ARCHITECTURE 324
Structures II

Recitation 12

Sections 04&05

Instructor
Peter von Buelow

GSI
Alireza Fazel

April 18, 2025

Contents

Tower project (April 22)

Architecture 324
Structures II

Prof. Peter von Buelow
Winter 2025

Tower Project

Description

This project gives students the chance to apply concepts learned in column analysis to the design of a structural system that carries primarily a compression load – a tower. Work is to be done in groups of up to four people. The project is divided into 3 parts: 1) initial conceptual design, 2) design development and testing, 3) final analysis and documentation.

Goals

- to explore design parameters of geometry and material under compression.
- to develop a design of a compression member to meet the criteria below.
- to make some rough hand calculation to estimate the expected performance.
- to test the compression member and record the results.
- to document the results in a well organized and clear report format.

Criteria

- The tower is to be made of wood. Either linear wood (sticks) or wood panels (sheets) can be used. Glue can be used to connect the elements. Gusset plates at the joints are allowed and can also be glued. But **no steel pins** or fasteners may be used.
- Wood: **any species**. **maximum cross-sectional dimension = 1/4".**
- **NO** paper, mylar or plastic or string or dental floss.
- If a member is made by laminating multiple pieces together, the maximum cross-sectional dimension or thickness still cannot exceed 1/4".
- The **height of the tower = 48"**.
- The tower **must hold at least 50 lbs**.
- The entire tower **can weigh no more than 4 oz**.
- The top of the tower must be loadable. The weights will be stacked on top of the tower, but you may optionally use a loose piece of MDF or plywood as a tray under the weights. (It will not be counted in either weight or load)
- Towers will be graded on their low weight, high load-carrying capacity, and the load/weight ratio. The evaluation formula is:

  (4/weight in OZ) + (load in LBS/50) + (load LBS/weight OZ)x1.5
- The score will be normalized to a range of 50 to 100. It is used together with report scores to assess your project (a detailed evaluation form is given separately).

Procedure

1. Develop a structural concept for a tower meeting the above criteria.
2. Analyze the design concept with **either** hand calculations or a computer program (e.g. Dr. Frame)
3. Determine the capacity of the major members and of the overall tower (total capacity in LBS)
4. Estimate your expected score using the formula above.
5. Write the preliminary report.
6. Construct the structural model.
7. Test the model. 5-pound steel bars will be placed on top of the model, until the model fails. (bar size: 1 ½" x 2" x 5 13/16").
8. Produce final report documenting requirements and process. See also score sheet.

Due Dates
See Course Schedule

Scoring	
Preliminary Report	40 pts
Testing	60 pts
Final Report	150 pts

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Guidelines for Final Report

After tower testing is over and you begin to write the final reports, here are some guidelines to follow.

1. **Clarity of calculations**: Don't just show numbers but give equations and define variables. Make it legible. Either very neatly by hand or use an equation editor like in Microsoft Word. In Word, go to Insert->Object and select Microsoft Equation. In just a few minutes you should be able to get a hang of producing equations. It's pretty simple to use. If you use Excel make sure you label the equations – don't just show results.

2. **Quality of graphics**. You should have clear line-drawings from programs such as Illustrator, AutoCAD, or similar to produce dimensioned drawings of your models. If using Rhino, use the Make2D function to get clear illustrations. Photographs of your final model before and/or after testing will be required in addition to your drawings.

3. **Submit reports on 8-1/2" x 11" paper only**. Reports on 11x17 paper will not be accepted.

4. **Be clean, polished, and professional.** Write clearly, legibly, and with good grammar. Proofread your report before turning it in. Use appropriate professional language in your report. The mark of a good report is one that is easy to understand by someone not familiar with the project.

5. **Turn in the ORIGINAL graded copy of your Preliminary Report with your Final Report.**

6. In the Revised/Tested Tower section of the Final Report (as listed on the Tower Project Tally Sheet - Final Report Requirements), do all the listed calculations for your tower as tested. That is, you should be analyzing the tower that you actually built and tested. This is not a reiteration of the Preliminary Report. We expect that certain changes were made from the preliminary design in your final design.

7. In calculating the overall tower bucking (buckling of whole tower as opposed to individual member buckling), you should use the Moment of Inertia (I) for the tower as a whole. I is taken from the tower cross-section ignoring any cross bracing (only primary vertical members). Using that value for I, you then apply the Euler Bucking Equation, using K = 1.0 (this assumes the mass of the load has an inertial force that holds the top in place at the moment of buckling).

8. Mechanical properties for basswood, are given on the preliminary requirements sheet. If you used materials other than basswood, show what values you used for E, F and density. Cite your sources.

9. Throughout your report, check that your numbers are reasonable. If you get, for example, a predicted load capacity of 70 kips, you probably did something wrong.

