ARCHITECTURAL STRUCTURE

Week 6: Masonry structure

Photo by Paul Rottmann on Unsplash

Outline

1
INTRODUCTION

Aims

LOs

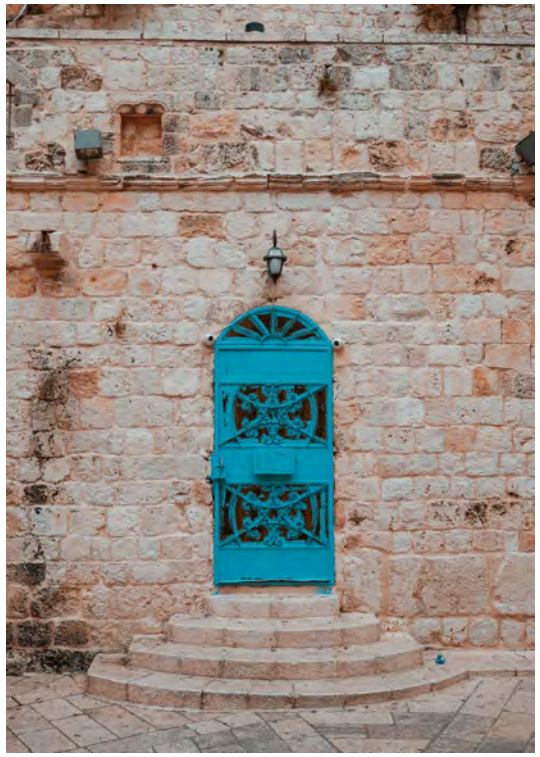
2
LECTURE:

- MASSONRY AS BUILDING MATERIAL
- ELEMENTS OF MASONRY STRUCTURE
- REINFORCED MASONRY

3
SEMINAR

- ONLINE REFLECTION
- GROUP 6 PRESENTATION
- Q&A

4
~~SUMMARY REFLECTION~~



A combination of student –led learning experience

LECTURE

The brief lecture to kickstart the discussion on concrete structure.

SEMINAR

Active learning through peer presentations, followed by Q&A session

Photo by Josh Appel and Anne Nygård on Unsplash

Aims and objectives

- To gain understanding on masonry as **building materials** and its characteristics
- To learn about masonry as main **structural materials**
- To expand on masonrywithin **construction system**

Learning outcomes

Students will be able to..

01 Understand strength and weaknesses of masonry as building materials

02 Potentially incorporate the use of masonry in future projects

03 Become aware of structural behaviour of the material

Part 1:

Masonry as building material system

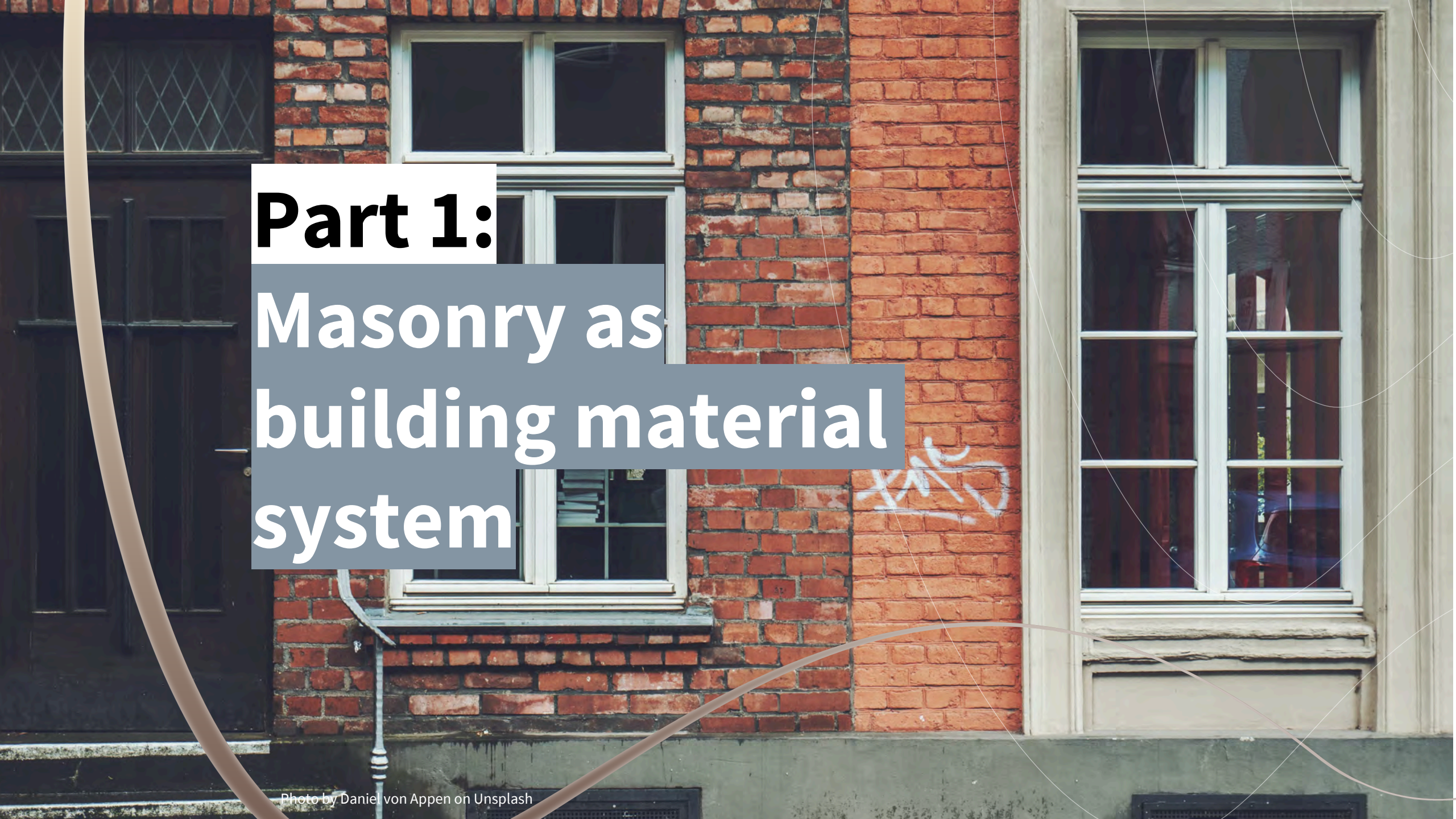
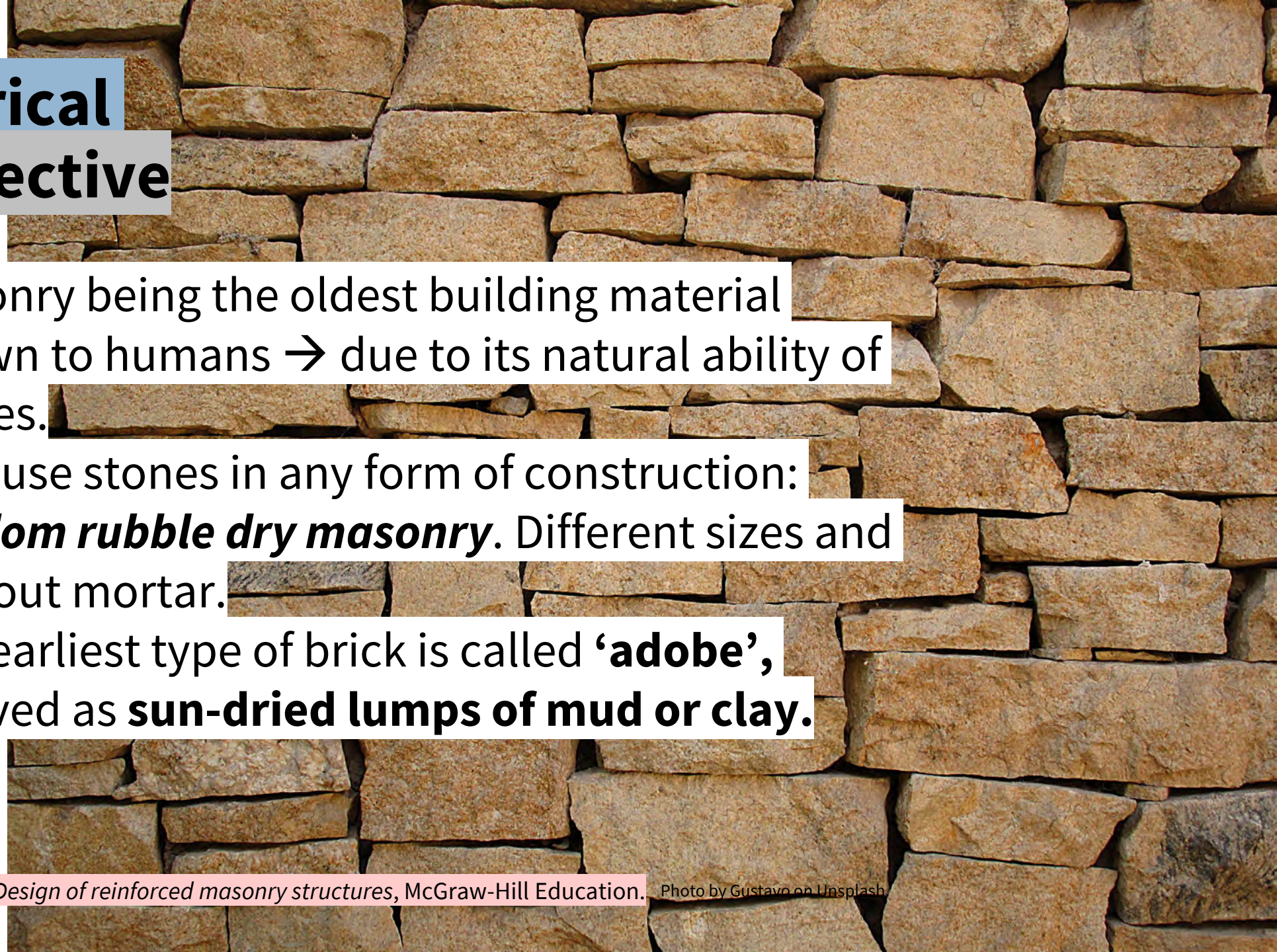


Photo by Daniel von Appen on Unsplash

Historical perspective

- Masonry being the oldest building material known to humans → due to its natural ability of stones.
- First use stones in any form of construction: ***random rubble dry masonry***. Different sizes and without mortar.
- The earliest type of brick is called **‘adobe’,** evolved as **sun-dried lumps of mud or clay.**



Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Photo by Gustavo on Unsplash

2) Traditional design: Discovery of agriculture in 8000 BC

Groups become geographically fixed.

Agriculture surpluses meant the needs to store them.

7500 BC: Catal Hüyük (Anatolia).
Mud-brick houses with plastered interior walls.
One of the early recorded urban settlement.

Historical perspective

- Hand-moulded **clay bricks** found in lower layer of Nile deposits date back as far as 14000BC.

- Earliest molded brick: in Mesopotamia in 5000BC
- **Fired brick** was invented in 3500BC. Firing gave the bricj quality of resilience which mud bricks lacked of.
- Fired brick in 3500BC revolutionised structural construction → the birth of permanent structure (all over the world).

Pfeifer, G., Pfeifer, G., Achtziger, J., Ramcke, R. & Zilch, K. (2001). *Masonry construction manual*, Birkhauser.
Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Historical perspective:

Great Wall of China

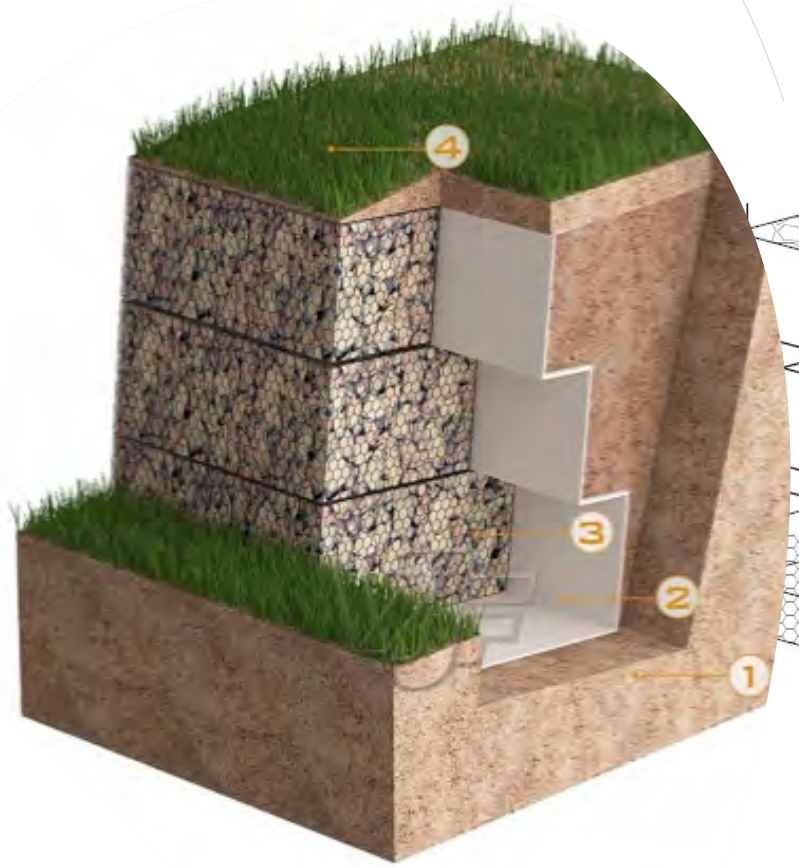
Historical perspective:

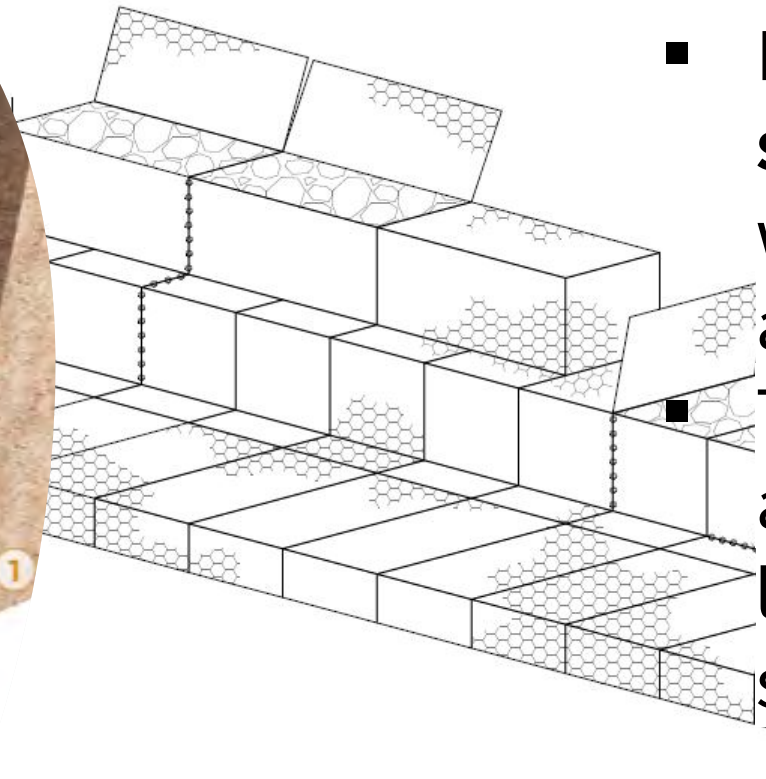
Hagia Sophia, Istanbul, Turkey

Photo by Rohan Reddy on Unsplash

Gabion wall

Gabion walls - function, application, advantage | Geotech





- Around 7000 years ago, early gabion type structure was used to protect bank of river in Nile.
- Mainly used for **soil stabilisation** behind the wall, but can also be used as a cover wall.
- The caged concept is now adapted in **contemporary landscape design,** as non structural element

Hacienda Sac Chich

What is masonry?

It is an **assemblage** of **individual units**, which may be of the same or different kind, which have been bonded together in some way perform intended function.

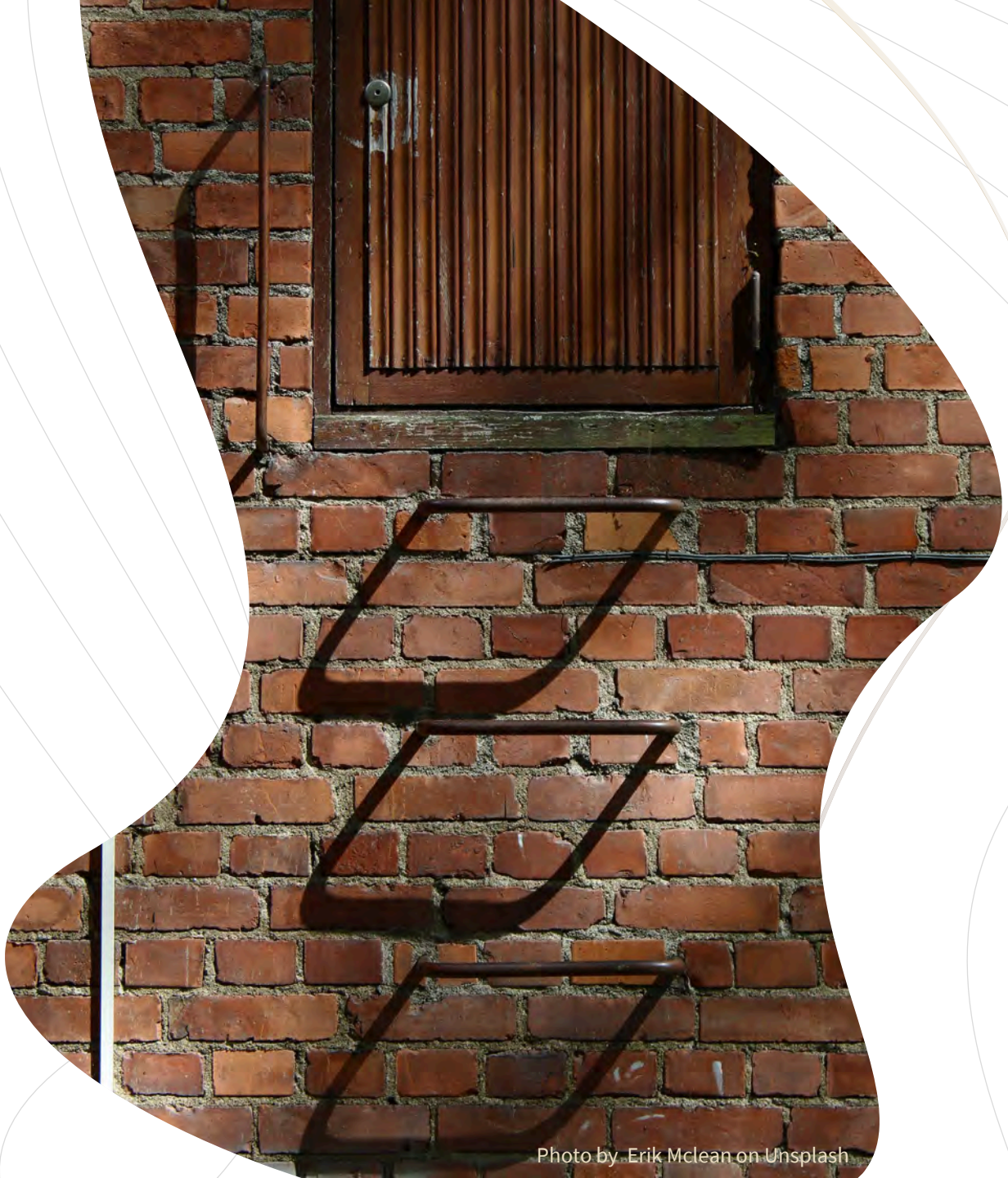


Photo by Erik Mclean on Unsplash

What is masonry?

