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ABSTRACT

This independent, self-study course on masonry was developed from military sources for use in vocational education. The course provides basic instruction in the skills and knowledge required to enter the masonry trade. The course involves theory and is intended to be used with laboratory or on-the-job training. Some of the job skills included are making and using mixes for erecting structures; reinforcing concrete; mixing mortar for masonry units; using plastering tools and techniques; laying brick; recognizing the characteristics and the use of concrete and stone units; selecting and laying ceramic and quarry tile; and estimating material requirements. The course consists of the following three lessons covering seven chapters in the text: concrete mixes and structures; mortar, plaster, and clay brick; and concrete blocks, stone, tiles, and estimates. Each lesson contains an objective, lesson assignment in the text, and review exercises. The answers to the exercises are keyed to the text, and a discussion of the answers is also provided. A course examination of 30 multiple choice questions, without answers, is included in the packet. (KC)

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

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MASONRY

Table of Contents

Course Description:

This course provides basic instruction in the skills and knowledge required to enter the masonry trade. This course involves theory and should be used along with laboratory or on-the-job training. Some of the job skills, included are:

- Make and use mixes needed for erecting structures
- Reinforce concrete
- Mix mortar for masonry units
- Correctly use plastering tools and techniques
- Lay brick
- Recognize the characteristics and the use of concrete and stone units
- Select and lay ceramic and quarry tile
- Estimate material requirements

The course consists of three lessons covering seven chapters in the text.

Lesson 1 — *Concrete Mixes and Structures* provides information on types of cement, additives, aggregates, water, handling and storage of materials, water-cement ratio, consistency, trial method of mix design, mix design with entrained air, mixing, reinforced concrete, and concrete structures.

Lesson 2 — *Mortar, Plaster, and Clay Brick* discusses mortar for masonry units; mixing mortar, plaster bases; control joints; types, uses, and proportioning of plaster; mixing plaster; tools; application, curing, cleaning and brickwork; and bricklaying procedures.

Lesson 3 — *Concrete Blocks, Stone, Tiles, and Estimates* explains characteristics of concrete units; laying corner leads; laying blocks between corners; closure block; tooling; anchor bolts and control joints; intersecting bearing and nonbearing walls; requirements of good building stone; types of building stone; shape and finish; bonding and patterns; cleaning stone; manufacture, description, and uses of tile; wall tiling; floor tiling; care of tools and equipment; estimating concrete, mortar, brick, concrete block and tile, stone, ceramic and quarry tile.

This course is designed for student self-study and would be most effective in conjunction with laboratory or on-the-job training. Each lesson includes an objective, lesson assignment in the text and review exercises. The answers to the exercises are keyed to the text which is coded. A discussion of the answers is also provided. A course examination of 30 multiple choice questions is included but no answers are available.

Developed by:

United States Army

Development and Review Dates

Unknown

Occupational Area:

Building and Construction

Cost:	Print Pages
$2.50	121

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Text; student workbook with lesson objectives, assignments, and exercises with solutions and discussion; and course examination

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Masonry				
Lesson 1	–	Concrete Mixes and Structures	30	Flexible
Lesson 2	–	Mortar, Plaster, and Clay Brick	30	Flexible
Lesson 3	–	Concrete Blocks, Stone, Tiles, and Estimates	29	Flexible
Workbook			22	
Examination			4	

Supplementary Materials Required:

None

Expires July 1, 1978

ENGINEER
SUBCOURSE 535-1 3

MASONRY

CORRESPONDENCE COURSE PROGRAM

U.S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

3-4

MOS: 51D20

EDITION 1 (NRI 101)

INTRODUCTION

This subcourse provides basic instruction in the skills and knowledge required for entry into the MOS 51-D Career Field — Mason. Concrete mixes are treated in detail and the standards required for the efficient use of these materials in concrete structures are tabulated and explained. Mortar and plaster, together with plastering tools and their uses, are also discussed. Clay brick construction and the use of stone and concrete blocks are discussed, with emphasis on their proper handling and use. Ceramic and quarry tile are distinguished through an explanation of the procedures that must be followed in properly setting floor and wall tile. A section on estimating provides examples of how to estimate the amounts of materials and the length of time required to complete various masonry jobs.

This subcourse consists of three lessons and an examination as follows:

Lesson 1. Concrete Mixes and Structures.

2. Mortar, Plaster, and Clay Brick.

3. Concrete Blocks, Stone, Tiles, and Estimates.

Examination.

Eleven credit hours are allowed for this subcourse.

You will not be limited as to the number of hours that you spend on the subcourse, any lesson, or the examination.

Text furnished: Memorandum 535: Masonry.

Each exercise has four choices with only ONE best answer. Select the choice you believe is best. Compare your answer with the solutions provided in this subcourse packet.

When you have completed all lessons to your satisfaction, complete the examination and forward the examination answer card to the USAES for grading. The grade you receive on the examination is your grade for the subcourse.

5

LESSON 1

CONCRETE MIXES AND STRUCTURES

CREDIT HOURS ---------------------------3

TEXT ASSIGNMENT ----------------------Study chapters 1 and 2 in Memorandum 535.

LESSON OBJECTIVE ---------------------To teach you how to make and use the mixes needed for erecting structures and the methods of reinforcing concrete.

EXERCISES

Requirement: Solve the following multiple-choice exercises.

1. Aggregates are rejected if they contain more than

a. 1½ percent shale by weight

b. 3 and less than 10 percent of silt and fines

c. 1½ percent thin, flaky, elongated particles by weight

d. 5 percent by weight of all above aggregate.

2. When would you generally use type IV portland cement?

a. when less heat is required during hydration

b. for constructing a large dam

c. in cold weather because it hardens rapidly

d. for buildings, sidewalks, and bridges

3. Which of the following aggregates contains about ½ gallon of water per cubic foot?

a. moist sand

b. moist gravel

c. moderately wet sand

d. moderately wet gravel

4. What does "saturated surface dry" concrete mean?

a. saturated surface must be dried

b. saturate the dry surface

c. water-cement radio is 60/90

d. voids in aggregate are filled with water but surface is dry

5. What is the best abrasion-resisting medium for fine aggregate?

a. natural sand
c. granite
b. traprock
d. gravel

6. You used 1½ sacks of cement in a concrete mix. You want to accelerate the rate of hardening. How many pounds of flake calcium chloride do you add?

a. 1½
c. 6
b. 3
d. 9

6

7. What is the minimum amount of time that you would machine mix 54 cubic feet of concrete?

a. 40 seconds
b. 1 minute
c. 1½ minutes
d. 2 minutes

8. Which type of portland cement would you use for laying masonry units?

a. IV
b. III
c. II
d. I

9. What causes freshly placed concrete to harden?

a. aggregation
b. composition
c. agglutination
d. hydration

10. You must construct a concrete pavement four inches thick. What is the maximum size in inches for aggregate that you would use in the mix?

a. 4
b. 3
c. 2
d. 1

11. How long will cement retain its quality if it does not come into contact with moisture?

a. 2 months
b. 6 months
c. 1 year
d. indefinitely

12. What would be the probable compressive strength in psi of a concrete slab after 28 days if you had added 5 gallons of water per sack of the normal portland cement used in the mix?

a. 1000
b. 2000
c. 4000
d. 5000

13. You have made a mixture of aggregate and hot water. Below what temperature should this mix be before you add the cement?

a. 80° F
b. 90° F
c. 100° F
d. 120° F

14. Concrete placed below what air temperature is classified as cold-weather concrete?

a. 50° F
b. 40° F
c. 30° F
d. 0° F

15. What is the maximum spacing in feet of the contraction joints for sidewalks and driveways?

a. 10
b. 20
c. 25
d. 35

16. You are constructing a permanent cement concrete slab at an air temperature between 40° and 50° F. How many days would be required at 50° F for curing this concrete?

a. 1
b. 3
c. 5
d. 7

17. Inclined ramps can be used for transporting concrete by buggy when the elevation in feet between the mixing and the placing is not more than

a. 13
b. 14
c. 15
d. 16

18. What joint would you use when constructing a nonreinforced concrete wall?

a. expansion
b. V-joint
c. contraction
d. keyway

19. What is the maximum temperature for heating water to warm concrete during cold weather concreting?

a. 90° F
b. 120° F
c. 145° F
d. 165° F

20. When you are placing concrete in high walls, what would be the maximum depth in inches of each separate layer that you would deposit?

a. 6
b. 8
c. 10
d. 12

7

LESSON 2

MORTAR, PLASTER, AND CLAY BRICK

CREDIT HOURS 3

TEXT ASSIGNMENT ....Study chapters 3 and 4 in Memorandum 535.

LESSON OBJECTIVE ....To teach you how to mix mortar for masonry units, the use of plastering tools and techniques, and how to lay brick.

EXERCISES

Requirement: Solve the following multiple-choice exercises.

1. You find a structural crack close to a corner bead lath in a completed plaster job. What most likely caused that crack?

a. scratch coat too thick

b. brown coat too thick

c. finish coat too thick

d. lath had been nailed to superstructure

2. What is the maximum number of feet that you would space the control joints for walls and ceilings when you work on plaster or stucco surfaces?

a. 10 | c. 20
b. 15 | d. 25

3. What is the minimum number of hours that you would moist-cure the brown coat of plaster when the air temperature is above 50° F?

a. 24 | c. 60
b. 48 | d. 70

4. You are about to apply the brown-coat layer of plaster. What is the minimum thickness for this layer?

a. 3/8 inch | c. 1/2 inch
b. 1/4 inch | d. 5/8 inch

5. You have put the dry plaster ingredients into a power mixer and have added the required amount of water. What is minimum number of minutes that you would mix the materials?

a. 2 | c. 4
b. 3 | d. 5

6. What is the minimum combined thickness of a three-coat application of plaster?

a. 1 1/2 inches | c. 3/4 inch
b. 1 inch | d. 1/2 inch

7. What could happen if you applied a new stucco surface over a weathered masonry surface?

a. plaster dries and cracks

b. final finish is potted

c. poor mechanical bond

d. stucco stiffens and is difficult to work

8

8. You are about to use 60 pounds of portland cement to plaster a surface. You decide to use hydrated lime as a plasticizer. What is the maximum number of pounds of lime that you would add?

a. 6 c. 4
b. 5 d. 3

9. When you nail metal lath to exterior walls, what is the minimum space that you leave between the wall and the lath?

a. ¼ inch c. ¾ inch
b. ½ inch d. 1 inch

10. What is the largest size aggregate that you would use in a well-graded plaster mix?

a. 1/16 inch c. ¼ inch
b. ⅛ inch d. ½ inch

11. What is the minimum size of the brick that you set in a wall corner?

a. a brick length
b. ¾ of a brick length
c. a brick width
d. ¼ of a brick width

12. What type of mortar joint would you be finishing if you used a convex jointer as shown in figure 99 of the text?

a. flushed c. raked
b. weathered d. flush concave

13. You place a good quality brick into a container of water for 24 hours. What is the maximum percent of its dry weight that the brick would absorb in moisture?

a. 15 c. 25
b. 20 d. 30

14. You are about to mix hydrochloric acid and water in order to clean mortar stains off brick. In what ratio do you mix the acid and water?

a. 9 parts acid to 1 part water
b. 7 parts acid to 1 part water
c. 1 part acid to 7 parts water
d. 1 part acid to 9 parts water

15. What is the pitch per foot of run that you give to the bricks that you lay to make a window sill?

a. 1 inch c. ½ inch
b. ¾ inch d. ¼ inch

16. You are forming horizontal mortar joints. How thick do you make the mortar bed for them?

a. 1 inch c. ⅜ inch
b. ½ inch d. ¼ inch

17. What is the average size in inches of a fire brick?

a. 2¼ x 3⅝ x 8
b. 2¼ x 4½ x 9
c. 2¼ x 3¾ x 8
d. 2¼ x 3 [illegible]/8 x 8

18. You are tying a 4-inch facing of brick to an old wooden frame structure. What is the minimum number of inches that you must widen the foundation?

a. 12 c. 6
b. 8 d. 4

19. What is the minimum number of inches that common brick should overlap one another?

a. 2 c. 6
b. 4 d. 8

9

20. Specifications require that you construct a brick wall that will be strong and have watertight joints. Which of these joint sizes do you select?

a. 1/16 inch

b. 1/8 inch

c. 5/16 inch

d. 3/8 inch

2—3

10

LESSON 3

CONCRETE BLOCKS, STONE, TILES, AND ESTIMATES

CREDIT HOURS 3

TEXT ASSIGNMENT .... Study chapters 5, 6, 7 in Memorandum 535.

LESSON OBJECTIVE .... To teach you the characteristics and use of concrete and stone units, how to select and lay ceramic and quarry tile, and how to estimate material requirements.

EXERCISES

Requirement: Solve the following multiple-choice exercises.

1. What is the minimum number of inches that vertical joints in stone walls should lap one another?

a. 4 c. 8

b. 6 d. 9

2. Which of the following bolt-size diameters is recommended for anchoring the tops on concrete block structures?

a. ¼ inch c. ¾ inch

b. ½ inch d. 1 inch

3. A concrete unit has been laid in a wall with 3/8"-inch mortar joints and exactly fills a space 8" x 8" x 16". What is its exact size?

a. 7⅝" wide 7⅝" high and 15⅝" long

b. 8" wide 8" high and 16" long

c. 7¾" wide 7¾" wide and 15¾" long

d. 8⅛" wide 8⅛" high and 15⅛" long

4. Why do you place a straightedge diagonally across the corners of the blocks when raising a concrete corner?

a. to check grade

b. to make certain the blocks are plumb

c. to check horizontal spacing of blocks

d. to get proper perpendicular spacing

5. How many quarts of sulfuric acid would you add to 10 gallons of water for cleaning white mortar stains off stone surfaces?

a. 5 c. 3

b. 4 d. 2

6. You are constructing a concrete block wall. What do you do to control cracking?

a. use control joints

b. apply calking compound

c. seal corners with tar

d. use only full-length blocks

7. What kind of stone would you use for roof facing?

a. lime stone
b. sand stone
c. slate
d. granite

8. You are constructing a rubble wall 50 feet long and 8 feet high. What should be the minimum thickness in feet of this wall?

a. 6
b. 4
c. 3
d. 2

9. Which of the following would be your guide in building a plumb rubble wall erected to a line?

a. lay each stone on its narrowest face
b. smaller stones should be in the lower courses
c. stone size should increase toward top of wall
d. lay each stone on its broadest face

10. You are using the buttering method to apply the neat coat of mortar to the tiles that will be set into the wall surface. Approximately how thick do you make this neat coat?

a. 3/8 inch
b. 1/4 inch
c. 1/8 inch
d. 1/16 inch

11. In setting quarry tile, about how thick would you make the mortar bed into which you set the tile?

a. 3/4 inch
b. 1/2 inch
c. 1/4 inch
d. 1/8 inch

12. After grouting the joints, they should be washed and smoothed to an even depth below the surface of the tile. What is this depth?

a. 1/32 inch
b. 1/16 inch
c. 1/8 inch
d. 1/4 inch

13. Which of the following joint sizes is normally used when setting quarry tile?

a. 1/8 inch
b. 1/4 inch
c. 1/2 inch
d. 3/4 inch

14. You are setting ceramic tile. You would apply the tile adhesive to an area no larger than you could cover with tile in

a. 2 minutes
b. 10 minutes
c. 54 minutes
d. 1 hour

15. What is the minimum amount of time that you would allow ceramic mosaic tile to set before you remove the kraft paper from it?

a. 10 minutes
b. 20 minutes
c. 30 minutes
d. 1 hour

16. You are using the plaster method of setting tile. What would be the minimum thickness of the scratch coat that you apply?

a. 1/8 inch
b. 1/4 inch
c. 3/8 inch
d. 1/2 inch

17. How many bags of cement would you need to mix 50 cubic feet of concrete using a 1:3:6 ratio?

a. 2
b. 4
c. 6
d. 8

18. How many standard size concrete blocks would you need to cover the surface of a 100-square-foot area?

a. 113
b. 110
c. 100
d. 90

19. How would you determine the number of rubble stone needed for 1 cubic yard of wall?

12

a. count them

b. by weight

c. by wall length

d. by wall height

20. You are assigned the task of tiling three walls of a room using 6" x 6" glazed ceramic wall tile. Each wall is 12 feet long and 8 feet high, but the specifications for the job state that each wall will be tiled only half way to the ceiling. How many tiles (not including breakage) do you need to complete this job?

a. 450

b. 500

c. 576

d. 580

14

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 535-1 . . . . Masonry.

LESSON 1 . . . . Concrete Mixes and Structures.

SOLUTIONS

Each exercise has a weight of 5. References are to Memorandum 535.

1. *d* (par 3-2)
2. *b* (par 1-5)
3. *c* (par 8-4(2))
4. *d* (par 6-3)
5. *a* (par 3-6)
6. *b* (par 2-3)
7. *c* (par 10-4)
8. *d* (par 1-2)
9. *d* (pars 1-3, 4)
10. *d* (par 3-3)
11. *d* (par 5-2)
12. *d* (par 6-1, table I)
13. *a* (par 12-42)
14. *a* (par 12-39)
15. *b* (par 12-29)
16. *c* (par 12-39)
17. *c* (par 12-9)
18. *b* (par 12-14)
19. *d* (par 12-42)
20. *d* (par 12-18)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

(NRI 101) EDITION 1

15

DISCUSSION

Exercise:

1. If all the materials mentioned in the exercise are present in the aggregate, their combined amount may not exceed **5 percent by weight of the combined aggregate** (d).

2. Type IV is a low-heat portland cement that generates a relatively small amount of heat while hydrating. It is used in large masses of concrete, such as **a large dam** (b).

3. Very wet sand contains ¾ to 1 gallon of water per cubic foot. Moist sand or gravel has about ¼ gallon, and **moderately wet sand** (c) has about ½ gallon of water per cubic foot.

4. The term "saturated surface dry" implies that the voids **in the aggregate are filled with water and the surface of the aggregate is dry** (d).

5. The abrasion-resisting medium in concrete is the aggregate. Traprock, gravel, and granite are usually the best materials for coarse aggregate, but **natural sand** (a) is better for fine aggregate.

6. There are two types of calcium chloride: flake and pellet. When you use the flake type, about 2 pounds of the calcium chloride are recommended per sack of cement; therefore, 3 (b) pounds of flake calcium chloride should be used.

7. Specifications usually require concrete to be mixed a minimum time of one minute for the first cubic yard, and an additional 15 seconds for each additional one-half cubic yard. 54 cu ft = 2 cu yd = 1½ **minutes** (c).

8. Type I (d) is normal portland cement and is used generally for pavements, sidewalks, and for laying brick, block, and for plastering.

9. Reaction between cement and water called **hydration** (d) results in the setting and hardening of the cement paste.

10. Normally, the maximum size of aggregate in the mix should not exceed 2 inches, and the largest particles should not be over **one-fourth the pavement thickness.** (d).

11. Sacks should be stored on a raised platform to prevent rain or water from reaching the bottom sacks. Cement which does not come into contact with moisture will remain its quality **indefinitely** (d).

12. Table I gives the quantity of water to be used for concrete of a desired strength. If 5 gallons of water per sack of cement were added, the compressive strength after 28 days would be **5000** psi (d). Note that the more water used, the less strength of the concrete.

13. The temperature of the water should never exceed 165°F. Mix the hot water with the aggregate so that the mix temperature will be below **80° F** (a) before you put in the cement.

14. Concrete placed when the air temperature is less than **50°F** (a) is classified as cold-weather concrete, and cold-weather precautions must be taken.

16

15. In sidewalks and driveways, contraction joints should be spaced at intervals equal to the width of the slab, but never more than 20-foot (b) intervals. It is good practice to use a straight board as a guide.

16. For permanent construction, the placed concrete must be cured at a temperature of 50° F for 5 days (c). If high-early-strength cement is used, the curing period would be 3 days at 50° F.

17. When concrete is to be elevated less than 15 feet (c) above ground, buggies of 2 to 3 cubic feet can be pushed up ramps to the placing level. Larger ones are too heavy to push up the incline.

18. The construction joint is used generally with reinforcing steel running from one section to the next, but when reinforcing steel is not used, it is better to use a **V-joint** (b).

19. The temperature of water should never exceed 165°F (d) because of the danger of causing a quick flash set of the cement.

20. When placing concrete in high walls, you should deposit it in level layers, not more than 12 inches deep (d). Each layer should be spaded just enough to make the concrete settle thoroughly before adding the next layer.

1—3

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 535-1 . . . . Masonry.

LESSON 2 . . . . Mortar, Plaster, and Clay Brick.

SOLUTIONS

Each exercise has a weight of 5. References are to Memorandum 535.

1. *d* (par 14-8)
2. *c* (par 14-12)
3. *b* (par 14-36)
4. *a* (par 14-34)
5. *d* (par 14-23)
6. *c* (pars 14-33, 34, 35)
7. *d* (par 14-9)
8. *a* (par 14-18)
9. *a* (par 14-5)
10. *b* (par 14-21)
11. *c* (par 16-20)
12. *d* (par 17-12)
13. *a* (par 15-4)
14. *d* (par 17-22)
15. *c* (par 16-23)
16. *d* (par 16-29)
17. *b* (par 15-1)
18. *b* (par 16-16)
19. *a* (pars 15-1, 16-3)
20. *d* (par 17-11)

For further explanation, see Discussion.

18

DISCUSSION

Exercise:

1. Be sure that the corner lath is not **fastened by nailing it through** to the superstructure (d), because this stress will be transmitted directly into the plaster, and cause it to crack.

2. Walls and ceilings should be divided into rectangular panels with control joints spaced a maximum of 20 feet (c) apart. This procedure will control cracking in plaster and stucco surfaces.

3. All three coats of plaster must be moist-cured for at least 2 days (**48 hours**) (b) at a temperature above 50° F.

4. The brown coat consists of a layer of plaster not less than ⅜ inch (a) thick. You apply and finish the brown coat in the same manner as the scratch coat.

5. You should mix the materials for a minimum of 5 (d) minutes after the water is added to the dry materials.

6. The scratch coat has a minimum thickness of ¼ inch, the brown coat ⅜ inch, and the finish coat ⅛ inch, or a minimum thickness of ¾ **inch** (c) for the three coats.

7. Weathered masonry surfaces may have too much suction. When you apply plaster to this type of surface, the **plaster stiffens and becomes difficult to work** (d).

8. Hydrated lime may be added to the mix to make it more workable. The amount added should not exceed 10% by weight or 25% by volume of the cement used. Therefore, 60 × .10 = 6 (a) pounds of lime would be required.

9. Furring nails hold the steel lath in place. There should be a minimum space of ¼ inch (a) between the structure and the reinforcing steel lath.

10. Sand for plaster ~~should be~~ graded with particles (maximum size, ⅛ **inch**) (b) ranging from coarse to fine.

11. The end brick should never be less than a **brick width** (c). When arranging brick in a corner, you must take both walls into consideration.

12. You can form a **flush concave** (d) joint (fig 99) by compressing the mortar in the joint with a convex jointer.

13. A characteristic of good quality brick is that it will not absorb more than 10 to 15 (a) percent of its dry weight in moisture when placed in a container of water for 24 hours.

14. To remove mortar stains from the brick use a solution of hydrochloric acid and water. The ratio of the mix 9:1, **nine parts water to one part acid** (d). Always add the acid to the water because acid reacts violently when water is added to it.

15. Bricks in sills are usually laid on edge at a pitch or incline equal to ½ **inch** (c) per foot of run.

2—2

16. When making bed joints, spread the mortar (about 1 inch (a) thick) uniformly over the top of the foundation or the lower brick course.

17. Bricks are made in several sizes but fire brick is ordinarily made 2¼ x 4½ x 9 (b) inches.

18. In facing old frame structures, an additional 8 inch (b) thickness of new foundation is extended below ground against the old foundation to support the brick.

19. In bricklaying, the practice is to make a brick lap other bricks ¼, ⅓, ½ or ¾ of its length, but a brick should not lap another brick by less than ¼ brick length or a minimum of 2 (a) inches ($8 \times \frac{1}{4} = 2$).

20. Common thicknesses of mortar joints range from ⅛ inch to ½ inch. Of these the ¼ and ⅜ inch (d) joints are used the most because they are strongest and most water resistant.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 535-1 . . . . Masonry.

LESSON 3 . . . . Concrete Block and Stone Tiles and Estimates.

SOLUTIONS

Each exercise has a weight of 5. References are to Memorandum 535.

1. *a* (par 19-9)
2. *b* (par. 18-13)
3. *a* (par 18-3)
4. *c* (par 18-9)
5. *d* (par 19-16)
6. *a* (par 18-14)
7. *c* (par 19-7)
8. *b* (par 19-9)
9. *d* (par 19-11)
10. *d* (par 21-6)
11. *c* (par 22-4)
12. *a* (par 21-16)
13. *c* (par 22-5)
14. *b* (par 21-18)
15. *c* (par 21-20)
16. *b* (par 21-4)
17. *d* (table 4, page 97)
18. *a* (table 6, par 27-1)
19. *a* (par 28-1)
20. *c* (par 29-1)

For further explanation, see Discussion.

21

DISCUSSION

Exercise:

1. The lap of vertical joints should be at least 4 inches (a). Vertical joints in a stone course should be staggered with the vertical joints in the courses above and below it.

2. Anchor bolts come in various sizes, but the size recommended is ½ inch (b) diameter and 18 inches long.

3. Unit sizes are usually determined by their nominal dimensions. In other words, a unit measuring 7⅝" wide, 7⅝" **high and 15⅝ inches long** (a) is considered 8" x 8" x 16" inches and would exactly fill such a space when the unit was placed in a wall.

4. When building corners, each course is stepped back a half block. You can check the **horizontal spacing of blocks** (c) by placing straightedge diagonally across the corners of the blocks.

5. A 5-percent phosphoric acid-water solution or a 5-percent sulphuric acid water solution should be used when the stone or the mortar is white (10 gal = 40 qts × .05 = 2 (d).

6. **Control joints** (a) are used to control cracking in masonry walls. These joints are vertical and are built into walls at points of possible stress.

7. Slates are composed chiefly of clay and sand. **Slate** (c) is in laminated form, can be split into sheets, and cut to size for roof facings.

8. The thickness of a rubble wall should be at least one-half its height. 8 ft × ½ = 4 ft (b) thick.

9. The larger stones should be placed in the lower courses, and **each stone must be laid on its broadest face** (d).

10. When the buttering method is used, about **1/16 inch** (d) of mortar is applied to the back of each tile. At least 60 percent of the back of each tile is covered with mortar.

11. Quarry tile is set in a bed of cement mortar about **¼ inch** (c) thick, consisting of a mixture of 1 part portland cement to 3 parts building sand.

12. Finish smoothing off the joints by gently rubbing over them with a damp cloth. Bring all joints to an even depth of **1/32 inch** (a) below the surface of the tiles.

13. Normally, **½ inch** (c) joints are used between quarry tiles, so set the remaining tiles in the first row ½ inch apart, using small pieces of of wood as spacers.

14. Most tile adhesives will set up in about **10 minutes** (b), so do not apply the tile adhesive to an area larger than you can finish in that time.

15. After the tile sheets have set in the adhesive for a minimum of **30 minutes** (c) you may remove the kraft paper from the top of the tiles.

16. Apply the scratch-coat mortar to the lath or clean concrete or plastered wall according to the specifications, but in no case less than ¼ inch (b) thick.

17. Using table 4, you follow the 50 cubic feet in the first column over to the 1:3:6 ratio, where 8 (d) bags of cement are shown as needed for this amount of mix.

18. The standard size concrete block is 7⅝" x 7⅝" x 15⅝", and from table 6 we get 112.5 units for the area, or 113 (a) blocks.

19. The number of rubble stones contained in one cubic yard depends upon the various sizes of the stones; therefore, if the average number of stones contained in a cubic yard must be known, the stones will actually have to be counted (a).

20. $12 \times 8/2 = 48$ sq ft per wall; 3 walls = 144 sq ft; $144 \times 4 = 576$ (c) tiles required.
4 (6" × 6") tiles = 1 sq ft

3—3

24

MEMORANDUM 535-1

MASONRY

U.S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

3-4

MOS: 51D20

EDITION 1 (NRI 101)

PREFACE

THE ARMY operates many installations located throughout the world. To accomplish its mission, there must be suitable living and working quarters constructed on these locations, and these structures must be properly maintained and repaired. In many cases, the actual construction is done by commercial contractors, but the maintenance and repair are carried on by personnel under the direction of the facilities engineer.

As a mason, your part of the overall construction, maintenance, and repair program will be with structures built of masonry materials.

This memorandum will give you the knowledge needed to meet the skill level demanded of a mason. By carefully studying this memorandum and the illustrations presented in it, you will quickly acquire the knowledge needed to accomplish each assignment.

Keep this memorandum for your own use.

26

CONTENTS

32

Materials and Concrete Mixes

THIS CHAPTER covers the materials and concrete mixes you must know to perform your duties properly. Upon completion of this chapter, you will know what ingredients to use in a concrete mix and how to properly proportion them to meet job specifications.

NOTE: There will be a number of new terms (terms of the trade) used in the text. These are explained wherever they are first used in the text, and they are also covered in the explanation of terms located in the glossary.

1. Types of Cement

1. Portland cement (manufactured in the United States) derives its name from Portland, England, where the process for making it originated. This cement is available in five different types, ranging from type I to type V.

2. Type I, normal portland cement, is most generally used for pavements, sidewalks, buildings, and bridges. It is also used for laying brick, block, and for plastering.

3. Type II, modified portland cement, generates less heat during hydration (reactions between cement and water result in the setting and hardening of the cement paste) than type I and is used for structures of considerable size.

4. Type III, high-early strength portland cement, is used when high strength is desired at a very early period. In cold-weather construction, the time required for protection against freezing is reduced. Type III cement is manufactured so that it attains normal 3-day strength in 1 day, 7-day strength in 3 days, and 28-day strength in 7 days. This is illustrated in figure 1. The evolution of heat during hydration is also accelerated. Normally, this cement is not used in large-scale operations since it is more expensive than ordinary portland cement.

5. Type IV, low-heat portland cement, generates a relatively small amount of heat while hydrating. It is intended for use in large masses of concrete, such as large dams.

6. Type V, sulphate-resistant portland cement is intended for use where the concrete will be in contact with soil or water of high alkali content.

7. The properties of any of these types of cement can be changed by the addition of certain chemicals or other materials.

8. Alumina cements, derived from bauxite ore, have a high alumina content. The high-early strength of alumina cements offers an advantage for cold-weather operation because of the rapid rate of hardening and the considerable chemical heat produced while the cement is developing its set. Concrete made with high alumina cement becomes as hard in 24 hours as normal portland cement concrete becomes in 28 days.

2. Additives

1. As you will see in the following discussion, it is often desirable to have either a concrete which contains billions of tiny air pockets or a concrete which will harden at a very rapid rate. Either of these effects may be obtained by the addition of certain materials to the cement.

2. **Air-Entraining.** Air-entrained cement is any cement in which an air-entrainment agent (see glossary at the end of memorandum) has been incorporated. This is done by blending the agents with the cement during manufacturing or by adding them at the mixing site. If mixed at the site, the agent is added to the mixing water. Manufactured air-entraining cements are indicated by the letter "A" in the type number (type IA, type IIA, type IIIA, etc.). Concrete made with this cement contain billions of extremely small, entirely separated air bubbles per cubic foot of the concrete, and these bubbles act very similarly to sand. The air volume is approximately 4 percent of the total volume. The presence of these air bubbles makes the concrete more resistant to freezing action. Although some reduction of strength results from the entrainment of air, this reduction is some-

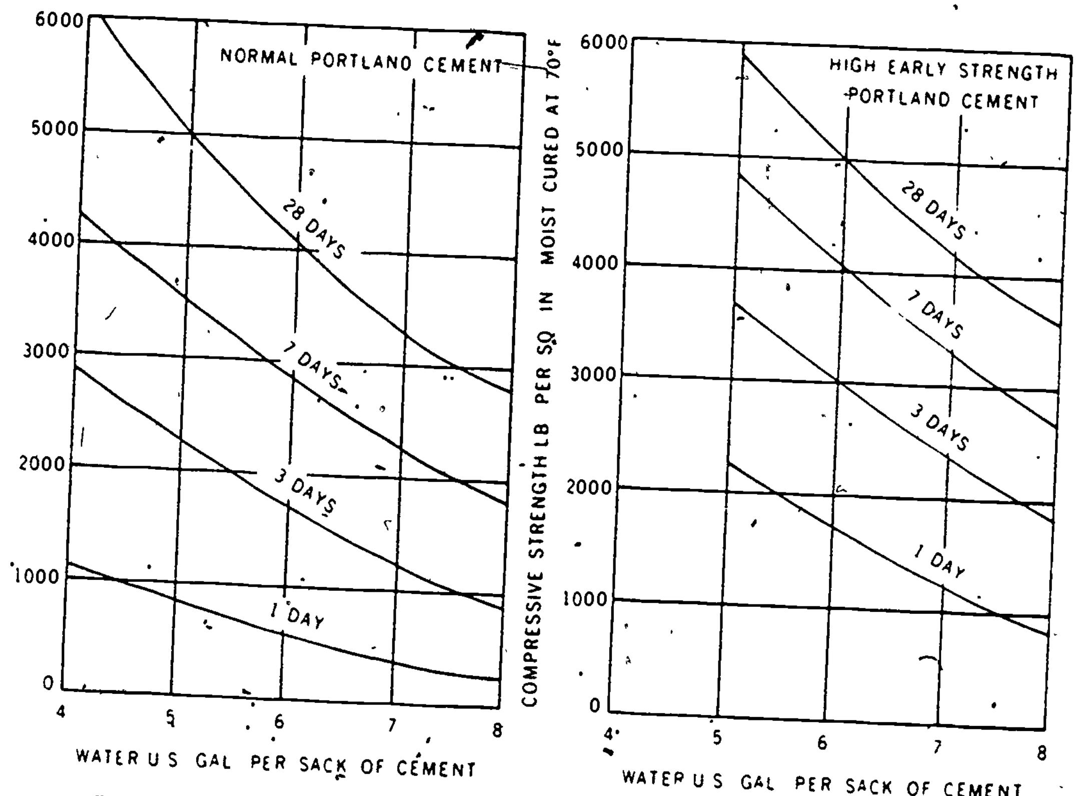


Figure 1. Age-strength relations for normal and high-early strength portland cement.

what offset by the reduction of the water-cement ratio. In other words, you can mix at least ½ gallon less water per sack of cement and still maintain the same workability. Air-entrainment is especially useful in severe climates where the concrete is exposed to weathering, particularly the freezing and thawing cycles.

3. **Hardening Acceleration.** The addition of calcium chloride (a crystalline compound used in its dry state as a drying agent) to a concrete mix accelerates the rate of hardening. This is an added advantage in cold-weather operations because the period during which the concrete must be protected from freezing is shortened. However, if used in warm weather, there is the probability of flash set (rapid hardening of the concrete). There are two types of calcium chloride: flake and pellet. Two percent of the flake type or 1.6 percent of the pellet type (by weight of the cement used) is generally the maximum amount to use. When you use the flake type, approximately 2 pounds of calcium chloride per sack of cement is recommended. However, if close control of hardening is desired, tests should be made to determine the amount of agent to use, because the acceleration effect is not the same for all cements.

3. Aggregate

1. Concrete aggregates are strong, durable, and chemically inert materials which constitute the major bulk of the concrete. They should consist of clean, uncoated particles having a good distribution between size limits. Materials commonly used as concrete aggregates are natural sands and gravels, crushed rock, crushed slag, or other similar materials.

2. **Harmful Substances.** Normally, aggregates are rejected or reprocessed if they contain soft, friable soils (that are easily crumbled, or pulverized), thin, flaky, elongated, or laminated particles totaling more than 3 percent by weight or shale in excess of 1½ percent by weight. Silt and fines (particles smaller than sand) should be held between the limits of 3 and 10 percent passing a Nr. 100 sieve (100 holes per square inch). A set of sieves is shown in figure 2. If all of these types of materials are present, their combined amount may not exceed 5 percent by weight of the combined aggregate. Clay, silt, and rock dust are very harmful because they reduce the strength and durability of concrete by inhibiting the proper bond between the cement and aggregate particles.

3. **Gradation.** Gradation of aggregate is a major factor in the workability, water requirement, and strength of concrete. Normally, the

29

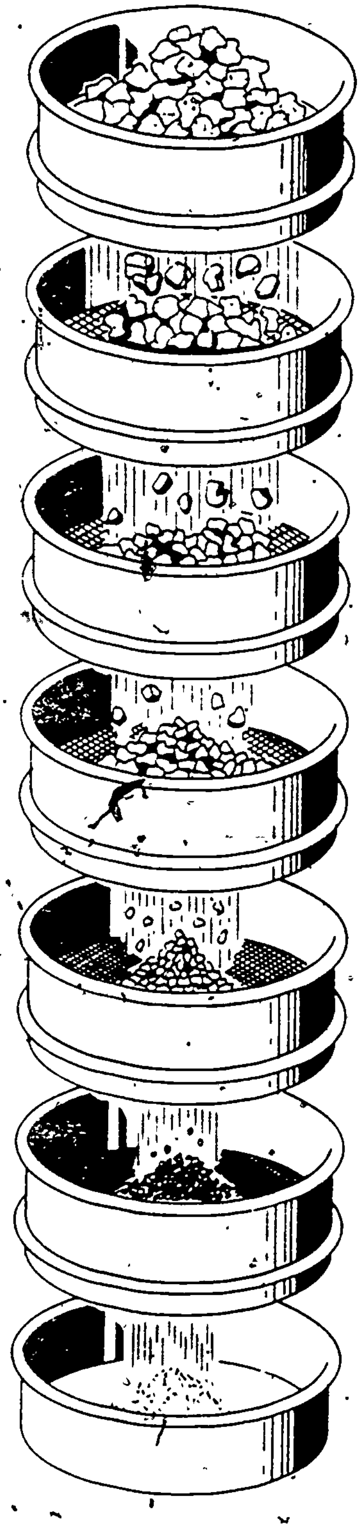


Figure 2. Set of sieves

maximum size of aggregate should not exceed 2 inches, and the largest particles should not be over one-fourth the pavement thickness. Fine and coarse aggregates are normally separated on the Nr. 4 sieve. Those passing through the sieve are classified as fine aggregates and those remaining are coarse aggregates. The fine and coarse aggregates are handled separately to permit adjusting the proportion of each to produce a dense and workable mixture. The gradation of the coarse aggregate is not too important but the gradation of the fine aggregate is very important, and the requirements given in the specifications should be followed. No universally accepted standard for gradation requirements has been developed; therefore, no aggregate will be rejected solely because its gradation does not meet some established standard.

4. **Physical Properties.** Specific gravity, absorption, and moisture content of aggregate are the important properties considered in designing concrete mixes. The specific gravity is used to determine the voids in the component. The average specific gravity of sand, gravel, and limestone is 2.65; the average value for granite is about 2.70; and for traprock about 2.95. The personnel responsible for making the test of specific gravity and absorption of aggregate should follow the procedure outlined in *Design and Control of Concrete Mixtures*, published by the Portland Cement Association.

5. The absorption capability and moisture content are used to obtain the water-cement ratio. The absorption capability is also used to detect soft aggregate. Traprock and granite absorb water to the extent of about ½ percent of their dry weight; good average sand, gravel, and limestone absorb about 1 percent; and porous sandstone absorbs about 7 percent. In very light, porous aggregate, the absorption may be as high as 25 percent. Aggregate which absorbs more than 1½ percent by weight after 24-hour submergence in water at 70° F. is checked for durability by comparative freezing and thawing tests if it is to be used in an area where freezing occurs.

6. **Composition.** The abrasion-resisting medium in concrete is the aggregate. Traprock, gravel, and granite are usually the best materials for coarse aggregate and natural sands are better for fine aggregate.

7. **Organic Impurities.** Natural sands sometimes contain organic materials, usually from decayed leaves and other plant life, which are detrimental to the hardening of concrete. The sand should be tested to determine the amount of these impurities. Two methods of testing for organic content can be used on the job. One test is known as the quart-jar method. Place 2 inches of sand in a quart jar and add water until the

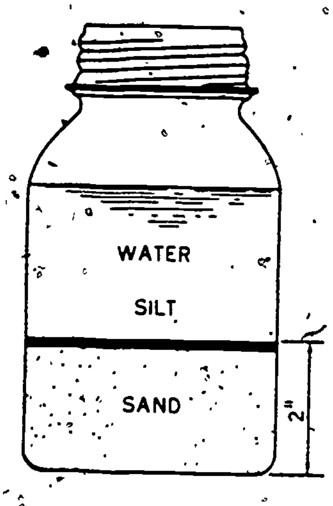


Figure 3. Quart-jar method of determining silt content of sand.

jar is about three-quarters full. Vigorously shake this mixture for 1 minute and allow it to stand for 1 hour. If more than a ⅛-inch layer of silt forms on the surface of the sand (fig. 3), the silt content is too high. Sand containing excessive silt must be discarded or washed to remove the silt. Small amounts of sand can be successfully washed on a device similar to the one shown in figure 4. The sand is thrown on the sloping device. The water washes it down to the bottom and the silt passes through the screen.

8. The second test can be made by placing a representative sample of sand in a 12-ounce prescription bottle. The bottle should be filled to the 4½-ounce mark, and enough sodium hydroxide added to bring the level to the 7-ounce mark. This solution should be thoroughly shaken and allowed to stand for 24 hours. If the liquid above the sand is colorless or light yellow, the sand is satisfactory. If the liquid is bright yellow or medium brown, the sand should not be used unless strength tests prove the color-producing organic matter to be harmless.

9. When using sand of doubtful quality or from a nonuniform source, make tests daily (or more often). Either of the two tests provide an excellent check for silt or clay content. The heavier sand particles settle in a very few minutes, and all sediment settles within 20 minutes. This leaves the sample deposited in layers by particle sizes, with the very fine matter in a well-marked layer on the top of the sand. If the bottle is not disturbed during the settling, both sand and silt will be level on top and the volumes can be compared with extreme accuracy.

4. Water

1. Water which is safe for drinking is safe for making concrete. However, water which is not potable (fit for drinking) may still be satisfactory for making concrete. If there is a reason to suspect the suitability of the water supply, tests may be run on mortar made with the suspected water. Normally, the tests are made on the mortar at the age of 28 days, but in emergencies, a test may be run after 24 hours, with a confirming test made at 7 days. If the engineer finds that the mortar made with the test water is at least 90 percent as strong as mortar made with water known to be practically pure, the water is considered usable. Waters containing strong acid or alkaline inorganic salts are not acceptable.

5. Handling and Storage of Materials

1. The methods by which the materials are handled and stored can be an important factor in maintaining consistent mixtures. There-

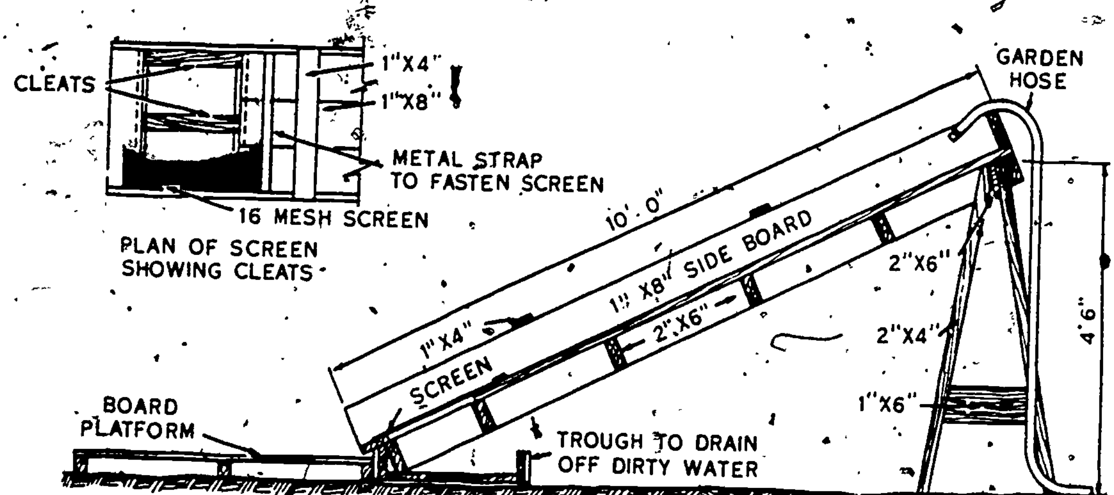


Figure 4. Device for washing sand and gravel with high silt content.

31

fore, handle and store materials according to specifications.