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Structures II

Group____________________
Winter 2025

Tower Project Score Sheet

PRELIMINARY REPORT (re-submit with final report)	**40**	
TESTING	**60**	
Tower weight ≤ 4oz (15 pts); height = 48" (5 pts); holds ≥ 50 lbs (5 pts) Correct Materials (5 pts) (scaled if doesn't meet requirements)	30	
Efficiency (4/weight OZ)+(load LBS/50)+(load LBS/weight OZ)x1.5 (scaled based on class rank)	30	
FINAL REPORT REQUIREMENTS	**150**	
Preliminary Design Development	**20**	
How cross-sectional design of preliminary tower was chosen	4	
How elevation of preliminary tower was developed (e.g. bracing, taper, etc.)	4	
Why/how cross-section was or was not adjusted from preliminary report	4	
Why/how elevation of tower was or was not adjusted from preliminary report	4	
Discussion of how basic principles of columns supported these decisions	4	
Revised/Tested Tower Design Analysis [SHOW WORK AND UNITS!]	**50**	
Calculated/modeled axial forces and derivation of required member cross-sectional areas from axial forces (consider both crushing and buckling)	10	
Estimated weight calculation using actual member sizes used – include weight from members, glue, and gussets, etc.	7	
Member properties table: A, r, L, slenderness ratio (L/r), utilization ratio (actual load / allowable load)	7	
Indicate critical member (largest utilization ratio)	8	
Tower stability (as a whole) - buckling calculation	8	
Prediction of capacity of tower and mode of failure	10	
Illustration of Final/Tested Design	**20**	
Cross-section and elevations(s) of tower	5	
Perspective(s) or isometric of tower (no screenshots!)	5	
Overall dimensions labeled (height, width, etc.) with units	5	
Member sizes labeled (cross-sectional area, length of vertical members and cross-bracing) with units	5	
Testing Results	**30**	
Final weight and height of tower	6	
Tested capacity of tower	6	
Observations of testing (loading, any buckling observed, etc.)	6	
Description of mode of failure	6	
Images of failure	6	
Post-Testing Analysis	**30**	
Comparison of testing results with predicted capacity and modes of failure	10	
Discussion of discrepancies between results	10	
Suggested improvements for future designs with reasoning discussed	10	
FINAL GRADE	**250**	

(Note: re-submit your Preliminary Design Proposal with your Final Report.)

Tower project (April 22)

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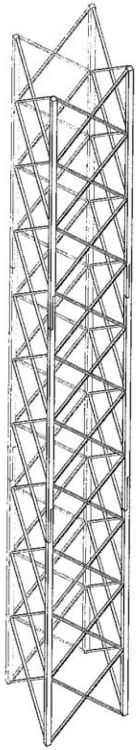
Tower Project:
Final Report

59/60



Paul Ligeti & Yinying Chen
"Tower Group"
Structures II
03/28/2016

Testing Results/Post-Testing Analysis

Final weight of tower: 4.1 oz +2
Final height of tower: 50 in
Tested capacity of tower: 230 lbs +2

The tower continued to hold steady and stand up straight until the 200-pound mark. We had been placing weights on the tower in pairs (so 10 pounds at a time), and right before we got the tower to 230 pounds, it began to lean towards the bench, to the right (facing the bench from the camera). After placing the final 10 pounds, the tower leaned significantly more and snapped - all within a very fast timeframe of less than half a second.

+2

As shown in the picture below (figures 5 and 6), the tower buckled outwards towards the left (facing the bench from the camera), and inwards on the right side. What likely happened is that the back right column bore more than 1/4 of the weight - perhaps due to brick placement, perhaps due to craft or material deficiencies - and snapped prematurely as a consequence - it had reached its critical buckling load (*not* critical crushing, as we had expected)! Once that column was broken, the rest inevitably fell because now *they* had to split the 230 pounds evenly, as well as deal with bending and twisting.

+4

More specifically, the column snapped at the intersection of one of the notched connections of the back right column. This makes it likely that the main reason for buckling was both craft and the inherent nature of our notched connection.

Fig. 5: Outward Buckling

+4

Fig. 6: Collapsing

Post-Testing Analysis

So why did we not meet our 848-lb goal? Due to the inevitable imperfections in craft, joints (both bracing and column notched connections), brick placement, material deficiencies (warping, knotting, etc.), and properties such as wood grain - which determine the integrity of the wood in certain axes - the tower did not hold the weight we expected. In fact, these properties make it incredibly likely that even under perfect environmental conditions - no humidity, a level ground, etc. - the 212 lb/column buckling capacity would have been impossible to achieve in any case.Rather, it held 230 pounds (which was still a significant amount, at 78% of the expected 296.56-lb crushing capacity)! In addition, these aforementioned factors, the tower ended up buckling, not crushing.

+2 +2

For future improvement, we could aim to make the aforementioned notched column connection stronger - either through a different methof of joining the three components of each column together, or additional support around the connection (such as a wrapping). Also the way the tower leaned suggests that there was an inbalance between the 4 columns, which caused one to bear more of the load. If we align all the columns better, it will carry more load.