- Generally refers to brick, tile, stone, concrete-block; usually bonded with mortar (although not always).
- **Unlike other materials** we have explored from Week 3, masonry **includes different materials** and types of **construction**.
- **Oldest building art practice** by humans

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Characteristics as building material

- Hardness
- Rigid and brittle
- Only supporting load in compression, does not do well in tension and shear
- Extremely fire retardant
- Excellent weather resistant
- Sustainability
- Versatile (drilling related etc)
- Mediocre thermal insulation
- With many hues and colours can create many attractive patterns

Types of masonry

- **Unreinforced masonry.**
  Has been around for centuries.
  Built to support only the gravity loads. Lateral forces from wind and earthquake were not included (due to the lack of basic knowledge of dynamic forces).
- **Reinforced masonry.**

Stone
Brick
Concrete

+

Mortar

+

Rules
of craft

Standard bricks and its faces

6 faces of brick:

- 2 bed faces
- 2 header faces
- 3 stretcher faces

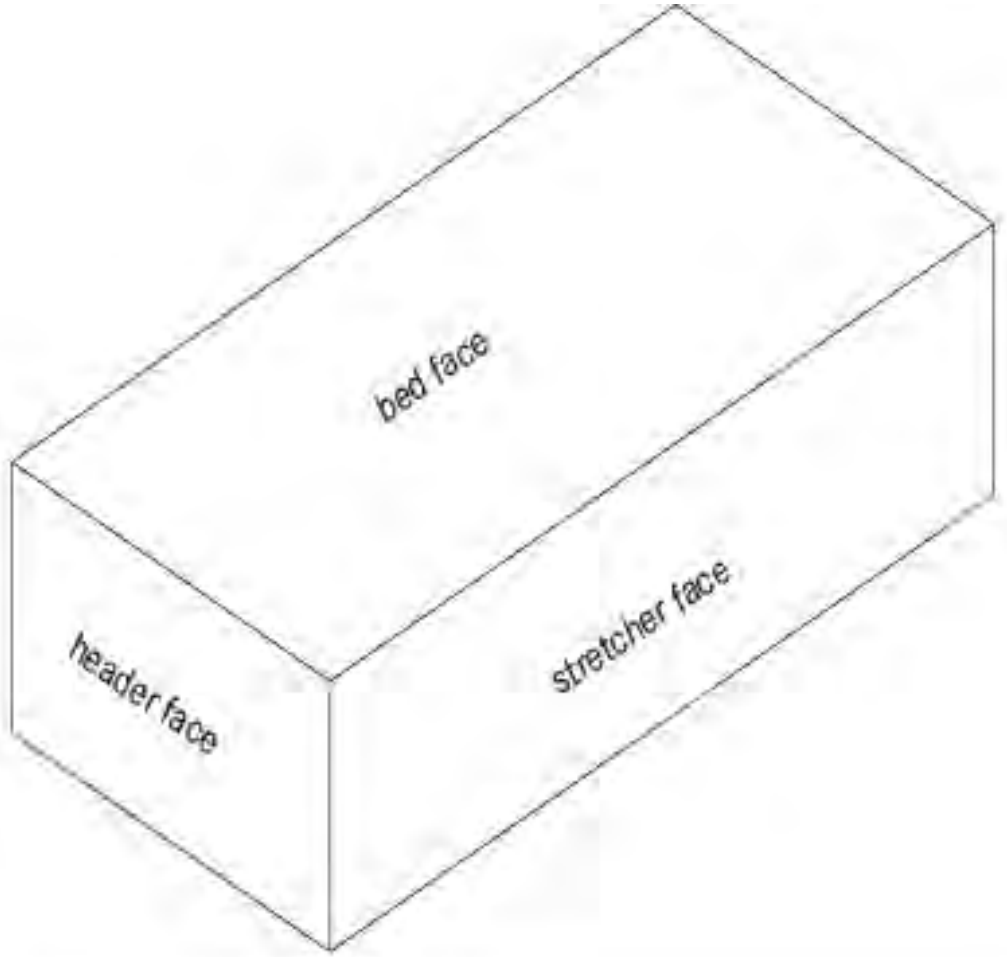
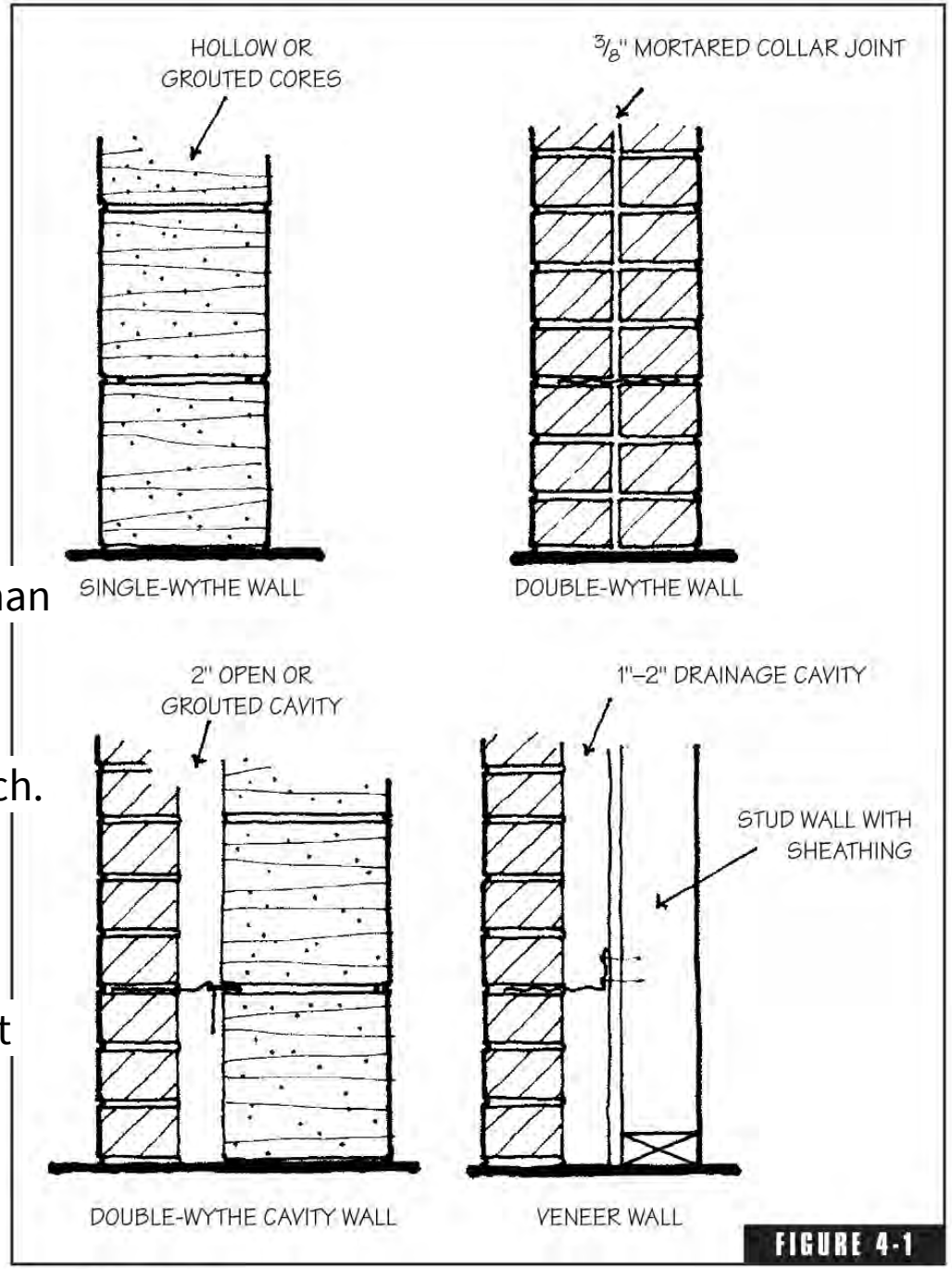


Fig. 1: Standard brick

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

Masonry wall types

- Single-wythe wall
  One unit in thickness and not anchored to backing
- Double-wythe wall
  Two units in thickness, if the space between is less than one inch, it s filled in with mortar or cement grout.
- Double-wythe cavity wall
  Two units in thickness, with space wider than one inch. It can be open gap or filled with grout or grout & reinforcing bars.
- Veneer wall
  It is non structural and support only their own weight while transferring wind loads to the backing wall.



Masonry wall types.

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Type 1:
Brick masonry

Size: 215mm (L) x 102.5mm (W) x 65mm(H)

Bulk delivery

Wienerberger Smooth Red Engineering brick (L)215mm (W)102.5mm (H)65mm

Buy a pallet of 504 and save £12.92. Discount applied at checkout.

★★☆☆☆ (2)

Bulk delivery

Wienerberger Mixed Facing brick (L)215mm (W)102.5mm (H)65mm

Buy a pallet of 430 and save £15.10. Discount applied at checkout.

★★★★★ (1)

£0.67

Bulk delivery

Wienerberger Harvest buff multi Heart Facing brick (L)215mm (W)102.5mm (H)65mm

Buy a pallet of 500 and save £17. Discount applied at checkout.

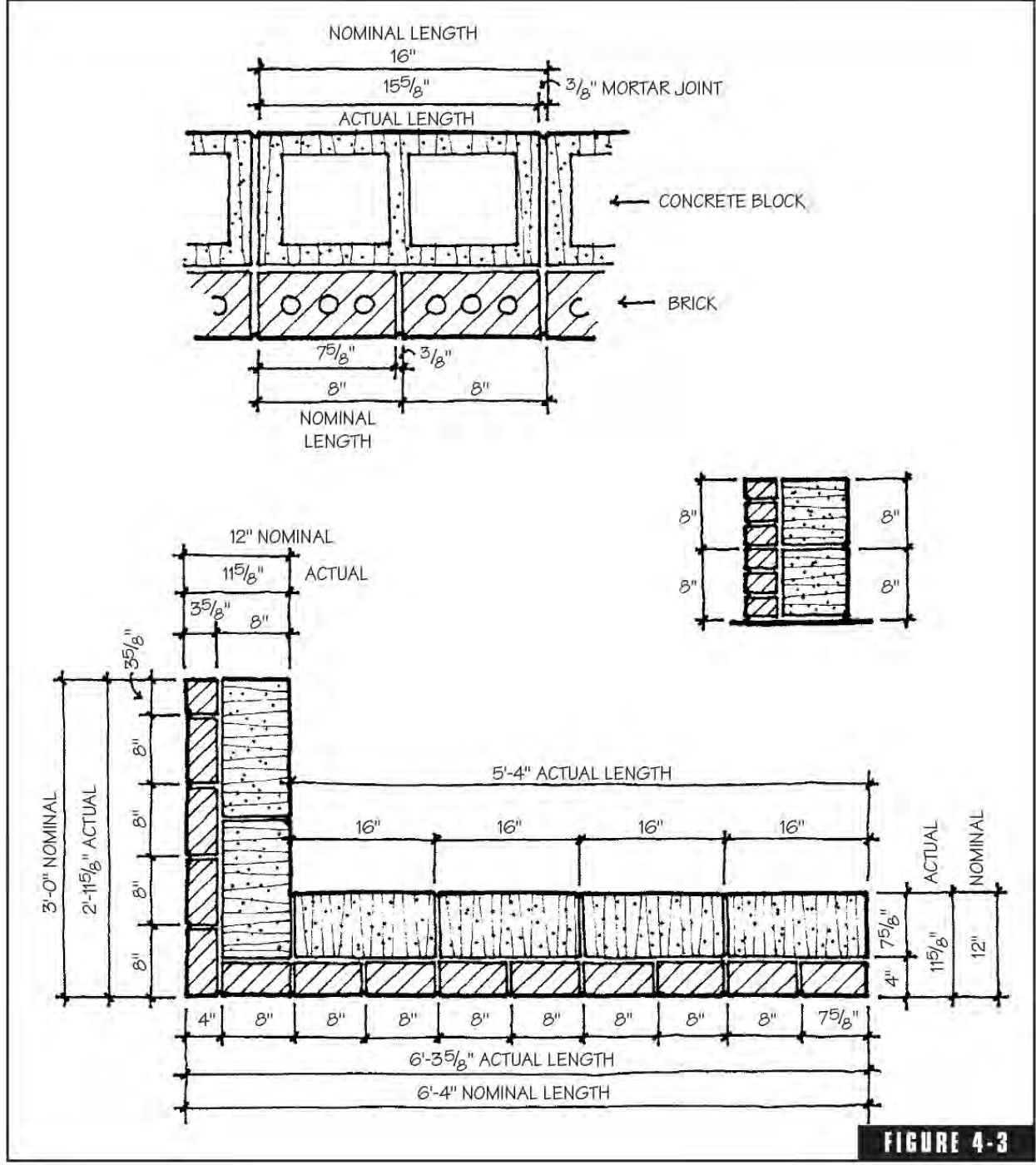
£0.67

Type 1:
Brick masonry

**Modular masonry layout,
as an example**

**CONCRETE BLOCK + CLAY BRICK
Total thickness: 30cm**

**Advantages:
Cheaper
Brisk blocks on the inner layer
insulates better than bricks**



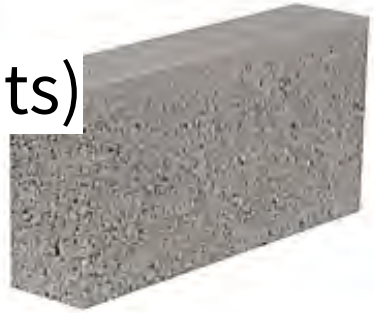
Modular masonry layout.

Type 1:
Brick masonry

MAIN PROPERTIES
Strength
Absorption
Free-thaw resistance

Type 2: Concrete masonry

CMUs (Concrete Masonry Units)



Made from **cement**, **sand** and **crushed stone** or **gravel aggregate** that is molded and cured at a manufacturing plant.

Stronger,
It is used for structural elements

Bulk delivery

Aggregate Industries Dense Concrete Block (L)440mm (W)100mm

Buy a pallet of 72 and save £6.52.
Discount applied at checkout.

★★½☆☆ (14)

£1.66

Add to basket

Good for backing

Bulk delivery

Toplite Aerated concrete Block (L)440mm (W)100mm

Buy a pallet of 90 and save £7.20.
Discount applied at checkout.

★★★★½ (2)

£1.48

Add to basket

Type 2: Concrete masonry

CMUs (Concrete Masonry Units) includes both large block and smaller brick size units.

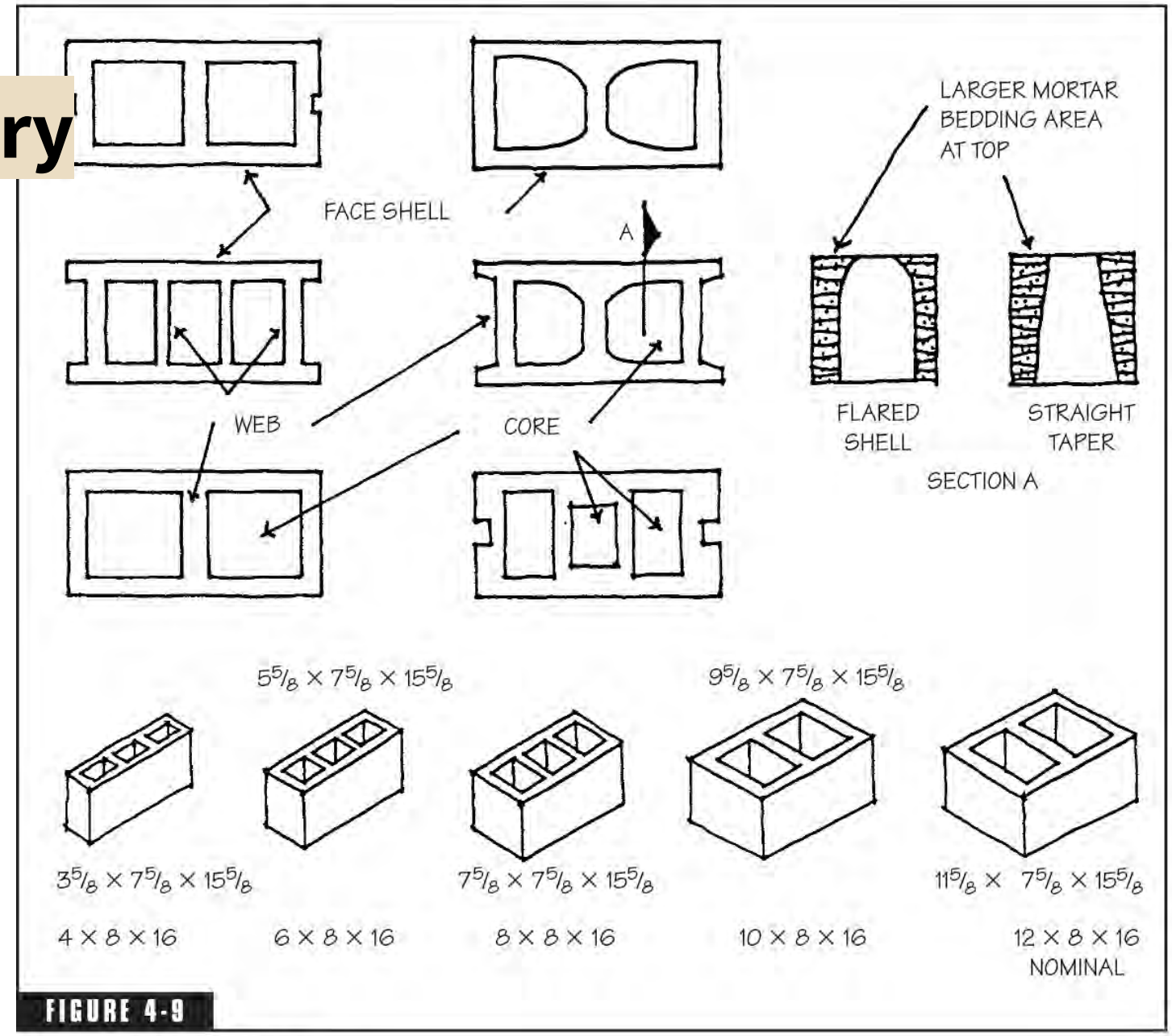


FIGURE 4-9

Concrete block terminology.