2. **Cement.** Sacked cement which is to be stored for a long period of time should be placed in a near airtight warehouse or shed. The floor of the shed should be aboveground and all cracks in the walls sealed. Sacks should be stacked close together to reduce air circulation. The sacks of cement should be stored on a raised floor away from the walls. A suitable temporary storage shed is shown in figure 5. Note that the tarpaulin extends over the edge of the platform to prevent rain from collecting on the platform and thereby reaching the bottom sacks. Cement which does not come in contact with moisture will retain its quality indefinitely. Cement which has been stored for a long period of time may develop what is known as warehouse pack. This condition results from tight packing; however, the cement retains its quality. Warehouse pack can be corrected by rolling the sack on the floor. At the time of use, cement should be free-flowing and free of lumps. If the lumps are hard to break up, the cement should be tested to determine its suitability.

3. **Aggregates.** Normally, aggregate is stored in stockpiles built up in layers of uniform thickness. Stockpile buildups should be accomplished in a manner which prevents the separation of large and small particles. Every batch of aggregate which comes to the mixer should be of the same composition and consistency. Therefore, stockpiles should not be formed in high cone shapes or allowed to run down slopes because this causes separation. Aggregate should be placed in layers, and in individual units not larger than one truck load. Damp, fine aggregate has less tendency to segregate than dry, fine aggregate. To further prevent separation, never allow aggregate to free-fall from the conveyor belt, and make the haul distances as short as possible. If batching equipment is used, some of the aggregate will be stored in bins. Bins should be located by allowing the material to fall vertically over the outlet. Chuting the material at an angle against the side of the bin causes segregation of particles. Correct and incorrect methods of storing aggregate are shown in figure 6.

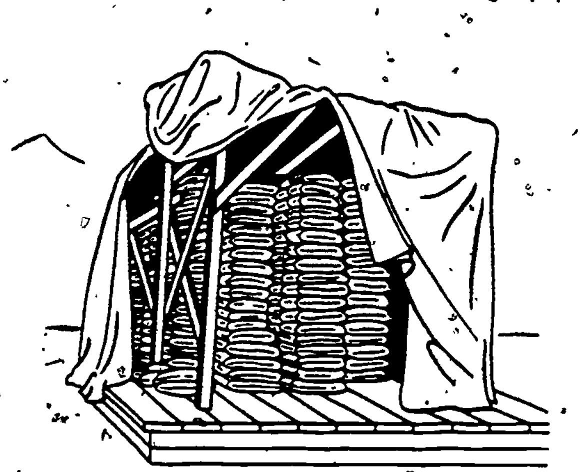


Figure 5. Cement stored under a tarpaulin.

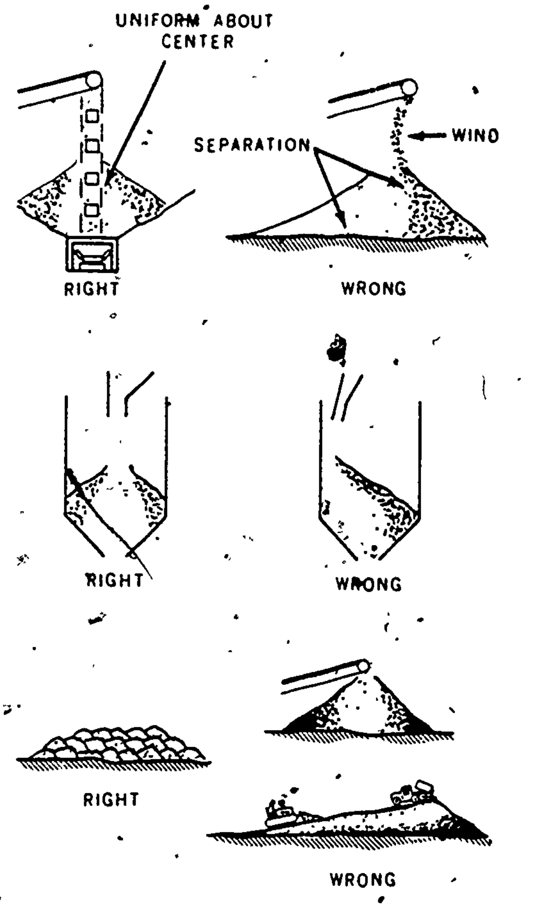


Figure 6. Methods of handling aggregate.

4. **Water.** Sediment tanks and 250-gallon water trailers are used to haul and store water and should be stored near the mixer.

6. Water-Cement Ratio

1. The amount of water used when mixing concrete is of critical importance in every case. If too much water is used, it will eventually evaporate and leave undesirable voids in the concrete. Water used for concrete is usually expressed in terms of gallons per sack of cement. It may also be expressed as the ratio of the weight of water used per sack of cement to the weight of the sack of cement. For example, if 50 pounds of water per sack of cement is used and the weight of one sack of cement is 94 pounds, the water-cement ratio is 50/94 or 0.53. However, the amount of

TABLE 1
RELATION BETWEEN MIXING WATER AND
COMPRESSIVE STRENGTH OF CONCRETE*

Gallons of water per sack of cement	4	5	6	7	8
Probable average 7-day strength in psi	4,400	3,500	2,800	2,200	1,800
Probable average 28 day strength in psi	6,000	5,000	4,000	3,300	2,800

*A safety factor of 15 percent should be allowed when selecting the water content required. If 2,800 pounds per square inch concrete at 28 days is required, a water content corresponding to a strength of 3,200 pounds per square inch should be selected.

water to be used will be given in gallons per sack of cement in the rest of this chapter. Table 1 gives the quantity of water to be used for concretes of a given strength. Note that the more water used, the less the strength of the concrete. Proper curing must be provided to obtain these strengths. The strength of concrete increases with time, as shown in figures 7 and 8. Figures 7 and 8 also show the compressive and flexural strength-time relations for concrete. Compressive strength is the ability of a concrete slab to resist crushing, and flexural strength is its ability to resist bending.

2. For construction, where strength and economy are important and the work is not hurried, tests for strength should be made with the materials to be used on the job and under job conditions. These tests should include not less than three different water contents. Sample batches of concrete are mixed, cured, and tested for strength. From these tests, the proper water content can be selected. The 15-percent safety factor recommended for use with table 1 should also be used here.

3. The amount of water in the aggregate, in excess of that present when the aggregate is in a saturated surface dry condition, must also be included as mixing water when the amount of water to be added in designing concrete mixtures is determined. The term "saturated surface dry" implies that the voids in the aggregate are filled with water and the surface of the aggregate is dry.

7. Consistency

1. A concrete mix with a fluid consistency flows easily into forms and around reinforcing steel. A stiff concrete mix does not flow readily, and usually requires additional labor or special equipment to place it. Immediately after being mixed, concrete should be plastic, neither fluid nor stiff.

2. The means of measuring consistency is the slump test. To perform this test, place the concrete mix in a cone-shaped form where it is rodded or tamped. After the mixture is stamped and the form is removed, the concrete slumps to a position of equilibrium. The amount of slump is then measured in the manner illustrated in figure 9. The greater the measured slump, the more fluid is the mix. The concrete should have no more slump than necessary to enable the placing crew to place it. If more slump is needed, it should be obtained by reducing the amount of sand and coarse aggregate rather than adding more water.

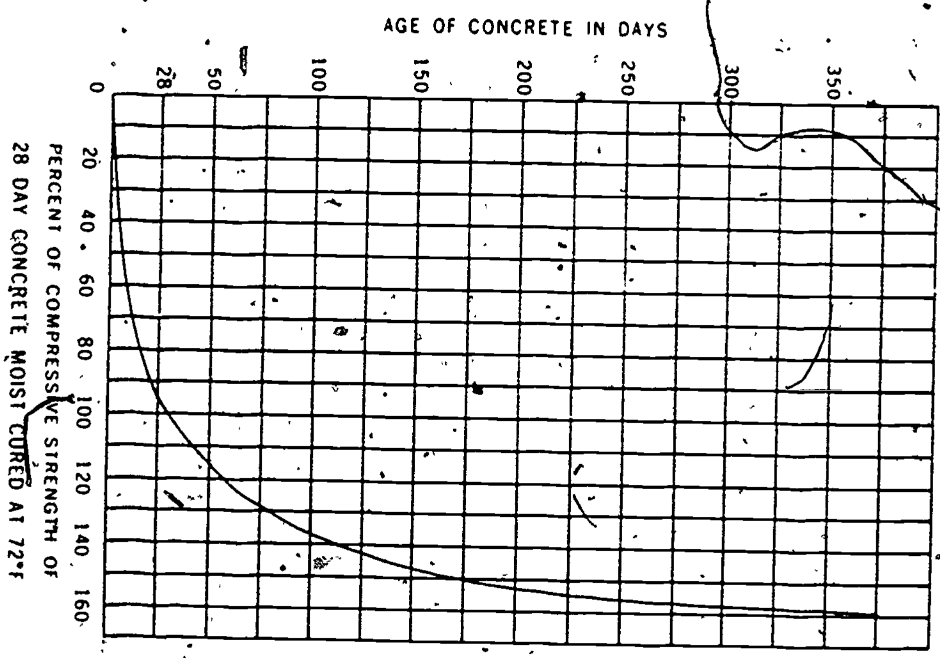


Figure 7 Compressive strength-time relations for concrete.

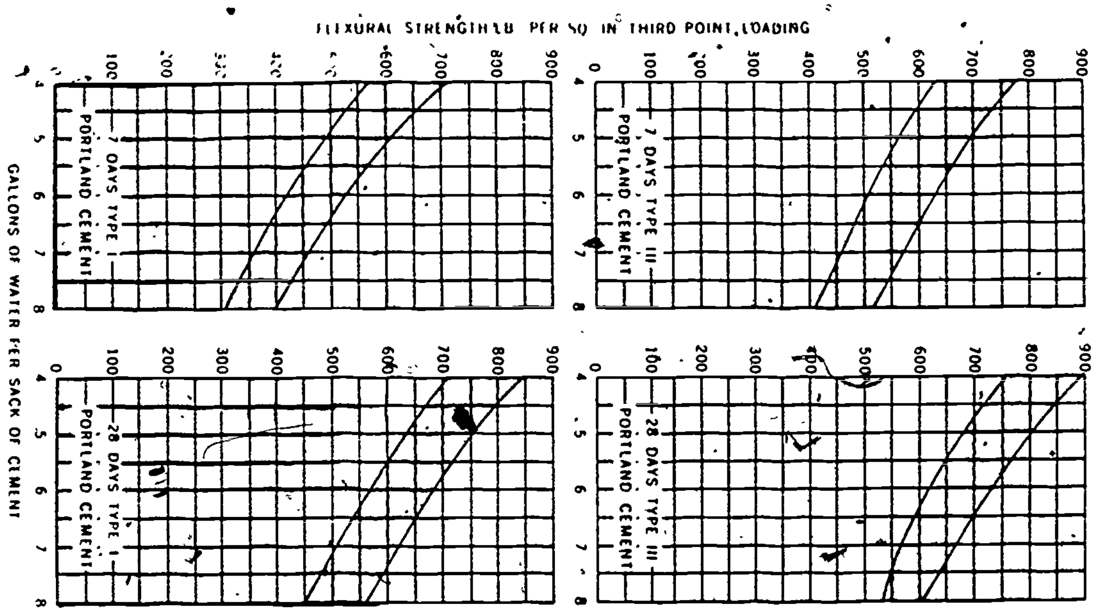


Figure 8 Flexural strength-time relations for concrete.

3. Workability refers to the ease with which a certain concrete mix can be placed in a particular position. However, this term has separate uses. For example, a concrete containing large aggregate particles with a stiff consistency would be workable in a large mass but would not be workable in a thin wall with closely spaced reinforcing bars.

8. Trial Method of Mix Design

1. Each particle of aggregate is completely surrounded by cement-water paste, and almost all of the spaces between the particles are completely filled with the paste if the concrete is properly mixed. This paste binds the aggregate into a solid mass, and the strength of the concrete primarily depends upon the strength of the paste. The binding properties of the paste are due to chemical reactions (hydration) between the cement and water. Favorable conditions must be present if maximum strength of the paste is to develop through hydration.

2. Aside from producing a material having the required strength, durability, and watertightness, economy is the important factor in designing concrete mixes. As much fine and coarse aggregate as possible should be used since this material is cheaper than cement. The trial-mix method of obtaining the proper amounts of fine and coarse aggregate to be combined with each sack of cement should be used. In most cases, the required strength of concrete has been established by the engineer responsible for the design of the project. The compressive strength of concrete made with various amounts of water was given in table 1. The amount of water selected includes free water present in the aggregate plus water added at the mixer.

3. Select the required slump from table 2 if the designer has not furnished this information. The amount of slump required will vary with the type of construction. Thin members and those which contain large amounts of reinforcing steel require more fluid or plastic mixes than do large

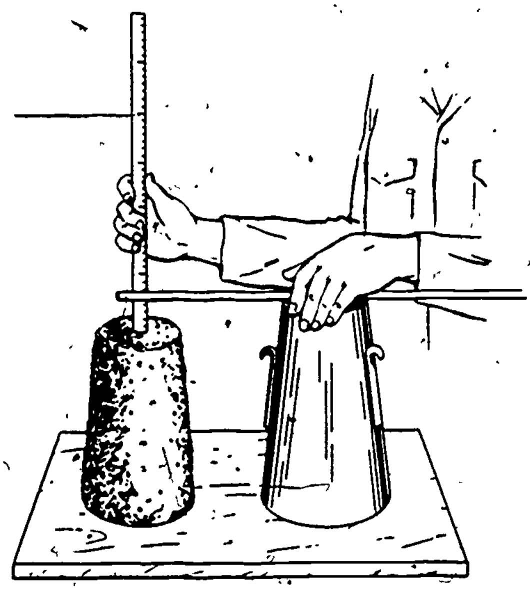


Figure 9 Slump test

TABLE 2

RECOMMENDED SLUMPS FOR VARIOUS TYPES OF CONSTRUCTION*

Type of Construction	Slump in inches	
	Maximum	Minimum
Reinforced foundation walls and footings	4	1
Plain footings, caissons, and substructure walls	4	1
Slabs, beams, and reinforced walls	5	2
Building columns	5	2
Pavements	3	2
Heavy mass construction	3	1

*When high-frequency vibrators are to be used, the table values should be reduced by one-third

masses of concrete with little reinforcing steel. Selecting the proper slump is important since it affects the amount of aggregate to be used and the amount of labor required to place the concrete.

4. When using any new combinations of fine and coarse aggregate, make trial mixes, and determine the amount of each to be used per sack of cement. In small or unimportant work, an arbitrary mix of 1 part cement, 2½ parts sand, and 3½ parts gravel (1:2½; 3½) may be used However, the amount of aggregate will vary with the water-cement ratio previously decided upon. Determine the amounts of moisture present in aggregate in the laboratory, or estimate it by using the following information:

(1) The percentages of water by weight which the various types of aggregate will absorb were given under "Physical Properties." (When thoroughly dry aggregate is used, this amount of water is added and is not considered in the water-cement ratio.

(2) The approximate quantity (in gallons) of surface water or free (unabsorbed) water carried by a cubic foot of average aggregate is as follows:

Very wet sand	¾ to 1
Moderately wet sand	about ½
Moist sand	about ¼
Moist gravel or crushed rock	about ¼

(3) The water in damp sand forms a film on the grain, fluffing them apart to an extent much greater than the actual volume of the sand. This bulking is greater at a moisture content of about 6 percent of dry weight, at which value the bulking may be as much as 20 or even 30 percent of the dry volume. Additional water packs the sand and decreases the bulking. Sand has about the same volume when completely flooded as it has when measured dry and loose. Bulking is allowed for when measuring sand by volume and is determined by tests if necessary However, the effect of moisture on the volume of coarse aggregate is negligible.

5. Allowing for free water and bulking, trial batches ($^1/_{10}$ sack of cement mixed by hand) or full-size mixer batches are made. The proportions for the first trial mix for the required water-cement ratio and selected slump are given in table 3.

6. Aggregate proportions should be adjusted to give the desired workability without changing the water-cement ratio. If the first batch looks and handles like good concrete and it is readily workable, small increases in the coarse aggregate can be tried to reduce the cement demand. If the mixture is too harsh, too dry, or otherwise unworkable, adjustments are made in the fine or coarse aggregate approaching the proportions given for the next greater slump. The following is given as an illustrative example:

7. A 2-sack batch composed of 1-inch maximum size aggregate, water-cement ratio of 7 gallons per sack, slump or 3 to 4 inches, and dry compacted volumetric proportions of 1:2. 3.3 6 is selected for trial. Batch quantities for 1 batch in a 14-cubic-foot mixer are:

Water	9.3 gallons
Cement	2 sacks
Fine aggregate	5 5 cubic feet (damp-loose)
Coarse aggregate	7.6 cubic feet (damp-loose)

These quantities were taken from table 3, under the column headed "Materials for 1 batch in 14-cubic-foot mixer, assuming the average damp materials." The quantities listed in this column are based on the following assumptions: moderately wet sand carrying ½ gallon of free moisture per cubic foot with damp-loose volume 1.20 times the dry-compacted volume; moist gravel carrying ¼ gallon of free moisture per cubic foot with damp-loose volume of 1.06 times dry-compacted volume. Water quantities have been adjusted for the moisture carried by the aggregate. The amount shown is to be added to the mixer. Batch quantities are for whole number of sacks of cement to give a batch quantity not greater than 14 cubic feet.

8. When poured, the above mix turns out to be too wet (large slump), and it appears to be oversanded. Investigation shows that the moisture content of the fine aggregate is about 4 percent and the coarse is about 2 percent by weight. To adjust this mix, the amount of coarse aggregate is increased with a corresponding decrease in added water, thus economizing on cement and tending to correct the oversanded condition. The coarse aggregate for the second batch is increased 0 4, from 7 6 to 8 0 cubic feet (damp-loose). The adding of 0 4 cubic foot of coarse aggregate which carries ¼ gallon of free water per cubic foot introduces ¼ · 0.4, or 0.1 gallon of extra water. The adjusted batch quantities for the second trial are:

Water	9.2 gallons (9.3-0.1)
Cement	2 sacks
Fine aggregate	5.5 cubic feet (damp-loose)
Coarse aggregate	8 cubic feet (damp-loose),

Table 3

Properties, Batch Quantities, and Unit Quantities for Concrete Mixes

Maximum size of coarse aggregate	Water-cement ratio (U.S. gal per sack)	Slump (inches)	Proportions by dry weight	Proportions by volume (dry-compacted)	Materials for 1 batch in 14-cubic-foot mixer, assuming average damp materials				Yield (cu. ft. of concrete per 1 bag batch)	Unit quantities of materials for 1 cubic yard of concrete				
					Water (U.S. gal.)	Cement (94 lb. sacks)	Fine (cu. ft.)	Coarse (cu. ft.)		Cement (94 lb. sacks)	Weight (damp)		Volume (damp loose)	
											Fine (tons)	Coarse (tons)	Fine (cu. yd.)	Coarse (cu. yd.)
1 inch	5	½ to 1	1 2.0 3.1	1 1.7 2.8	9.7	3	6.1	8.9	4.07	6.64	0.65	0.99	0.51	0.73
		3 to 4	1 1.7 2.5	1 1.5 2.2	14.1	4	7.2	9.3	3.56	7.59	.63	.91	.49	.67
		5 to 7	1 1.4 2.0	1 1.2 1.8	15.2	4	5.7	7.6	3.11	8.68	.60	.83	.47	.61
	5½	½ to 1	1 2.2 3.4	1 1.9 3.0	10.7	3	6.9	9.5	4.40	6.14	.66	1.00	.51	.73
		3 to 4	1 1.9 2.9	1 1.6 2.6	11.5	3	5.8	8.3	3.95	6.83	.64	.95	.50	.70
		5 to 7	1 1.6 2.3	1 1.4 2.1	16.4	4	6.8	8.9	3.50	7.71	.60	.85	.47	.62
	6	½ to 1	1 2.5 3.8	1 2.2 3.4	11.4	3	7.9	10.8	4.92	5.48	.67	1.00	.52	.73
		3 to 4	1 2.2 3.4	1 1.9 3.0	12.2	3	6.9	9.6	4.47	6.03	.65	.98	.51	.72
		5 to 7	1 1.9 2.8	1 1.6 2.5	13.1	3	5.8	8.0	3.95	6.83	.64	.92	.50	.67
	6½	½ to 1	1 2.8 4.1	1 2.4 3.7	8.1	2	5.8	7.9	5.32	5.07	.70	1.00	.54	.73
		3 to 4	1 2.5 3.7	1 2.1 3.3	13.1	3	7.6	10.5	4.86	5.55	.68	.98	.53	.72
		5 to 7	1 2.2 3.3	1 1.9 3.0	13.7	3	6.9	9.6	4.54	5.95	.64	.94	.50	.69
	7	½ to 1	1 3.0 4.3	1 2.6 3.9	8.8	2	6.3	8.3	5.63	4.80	.70	1.00	.54	.73
		3 to 4	1 2.7 4.0	1 2.3 3.6	9.3	2	5.5	7.6	5.24	5.15	.68	.99	.53	.72
		5 to 7	1 2.4 3.6	1 2.1 3.2	14.7	3	7.6	10.2	4.86	5.55	.65	.96	.51	.70
	8	½ to 1	1 3.4 4.9	1 2.9 4.4	10.2	2	7.0	9.4	6.29	4.30	.72	1.01	.56	.74
		3 to 4	1 3.1 4.7	1 2.7 4.2	10.5	2	6.5	8.5	6.04	4.47	.68	1.01	.53	.74
		5 to 7	1 2.8 4.4	1 2.4 3.9	11.0	2	5.8	8.3	5.64	4.79	.66	1.01	.51	.74
2 inches	5	½ to 1	1 2.0 3.7	1 1.7 3.3	9.3	3	6.1	10.5	4.40	6.13	.60	1.06	.47	.78
		3 to 4	1 1.7 3.0	1 1.5 2.7	10.2	3	5.4	8.6	3.88	6.96	.58	1.00	.45	.73
		5 to 7	1 1.4 2.5	1 1.2 2.2	14.8	4	5.7	9.3	3.36	8.00	.55	.96	.43	.70
	5½	½ to 1	1 2.3 3.9	1 2.0 3.5	10.1	3	7.2	11.1	4.79	5.64	.64	1.06	.50	.78
		3 to 4	1 2.0 3.4	1 1.7 3.0	11.1	3	6.1	9.6	4.30	6.28	.61	1.03	.47	.76
		5 to 7	1 1.7 2.9	1 1.5 2.6	11.7	3	5.4	8.3	3.88	6.96	.58	.97	.45	.71
	6	½ to 1	1 2.6 4.4	1 2.2 3.9	7.3	2	5.3	8.3	5.24	5.15	.65	1.06	.51	.78
		3 to 4	1 2.2 3.8	1 1.9 3.4	11.9	3	6.9	10.8	4.73	5.70	.62	1.04	.48	.76
		5 to 7	1 2.0 3.4	1 1.7 3.0	12.6	3	6.1	9.6	4.34	6.22	.61	1.01	.47	.74
	6½	½ to 1	1 2.8 4.7	1 2.4 4.2	7.9	[illegible]	5.8	8.9	5.64	4.80	.66	1.07	.51	.79
		3 to 4	1 2.5 4.2	1 2.1 3.8	[illegible]	2	5.1	8.1	5.18	5.21	.64	1.05	.50	.77
		5 to 7	1 2.2 3.8	1 1.9 3.4	13.4	3	6.9	10.8	4.80	5.62	.61	1.03	.47	.76
	7	½ to 1	1 3.0 5.0	1 2.6 4.5	8.5	2	6.3	9.5	6.03	4.48	.66	1.07	.51	.79
		3 to 4	1 2.7 4.5	1 2.3 4.0	9.1	2	5.5	8.5	5.51	4.90	.64	1.05	.50	.77
		5 to 7	1 2.4 4.1	1 2.1 3.7	9.5	2	5.1	7.9	5.18	5.21	.61	1.03	.47	.76
	8	½ to 1	1 3.4 5.5	1 2.9 4.9	9.9	2	7.0	10.4	6.62	4.07	.68	1.07	.53	.79
		3 to 4	1 3.1 5.1	1 2.7 4.6	10.3	2	6.5	9.8	6.29	4.30	.65	1.05	.51	.77
		5 to 7	1 2.8 4.6	1 2.4 4.1	10.9	2	5.8	8.7	5.77	4.68	.64	1.03	.50	.76

9. By using table 3 you can quickly estimate the quantity of cement and aggregate required to produce 1 cubic yard of concrete. To estimate quantities for a particular job, multiply unit quantities by the total volume in cubic yards of concrete to be placed, and add 5 percent to cover unavoidable loss and waste. As an example, 120 cubic yards of concrete are to be placed, a 1:2.3:3.6 mix (dry-compacted volume), water-cement ratio of 7 gallons per sack of cement, and 1-inch maximum size aggregate being used. Estimates of quantities of materials needed with a 5-percent margin for loss and waste are shown below.

	Concrete To Be Placed		*Allowance for Waste*		*Unit Quantity from Table*		*Quantity Needed*
a. By volume:							
Cement	120	×	1.05	×	5.15	=	649 sacks (162 barrels)
Fine aggregate	120	×	1.05	×	0.53	=	67 cubic yards (damp-loose)
Coarse aggregate	120	×	1.05	×	0.72	=	91 cubic yards (damp-loose)
b. By weight:							
Cement	120	×	1.05	×	5.15	=	649 sacks at 94 pounds each = 61,000 pounds
Fine aggregate	120	×	1.05	×	0.68	=	86 tons (damp)
Coarse aggregate	120	×	1.05	×	0.99	=	125 tons (damp)

9. Mix Design with Entrained Air

1. The method for designing concrete mixes containing air is essentially the same as the method for designing those that do not contain air. Using table 3 with some slight changes, you may estimate a trial mix. The quantity of sand selected from table 3 will be reduced, but the amount of coarse aggregate will remain the same. The procedure as follows applies to the design of a concrete that is to have a given strength with 4 percent entrained air.

2. The amount of water to be used for the strength required is obtained from table 2. This amount of water should be reduced by 1 gallon in order to compensate for the reduction in strength that always accompanies the use of entrained air. The weight of the sand given in table 3 should be reduced about 40 pounds for the first trial. After the first trial proportions are obtained, the procedure is identical to that of mixes using standard cement. Experience has proved that a concrete mix with 4 percent entrained air may have 1 to 2 inches less slump than a concrete mix without entrained air and still be placed easily. For a trial mix containing 2 sacks of cement, a water-cement ratio of 6 gallons of water per sack of cement, and a 1- to 2-inch slump, the proportions by weight, for saturated surface dry aggregate, would be 2 sacks of cement, 240 pounds of sand, 580 pounds of coarse aggregate, and 10 gallons of water. The weight of sand and the amount of water added at the mixer will need to be adjusted, as described earlier, to account for the amount of water in the sand.

3. If the volume measurement is used, the volume of sand listed in table 3 should be reduced by about 0.4 cubic foot.

4. The small entrained air bubbles act very similarly to sand. They lessen the possibility of "bleeding," a term referring to the flow of cement paste out of the concrete creating an extremely undesirable condition. On large jobs the amount of entrained air should be measured at least once a day by the engineer.

5. Air entrainment can be done by the use of air-entraining cement or by the addition of commercially available air-entraining compounds. These compounds must be used according to the manufacturer's instructions.

10. Mixing

1. The objective of mixing is to insure that the aggregate is well distributed throughout the concrete, and each particle is fully coated with a film of cement paste. Concrete may be mixed by hand or in a mixer. The mixing should be done as close to the point where the concrete is to be placed as possible.

2. Mixing concrete by hand (for small jobs) can best be done in a mortar box (fig. 10) or on a tight wooden platform which will not leak nor absorb water from the concrete. A measuring device (pail, measuring box, shovel, or wheel-

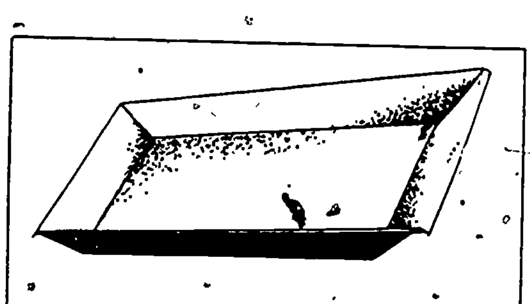


Figure 10. Metal mortar box.

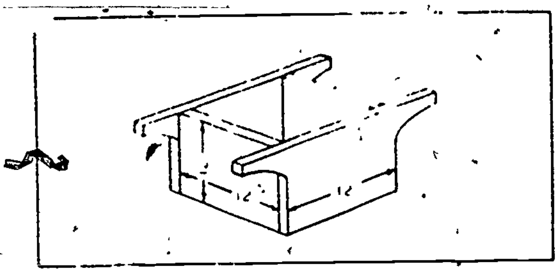


Figure 11. Measuring box.

barrow) can be used to obtain the correct amount of sand. A measuring box is shown in figure 11. To hand-mix concrete, the sand should be spread uniformly in the center of the platform. Next, the correct amount of cement should be uniformly spread over the sand. The sand and cement should then be thoroughly mixed with a mortar hoe (see fig. 12). When the ingredients are well-mixed, the combination is of uniform gray color, free from streaks. Then the coarse aggregate should be measured and mixed with sand and cement until it is well distributed in the mass. At least three or four complete turnings are necessary to properly distribute the aggregate in the ingredients.

3. After the dry ingredients are completely mixed, a depression is made in the center of the pile to hold the water. A specified amount of water is measured and slowly poured into the depression as shovelfuls of the ingredients are turned into the water. Then, the remainder of the water is added and the ingredients mixed until the concrete has the proper plasticity. A concrete mixer is best suited for mixing concrete for large jobs. A concrete mixer is shown in figure 13. A manually charged mixer should have the dry materials measured into the hopper and about 10 percent of the water poured into the mixer drum. As the dry ingredients are poured into the drum, approximately 80 percent of the water should be added along with them. After all of the other ingredients are in the drum, the remaining 10 percent of the water is added to the mix.

4. The length of time concrete should be mixed varies with different mixers. Specifications usually require concrete to be mixed a minimum time

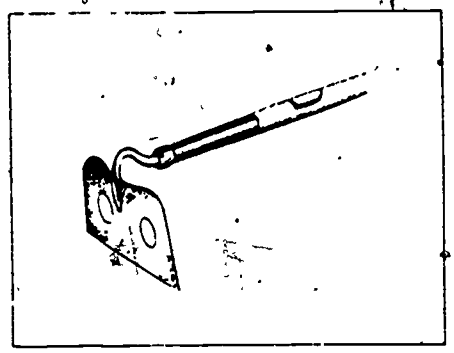
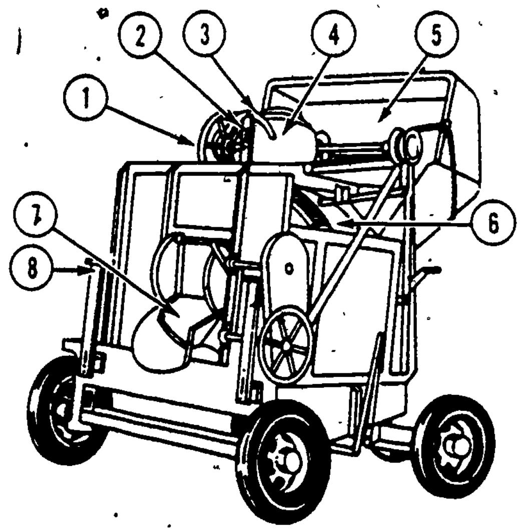


Figure 12. Mortar hoe.



1. HAND WHEEL AND SKIP SHAFT
2. WATER DIAL ARM
3. WATER DIAL
4. WATER TANK
5. SKIP LOADER OR HOPPER
6. MIXING DRUM
7. DISCHARGE CHUTE
8. STABILIZING STAND

Figure 13. Concrete mixer.

of 1 minute for the first cubic yard, and an additional 15 seconds for each additional one-half cubic yard. However, manufacturer or technical order instructions regarding the operation of a specific mixer should be followed.

38

STUDENT NOTES

(pages 13-14 . Student Notes were deleted)

11

CHAPTER 2

Reinforced Concrete and Concrete Structures

MOST OF US have seen the enormous concrete skyscrapers of our modern cities. It is doubtful that many of us ever thought of the other materials, besides concrete, that are used in constructing these huge structures. Without the great tensile strength provided by steel reinforcing material, concrete structures would be subject to the same limitations in design as those imposed upon architects of several centuries ago. Tensile strength is the greatest longitudinal stress a substance can bear without tearing apart. The use of steel reinforcing material is responsible for the large areas of clear floor space (free from supporting columns and bearing partitions) found in aircraft hangars, auditoriums, factories, stadiums, etc.

2. Besides talking about the material, methods, and procedures used in reinforcing concrete with steel, we will also cover the preparation of concrete for structures. This will include concrete forms, handling and transporting, placing, finishing, and curing concrete under different weather conditions. Watertight concrete, waterproofing compounds, and membrane waterproofing are also discussed.

11. Reinforced Concrete

1. Reinforced concrete units are metal (usually steel) and concrete bonded together. The patterns of steel rods (bars) in a reinforced concrete building are designed to withstand the stresses and strains imposed by other parts of the building. They also permit the concrete to withstand most of the compressive stresses. The combination of steel and concrete forms an excellent structure of economic design.

2. Because of its tensile strength, steel is considered the best metal for reinforcing concrete. To make sure the reinforcement purposes are not defeated, there must be a good bond between the steel and the concrete. Bonds are created by natural means and are improved by mechanical means. The natural bonding of concrete to steel is brought about by the adhesion and shrinkage of concrete during hydration. This action causes the concrete to grip the metal tightly. The mechanical bonding of concrete to steel is brought about by twisting or otherwise deforming the metal. There are a variety of types and sizes of reinforcing material used to reinforce concrete.

3. **Materials.** Reinforcement steel is available in rods of various sizes. They are plain, twisted, or deformed by rolling or stamping. The individually used rods are often woven, welded, or tied together to construct reinforcement units. Units of special design are constructed and placed together according to a predetermined system or pattern. When used for concrete floors, columns, and slabs, reinforcing steel is assembled at the beginning of the job so that it is ready for installation when the form-work is completed.

4. A plain rod is a straight piece of steel stock that has not been twisted or deformed. A deformed rod is one that has been stamped or rolled to form rough designs on the outer surface. Plain and deformed reinforcing rods are shown in figure 14.

5. After reinforcing units are constructed, they are placed in a form and braced so that they will retain their shape and position while concrete is

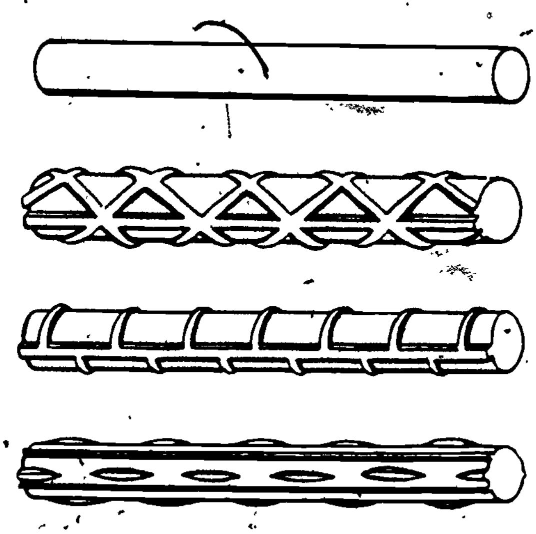


Figure 14. Types of steel reinforcing rods.

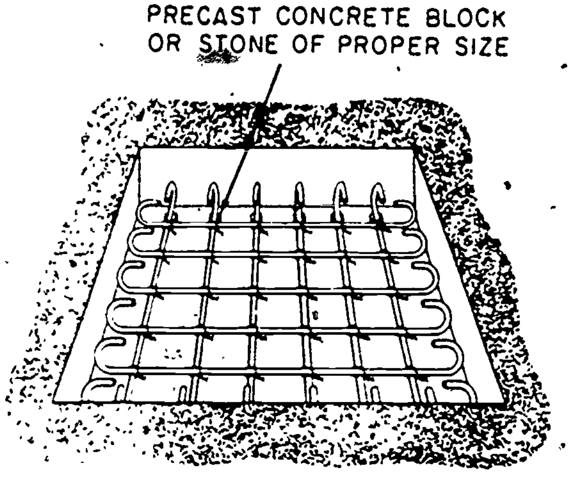


Figure 15 Steel placed in a footing.

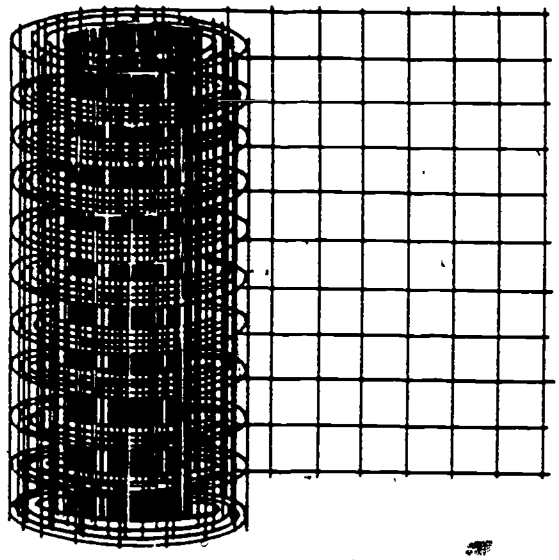


Figure 17.. Welded wire fabric.

placed around them. After reinforcing units are placed they should be inspected for defects such as loose tie wires. A reinforcing unit placed in a form is shown in figure 15 The arrow in figure 15 points out the small precast concrete block that is used to support, fasten, and correctly space the unit.

6 Woven wire is a steel reinforcing fabric having a rectangular or any number of different mesh patterns The mesh can be purchased in several sizes with different sizes of wire. The longitudinal wires are spaced and then tied in position by smaller transverse locking wires, as shown in figure 16

7 Welded wire fabric is commonly used as steel reinforcement in footings, walls, and slabs Variations in mesh are obtained by welding. Welding produces a more rigid, less distorted fabric than woven wire. A roll of welded wire fabric is shown in figure 17.

8 A number of different devices are used to support and correctly space reinforcement steel. The steel rods must be correctly spaced in relation to each other and the sides of the form-work. Supports and spacers (also called chairs and saddles) are used in the forms to support and space the reinforcing material. Slab bolsters, stone of the proper size, and precast concrete block with metal ties, as shown in figure 18, are used to support the steel. Stirrups are used to support reinforcing material used in concrete girders and beams. Several types of supports and spacers are shown in figure 19.

9 The height of the supports used to hold the reinforcing material in a concrete slab is determined by the concrete protective cover specified. Footings and other principal structural members (against the ground or exposed to the weather) should have at least 3 inches of concrete between the steel reinforcement and the ground and a 2-inch protective covering of concrete above the steel reinforcements.

10. **Anchors.** Steel reinforcing rods must be securely anchored at the ends. Three types of anchors are shown in figure 20. They are large washers and nuts, right angle bends, and hooks.

11. **Reinforcement Structures.** The construction of the reinforcing unit and the form-work for the concrete should be built simultaneously

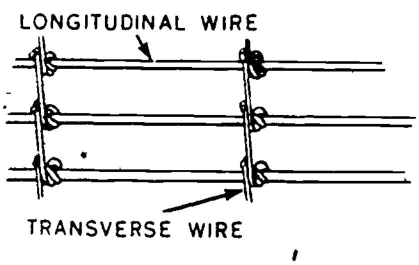


Figure 16 A section of woven wire.

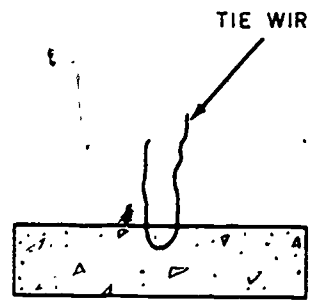


Figure 18. Precast concrete block.

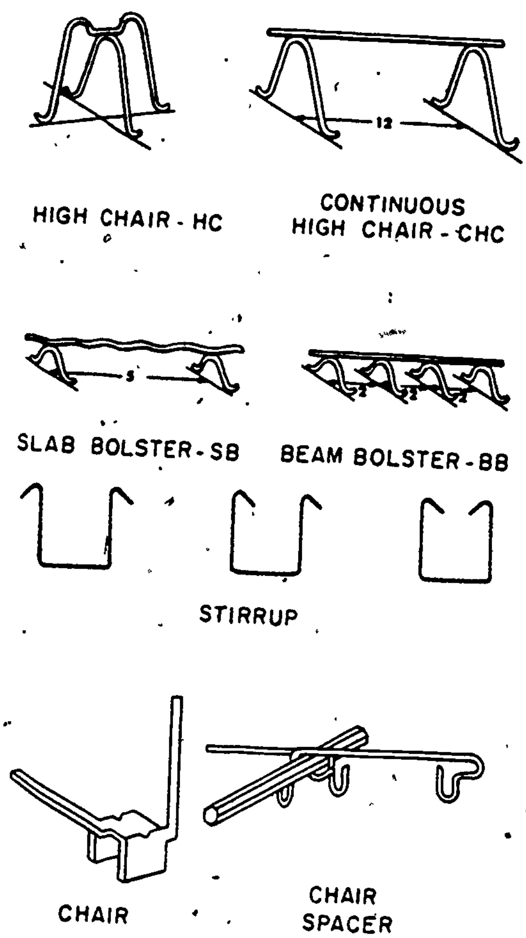


Figure 19. Types of supports and spacers.

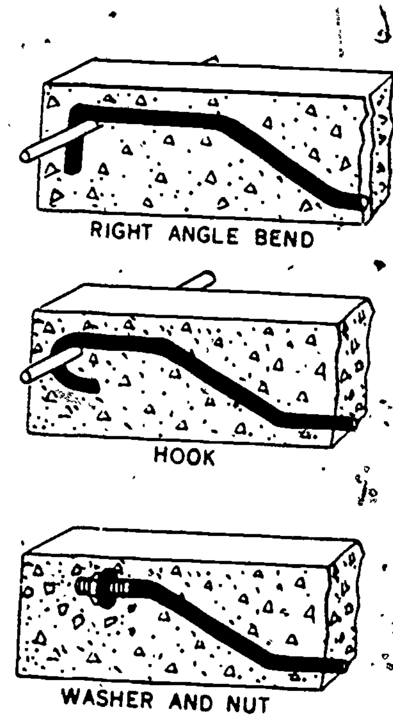


Figure 20. Types of anchors.

so there will be no loss of time. The type, size, shape, and placement of reinforcing materials are specifically covered in the drawings and specifications for the structure. Walls, floors, and columns are three of the principal structures you will be reinforcing.

12. *Walls.* Wire mesh and steel reinforcing rods are used for reinforcing concrete walls. The type of materials used will depend on the strength required. If wire mesh is used, the wire is attached to the wall with suitable chair spacers which support and space it correctly. If reinforcing rods are used, they will be connected to the wall, as shown in figure 21. The placement of steel in walls is the same as placing steel for a concrete slab or floor, except that the steel is erected in place rather than preassembled. Note, in figure 21, that horizontal steel is tied to vertical steel wherever the two intersect. Eighteen-gage soft annealed iron wire is used for making ties. The wooden blocks at the top of the wall, in figure 21, are used to space the steel reinforcement a predetermined distance from the form-work. The wire ties at the top and bottom of the form-work serve the same purpose as the wooden blocks as well as to hold the steel in place. Holes are drilled through the form-work, and the wire ties are passed through the holes. They are connected to boards on the other side to hold the wire in place. The wooden blocks are removed from the top of the form when the form is filled with con-

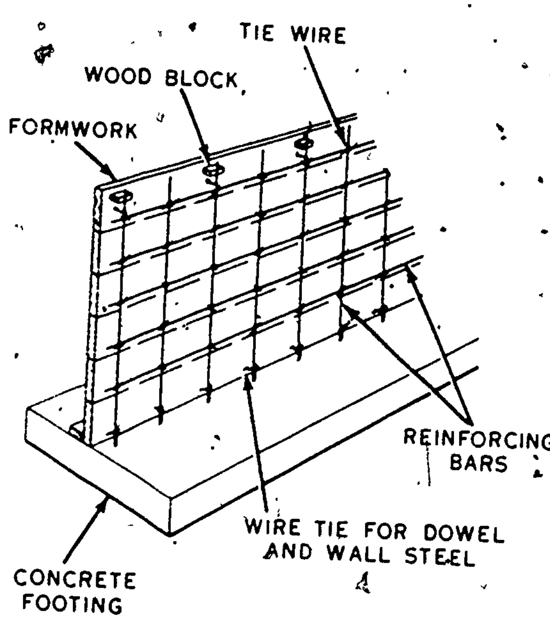


Figure 21. Reinforcing rods in a concrete wall.