+6

+20 bonus points

Complete your course and recitation evaluations for ARCH-324 to earn **20+ bonus points**! All you need to do is:

- **Finish both evaluations.**
- **Send me a quick screenshot of your completion confirmation.**

Email: arfazel@umich.edu

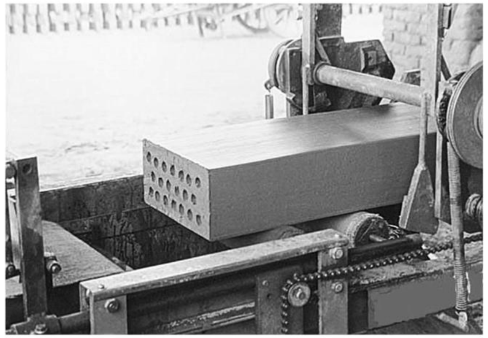
Brick

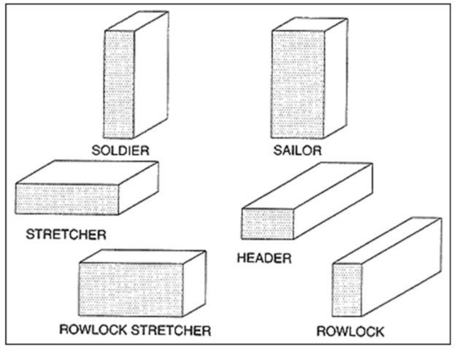
Clay Brick

- Molded
  or
- Extruded
- Cored – adds stability, strength
  cored < 25% > hollow
- Fired (2000° F)

- Sizes – use 3/8” mortar bed

- Six ways to position in wall:





3/8" Mortar Joint Between Bricks (Most Common)

BRICK TYPE	SPECIFIED SIZE D X H X L (INCHES)	NOMINAL SIZE D X H X L	VERTICAL COURSE
Standard	3 5/8 x 2 1/4 x 8	Not modular	3 courses = 8"
Modular	3 5/8 x 2 1/4 x 7 5/8	4 x 2 2/3 x 8	3 courses = 8"
Norman	3 5/8 x 2 1/4 x 11 5/8	4 x 2 2/3 x 12	3 courses = 8"
Roman	3 5/8 x 1 5/8 x 11 5/8	4 x 2 x 12	1 course = 2"
Jumbo	3 5/8 x 2 3/4 x 8	4 x 3 x 8	1 course = 3"
Economy	3 5/8 x 3 5/8 x 7 5/8	4 x 4 x 8	1 course = 4"
Engineer	3 5/8 x 2 13/16 x 7 5/8	4 x 3 1/5 x 8	5 courses = 16"
King	2 3/4 x 2 5/8 x 9 5/8	Not modular	5 courses = 16"
Queen	2 3/4 x 2 3/4 x 7 5/8	Not modular	5 courses = 16"
Utility	3 5/8 x 3 5/8 x 11 5/8	4 x 4 x 12	1 course = 4"

Clay Brick

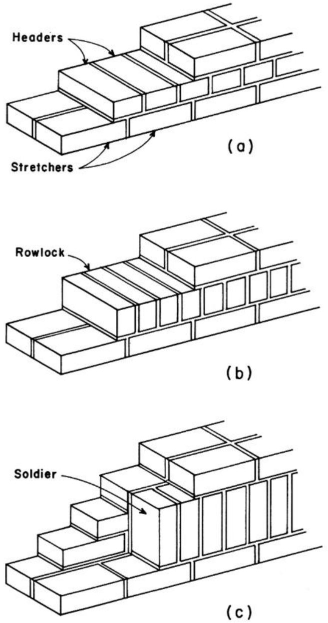
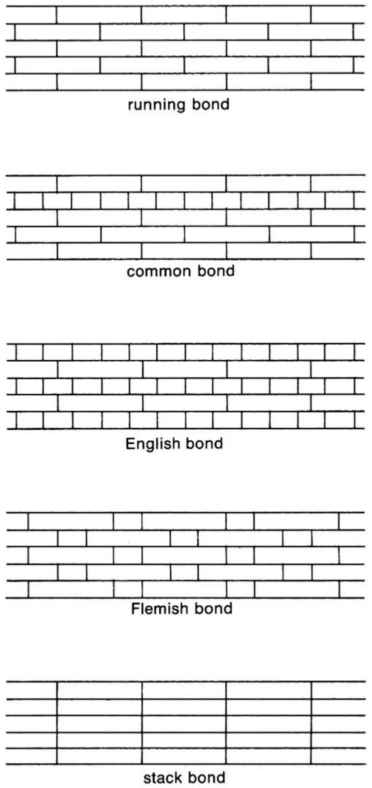


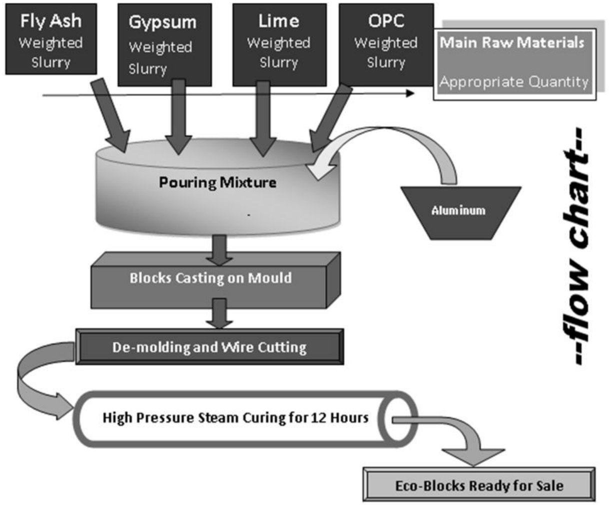
FIGURE 4.2. Ordinary positions for bricks.