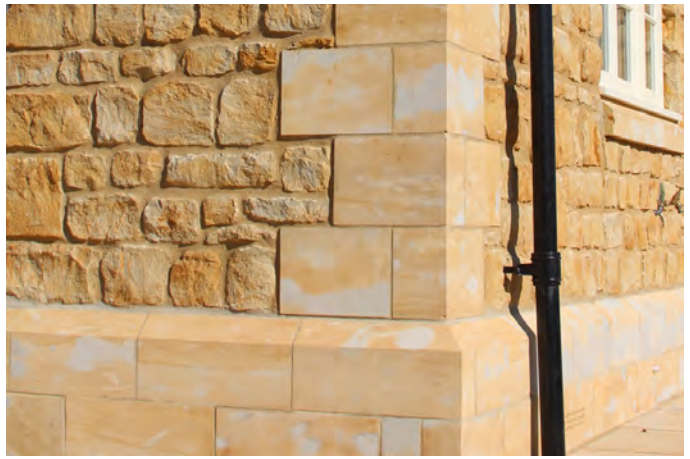
Type 3:
Stone masonry:
Natural stone

Excluding cast stone and cultured stone

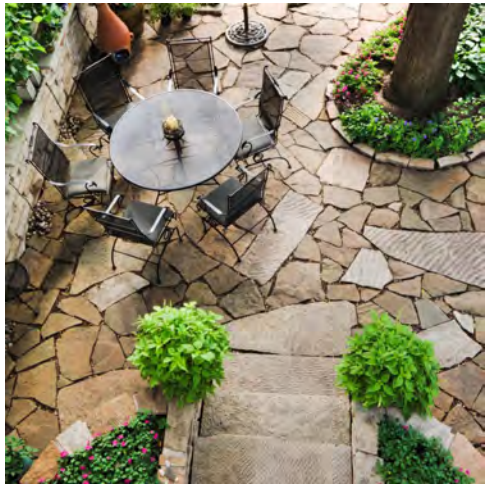
Types of stone:

- Rubble stone
- Ashlar
- Flagstone

Rubble stone is irregular in size and shape.



Ashlar is a type of cut stone processed at a quarry to produce relatively smooth, flat bedding surfaces that stack easily.



Flagstone may be quarried material that has been cut into flat slabs for use as paving.

Masonry's rules

Important aims are:

- Optimising the loadbearing and resistance properties of construction
- Minimising loss of material
- Speeding up the building process
- Executing a design that does justice to material and use

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

How to make bricks

https://youtu.be/mtQ5bc-R99I

Duration: 5 minutes

How to Make Bricks | This Old House

62,651 views • 23 Jun 2020

1.1K 22 SHARE SAVE

Traditional brick making

https://youtu.be/Vl01xf8D5js

Duration: 8 minutes

#Bricks #Making

Traditional Way Bricks Making In Bangladesh | The Whole Process Of Making Bricks

1,817,053 views • 17 Jan 2019

7K 854 SHARE SAVE

Common use in building

1. Exterior load-bearing walls (below and above grade)
2. Interior load-bearing and nonload-bearing walls
3. Firewalls, party walls, curtain walls
4. Partitions, panel walls, solar screens
5. Piers, pilasters, columns
6. Bond beams, lintels, sills
7. Chimneys and fireplaces (indoors and outdoors)
8. Retaining walls, slope protection, ornamental garden walls, and highway sound barriers

Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Common use in building

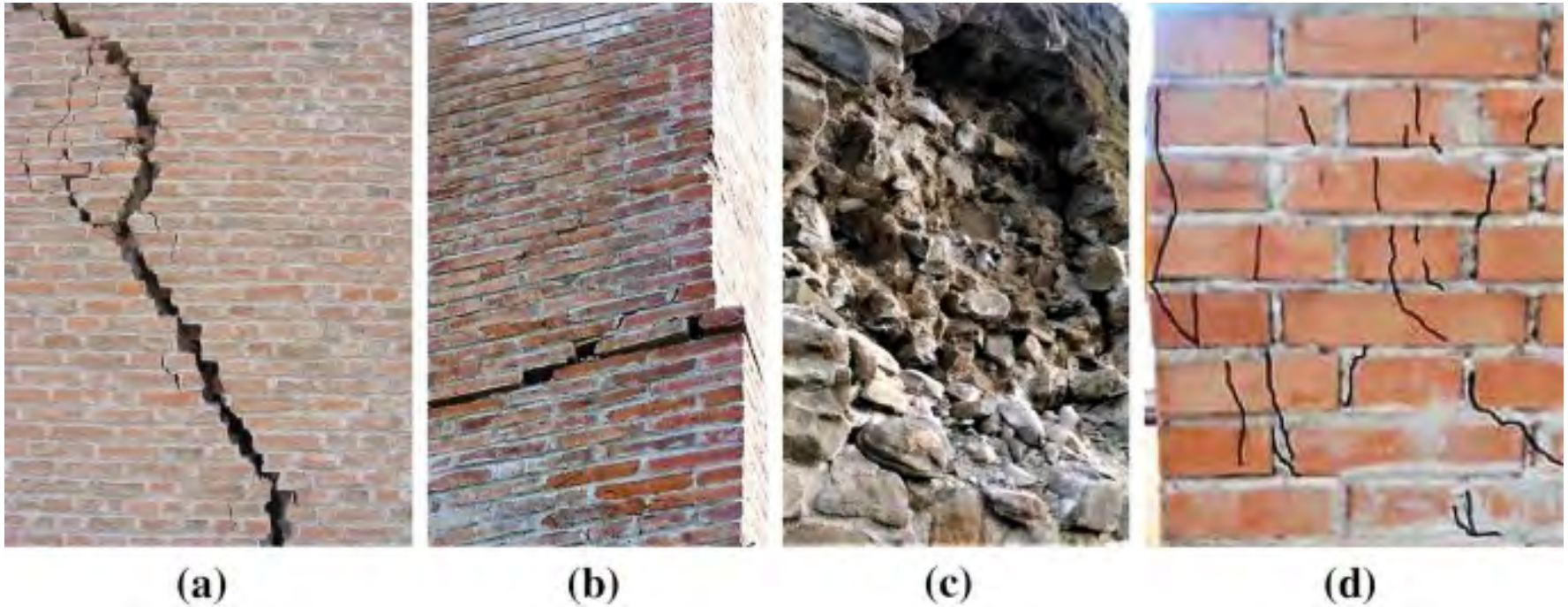
9. Backing for screens
10. Backing for brick, stone, stucco, and exterior insulation and finishing systems
11. Veneer or nonstructural facing for steel, wood, concrete, or masonry
12. Fire protection for steel structural members
13. Fire-safe enclosures of stairwells, elevator shafts, storage vaults, or fire-hazardous areas
14. Catch basins, manholes, and valve vaults
15. Paving for walkways and landscaping

Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Advantages of masonry for structural elements

- Versatile system
- Fast, efficient and economical
- Widely available

Cracks:



D’Altri, A. M., Sarhosis, V., Milani, G., Rots, J., Cattari, S., Lagomarsino, S., Sacco, E., Tralli, A., Castellazzi, G. & de Miranda, S. (2019). Modeling strategies for the computational analysis of unreinforced masonry structures: review and classification. *Archives of computational methods in engineering*, 1-33.

Part 2:
Structural elements

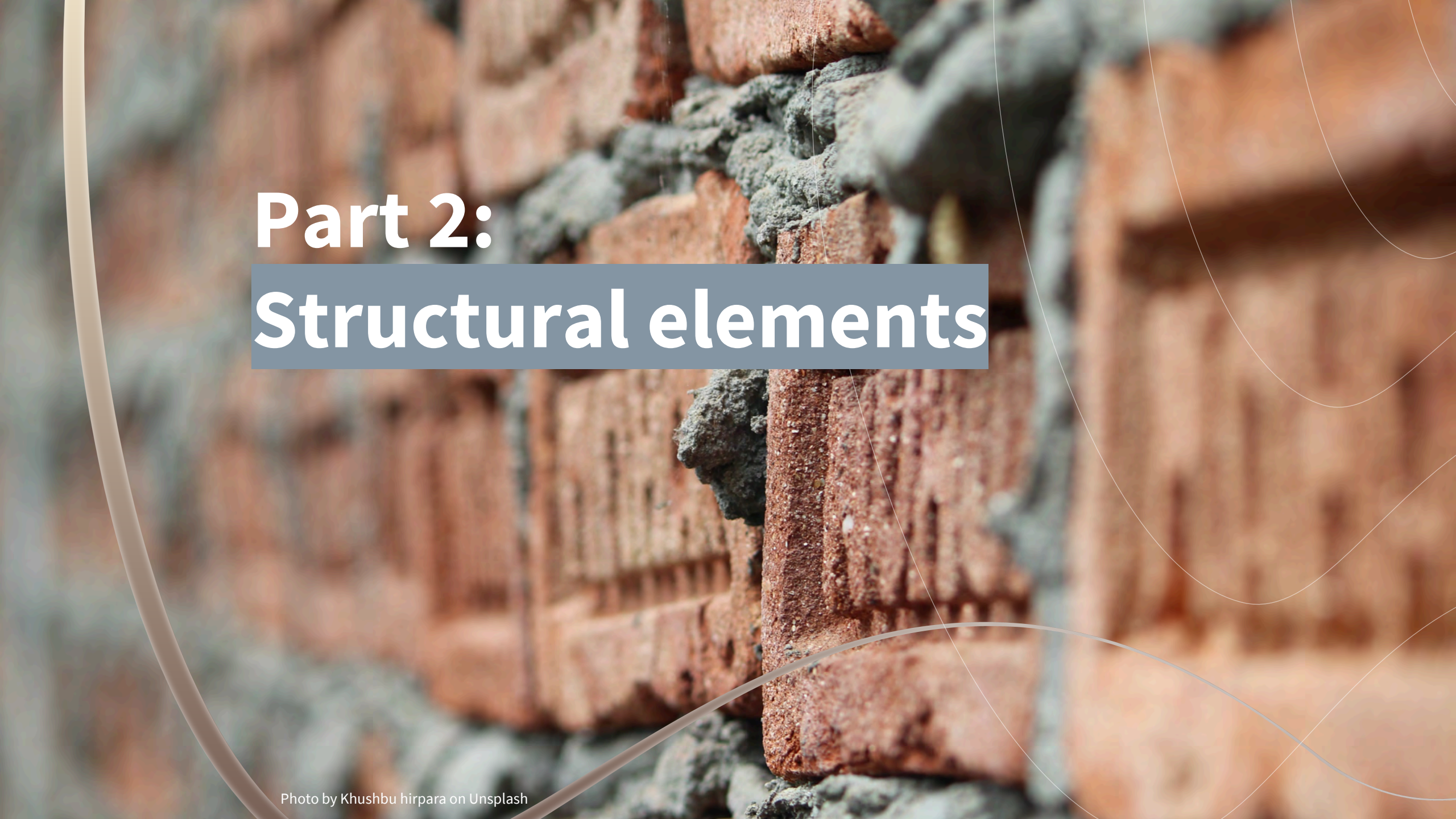
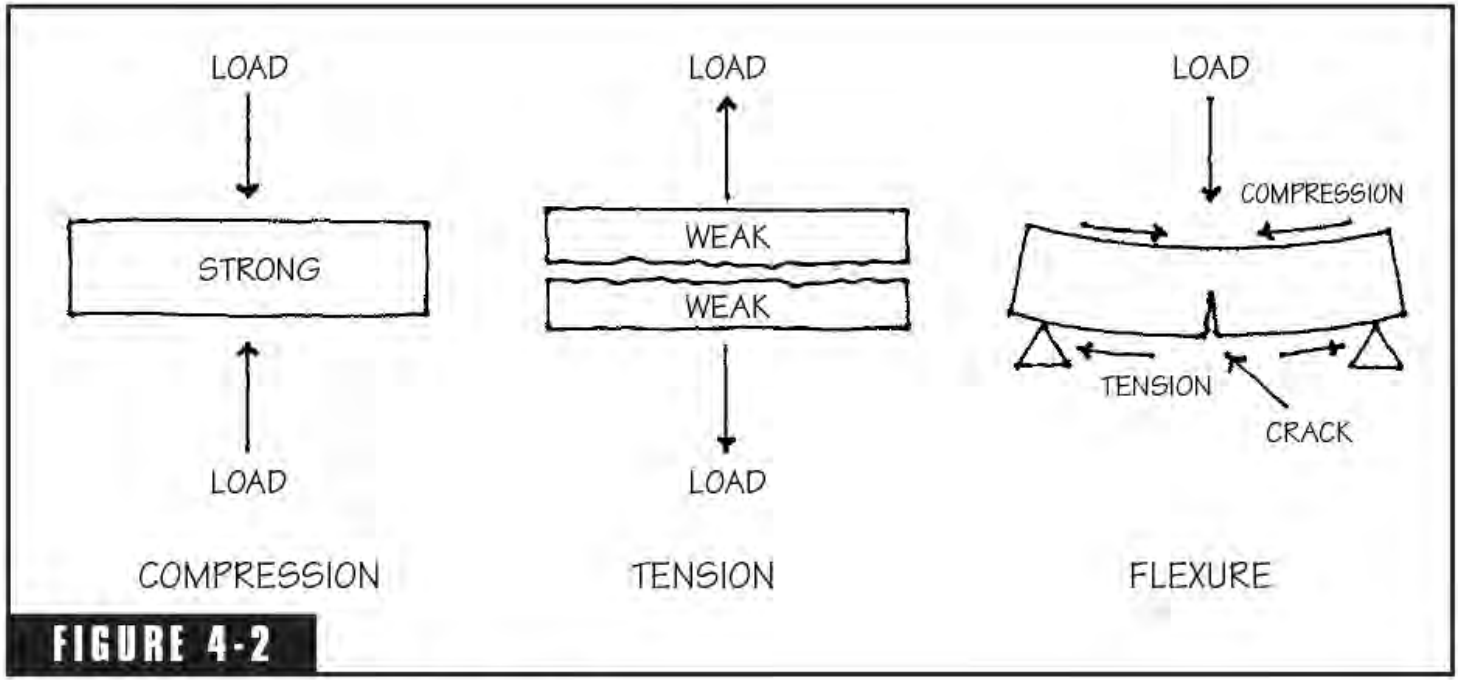


Photo by Khushbu hirpara on Unsplash

Primary use as structural members

- Loadbearing/ partitioning shear wall



Tension and compression in masonry.

