a			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	Good Quality	Bad Quality	Good Quality
Juniper Forest Soil	Bad Quality	Good Quality	Good Quality
Grass	Good Quality	Bad Quality	Good Quality

Task 3.3 Compressive Strength Test

- This test is done to determine the compressive strength of the brick.
- Modified standard method of ASTM (D-2166)

Table 8. Compression Test Results

Compressive Strength (psi)			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	0.49	1.94	3.33
Juniper Forest Soil	0.66	2.07	2.73
Grass	0.56	2.54	3.13

- From the Compressive test, 3.33 psi was the maximum load of the brick before shattering

Fig 19: *Compressive Strength Test Machine*

Task 3.4 Structure Test

- In this test the broken bricks from the compression test are obtained and are closely observed
- If flows, cracks, or holes appeared on the broken face then the brick is considered bad quality

Table 9. Structure Test Results

Structure Test			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	Bad Quality	Good Quality	Bad Quality
Juniper Forest Soil	Good Quality	Good Quality	Good Quality
Grass	Good Quality	Good Quality	Good Quality

- From the Structure test, **Floodplain** had the worst soil quality.

Fig 20: *Compressive Strength Test Machine*

Task 3.5 Water Absorption Test

- This test is conducted by weighing the dry brick samples, then re-weighing the brick samples after immersing them in water for 24 hours.
- The difference between weights is the absorbed amount of water by the bricks.

Table 10. Water Absorption Test Results

Water Absorption (%)			
Soil Type	**12%** Cement	**9%**Cement	**18%**Cement
Floodplain	19.9%	19.35%	23.39%
Juniper Forest Soil	15.76%	23.04%	20.77%
Grass	15.05%	17.13%	20.17%

Conclusion:

◎ The best quality soil was found to be grassy soil for a 4inx4inx4in adobe brick that weighs 4 lb. with a maximum compressive strength of 3.13 psi

Table 11. Comparison Between Grass Soil Adobe Brick Results and US Standard adobe brick

	Brick Dimensions	Volume (in^3)	Weight (lb.)	Compression Strength (psi)
US Standard Adobe Brick	4”x8”x16”	512	28	300
Grass Soil Adobe Brick	4”x4”x4”	64	4	3.13

Table 12. The Recommended Adobe Brick Characteristics

	Percentage	Soil Type
Soil	58%	Grass
Cement	18%	
Water	24%	

Cost Analysis

Table 13. Hours Spent in Conducting each Task pertaining the Project

Task	Hours
Preparatory Research	24
Background Research	8
Professional Consultation	30
Soil analysis	60
Cement Analysis	40
Soil And Brick Testing	30
Project Management	90
Construction Process	60
Team Meetings	40
Total Hours	314

Table 14. Staffing Cost

Classification	Hours	Pay Rate/ Hour	Cost $
Senior Engineer	72	95	6840
Engineer	113	55	6215
Lab Technician	58	30	1740
Administrative Assistance	23	25	575
Total Cost			15,370

Table 15. Hours Spent on the Project per Team Member

Role	Name	Hours
Team Leader	Zahraa Alqallaf	107
Design Specialist	Zahraa Alhusaini	102
Team Supervisor	Hawra'a Farman	105

Cost Analysis

Table 16. Equipment's Cost

Equipment's Cost		
equipmnet name	quantity	Cost $
8ft. (2” X 4”) wood.	3	18
wood glue	1	4
(2.5”) Nail box.	1lb	3
Drill	2	190
Sliding Table Saw	1	2,970
Cutoff Saw	1	900
Cement Bag	900 lb	12
Total Cost		4,097

Total Project Cost = Total Staffing Cost + Total Equipment's Cost

**19,467$** = 15,370$ + 4,097$

Acknowledgment

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- Instructor Wilbert Odem – P.E.
- Instructor Thomas Nelson – Technical Advisor
- Gerjen Slim – Lab Instructor and Lab Manager
- Junyi Shan- Technical Advisor

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Any Questions ?