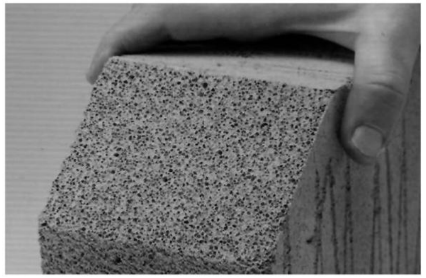


Concrete

Autoclaved Aeriated Concrete
(AAC)

Used predominately in Europe
Developed by Dr. Johan Axel Eriksson in
mid- 1920s in Sweden as “Ytong”
since 1943, Hebel blocks in Germany
Current largest production in China
Lighter weight
Better insulation value
Better fire resistance
Better moisture transmission
Larger blocks for faster erection
Can be shaped on site



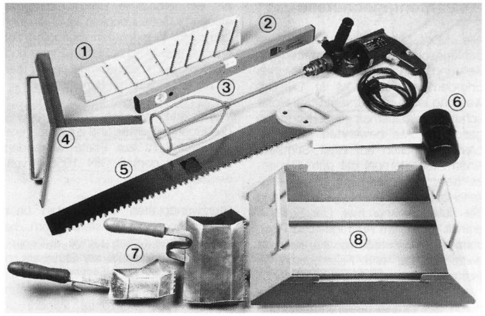


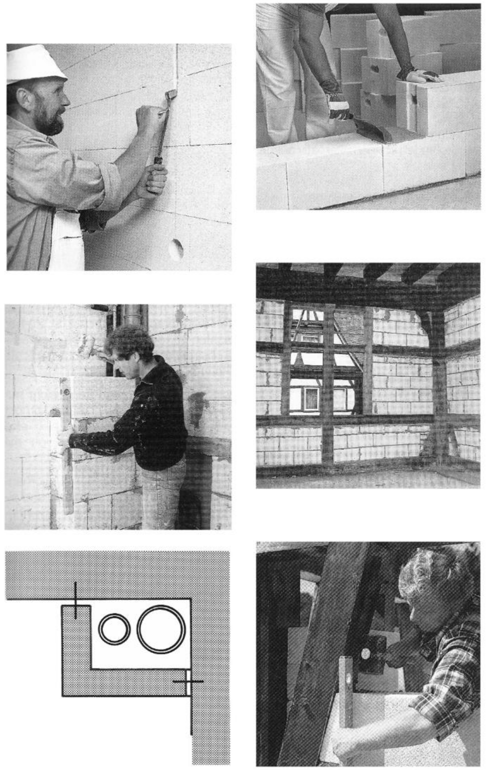
Autoclaved Aeriated Concrete
(AAC)

Easily shaped on site

Thin mortar bed – 1/8” (1mm to 3mm)

Tools for placement (below)





Mortar

Mortar Types

Type M, S, N, O

Slump is higher than cast concrete and based on workability

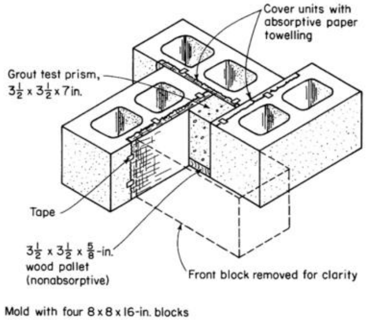


Fig. 2-29. ASTM C1019 method of using masonry units to form a prism for compression-testing of masonry grout.

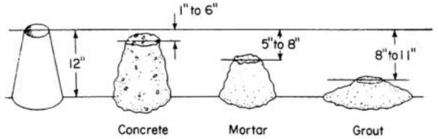


Fig. 2-27. Slump test comparison of concrete, mortar, and masonry grout.

Mortar Types

Types M, S, N, O

The following mortar designations took effect in the mid–1950's:

M a **S** o **N** w **O** r **K**

strongest weakest

Table 2-3. Guide to the Selection of Mortar Type*

Location	Building segment	Mortar type: Recommended	Mortar type: Alternative
Exterior, above grade	Load-bearing walls Non-load-bearing walls Parapet walls	N O** N	S or M N or S S
Exterior, at or below grade	Foundation walls, retaining walls, manholes, sewers, pavements, walks, and patios	S†	M or N†
Interior	Load-bearing walls Non-load-bearing partitions	N O	S or M N

*Adapted from ASTM C270. This table does not provide for specialized mortar uses, such as chimney, reinforced masonry, and acid-resistant mortars.

**Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated or unlikely to be subjected to high winds or other significant lateral loads. Type N or S mortar should be used in other cases.

†Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to weathering. Mortar for such masonry should be selected with due caution.

Note: For tuckpointing mortar, see "Tuckpointing," Chapter 9.