43

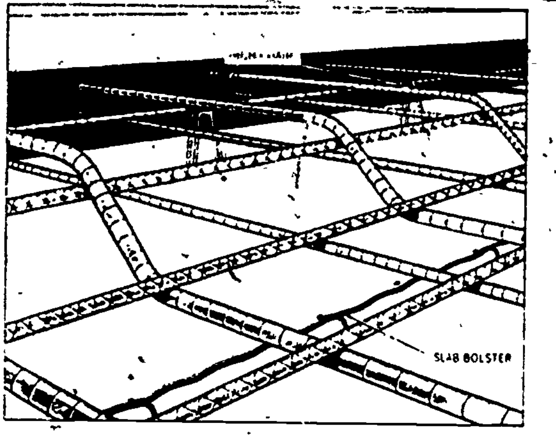


Figure 22. Steel in place in a floor slab.

crete to the level of the blocks. When constructing high walls (6 feet or more) use additional ties between the top and the bottom of the form-work.

13. *Floors.* Steel rods are used to reinforce concrete floors containing girders and beams. The reinforcements are generally placed with girders and perpendicular to beams. Steel in place in a floor slab is shown in figure 22. Before placing concrete, be sure the reinforcing material is tied where the steel rods intersect. The height of the slab bolster and high chairs, shown in figure 22, will depend on the specifications for the job.

14. *Columns.* Steel rods and wire ties are used to build reinforcing units for columns. Steel reinforcing units are built in sections, as shown in figure 23, and the number of sections used depends on the height of the column. Where two sections are connected, they overlap each other, as shown in figure 24, and are secured with wire ties. After the reinforcement is in place, the form-work is built around it and the steel is attached to the form with wire ties, as shown in figure 25. In order to build reinforcing units for various structures,

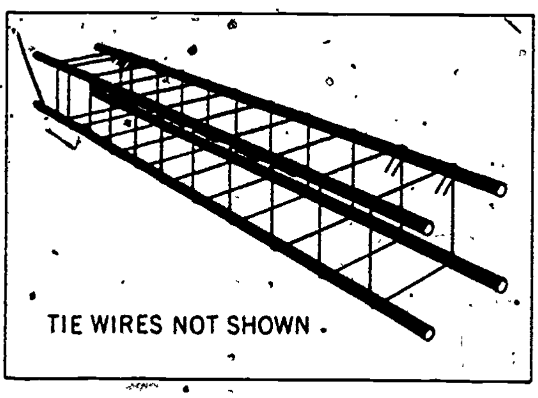


Figure 23. Column reinforcing steel assembled.

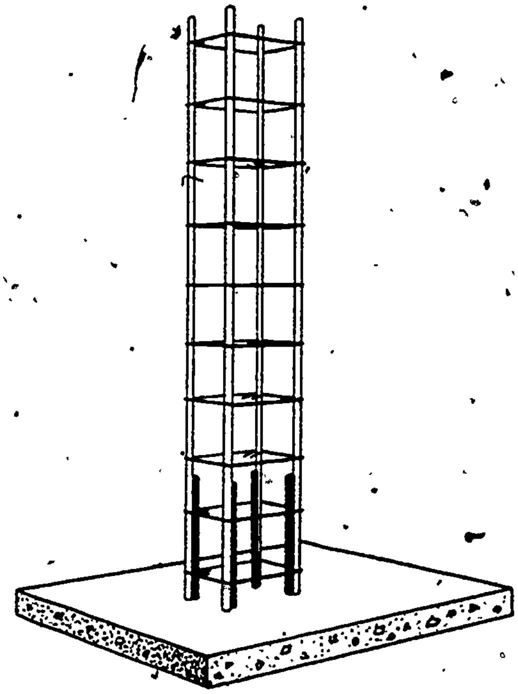


Figure 24. Column reinforcing steel in place.

the individual rods must be bent and cut to form these units.

15. **Bending and Cutting Reinforcement.** There are various bends used in bending steel reinforcement rods. The standard sizes of steel rods are shown in figure 26. When large numbers of reinforcing rods of various lengths and shapes are required, they are bent on a bar-bending table like that shown in figure 27. Shears are available

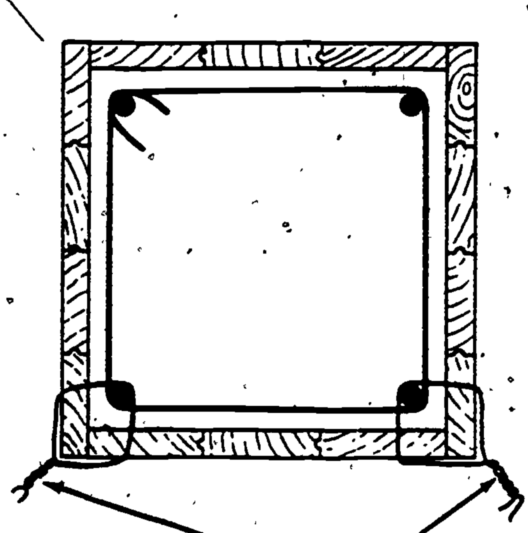


Figure 25. Method of holding column steel in place.

Bar No.	Diameter (in)	Area (sq in)	Weight (lb per ft)
- - - - - - - - - -	* 1/4	0 05	0 17
3 - - - - - - - - -	3/8	11	38
4 - - - - - - - - -	1/2	20	.67
5 - - - - - - - - -	5/8	.31	1.04
6 - - - - - - - - -	3/4	.44	1.50
7 - - - - - - - - -	7/8	.60	2.04
8 - - - - - - - - -	1	.79	2.67
9 - - - - - - - - -	** 11/8	1.00	3.40
10 - - - - - - - - -	** 11/4	1.27	4.30
11 - - - - - - - - -	** 13/8	1.56	5.31

*The 1/4-inch round bar can be obtained only as a plain bar.
**Approximate diameter. These round bars are equivalent in area to the obsolete 1-, 1 1/8-, and 1 1/4-inch square bars.

Figure 26. Standard sizes of steel reinforcing rods.

that will cut the largest size rods used for reinforcing material. Before placing reinforcing material, always check to see that it is free of loose scale, rust, and other foreign matter which will interfere with the bond between the concrete and the steel. Placing reinforcing material is only part of your overall task in preparing concrete structures. Now, let's discuss the other procedures you must follow to properly accomplish this task.

12. Concrete Structures

1. Portland cement concrete is the most important masonry material used in modern construction. It is used in all types of masonry, such as foundations, footings, retaining walls, etc. As a building material, it has many advantages. Local material can usually be used in the mix. It can be cast into any shape, and in its plastic or fluid state, it can be readily handled and placed in forms.

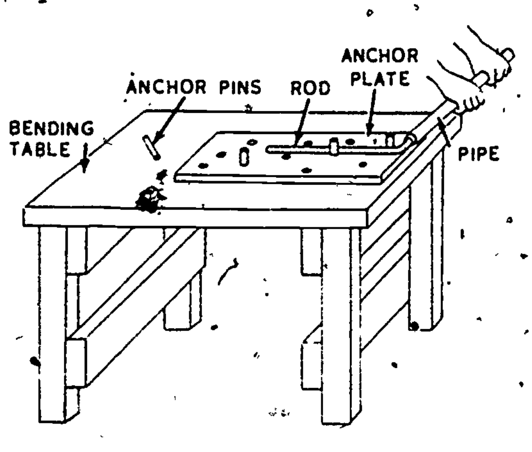


Figure 27. Bar-bending table.

2. **Forms.** All forms for concrete are constructed by the carpenter specialist. As a masonry specialist, if asked by the carpenter, you will advise him in building and placing concrete forms from the design drawings, blueprints, and sketches for the job. Before pouring concrete you should check the forms to be sure that they are tight, rigid, and strong. Also check the sides of structural forms to be sure the wood spacers and wire ties are in place. By looking at figure 28, you can see that the spacers hold the forms apart and the ties keep the sides of the form from spreading apart while the concrete is being placed. The wood spacers must be removed as the forms are filled so that they will not become imbedded in the concrete. An easy way to remove the spacers is to fasten a wire to the bottom spacer, pass the wire through the holes drilled to one side of the center of the other spacers, and pull the spacers (one after another) as the concrete level rises in the form. This method of removing spacers is shown in figure 29.

3. **Oiling Forms.** Before pouring concrete in forms, be sure that they have been treated with a suitable form oil that will prevent concrete from sticking to them. Oil used on wood forms should be capable of penetrating the wood and preventing the wood from absorbing water from the concrete. (If water is absorbed from the concrete, its edges will dry up and eventually crack.) Lightweight petroleum oil is good for oiling wood forms, but it

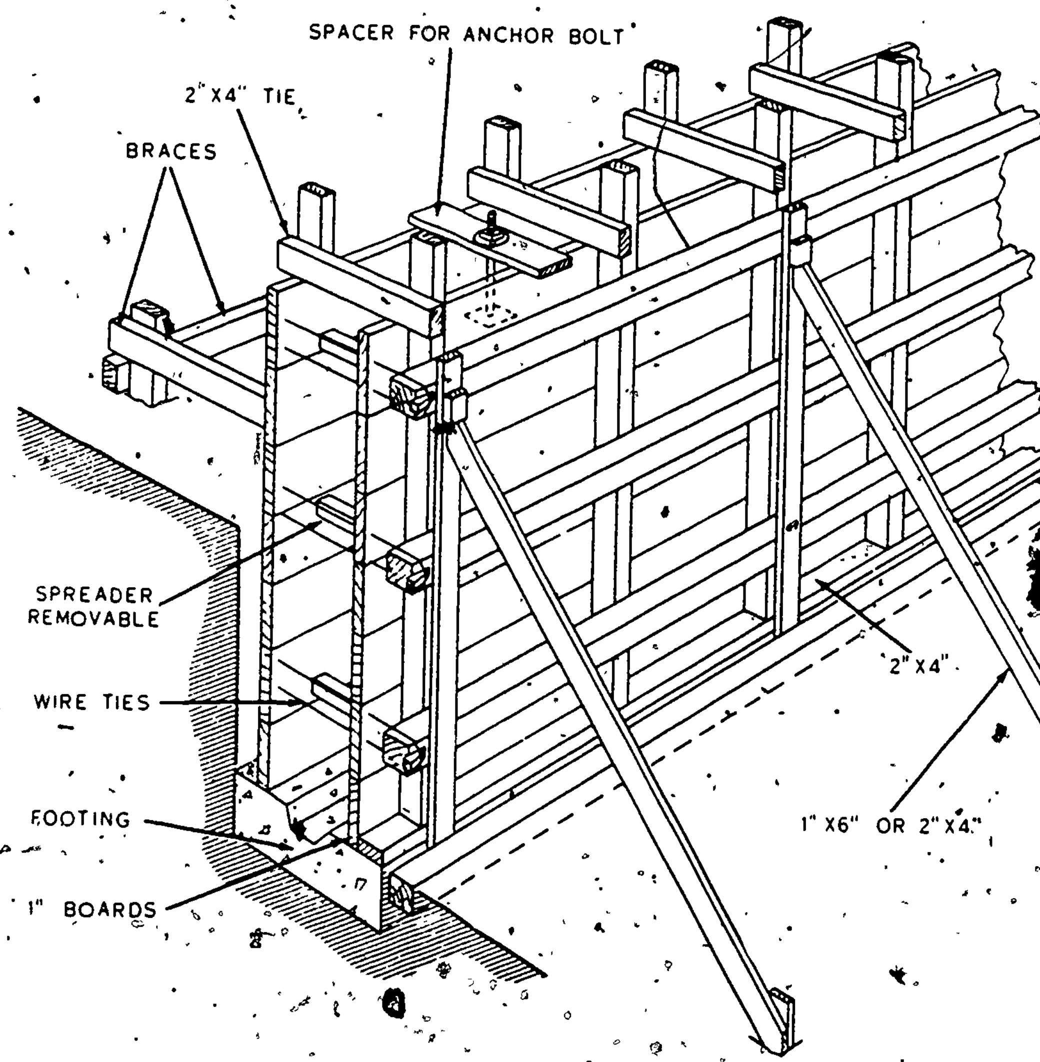


Figure 28. A wall form.

may not be satisfactory for steel forms. Specially compounded petroleum oils, such as synthetic castor oil and some marine engine oils, work better on steel to keep the concrete from sticking.

4. To get the most out of form oil, always apply it with a brush to a clean surface. Column and wall forms should be oiled before erection. All other forms can be oiled whenever convenient, but must be oiled before reinforcing steel is placed. If form oil is spilled on reinforcing material, it will reduce the bond between the steel and the concrete. After the forms are oiled and the steel is in place and secured, you can prepare to place the concrete. There are times when the concrete cannot be mixed at the construction site and must be transported.

5. **Handling and Transporting Concrete.** After concrete leaves the mixer, it must be carefully handled and transported to prevent the aggregate separating from the mortar or the water from the other ingredients. Improper handling and transporting can spoil the most carefully designed and properly mixed concrete. Separation or segregation occurs because concrete consists of materials of different sizes and weights. If you were to place a portion of a concrete mix in a bucket, the coarse aggregate particles in the mix would tend to settle to the bottom and the water would rise to the top. This would probably leave voids in the concrete. These voids are called honeycombing and, sometimes, rock pockets.

6. The equipment used in handling and transporting concrete depends on the size and type of job. If ready mix concrete is used, the concrete should be deposited in the forms straight from the truck, if possible. For the usual small job requiring

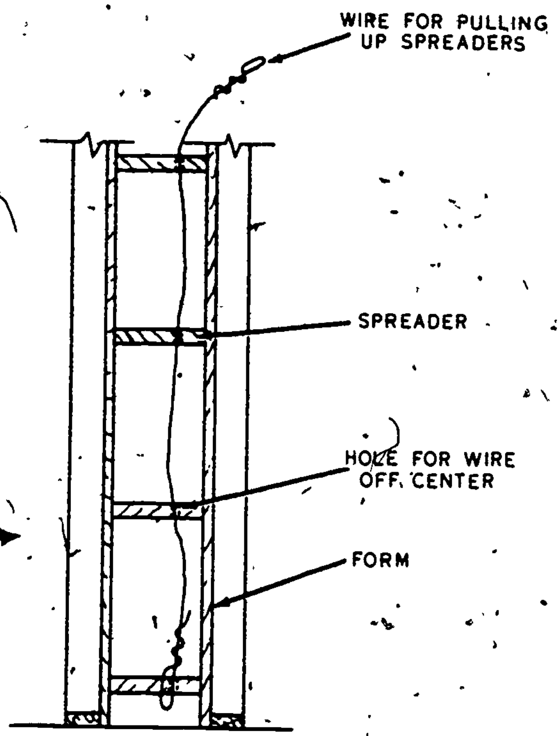


Figure 29. Removing wood spacers.

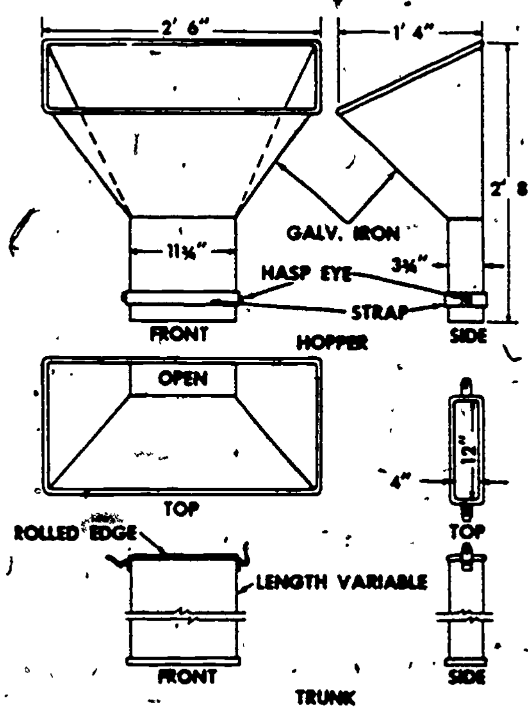


Figure 31. Concrete drop chute.

no high lifts, transporting by wheelbarrow or buggy is the most economical method. Sometimes chutes must be employed in conjunction with the wheelbarrow and buggy in order to place the concrete properly in the forms. Stiff mixes require chutes to be placed on steeper slopes. Specially designed buckets are used to move concrete above and below the level of the mixer. The lifting and lowering is done with a crane. The equipment used to transport concrete should be thoroughly cleaned at the end of every period of use, because it is easier to remove concrete before it has hardened.

7. *Wheelbarrows and buggies.* Rubber-tired wheelbarrows and buggies, which furnish a smooth ride, are preferred to those with steel wheels because less segregation of materials used in the mix will occur. A rubber-tired buggy is shown in

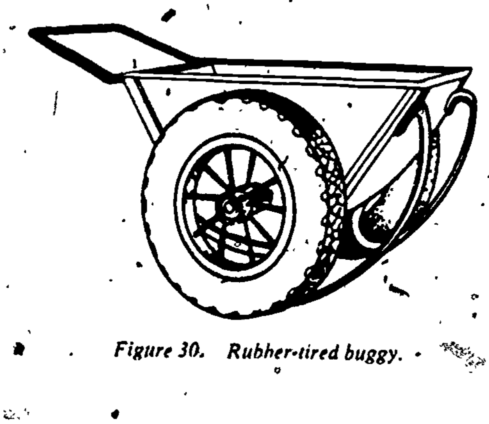


Figure 30. Rubber-tired buggy.

figure 30. Concrete for foundations and foundation walls can be economically transported by buggy.

8. If the concrete is to be deposited below or about the same level as the mixer, a simple arrangement of 2-inch-thick plank runways placed on the ground can be used for the buggy to ride on. If the difference in level is large, then a drop chute, like that shown in figure 31, should be used. Concrete can be allowed to drop freely, without a chute, for a maximum of 5 feet when being dropped in forms and 3 feet for exposed work.

9. When concrete is to be elevated above the mixing level, less than 15 feet aboveground, incline runways for transporting the concrete to the required elevation can be built at low cost. When working under these conditions, you should use wheelbarrows or buggies with a capacity of 2 to 3 cubic feet because the larger ones are too heavy to push up the incline.

10. *Chutes.* For short distances, chutes can be used for transporting concrete. You should never transport concrete for long distances by chutes or chute systems. When concrete is transported in this manner for long distances, it tends to dry out and segregate. For the usual concrete mix, the slope of the chute should be from 2 to 3 feet horizontal to 1 foot vertical. If you are working with a stiff mix, a steeper slope should be used. A down pipe should be provided at the end

of the chute so that the concrete will drop vertically and not segregate.

11. *Trucks.* When concrete is transported long distances (over ½ mile) in a nonagitating truck, severe segregation will occur unless the roadway is very smooth. In most cases the ordinary flat-bottomed truck with a wide tailgate is not suitable for hauling concrete. If it becomes necessary to use this type of transportation for jobs calling for small amounts of concrete, you should first deposit the concrete in a mortar-mixing box. You should also slightly remix the concrete with a mortar hoe before placing it in the forms. When large amounts of concrete are hauled, specially built truck bodies that have a rounded and sloping front with the rear end sloped to a discharge gate should be used. This type truck body is used to haul air-entrained concrete over relatively long distances where the conditions are favorable. The distance over which these trucks can haul concrete will depend on the characteristics of the concrete and the condition of the roadways. Their use should be limited to where uniform batches of concrete free from segregation can be delivered to the construction site.

12. **Joints.** Concrete expands slightly when the temperature rises and contracts when the temperature falls. Concrete shrinks as it dries (concrete never completely dries) and expands when it becomes wet. It will never expand over a greater area than when in its plastic state (freshly poured). To allow for these changes and to preserve the appearance and the strength of concrete structures, joints are used. There are three major types of joints: contraction, construction, and expansion.

13. *Contraction joints.* Contraction joints are used to control contraction cracking from temperature changes and the initial shrinkage of concrete. A contraction joint, sometimes called a dummy contraction joint, is shown in figure 32. The joint is formed by cutting the slab with a concrete saw to a depth of one-third to one-fourth the slab thickness. This joint also gives some relief from expansion forces because the initial shrinkage of the concrete opens the joint slightly, cracking the concrete below the joint and providing room for expansion. When filling this joint, you should use a bituminous joint filling material. The

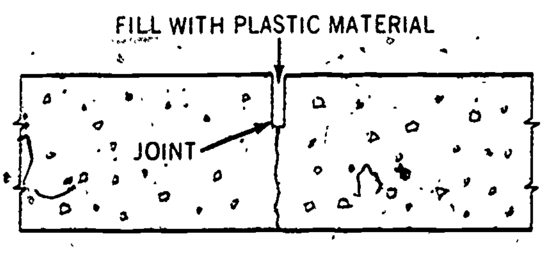


Figure 32. Contraction joint.

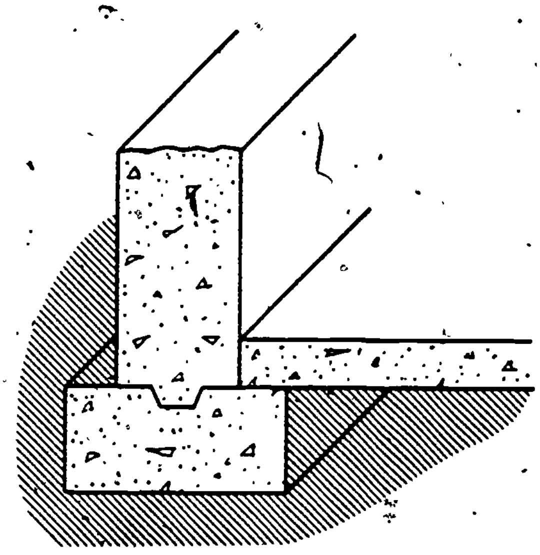


Figure 33. Keyway joint between a wall and footing.

use of material will prevent water from infiltrating through the joint to the subgrade. If water passes through the concrete to the subgrade, it will wash away some of the dirt, leaving a hole in the subgrade directly under the joint. When excessive weight is applied to the surface above the hole, the concrete will crack.

14. *Construction joints.* Construction joints are used to separate areas of concrete placed at different times. A keyway construction joint is shown in figure 33 between a wall and a footing. If the wall and the footing are placed at the same time, a construction joint is not needed. The keyway construction joint is also shown in figure 34 in a vertical position. Note the beveled 2" x 4" used to form the keyway in figure 34. This type of joint is generally used with reinforcing steel running from one section to the next. When reinforcing steel is not used, it is better to use a V-joint like that shown in figure 35. The V-joint is not as likely to break off as the keyway joint.

15. *Expansion joints.* Expansion joints are used to relieve the forces resulting from expansion of a concrete structure. An expansion joint for a concrete wall is shown in figure 36. A nonextruding type filler material should be used for expansion joints. This usually consists of a preformed bituminous or wood material ¾ inch thick. Make sure the expansion joint is designed so it will provide a complete and uniform separation between sections of the structure. The drawings and specifications for the job will specify the type, size, and spacing of joints.

16. **Placing Concrete.** Before placing concrete we must be sure that the surface to receive the concrete, the forms, and reinforcing material is

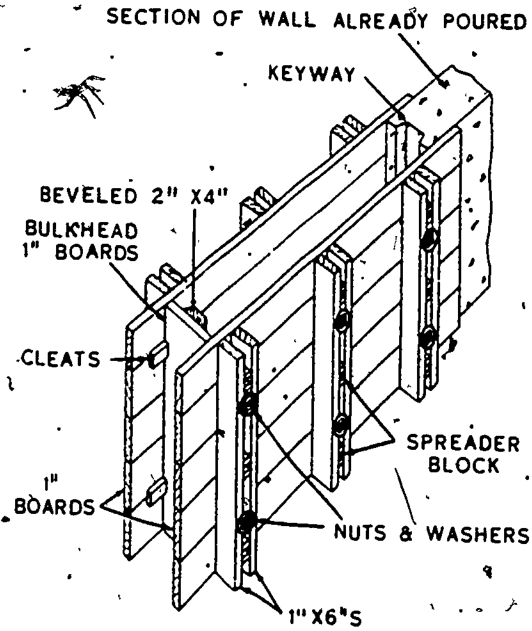


Figure 34. Vertical keyway joint.

properly prepared. It only takes a few minutes to give these items one last check.

17. The subgrade should be moistened to prevent too rapid extraction of water from the concrete and to aid the concrete in curing. By slowly sprinkling it intermittently with water, you can saturate the subgrade without its becoming muddy. Be sure the surface is free of sawdust, nails, and other debris before placing concrete.

18. When placing concrete in high walls, you should deposit it in level layers, not more than 12 inches deep. Each layer should be spaded just enough to make the concrete settle thoroughly and produce a dense mass before the next layer is placed. The method of spading and consolidating a concrete wall is shown in figure 37. When you get ready to pour the last layer of concrete at the top of the wall, overfill the form 2 to 3 inches and remove the excess concrete after it has stiffened slightly. This will remove the weak watery concrete at the top of the form.

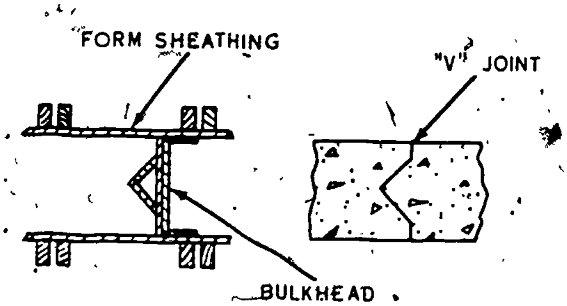


Figure 35. Top view of vertical V-joint for wall

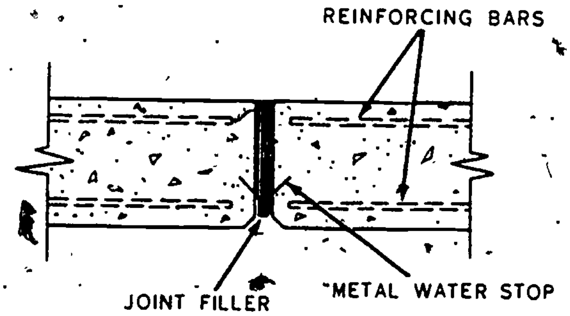


Figure 36. Top view of expansion joint for wall.

19. If you have to stop placing concrete in the wall for a long period of time, or at the end of the days work, you should roughen the top surface of the wall just before it hardens. This will provide a good bond for the next layer of concrete. Before starting to place concrete again, you should clean the roughened surface and apply a thick creamy coat of cement-water paste with a brush just ahead of the freshly placed concrete. This will give you a good bond between the different layers

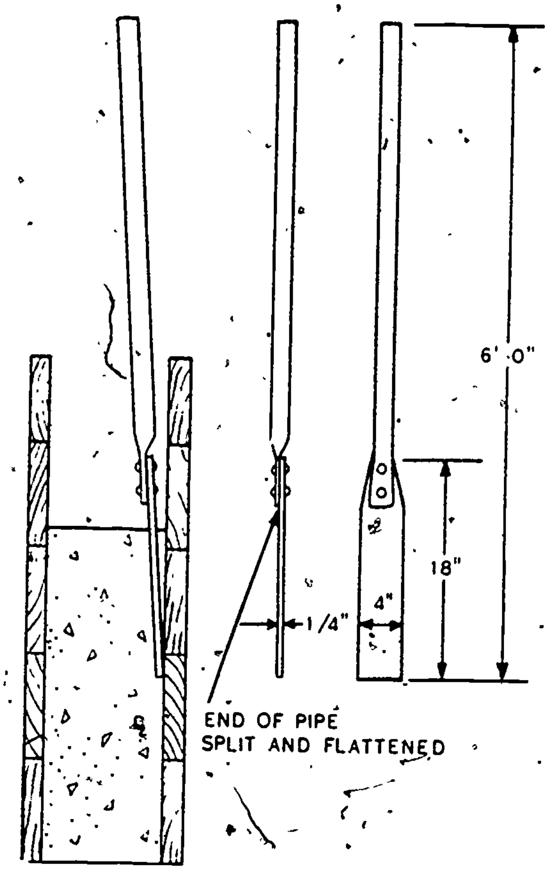


Figure 37. Consolidation by spading and spading tool.

of concrete and also enable the wall to be watertight.

20. If concrete is to be placed in a slab, it should be placed at the far end of the slab form, working back to the source of the concrete. This method of placing concrete is best because you never have to work over the freshly placed mix. Be sure that each batch of concrete is dumped against the previously placed concrete and not away from it. You should never dump concrete in piles and work the piles together because this causes severe segregation of the concrete materials.

21. **Consolidating.** All concrete, with the exception of that placed under water, should be compacted and worked into place by spading, puddling, or by mechanical vibrators. Compacting devices, such as spades or puddling sticks, long enough to reach the bottom of the form and thin enough to pass between the reinforcing material should be used. Consolidation eliminates rock pockets and large air bubbles and brings enough fine material to the surface to produce the desired finish. In the process of consolidation, you should carefully work the concrete around the reinforcing steel to assure proper embedding of the steel in the concrete. When consolidating, try to avoid displacing the reinforcing steel because the strength of the concrete structure depends on its proper location.

22. Concrete can be effectively consolidated by using mechanical vibrators. With vibration, it is possible to place mixtures too stiff to be placed by hand. Stiff concrete mixes require less cement and are more economical. There is also less danger of segregation in this type of mix. The mix should never be so stiff that an excessive amount of labor is required to place it.

23. The internal vibrator involves insertion of a vibrating element into the concrete. The external type is applied to the forms. They are powered by electric motor, gasoline engine, or compressed air.

24. The internal vibrator should be inserted in the concrete in a vertical position, at intervals of approximately 18 inches to allow some overlap of the area vibrated at each insertion. It should also pass through several inches of the previous layer to insure a good bond between layers. You will know that sufficient vibration has taken place when a thin line of mortar appears along the form. When you are using an internal vibrator, as shown in figure 38, be careful not to let it contact the forms because the vibrator could damage them. Mixes that are not too stiff and can be consolidated by spading or puddling should not be vibrated because vibration of this type mix could cause segregation.

25. External vibrators are rigidly attached to the forms by means of a clamp or vise. Part of

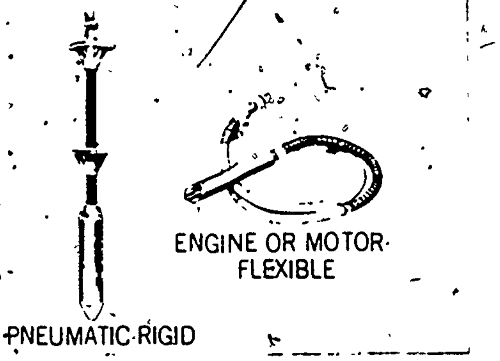


Figure 38. Rigid and flexible handled internal vibrators.

the energy of the form vibrator is absorbed by the forms, because the vibratory action must be transmitted through the forms to the concrete. Form vibrators should not be placed farther apart than the radius through which the vibration is visibly effective. You should raise the vibrators as the forms are filled, but keep them below the level of the concrete. The distance on the form below the level of the concrete at which the vibrator is placed depends on the consistency and thickness of the concrete. As with internal vibrators, sufficient vibration has taken place when a thin line of mortar appears on the edge of the form. After the concrete has been properly vibrated, you should immediately start the finishing operation before the concrete starts to set.

26. **Finishing Concrete.** After a floor slab, sidewalk, etc., has been placed, the top surface is rarely at the exact elevation desired. The process of striking off the excess concrete, to bring the surface to the proper elevation, is called screeding. In this operation a templet or a straightedge (a 2 x 4 or 2 x 6 board with a straightedge) is moved back and forth across the concrete with a sawing motion, as shown in figure 39. The templet rides on wood or metal forms that are used as guides. With each sawing motion, the templet is moved forward a short distance. You should always keep a small amount of concrete ahead of the templet to fill in low spots and maintain a level surface as the templet is moved forward. If there is a tendency for the templet to tear the concrete surface, the rate of forward movement should be reduced, or the bottom edge of the templet covered with metal. In most cases, just slowing the templet will stop the tearing action. You will encounter this tearing problem when you use air-entrained concrete (because of its sticky nature). After the concrete is struck off, a hand tamper, better known as a jitterbug, can be used to further compact the concrete into a dense mass. A hand tamper, or jitterbug, is shown in

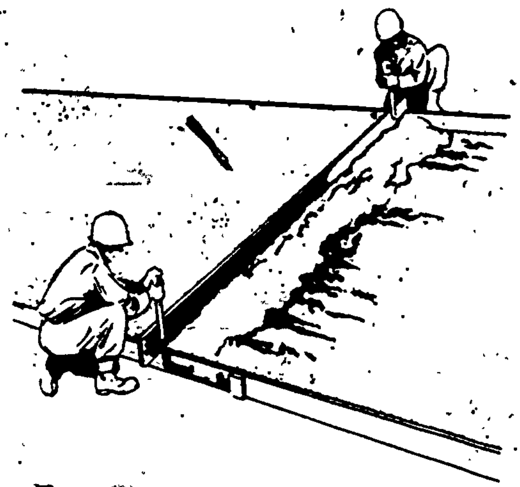


Figure 39. Screeding operation.

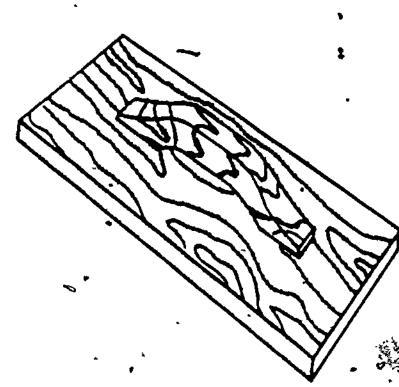


Figure 41. Wood float.

figure 40. Now that the concrete is leveled off and tamped, it may be necessary to float, trowel, broom, or rub the surface, depending on the finish desired.

27. If a smoother surface is required than one obtained by screeding, the surface should be worked sparingly with a wood or metal float or a finishing machine. Figures 41, 42, 43, and 44 illustrate a wood float, a long-handled wood float, a steel trowel and edger, and a typical power trowel for finishing concrete. The floating process should take place shortly after screeding and while the concrete is still plastic and workable. You should eliminate high spots, fill in low spots, and at the same time, bring sufficient mortar to the surface to produce the desired finish. Do not overwork the concrete while it is still plastic, because this will bring an excess of water and mortar to the surface. A mixture of water and mortar will form a thin, weak layer which will scale or wear off under usage, as shown in figure 45. Where a coarse finish is desired (as the final finish), you should float the surface a second time after it has partially hardened. When working on large concrete slabs, use a long-handled wood float, as shown in figure 42. Before we go any further with the finishing operation, let's edge and joint the concrete before it becomes too stiff.

28. Where edging is necessary, it should be done immediately after the floating and before the concrete has stiffened too much. Edging will give you a rounded edge that will prevent chipping or damage to the concrete slab. You should run the edger back and forth between the concrete and the form until a finished edge is produced. You should be very careful that all coarse aggregate particles are covered and that the edger does not leave too deep an impression in the surface of the slab. Too deep an impression in the top of the slab may be difficult to remove with the final finishing operations. An edger was shown in figure 43.

29. Now that we have edged the concrete, the next step is to joint (groove) the slab. The cutting edge or bit of the jointer tool cuts joints in the slab called contraction joints. In sidewalks and

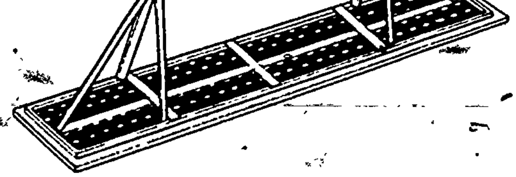


Figure 40. Hand tamper, or jitterbug.

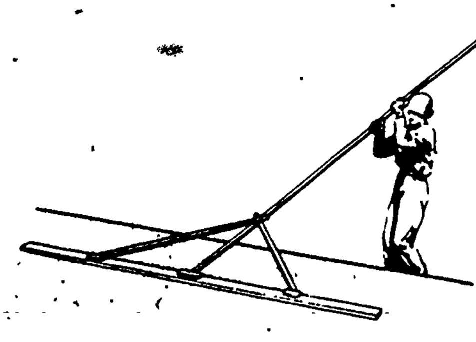


Figure 42. Long-handled wood float.

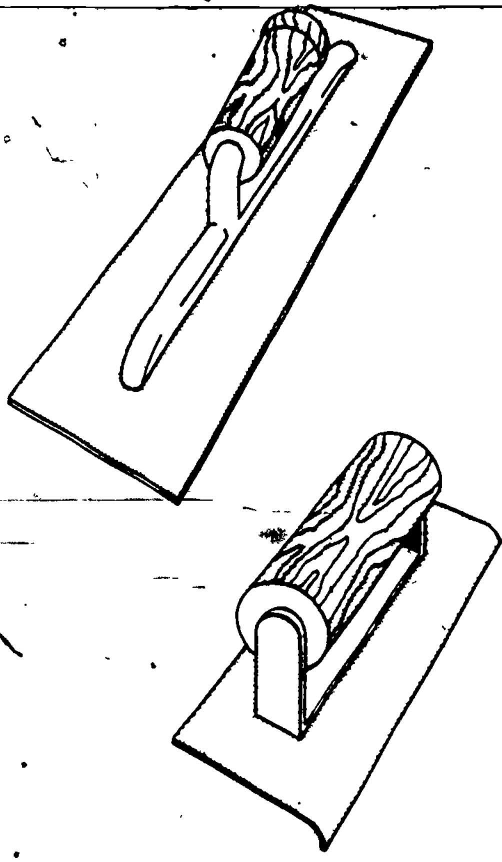


Figure 43. Steel trowel and edger.

driveways, contraction joints should be spaced at intervals equal to the width of the slab, but never more than 20-foot intervals. It's a good practice to use a straight board as a guide when you are cutting joints in the concrete. On large

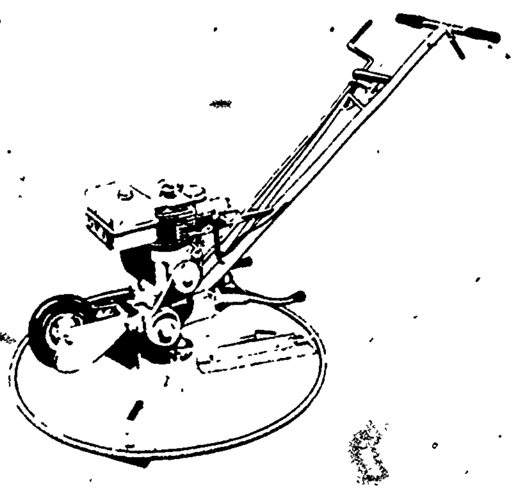


Figure 44. A typical power trowel.

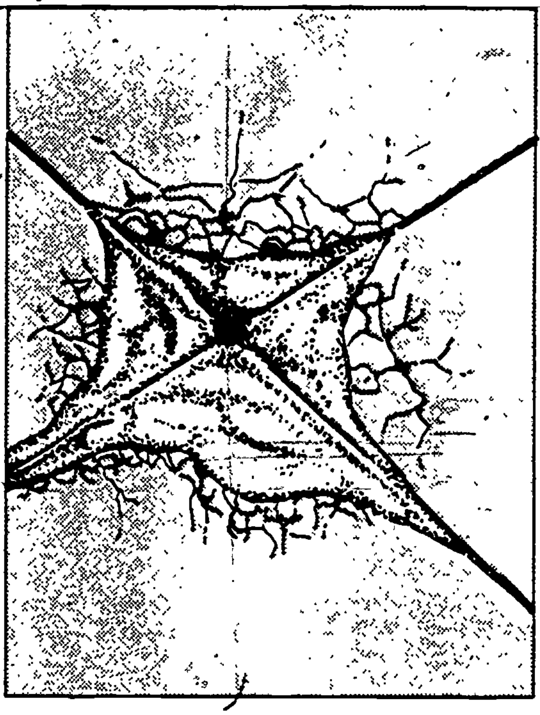


Figure 45. Scaling due to overfinishing.

surfaces, joints can be cut with an electric or a gasoline-driven power saw. Joints made with a power saw should be cut within 4 to 12 hours after the slab has been placed and finished. A jointer or groover is shown in figure 46. Now that the slab is edged and jointed, let's continue with the different finishes for concrete surfaces.

30. If a dense, smooth surface is desired, floating should be followed by steel troweling. Steel troweling operations are shown in figure 47. You should perform this troweling operation after the moisture film or shine disappears from the

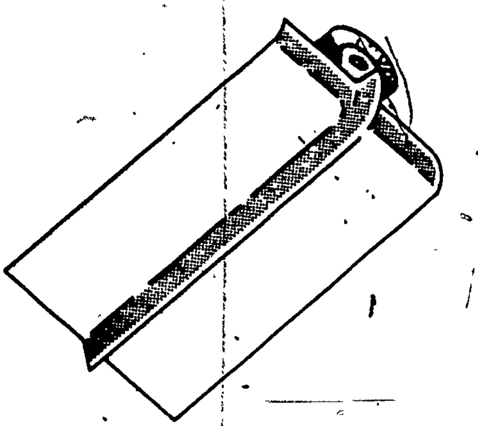


Figure 46. Jointer or groover.

Figure 47. Troweling operation.

floated surface and the concrete has hardened enough to prevent the fine material and water from working to the surface. Excessive and too-early troweling tend to produce crazing (break into pieces) and lack of durability; too long a delay in troweling results in a surface that is too hard to finish properly. The usual tendency is to start to trowel too soon. Troweling should leave the surface smooth, even, and free of marks and ripples. Spreading dry cement on a wet surface to take up the excess water is not a good practice if a wear-resistant and durable surface is required. If excess water is present on the surface of the slab, finishing operations should be delayed until the water has evaporated or been carefully blotted up.

31. To obtain a surface that is fine-textured but not slippery, you should trowel over the surface with a circular motion immediately after the first regular troweling. In this process, you should keep the trowel flat on the surface of the concrete.

32. Where a hard, steel-troweled finish is required, the first regular troweling should be followed by a second troweling after the concrete has become so hard that no mortar adheres to the trowel and a ringing sound is produced as the trowel is passed over the surface. When you are giving the surface a final troweling, you should hold the trowel in a slightly tilted position and apply heavy pressure so that the surface is thoroughly compacted.

33. Hairline cracks in a slab are usually caused by a concentration of water and fines at the surface, resulting from overworking the concrete during finishing. Rapid drying will also cause cracking. Voids that develop prior to troweling usually can be closed by pounding the concrete with a hand float.

34. If a nonskid surface is desired, it can be produced by brooming the concrete before it has thoroughly hardened. You should carry out the brooming operation immediately after the slab has been floated. For some floors and sidewalks where severe scoring is not desirable, the broomed finish can be produced with a hairbrush (paint brush) after the surface has been troweled to a smooth finish. Where rough scoring is required, use a stiff broom made of steel wire or some type of coarse fiber. Always broom the concrete in such a manner that the direction of the scoring is at a right angle to the direction of traffic.

35. Another method of producing a nonskid surface is to drag a wet burlap belt longitudinally along the length of the strip. The burlap must be clean and kept well saturated. After the desired finish is obtained, the curing operation should be started immediately.

36. **Curing Concrete.** One of the most important jobs in any concreting operation is properly curing the concrete. Regardless of the care taken in mixing, placing, and finishing concrete, a poor finished product may result without proper curing. The object of curing is to prevent or replenish the loss of necessary moisture during the early, relatively rapid stages of hydration. You can accomplish this by keeping the exposed surface continuously moist. This can be done by continuously spraying or by keeping the surface covered with a wet covering of burlap, canvas, or building paper. When building paper is used, the concrete surface is moistened before the paper is applied. As soon as the concrete has hardened enough so that the surface will not be marred, you can replace the burlap, canvas, or building paper with coverings of earth, sand, or straw that has been kept moist for at least 3 days by occasional sprinkling.

37. Another method of moist curing is ponding. This is done by keeping about 1-inch of water on the concrete surface. The water can be confined by earth dikes around the edges of the slab. Early drying must be prevented or the concrete will not reach its full potential strength.

38. Concrete surfaces can also be cured with commercial curing compounds (containing wax or resin) if they seal the surface without penetrating. With the use of curing compounds, the concrete will cure for an indefinite period of time while the slab, sidewalk, etc. are in use. When using curing compounds, you should follow the manufacturer's instructions for application. Precautions must be taken when placing, finishing, and curing concrete in excessively hot or cold temperatures.