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Common problems as structural members

- Fixing grid dimensions → impossible to work with dimensions of the bricks alone. Allowing mortar joints between the bricks.
- **Specified** and **nominal** dimensions

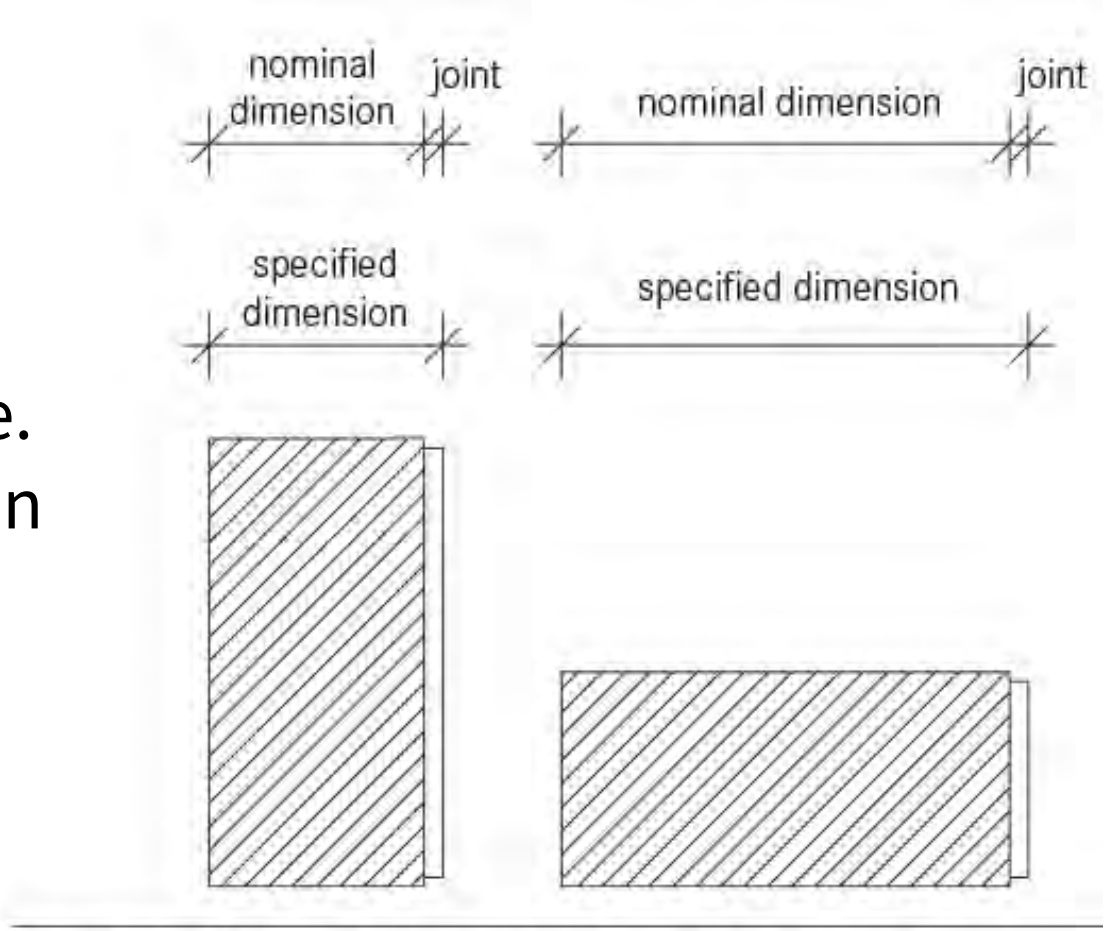


Fig. 2: Specified dimension and nominal dimension

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

Common problems as structural members

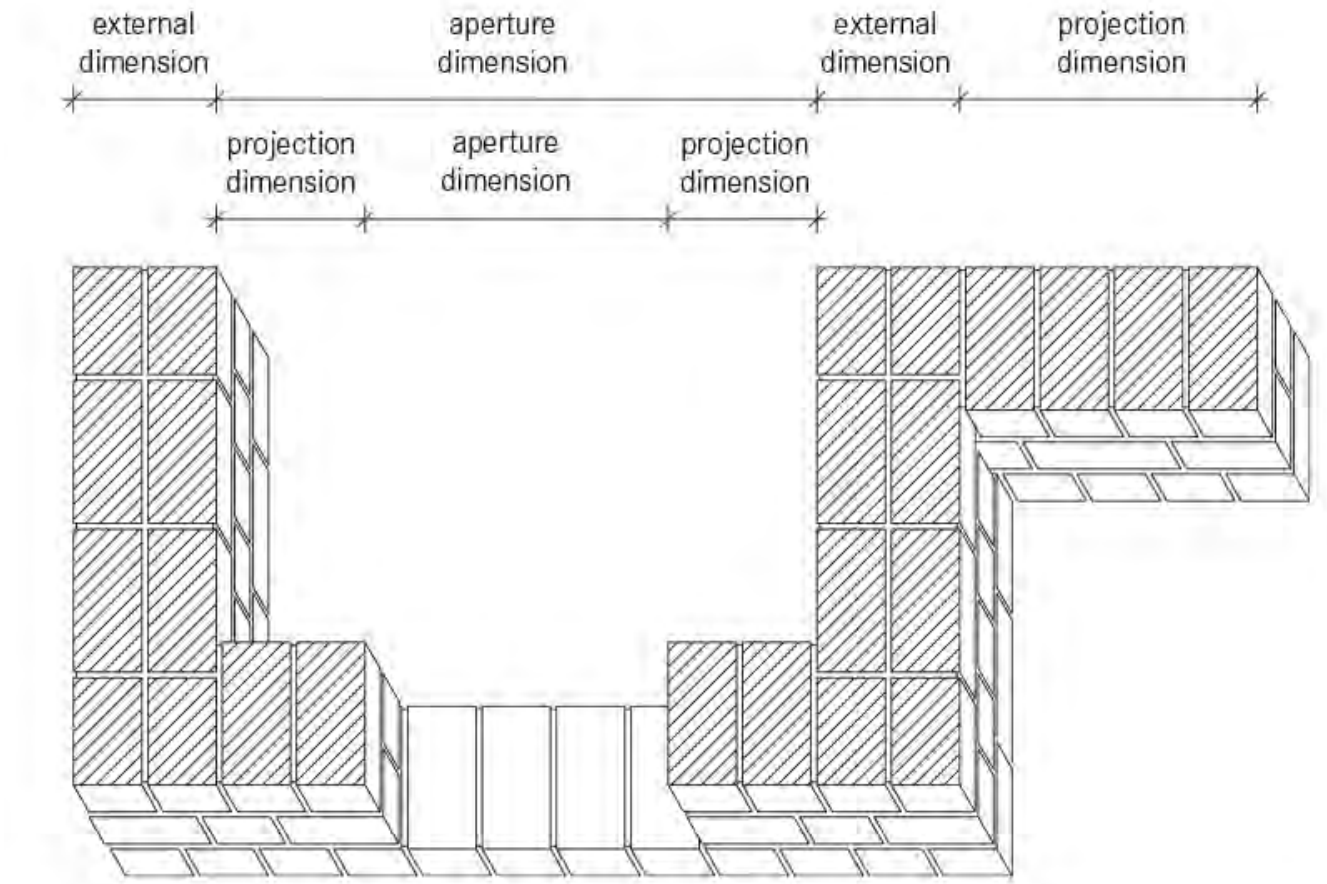


Fig. 4: Shell construction dimensions

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

Loadbearing behaviour

- **Compression strength** of masonry depends on:
  - Masonry units
  - Mortar
  - Grout
- The strength of these three materials measured separately are **required to be at least equal or greater than** the specified compressive strength of masonry.

Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Compressive strength

TABLE A.4 Compressive Strength of Clay Masonry Based on the Compressive Strength of Clay Masonry Units and Type of Mortar used in Construction (MSJC-08 Table 1) (Reprinted with permission.)

Net area compressive strength of clay masonry units (psi)		Net area compressive strength of masonry (psi)
Type M or S mortar	Type N mortar	
1,700	2,100	1,000
3,350	4,150	1,500
4,950	6,200	2,000
6,600	8,250	2,500
8,250	10,300	3,000
9,900	-	3,500
11,500	-	4,000

For SI: 1 lb per square in. = 0.00689 MPa.

TABLE A.5 Compressive Strength of Concrete Masonry Based on the Compressive Strength of Concrete Masonry Units and Type of Mortar Used in Construction (MSJC-08 Table 2) (Reprinted with permission.)

Net compressive strength of concrete masonry units (psi)		Net area compressive strength of masonry (psi)
Type M or S mortar	Type N mortar	
	1,900	1,350
1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

For SI: 1 in. = 25.4 mm, 1 lb per square in. = 0.00689 MPa.

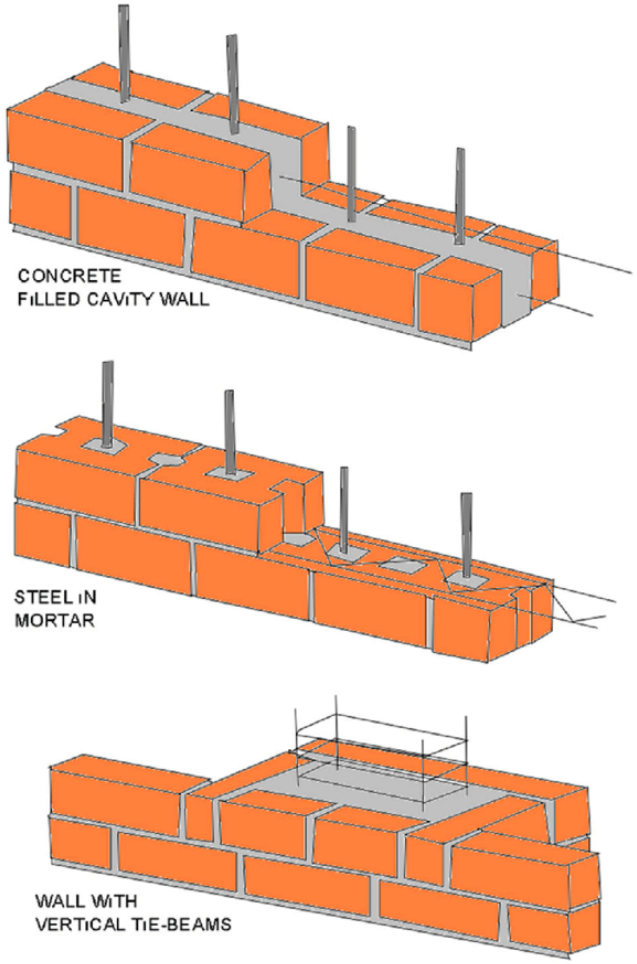
Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

Design of reinforced masonry

- In unreinforced masonry (URM) structures, lateral stability is provided by gravity.
- URM tends to be sufficiently massive → imposes on **economic limit of height** of masonry structures that can be built.
- **Incapability of withstanding lateral loads** due to earthquakes.

Taly, N. (2010). *Design of reinforced masonry structures*, McGraw-Hill Education.

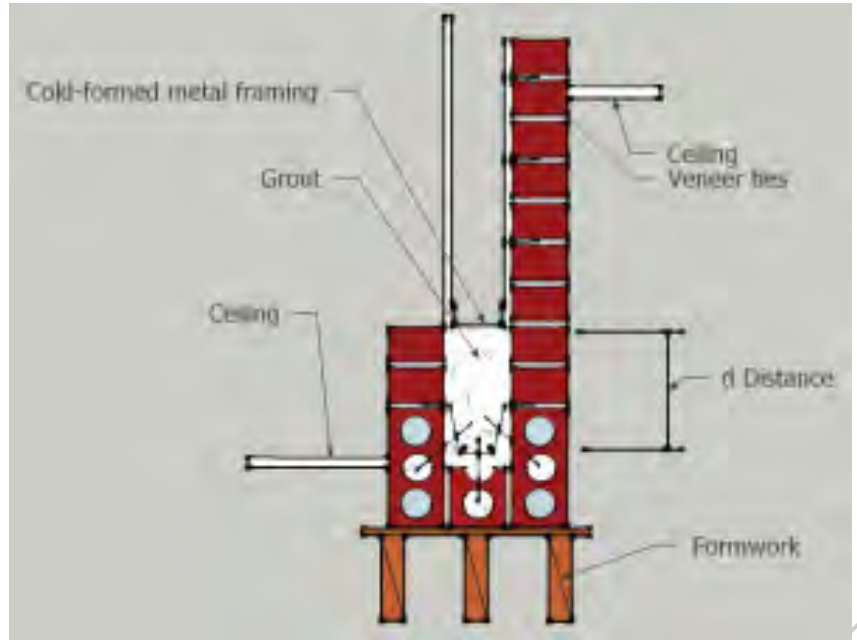
Design of reinforced masonry



STRUCTURE magazine | Reinforced Masonry Construction

Structural elements:
Reinforced beams

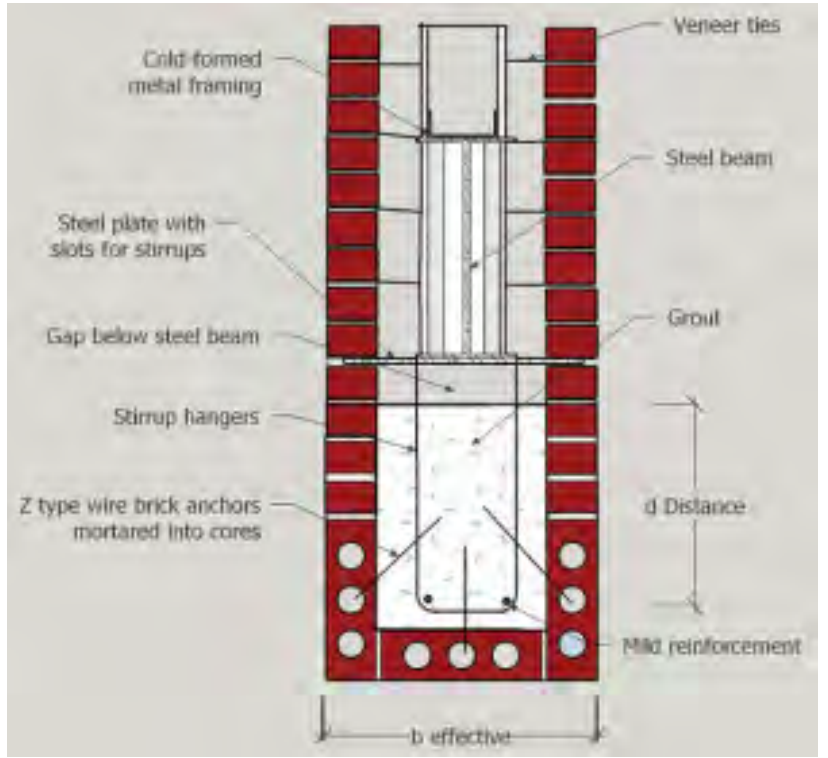
1. **Interior brick beam**
2. Interior brick beam with steel framing
3. Exterior brick beam with steel framing



STRUCTURE magazine | Brick Beams

Structural elements: Reinforced beams

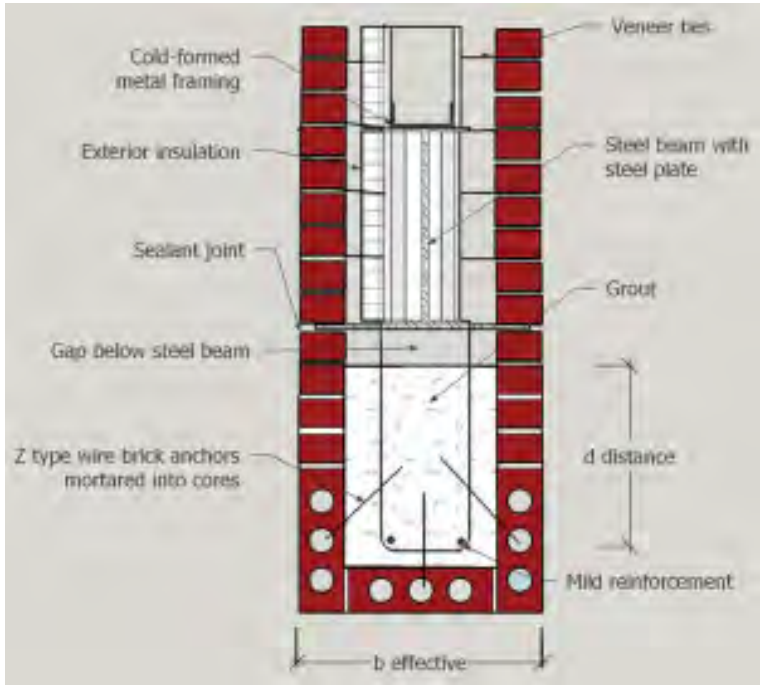
1. Interior brick beam
2. **Interior brick beam with steel framing**
3. Exterior brick beam with steel framing