Relative Parts by Volume

mortar type	Portland cement	lime	sand
M	1	$\frac{1}{4}$	$3\frac{1}{2}$
S	1	$\frac{1}{2}$	$4\frac{1}{2}$
N	1	1	6
O	1	2	9

sum should equal 1/3 of sand volume
(assuming that sand has void ratio of 1 in 3)

Analysis and design

Analysis and Design

Empirical approach
- based on experience
- limits on lateral loading
- limits on height
- limits on eccentricity
- (basically, no flexure)
- non-reinforced

Rational approach
- based on Strength Design (LRFD)
- either reinforced or non-reinforced
- limited by strength

Rational Masonry Analysis

Procedure
Strength Design (LRFD) – **non-reinforced**

Rational Approach
for axial compression
using TMS 402 (2016)

Given: geometry, material
Find: axial compressive load capacity, Pn

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type (table)
2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B with HW problem pdf.)
3. Calculate radius of gyration, $r = \sqrt{I/A}$
4. Calculate h/r
5. Choose the axial strength equation, Pn:
   If $h/r < 99$ use TMS 402 eq.9-11
   If $h/r > 99$ use TMS 402 eq.9-12
6. Calculate øPn where ø for axial force = 0.90
7. Check that øPn is greater than Pu.

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80 A_n f'_m \left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

(Equation 9-12) for h/r > 99

$$P_n = 0.80\left[0.80 A_n f'_m \left(\frac{70r}{h}\right)^2\right]$$

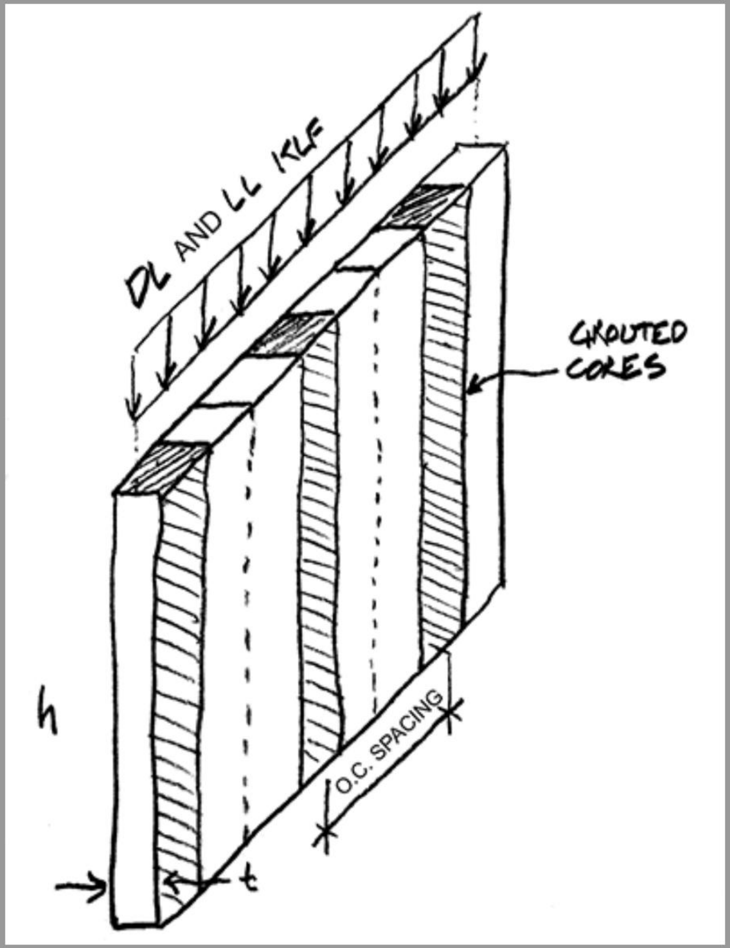
Problem Set 10

11. Masonry Walls

Using the strength method for axial compression (masonry spanning vertically) described in TMS 402, determine the safety of the given concrete masonry wall (pass or fail). Calculate the factored nominal axial strength, phi_Pn and compare it to the required strength, Pu for the given loads. (loads are given without factors)

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF



Problem Set 11

#Q1: Actual wall thickness, t (see TEK 14-1B)

11. Masonry Walls

Using the strength method for axial compression (masonry spanning vertically) described in TMS 402, determine the safety of the given concrete masonry wall (pass or fail). Calculate the factored nominal axial strength, phi_Pn and compare it to the required strength, Pu for the given loads. (loads are given without factors)

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF

$$t_{nominal} = 10 \text{ “}$$

$$\boldsymbol{t_{actual}} = 9\frac{5}{8} = 9.625 \text{ “}$$

NCMA TEK

acm CHEMISTRIES

National Concrete Masonry Association

an information series from the national authority on concrete masonry technology

SECTION PROPERTIES OF CONCRETE MASONRY WALLS

TEK 14-1B

Structural (2007)

Keywords: concrete masonry walls, engineered design, gross area, moment of inertia, net area, radius of gyration, reinforced concrete masonry, reinforced properties, section modulus, section properties, structural properties

INTRODUCTION

Engineered design of concrete masonry uses section properties to determine strength, stiffness and deflection characteristics. These design philosophies are summarized in *Allowable Stress Design of Concrete Masonry*, *Strength Design of Concrete Masonry* and *Post-Tensioned Concrete Masonry Wall Design* (refs. 1, 2, 3).