39. **Cold-Weather Concreting.** Concrete placed when the air temperature is less than 50° F. is classified as cold-weather concrete, and certain precautions are necessary for cold-weather concreting. Concrete hardens slowly and gains strength slowly at low temperatures. If the concrete freezes during the first 2 days after placing,

it will be severely damaged. You should never place concrete on a frozen subgrade because of the danger of settling when the ground thaws. Before placing concrete in forms, be sure you remove all ice, snow, and frost from the forms and reinforcing material. You can efficiently do this with live steam. If protective covering is required, it should be installed as completely as possible before the concrete is placed. After the concrete is placed, the remainder of the covering should completely inclose the freshly placed concrete to minimize heat loss. If warm concrete is to be placed on a cold surface of hardened concrete, the hardened concrete must be warmed and its surface sufficiently moistened before the new concrete is deposited. The precautions to be taken in cold weather depend upon the air temperature. Suitable precautions for three different temperature classifications are as follows

- 40° to 50° F For air temperatures of 40° to 50° F., the temperature of the placed concrete should be from 60° to 70° F. You can produce a placed concrete mix of 60° to 70° F. by heating the mixing water and aggregate, if necessary, to a temperature between 70° and 80° F. when it is placed in the mixer For permanent construction, the placed concrete must be cured at a temperature of 50° F for 5 days or 70° F for 3 days. If high-early-strength cement is used, the curing period can be reduced to 2 days at 70° F or 3 days at 50° F
- 32° to 40° F. For air temperatures from 32° to 40° F., high-early-strength cement should be used, or 2 pounds of calcium chloride per sack of cement should be added to accelerate hardening. Also, you may have to heat the forms to remove ice, snow, or frost. The concrete temperature at the time of mixing should be from 70° to 80° F. You can obtain this temperature by heating the water or heating both the water and aggregate. In no case should the concrete mixing temperature exceed 80° F.; higher temperatures will reduce its strength. Remember, the curing conditions described in the previous classification must be provided.
- 0° to 32° F. For air temperatures in this range, high-early-strength cement should be used, however, if this type of cement is not available, calcium chloride should be added in the amount of no more than 2 pounds per sack of ordinary cement. Calcium chloride is an accelerator which enables the concrete to develop strength more rapidly. The aggregate and water must be heated to provide 70° to 80° F. concrete temperature at the mixer. It is also advisable to heat the forms. Curing conditions as described in the first classification must be provided. After the required curing period, the concrete can be allowed to cool to the temperature of the atmosphere, regardless of how cold it is. You should never attempt to place concrete in temperatures below 0° F. unless the amount of concrete is exceptionally small and can be easily protected.

40. If concrete is frozen before it has taken its initial set, it will not be damaged if thawed out rapidly and properly. It will later develop almost the same strength and durability as it would have if freezing had not occurred. Rapid thawing is done with the use of heated inclosures.

41 The freezing of concrete before it sets up will cause the water to expand and disrupt the bond between the cement and aggregate particles. If the freezing occurs after the concrete has set up and after it has been cured as required, there will be no damage.

42. Heating the mixing water is the most practical means of warming the concrete. Water is not only easy to heat, but each pound of water heated to a given temperature has roughly five times as many heat units stored in it as are stored in a pound of aggregate at the same temperature. Water is commonly heated in a boiler by live steam or by heating coils. The temperature of water should never exceed 165° F. because of the danger of causing a quick flash set of the cement. Mix the hot water with the aggregate so the mix temperature will be below 80° F. before you put in the cement. Take care so that the hot water does not come immediately into contact with the cement.

43. **Hot-Weather Concreting.** During hot weather, precautions should be taken to maintain concrete temperature during curing at not more than 85° to 90° F. There will be climatic conditions where this limitation cannot be observed. Mixing, placing, and curing concrete at high temperatures affect it in three different ways:

(1) The strength of concrete that is mixed and cured at high temperature is never as great as that of concrete mixed and cured at temperatures below 70° F.

(2) The cracking tendencies are increased because of the greater range between the high temperature at the time of hardening and the low temperature to which the concrete will later drop.

(3) Concrete which is mixed, placed, and cured at high temperatures has been found to fail sooner, as a result of repeated cycles of moisture and temperature changes above the freezing point, than concrete which is mixed, placed, and cured at lower temperatures.

44 You can lower the temperature of a concrete mix by any of several means. These means include (1) Using cold mixing water (slush ice can be used in extreme cases to cool the water), (2) avoiding the use of hot cement, (3) cooling the coarse aggregate by sprinkling, (4) insulating

mixer drums by cooling them with sprays or wet burlap coverings, (5) insulating water supply lines and tanks, (6) shading materials and facilities not otherwise protected from the heat, and by (7) working only at night.

45. Concrete curing is difficult to accomplish in hot weather because the water evaporates rapidly. However, it is especially important in hot weather because of the greater danger of crazing and cracking from rapid loss of moisture. Therefore, moist curing, especially ponding, should be used.

46. **Cleaning Concrete.** Concrete surfaces frequently become discolored. If appearance is important, the surface should be cleaned. You can clean the surface with a cement-sand mortar consisting of 1 part portland cement to 1¼ parts fine sand. You should apply the mortar to the surface with a brush after all defects have been repaired. If a light-colored surface is desired, white portland cement can be used. Immediately after the mortar has been applied, you should scour the surface vigorously with a wood or cork float. After a period of 1 to 2 hours, remove all excess mortar from the slab with a trowel. This will allow sufficient time for the mortar to harden enough so that the trowel will not remove it from the small voids in the slab. After the surface has dried, you should rub it with dry burlap to remove any loose material. There should be no visible film of mortar after the rubbing operation. When you are working on large concrete surfaces, complete one section without stopping before starting on the next.

47. Surface stains can be washed with acid if the staining is not too severe. You can do this by first wetting the surface, and while the surface is still damp, scrub it thoroughly with a 10-percent solution of hydrochloric acid. You should then remove the acid from the surface with clean water. If acid will not remove the stains, they can be removed by sandblasting. When you are handling acid, wear goggles to protect your eyes and loose clothing and gloves to protect your skin.

48. **Watertight Concrete.** If you intend for concrete to be watertight, it must be as dense as possible and moist-cured for a longer period of time than would be necessary if watertightness were not important. Listed below are six requirements that must be followed if you are to have watertight concrete:

(1) No more than 6 gallons of water should be used per sack of cement.
(2) The concrete must be workable so it will not be difficult to place.
(3) The aggregate must be sound and have low porosity to prevent it from absorbing water.
(4) The concrete must be properly placed and thoroughly compacted.
(5) The concrete must be maintained at a temperature of 50° F. and be kept moist throughout the curing period.
(6) Reinforcing steel must be used to prevent the concrete from cracking.

49. **Waterproofing Compounds.** Waterproofing compounds are divided into two classes. The first includes compounds mixed with the concrete. They consist of finely ground clay or hydrated lime. The second consists of surface washes, which are recommended over the mix compounds.

50. There are a number of surface washes or coatings that give good results and they are sold under various trade names. Bituminous coatings, emulsified asphalts, mastic cement plaster, metallic powder, and portland cement paint are among the suitable waterproofing compounds. All of these deteriorate with time. You should always apply surface washes according to the manufacturer's specifications. When backfilling against a foundation that has been waterproofed, be careful not to damage the waterproofed coating.

51. **Membrane Waterproofing.** Membrane waterproofing is the most effective method of preventing the passage of water through concrete. The method normally used on horizontal surfaces consists of first coating the surface that is to be waterproofed with hot roofing asphalt. You should apply the hot material with a mop as soon as the concrete surface is dry enough to allow the hot asphalt to stick to the surface. One layer of roofing felt is placed on this coating while it is still hot. The layer of roofing felt is then mopped with hot asphalt and a second layer is placed over the first. You can use a push broom to spread the roofing felt. The second layer of felt should also be coated with hot asphalt. Cool tar can be substituted for asphalt. On vertical surfaces, a thick trowel coat of bituminous plastic material is applied to the concrete surface and a layer of flexible bituminous-treated burlap is embedded in the trowel coat.

MODIFICATIONS

Pages 31-34 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Mortar and Plaster

SEVERAL centuries ago man accomplished heavy stone construction by using adhesive materials to hold the stones together. Ancient Egyptians laid mud between each course of sun-dried clay brick. At a later date, they burned gypsum (hydrous calcium sulphate) and mixed the end product with sand and water to use as a mortar in the joints of their stonework. The biggest advance in mortar was made in 1824 when Joseph Aspdin manufactured an improved cement, produced by heating a mixture of limestone and clay and crushing the mixture to a fine powder. He called this powder portland cement because it resembled stone found in various quarries on the Isle of Portland, England. For this reason, Aspdin is recognized as the father of modern portland cement.

2. As a masonry specialist, you will use this modern portland cement or portland masonry cement with sand and water to lay masonry units. Masonry cement has additives that make it adhere better to masonry units. You will build structures with this mortar and various type of masonry units, such as brick, block, tile, etc. How well you learn your job depends on you. By properly accomplishing your duties as a mason, you will become more skilled in your job and this can also mean more money for you. You probably ask how? Well, the better job you do for your supervisor, the faster you will be promoted and a promotion means a pay raise. The material contained in this chapter will help you accomplish this task. Our discussion covers the materials, methods, and procedures for properly preparing mortar. Plaster bases, use of plaster, and repair of plastered surfaces are also covered. Before you learn the procedures for laying masonry units, you must first learn to make mortar.

13. Mortar

1. Mortar is defined as "a combination of cement, sand, and water mixed in the correct proportions to produce a mix of workable consistency."

2. **Mortar for Masonry Units.** The mortar commonly used for laying masonry units is made with masonry cement. If this cement is not available, you can use normal portland cement and hydrated lime mixed in the proper proportions. The recommended amount of materials proportioned by volume for mortar mixes is shown in figure 48. Mortar made with these mixtures

Type of Service	Cement	Mortar sand in damp, loose condition	Hydrated lime
For ordinary service	1—masonry cement or 1—portland cement	2 to 3 4 to 6	— 1 to 1-1/4
Subject to heavy loads, violent winds, and severe frost action	1—masonry cement plus 1—portland cement or 1—portland cement	4 to 6 2 to 3	— 0 to 1/4

Figure 48. Recommended mortar mixes.

will produce a strong bond between masonry units. Good mortar is necessary for good workmanship. Since mortar must bond masonry units into a strong, well-knit, watertight wall, it must contain a number of desirable properties. Let's examine some of them.

3. One necessary property is workability. Mortar is said to be workable when it spreads easily and remains firmly in the mortar joints. A workable mortar will always adhere to masonry units. There is no need to add agents (lime, etc.), to mortar made with masonry cement, because the cement itself produces the desired workability. The workability also depends partly on good mortar sand. Mortar made with masonry cement also has good water retention, which prevents rapid loss of moisture when used with dry masonry units. It will also remain soft and plastic long enough for you to aline and level the masonry units. To avoid the rapid loss of water from suction, some masonry units must be moistened before they are used.

4. You should never wet the concrete block to control the loss of moisture because a concrete block will not absorb water from the mortar like other types of masonry units. Masonry units, such as clay brick, tile, etc., must be wetted before they are used. The use of entrained air will add to the workability and water retention of the mortar. Now let's discuss the other materials you will use to make a good mortar.

5. **Aggregate.** To make a good mortar, you must use sand that is free of dirt, vegetable matter, and salts. You can even produce a better mortar if the sand is uniformly graded and proportionately mixed. In a well-balanced aggregate mixture, a certain percentage of the sand must pass through a sieve of a given size. The sieve numbers and the percentages of sand that should pass through the sieves are shown in figure 49. There are several types of mortar sand, each having its own characteristics; so it would be difficult to specify the exact amount to use in preparing mortar. There should be enough particles of fine sand

Sieve Number	Percentage of Sand Passing Through Sieve
4	100
8	97
16	84
30	50
50	27
100	6

Figure 49. Graded mortar sand mixes.

so that, when coated with cement paste, they fill to avoid the major voids between the coarser sand particles. An excessive number of fine sand particles requires more cement paste than a well-graded mixture.

6. **Water.** The water used for making mortar should be as pure as drinking water. It should be free from chemicals, such as salts and alkalies. Large amounts of these chemicals or organic matter will affect hydration and the quality of mortar. To have the best possible mortar, the materials must be properly wetted and thoroughly mixed.

7. **Mixing.** Machine mixing should always be used except on jobs where the requirement for mortar is small. After the proper ingredients have been proportioned and placed in the mortar box or mixer, the quality of mortar will depend on the mixing time. You can improve the quality of hand-mixed mortar by mixing it for a long period of time. The same tools are used to mix mortar and concrete. These tools were explained and illustrated in Chapter 1.

8. Mortar that has stiffened on the mortar board should be retempered to regain its workability by remixing and adding more water. After mixing the mortar, you should use it within 2 to 2½ hours if the temperature is 78° F., or higher. If the temperature is below 78° F., the mortar should be used within 3½ hours. Any mortar you don't use within the time indicated should be disposed of.

14. Plaster

1. Plaster is a facing material that is applied to walls and ceilings. When plaster is used on the exterior of buildings and structures, it is referred to as stucco. The most commonly used plasters are gypsum, Keene's cement, and portland cement. They are usually applied in three coats: scratch, brown, and finish. Before we talk about the types, uses and proportioning of plasters, let's discuss the different bases used for plaster.

2. **Plaster Bases.** There are several bases to which plaster is applied. Wood, metal, and masonry laths are the most commonly used bases.

3. *Wood.* Wood laths are thin strips of wood, approximately 1½ inches in width, with rough surfaces. They are nailed on wooden studs. The laths are spaced ⅜ inch apart at the edges and ¼ inch apart at the ends. The ends of the lath should be staggered on the studding to provide a stronger base for the plaster. Wood laths must be dampened before plaster is applied to prevent them from drawing moisture from the plaster.

4. *Metal.* Plywood sheeting covered with building paper and metal lath is used as a plaster base. Metal lath provides an excellent key (bond) for plaster. It must be galvanized or coated with

58

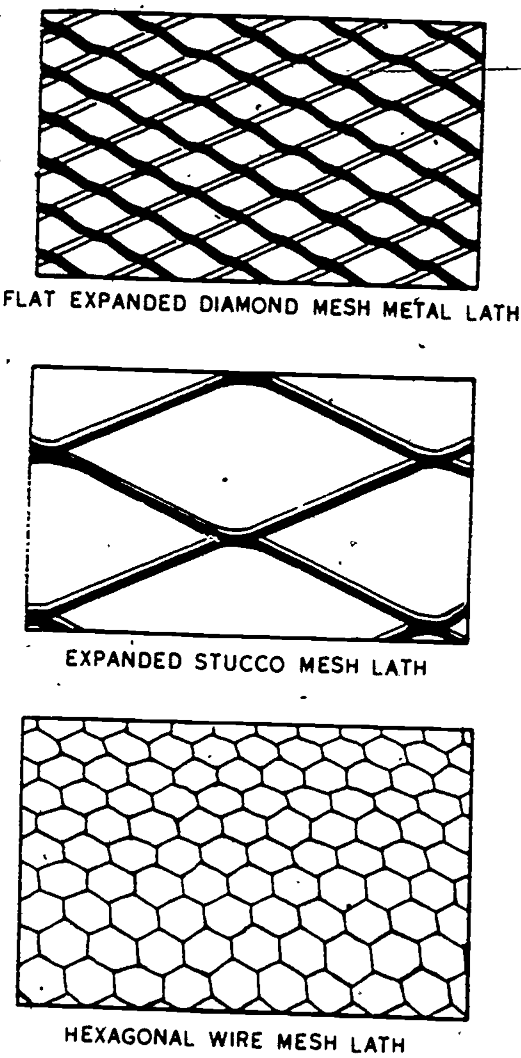


Figure 50. Common types of metal lath.

rust inhibitive paint. You should never use uncoated metal lath because it rusts and corrodes rapidly in plaster. There are several different kinds of metal lath available. Flat expanded diamond mesh metal lath, expanded stucco mesh lath, and hexagonal wire mesh lath are the most common. These three types are shown in figure 50.

5. The openings in metal lath should not exceed 4 square inches in area. Metal lath used on interior walls and ceilings has smaller mesh openings than that used on exterior walls. This is because of the fine grade of plaster used to obtain a smooth finish on interior work. Metal lath for stucco is attached to exterior surfaces with special furring nails after the surface is covered with waterproof building paper or felt. These nails hold the reinforcement steel lath in place and there should be a minimum space of ¼ inch be-

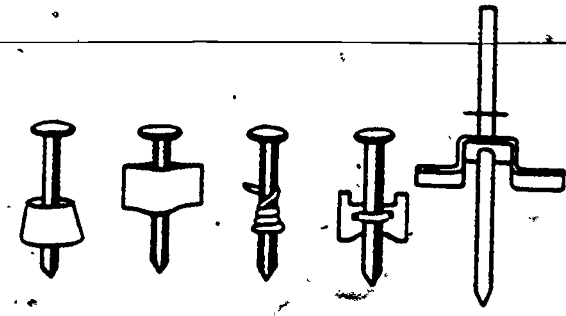


Figure 51. Types of furring nails.

tween the supporting structure and reinforcement. The different types of furring nails are shown in figure 51.

6. Special metal lath (corner bead), shown in figure 52, serves two purposes in plastering. Corner bead laths reinforce external corners and also serve as a guide, or gage, for acquiring a uniform thickness. Corner beads are manufactured in two all-metal strips: the bullnose bead, which has a wide radius bead and is designed especially for corners receiving hard usage; and the standard bead, which has a very small radius bead and is designed to provide sharp, clean corners. The bead shown in figure 52 is the standard bead.

7. A corner lath for interior corners is an angle-shaped strip of lath, with 2- to 3-inch legs. It is used to reinforce interior plastered corners to prevent them from cracking. If preformed strips are not available, you can cut them from metal lath sheets and form them on the job to fit the particular corners in which they are to be installed.

8. Take care when fastening any type of corner lath. Fasten the corner lath at its edges, using staples over wood lath and tie wires over metal lath. Be sure the corner lath is not fastened by nailing through to the superstructure because stresses in the framing will then be transmitted directly into the plaster and cause it to crack.

9. *Masonry*. When applying portland cement plaster or stucco to any masonry surface (brick, block, concrete, etc.), be sure to obtain a good bond. A good bond with masonry surfaces is dependent on two factors: mechanical bond and suction. If the surface is coarse enough for the

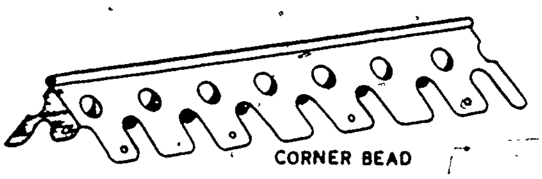


Figure 52. Corner bead.

plaster to cling, it has good mechanical bond characteristics. Suction is the amount of moisture the masonry will absorb, aiding fresh plastering material to stick to the base. You can check a masonry surface for good suction by spraying it with water and observing the reaction of the masonry. If some of the water is not drawn in, it is impossible to obtain a good bond. In this case you will have to use metal lath to key the plaster to the masonry. Weathered masonry surfaces may have too much suction. When you apply plaster to this type of surface, the plaster stiffens quickly and becomes difficult to work. To stop this from happening, spray (not soak) the masonry with several applications of water. It is also important that the suction be controlled uniformly over the entire masonry surface. If you do not wet the surface evenly, some parts of the masonry will draw more moisture from the plaster than others and the final finish may be spotted.

10. If a masonry surface is dense and smooth, a good bond cannot be obtained unless the surface is roughened. There are several ways you can roughen a masonry surface. One way is to chip the surface with a brick hammer. If this method is used, at least 70 percent of the surface should be roughened and the marks or chips should be uniformly spaced over the entire surface. A brick hammer is shown in figure 53. You can also roughen the surface with a power-driven roughening machine. This machine is equipped with a series of steel cutters mounted to provide a flailing action which results in a scored pattern. Another method of roughening the surface, when working with portland cement plaster, is to apply a dash bond coat. A dash bond coat consists of one part portland cement and one to two parts sand mixed with the correct amount of water to give the mix an adhesive consistency. To apply this mix, you dip a long stiff-fibered brush in the mix and splatter the material on the surface. Allow the material to harden to produce a rough surface. You should never trowel a dash bond coat. Be sure it has set before you apply the plaster. If the dash bond coat fails to give a good mechanical bond, you will have to cover the surface with building paper and metal reinforcement lath before plastering. Regardless of the efforts spent preparing a surface for plaster, it may still crack. Although we can't prevent plastered surfaces from cracking, we can control the cracking by the use of control joints.

11. **Control Joints.** Cracks can develop in plaster or stucco surfaces for various reasons, such as building movement, shrinkage stresses, and foundation settlement. It is difficult to prevent cracking from all possible causes, but it can be controlled by dividing large areas into rectangular sections by means of metal control joints. A control joint in a concrete wall ready to receive stucco is shown in figure 54.

12. Walls and ceilings should be divided into rectangular panels with control joints spaced a maximum of 20 feet apart. The metal used for control joints on exterior surfaces should be

Figure 53. A brick hammer.

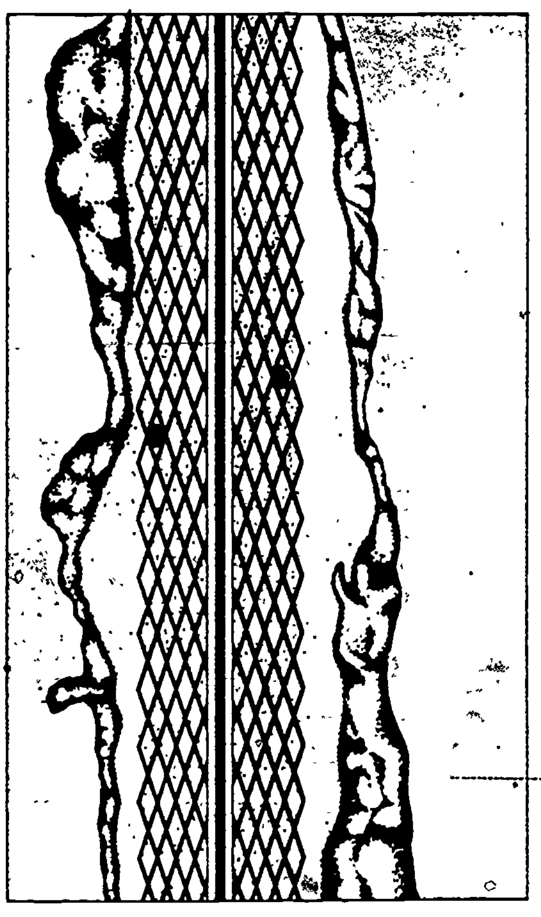


Figure 54. Control joint.

weatherproof and corrosion-resistant. When plaster or stucco is applied to metal reinforcement or directly to a masonry surface, control joints must be installed directly over all existing joints in the wall.

13. **Types, Uses, and Proportioning of Plaster.** There are various types of plaster, and they are similar in composition and method of application. Each is designed to fulfill certain basic requirements.

14. *Gypsum plaster.* Gypsum plaster is the most widely used plaster and is the type most generally used for interior construction. It can be readily applied to interior lath, interior masonry surface, and metal lath surfaces of exterior masonry.

15. The proportions for gypsum plaster used in the scratch coat consist of one part plaster to two parts sand. (When the scratch coat is to be used over masonry units, the mix should contain one part plaster to three parts sand). The brown coat consists of one part plaster to two and one-half parts sand, and the finish coat consists of one-fourth part plaster, three-fourths part hydrated lime, and three parts sand.

16. *Keene's cement plaster.* Keene's cement plaster produces a very hard, moisture-resistant surface suitable for rooms or surfaces subject to hard usage and in areas subject to continued moisture conditions, such as bath or shower rooms Keene's cement plaster can only be applied over gypsum plaster bases and is generally used as a finish coat. Always apply Keene's cement plaster in accordance with the manufacturer's instructions.

17. *Portland cement plaster.* Portland cement plaster may be applied directly to interior and exterior masonry surfaces. When used elsewhere it should be applied over metal lath. Portland cement plaster is not suitable for application over gypsum plaster. Each coat of portland cement plaster must be moistened with an even fog spray of water before the next coat is applied. This will prevent the hardened plaster from drawing moisture from the freshly placed plaster, causing it to eventually crack.

18. The proportioning of portland cement plaster consists of one part portland cement and three to five parts damp, loose aggregate for the scratch and brown coats. Hydrated lime may be added to the mix as a plasticizer (to make it more workable) but the amount used should not exceed 10 percent by weight or 25 percent by volume of the cement used. When available, you should use masonry cement because it already contains plasticizers. By using this cement you can simplify job site proportioning and mixing, because only sand and water are added to masonry cement.

19. When preparing the finish coat of plaster, you will get truer colors and better appearances if you use white portland cement and a fine-graded, light-colored sand. This mixture consists of one part white portland cement, not more than one-fourth part hydrated lime, and between two and three parts sand. Now that we know the amount of materials used in a plaster mix, let's discuss the quality of these materials.

SIEVE NO.	PERCENT RETAINED MIN.	MAX.
4	0	0
8	0	10
16	10	40
30	30	65
50	70	90
100	95	100

Figure 55. Gradation of aggregate.

20. **Water.** Water used for making plaster should be clean, fresh, suitable for domestic purposes, and free from minerals and other organic substances.

21. **Aggregate.** The aggregate used for making plaster can greatly affect the quality of the finished product. Aggregate should be well graded, clean, and free from foreign material that prevents the cement paste from binding the aggregate particles. Sand for plaster should be graded with particles ranging from coarse (maximum size, 1/8-inch) to fine. In well-graded sand, the smaller particles will fill the major voids between the larger particles. The amount of sand for a properly graded plaster mix that will be retained on each sieve is shown in figure 55.

22. Lightweight aggregates weigh approximately one-tenth as much as dry sand. They are manufactured materials, more expensive than sand and should only be used where their cost can be justified. Lightweight aggregates are especially useful for insulating against sound and heat; therefore, their fireproofing qualities are important.

23. **Mixing.** The materials for all coats of plaster must be thoroughly mixed. Always mix the dry materials before adding water. A power mixer should be used for uniform mixing and blending of materials. A power mixer for plaster and stucco is shown in figure 56. You should mix the materials for a minimum of 5 minutes after the water is added to the dry materials. It may be necessary to use trial mixes to determine a good workable mix. You can recognize a good mix by its workability and adhesiveness to plaster bases. When a colored finish is desired, it can be obtained by adding color pigments to the finish coat. Color pigments are added to the cement in the plaster mix at a 9:1 ratio: 90 percent cement to 10 percent color pigment.

61

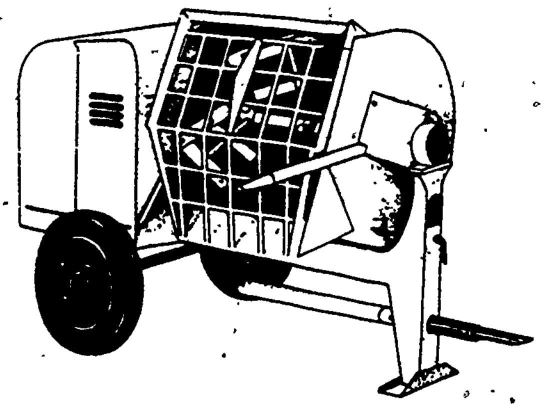


Figure 56. Power mixer for plaster and stucco.

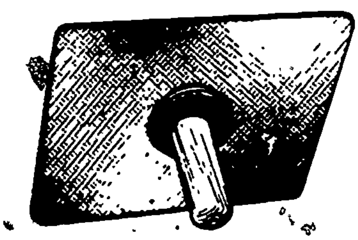


Figure 57. Plasterer's hawk.

24. Now that we have discussed the mixing process, the next step is the application of plaster. Before we get into the application, let's talk about some of the tools you will be using.

25. **Plastering Tools ~~and Their~~ Uses.** The tools used by ~~the~~ mason when plastering are the plasterer's hawk, a variety of shapes and sizes of trowels and floats, the scarifier, rods, darbies, levels, and screeds (straightedges). Let's discuss the plasterer's hawk first.

26. *Hawk.* The plasterer's hawk, as shown in figure 57, is available in sizes from 10 to 14 inches square. It is used to hold an immediate supply of plaster. A trowel is used to push a ready supply of plaster on the hawk.

27. *Trowels.* A variety of shapes and sizes of trowels which you will use for plastering are shown in figure 58. Most of them are used for

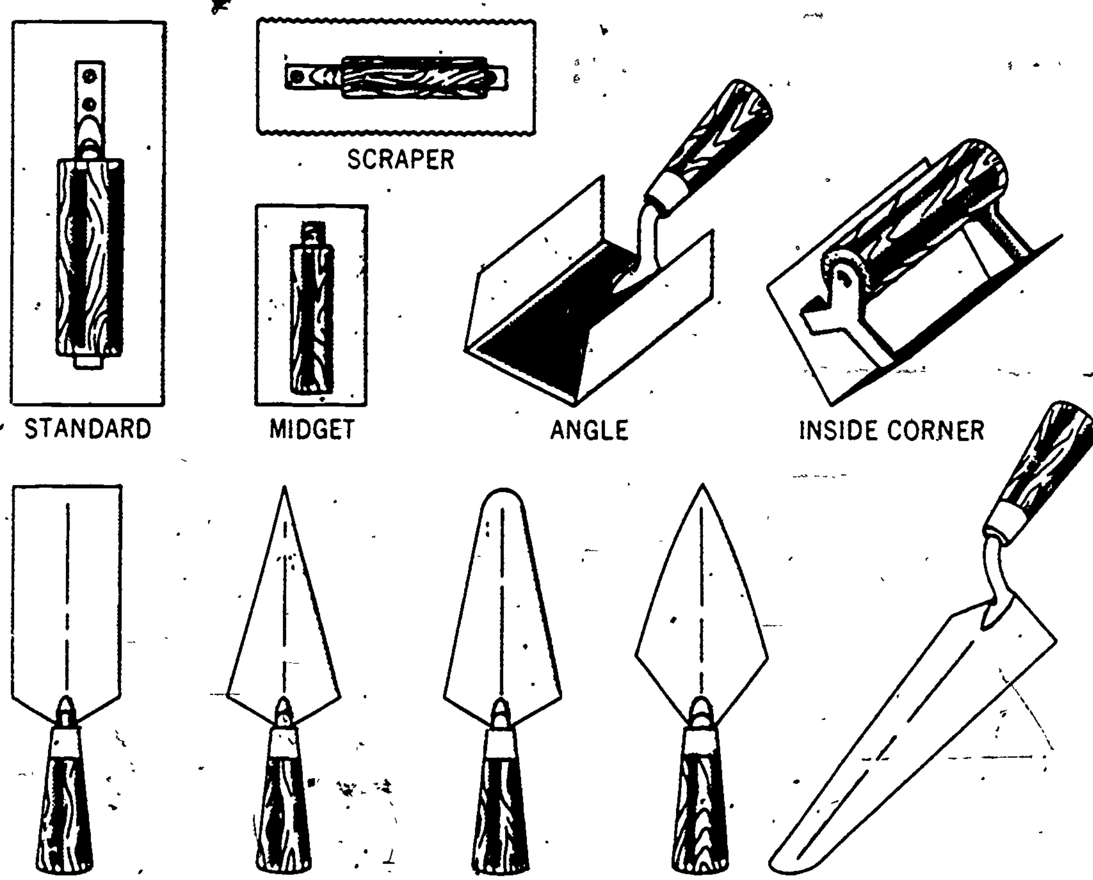


Figure 58. Types of plastering trowels.

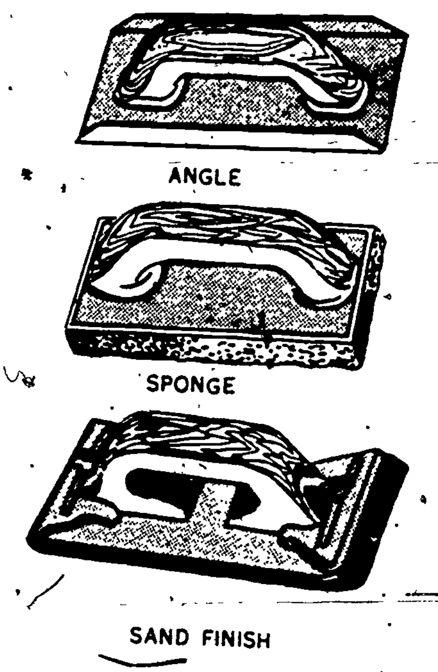


Figure 59. Types of floats.

special work rather than for general plastering work such as walls and ceilings. The midget trowel is used for covering small areas and hard to get at places where the standard trowel would be too large. The angle trowel is a flat-bottomed, two-sided trowel used for smoothing close, opposing, 90° inside corners. The inside trowel is used for working single 90° corners. The margin trowel is used in narrow places; the gauging trowel behind pipes: the scraper trowel to knock off high spots; the pointing trowel to point up joints; and the covering trowel to cover asbestos pipe.

28. *Floats.* Different types of floats are used for finishing plaster. Some are designed for flat work, while others are for corners or angle work. Smooth-bottomed floats are made of Fiberglas, wood, steel and other metals. Floats designed to produce textured finishes, such as a sand finish, have bottoms made of rubber or carpet. The texture of sponge rubber used on the floats is classified as compact, dense, cellular, porous, soft, or open. The steel angle, sponge, and sand finish floats are shown in figure 59.

29. *Scarifier.* The scarifier is used to roughen plastered surfaces so that the next coat of plaster will have a rough surface to cling to. The scarifier is made up of tempered flat steel tines that are flexible and uniformly spaced. A scarifier is shown in figure 60.

30. *Rods.* Several types of rods are used to level freshly plastered surfaces. Lightweight rods are made of aluminum alloy or magnesium alloy. If aluminum rods are not available, you can use a 1- by 4-inch piece of wood as a straightedge. Common sizes of rods run from 5 to 8 feet in length. The standard type rods, shown in figure 61, are the browning, lightweight browning, and a combination rod and featheredge. The browning rods are used for leveling large flat areas of plaster; the combination is used for truing corners and smoothing the finish coat of plaster.

31. *Darbies.* Darbies are long floats that are used to smooth freshly plastered surfaces, eliminating high or low spots left by the rod or straightedge. Some darbies are flat and flexible, some are wedge shaped, and others are channel shaped, as shown in figure 62. The darbies with serrated edges are used to roughen the leveled undercoats of plaster to prepare them for the next coat.

32. *Screeds and levels.* Screeds used for leveling plastered surfaces are the same as those previously discussed for leveling concrete; however, base screeds (grounds) are used to determine the proper thickness of plastered surfaces. Base screeds consist of strips of wood placed vertically from the top to the bottom of walls to aid you in obtaining a smooth and uniform thickness of plaster. You secure the screeds by nailing them to the wall studs. After applying the scratch coat between two of the wood screeds, the surface is screeded or leveled with a straightedge. After the plaster is straightedged, you should place a level on the straightedge which is pressed tightly against the base screeds to insure that the surface is level, plumb, and perfectly vertical or horizontal. Screeds used to obtain the desired thickness of the brown and finish coat consist of strips of plaster. You form these strips by holding a wood screed (of the plaster thickness desired) flat against the scratch coat and applying a strip of plaster 2 inches wide against one side of the screed. Then you run your trowel along the top of the screed and remove any overhanging plaster. Remove the wood screed

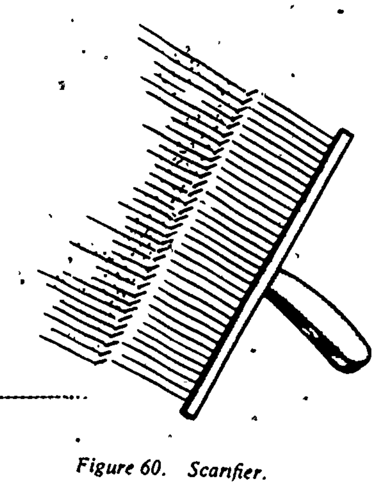


Figure 60. Scarifier.

63

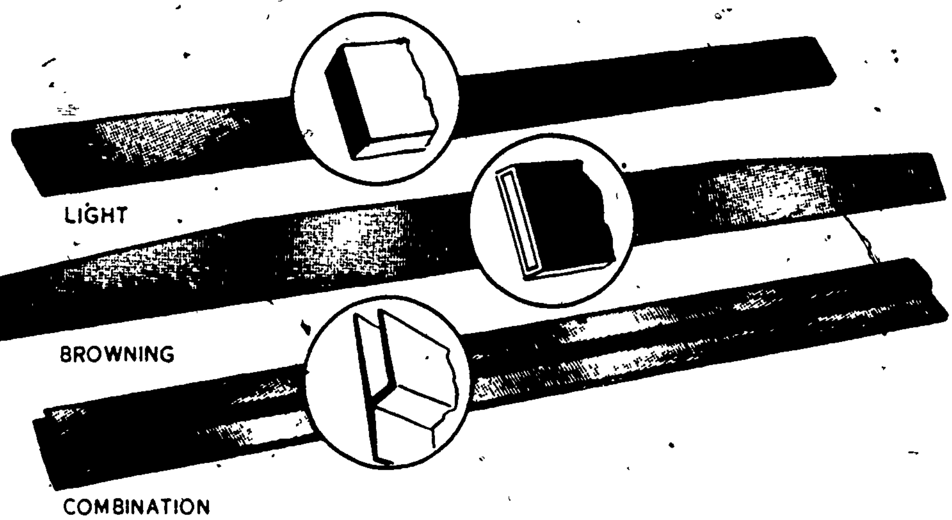


Figure 61. Types of rods.

and allow the plaster strips to set. Now you can apply the plaster, and straightedge and level the plastered surface between the screeds as you did for the scratch coat. Follow the same procedures for applying the finish coat as you did for the brown coat. Remember, after each coat of plaster is applied, you must level the surface. Three of the levels you will be using are shown in figure 63. The sprint bubbles near the ends of the level give the plumb reading, and the sprint bubbles near the center give the level reading.

33. **Application.** Plaster is usually applied in three coats. You apply these three coats in the following order: scratch, brown, and finish. (However, if the base to receive the plaster is masonry and no reinforcement is used, two coats may be sufficient.) When applying the scratch coat, push the plaster through the lath to insure complete coverage, as shown in figure 64. The thickness of the scratch coat should be between ⅜ and ⅝ inch, but in no case less than ¼ inch. After applying the scratch coat between two of the base

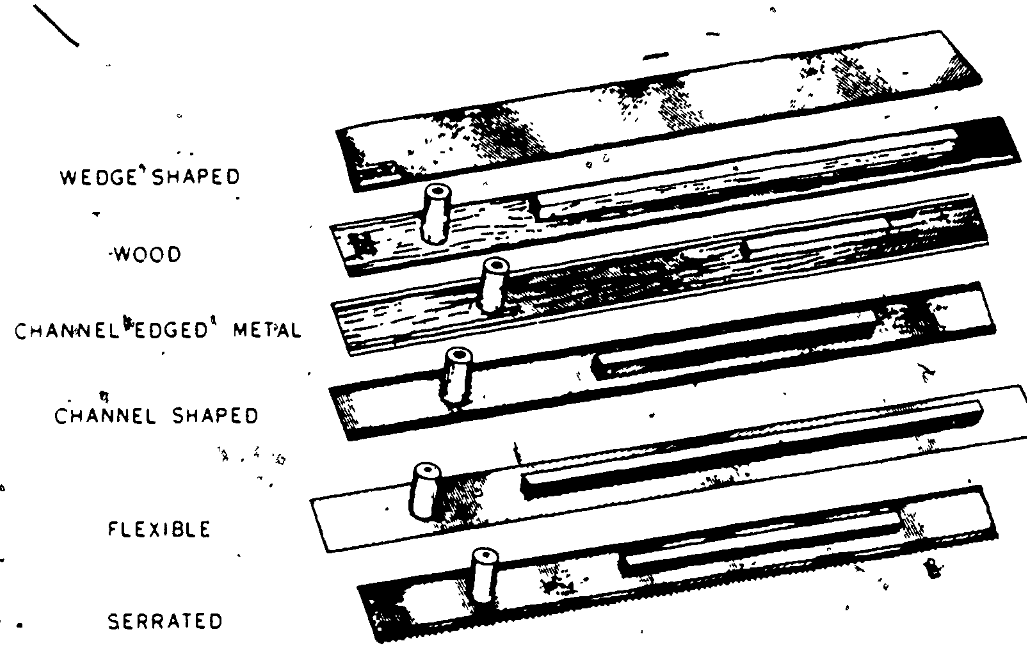


Figure 62. Types of darbies.

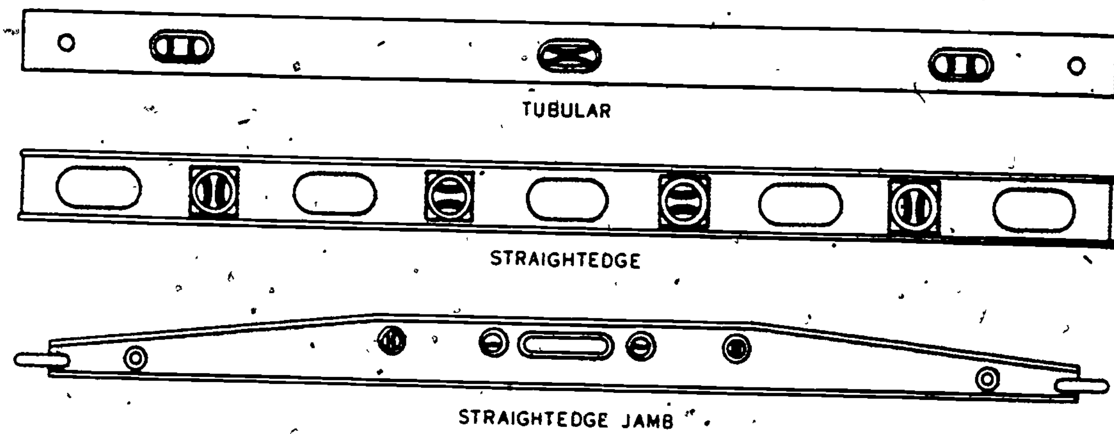


Figure 63. Types of levels.

screeds, you should screed, level, and scarify that area before applying the scratch coat to the next area You continue working in this manner until the scratch coat is applied to the entire surface. The scratch coat must be set hard, but not dry, before you form the plaster screeds for the brown coat This is usually 4 to 5 hours at a temperature of 70° F.

34. As soon as the plaster screeds are able to support a straightedge, you can start applying the brown coat The brown coat consists of a layer of plaster not less than 3/8-inch thick. You apply and finish the brown coat in the same manner as the scratch coat Like the scratch coat, the brown coat must be set hard, but not dry, you form the plaster screeds for the finish coat.

35. You can start to apply the finish coat as soon as the plaster screeds will support a straightedge Apply the finish coat not less than 1/8-inch thick. After applying the finish coat, you should screed, level, and float the surface. You should allow the surface to dry for a few minutes and trowel it to a true finish. The three-coat application of plaster is shown in figure 65. Unlike other plastered surfaces, portland cement plaster must be moist cured.

36. **Curing.** Portland cement plaster requires moist-curing the same as portland cement concrete. All three coats of plaster must be moist cured for at least 2 days at a temperature above 50° F. After the scratch or brown coat is moist cured 2 days, it must be allowed 5 days to dry before the next coat of plaster is applied. At the end of each curing period, before the next coat of plaster is applied, the plastered surface must be evenly wetted to prevent the hardened plaster from drawing moisture from the freshly placed plaster. Now that you understand the procedures of plastering, let's talk about the repairs you will be making to plastered surfaces

37. **Repair of Plastered Surfaces.** There are different types of cracks and breaks that appear in plastered surfaces. They consists of structural, map, and shrinkage cracks, and also sections of loose or broken plaster. Cracks and breaks are

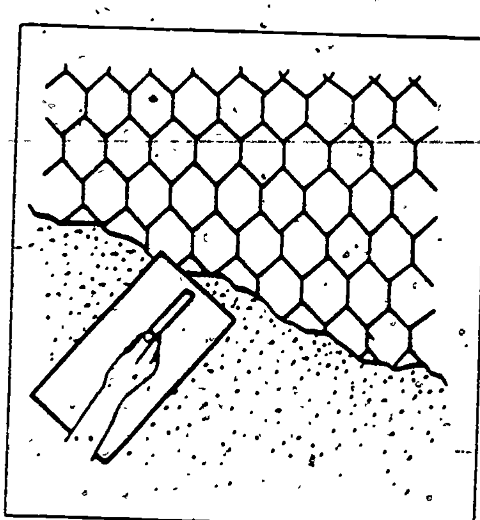


Figure 64. Applying plaster over wire mesh

Figure 65. Three-coat application of plaster

65

caused by a number of things. Some of these are settling of a structure, moisture infiltration caused by water leaking through a structure, and excessively moist air inside the structure. Before you repair any cracked or broken plastered surface, make sure the cause of the failure has been determined and the necessary repairs made to the structure so that the failure will not recur.