STRUCTURE magazine | Brick Beams

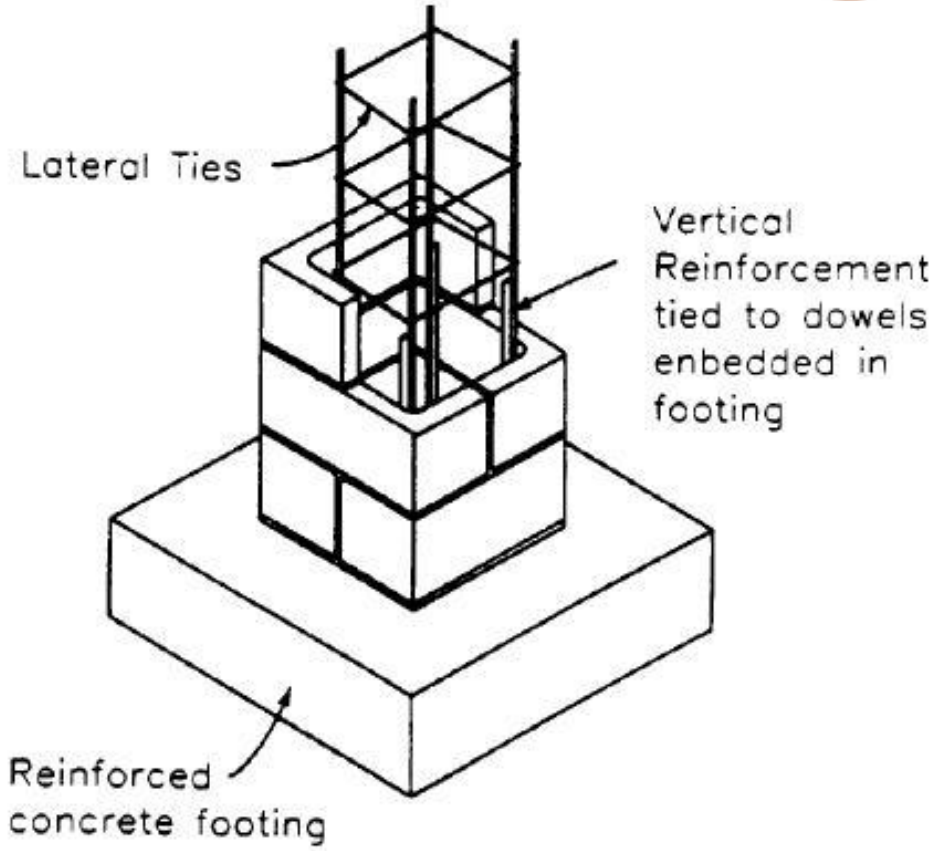
Structural elements:
Reinforced beams

1. Interior brick beam
2. Interior brick beam with steel framing
3. **Exterior brick beam with steel framing**



STRUCTURE magazine | Brick Beams

Structural elements:
Reinforced Columns



U. S. ARMY CORPS OF ENGINEERS

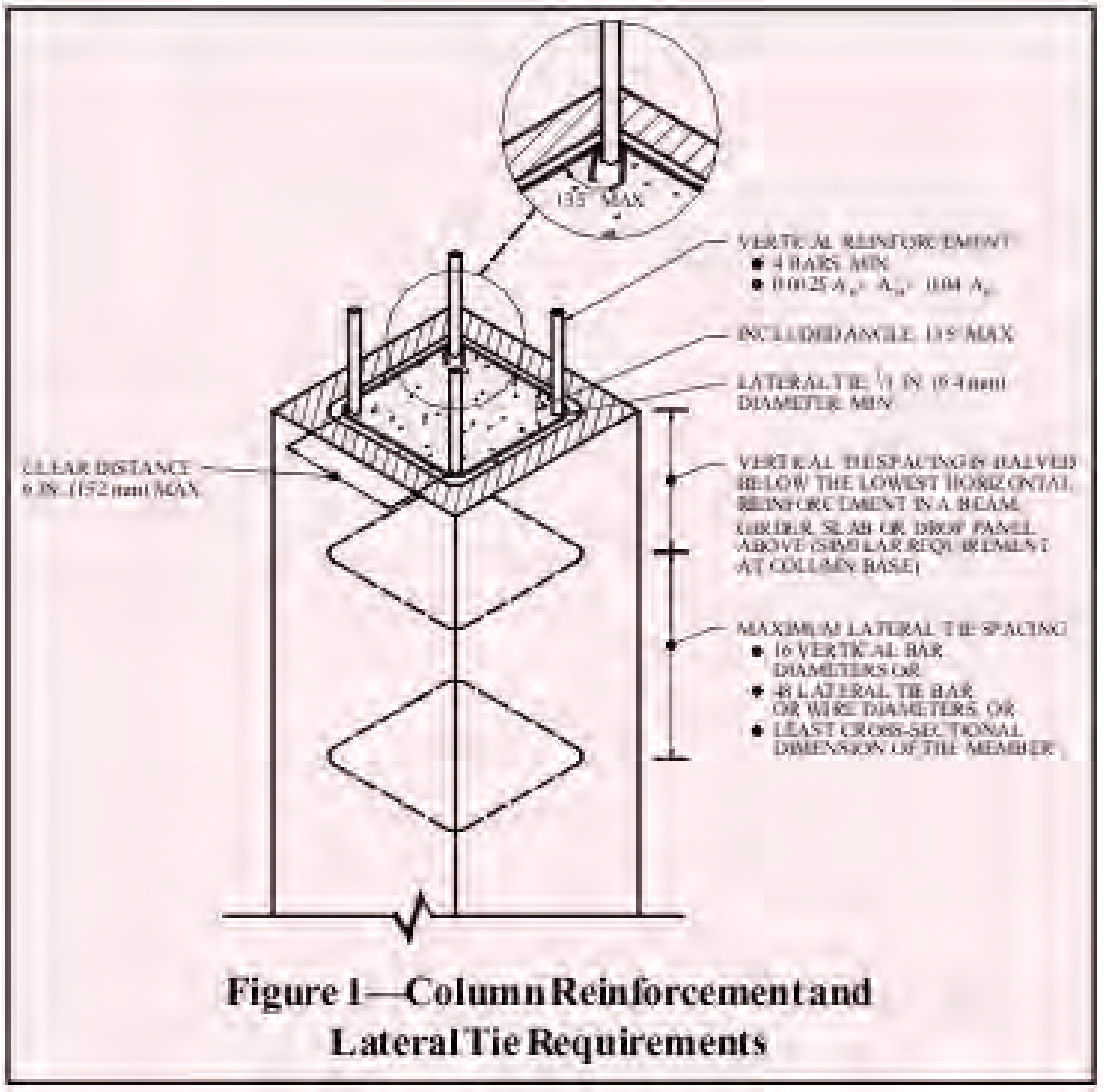
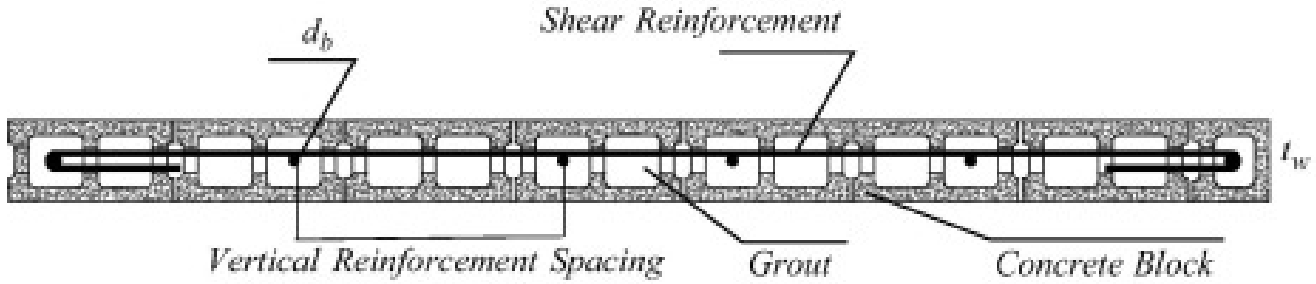
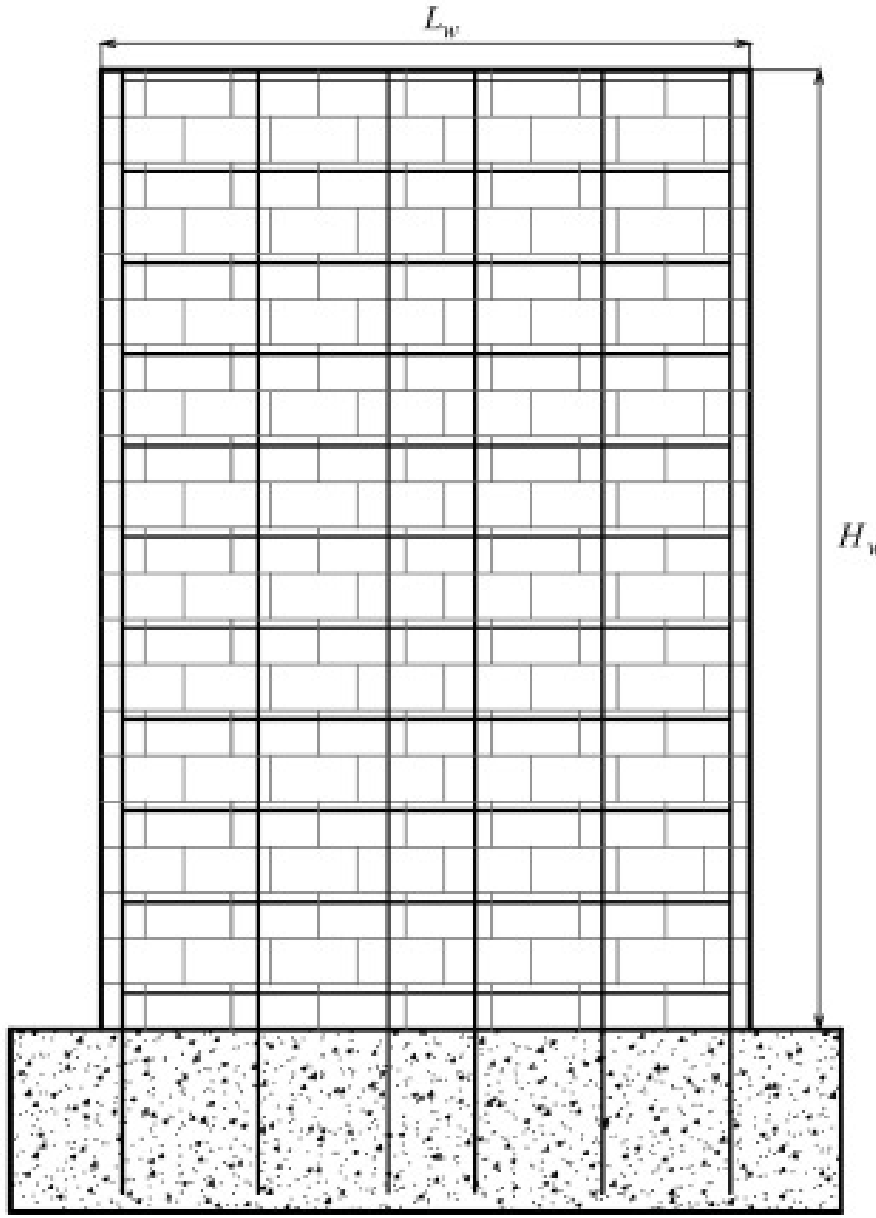


Figure 1—Column Reinforcement and Lateral Tie Requirements

Structural elements:
Reinforced shear walls

Typical Reinforced Masonry Shear Wall (RMSW) cross section and elevation

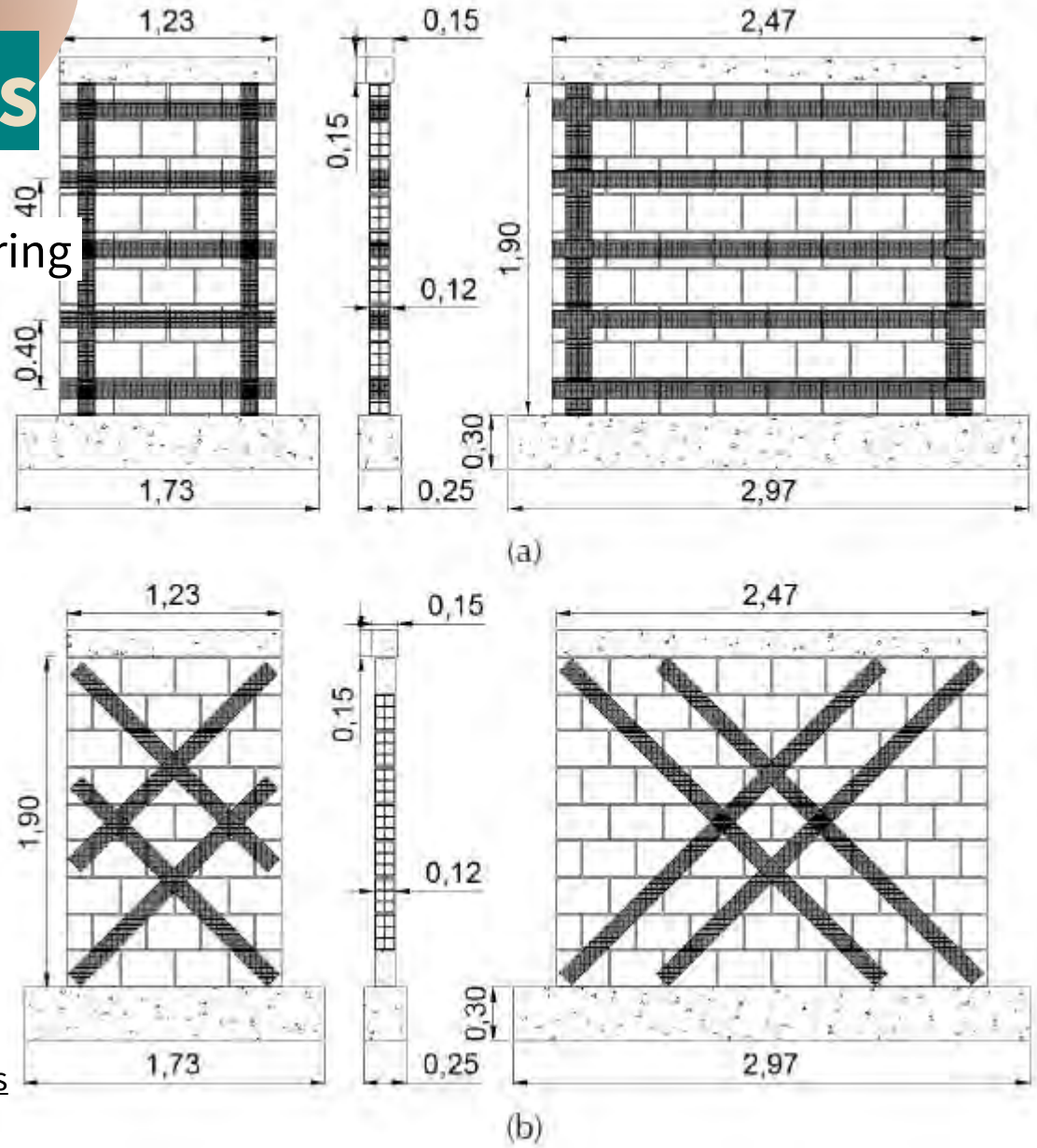




Siam, A. S., Hussein, W. M., & El-Dakhakhni, W. W. (2017). Scoring models for reinforced masonry shear wall maximum displacement prediction under seismic loads. Engineering Structures, 136, 511-522.

Structural elements:
Unreinforced shear walls

CFRP (Carbon Fibre Reinforced Polymer) or repairing and strengthening unreinforced masonry.



External strengthening of unreinforced masonry walls with polymers reinforced with carbon fiber (scielo.org.co)

Structural elements:
Reinforced retaining walls

- The grid etc

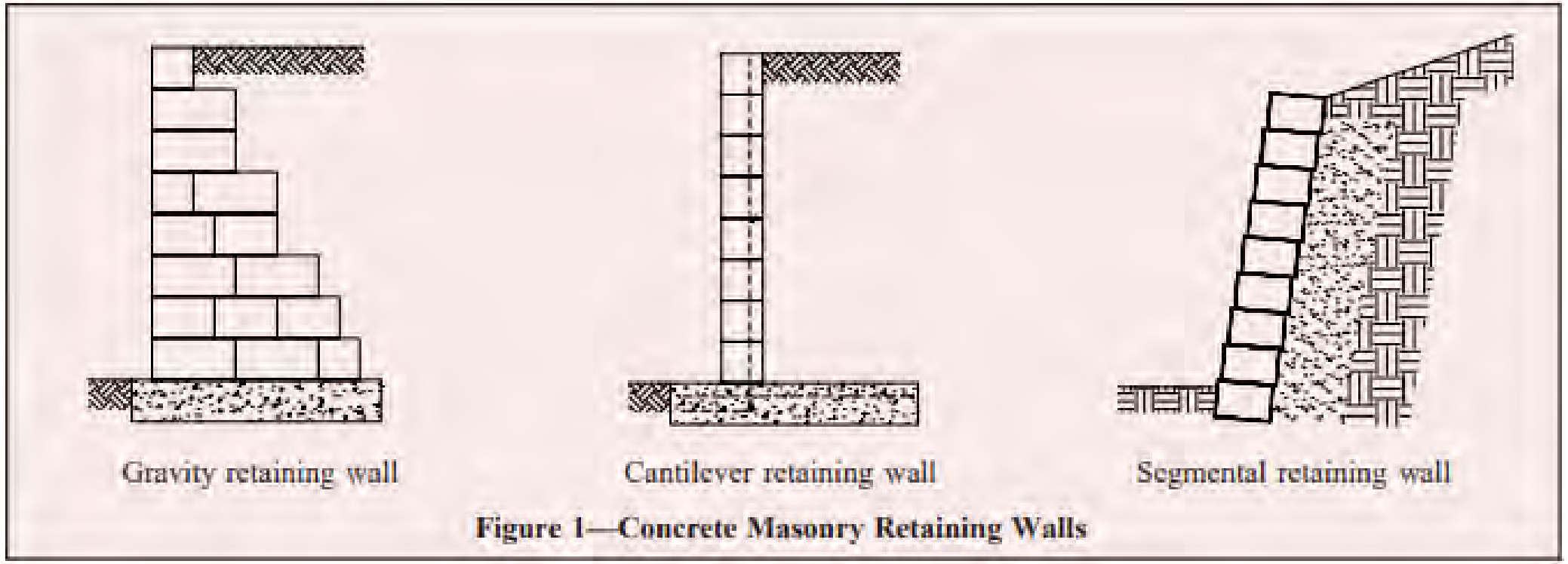
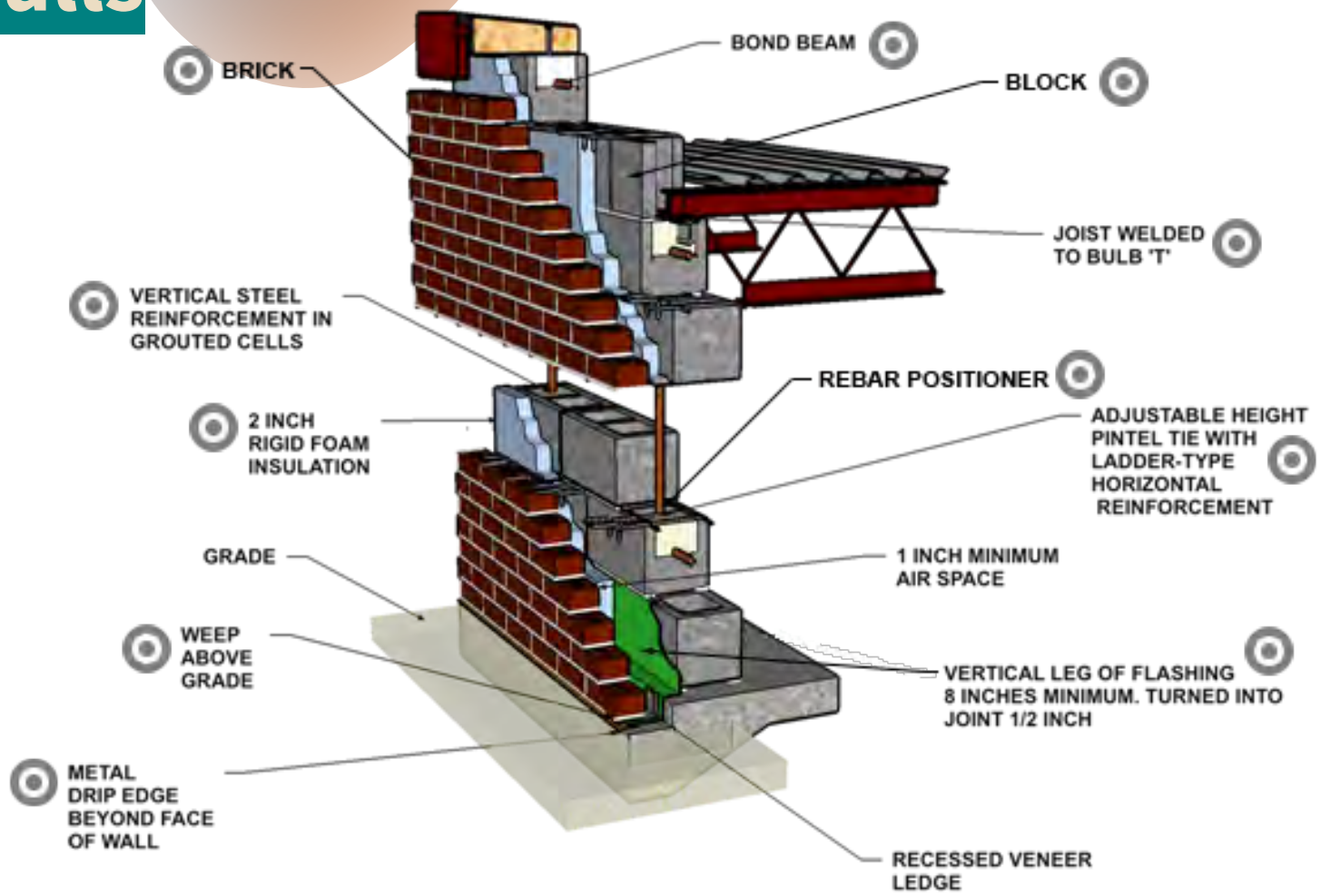