SECTION PROPERTIES

Tables 1 through 13 summarize section properties of grouted and ungrouted 4-, 6-, 8-, 10-, 12-, 14- and 16-in. (102-, 152-, 203-, 254-, 305-, 356- and 406-mm) wide concrete masonry walls, based on:

- standard unit dimensions are based on the minimum face shell and web thickness requirements of *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90-06 (ref. 4) as shown in Figure 1, except as noted in Tables 8 through 13. Note that prior to ASTM C 90-06, two minimum face shell thicknesses for units 10-in. (254-mm) and wider were specified. With the introduction of ASTM C 90-06, the two face shell thicknesses were replaced with one minimum thickness requirement (1¹/₄ in. (32 mm)). See Reference 5 for further information. Tables 10 through 13 can be used for section properties of units complying with previous

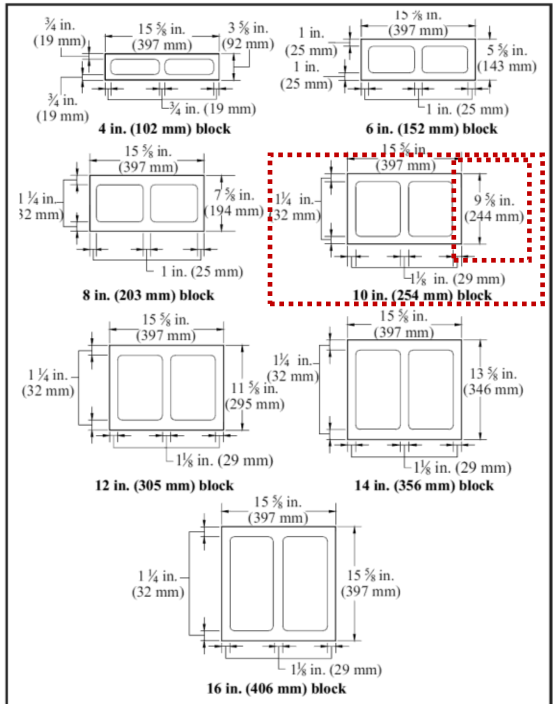


Figure 1—Specified Block Dimensions and Minimum Face Shell and Web Thicknesses (ref. 4)

Problem Set 11

#Q2: Net area per foot of wall, An
#Q3: Net moment of inertia per foot of wall, In

11. Masonry Walls

Using the strength method for axial compression (masonry spanning vertically) described in TMS 402, determine the safety of the given concrete masonry wall (pass or fail). Calculate the factored nominal axial strength, phi_Pn and compare it to the required strength, Pu for the given loads. (loads are given without factors)

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF

$$A_n = 59.8\ IN^2/ft$$

$$I_n = 656.2\ IN^4/ft$$

Table 4—10-inch (254-mm) Single Wythe Walls, $1^1/_4$ in. (32 mm) Face Shells (standard)

4a: Horizontal Section Properties (Masonry Spanning Vertically)

Unit	Grout spacing (in.)	Mortar bedding	Net cross-sectional properties[A] A_n (in.^{2}/ft)	I_n (in.^{4}/ft)	S_n (in.^{3}/ft)	Average cross-sectional properties[B] A_{avg} (in.^{2}/ft)	I_{avg} (in.^{4}/ft)	S_{avg} (in.^{3}/ft)	r_{avg} (in.)
Hollow	No grout	Face shell	30.0	530.0	110.1	48.0	606.3	126.0	3.55
Hollow	No grout	Full	48.0	606.3	126.0	48.0	606.3	126.0	3.55
100% solid/solidly grouted		Full	115.5	891.7	185.3	115.5	891.7	185.3	2.78
Hollow	16	Face shell	74.8	719.3	149.5	80.8	744.7	154.7	3.04
Hollow	24	Face shell	59.8	656.2	136.3	69.9	698.6	145.2	3.16
Hollow	32	Face shell	52.4	624.6	129.8	64.4	675.5	140.4	3.24
Hollow	40	Face shell	47.9	605.7	125.9	61.1	661.6	137.5	3.29
Hollow	48	Face shell	44.9	593.1	123.2	58.9	652.4	135.6	3.33
Hollow	72	Face shell	39.9	572.0	118.9	55.3	637.0	132.4	3.39
Hollow	96	Face shell	37.5	561.5	116.7	53.5	629.3	130.8	3.43
Hollow	120	Face shell	36.0	555.2	115.4	52.4	624.7	129.8	3.45

4b: Vertical Section Properties (Masonry Spanning Horizontally)

Unit	Grout spacing (in.)	Mortar bedding	A_n (in.^{2}/ft)	I_n (in.^{4}/ft)	S_n (in.^{3}/ft)	A_{avg} (in.^{2}/ft)	I_{avg} (in.^{4}/ft)	S_{avg} (in.^{3}/ft)	r_{avg} (in.)
Hollow	No grout	Face shell	30.0	530.0	110.1	46.3	597.4	124.1	3.59
Hollow	No grout	Full	30.0	530.0	110.1	48.0	606.3	126.0	3.55
100% solid/solidly grouted		Full	115.5	891.7	185.3	115.5	891.7	185.3	2.78
Hollow	16	Face shell	72.8	710.8	147.7	89.1	778.3	161.7	2.96
Hollow	24	Face shell	58.5	650.5	135.2	74.8	718.0	149.2	3.10
Hollow	32	Face shell	51.4	620.4	128.9	67.7	687.9	142.9	3.19
Hollow	40	Face shell	47.1	602.3	125.2	63.4	669.8	139.2	3.25
Hollow	48	Face shell	44.3	590.2	122.6	60.6	657.7	136.7	3.29
Hollow	96	Face shell	37.1	560.1	116.4	53.5	627.6	130.4	3.43
Hollow	120	Face shell	35.7	554.1	115.1	52.0	621.6	129.2	3.46