38. *Structural cracks.* Structural cracks are easy to identify since they are usually large cracks (1/4 inch or wider) extending either horizontally or vertically entirely through the plaster. The tools used to repair structural cracks consist of a putty knife, a pointing and finishing trowel, a sharp chisel, linoleum knife, a hammer, and a shallow mixing pan. Other tools may be used depending on the width and position of the crack. To repair a structural crack, you must first remove the loose material with a linoleum knife or chisel. Form the cracked surface in a "V" shape so that the surface opening is narrower than the base. A crack shaped in this manner will help bond the old and new plaster together. Only widen the crack enough so that you can clean the mesh openings in the expanded metal or wire mesh lath so that when you force the patching plaster in the opening a good key is formed. If the lath is wood, you must chip out the old keyed plaster between the wood lath so that a new key is formed when the patching material is forced in place Brush all loose material out of the grooved area and wet the wood lath and the edges of the grooved area to prevent suction of water from the fresh plaster. Now you are ready to prepare the plaster mix and complete the repair job.

39. Structural cracks are generally repaired with two coats of patching material. The first coat consists of one part gypsum plaster and two and one-half parts sand by volume. Materials for the second coat may be either gypsum plaster or a mix of one part hydrated lime and one-half part calcined gypsum. Both the first and second coats are mixed with clean water to a uniform color and workable consistency. The cracked area can always be repaired with the same type of material used in the original construction.

40. You should press the first coat of patching plaster firmly into place, filling the groove almost to the surface of the original plaster. Allow the plaster to set until it is nearly dry, but not hard, then complete the patch by applying the finish coat. The last part of the patching operation is to strike the plaster off flush with the original surface and trowel it smooth. Make sure that a solid bond exists between the edges of the patch and the new plaster.

41. *Map cracks.* Map cracks are less noticeable than structural cracks. They penetrate through the plaster but do not extend entirely across the plastered surface. Map cracks consist of several small lined cracks covering an area 6 inches or more in width and up to several feet in length This type of crack is usually caused by improper bonding between the plaster and the lath. To repair map cracks, use a mixture of gypsum plaster and water, mixed to a creamy consistency, and apply it to the cracked area with a paint brush It may be necessary to paint the surface a second time after the first application has dried to completely seal all the cracks.

42. *Shrinkage cracks.* Shrinkage cracks resemble map cracks in appearance but are ordinarily confined to the finish coat. They do not extend entirely through the plastered surface. Shrinkage cracks usually result from careless workmanship, too rapid drying on the surface, insufficient troweling, troweling while the surface is too wet, or by not troweling until the surface has become too dry. Use the same materials and procedures for repairing shrinkage cracks as you did with map cracks Where shrinkage cracks penetrate through to the lath and will not retain a paint mixture, you should cut out the area and repair it in the same manner used with structural cracks. Also follow the same procedure for repairing structural cracks when you are repairing holes in plastered surfaces.

43. *Loose plaster.* Loose plaster is indicated by bulging and cracking of large areas of plaster surfaces. To determine the extent of loosened plaster, tap the surface lightly with a small hammer and the resulting sounds will indicate the extent of the loose area. Loose plaster may result from excessive moisture from leaks in the roof, seepage through the exterior wall, and plumbing leaks in the structure. The excessive moisture causes the plaster to become soft and destroys the bond of the plaster to the base. Remember, before you repair any damaged area the source of moisture must be located and eliminated. To repair this type of failure, you must remove all the loose plaster around the break until you locate solid plaster that is well keyed to the lath. Also be sure that the lath is solidly secured to the structural frame of the building. If the lath is defective, remove it and replace with suitable lath. After the loose plaster is removed and the lath replaced, you can prepare to plaster the area Keene's cement plaster is the best plastering material to use on the interior of structures subject to dampness. When repairing a broken area with Keene's cement plaster, follow the same procedures you used for repairing areas of gypsum plaster. Always prepare Keene's cement plaster according to the manufacturer's instructions.

44. **Cleaning Plastered Surfaces.** There are several types of all-purpose synthetic detergents recommended for washing plaster surfaces. The

70

other materials you will need to wash plastered surfaces consist of two clean sponges to wash and rinse the surface, two 14-quart buckets for the washing solution and rinse water, a few soft, clean cloths for drying the surface, and possibly a ladder. To prepare for washing the wall, you should first add a small amount of detergent (about 1/4 cup) to a bucket 3/4 full of warm water. Mix the detergent and water thoroughly. Next you should fill the other bucket with warm clean water. Now you should check the strength of the detergent on a small portion of the surface. After you adjust the strength of the detergent, if adjustment is necessary, you should completely soak your washing sponge in the solution. Squeeze out the sponge until it doesn't drip water and start washing the surface. If the surface to be washed is a wall, you should start washing at the bottom and wash an area about 4 feet wide halfway to the ceiling. (Never start washing at the top of the wall, because the solution will cause streaking on the lower portion of the wall.) Rinse out your washing sponge as often as necessary until the portion of the wall being washed is clean. Next you should take the sponge from the rinse water, squeeze it until it doesn't drip, and rinse the area starting from the bottom and working up the wall. Rinse the surface as many times as necessary to remove all the detergent. You should finish drying the surface with a soft, clean cloth. The above operation should be followed until the entire surface is washed. Change your washing and rinsing water as often as necessary. When cleaning portland cement plaster, follow the procedures used for cleaning concrete.

MODIFICATIONS

Pages 46 - 48 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Clay Brick Construction

ONE OF THE earliest indications of man's development was brick masonry. Adobe bricks were made long before history was written. Sun-dried brick estimated to be 6000 years old have been found in excavations at ancient Babylonian cities. About 2500 years ago, the men of Babylonia were molding and making hard-burned brick. Babylonia was the brickmaking and bricklaying center of the world: and it was probably from there that the art of brick masonry spread westward to Rome and eastward to China.

2. The term "brick masonry" identifies construction work that uses small brick blocks made of various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably. The color and hardness of the brick depend on the ingredients, kiln (oven) temperature, and baking time.

3. As a masonry specialist, you will build various types of structures, using clay brick. Brick masonry offers you the possibility of exhibiting your skill and perfection in probably the most complicated of the masonry trades. You will be working with various colors and textures of brick in connection with different bonds and patterns. Our discussion will cover the characteristics and procedures for laying brick. This will include bonding brick, strength of brick, and making and finishing joints in brickwork. Let's start our discussion with the characteristics of brick.

15. Characteristics of Brick

1. There are two standard sizes recommended for ordinary brick. Common brick and rough-faced are 2 1/4 by 3 3/4 by 8 inches. That is, a brick this size is 2 1/4 inches high or deep, 3 3/4 inches wide, and 8 inches long. Smooth-faced brick or pressed brick are 2 1/4 by 3 7/8 by 8 inches. Brick will vary slightly from these sizes because of shrinkage during the burning process. Aside from the two sizes mentioned above, bricks are also made in other sizes. Firebrick is ordinarily made 2 1/4 by 4 1/2 by 9 inches in size.

2. A portion of a brick is called a bat or brickbat. More specifically, one-half of a brick is known as a 4½-inch bat. A length of brick that is shorter than full length, but longer than a 4½-inch bat is known as a three-quarter bat.

3. The weight of a brick varies according to its size, the amount of burning, and the type and processing of material used in its manufacture. The approximate weight of a common brick is 4½ pounds.

4. Good quality brick must be uniform in size and shape. Their edges should be straight, square, and well defined. Also, good bricks produce a metallic ring when two of them are struck together. The bonding surfaces are slightly rough so that a good bond can be obtained. Another characteristic of good quality brick is that it will not absorb more than 10 to 15 percent of its dry weight in moisture when placed in a container of water for 24 hours.

5. The standard rectangular-shaped brick has been given different names, depending upon its location in the bond and pattern. Notice the views of a standard brick (fig. 66) and its names. If it forms the corner, it is a quoin. If it is trimmed for a miter fit at the inside of a corner, it is a king. The queen is a half-width brick.

6. A large percentage of the brick produced in this country are red in color, but some from certain localities are yellow. Differences in the clay and the manufacturing process used account

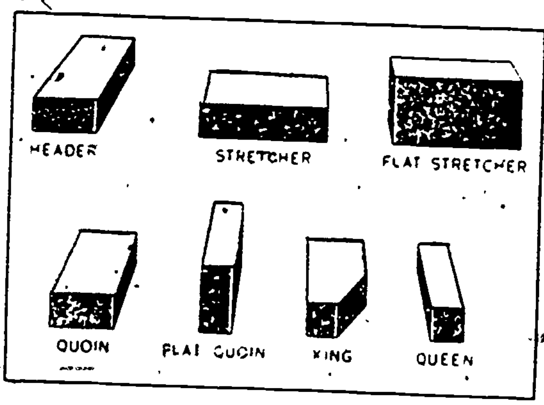


Figure 66: Various brick shapes and nomenclatures.

for the different shades. The amount of burning also causes slight differences in color, and bricks burned at different times may vary in color. When possible, enough brick to complete a job should be obtained at one time to get uniform coloring.

7. Common bricks are made of common types of clay. They do not have special markings, scorings, colors, or surface textures. Grades of common brick will vary in different localities. In some sections, the bricks are graded and sold as front and back bricks. The front bricks are those which have been burned to a higher degree of hardness. In nearly all localities, the overburned brick are called clinkers. These bricks are hard and durable. Manufacturers will sometimes classify bricks according to their position in the kiln. Such terms as arch. clinker, rough-hard. red. well-burned, straight-hard, stretcher, soft. and salmon are applied. Arch, clinker, and rough-hard bricks are hard, durable. and slightly irregular in shape. Red, well-burned and straight-hard bricks are well-baked but not overburned; and the most select of these bricks in size. hardness. and durability are called stretchers.

8. Among the front brick. those hard enough for exterior walls and structures. are those known by names such as hard. common building. paving. hard building, outside. hard red. straight hard. select hard. rough hard. hard washed. kiln run hard. and common hard brick.

9. Soft. or salmon. brick includes brick not hard enough for exterior walls of structures. Such brick are baked at a lower oven temperature. These bricks are known by such names as soft. salmon. backing-up. pale light. chimney. filling-in. inside wall. and foundry brick. Soft and salmon brick. farthest from the fire. are underbaked and are not as strong and durable as the other bricks.

10. The compressive and tensile strengths of brick vary with the amount of burning (baking) and the types of materials used to manufacture them. When brick is classified as vitrified. hard. medium. or soft. the vitrified brick is considered to be the strongest. The strengths of the other classes are in the order given. With any given brick strength. the strength of a wall constructed still depends on the workmanship and quality of the mortar joints. The strongest brick can't make a strong wall without the skill of a capable mason.

11. Other names or classifications are given common bricks, but the most important thing is to know the hardness and durability of the brick before it is laid. Hard and durable brick should be laid in the exterior surface of the wall exposed to the elements.

12. Face brick is made of selected materials so that the hardness. size. strength. color. texture. etc. will be uniform and all bricks will be of a high-grade classification. It has surface markings or scorings to give it a pleasing appearance. Face brick is generally used for exterior tiers in walls exposed to the weather. It is also used for veneering, walks, steps, walls, etc., where beauty is desired, and expense is no object.

13. Any brick made by the dry-press process is called pressed brick. The brick may be common. faced, or other kinds. depending upon the clay. coloring, and burning. Only the better grades of common brick are pressed. Pressed bricks are excellent for the exterior tiers of brick in outside walls. Burned pressed bricks are uniform in size. adhere more closely to standards of size, and are used in structures built to exact dimensions.

14. Firebrick is made from special clays. Bricks made from these materials withstand high temperatures without cracking. and are used to line interiors of furnaces. fireplaces. and other surfaces exposed to extreme heat.

15. A glazed brick is one that. has had one or more surfaces covered with a transparent glass-like (vitreous) coating. Glazed brick are used in exterior tiers of walls or partitions in bathrooms. hospitals. kitchens. and other places where cleanliness and ease of cleaning are essential.

16. Imitation brick is similar in size and shape to clay brick but is made primarily of portland cement and sand. Imitation bricks are not burned and have the same qualities as good cement mortar

16. Fundamentals of Brickwork

1. Now that you are familiar with the characteristics of brick. let's take a look at some fundamentals of using brick in construction. Specifically. we will discuss brick bonding. wall thickness. corners and intersections. window and door openings. strength of brickwork. brick handling. and joints in brickwork

2. **Bonding Brick.** The purpose of bonding brick in masonry work is to make the brickwork strong. solid. and durable. To do this. you must place the bricks in such a manner that they are all tied together in a cohesive mass. Mortar joints will tie all bricks together but if you fail to place the bricks properly so that they will form a strong bond. the structure will not have the strength to support heavy loads. Bonding joints are made by lapping one brick over two bricks in the course just below it.

3. Since the brick of one course must overlap the brick in another course. the natural consideration is how much they should lap. In bricklaying. the practice is to make a brick lap other bricks ¼, ⅓, ½ or ¾ of its length. A brick should not lap another brick less than ¼ brick length. Figure 67 illustrates how vertical mortar joints are broken by lapping bricks.

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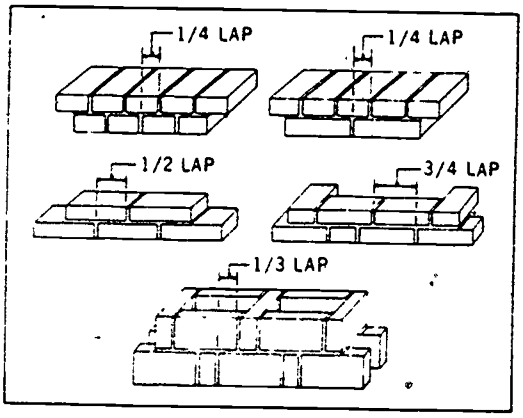

Figure 67. Lapping bricks.

4 As work progresses, the lap may be lost because of irregularities in the size of the brick and vertical mortar joint thickness unless special attention is given to maintaining lap. You should keep each vertical joint directly over the vertical joint two or more courses below. The process of keeping vertical joints perpendicular is referred to as keeping the perpends.

5 Lapping places vertical joints between bricks in adjacent courses at relatively different positions. This may require that one or more brick bats of special size be used to make the course end properly at the ends or corners. The special brickbats act as spacers or fillers to fill in space created by lapping the brick. Brickbats are placed in the course, one or more bricks from the end, rather than at the end. This is particularly true when you are using small bats, because they tend to weaken the bond at the corner when placed as the last brick in the course. Figure 68 shows how quoins, bats, and closers are used as spacers and fillers.

6. There are several different types of bonds used in bricklaying. Of all the different types, common, or American, bond is probably the most used. This bond is a combination of the stretcher and header bonds. It combines advantages of both bonds and is stronger than either one used alone. Usually a header course is laid every sixth course; the other courses are stretchers. The header course is sometimes laid every fourth, fifth, or seventh course according to specifications for the job. A correctly bonded common, or American, bond wall is shown in figure 69.

7. The common, or American, bond is used extensively in walls, particularly when common bricks are being used. The variation in this bond straightens the brickwork. This bond is often

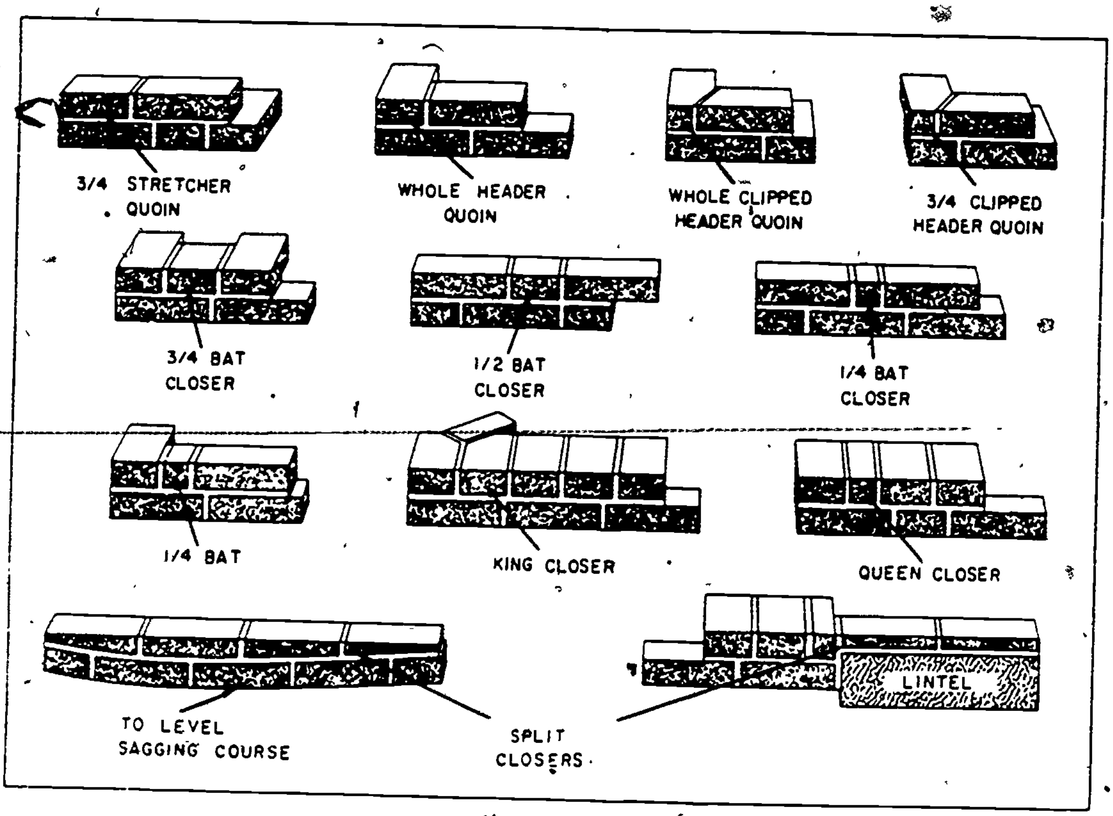

Figure 68. Use of quoins, bats, and closers.

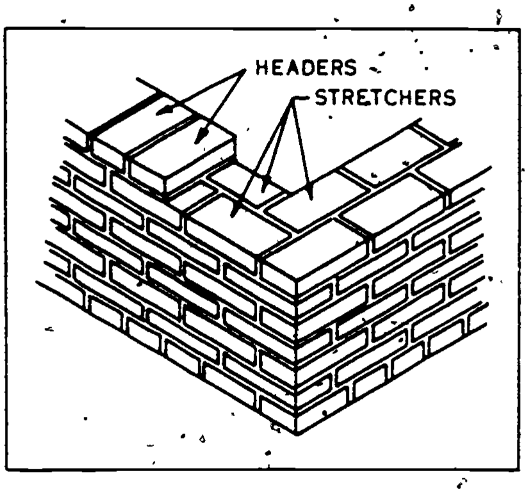

Figure 69. A correctly bonded brick wall.

used to back up face brick or other masonry materials used in the exterior tiers of walls.

8. Metal ties are used to help bond both solid and hollow (cavity) walls. There are a number of different metal ties used for bonding bricks or wall sections together. Metal ties used in solid and hollow brick walls are shown in figure 70. Metal ties are never thicker than the mortar joint because this would raise the brick over the ties out of line with the rest of the wall.

9. Head flashings are bent metal strips placed over openings in brick walls as moisture barriers. and may extend completely through the wall. Copper stripping is the best metal for this purpose; however, galvanized steel and aluminum strips are also used. Note that the inside edges of the head flashings in figure 71 are higher on the inside of the wall than on the outside. This directs the moisture downward and outward. Sill flashings are metal strips, similar to head flashings. used at the bottoms of openings as a moisture barrier.

10. Copings are used to protect the tops of walls and other brickwork exposed to the weather. A concrete coping on top of a brick wall is shown in figure 72. The coping bonds the top course of bricks and tends to prevent water from seeping into the mortar joints. Mortar joints saturated with water will freeze and may separate the brick during freezing weather. The drip, as shown in figure 72, is a groove or slot extended all the way around the bottom of the coping so that the water passing from the top of the wall will be caught by the groove and drip to the ground without coming in contact with the wall.

11. A soldier course consists of brick which been placed on end with their edges visible. They are used on flat arches and laid on steel lintels over wall openings. A soldier course of brick is shown in figure 73.

12. A rowlock course of brick consists of bricks which have been placed on edge with their ends visible. They are used directly under window openings in brick buildings. A rowlock course is also shown in figure 73. Now that we have discussed the procedures of bonding brick, let's talk about the different wall thicknesses constructed with standard brick.

13. **Wall Thicknesses.** The arrangement of standard size brick may be bonded in any combination of stretcher and header courses for constructing walls of various thicknesses without cutting the brick. From the standpoint of variety in bonding and patterns, no two successive courses need to be the same.

14. By placing standard brick in various positions. you can construct walls in any thickness relative to the width and length of the brick. The width and length of standard brick are 4 inches by 8 inches when laid; therefore. walls may be constructed so that their thicknesses are any multiple of the width of the brick. Thus, the thickness of walls constructed of standard brick may be 4. 8. 12. 16. 20. 24. etc. inches.

15. Four-inch walls are used for non-load-bearing walls and partitions. Interior partitions should be built up from the basement floor level or supported at the first floor level by beams supported by columns, or piers built up from the basement to the first floor level. In other words, never build non-load-bearing partitions other than at ground level unless you have been informed that the floor is able to support the weight. Non-load-bearing, 4-inch, brick-veneer, exterior walls are often built in conjunction with inner walls of wooden frame construction.

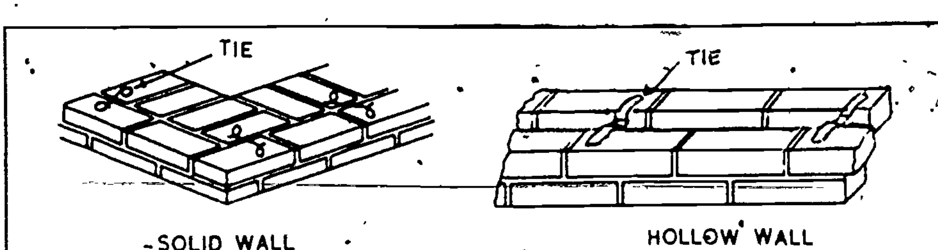

Figure 70. Bonding with metal ties.

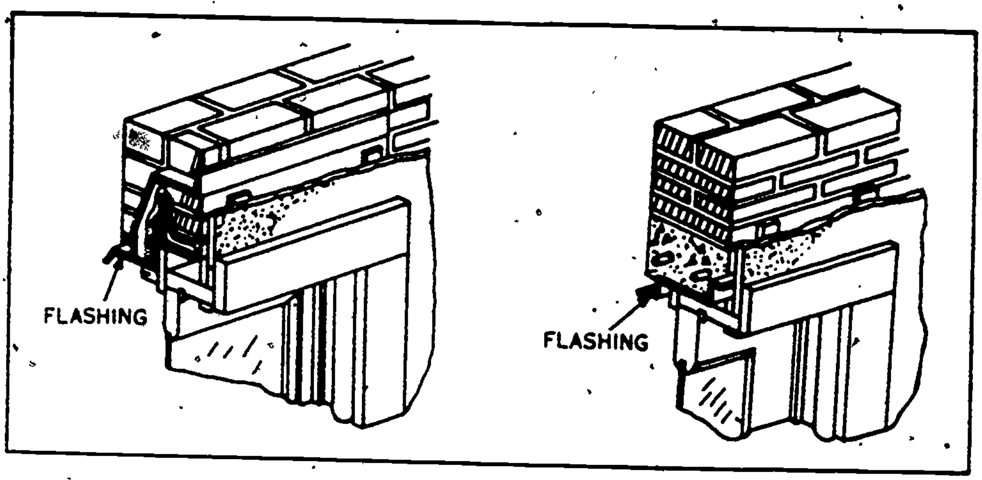

Figure 71. Head flashings.

16. The wooden frame is covered with a 4-inch facing of brick tied to the frame of the building with metal ties. Brick veneer may be applied to either new or old buildings. For new buildings, the foundation is made wide enough to accommodate the 4-inch brick wall. In old buildings, an additional 8-inch thickness of new foundation is extended below the ground against the old foundation to support the brick. The surfaces of frame buildings are covered with a good grade of waterproof building paper, and the face brick bonded to the metal ties about 1 inch from the frame wall.

17. The arrangement of face brick in veneer walls is the same as in solid masonry except that the ends of brick around openings are cut to fit the framework. Lintels over door openings must be used, the same as they are used in solid brickwork, to support the brick above the openings. The brick used in 4-inch porch walls and other walls visible from both sides should be faced on both edges or sides.

18. Eight-inch brick walls are used in many small structures, and under normal load conditions are thick enough to support the load placed on them. There are several bonds used for 8-inch walls. American, English, and Flemish are three of them and these are shown in figure 74.

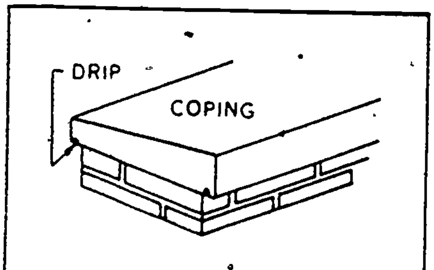

Figure 72. Coping.

19. **Corners and Intersections.** A corner is formed when the ends of two walls meet, and it is here that the bond starts. Corners may be classed as being square, acute, or obtuse; or they may be classed as being outside or inside corners. A square corner is a 90° corner. An acute corner is one that is less than 90°, and an obtuse corner is over 90° and less than 180°. Figure 75 shows the various types of corners.

20. Special arrangements for brick and special brick shapes are required to obtain the proper lap when starting a bond. The arrangement required in a 4-inch wall starting with the stretcher bond having one-half lap and three-quarter lap are shown in figure 76. The end brick should never be less than a brick width.

21. When arranging brick in a corner, you must take into consideration both walls. In some cases, the end of a wide wall may meet the end of a narrower wall to form a corner. Figure 76 shows the arrangements of standard and special bricks required in an 8-inch and a 12-inch wall, meeting at a corner, to start an American bond corner.

22. **Window and Door Openings.** The architect or structural engineer works out the type of bond to be used in building a structure when it is designed. At that time, the sizes of openings and the distances between the openings are calculated

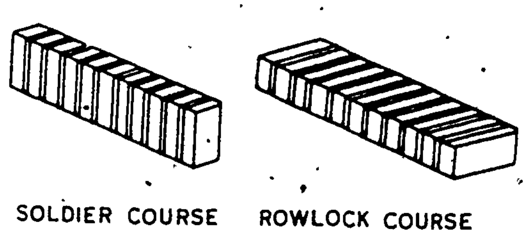

Figure 73. Soldier and rowlock courses.

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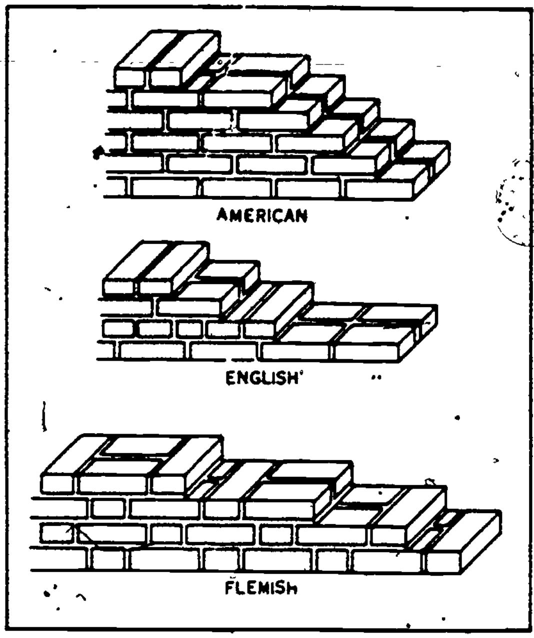


Figure 74. Bonds for 8-inch walls.

to avoid any irregularities in lapping the brick and reduce cutting brick to a minimum. You should make a trial layout course of brick (without mortar) in the bond specified. When the course is laid out, the end brick should have at least one-half lap. When there is one-fourth lap, a bat must be used as a closer (fig. 76) inside the quoin. In ordinary brickwork, an adjustment can be made by slightly stretching or compressing several end (vertical) mortar joints.

23. Bricks in sills are usually laid on edge at a pitch or incline equal to one-half inch per foot of run. The method of starting a window opening

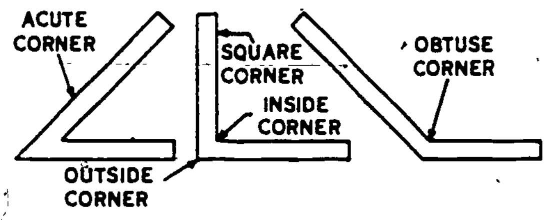


Figure 75. Types of corners.

and the position of the bricks placed in the sill mortar bed are shown in figure 77.

24. A steel lintel is used to support the brickwork over a window. A soldier course of brick is used over the window opening, and figure 78 illustrates how the brick is placed on the lintel. Figure 78 also points out the window masonry nomenclature.

25. For the construction of door sills, brick can be laid flat as a header course or on edge as a rowlock course. Bricks over door openings are supported by steel lintels similar to those used over window openings. A soldier course may be used over door openings or the pattern of brick used in the wall construction may be continued.

26. **Strength of Brickwork.** The compressive strength of brick is the amount of weight it can withstand (firmly supported below) without cracking. The results of compressive strength tests on individual clay brick (tested flat) are shown in figure 79. The results of this test indicate the importance of specifying the kind of brick to be used for various structures. This is especially true of brick load-bearing walls which are subject to high compressive stresses.

27. **Handling Material.** A sample of face brick to be used on a construction job should be kept from the first load of brick, and all later loads of

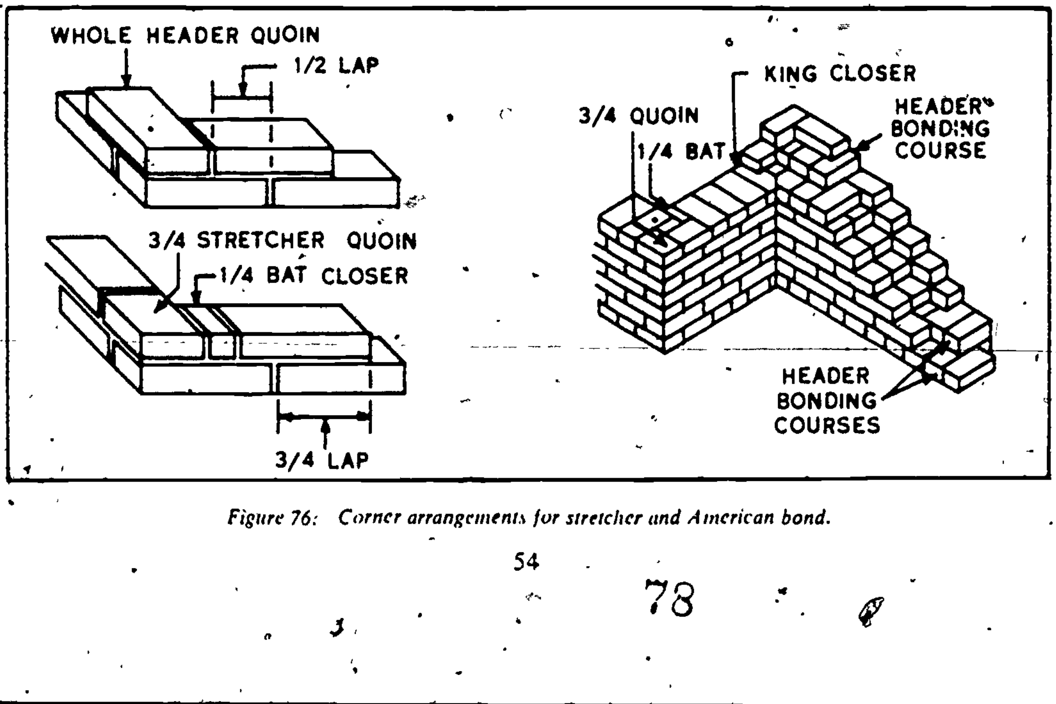


Figure 76: Corner arrangements for stretcher and American bond.

78

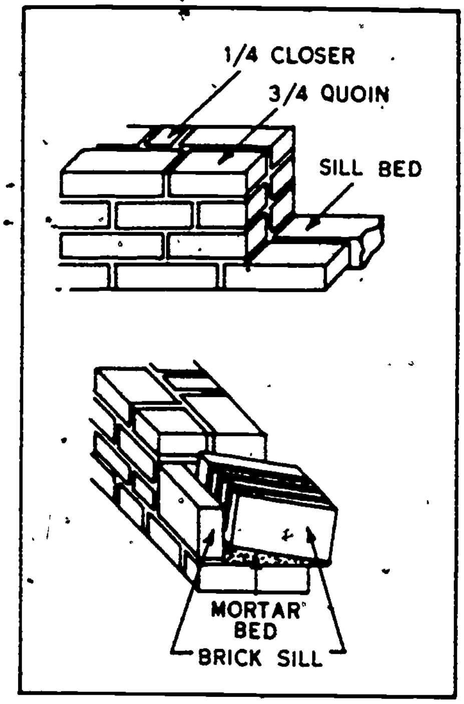


Figure 77   Constructing a brick window sill.

face brick delivered to the job site inspected and compared with the sample as they are being unloaded. By doing this you will be sure that the bricks are uniform in quality, size, and color. You should stack face brick in neat piles when storing them on the job site. Layers of straw should be placed between the courses to protect the faces of the brick. Face brick carried to the mason should be stockpiled face up for his convenience in handling.

28. Common brick for small jobs are placed (not stacked) where they can be conveniently wetted before they are used. When large quantities of common brick must be stored for a long period of time, the brick should be stacked in piles. All clay bricks must be wetted before they are laid. The hotter and drier the weather, the more water the brick will absorb. If they are not wetted, they will absorb water from the mortar very rapidly, causing premature setting of the mortar and a poor bond between the bricks. Bricks must not be so wet that they will slide on the mortar bed.

29. **Joints in Brickwork.** Bed joints are the horizontal mortar j s between courses of brick or, more simply, th d of mortar on which brick rest. It is importa t bed joints be properly made because the nd the bricks together, distribute pressures uniformly throughout the wall, and make the wall moisture and air resistant. When making bed joints, spread the mortar (about 1 inch thick) uniformly over the top of the foundation or lower brick course. After spreading the mortar over four or five bricks at one time, make several shallow channels (riffles or furrows) down the center of the bed, as shown in figure 80. During hot weather, mortar will not remain plastic on the mortar bed for a long period of time; therefore, you should only apply mortar to a few bricks at one time and then lay the bricks.

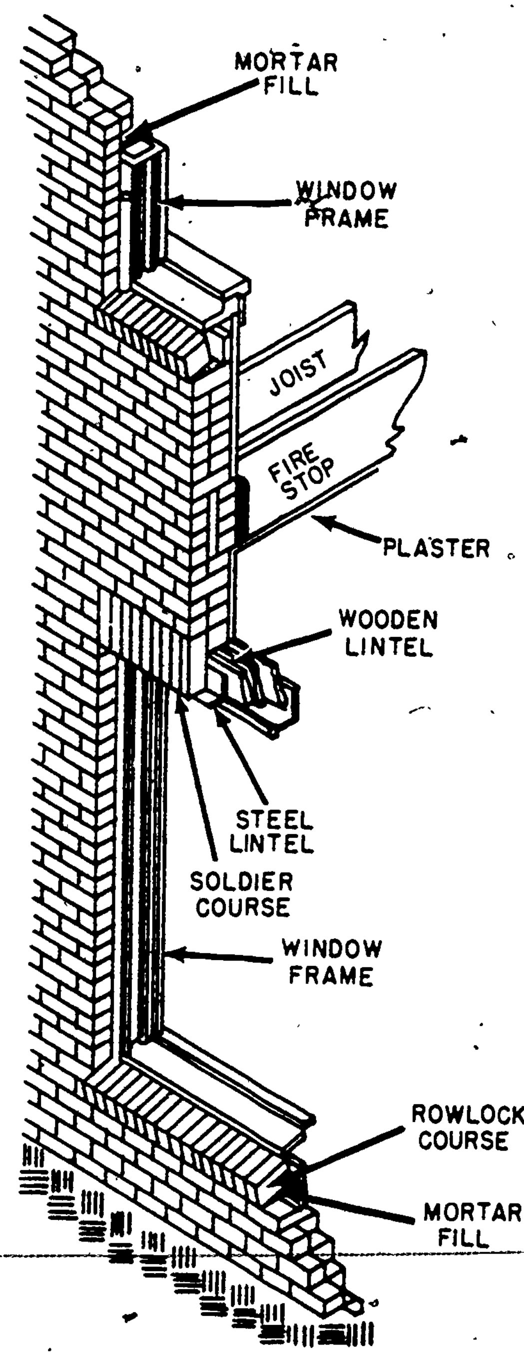


Figure 78.   Soldier course above a window opening.

75

Clay Source	Type Brick	Grade Brick	Lbs. per Sq. In.
Arkansas	Red	1 2 3	12,253 11,966 5,620
Illinois	Shale Building Underburned Common		10,690 3,920
Kentucky	Dark Gray Gray Dark Green Red		20,030 16,793 7,243 5,290

Figure 79. Compressive strength of brick.

30. Head joints are vertical mortar joints that bond bricks together at their ends. Head joints are made by buttering a thick layer of mortar on one end of the brick to be laid. The buttered brick is then placed on the mortar bed and is pressed and shoved until the specified thickness of the bed and head joints is obtained. When pressure is applied to the brick, excess mortar will be squeezed out of the head joint and bed joint. This excess mortar is cut or struck with a trowel and buttered on the end of the next brick to be laid. A brick being placed to form a head joint is shown in figure 81.

31. The last two head joints in a course of brick are called closure joints. To make closure joints, the clean ends of both brick already laid in the course are well buttered with mortar. Both ends of the closure brick are also buttered, and it is then set in place between the two bricks already laid. The closure joints should be completely filled with mortar, and the excess mortar should be squeezed out from between the bricks and cut off. A closer brick being placed in a stretcher course to form closure joints is shown in figure 82.

32. Bed and head joints in backing courses of brick are just as important as the bed and head joints in face course brick. Although the backing courses can not be seen after the wall is constructed, they help determine the overall strength of the wall. A bed and head joint being formed in a backing course is shown in figure 83.

33. Although header bricks are laid to form the horizontal bed joint, the vertical joints formed are often referred to as cross joints instead of head joints because the edges of the brick, rather than the ends are buttered to form the vertical joints. A cross joint being formed in a header course is shown in figure 84.

34. Closure joints in header courses are made similar to closure joints in stretcher courses. The edges of the two adjacent header bricks, as well as the edges of the closer brick, are buttered with mortar. By buttering the two bricks on either side of the closure, along with the sides of the

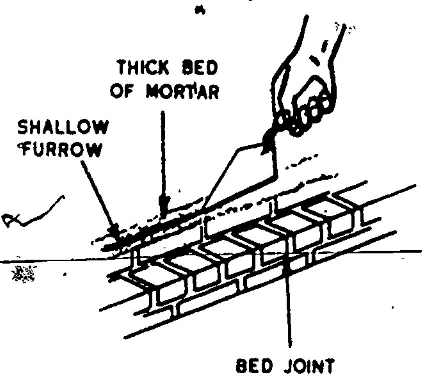


Figure 80. Making a bed joint.

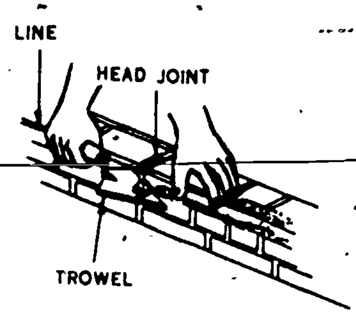


Figure 81. Forming a head joint.

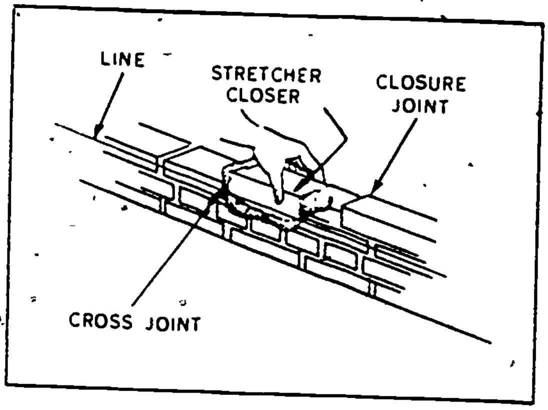


Figure 82. Forming a closure joint in a stretcher course.

closure brick, you can be sure that the joints are full of mortar after the brick is pressed into position. A closer header brick being placed to form a closure joint is shown in figure 85.

17. Bricklaying Procedures

1. We are now ready to discuss the procedures used in building a structure. This includes laying brick, making joints, finishing joints, laying rowlock and soldier brick, cutting and splitting brick, building an 8-inch wall, and cleaning brick surfaces.

2. **Laying Brick.** The quality of the brickwork you do will depend a lot on the way you use your tools. You should grasp the trowel in the palm of your hand so that the tool may be turned upside down to throw and spread mortar. The proper way to grasp a trowel is shown in figure 86.

3. The first step in bricklaying is chasing out (measuring) the bond. This consists of laying out the first tier or course of brick, without mortar, the length of the wall to be constructed. To chase (measure) the bond, place the first brick on the foundation where the corner will be located. Then place a rule or stick, the desired thickness of the vertical mortar joint, against the corner brick and place the second brick in position against the rule or stick. Follow this process until the first course is laid out. The last whole brick in the wall should fit within the outer dimension of the foundation. If the last brick fails to fit by 1 or 2 inches, you can adjust the thickness of the head joints accordingly. When the corner brick fails to fit by 4 inches or more, use a whole brick on the corner and cut a brick of the proper size to use as a closure, two or three brick back from the corner.

4. After laying out the bond, chalkmark the position of each head joint on the edge of the foundation. If the job is not too large, you can lay out the bond around the complete foundation. After marking all the head joints on the foundation, the job is ready for mortar. Before placing mortar for the first bed joint, you should stretch a chalk line and mark the foundation from one corner to the other to act as a guide in keeping the wall straight. The corners or first portions of the wall to be laid are called leads. You raise the leads at the corners of the wall and at intermediate

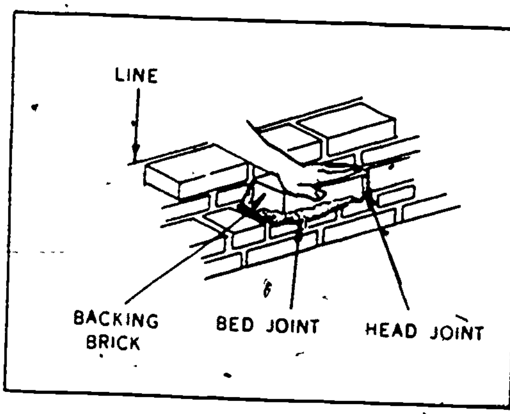


Figure 83. Bed and head joints in backing courses.

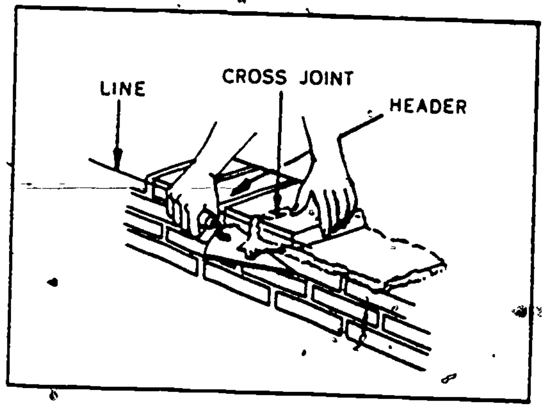


Figure 84. Forming a cross joint in a header course.

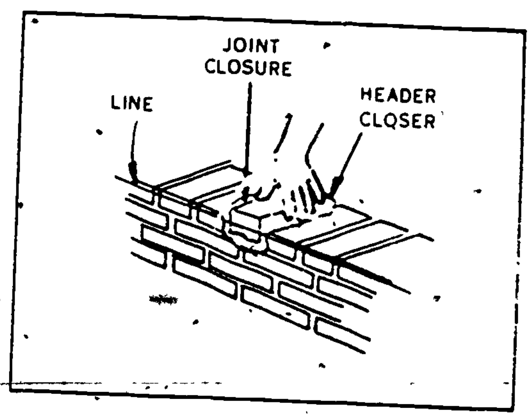


Figure 85. Forming closure joints in a header course.