Figure 1—Concrete Masonry Retaining Walls

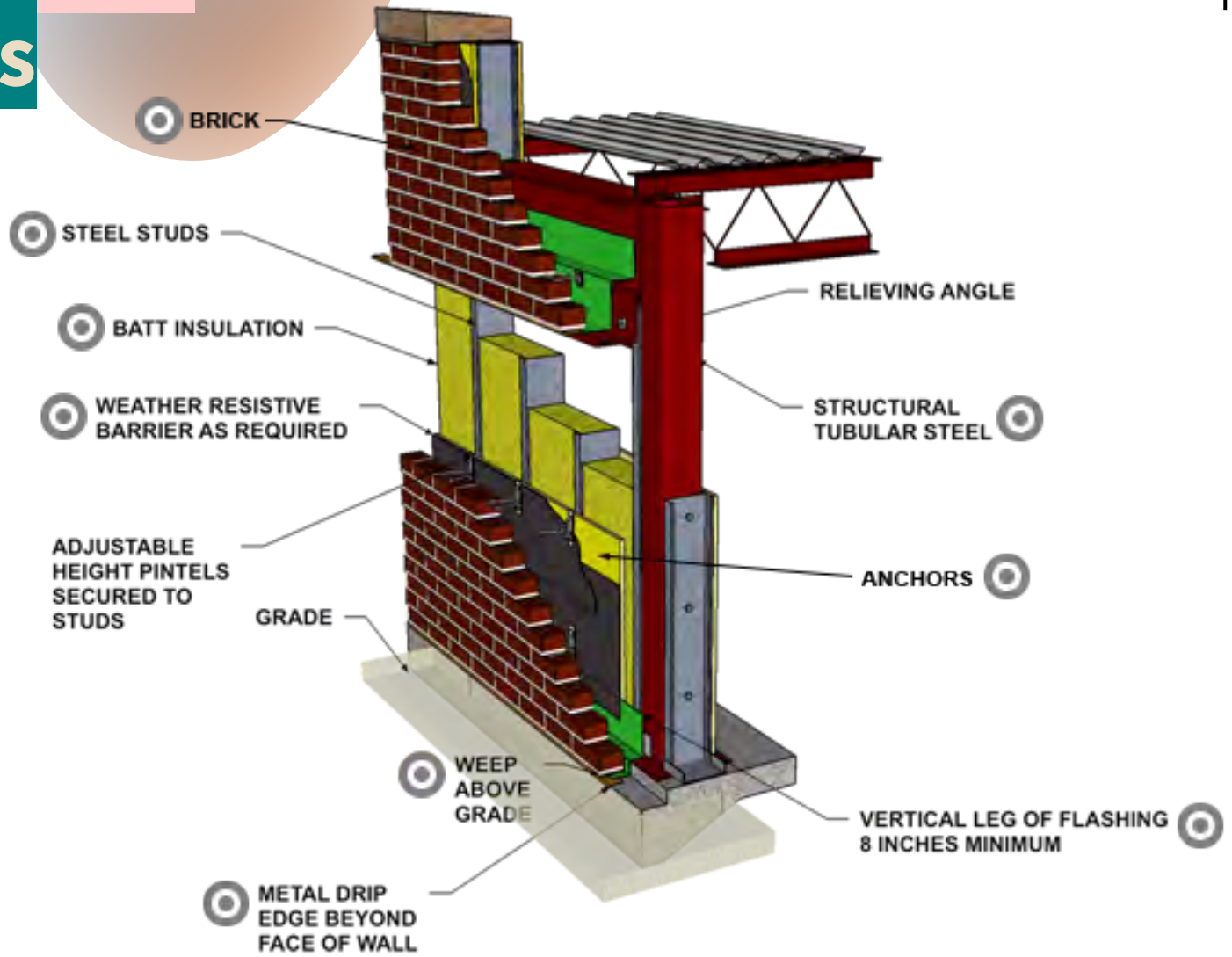
CONCRETE MASONRY GRAVITY RETAINING WALLS - NCMA

Structural elements:
Reinforced walls



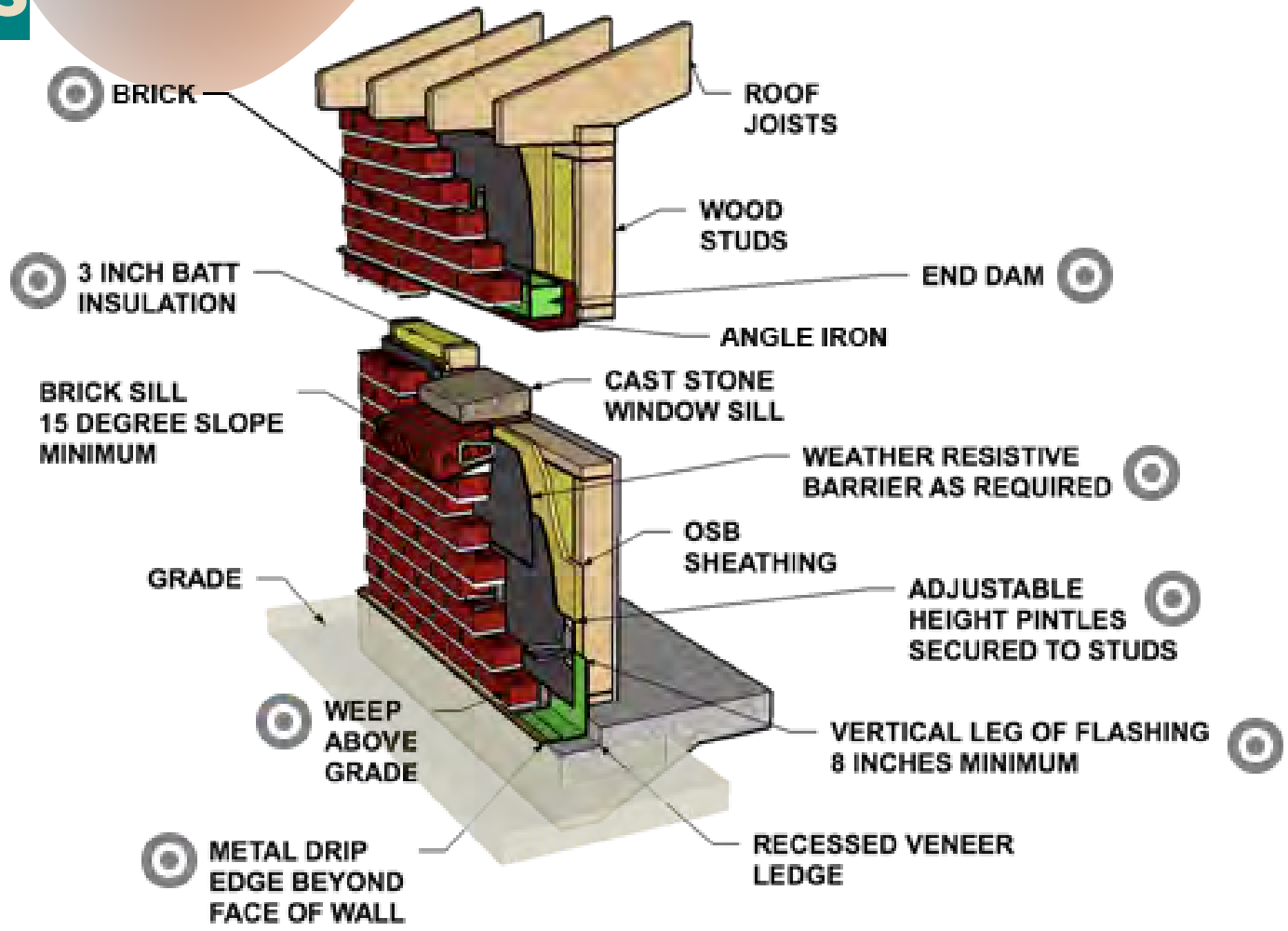
Emco Block | Wall Systems

Structural elements:
Reinforced walls



Emco Block | Wall Systems

Structural elements:
Reinforced walls



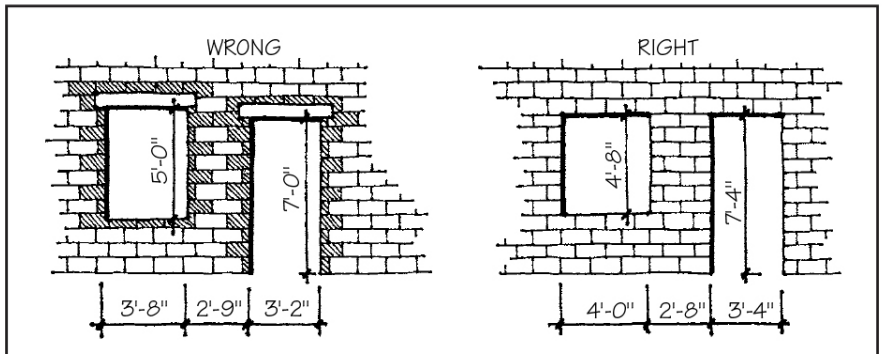
Emco Block | Wall Systems

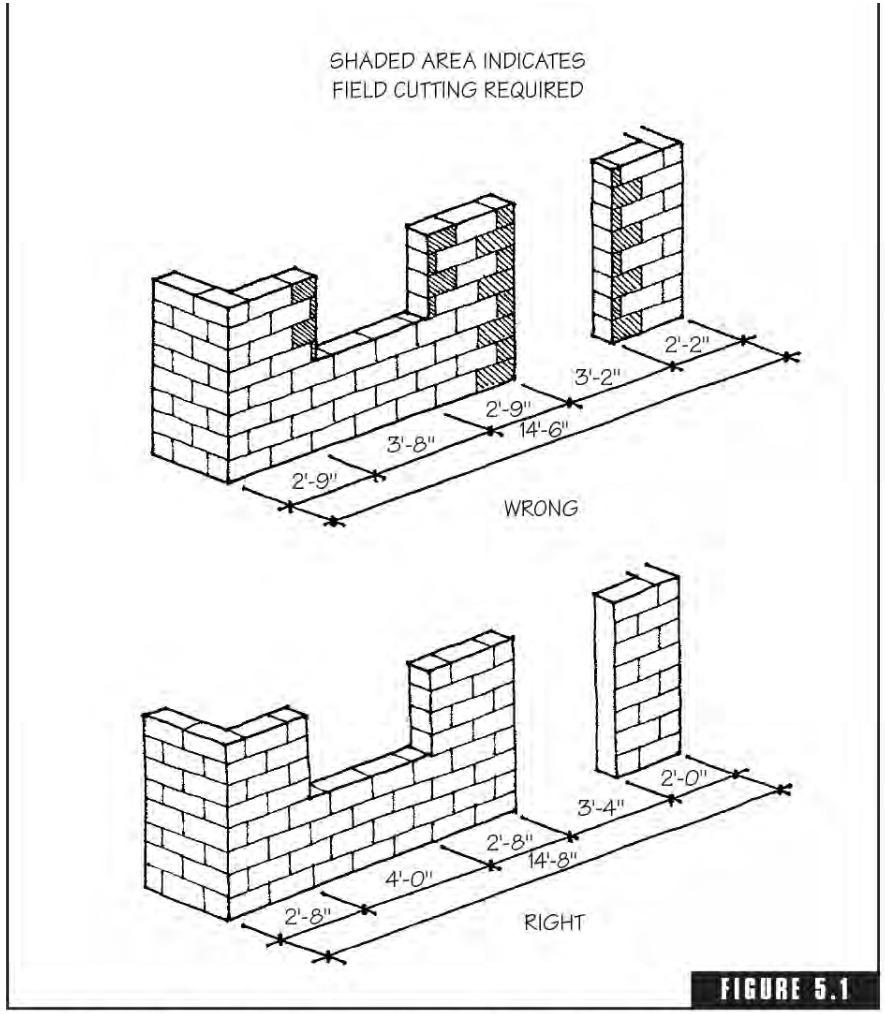
Part 3:
Building the masonry

Photo by Ryan Gerrard on Unsplash

Planning

- **Modular planning**, multiples of **4 inch**.
- Either full brick or half brick



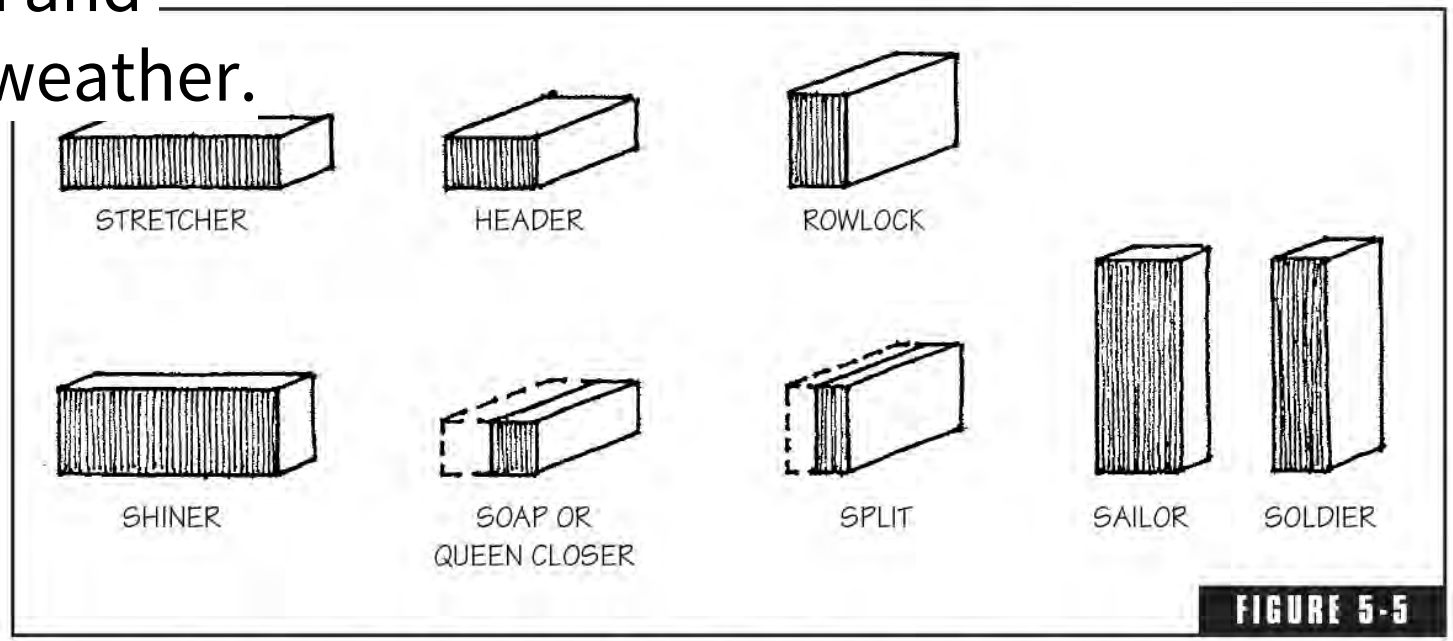


Modular layout of openings in masonry walls. *(adapted from NCMA,* TEK 14, *National Concrete Masonry Association, Herndon, VA).*

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Planning

- Before construction, **materials need to be properly stored** and protected from weather.



Terminology for various orientations of bricks. ***(from Beall, Christine,*** **Masonry Design and Detailing,** ***4th edition, McGraw-Hill, New York).***

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Mixing mortar

- Mortar is the **cementitious material** that bonds units, connectors and reinforcement together for strength and weather resistance.
- Main jobs are to: provide bond strength and in sealing joints between units against passage of air and water.
- Ingredients: Portland cement, lime and sand

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Mixing mortar

How to Choose the Right Mortar Mix: N, O, S, or M (thebalancesmb.com)