FOOTNOTES:

[A] Net cross-sectional properties determined from a vertical plane that coincides with the face shells of the units. Net cross-sectional properties are to be used for determining stress and strain resulting from the application of load.

[B] Average cross-sectional properties determined from two vertical planes calculated as the average of the net and solid properties. Average cross-sectional properties are to be used for determining stiffness and deflection of an element.

[C] Because of the small core size and resulting difficulty consolidating grout, 4-in. (102-mm) units are rarely grouted.

Problem Set 11

#Q4: Radius of gyration per foot of wall, r
#Q5: Ratio of h/r
#Q6: Which TMS equation used? (11 or 12)

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF

$$\boldsymbol{r} = \sqrt{\frac{I}{A}} = \sqrt{\frac{656.2}{59.8}} = \mathbf{3.31\ IN}$$

$$\frac{\boldsymbol{h}}{\boldsymbol{r}} = \frac{21\ FT\ \times 12}{3.31} = \mathbf{76.07}$$

$$76.07 < 99 \Rightarrow \mathbf{TMS\ 402\ eq.\,9-11}$$

Rational Masonry Analysis

Procedure
Strength Design (LRFD) – **non-reinforced**

Rational Approach
for axial compression
using TMS 402 (2016)

Given: geometry, material
Find: axial compressive load capacity, Pn

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type (table)
2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B with HW problem pdf.)
3. Calculate radius of gyration, $r = \sqrt{I/A}$
4. Calculate h/r
5. Choose the axial strength equation, Pn:
   If $h/r < 99$ use TMS 402 eq.9-11
   If $h/r > 99$ use TMS 402 eq.9-12
6. Calculate øPn where ø for axial force = 0.90
7. Check that øPn is greater than Pu.

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80 A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

(Equation 9-12) for h/r > 99

$$P_n = 0.80\left[0.80 A_n f'_m\left(\frac{70r}{h}\right)^2\right]$$

Problem Set 11

#Q7: Nominal axial strength, Pn
#Q8: Factored nominal axial strength, phi_Pn

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF

$$P_n = 0.8\left\{0.8A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

$$= 0.8\left\{0.8(59.8)\,1.5\left[1-\left(\frac{21\times 12}{140(3.31)}\right)^2\right]\right\}$$

$$= 40.43\ KLF$$

$$\varphi P_n = 0.9\times 40.43 = 36.38\ KLF$$

Rational Masonry Analysis

Procedure

Strength Design (LRFD) – **non-reinforced**

Rational Approach

for axial compression using TMS 402 (2016)

Given: geometry, material

Find: axial compressive load capacity, Pn

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type (table)
2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B with HW problem pdf.)
3. Calculate radius of gyration, $r = \sqrt{I/A}$
4. Calculate h/r
5. Choose the axial strength equation, Pn:
   If $h/r < 99$ use TMS 402 eq.9-11
   If $h/r > 99$ use TMS 402 eq.9-12
6. Calculate øPn where ø for axial force = 0.90
7. Check that øPn is greater than Pu.

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

(Equation 9-12) for h/r > 99

$$P_n = 0.80\left[0.80A_n f'_m\left(\frac{70r}{h}\right)^2\right]$$

Problem Set 11

#Q9: Axial strength required by loads, Pu
#Q10: Factored nominal axial strength, phi_Pn

DATASET: 1 -2- -3-

Height of wall, h	21 FT
Nominal thickness of wall	10 IN
grouted cells o.c. spacing	24 IN
Masonry compressive strength, f'm	1500 PSI
The wall DL	13 KLF
The wall LL	16 KLF

$$P_u = 1.2\,DL + 1.6LL$$
$$= 1.2\,(13) + 1.6(16)$$
$$= 41.2\ KLF$$

$$P_u = 41.2\,,\ \varphi P_n = 36.38$$

$$P_u > \varphi P_n \Rightarrow FAIL$$

Rational Masonry Analysis

Procedure
Strength Design (LRFD) – **non-reinforced**

Rational Approach
for axial compression
using TMS 402 (2016)

Given: geometry, material
Find: axial compressive load capacity, Pn

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type (table)
2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B with HW problem pdf.)
3. Calculate radius of gyration, $r = \sqrt{I/A}$
4. Calculate h/r
5. Choose the axial strength equation, Pn:
   If $h/r < 99$ use TMS 402 eq.9-11
   If $h/r > 99$ use TMS 402 eq.9-12
6. Calculate øPn where ø for axial force = 0.90
7. Check that øPn is greater than Pu.