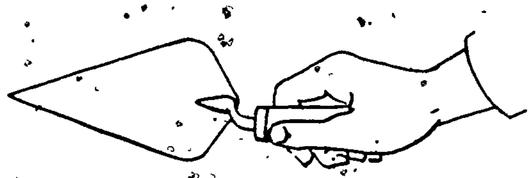


Figure 86. Grasping the trowel.

points in between, when the distance between corners is long. Build up the corner leads six or seven courses high before filling in the courses of brick between the corner leads.

5. When laying brick always keep your mortar pile rounded and well mixed. You can gather mortar by scraping a small amount away from the main pile and slipping your trowel under it trying not to disturb its shape. Different methods of removing mortar from the mortar pile are shown in figure 87. After taking mortar from the mortar pile, you throw it on the bricks.

6. During the throwing stroke, the mortar must flow evenly off your trowel from start to finish of the stroke. To start the throwing stroke, bring the trowel of mortar to the horizontal position, as shown in figure 88, slightly ahead of where depositing is to start. Then, with a quick arm and wrist movement (toward the body) turn the trowel to a vertical position, depositing the mortar on the brick. The throwing stroke from start to finish is shown in figure 88.

7. After depositing the mortar, turn the trowel in the upside down position and riffle the mortar as shown in figure 89. To riffle mortar, run the point of the trowel down the center of the mortar to spread it. Then run the trowel down each side of the center to work the mortar toward the edges of the brick or foundation for the first course. You should spread the mortar just short of the edges of the brick and not over the edges so that it overhangs. The riffling operation from start to finish is shown in figure 89.

8. After the riffling operation is completed, grasp a brick from the pile with the hand not used for handling the trowel. The corner brick of the first course is the first brick you lay. Grasp and place it on the mortar bed slightly away from its final resting place, as shown in figure 90. As the brick touches the mortar bed, press and shove it (with a downward motion) to as near its final resting place as possible. Then force it down with the palm of your hand until mortar is squeezed out all around the edges of the brick, and the bed

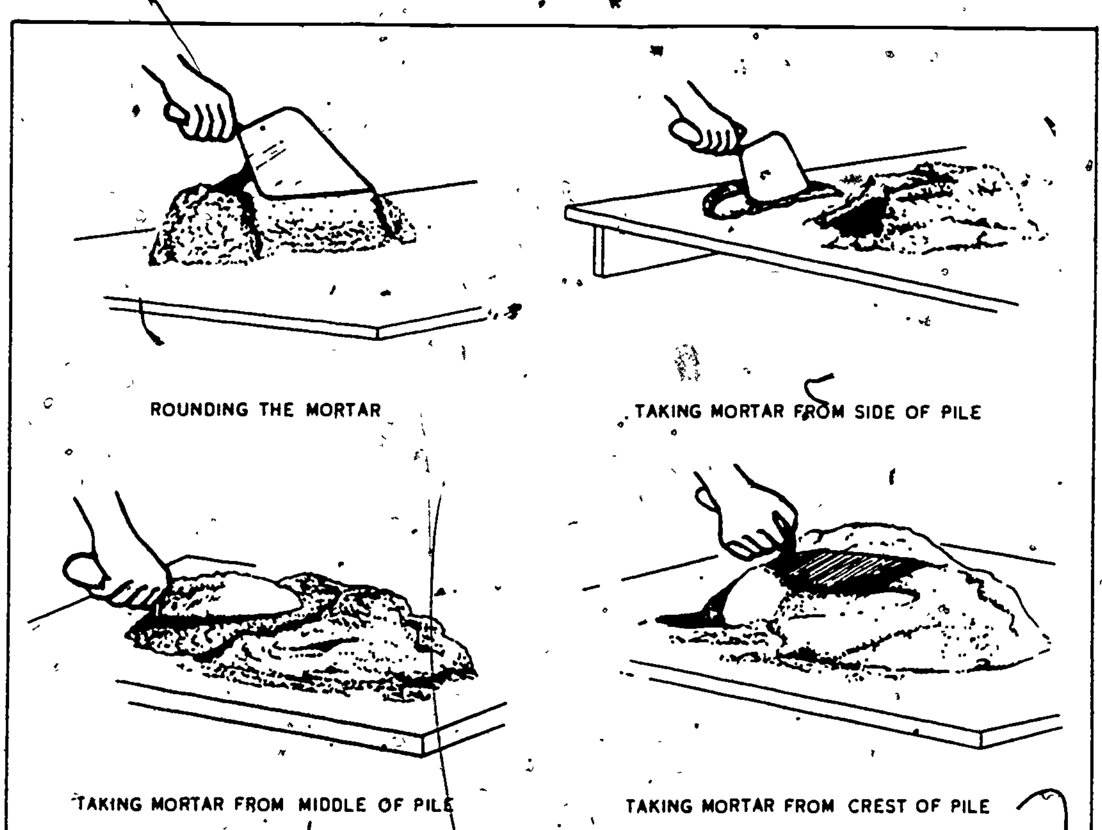


Figure 87. Rounding mortar and common ways of taking from the pile

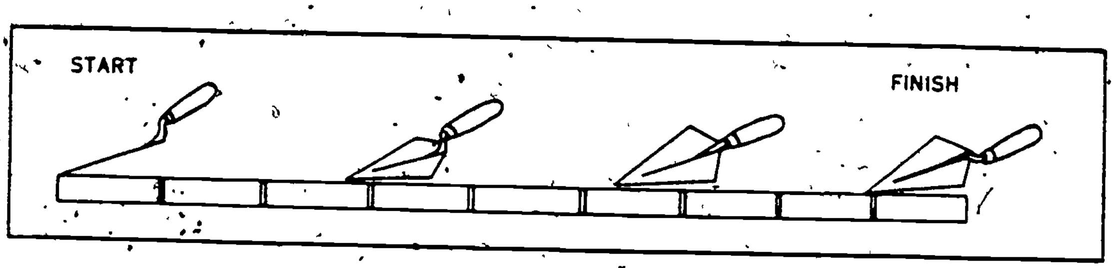


Figure 88 Throwing mortar.

joint is of the correct thickness. If the brick is exactly in its final resting place after being pressed and shoved, no more movement of the brick is necessary. However, this does not always happen and it may be necessary to tap the brick into its final position. Tap the brick with the handle of the trowel, as shown in figure 90.

9 When mortar oozes out around the edges of the brick during pressing and shoving, cut it off with your trowel, as shown in figure 91. This will make the mortar joint flush with the face of the brick. You should cut off the overhanging mortar in such a way that you do not pull the mortar out of the joint. Make sure your trowel is flush with both the brick and the foundation, as shown in figure 91. Use the mortar you cut from the joint to butter the end of the next stretcher brick.

10. You should use a tightly drawn line, secured by line holders (pins, corner blocks, etc.) to help you to obtain a true wall surface. (Corner blocks used to secure the line are shown in fig. 92.) Fasten the line so it is approximately 1/32 inch outside the top edge of the brick and level with it. Place bricks between corners without touching the line so that the line will not be shoved or crowded out of line each time a brick is laid. A line stretched between leads is shown in figure 93. When the distance is long between corners, use an intermediate lead (twig) held in place by a brickbat to help support the line between corners. An intermediate lead is shown in figure 94. To avoid disturbing the line, grasp the brick as shown in figure 95. The left view shows how the brick is grasped when you are standing outside the line and laying the brick across the line. The right view shows how the brick is grasped when you are standing inside the line. After grasping the brick, place, press, and shove it into place to obtain the correct thickness of head or cross joint. Next, you should release it and then press down once more to obtain the correct thickness of the bed joint. The procedure of laying the brick to the line is shown in figure 96.

11. **Making Joints.** Common thicknesses of mortar joints range from 1/8 inch to 1/2 inch. Of these, the 1/4 and 3/8 inch mortar joints are used the most because they are the strongest and the most water resistant. Mortar joint thicknesses will be specified in the building plans and specifications for the job. You should lay out the height of each course (including bed joints) on a strip of wood, called a gage strip or rod, so that the height of each course can be checked against the rule as the brickwork progresses. A strip of wood can be marked, like that shown in figure 97, and used as a gage strip. Another similar wooden strip, referred to as the story pole, is marked to show where head joints or cross joints are located, as well as the marked locations and widths of openings in the wall.

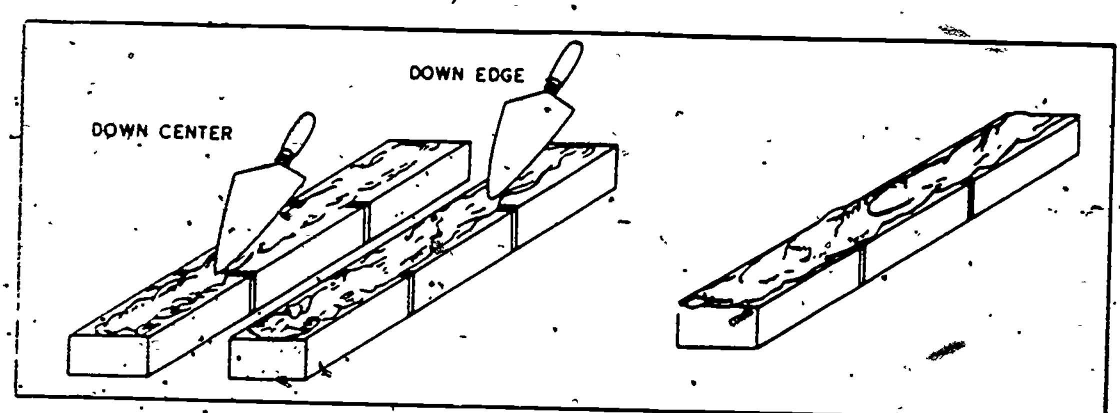


Figure 89 Mortar being riffled from start to finish.

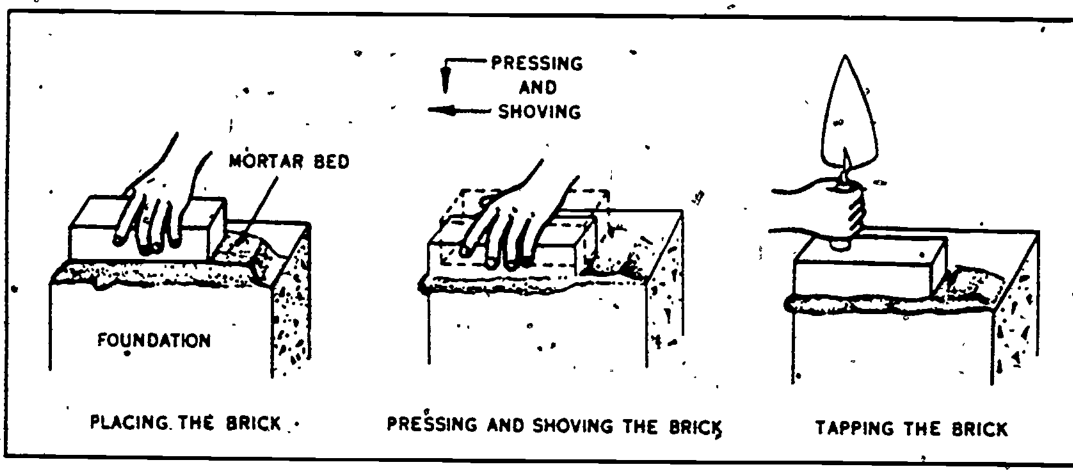


Figure 90. Laying the corner brick.

12. **Finishing Joints.** After laying a few courses of brick, you should strike or finish the joints. To make flat, or struck, joints use a brick trowel (like those shown in fig. 98) holding its face almost parallel to the face of the brick pulling the trowel along the joint after you cut off the overhanging mortar. A flat of flush mortar joint is shown in figure 99. To form an inclined or weathered type joint (like that in fig. 99) turn the trowel to a slight angle and strike the joint downward with the top edge of the blade. To form a raked joint, rake out a portion of the mortar in the joint with a flat jointer which is similar to those shown in figure 100. You can form a flush concave joint (like that in fig. 99) by compressing the mortar in the joint with a convex jointer.

13. **Laying Rowlock and Soldier Brick.** To form rowlock courses, lay brick on their edge; to form soldier courses, lay brick on their end on a bed of mortar like that prepared for stretcher or header brick. There are additional procedures you must follow when buttering these brick: (1) apply mortar to the entire face of each brick; (2) butter all four edges of one side of the brick to form a full, complete cross joint when the brick is laid. Buttering of a rowlock of solidier brick and a completely buttered brick are shown in figure 101. Now let's discuss the methods of cutting brick.

14. **Cutting and Splitting Brick.** Use a brick set when cutting brick across or at a specified angle. To cut a brick, place the beveled edge of the tool on the portion of the brick where you want the brick to break, as shown in figure 102. It's a good practice to groove the four sides of the brick slightly if you want a clean, even break. Now place the brick set on the brick and strike it with the hammer, as shown in figure 102. You can also cut brick with a trowel, particularly when you are making square cuts on common brick. Hold the trowel and the brick as shown in figure 102.

15. **Building an 8-Inch American Bond Wall.** To locate the corners of a brick wall, drop a plumb bob from the lines on the batter boards (where the lines cross) to establish the corner points. Corners being located in this manner are shown in figure 103. You should first mark these points on the foundation with a chisel or a chalkmark, and then strike a chalk line from

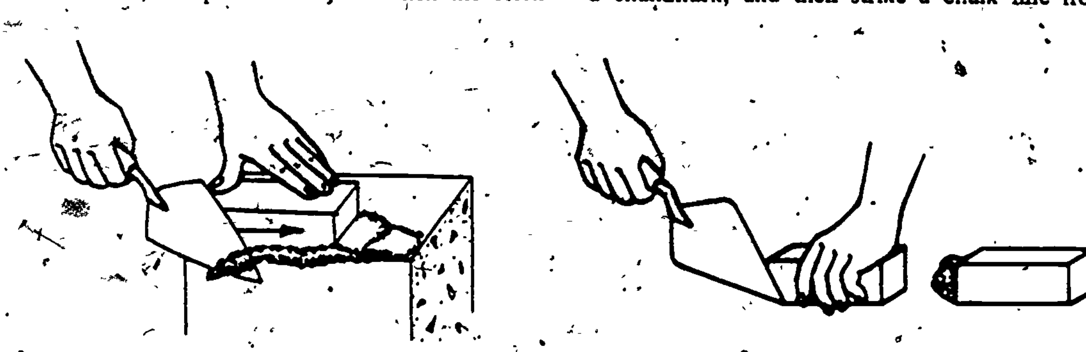


Figure 91. Cutting off mortar and buttering a stretcher.

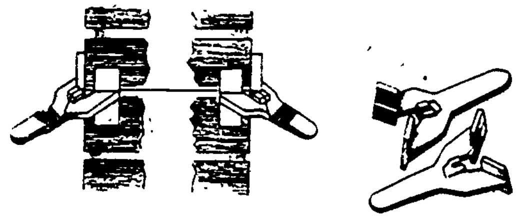


Figure 92. Corner blocks.

corner to corner. A combination self-chalking line box and plumb bob is shown in figure 104. The chalk line establishes the outer edge of the first course of brick, and the length of the course. Next, you should lay out the bond on the foundation along the chalkmark to be sure that the number of brick specified for the first course in the front tier will fit between the corner points. Space each brick to allow for the mortar joint size specified, and mark the edge of foundation with a chalkmark where the joint is located. Mark the gage strip to show the heights of courses, and the story pole to show the locations and widths of openings in the wall. Also mark the locations of the head joints on the story pole.

16. The height of the first corner lead will depend on the number of courses in the wall and the bond being used. In this case we are using the American bond to construct a wall. The American bond starts with a header course and has other header courses every sixth course thereafter. Two three-quarter quoins with six headers on each side are used in the first course, as shown in figure 105.

17 Throw and spread the mortar for the first course on the line side (side where the line is installed first) of the corner Then spread the mortar close to the chalkline without covering it Lay the first three-quarter quoin directly over the corner mark and in alinement with the chalk line The three-quarter quoin is brick Nr. 1 on the line side in figure 105. Now you should butter the headers (Nrs. 2, 3, 4, 5, 6 and 7, fig. 105) on the narrow side of the brick and lay them. You should now level the first course lead on the line side, if necessary, by tapping the brick. After leveling the brick, straightedge the headers to insure they are in alinement with the chalk line on the foundation.

18. Now you can throw and spread mortar on the foundation to lay the seven bricks on the return side. This includes the three-quarter quoin (Nr. 8, fig. 105). Level, straightedge, and square the first course to eliminate inaccuracies that may develop during laying. Check the height of the first course with a gage strip to assure that it is the correct height from the foundation. Cut off all overhanging mortar and strike the joints as required.

19. Next, you should spread mortar on the return side of the first course and lay the four stretchers (numbers 15, 16, 17, and 18). Then spread mortar on the line side of the course and lay the three stretchers (numbers 19, 20, and 21). Lay the stretchers in the third course in a similar manner to the way you laid the second course. The stretchers in the third course include Nrs. 22, 23, 24, 25, 26, and 27. At this stage of work, you should make sure the wall is plumb.

20. If it is necessary to aline a brick by tapping, be sure to do this while the mortar is still plastic. Otherwise, you will break the bond between the brick and the mortar and it will not take hold again. You should once again level, straightedge, and square the corner. Cut off the overhanging mortar and tool the joints as needed. Now you should lay the remaining stretcher brick (Nrs. 28–39) in the corner. After spreading mortar on the sixth course, you should lay brick Nr. 40, a three-quarter quoin. The three-quarter quoin is the corner brick of the seventh course, which is composed of headers. Make sure the quoin is level, straight, and square with both sides of the corner. Lay the three-quarter closer (Nr. 42) and the two header brick (Nrs. 41 and 43) to form the seventh course in the corner lead. Top the seventh course with the corner brick (Nr 44, fig. 105) for the eighth course. You should strike and tool the mortar joints as work progresses and examine and touch up the joints from time to time

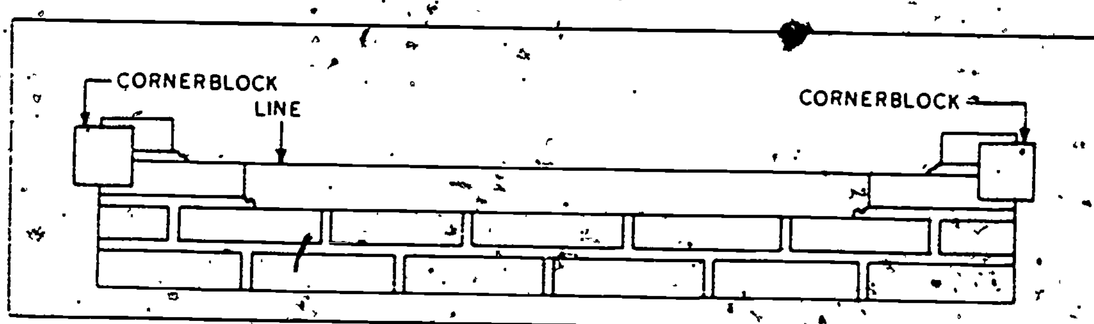


Figure 93 Line fastened between leads.

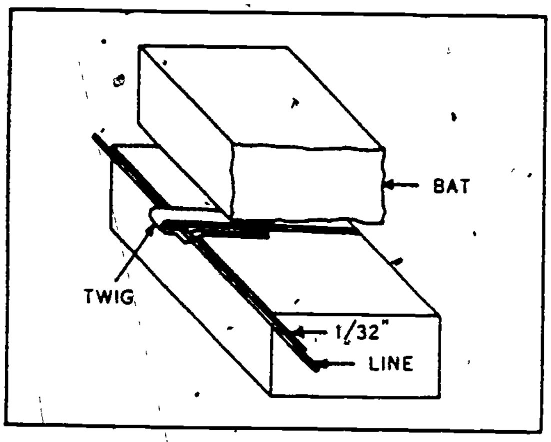


Figure 94. Intermediate lead.

as needed. Now that the corner is completely raised, you should brush it down to eliminate the thin fringes of mortar around the edges of the mortar joints.

21. Raise the second corner in the same manner as you raised the first corner and then start to fill in the courses of brick between corners. When filling in the first course, throw and spread mortar for as many bricks as you can lay and aline before the mortar starts to set. Since the first course consists of a row of headers, you should butter each brick on the narrow side to form cross joints and lay the brick using the chalk line as a guide. You should install a line to use as a guide for the second course which is composed of stretchers. You should stretch the line across the corners with the top of the line level with the top of the second course and

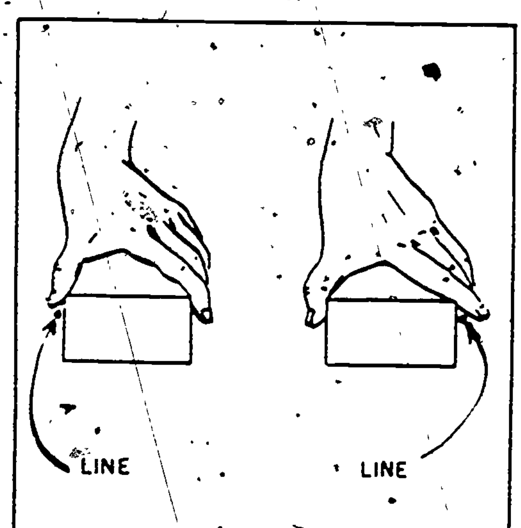


Figure 95 Grasping brick

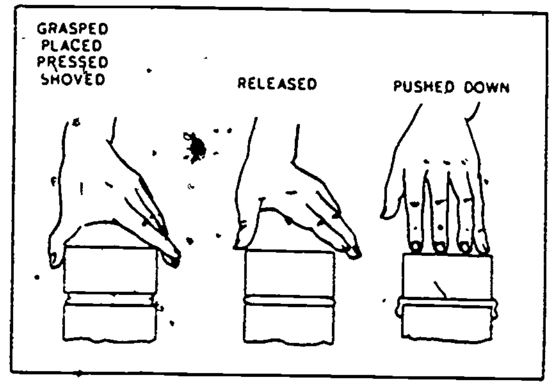


Figure 96. Laying brick to the line.

slightly out away from the face of the brick. Use corner blocks to raise the line from one course to the next. Lay the remaining stretcher courses (two, three, four, five, and six) and level and

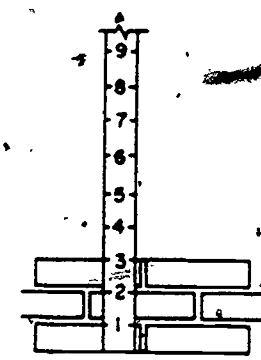


Figure 97 Gage strip.

straightedge the wall and strike and tool the joints as the work progresses. Before the mortar has set, touch up the joints and brush down the wall. Lay the brick in the backup course in the same

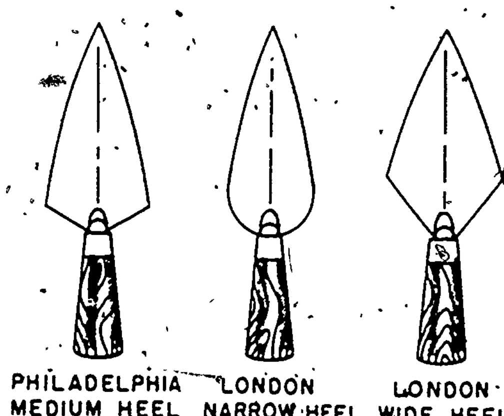
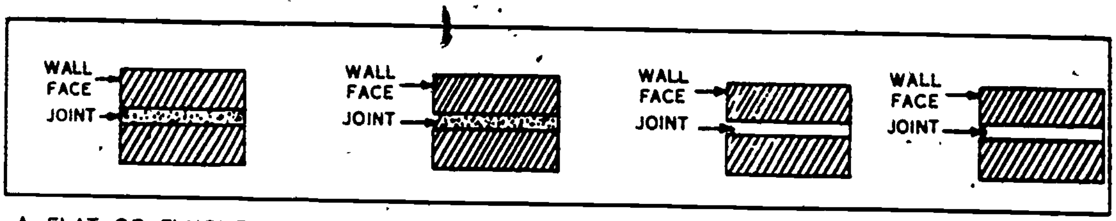


Figure 98. Brick trowels.



A FLAT OR FLUSHED MORTAR JOINT

AN INCLINED OR WEATHERED MORTAR JOINT

A RAKED MORTAR JOINT

A FLUSH CONCAVE MORTAR JOINT

Figure 99. Types of mortar joints

manner as you laid the front course or face brick up through the sixth course. Lay the headers in the seventh course in the same manner as the headers in the first course. The corner bricks in the eighth course will aid in holding the corner blocks and line in place when you lay the seventh course. After the project is finished, the mortar stains must be cleaned off the brick.

22. **Cleaning Brick.** After completing any brick laying project, regardless of how careful you are, there will be mortar stains on the bricks. To remove these stains, use a solution of hydro-

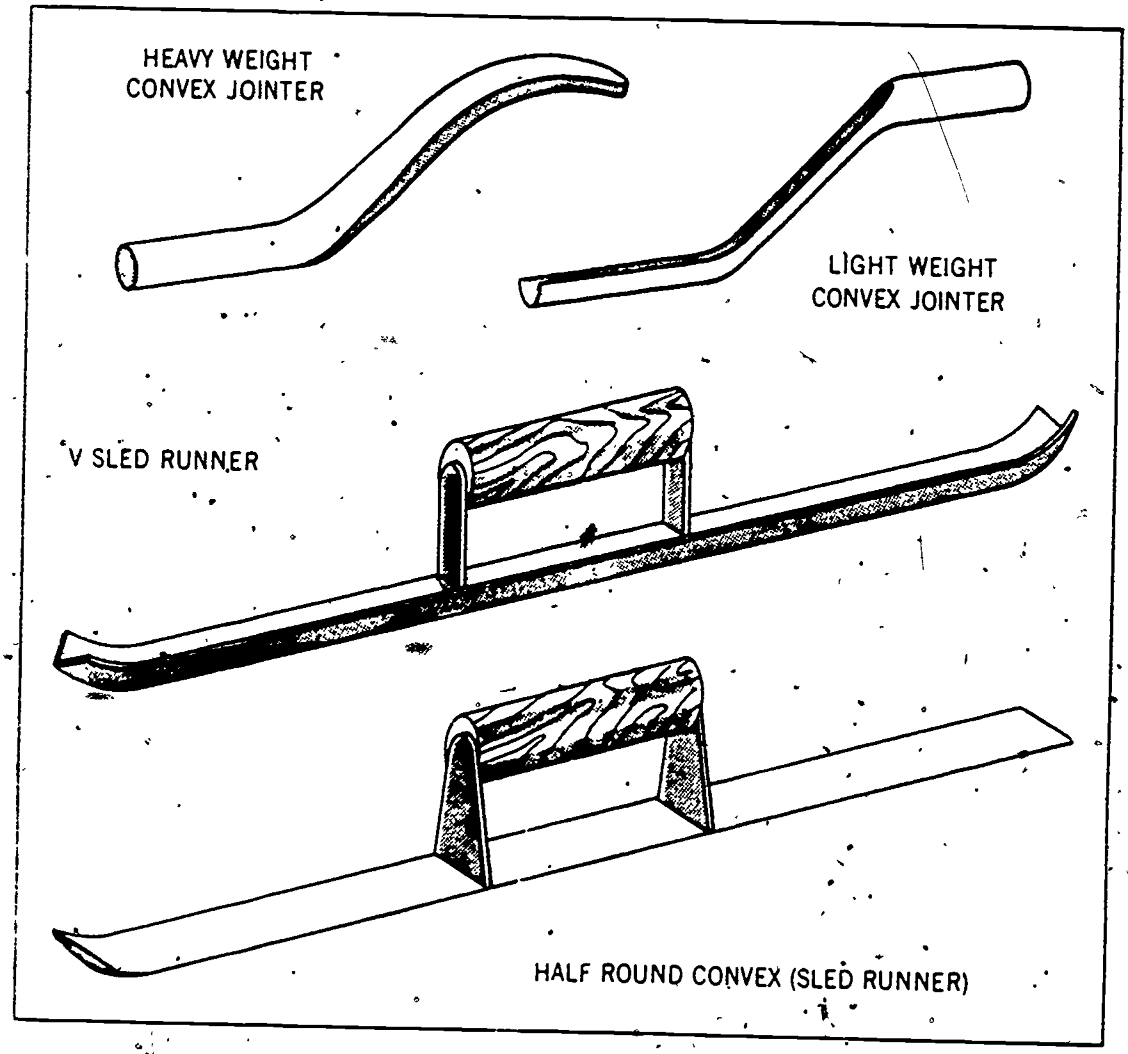


Figure 100 Types of jointers.

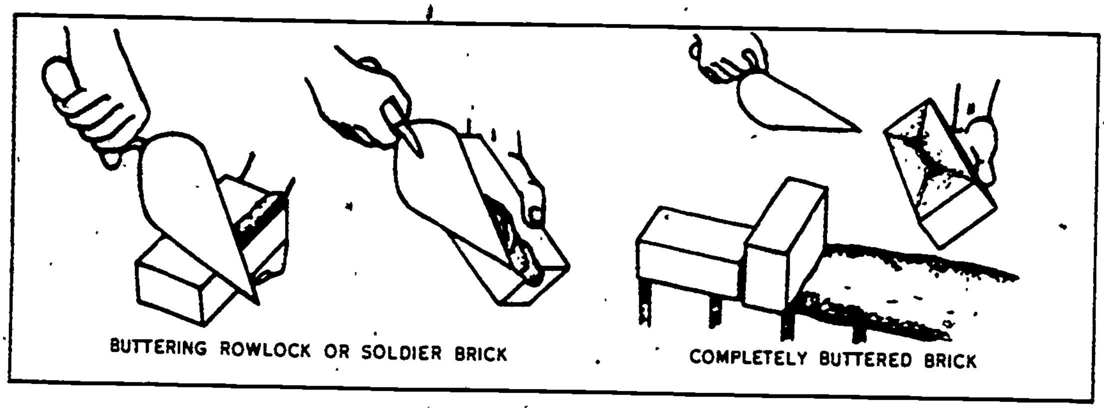


Figure 101. Buttering brick.

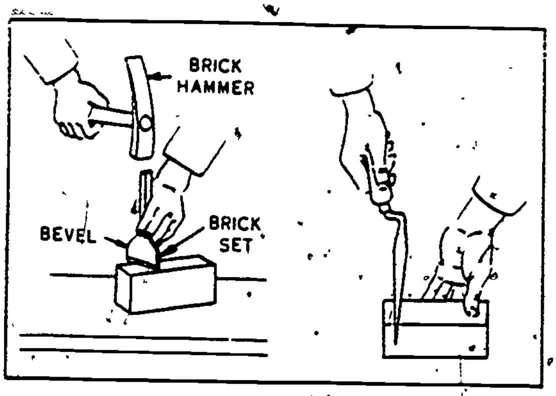


Figure 102. Cutting brick.

chloric acid mixed with water. The ratio of the mix is 9:1; nine parts water to one part acid. Always add the acid to the water; acid reacts violently when water is added. Thoroughly wet the bricks with water before cleaning them to prevent the mortar stains from being drawn into the pores of the bricks. Be sure to wear protective clothing, such as gloves, coveralls, and goggles. before applying the acid solution. Apply the acid with a long-handled, stiff-fiber brush. Scrub an area of 15 to 20 square feet and then immediately wash the area with clear water to prevent the acid from damaging the mortar joints.

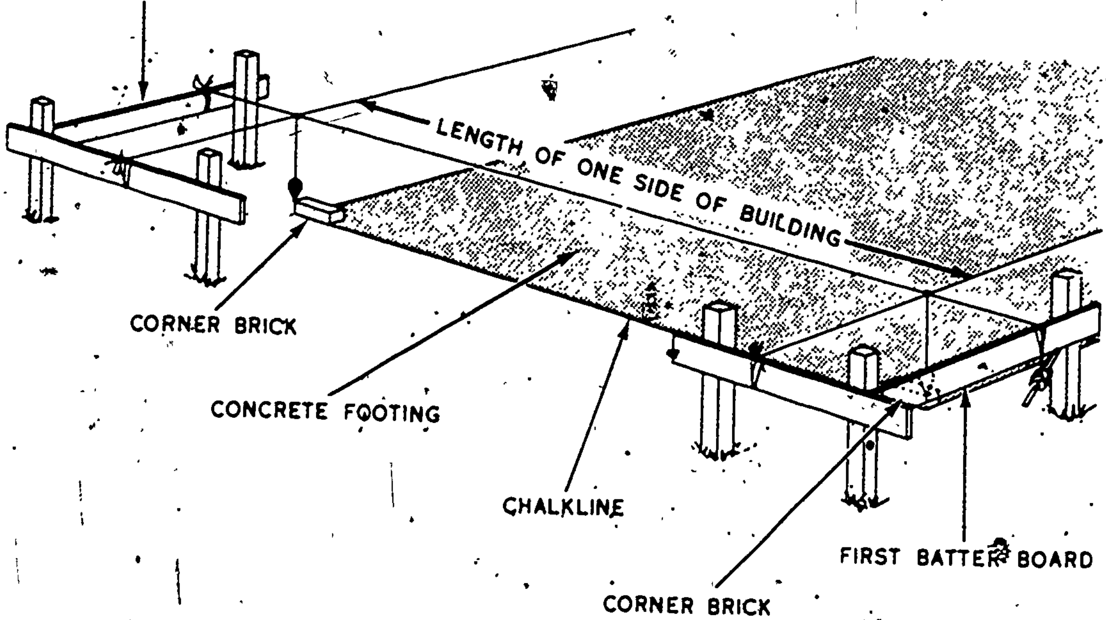


Figure 103. Corner location.

Figure 104. Self-chalking line box and plumb bob.

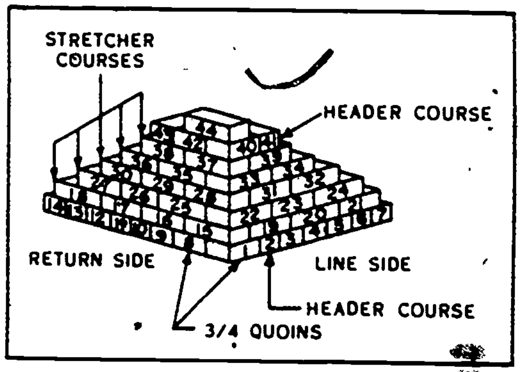


Figure 105. Arrangement of bricks in American bond course lead.

85

MODIFICATIONS

Pages 46 - 69 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 5

Concrete Block and Tile and Stone

THE MANUFACTURE of concrete block and tile has produced another of the many uses for concrete as a building material. The various sizes of concrete units, the uniformity of size, and the consistency of unit patterns make the units easy to use in building construction.

2. Stone is also used in building construction. It is found in formations in the ground from which many varieties of building stones are quarried. Other stones are found on top of the ground and are used for building purposes. Stones have a varying degree of hardness, depending mainly upon their chemical composition. When used with a properly prepared mortar, they are laid to form strong and durable structures.

3. As a masonry specialist, in addition to your work with clay brick, you will build different types of structures using concrete block and stone. In this chapter we will talk about the characteristics and procedures for laying concrete block; the requirements, types, and shapes of good building stones; bonding and patterns used in stone masonry; and laying and cleaning stones. First, we will discuss concrete units.

18. Concrete Block

1. There are four basic units made for common concrete construction: hollow concrete block, solid concrete block, concrete building tile, and concrete brick. The hollow concrete blocks are classified into two types: hollow load-bearing and hollow non-load-bearing. These blocks are made from different materials and come in a variety of sizes.

2. **Characteristics of Concrete Units.** Concrete units can be purchased in either heavyweight or lightweight construction. The heavyweight units are usually made from sand, gravel, slag, and crushed stone. The lightweight units are made from shale, coal cinders, clay or slag, and other lightweight aggregates. The use of heavyweight or lightweight units is determined by the unit available and the requirements of the structure under consideration.

3. Concrete units are made in various shapes and sizes to fit different needs. Unit sizes are usually determined by their nominal dimensions. In other words, a unit measuring 7⅝ inches wide, 7⅝ inches high, and 15⅝ inches long is considered an 8″ x 8″ x 16″ inches. When this particular unit is placed in a wall (blueprint specification: ⅜-inch mortar joints), it will fill a space exactly 8″ x 8″ x 16″ inches. (See fig. 106.)

4. Concrete tile, like concrete block, may be of solid or hollow construction. Some of the common shapes and sizes of concrete tile are shown in figure 107.

5. **Laying Corner Leads.** The same general rules for laying clay brick also apply to concrete block and tile. Corner points for a concrete block wall are located in the same manner as the corner points for a brick wall. After locating the corner points, string out the blocks for the first course without mortar to check the layout. To make sure your layout is accurate, strike a chalk line to aid you in alining the block. The number of blocks you use in the first course depends on the unit size, bond, and pattern.

6. After you determine the number of blocks for the first course, prepare a full mortar bed so there will be plenty of mortar along the bottom edges of the face shells. Prepare the mortar bed (fig. 108) just prior to placing the first block.

7. Lay the corner block first and position it carefully. Be sure to lay the corner block and all other blocks with the thicker edge of the face shell up to provide for a larger mortar bed for the next course of block. The arrangement of the corner block in a corner lead is shown in figure 109.

8. After laying the corner block, prepare the mortar bed and butter the ends of the next block to be placed. Hold the block over its final position and push it downward into the mortar bed and against the previously laid block. If you properly position each block in the mortar bed against the previously laid block, you will have well-filled mortar joints. After laying the first three or four blocks, aline them correctly by using your level

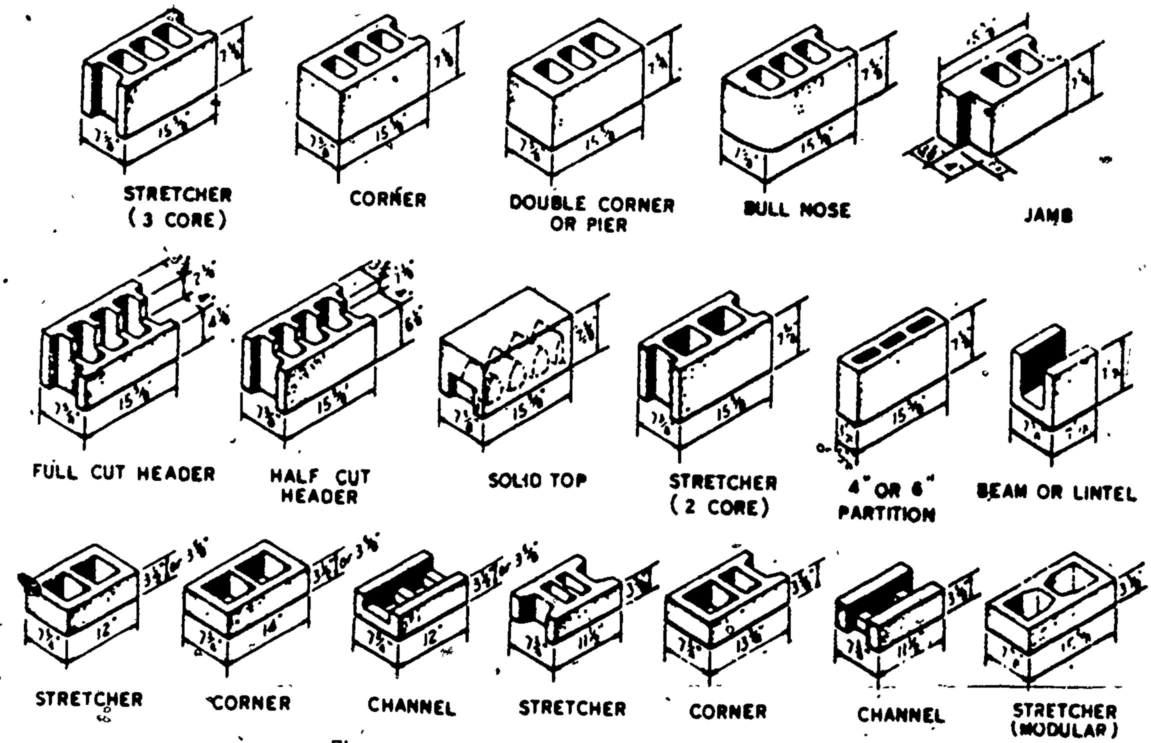


Figure 106. Three-celled concrete block shapes.

as a straightedge. Next, make sure they are at proper grade and plumb. You can check them for proper grade with a level, and make them plumb by tapping them with the handle of your trowel. When the first course is completed, make sure it is properly alined, level, and plumb before laying the succeeding courses. Unlike the full mortar bed used in the first course, the mortar beds for the succeeding courses consist of face-shell mortar beds. To form face-shell mortar beds, apply the mortar to the horizontal face shells, as shown in figure 110. For vertical joints, apply the mortar to the lips on the vertical end of the block.

9. Build concrete block corners three to five courses high before filling in between the corners. To find the top of the unit for each course, use a story pole or gage strip. Mark the story pole or gage strip in 8-inch increments for finding the top of course units or mortar bed joints for 8-inch blocks. When building corners, each course is stepped back a half block. You can check the horizontal spacing of these blocks by placing a straightedge diagonally across the corners of the blocks, as shown in figure 111.

10. **Laying Blocks Between Corners.** To fill in the wall between the corners, stretch a line

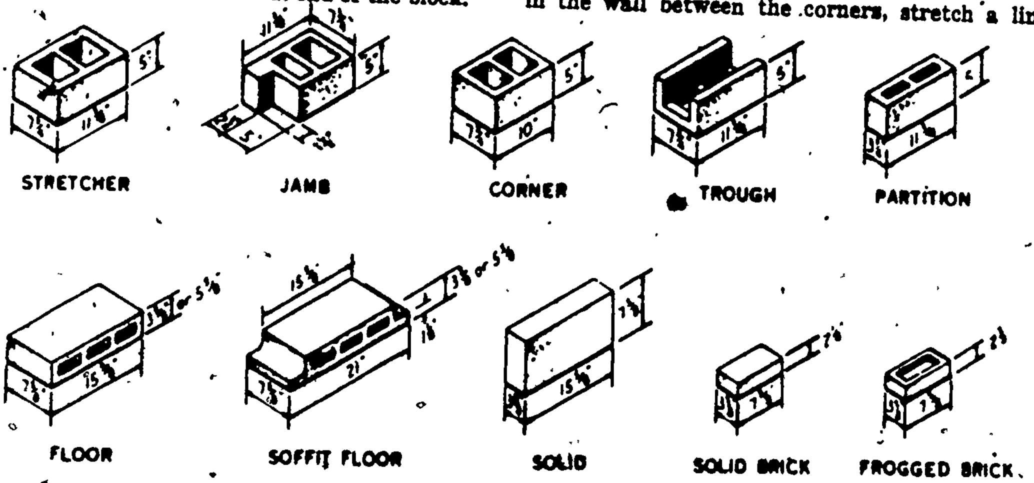


Figure 107. Typical concrete tile units.

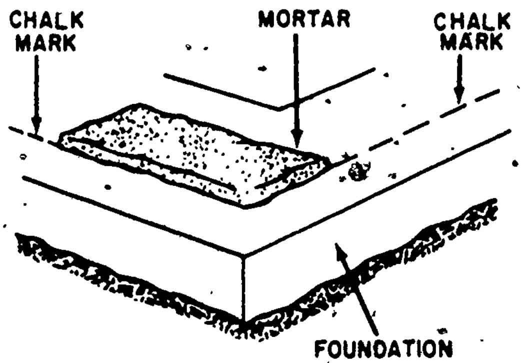


Figure 108. Full mortar bed.

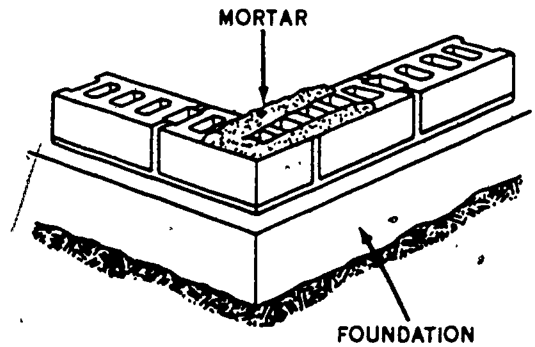


Figure 110. Spreading mortar for the second corner unit.

from corner to corner (for each course) and lay each block with the top outside edge parallel to the line, as shown in figure 112. To eliminate the probability of the mortar stiffening and losing its plastic quality, never spread mortar too far ahead of the actual laying of the block. After laying each block, cut off all mortar extruding from the joint. In some localities, depending upon climatic conditions and other criteria, a full mortar bed may be specified for all concrete block construction. In this case, place mortar on the cross webs of the block as well as the face shells.