Masonry joints

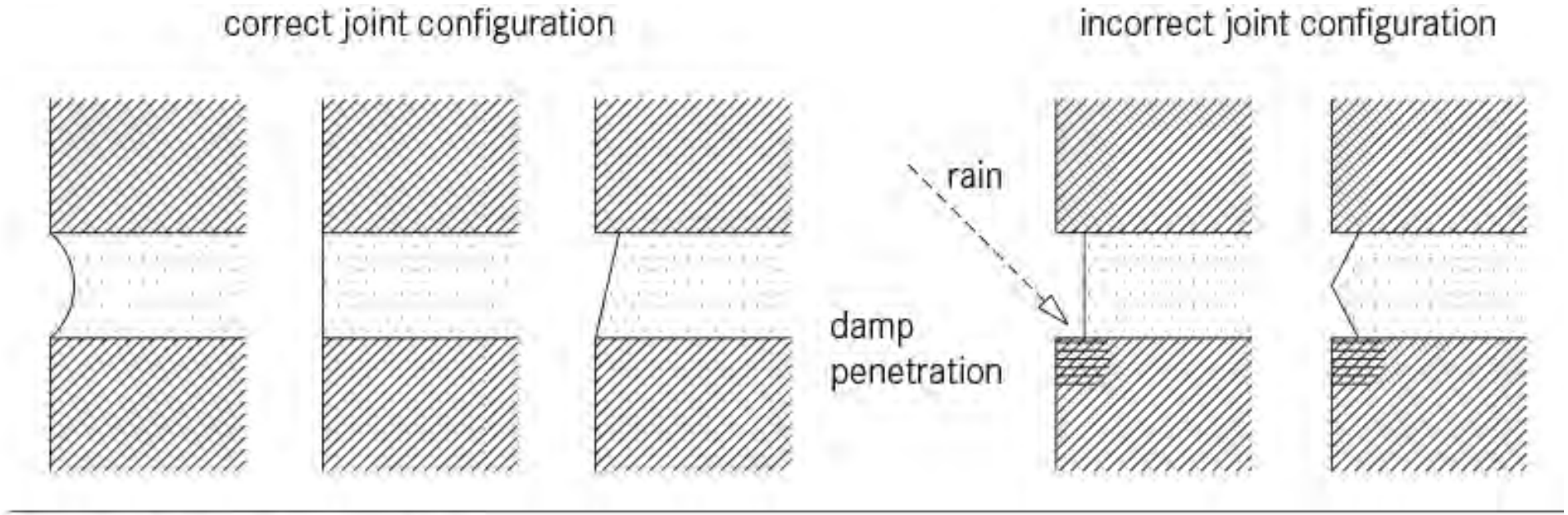
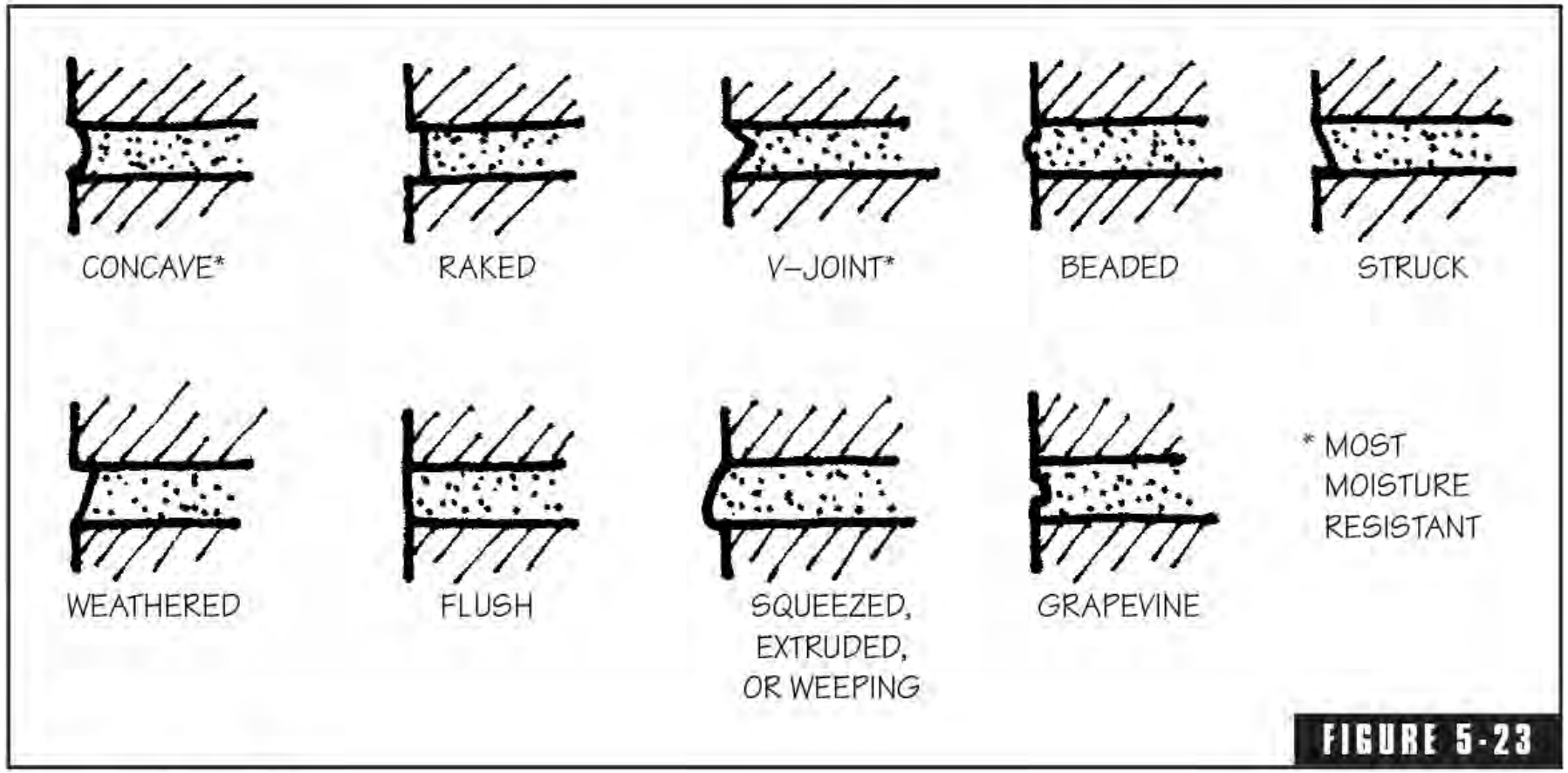


Fig. 27: Joint configuration

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

Masonry joints



Masonry joint profiles.

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Masonry accessories

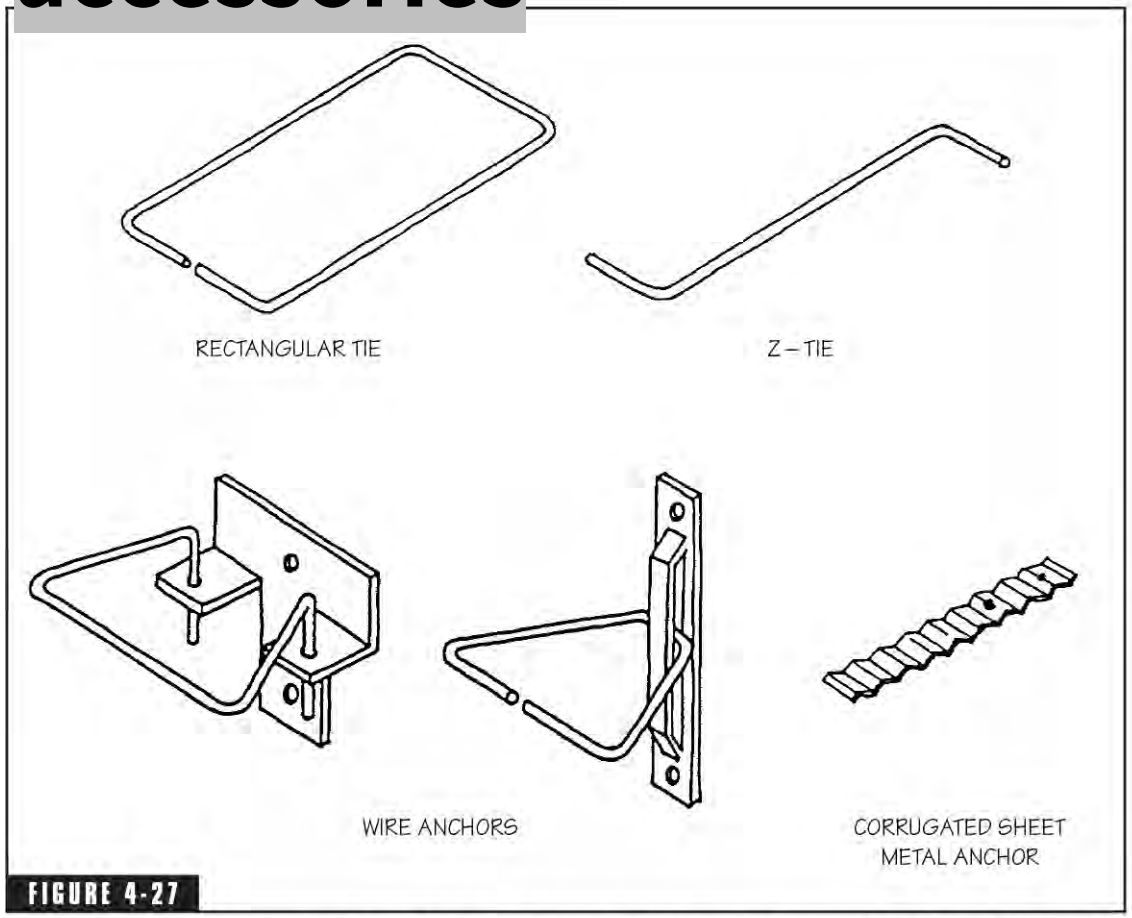


FIGURE 4-27

Masonry anchors and ties. *(from Beall, Christine,* Masonry Design and Detailing, *4th edition, McGraw-Hill, ork).*

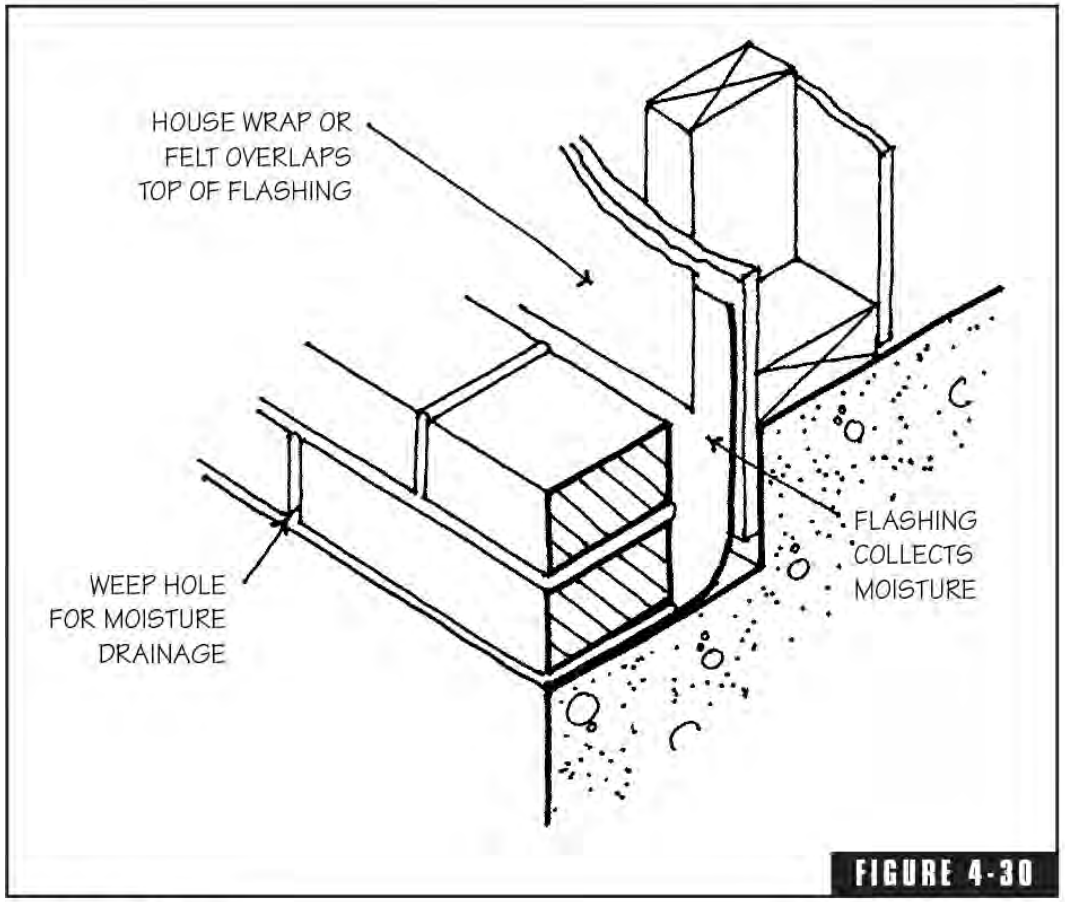


FIGURE 4-30

Flashing and weeps.

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Masonry bonds

- The bond rules: craft rules for laying bricks.

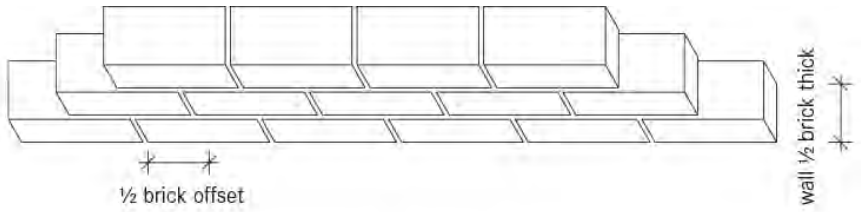


Fig. 11: Stretcher bond

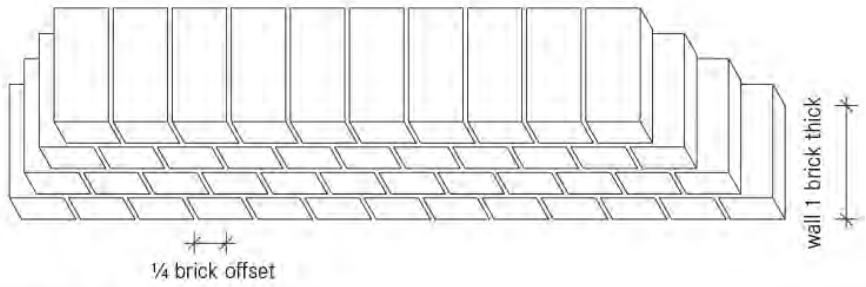


Fig. 12: Header bond

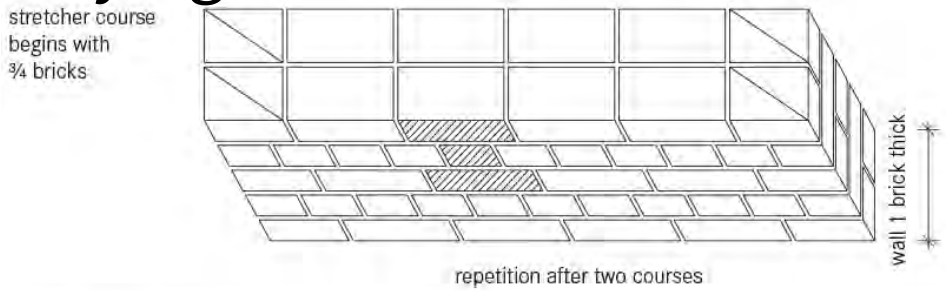


Fig. 13: English bond

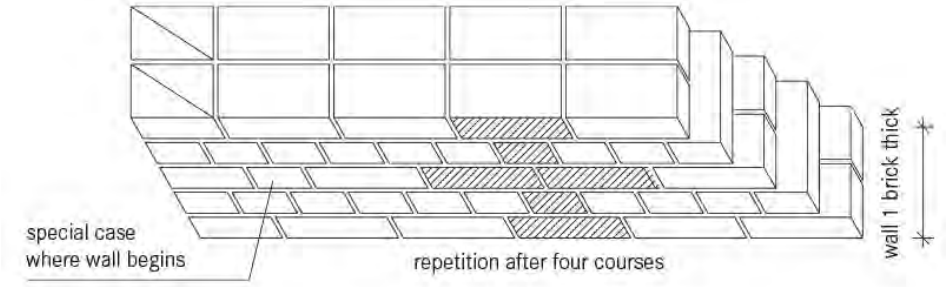
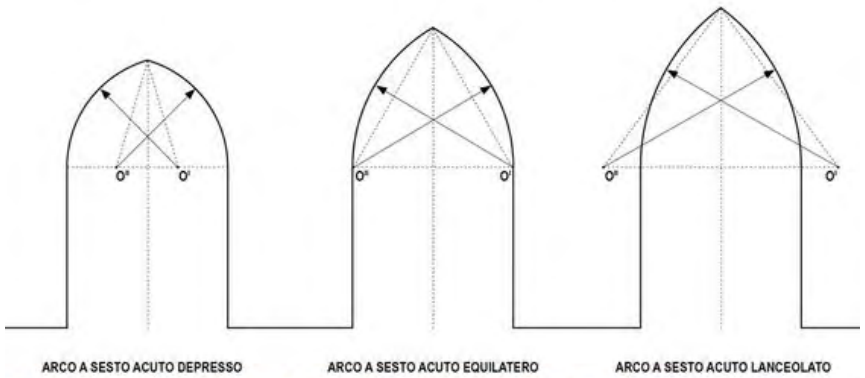


Fig. 14: English cross bond

Kummer, N. (2017). *Basics masonry construction*, Birkhäuser.

Masonry aperture

- Aperture for windows, doors or passageways.
- On **top of window or door** → concrete / wood / stone can be placed to dissipate impose load from masonry above to the side walls.
- **Masonry arches** → Transforms all imposed loads into pressure force and transfers them to their points of support.

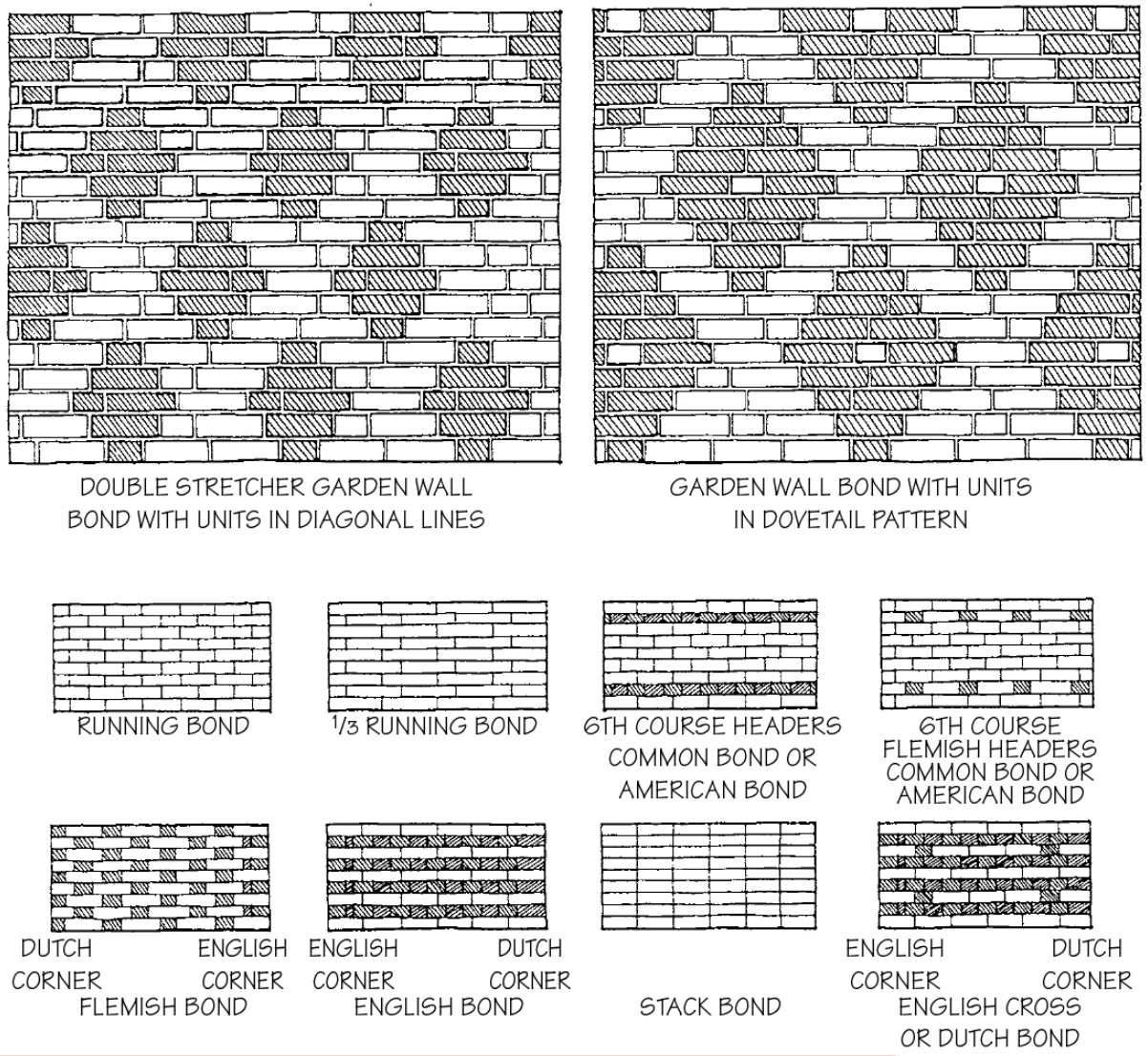


Weather-resistance

- Brick, concrete block, stone and mortar are **porous** and they absorb moisture easily, they also dry out easily.
- Most walls are built with the **drainage space**
- Assuring good weather resistance on masonry walls:
  - **Limit moisture penetration** (full mortar joints, control cracking, apply protective coating)
  - **Prevent moisture accumulation** (install flashing to collect moisture and weep holes to drain moisture)

Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

Masonry bonding patterns



Beall, C. (2001). *Masonry and concrete*, McGraw-Hill Education.