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80 A_n f'_m \left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

(Equation 9-12) for h/r > 99

$$P_n = 0.80\left[0.80 A_n f'_m \left(\frac{70r}{h}\right)^2\right]$$

Lab09

Structures II — Name 1 ____________________

Arch 324 — Name 2 ____________________

Name 3 ____________________

Lateral Stability

Description

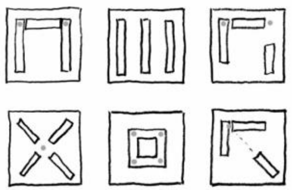
This project investigates stable arrangements of structural walls against lateral loading.

Goals

To observe the effects of lateral loading
To investigate the criteria of stable wall patters
To develop stable arrangements of shear walls based on the 2 point rule

Procedure

1. Arrange the small wood walls on the foam core base to support the MDF slab.
2. Make each of the six arrangements.
3. Apply lateral and torsional accelerations to the base and note the effects on the assembly. Mark on the diagrams below which fail and which remain stable.
4. Make your own stable and unstable arrangement.
5. Sketch the arrangements below and mark the intersection points.

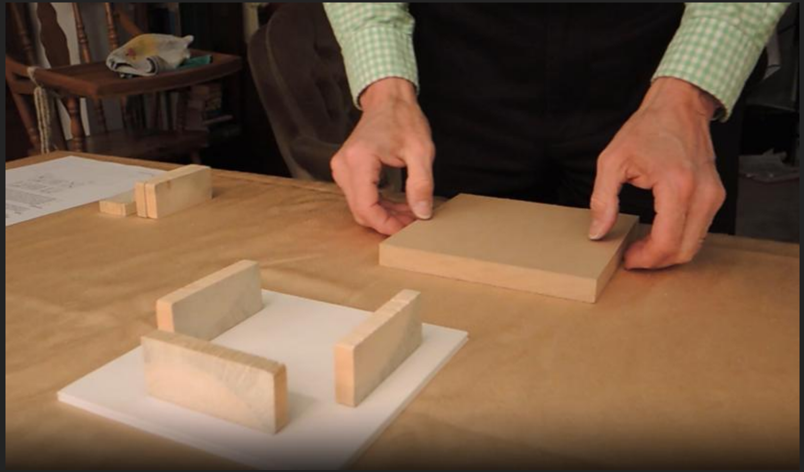


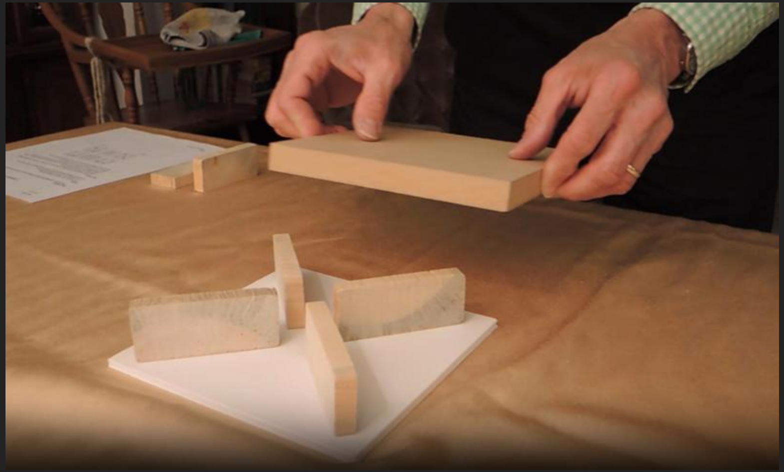
Stable

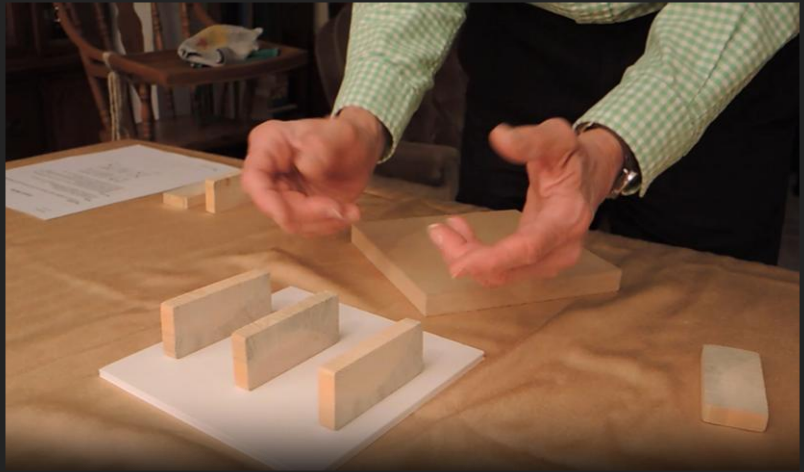
Unstable

Due

11 April 2021







Lab09

→ Group work instructions

Please form groups of 2 to 4 students.

Please do not forget to write all group members' names on both sheets.

Return the completed sheets to me at the end of the session.

Please ensure that you attend the recitation sessions.

If you are unable to attend a session, send me an email so that we can discuss how to proceed. *Email: arfazel@umich.edu*