11. **Closure Block.** The closure block is the last block laid in a course, as shown in figure 112. To install the closure block, butter all four vertical edges of the block with mortar. Carefully lower the block into position making sure all mortar remains in position. If any of the mortar should fall, it would cause an opening in the joint. If this should occur, remove the closure block, put on fresh mortar, and reinstall it into position.

12. **Tooling.** All mortar is tooled after the wall section is filled in or when the mortar has become "thumbprint" hard. Tooling compacts the mortar and forces it tightly against the units on each side of the joint. Tooling also produces joints of uniform appearance. In most cases, block tooling is done with a concave or V-shaped jointer. After the joints have been properly tooled, remove all mortar burs from the face of the wall by brushing with a soft fiber brush. If the mortar burs have hardened, use a wire brush to remove burs.

13. **Anchor Bolts and Control Joints.** After the concrete block structure walls are completed, some provisions must be made to anchor the top of the building. The top is attached to or anchored by wooden plates fastened to the concrete block wall with anchor bolts. Anchor bolts come in various sizes. However, the size recommended is ½ inch in diameter and 18 inches long. The anchor bolts are usually placed in cores of the top two courses of block. After the anchor bolts are placed, fill the cores with concrete or mortar. To retain the concrete or mortar in the cores, place a piece of metal lath in the second horizontal mortar joint (under the first two blocks in the second course from the top) and under the cores to be filled. The threaded end of the bolt must extend above the top of the block far enough to pass through the hole in the plate and receive a nut.

14. Control joints are used to control cracking in masonry walls. Control joints are continuous vertical joints built into walls at points where

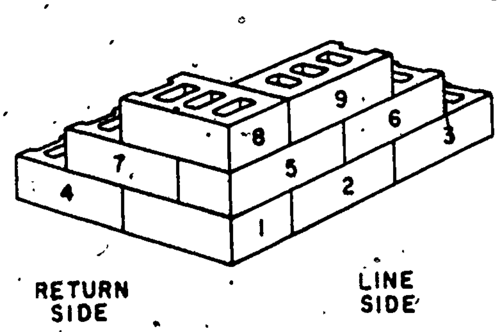


Figure 109. Arrangement of corner blocks in a corner lead.

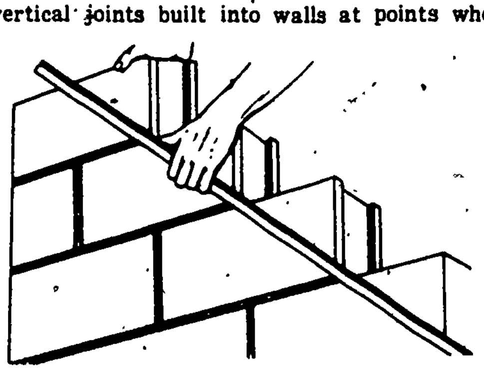


Figure 111. Checking horizontal spacing.

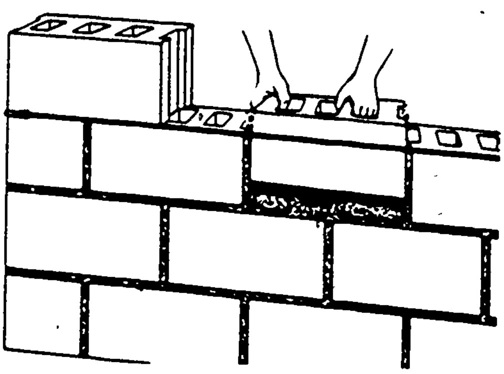


Figure 112. Laying block to the line.

these stresses might concentrate. To form a continuous vertical joint, full- and half-length blocks are used. Control joints can also be formed with special control joint blocks. These blocks have tongue-and-groove-shaped ends and are available in full- and half-length units. When half-length units are not available, special carbide saw blades are used for cutting the block. The blades are inserted in portable power saws. When cutting blocks with power saws, wear goggles to protect your eyes. When control joints are exposed to the weather, seal them with an approved calking compound. When using calking compound, apply it with a calking gun having a tip slightly narrower than the joint, following the recommendations of the compound manufacturer. The compound is applied by inserting the tip of the gun in the joint, pulling the trigger, and moving it up and down along the joint until the joint is filled. Calking compound can also be applied with a putty knife, although better results are obtained with a gun. Sometimes oakum is used for sealing control joints. Oakum consists of strands of rope (loose fiber) pressed firmly in the joint and is normally sealed with tar applied to the joint with a putty knife.

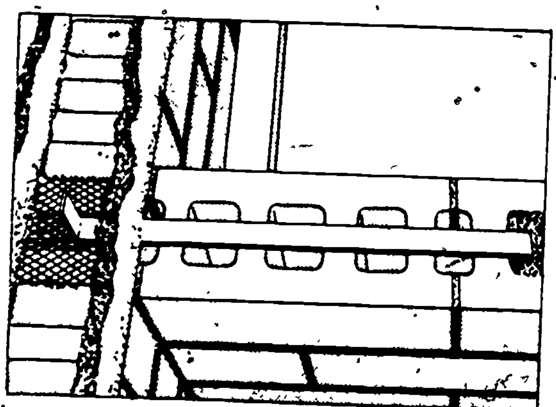


Figure 113 Metal tie bar

15. **Intersecting Bearing and Nonbearing Walls.** When load-bearing and non-load-bearing walls meet or intersect, they should be tied together with metal tie bars. An intersecting wall being tied together is shown in figure 113. If the walls meet at corners, they must be tied together with a masonry bond.

16. **Lintels and Sills.** To support concrete block over openings, steel lintel angles are used. In some of the modern concrete block structures, precast concrete lintels are used over openings. To uniformly distribute the lintel load, a full mortar bed should be spread over the lintel. Sills are usually constructed of precast concrete, and installed after the walls have been built. For proper protection against moisture, joints at the end of sills should be filled with mortar or calked with compound.

19. Stone

1. Building stone which supports heavy loads must be strong. The weight a stone wall can support depends on the strength of the stone.

2. **Requirements of Good Building Stone.** The durability of stone depends greatly upon its physical structure and chemical composition. Durability of stone varies greatly according to the atmospheric conditions to which it is subjected. A building stone that is durable under certain atmospheric conditions may not be durable under different weather conditions.

3. Good appearance is a requirement of building stone, because stone is historically representative of beauty in building construction. Stone that contains too much iron should be avoided, because oxidation of the iron by atmospheric conditions may cause the building to be marred by rust stains. Another requirement of building stone is low cost. The lowest priced stone which will meet building requirements should be used.

4. **Types of Building Stone.** Limestones are composed chiefly of carbonate of lime or varying proportions of carbonate of lime and carbonate of magnesia. The stones may be close-grained, medium-grained, or coarse-grained. The coarseness of grain depends upon whether clay, sand, or shale is included in the formation. Generally speaking, the stones are deteriorated by the action of fire and abundant amounts of acids in the air.

5. Sandstones are composed of grains of sand cemented together by silica, alumina, carbonate of lime, or an oxide of iron. The stones may be of varied colors of cream, blue, pink, red, gray, and brown. The best sandstones are those which are close-grained and which contain silica or glasslike cementing material. Sandstones containing lime are susceptible to acids in the air and

to fire. Those containing an oxide of iron may stain.

6. Granites are composed chiefly of quartz, feldspar, and mica. Those containing a greater proportion of quartz are the strongest and most durable of building stone. For these reasons, granite stone is used for foundations, bases, facings, columns, pavings, and other like structures.

7. Slates are composed chiefly of clay and sand which have been combined into a close-grained stone by earthly actions of pressure, heat, and water. It is in laminated form and can be split into sheets and cut to size for roof facings, blackboards, and other forms of building stone.

8. **Building Stone Shape and Finish.** Building stones may be left rough, they may be roughly squared and dressed before they are used, or they may be accurately cut and highly dressed. Before building stone is laid, it is sometimes necessary to face (chip) it with a facing or napping hammer so it will be uniform. Rough stones are used extensively for constructing walls of small buildings and fences. In many localities, stones are picked up off the ground and used for constructing buildings and other structures. These rough field stones produce the simple bond and pattern of rustic stone construction.

9. **Bonding and Patterns.** The bonding and patterns in stone construction are selected for beauty and for the more practical purpose of getting the strongest wall with the available stone. Vertical joints in a stone course should be staggered with the vertical joints in the courses above and below it. The lap of vertical joints should be at least 4 inches. The thickness of a rubble wall should equal at least one-half its height. The largest stones should be used in the lowest course. Stratified or laminated stones should be laid with the layers positioned flat or horizontally. There are several patterns in which stone can be laid. Some of these are uncoursed rubble, coursed rubble, random rubble, and many others. The uncoursed and coursed rubble patterns are shown in figures 114 and 115.

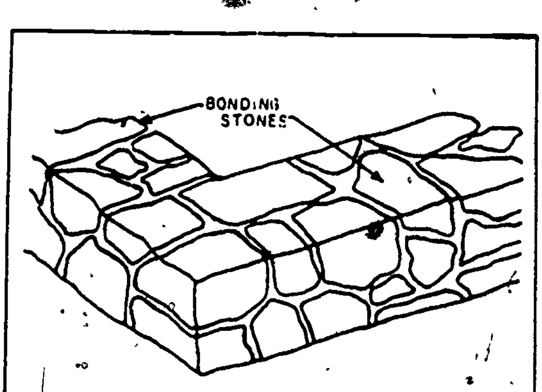


Figure 114. Uncoursed rubble.

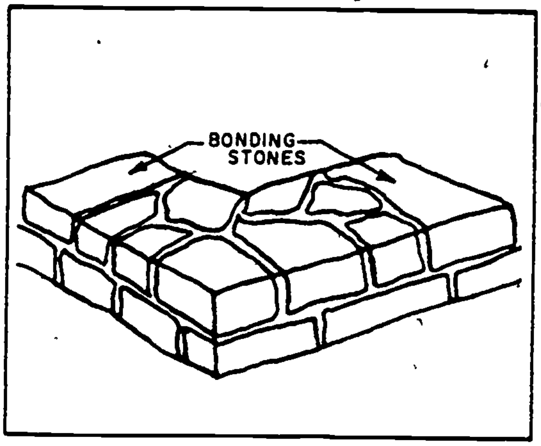


Figure 115. Coursed rubble.

10. **Laying Stone.** Lime mortar is normally used for stonework above ground level, because it does not stain the stone. However, it is not as strong as mortar made of ordinary cement. Mortar made with ordinary cement forms a strong bond, but it stains the stones. For this reason, ordinary cement is used only for footings and foundations of stone below the ground level. Non-staining white portland cement has the same qualities as ordinary cement and is normally used where stains must be prevented.

11. If the wall being constructed must be exactly plumb and erected to a line, corner posts of wood should be erected to serve the purpose of corner leads to hold the line in place. Because of the different shapes of stone, some parts of the stone will be farther away from the line than other parts. Each stone must be laid on its broadest face. If appearance is to be considered, the larger stones should be placed in the lower courses. A crowbar is used to position large stones after they are laid, and a carborundum stone (rub brick) is used to smooth rough edges of the stone. The size of the stones should gradually diminish toward the top of the wall. Porous stones should be moistened before being placed in the mortar bed to prevent the stone from absorbing water from the mortar.

12. The thickness of bed joints will depend upon the stone used. When making bed joints, spread enough mortar on the stone below the one being placed to fill the space between the two stones completely.

13. Head joints in stone walls are made after three or four stones have been laid. You make these joints by slushing mortar (with your trowel) in the small spaces between the stones. Fill the

91

larger spaces between the stones with small rock (gravel) and mortar. Be sure to form the head joints before the mortar in the bed joint has set.

14. Bond stone (headers) should occur at least once in each 6 to 10 square feet of wall. Foundations must have a header in each 5 square feet. These stones pass all the way through the wall or at least two-thirds through the wall thickness. Each head joint should be offset from adjacent head joints above and below as much as possible. Properly spaced head joints are shown in figures 114 and 115.

15. Cleaning Stone. Small cement stains on new stonework are sometimes left to bleach under the actions of the elements. However, mortar and films of soot and dirt may be washed off the surface of the new stonework with soap putty. The putty is made by boiling strong laundry soap flakes in water until the mixture is of a thick consistency. Three tablespoonfuls of household ammonia per gallon of water are mixed in after the liquid soap has cooled. Enough white sand is then worked into the mixture to make it putty-like.

16. Stains of various types may be removed from stonework with a 10-percent muriatic acid-water solution. A 5-percent phosphoric acid-water solution or a 5-percent sulfuric acid-water solution should be used with the stone or the mortar is white. By the use of this solution, the slightly yellow discoloration which may result from the use of muriatic acid on these materials is avoided. All stone surfaces treated with acid solutions must be thoroughly washed with clean water to neutralize the acid and stop further chemical action. Protective clothing such as goggles, rubber gloves, an apron, and boots should be worn when cleaning with chemicals.

MODIFICATIONS

Pages 76 - 79 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Ceramic and Quarry Tile

FROM ANCIENT times man has used thin baked clay shapes (tile) to cover other structures. Specimens of tile made in 6000 B.C. exist in museums of the world. Originally the word "tile," as related to building construction, referred to the baked clay tiles used to cover floors, roofs, walls, and other structures.

2. Today there are several types of building material referred to as tile that are used to cover various parts of structures. In most cases, tile made from products other than clay are designated by placing the type of material before the word "tile." Some of these are aluminum, plastic, asphalt, and acoustic.

3. As a masonry specialist, you will be working with ceramic and quarry (clay) tiles. Any tile made of clay and baked in kilns is called ceramic tile (this includes quarry tile). In this chapter we will discuss the manufacture of tile, common tile shapes, classification of tile, uses of tile, and tile trim. The procedures for preparing wall and floor surfaces to be tiled, setting wall and floor tile, cutting tile, and care of tools and equipment will also be discussed.

20. Manufacture, Description, and Uses

1. Before you can set tile, you need to know something about it so you can make sure that the best and most economical tile for the job is selected. To help you understand the characteristics of tile, we discuss its manufacture, size, classification, and use.

2. **Manufacture of Tile.** Over the years, there have been many changes made in the manufacturing process of ceramic tile. It has changed from a crude manual process to a completely automatic process. Two general processes are now used to manufacture tile: the dust pressed process and the plastic process. The dust pressed process is used to make ceramic wall and floor tile. Ceramic floor tile have the same color throughout the tile. instead of only a surface glaze like wall tile.

3. In the dust pressed process, the dry ingredients are mixed with water and then finely ground. The mix is then passed through a filter press to remove most of the water. The clay mixture is then fed to the mechanical tile press line, where it is distributed over steel dies. The press descends on the clay material and a moving blade pushes the newly formed tile onto a conveyor, where it is inspected.

4. Inspection passed, an automatic brush cleans the tile before it enters a metal inclosure where glazing material is applied to the top surface with automatic spray guns. The type of chemicals used in the glaze determines the color of the finished tile. The glaze on the tile dries quickly and the tiles are unloaded from the conveyor belt into setters, which are ceramic racks used to support the tile in the kiln. The setters are then placed on kiln cars that carry the tile through the firing kiln. The kiln tunnels are a couple of hundred feet in length and it takes the tile approximately 24 hours to pass through the tunnel. The temperature in the center of the tunnel is about 2,000° Fahrenheit, and the tile reaches this temperature gradually as it approaches the center and then gradually cools as it reaches the end of the tunnel. The uniformity of the tile is due to the exact control of the kiln temperature. After the tile leaves the tunnel, it is inspected for size, warpage, and variation in the shade of color. The product is now ready for shipment.

5. Floor tile does not receive a glaze. Because of the small size of ceramic mosaic floor tile and for ease of installation, they are mounted in various patterns. The tiles are assembled and glued to a piece of kraft paper so that the individual tiles are held in position during installation.

6. Nonslip tile is made by adding a small percentage of aluminum oxide powder, of a predetermined grain size, to the tile mix just before the pressing operation.

7. Quarry tiles are floor tiles that are larger in size than ceramic floor tiles and are made by a simpler process. They do not require the precision expected of regular wall and floor tile, or the uniformity of clay in the mixture. Quarry tile have a dense body. They are unglazed and are made in colors of orange, red, and brown The

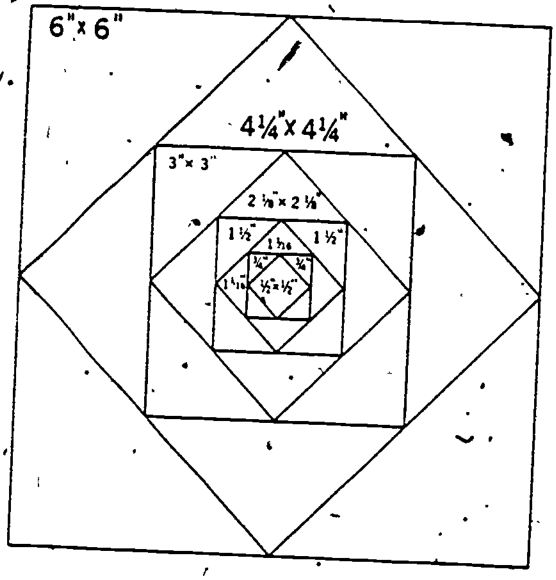


Figure 116. Basic 6-inch square.

color depends on the iron oxides in the clay from which they are made.

8. Quarry tile is made by the plastic process in which the clay mixture (containing about 25 to 30 percent water) is extruded and the tiles are cut to length by means of a wire. Then they are fired in the kiln. Now that we understand the process of manufacturing tile, let's discuss the various tile sizes.

9. **Common Tile Sizes.** Tile can be obtained in a variety of sizes. The 6-inch square, in figure 116, is the basis for the standard sizes of tile. Tile shapes and sizes have been developed by dividing the square into diagonal halves, quarters, and smaller squares. Other divisions of the square into oblongs, hexagons, octagons, and other geometrical shapes have brought about the development of still other tile forms.

10. **Classification of Tile.** The ceramic tile industry has adopted a classification for ceramic tile based on the percentage of water the tile will absorb. On this basis there are four classes of tile:

(1) Nonvitreous - A tile that will absorb more than 7 percent of its weight in moisture.

(2) Semivitreous - A tile that will absorb more than 3 percent, but less than 7 percent, of its weight in moisture.

(3) Vitreous - A tile that will absorb less than 3 percent of its weight in moisture.

(4) Impervious - A tile that will resist the absorption of moisture.

The semivitreous and nonvitreous tiles must be soaked in water before they are laid to prevent them from absorbing water from the mortar.

11. **Uses of Tile.** Ceramic tiles are used to cover various floor and wall surfaces. You wouldn't think of using a glazed tile in the construction of a patio, anymore than you would use quarry tile to cover a bathroom wall. So let's discuss the various ceramic tiles and where they are used.

12. *Glazed interior tile.* This is the type of tile you will be working with the most. It is a nonvitreous tile, having either a buff or white body, and is coated with a number of various color glazes. It is used mostly for covering bathroom, shower room, and kitchen walls. It comes in squares, oblongs, hexagons, and octagons. The most popular size is the 4¼" x 4¼" square tiles. It comes in thicknesses of ½ and ⅜ inch. Some of the glazed wall tile sizes are shown in figure 117.

13. *Ceramic mosaic tile.* This type of tile is a vitreous nonglazed tile and is available in red, brown, blue, black, and gray through the body of the tile. It is used mostly for bathroom and shower room floors. Mosaic tile comes in squares, oblongs, hexagons, and other shapes. The small pieces of mosaic tiles (½" x ½", 1" x 1", 2" x 1", 2" x 2" etc.) are glued to kraft paper and delivered to the job in sheets of various sizes. The thickness of this tile is ¼ inch. A piece of kraft paper mounted ceramic mosaic floor tile is shown in figure 118. The tile is always laid with the kraft paper facing up. Ceramic mosaic tile with a glazed finish is also available for walls.

14. *Glazed exterior tile.* This is weatherproof tile and is similar to glazed interior tile. The main difference is that this tile has a semivitreous or vitreous body which enables it to withstand severe freezing. It is used for covering fronts of buildings, swimming pools, etc. It is available in the same sizes and shapes as glazed interior tiles and can be obtained in a variety of colors.

15. *Quarry tile.* This is an unglazed tile, having a dense body, available in colors of orange, red, and brown. Quarry tile is impervious. These tiles are very durable and are resistant to freezing, abrasion, and moisture. They are used to cover

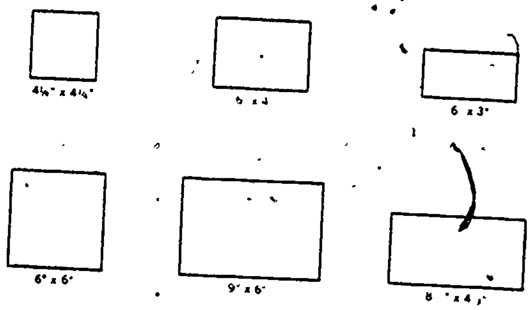


Figure 117. Sizes of glazed wall tiles.

95

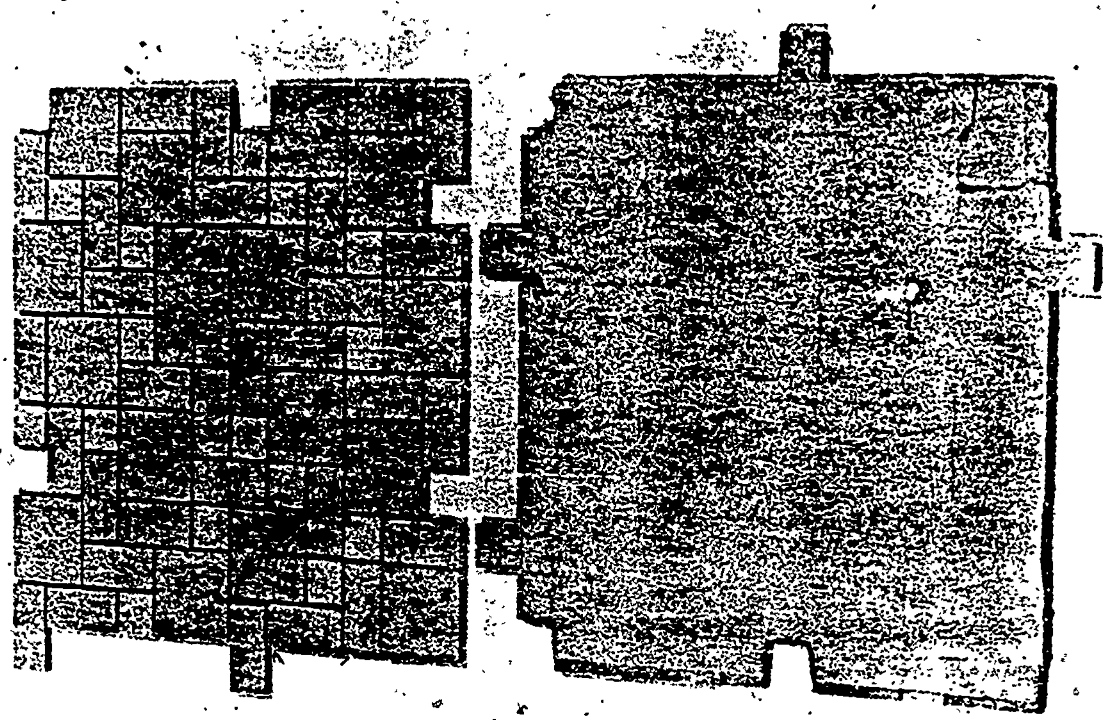


Figure 118. Ceramic mosaic tile.

floors in public buildings and for such residential purposes as entranceways, patios, etc. They are normally made in 6" x 6" squares and 6" x 9" oblongs and range from ½ to 1 inch in thickness. The smooth face and the grooved back of a quarry tile is shown in figure 119. The tiles are laid with the smooth surface facing up.

16. **Tile Trim.** For the tile setter, the word "trim" refers to various kinds of tile moldings used to give a finished appearance to floors, walls, and other types of work. These pieces of tile have rounded corners and serve as starting and stopping

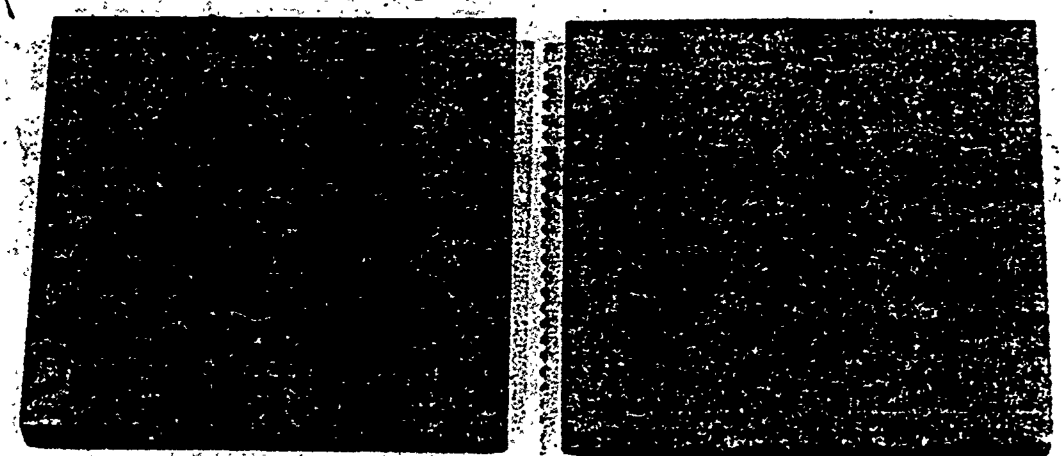


Figure 119. Quarry tile.

96

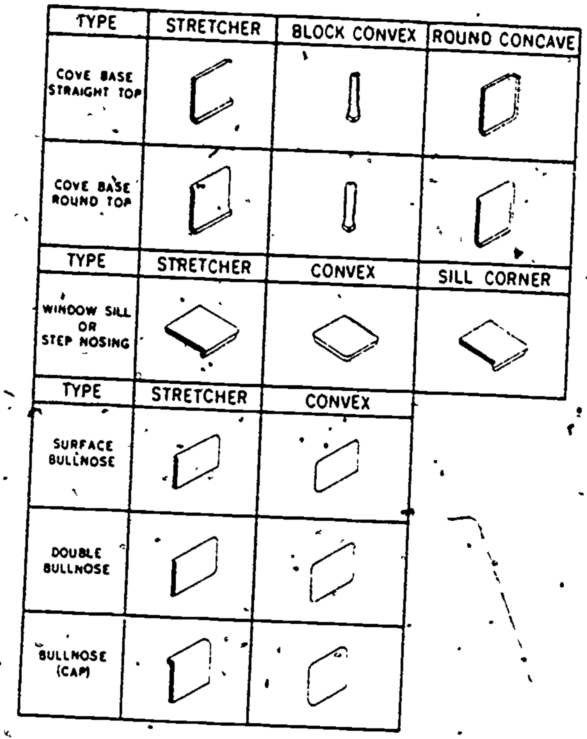


Figure 120. Tile trim shapes.

places for tile work. The most commonly used types are the cap, bullnose quarter rounds, base, and angles of various shapes and sizes for making turns. Some tile trim shapes are shown in figure 120.

17. Tile trim may be of the same color as the main body of wall or floor tile, or it may be used for contrasts.

21. Wall Tiling

1. There are two different methods and materials used for applying the base material to hold the tile to the wall: the plaster method, which is similar to plastering a wall; and the dry wall method, which consists of applying a small amount of adhesive to the back of each tile. Some people refer to the dry wall method as the buttering method. Let's first discuss the plaster method.

2. **Plaster Method.** Preparing a wall surface to receive tile is almost the same as preparing it to be plastered. All walls to be tiled (except masonry and plaster walls that have good suction and are in good condition) must be covered with metal lath backed with waterproof building paper. Before applying the lath, make sure you remove the baseboard (molding at the bottom of the wall) and any other objects that will interfere with the placement of the lath. Like in plastering, special furring nails are used to hold the lath in place. After the metal lath is properly secured, you can start to mix the mortar.

3. There are three coats of mortar used in preparing a wall surface to be tiled: a scratch coat, float coat, and a neat coat. The scratch coat consists of 1 part portland cement to 3 parts sand, with the addition of 10-percent hydrated lime by volume of the cement used. The float coat consists of 1 part portland cement, 1 part hydrated lime, and 3½ parts sand. The neat coat consists of a mixture of portland cement and water mixed to a consistency of putty.

4. After properly mixing the materials for the scratch coat, apply the mortar to the lath or clean concrete or plastered wall according to the thickness indicated on the drawings but in no case less than ¼ inch thick. While the mortar is still plastic, score or scratch the surface with a scarifier. Keep the scratch coat moist until it is damp set before applying the float coat.

5. After properly mixing the float coat, use the mortar to fasten the base screeds (strips of wood ⅜ inch thick and 1 inch wide) securely against the scratch coat. To do this, apply a strip of mortar about ½ inch thick to the wall and press the base screed firmly against the mortar. This will temporarily hold the base screed in place. Then apply mortar to an area (against the sides of the base screed) 3 inches on each side of the base screed to be sure it will stay in place. Now tap the base screed into the mortar with the handle of your trowel until there is ¾ inch between the front side of the screed and the scratch coat. Like in plastering, the screeds will act as a guide to help you obtain a straight wall with a uniform thickness during the screeding off process. Apply the float coat between the base screeds and screed the surface off until it is level and plumb. Use a level to make sure you have a true surface. Now you are ready to mix the neat coat and start to set the tile.

6. Before wall tile can be set it must be thoroughly soaked in water. Soak the tile in a mortar box or large buckets for a minimum of 1 hour to prevent the tile from drawing moisture from the neat coat. There are two methods used for applying the neat coat of portland cement mortar: the floating method and the buttering method. The floating method consists of applying a skim coat of mortar about 1/16 inch thick to a section of wall surface that can be covered with tile within 20 minutes. If the tile is not set within 20 minutes, the mortar will dry up and the tile will not adhere properly to the mortar. When the floating method is used, the tile must be snapped into place to force the air from behind the tile. Using the buttering method, you apply about 1/16 inch of mortar to the back of each tile. When this method is used, at least 60 percent of the

101

back of each tile must be covered with mortar after it is set and tapped into place. (The buttering method is always used to set tile trim). Now that you understand the two methods of applying the neat coat of portland cement mortar, we will discuss the procedures for setting wall tile.

7. *Setting wall tile.* When tiling a wall, always set the cove base tile (tile at the base or bottom of the wall) first. (The cove base tile was shown in fig. 120). Starting at one end of the wall, butter the first cove base tile with mortar and press it firmly into place. Using the handle of your trowel tap the tile to insure that the mortar is evenly spread behind it. Set the remaining cove base tile in the same manner. Some ceramic tile have lugs at their edges which correctly space the tile 1/16 inch apart. Whether or not the tiles have lugs depends on the manufacturer. If the tiles do not have lugs, small rubber spacers can be purchased to properly space the tiles. If rubber spacers are not available, use round toothpicks to space the tiles by pushing them between the tiles one-third the length of the toothpick into the mortar. After the cove base tiles are set, you can start setting the wall tiles.

8. Using the buttering method, pick up the tiles one at a time, butter them and set them in a horizontal row just above the cove base tile. Make certain that the friction bars (ridges) on the back of the tiles are horizontal. Tap the tile lightly with the handle of your trowel as you set them on the wall. This will set the tile firmly enough to keep it in place. Continue setting the tile until you have one row extending the length of the wall to be covered. After completing the first row, check the joints to make sure they are all the same width and use the point of your pointing trowel to adjust any tiles that are not spaced properly. If you are using tiles with lugs, the lugs should come together and touch. This will provide a suitable joint width.

9. After you have laid one complete row of wall tile, place a level on top of the tiles to make sure they are level. The proper method of leveling tiles is shown in figure 121. If the reading is level, push up any low tile to the bottom edge of the level by raising them with the point of your pointing trowel. If necessary, place a nail, a small tile chip, or a wedge of mortar under the tile you lift to hold them in place until they set. If the tiles are not level, raise them up against the level until you get a level reading. After you get a level reading, bring the remaining tiles to the line established by your level.

10. When the first row of tile is level, set a few more rows using the same procedures. Level the rows as you complete them. After the tile wall is raised to the desired height, according to the drawings and specifications for the job, butter and set the bullnose cap at the top of the tiled surface. Any vertical joints that need adjustment can be adjusted by eye. Now that the tiles are set in position they must be beat into place, the tile and their joints must be cleaned, they must be floated back into position and their joints must be grouted to bring the entire surface into a uniform smooth plane. First, the tiles must be beat into place.

11. *Beating tile.* After tiles are set, they must be beat into place if a smooth wall surface is to be obtained. Variations in individual thicknesses and differences in depth to which the tiles have been set make it necessary to bring the whole surface into a uniform, smooth plane. The only tools needed for this operation are a hammer and a wooden block. To beat the tile into a smooth plane, hold the block at one end with the flat side against the surface of the tile. Then move the block along the wall and beat the tile in, as shown in figure 122. After completing the beating operation, clean the tile joints to allow room for the grout material and to prevent the dark mortar from showing through the white grout.

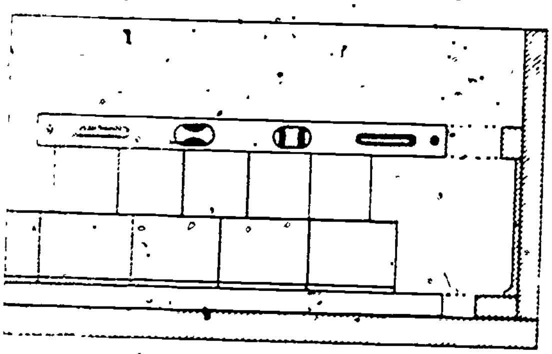


Figure 121. Leveling wall tile.

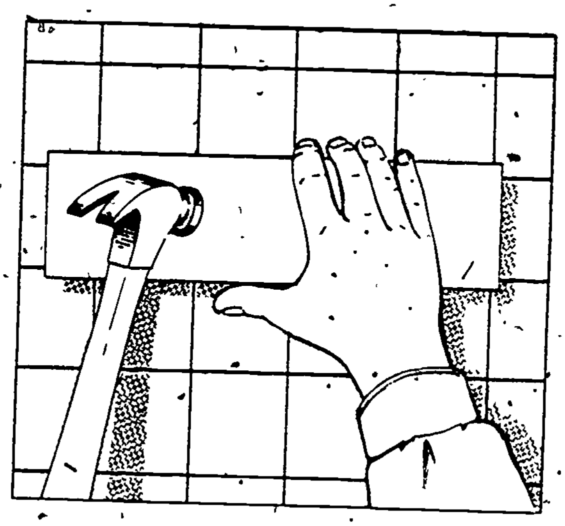


Figure 122. Beating tile.

98

12. *Cleaning tile.* All that is required to clean tile is a scrub brush, a bucket of clean water, and a soft cloth. First, wet the brush and gently scrub the joints to remove any sand or mortar that may be between the tiles. It may be necessary to scrub the joints more than one time to remove all the mortar. After the joints are clean, use a moist, damp cloth to clean the tile surface.

13. *Floating tile.* The purpose of floating a tiled surface is to aline the tile and space the joints like they were before they were beat in. During the process of beating the tiles, you will have set up considerable vibration and brought moisture to the surface (back of the tiles) that may have caused some of the tiles to be loose. To get these tiles back in their proper position, you must gently float the tiled surface with a beating block. Hold the block with the flat face against the tiled surface and move it back and forth, applying very little pressure, as shown in figure 123. Adjust the space between the joints with the point of your pointing trowel. Allow the tiles to set for at least 30 minutes, while you are mixing the tile grout.

14. *Grouting tile.* Grouting seals the joints between the tiles and gives the surface a finished appearance. The success of any tile job depends greatly on the application of the grout. To mix the grout, pour about 1 inch of water into a clean bucket and add about two or three handfuls of white portland cement grout. Add enough cement to make a thick paste, because the tiny lumps of cement will mix easier when the mix is thick. After the grout is thoroughly mixed, add enough water to give the mix a thin creamy consistency.

15. To apply the grout to the tile joints, dip a water brush (long-fibered paint brush) into the grout and brush the grout in various directions both with and across the joints until they are flush with the surface of the tiles. If the joints are not properly taking the grout, dip the brush into water and this will make the grout thin enough to penetrate into every joint. When all the joints are filled flush with the surface of the tiles, you can start the washing process.

16. The initial washing is done with a clean water brush and a bucket of water. Wet the brush and wash the surplus grout from the joints. After going over the surface a couple of times with the water brush, wipe the surface thoroughly with a soft, damp cloth, using a circular motion. After nearly all the grout is removed from the surface of the tile, finish smoothing off the joints by gently rubbing over them with a damp cloth. Try to bring all joints to an even depth of $\frac{1}{32}$ inch below the surface of the tiles. As the tile joints dry (cure), work the joints over lightly with a damp cloth to prevent them from drying fast thereby causing the grout to crack. As long as the joints are rubbed with a damp cloth, there will be a thin film of grout on the tiles. When the tile joints are properly cured, clean the tiles by rubbing them with a soft dry cloth.

17. **Dry Wall Method.** The dry wall method of setting tile is the easiest and fastest method. It consists of buttering a small amount of tile adhesive (about 3 inches in diameter and $\frac{1}{16}$ inch thick) to the back of each ceramic tile and setting the tile on the wall. Using this adhesive you can set wall tile directly on gypsum wallboard, painted plaster, brick masonry, concrete, plywood, and asbestos board surfaces. After setting ceramic wall tile with the adhesive, beat, clean, float, and grout the tile in the same manner as you did when you used the plaster method.

18. Ceramic mosaic tiles are used to cover walls and floors. The only difference between the wall and floor tile is that the wall tile is glazed and the floor tile is not. Tile adhesive is preferred over portland cement mortar for setting ceramic mosaic wall and floor tiles because it is easier to work with. Portland cement mortar sticks in the joints of the small paper-mounted tiles causing the joints to be very difficult to clean. The biggest difference in setting regular ceramic tile and ceramic mosaic tile is in the application of the adhesive. When setting ceramic mosaic tile, apply the adhesive $\frac{1}{16}$ inch thick to the surface being tiled rather than to the tile. Do not leave any bare spots on the surface. Most tile adhesives will set up in about 10 minutes, so don't apply the tile

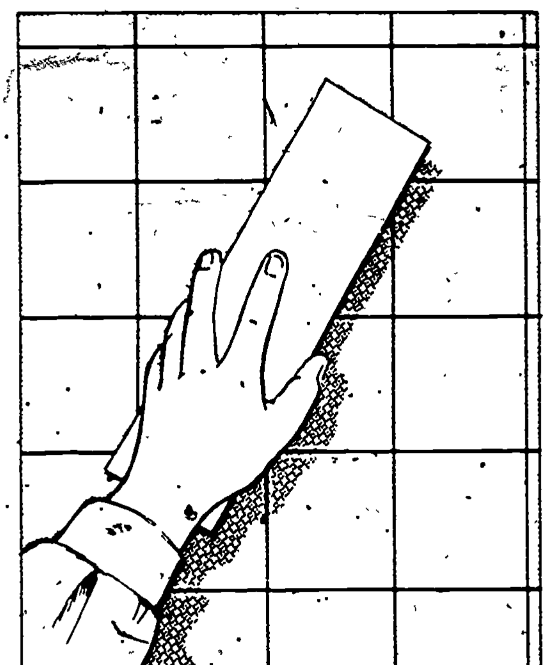


Figure 123. Floating tile.

adhesive to a larger area than you can finish within that time. Since there are different types of tile adhesive, follow the manufacturers instructions on the container. After applying the tile adhesive to the wall or floor, set the sheets of tile in place with a slight sliding motion so that you will break the initial film set that forms on top of the adhesive. Try not to slide the tile so much that some of the adhesive is forced between the tiles

19. Level the tile by working a beating block back and forth over its surface. After leveling the tile, place the beating block against the tile and tap it lightly with a hammer to force the small tiles to lay flat in the adhesive. Be sure that there are no ridges between the tile sheets.

20. After the tile sheets have set in the adhesive for a minimum of 30 minutes, you can remove the kraft paper from the top of the tiles. This is done by wetting the paper with a sponge until the glue (between the paper and the tile) softens. After removing the mounting paper, adjust the individual tiles, if necessary, with the point of your pointing trowel. Allow the adhesive 24 hours to set hard before you grout the tile.

21. Before applying the grout, check the tile joints to be sure that the tile adhesive is not in the joints. If some of the joints need cleaning, use a sharp knife to remove the adhesive from the joint. Wipe the surface of the tile with a damp cloth until it is clean, and grout and clean the tiles as previously explained.

22. Floor Tiling

1. In most respects, the procedures for installing floor tile are the same as for setting wall tile. However, there are some minor variations which we will cover in this section.

2. Quarry tile can be set on wood or masonry floor surfaces. Let's say for instance you are setting quarry tile on a concrete floor. You should first examine the surface for defects such as cracks and chipped areas, and then make the necessary repairs. You should also check for low spots in the concrete, by placing a long level or straightedge on the surface, and mark the low areas with chalk. When setting the tile, use additional mortar at these low areas so the tile surface will be level. A concrete surface to be tiled must not be smooth because mortar will not properly bond to a smooth surface. If the surface is smooth, you will have to roughen it. To roughen a concrete floor, use a sharp-pointed bullnose chisel and a hammer. Chisel spots, about 1 to 1½ inches apart, and about ⅛ inch deep over the entire surface. These rough spots will assure you of a good bond between the mortar and the concrete.

3. Before you are ready to set the tile, check the starting corner of the base surface with a 2-foot

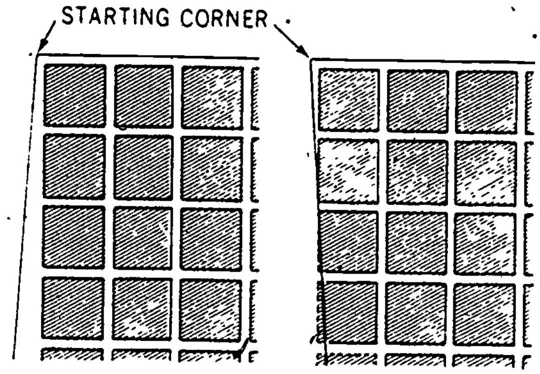


Figure 124. Checking starting corner for squareness.

steel square. The corner might be square or it might run out, as shown in figure 124. Using the square, draw lines at right angles to each other on the base surface to locate the first row of tile. These lines will show the out of square runout of the surface. They will also indicate if it will be necessary to cut some of the tiles on an angle to prevent the runout. After you check the surface for squareness, you can start mixing mortar and prepare to set the tile.

4. **Setting Floor Tile.** Quarry tile is set in a bed of cement mortar, about ¼ inch thick, consisting of a mixture of 1 part portland cement to 3 parts building sand. After properly mixing the materials, spray the concrete slab with water where the tile are going to be set. This will prevent the concrete from absorbing water from the mortar used to set the tile. Repeat the wetting of the slab at intervals if the concrete surface tends to dry out.

5. The mound system is usually used to lay quarry tile on masonry surfaces. It consists of placing five small mounds of mortar on the back of each tile, as shown in figure 125. Using your trowel, apply a small mound of mortar on each corner and one in the center of the tile. Then turn the tile over, set it on the slab, and tap it lightly with the handle of your trowel or a mallet and this will spread the mortar evenly over the bottom of the tile. Check the tile to be sure it is level. Normally, ½ inch joints are used between quarry tiles; so set the remaining tiles in the first row ½ inch apart, using small pieces of wood as spacers. When the first row of tiles are set, place a straightedge or a long level over them and adjust the tiles by lifting them (adding mortar) or by tapping them down with a mallet until the row is level. After leveling the tile, check the joints to make sure they are the required width. When the first row of tile is level and the joints are the desired width, start setting the remaining rows of tile using the same procedure that you used to lay the first row. When you are finished

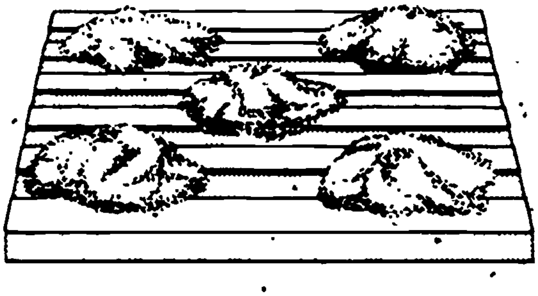


Figure 125. Mound system of applying mortar.

setting the tiles, they must be beaten in, cleaned, leveled, and grouted.