FIGURE 5-7

Masonry bonding patterns

Part 4:
Contemporary brick structure

Photo by Daniel Vonhappe on Unsplash

Can Sau Emergency scenery, Olot, Spain

By: unparelld'arquitectes

unparelld'arquitectes adds inhabitable brick façade to party wall in olot, spain (designboom.com)

Bricktopia Barcelona

By: Map13

Bricktopia: contemporary crafts in EME3 Festival, Barcelona | ArchDaily

ACTIVITIES

1. BUILDING BRICK WALL
2. BUILDING BRICK ARCH FEATURE
3. (SPEND 30 MINS TO GO THROUGH ACTIVITY 1 AND 2), THEN SUBMIT A BRIEF REFLECTION
4. PRESENTATION BY MASONRY GROUP: 30MINS.
5. Q&A (OTHER GROUPS SHOULD AT LEAST POSIT ONE QUESTION).

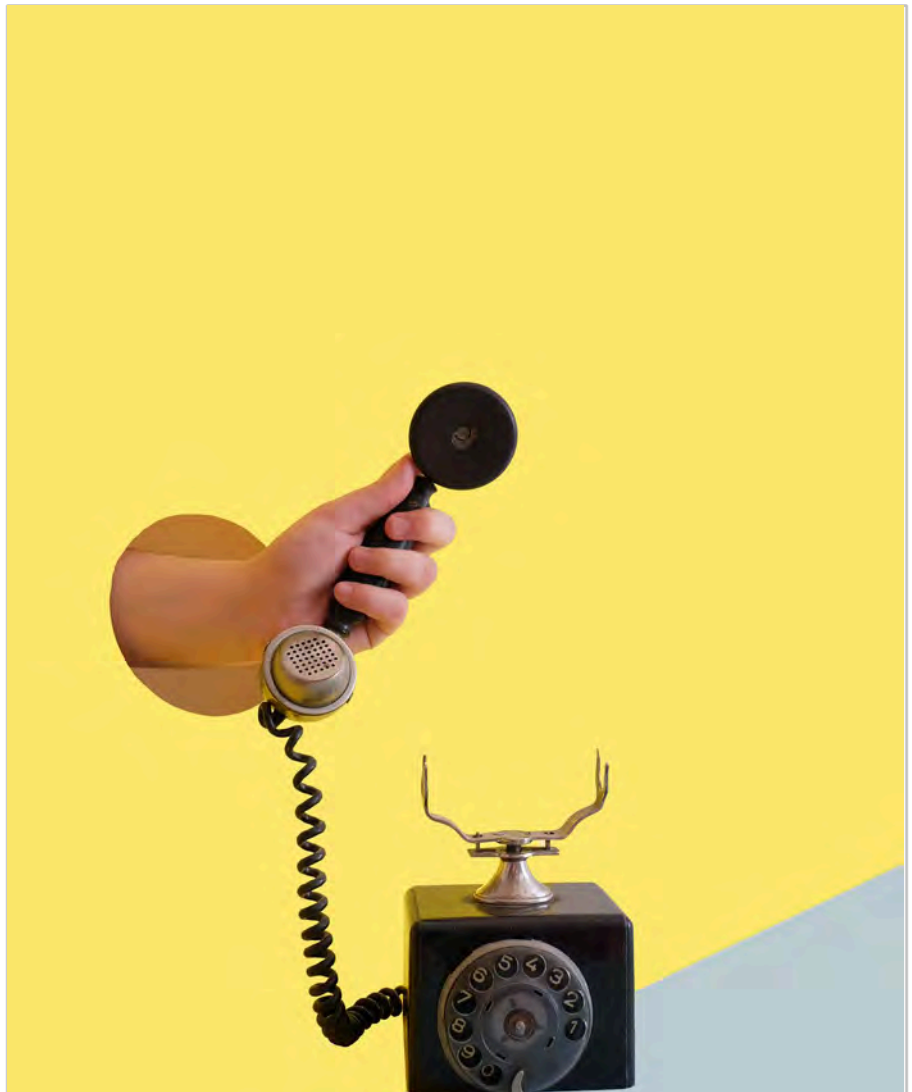
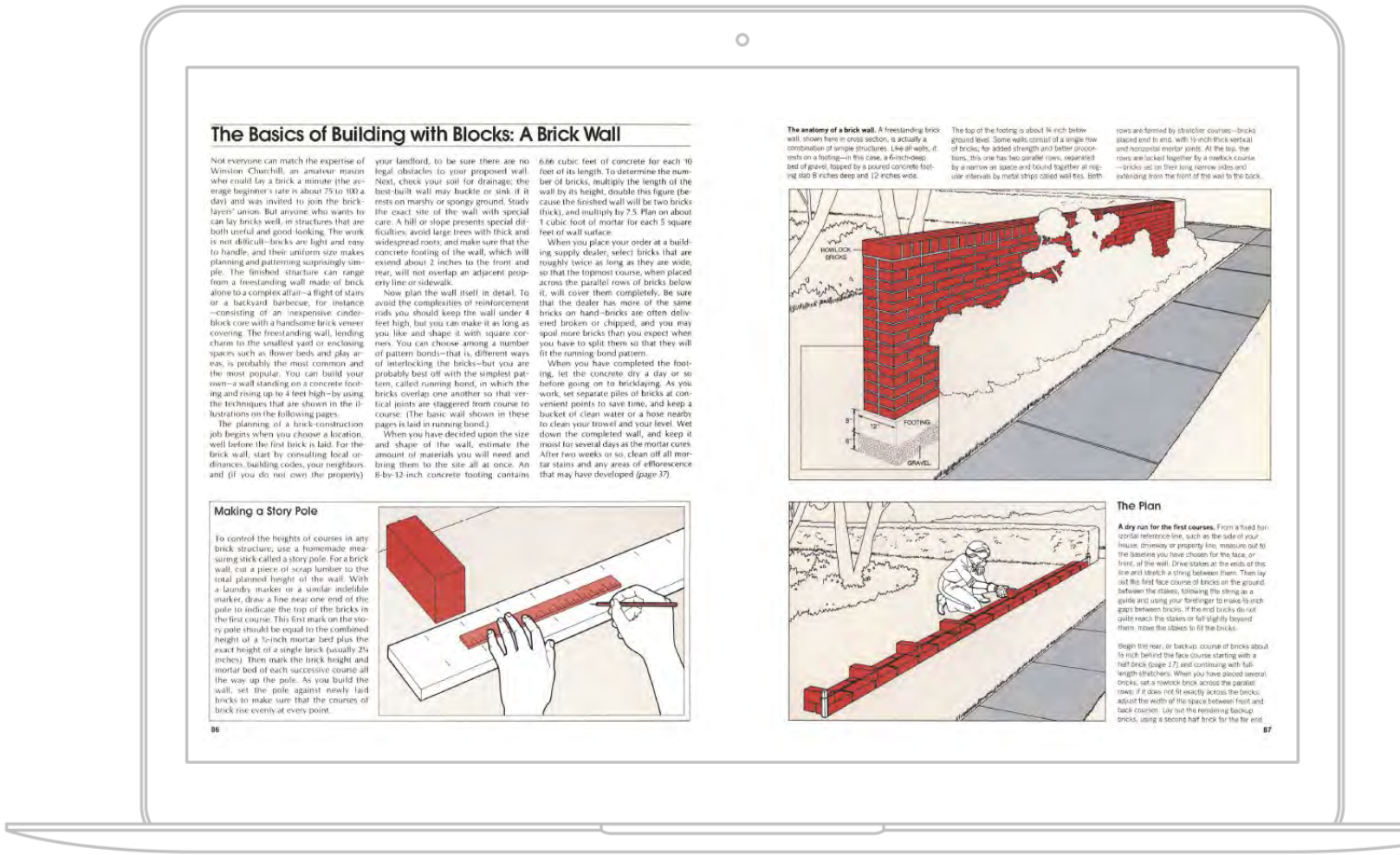


Photo by Elena Koycheva on Unsplash

1: Constructing a brick wall

Supporting material



The Basics of Building with Blocks: A Brick Wall

Not everyone can match the expertise of Winston Churchill, an amateur mason who could lay a brick a minute (the average beginner's rate is about 75 to 100 a day) and was invited to join the bricklayers' union. But anyone who wants to can lay bricks well, in structures that are both useful and good-looking. The work is not difficult—bricks are light and easy to handle, and their uniform size makes planning and patterning surprisingly simple. The finished structure can range from a freestanding wall made of brick alone to a complex affair—a flight of stairs or a backyard barbecue, for instance—consisting of an inexpensive cinder-block core with a handsome brick veneer covering. The freestanding wall, lending charm to the smallest yard or enclosing spaces such as flower beds and play areas, is probably the most common and the most popular. You can build your own—a wall standing on a concrete footing and rising up to 4 feet high—by using the techniques that are shown in the illustrations on the following pages.

The planning of a brick-construction job begins when you choose a location, well before the first brick is laid. For the brick wall, start by consulting local ordinances, building codes, your neighbors and (if you do not own the property) your landlord, to be sure there are no legal obstacles to your proposed wall. Next, check your soil for drainage; the best-built wall may buckle or sink if it rests on marshy or spongy ground. Study the exact site of the wall with special care. A hill or slope presents special difficulties; avoid large trees with thick and widespread roots, and make sure that the concrete footing of the wall, which will extend about 2 inches to the front and rear, will not overlap an adjacent property line or sidewalk.

Now plan the wall itself in detail. To avoid the complexities of reinforcement rods you should keep the wall under 4 feet high, but you can make it as long as you like and shape it with square corners. You can choose among a number of pattern bonds—that is, different ways of interlocking the bricks—but you are probably best off with the simplest pattern, called running bond, in which the bricks overlap one another so that vertical joints are staggered from course to course. (The basic wall shown in these pages is laid in running bond.)

When you have decided upon the size and shape of the wall, estimate the amount of materials you will need and bring them to the site all at once. An 8-by-12-inch concrete footing contains 6.66 cubic feet of concrete for each 10 feet of its length. To determine the number of bricks, multiply the length of the wall by its height, double this figure (because the finished wall will be two bricks thick), and multiply by 7.5. Plan on about 1 cubic foot of mortar for each 5 square feet of wall surface.

When you place your order at a building supply dealer, select bricks that are roughly twice as long as they are wide, so that the topmost course, when placed across the parallel rows of bricks below it, will cover them completely. Be sure that the dealer has more of the same bricks on hand—bricks are often delivered broken or chipped, and you may spoil more bricks than you expect when you have to split them so that they will fit the running-bond pattern.

When you have completed the footing, let the concrete dry a day or so before going on to bricklaying. As you work, set separate piles of bricks at convenient points to save time, and keep a bucket of clean water or a hose nearby to clean your trowel and your level. Wet down the completed wall, and keep it moist for several days as the mortar cures. After two weeks or so, clean off all mortar stains and any areas of efflorescence that may have developed *(page 37)*.

Making a Story Pole

To control the heights of courses in any brick structure, use a homemade measuring stick called a story pole. For a brick wall, cut a piece of scrap lumber to the total planned height of the wall. With a laundry marker or a similar indelible marker, draw a line near one end of the pole to indicate the top of the bricks in the first course. This first mark on the story pole should be equal to the combined height of a ½-inch mortar bed plus the exact height of a single brick (usually 2¼ inches). Then mark the brick height and mortar bed of each successive course all the way up the pole. As you build the wall, set the pole against newly laid bricks to make sure that the courses of brick rise evenly at every point.

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The anatomy of a brick wall. A freestanding brick wall, shown here in cross section, is actually a combination of simple structures. Like all walls, it rests on a footing—in this case, a 6-inch-deep bed of gravel, topped by a poured concrete footing slab 8 inches deep and 12 inches wide.

The top of the footing is about 14 inch below ground level. Some walls consist of a single row of bricks; for added strength and better proportions, this one has two parallel rows, separated by a narrow air space and bound together at regular intervals by metal strips called wall ties. Both rows are formed by stretcher courses—bricks placed end to end, with ½-inch thick vertical and horizontal mortar joints. At the top, the rows are locked together by a rowlock course—bricks set on their long narrow sides and extending from the front of the wall to the back.

ROWLOCK BRICKS

FOOTING

GRAVEL

The Plan

A dry run for the first courses. From a fixed horizontal reference line, such as the side of your house, driveway or property line, measure out to the baseline you have chosen for the face, or front, of the wall. Drive stakes at the ends of this line and stretch a string between them. Then lay out the first face course of bricks on the ground between the stakes, following the string as a guide and using your forefinger to make ½-inch gaps between bricks. If the end bricks do not quite reach the stakes or fall slightly beyond them, move the stakes to fit the bricks.

Begin the rear, or backup, course of bricks about ½ inch behind the face course starting with a half brick (page 17), and continuing with full-length stretchers. When you have placed several bricks, set a rowlock brick across the parallel rows; if it does not fit exactly across the bricks, adjust the width of the space between front and back courses. Lay out the remaining backup bricks, using a second half brick for the far end.

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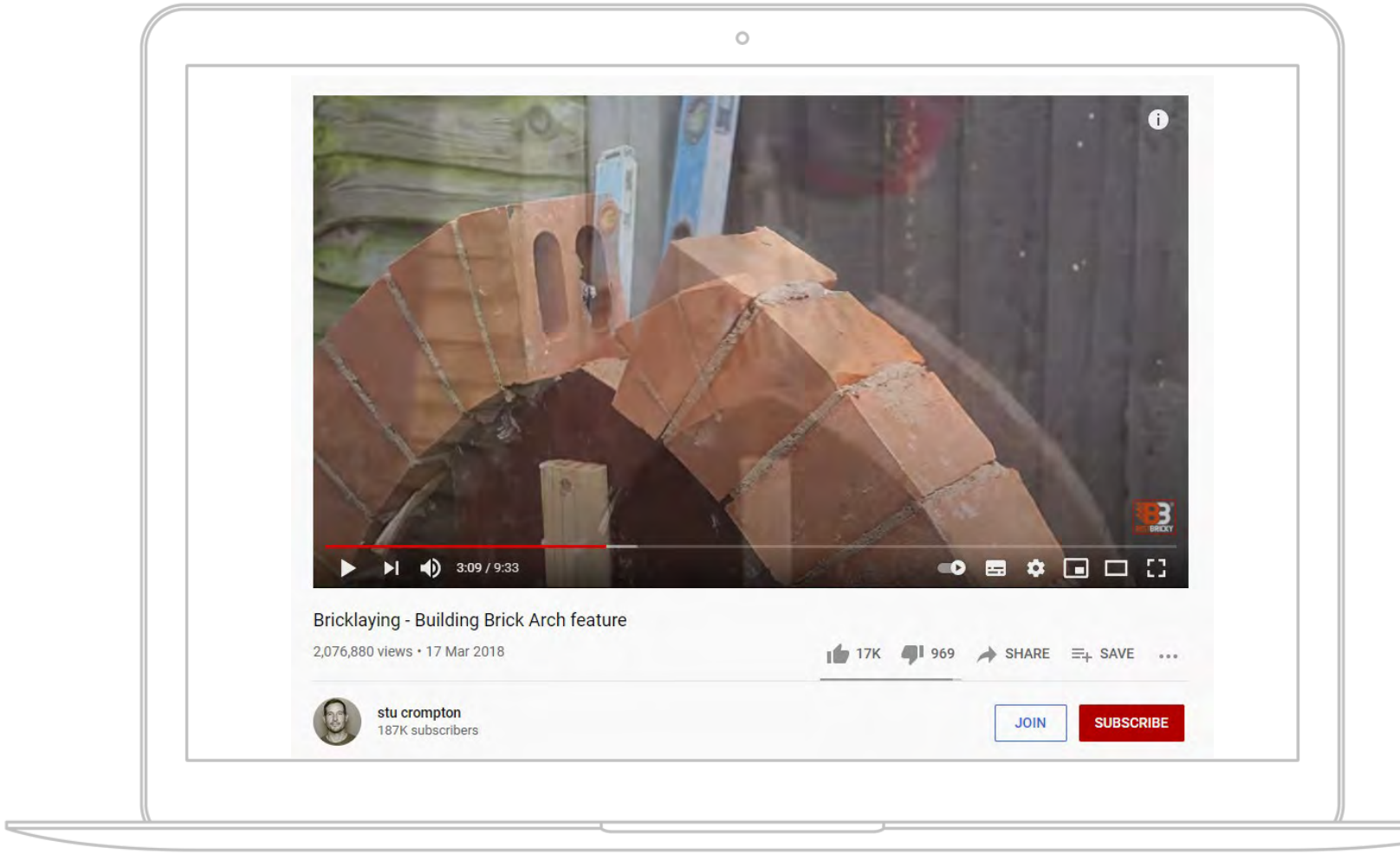
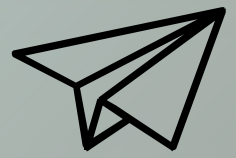
2: Constructing an arch

https://youtu.be/hrE599A_shA





3: Question-

What do we need to consider while designing masonry structure?

Post your short reflection here: https://miatedjosaputro.com/2021/04/07/as-week-6/

Re-iterating aims and objectives

- To gain understanding on masonry as **building materials** and its characteristics
- To learn about masonry as main **structural materials**
- To expand on masonrywithin **construction system**