6. The beating in, cleaning, and leveling can be done in one operation. Using kneeling and walking boards to prevent walking on the newly set tiles, beat the tiles in with a mallet, clean them with a damp cloth, and level them. Continue doing sections of the floor in this manner, working from board to board, until the floor is finished. You should grout the tiles within 2 or 3 hours after they are set so a good bond will be obtained between the mortar used to set the tiles and the cement grout. When grouting quarry tile, you can prepare the grout mixture with the same ingredients as the cement mortar used to set the tiles or with white portland cement grout. The grout mixture for quarry tile is made up of 1 part cement to 2½ parts sand. Add enough water to the mix so it has a creamy consistency. Before grouting the tiles, remove the wood spacers. After grouting a section of the tile joints, rub a wet rag over them to force the grout into the joints so that they are filled just below the surface of the tiles. Continue this procedure until all the joints are grouted. If necessary, work the joints over with a jointer.

7. When the grouting is completed, wait about 30 minutes and wash the tiles with a wet cloth to remove any cement spots on the tiles. Then rub over the tiles with a dry cloth. Keep the joints damp for at least 24 hours so the grout will properly cure and prevent the joints from cracking. You can cure the mortar joints by placing wet burlap bags over the floor surface. When you remove the burlap bags, wash the tiles with water once again. If the cement grout causes discoloration of the tiles, the true color of the tiles can be restored by applying one or more coats of linseed oil over them.

8. Use tile adhesive to set quarry tiles on wood surfaces. Wood floors must be sealed before the tiles are set. You can seal the floor by applying one or two coats of shellac. Allow the shellac to dry thoroughly before you set the tile. Apply the adhesive to the back of the quarry (¼ inch thick) in the same manner as you applied it to ceramic tile. Use the same process for finishing the floor that you used for setting the tiles with cement mortar. There will be times when you will have to cut tiles to make them fit properly.

9. **Cutting Tile.** Cutting tile is a very simple operation. The tile cutting machine, shown in figure 126, is a mechanical device provided with a measuring guide and a scoring wheel. Using this device, you can cut ceramic or quarry tile to different sizes and shapes in a matter of seconds. Before cutting a tile, draw a line on it with a pencil and a ruler where you want the tile to break. Then place the tile at the back edge of the tile cutter, firmly against the measuring guide, as shown in figure 127. Move the adjustable gage against the side of the tile and lock it when you have the mark for your cut directly below the scoring wheel. Hold the handle of the tile cutter firmly and, beginning at the edge of the tile furthest from you, pull it toward you, causing the tile cutter to ride over the tile. This will leave a score line on the tile, as shown in figure 128. Lift up on the handle and position the breaking bar (the extension at the bottom of the handle which runs at right angles to the handle) over the center of the tile. Press down on the handle until the breaking bar is touching the tile and then apply more pressure to the handle until the tile breaks, as shown in figure 129. This will give you a clean cut. If there are any rough edges on the tile after it is cut, rub the rough spots off with a carborundum stone.

10. When it is necessary to cut a small amount off the edges of tile to fit around protruding pipes, etc., the tile nippers are the most convenient hand tool to use. A tile cut to fit around a pipe and the tile nippers used to cut the tile are shown in figure 130. If available, a tile saw can also be used to cut the tile. Mark a line on the tile where you want to make the cut. As you cut the tile along the line with tile nippers, make small cuts breaking off a little tile at a time until the area is cut out. Don't try to cut an area on the tile, like that shown in figure 130, in one or two cuts because the tile might break in the wrong direction. Use a small carborundum stone to smooth the cut edges of the tile.

23. Care of Tools and Equipment

1. Masonry and concrete tools and equipment must be cleaned immediately after each use. If cleaning is delayed, the mortar or concrete will harden and make the cleaning very difficult. In most cases, you can remove concrete and mortar from tools and equipment by washing them with water.

2. To prevent concrete from sticking to the outside surface of a concrete mixer, apply a light coat of oil to the surface of the mixer before

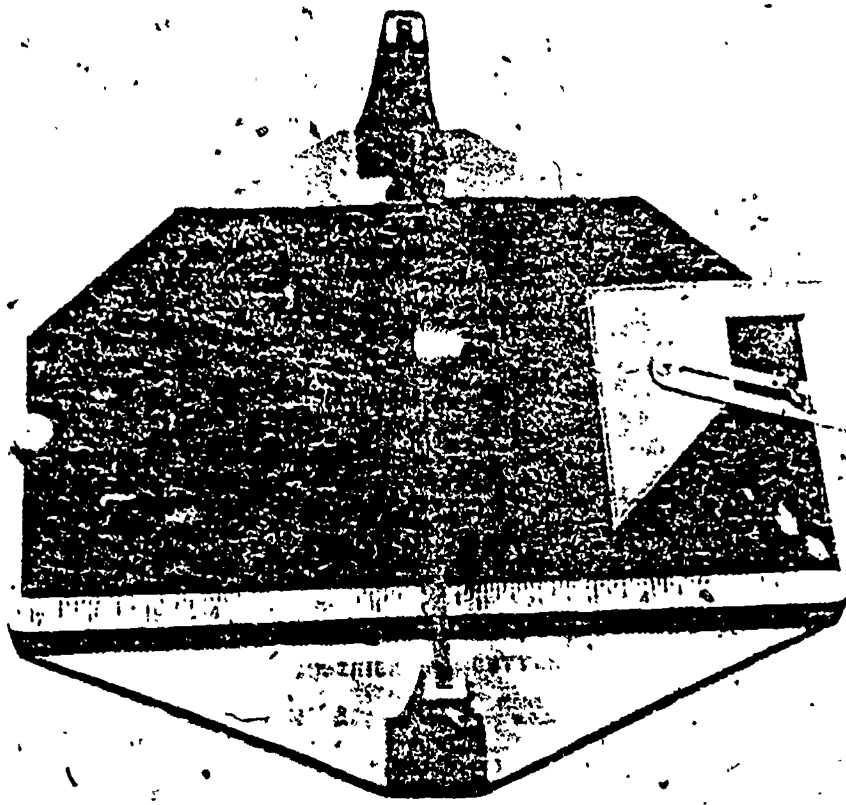


Figure 126. Tile cutting machine.

using it. When storing a concrete mixer for a long period of time, apply a light coat of oil or grease to all unpainted parts of the mixer. Immediately after using a concrete mixer, place a small amount of coarse aggregate and water in the mixing drum and run the mixer for a few minutes. The action of the water and the aggregate in the drum will wash away the loose concrete. Before each use the mixer must be serviced, greased, etc., according to the manufacturer's instructions.

3. Clean and oil all metal parts of hand tools to prevent them from rusting. If the tools are used with tars or adhesives, clean them with kerosene or naphtha and apply a light coat of oil to them. See that all cutting tools are kept sharp and handles and other broken parts of the tools repaired or replaced. Store hand tools on shelves or racks in the tool crib or tool room. If tools are to be stored for long periods of time, coat the metal parts of the tools with rust-preventive compound and wrap them in heavy paper.

4. Before using power tools, inspect them to be sure they were serviced. At the end of each workday, and before they are stored, all power tools should be cleaned, inspected, and serviced. Store small power tools in racks, closed cabinets, drawers, etc., to prevent them from collecting dust. The inspection and servicing of all power tools and equipment should be in accordance with the manufacturer's instructions.

102

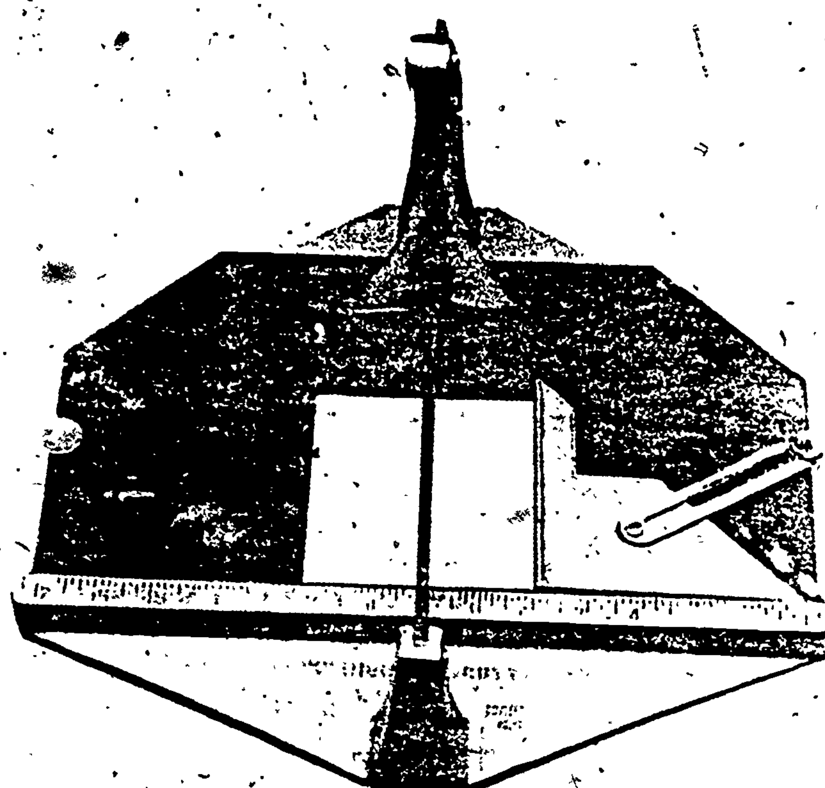


Figure 127. Placing tile on tile cutter.

107

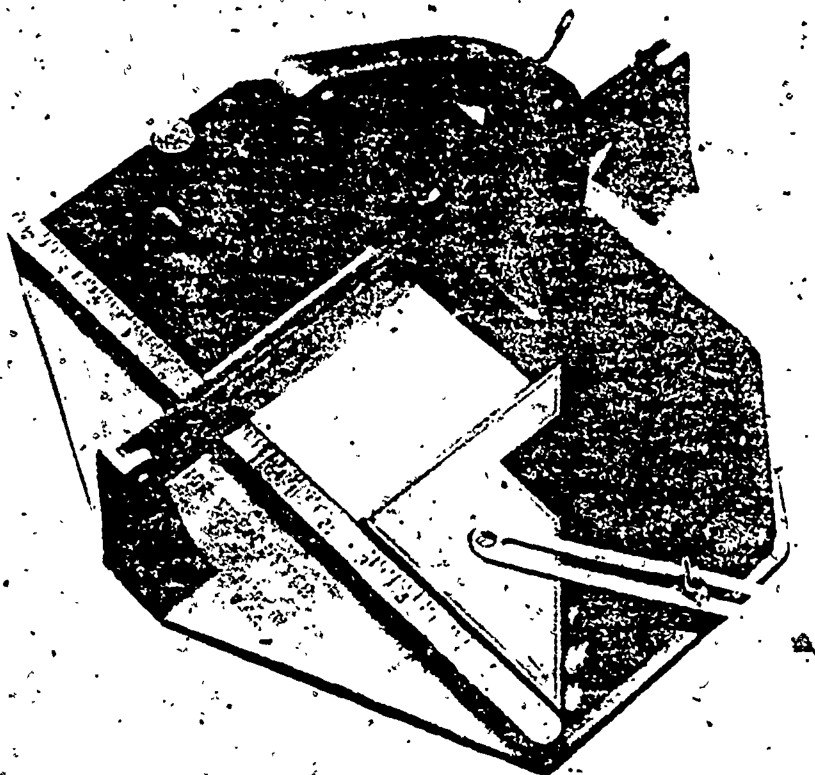


Figure 128. Scoring the tile.

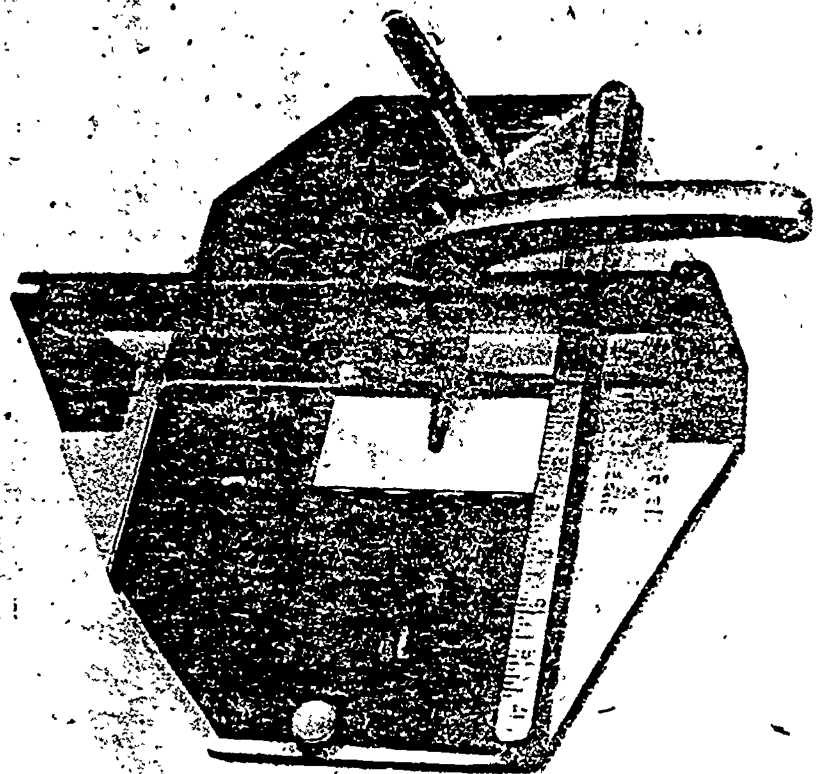


Figure 129. Breaking tile.

103

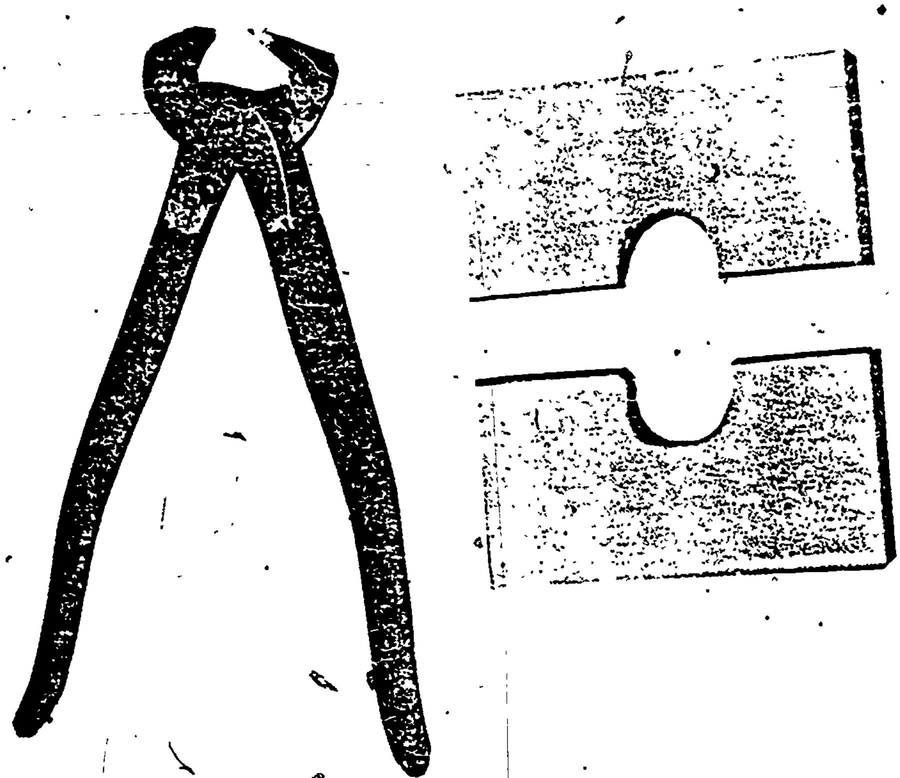


Figure 130. A cut tile and tile nippers.

106

STUDENT NOTES

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CHAPTER 7

Estimating

REFERENCE books by the hundreds have been written on the process and procedures for estimating construction projects. Many of these books are used in estimating building construction costs. They contain tables which give the amounts of materials and time required to do many jobs under any condition. However, estimating construction jobs was done before the tables were formulated. In the early days, a lot of figuring was required to make an estimate on a complicated job. Basically, the final estimated cost for the masonry work on the job was derived from the material and time required to construct one square foot of wall, floor, or roof.

2. When you are given a work order for a particular job, it will be your responsibility to check the job and estimate the amount of materials needed to complete it. We will help you accomplish this task by giving you the necessary information needed to estimate the different materials you will be working with. This will include the methods used in estimating concrete, mortar, brick, concrete block and tile, stone, and ceramic and quarry tile.

3. There are two types of estimates you will be working with: quantity and time estimates. The most important factor in estimating data is the quantity of materials needed to complete a job. Quantity estimates are those which indicate the amounts of material required for a given unit of construction. The basic units used in estimating masonry work are: square feet, cubic feet, and cubic yards. Time estimates are those which indicate the time required to constuct or apply the building materials under given conditions.

4. Let's start our discussion on estimating by covering the procedure for making estimates on concrete construction.

24. Concrete

1. To estimate concrete, determine the number of cubic yards necessary to complete a given job. There are 27 cubic feet in 1 cubic yard. Let's say, for example, you are given the drawing in figure 131. The drawing indicates that the project is a portland cement concrete dumpster pad 15 feet square and 6 inches in thickness. To determine the number of cubic yards needed, multiply the length in feet, by the width in feet, by the thickness in feet, and divide this product by 27. When you multiply these numbers (15′ × 15′ × 0.50′), the product will be 112.50 cubic feet. To convert the 112.50 cubic feet to cubic yards, divide by 27. The result of this division is 4.17 cubic yards. This is the amount of concrete you will need to complete the job. Always add 5 percent of the total amount for loss or waste. Five percent of 4.17 cubic yards is approximately 0.21 cubic yard. The total amount of concrete

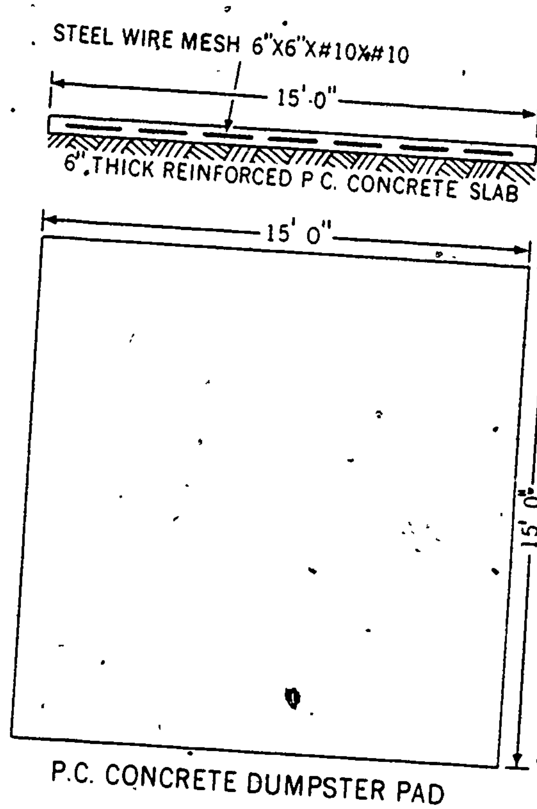


Figure 131. Portland cement concrete dumpster pad.

TABLE 4
MATERIALS FOR CONCRETE

CU. FT.	1:1.5:3			1:2:3			1:2:4			1:2.5:5			1:3:6		
	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*
100	28.0	42.0	84.0	25.8	51.6	77.4	22.0	44.0	88.0	18.0	45.0	90.0	16.0	48.0	96.0
50	14.0	21.0	42.0	13.0	26.0	39.0	11.0	22.0	44.0	9.0	22.5	45.0	8.0	24.0	48.0
40	11.2	16.8	33.6	10.3	20.6	31.0	8.8	17.4	35.2	7.2	18.0	36.0	6.4	19.2	38.4
30	8.4	12.6	25.2	7.8	15.5	23.3	6.6	13.2	26.4	5.4	13.5	27.0	4.8	14.4	28.8
20	5.6	8.4	16.8	5.2	10.4	15.6	4.4	8.8	17.6	3.6	9.0	18.0	3.2	9.6	19.2
10	2.8	4.2	8.4	2.6	5.2	7.8	2.2	4.4	8.8	1.8	4.5	9.0	1.6	4.8	9.6
9	2.5	3.8	7.6	2.3	4.6	7.0	2.0	4.0	8.0	1.6	4.0	8.0	1.5	4.3	8.6
8	2.3	8.4	6.8	2.0	4.2	6.3	1.8	3.5	7.0	1.4	3.6	7.2	1.3	3.8	7.8
7	2.0	3.0	6.0	1.8	3.5	5.4	1.5	3.0	6.0	1.3	3.1	6.3	1.1	3.4	6.8
6	1.6	2.5	5.0	1.6	3.2	4.6	1.3	2.7	5.3	1.1	2.8	5.5	1.0	3.0	6.0
5	1.4	2.1	4.2	1.3	2.7	4.0	1.1	2.2	4.4	1.0	2.3	4.5	.8	2.4	4.8
4	1.1	1.8	3.1	1.0	2.0	3.2	.8	1.8	3.5	.7	1.8	3.6	.6	2.0	4.0
3	.8	1.3	2.5	.8	1.5	2.3	.7	1.3	2.6	.5	1.5	2.7	.5	1.5	3.0
2	.5	.8	1.6	.5	1.0	1.5	.5	.8	1.8	.3	.9	1.8	.3	1.0	2.0
1	.3	.5	.8	.3	.5	.8	.2	.5	.8	.2	.5	1.0	.2	.5	1.0

*1 Bags of cement.

*2 Cubic feet of sand.

*3 Cubic feet of stone.

needed to complete this job, including loss or water, would be 4.38 cubic yards. This procedure is also used for estimating plaster.

2. The estimated cost of mixing and placing concrete depends on the methods used, the size of the job, and other factors. Normally, very little hand work is done any more except on small jobs. The proportions of ingredients for estimating from 1 to 100 cubic feet of concrete are given in table 4. One man should be able to hand-mix from 2 to 2½ cubic yards of concrete in an 8-hour day. Inexperienced men will mix about 25 percent less concrete than an experienced man. When the concrete must be wheeled from the mixing site to the placing site, extra time must be added to the mixing time depending on the haul distance. The air temperature and the experience of the men placing and finishing the concrete must also be considered.

3. Concrete mixed in small mixers is mixed and placed at rates of 6 to 6½ cubic yards per day, and it takes from 8 to 10 men to run a job at this rate. We must also consider the methods used in loading and hauling the aggregate, water, and other materials and equipment to the job site. If equipment is not available to load the aggregate and other materials, more time and manpower will be needed to complete the job. As you can see, time estimates are very difficult to make unless you are familiar with all the factors of the job that must be considered. The making of accurate estimates will come with experience on the job.

4. When large amounts of concrete are needed, it is more economical to use ready-mix concrete when there is a ready-mix plant close by. By using ready-mix concrete, you can eliminate hauling materials and equipment to the job site and cut down considerably on the man-hours for the overall job.

25. Mortar.

1. Ordinarily, 1 yard of sand and the usual amounts of cement and water will make approximately 1 cubic yard of mortar. (The material for mixing mortar, proportioned by volume, was given in Chapter 3, fig. 49.) Factors such as the size and shape of masonry units, the thickness of mortar joints, and the type of bond will affect the quantities for mortar. Also, because of differences in cementitious materials and aggregates, no accurate set of values can be tabulated for all conditions.

2. The labor or time used for mixing mortar depends on the same factors that affect the time required to mix concrete.

26. Brick

1. To determine the number of brick needed to build a wall, multiply the length by the height and this will give you the total number of square feet of surface. Using ordinary brick 2¼ inches high, 3¾ inches wide, and 8 inches long, you

Table 5

Common Brick for a Square Foot of Wall

Wall Thickness		Bed Joints					
Inches	Bricks Wide	1/8	1/4	3/8	1/2	5/8	3/4
[illegible]	1	7.4	7	6.7	6.3	6.1	5.8
[illegible]	2	14.7	14	13.3	12.7	12.7	11.6
12-13	3	22.0	21	20.0	19.0	18.3	17.4
16-17	4	29.3	28	26.7	25.3	24.3	23.2
20-21	5	[illegible]	35	33.3	31.7	30.4	29.0
24-25	6	44.	42	40.0	38.0	36.5	34.8

will find that it takes about 7 brick (using ¼-inch mortar joints) to cover 1 square foot. We will figure 8 brick, and this will allow for breakage and cutting brick. You multiply the total number of square feet by the number of brick needed to cover 1 square foot and this will give you the total number of brick needed for the surface. Let's say, for instance, we are constructing a partition wall 20 feet long, 6 feet high, and 4 inches wide. By multiplying the length (20 feet) by the height (6 feet), you will have 120 square feet of wall surface. By multiplying 8 (the number of brick needed to cover 1 square foot) by 120 square feet, you will get a total of 960 brick. This is the number of brick needed, including ¼-inch mortar joints and breakage to complete the job. If the wall were 8, 12, 16, etc., inches wide, you would have to multiply 960 brick by the number of brick in the width of the wall. In other words, if the wall were 16 inches wide (4 courses wide), it would take $4 \times 960 = 3840$ brick to complete the wall. The number of brick for a square foot of wall for different size mortar joints is shown in table 5.

2. If a brick wall or building has openings, such as windows and doors, the square footage of the openings must be deducted from the total amount of wall surface.

3. Many factors enter into the time required to lay brick; consequently, it is impossible to provide a set of values that will work in all cases. Some of these factors include differences in bricklaying ability, sizes and types of brick, type of structure being constructed, sizes of joints, and types of bonds and patterns used.

27. Concrete Block and Tile

1. Concrete block and tile units are estimated by the number of units in one square foot or by the number of units per 100 square footage. You multiply the height of the wall by its length to get its square footage. Let's say, for example, you are to construct a concrete block wall 6 feet high and 25 feet long with standard size units 7⅝" x 7⅝". You are to use ⅜-inch mortar joints. The block will fill a space 8 x 8 x 16 inches which equals .889 (to the nearest thousandth) of a square foot. This figures out to take 9 blocks to fill an area of 8 square feet. It takes 112.5 blocks to fill an area of 100 square feet. By multiplying the length of the wall (25 feet) by the height (6 feet), you have 150 square feet of wall surface. Using .889 equals the square footage in one block, or using 112.5 blocks for 100 square feet, it will take 169 (to the nearest whole block) blocks (using ⅜-inch mortar joints) to complete the wall. For a wall this size, about 10 percent of the total number of blocks needed for the job should be added to the total to allow for breakage and cutting. Ten percent of 169 blocks is 17 blocks (to the nearest whole block), which would give you a total of 186 blocks needed for the job. Table 6 gives the number of units needed per hundred square feet, when you are using different size units and thicknesses, including ⅜-inch mortar joints. If you use this chart, you will have to allow extra blocks for cutting and breakage. For example, table 6 shows that when a 7⅝" x 7⅝" x 15"⅝ (third line from bottom) unit is used, it will take 112.5 blocks for 100 square feet. This includes the mortar joints. You will need another 11 blocks for a total of 124 (to the nearest whole block) blocks to allow for waste.

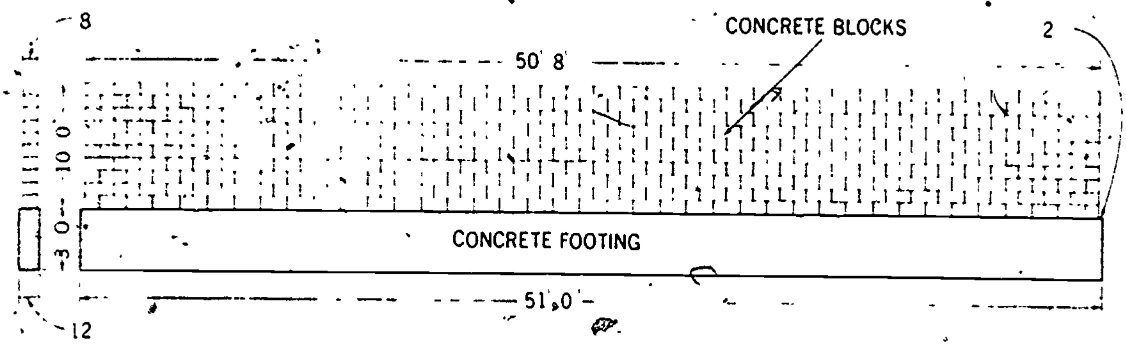
Table 6

Units for Concrete Walls

Size of Units	Thickness Inches	No. Units 100 Sq. Ft.
3 5/8 X 3 5/8 X 15 5/8	4	225
5 5/8 X 3 5/8 X 15 5/8	6	225
7 5/8 X 3 5/8 X 15 5/8	8	225
3 5/8 X 7 5/8 X 15 5/8	4	112.5
5 5/8 X 7 5/8 X 15 5/8	6	112.5
7 5/8 X 7 5/8 X 15 5/8	8	112.5
9 5/8 X 7 5/8 X 15 5/8	10	112.5
11 5/8 X 7 5/8 X 15 5/8	12	112.5

2. A typical concrete-block job you may be required to build is shown in the drawing in figure 132. By looking at the drawing, you can see that it is a concrete footing supporting a concrete block wall. The drawing gives you the dimensions of the footing and the wall. The written specifications you will receive along with the drawing will explain the requirement that each material used on this project must meet. The specifications for this project state that type I portland cement will be used for preparing both the mortar for laying the concrete units and the footing. They will

111



CONCRETE FOOTING AND BLOCK WALL

Figure 132. Concrete footing and block wall.

also state the amount of fine and coarse aggregate that must pass through each sieve and the sieve numbers they must pass through. The water used for mixing and curing will be clean and free from injurious amounts of oil, acid, salt, alkali, silt, organic matter, and other harmful substances. The specifications will also state the mixing time, the amount of slump the concrete will have, and how soon the mix will be placed after all the ingredients are in the mixer. The type of concrete block, the size of the concrete block, and the size mortar joints are also stated. The forms must be built for the concrete and the materials must be estimated before construction is started.

3. As with other masonry work, the time required for laying concrete units varies a great deal. Various sizes and shapes of concrete tile, the ability of the mason, and differences in working conditions affect laying time.

28. Stone

1. Amounts of rubblestone for walls may be estimated by the square foot, cubic foot, and cubic yard. Converting the stone requirements to cubic yards is usually the best method. The number of rubblestones contained in 1 cubic yard depends upon the sizes of the stones; therefore, if the average number of stones contained in 1 cubic yard must be known, they will have to be counted. The sale of stones varies in different parts of the country. Whether it is sold by the ton, perch, cord, or cubic yard, depends upon its shape and upon the locality. (A perch is 24¾ cubic feet and a cord is usually 128 cubic feet.)

2. A greater number of factors must be considered when estimating the time required to lay cut stone. Such things as the size of the job, average size of stone, workmanship and the method of setting (hand, hand derricks, power cranes, etc.) must be considered.

29. Ceramic and Quarry Tile

1. Nearly all tile for floors and walls are estimated by the square foot. When trimmers, base cap, and similar pieces of tile are used, they are estimated by lineal or running foot. The square and/or lineal footage requirements of a room are determined, and the number of tile for 1 square foot is multiplied by the total. This will give you the number of tile needed to cover a given surface. Let's say, for example, that we are covering a wall 7 feet high and 36 feet long with 6" x 6" glazed ceramic tile. When you multiply the length (36 feet) by the height (7 feet), you will have the total number of square feet of surface (252 sq. feet). It takes four 6" x 6" tile to cover 1 square foot of surface. By multiplying 4 (the number of tile needed to cover 1 square foot) by 252 square feet, you will have a total of 1008 tile. This is the number of tile you will need to cover the wall. Add a small percentage of the total number for breakage. The percentage you allow for breakage will depend on the skill of the mason placing the tile.

2. Estimating labor or time for tile setting, like other types of masonry work, comes from experience on the job. In small rooms, such as bathrooms, an experienced mason can complete approximately 25 to 40 square feet a day. Working on larger rooms, an experienced mason can set from 50 to 80 square feet of tile per day. To estimate the time required to set tile with accuracy, you almost have to know the tile setters and the type and size of the tile they will be working with.

Glossary

AGGREGATE, COARSE—Gravel or crushed rock.

AGGREGATE, FINE—Sand.

AGGREGATE GRADATION—The arrangement of sizes.

AIR-ENTRAINING AGENT—A concrete additive that enables concrete to resist freezing and to protect pavements from adverse effects of salts during snow removal.

ANCHORS, OR TIES—Metal shapes used to secure masonry wall intersections and to fasten other structural members to masonry walls.

BASEBOARD—Molding at the bottom of a wall.

BASE SCREED—Wooden strips or strips of plaster used for gaging the thickness of plaster coats.

BEATING IN—The process of moving a small board over a tiled surface and tapping it lightly with a hammer to set the tile firmly into the mortar and in one smooth plane.

BED JOINTS—The horizontal mortar joints between courses of brick or, more simply, the bed or mortar on which brick rest.

BOND—Refers to adherence of one material to another, as coats of mortar, etc.

BOND STONES—Stones consisting of headers.

BRICK BAT—A portion of a brick.

BRICK SET—A tool used to cut brick.

BRICK VENEER—The outside facing of brickwork used to cover a wall constructed of other material. The term generally refers to brick walls inclosing a frame building.

BROWN COAT—Second coat of plaster used to cover walls and ceilings. Never applied less than 3/8 inch thick.

BULLNOSE CAP—Tile trim used at the top of finished tile surfaces.

BUTTERING—The spreading of mortar on masonry units before they are laid.

BUTTERING METHOD—The process of applying the neat coat of mortar to the back of each tile.

CALCIUM CHLORIDE—A crystalline compound used in its anhydrous state (as a white porous solid) as a drying agent, to lay dust, etc. Accelerates the hardening of concrete.

CERAMIC—An article made of baked clay. In the tile trade, the word is used to designate a tile made of compressed clay and silica.

CERAMIC MOSAIC TILE—Small pieces of tile, usually mounted on kraft paper, mounted in various patterns. The glazed tiles are used to cover walls and the unglazed tiles are used to cover floors.

CHASING OUT THE BOND—Laying out the first tier or course of masonry units, without mortar, the length of the wall to be constructed.

CLOSURE JOINTS—The last two head joints in a course of brick.

COMMON OR AMERICAN BOND—The bond in which a header course usually occurs every seventh course, but may appear every fifth or sixth course.

COMPRESSIVE STRENGTH—The ability of a concrete slab to resist crushing.

CONCRETE—A hardened mixture of cement, sand, gravel, and water.

CONCRETE BLEEDING—The flow of cement paste out of a concrete mix.

CONTRACTION JOINT—Sometimes referred to as a dummy contraction joint is used to control cracks caused by contraction.

CONTROL JOINTS—Joints used to control cracking in plaster surfaces.

CONSTRUCTION JOINTS—Joints placed at the start and end of a days pour, or those joints used to separate areas of concrete placed at different times.

COPINGS—A layer of concrete or a row of brick, generally projecting, used to cap or finish the top of a wall and protect it from the weather.

CORNER LEAD—The part of a wall, at the corners or elsewhere, built in advance of the rest of the wall as a guide to which the corner blocks and line is attached.

COVE BASE—Wall tile having a curved upper edge and a curved bottom lip, used as a single wall tile course above the floor tile.

CRAZING—To break into pieces.

CROSS JOINTS—The vertical joints formed when laying a header course of brick.

DASH BOND COAT—Mortar applied to a masonry surface by splattering it with a brush. When the mortar hardens, it leaves a rough surface that makes a good bond between the masonry surface and the scratch coat of plaster.

DRY WALL METHOD—Applying tile adhesive to the back of each tile before setting them. Sometimes referred to as the buttering method.

EMULSIFIED ASPHALTS—A mixture of asphalt cement and water which contains a small amount of an emulsifying agent.

EVOLUTION OF HEAT—The heat that leaves the concrete as it hardens.

EXPANSION JOINT—Joints installed primarily to relieve compressive stresses by expansion of concrete. They usually consist of some form of nonextruding filler such as wood, asphalt, etc., which will permit horizontal expansion of the concrete.

FINISH COAT—Third coat of plaster used to cover walls and ceilings. Never applied less than 1/8 inch thick.

FLASH SET OR PREMATURE SETTING—Rapid hardening of concrete or mortar.

FLEXURAL STRENGTH—The ability of a concrete slab to resist bending.

FLOAT COAT—The second coat of mortar applied to walls that are to be tiled.

FLOATING METHOD—The process of applying the neat coat of mortar to the surface that is to be tiled.

FLOATING TILE—The process of moving a beating block over the tiled surface to get the tiles back in their proper position after they are beat in.

FRIABLE—Soils that are easily crumbled or pulverized.

GAGE STRIP OR ROD—A wooden stick with the height of each course (including bed joints) marked on it. As the wall is being built the height of each course is checked with the gage strip or rod.

GLAZE—Melted silica or sand used to coat the tile body, giving it a transparent glassy finish.

GLAZED MASONRY UNITS—Masonry units finished with a glasslike coating.

GROUTING—The process of finishing tile joints by filling them with mortar.

HEAD FLASHINGS—Bent metal strips placed over openings in brick walls as moisture barriers. When the metal strips are used at the bottom of openings, they are called sill flashings.

HEAD JOINT—The joint between the ends of two bricks in the same course. It is also called a vertical joint.

HEADER COURSE—A course of brick which have been laid flat with their ends visible.

HONEYCOMBING—An area in the concrete having voids or cavities that are sometimes referred to as rock pockets.

HYDRATION—Reactions between cement and water resulting in setting and hardening.

IMPERVIOUS TILE—A tile that will resist the absorption of moisture.

JOINT—The narrow space existing between adjacent stones, bricks, and other masonry material.

KEEPING THE PERPENDS—The process of keeping vertical joints perpendicular.

114

KING—A brick trimmed for a miter fit at the inside of a corner.

LAMINATED—Formed or arranged in layers.

LAP—The distance one brick extends or projects over another.

LIMESTONE—A rock consisting chiefly of calcium carbonate, usually an accumulation of organic remains, such as shells, that yields lime when burned.

LINE—The string or cord stretched tight from lead to lead as a guide for laying the top edge of a brick course.

LINTELS—Usually strips of steel or precast concrete used to support masonry units over openings.

MASONRY CEMENT—A mixture of portland cement and hydrated lime.

MASONRY UNITS—Units of different shapes and sizes (brick, block, tile, and stone) used with cement mortar to build structures.

MASTIC CEMENT PLASTER—Any of various pasty cements made by boiling tar with lime.

MEMBRANE WATERPROOFING—Layers of roofing felt and hot asphalt used to waterproof surfaces.

METAL LATH—Metal mesh used as a base for the scratch coat of plaster.

MORTARBOARD—A board about 3 feet square used to receive mortar ready for use by the mason.

MOUND SYSTEM—The process of shaping mortar on the back of quarry tiles before setting them.

NEAT COAT—The finish (third) coat of mortar applied to walls that are to be tiled.

NONVITREOUS TILE—A tile that will absorb more than 7 percent of its weight in moisture.

ORGANIC MATTER—Rock or mineral material formed by the activity of plants or animals, or composed of their remains, as coal, chalk, etc.

PIER—Masonry units built up to support arches, beams, girders, and non-load-bearing walls and partitions.

PLASTER—A facing material that is applied to walls and ceilings.

PLASTER METHOD—Referred to setting tile. Applying mortar to the surface being tiled rather than the tile.

PLASTICIZERS—Materials, such as lime, used to make mortar and concrete more workable.

PLUMB BOB—The pointed weight used to make a plumb line taut.

POROSITY—State of being porous.

PORTLAND CEMENT—(Not a brand name but a type of cement.) A finely ground material consisting principally of lime with silica, alumina, and iron oxide capable of hardening into a solid mass.

PRESSED BRICK—Bricks which are pressed in a mold by mechanical power before they are burned.

QUARRY TILE—Generally, a dark reddish tile, very dense, made from natural clays, and used to pave floors.

QUEEN—A half-brick made by cutting a brick lengthwise.

QUOINS—The solid exterior angle or the selected units by which the corner is marked.

RETEMPERED—The act of softening mortar or concrete by remixing and adding water.

RIFFLING—The process of spreading mortar on bricks with the trowel.

ROWLOCK COURSE—A course of brick which have been placed on edge with their ends visible.

RUBBLE—Field or beach stone, or rough stone as it comes from the quarry.

SATURATED SURFACE DRY—Voids in the aggregate are filled with water and the surface is dry.

115

SCALING—The chipping and breaking of the top portion of concrete surfaces.

SCRATCH COAT—The first coat of plaster used to cover walls and ceilings. Usually applied between 3/8 and 5/8 inch thick but in no case less than 1/4 inch thick. Also, the first coat of mortar applied to a surface that is to be tiled.

SCREEDING—The process of striking off the excess concrete to bring a surface to the proper elevation.

SEMIVITREOUS TILE—A tile that will absorb more than 3 percent, but less than 7 percent, of its weight in moisture.

SHALE—A rock capable of being split and formed by the consolidation of clay, mud, or silt.

SILT—Loose sedimentary material (rock particles less than 1/16 millimeter in diameter) suspended in water. Also, a deposit of this sediment.

SODIUM HYDROXIDE—A white, brittle solid used in making soap, rayon, and paper. Also, used for bleaching.

SOLDIER COURSE—A course of brick which have been placed on end with their edges visible.

STORY POLE—A piece of wood with marks on it to indicate where the head or cross joints are located as well as the marked locations and widths of openings in the wall.

STRAIGHTEDGE—A board or tool having a true and straight edge used for leveling and plumbing purposes.

STRETCHER COURSE—A course of brick which have been laid flat with their edges or faces visible.

STUCCO—Plaster applied to the exterior of buildings.

TENSILE STRENGTH—The greatest longitudinal stress a substance can bear without tearing apart.

TIER—One row of brick in a wall.

TILE—The designation for all glazed and unglazed tiles made exclusively from clay, with or without other ceramic materials, and burned in the process of manufacture.

TILE ADHESIVE—A plastic type material used for setting tiles.

TILE TRIM—Refers to various kinds of tile moldings used to give a finished appearance to floors, walls, and other types of work.

TOOLING JOINTS—The process of compacting mortar in the joints between masonry units that leaves structures having a uniform appearance.

TWIG—A tool installed with bricks laid in the middle of a wall between corner leads to hold the line and overcome sag.

VITREOUS TILE—A tile that will absorb less than 3 percent of its weight in moisture.

WOOD LATHS—Strips of wood with rough surfaces, approximately 1½ inches in width, used as a base for the scratch coat of plaster.

WORKABILITY—The consistency of a mix that determines the ease with which a mixture can be placed and worked.

EXAMINATION

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 535-1

MASONRY

CREDIT HOURS ---------------------------2

TEXT ASSIGNMENT ---------------------Review previous text assignments in Memorandum 535.

EXERCISES

1. What type of cement would you use for constructing a footing in an area where the soil contained large amounts of alkali?

a. V c. II

b. IV d. I

2. What type of cement would you use for making repairs on a runway that must be used the following day?

a. I c. IV

b. alumina d. V

3. A pavement was constructed using 5½ gallons of water per sack of type I portland cement. After one week, what is the minimum flexural strength of this pavement?

a. 400 c. 450

b. 425 d. 460

4. You are constructing concrete pavement. What is the maximum slump in inches that you allow?

a. 2 c. 4

b. 3 d. 5

5. What is the minimum mixing time for 1 cubic yard of concrete?

a. 30 seconds c. 90 seconds

b. 1 minute d. 2 minutes

6. You are curing concrete under cold weather conditions. What is the highest temperature of the concrete at the time of mixing?

a. 100° F c. 80° F

b. 90° F d. 70° F

7. If you were placing concrete in exposed work, what is the maximum height in feet from which you would allow it to drop?

a. 3 c. 7

b. 5 d. 9

8. What metal is best to reinforce concrete?

a. iron c. woven wire

b. copper d. steel

9. What should be the maximum capacity in cubic feet of a wheelbarrow

that you would use to transport concrete when the placing level is 13 feet above the mixing level?

a. 5
b. 3
c. 4
d. 2

10. You must construct a high concrete wall. How high a wall in feet would require the use of additional ties between the top and the bottom of the formwork?

a. 6
b. 8
c. 12
d. 14

11. You must construct a brick wall. You have chosen masonry cement instead of portland cement for this job. Why did you choose masonry cement?

a. needs less time for workability
b. hardens quickly
c. gives strong bond between units
d. requires no sand

12. You have mortar that has been mixed at an air temperature of 70°. What is the maximum number of hours that you can wait before using it?

a. 4
b. 3½
c. 2
d. 1

13. For ordinary service, portland cement, compared to masonry cement, has

a. twice as much hydrated lime
b. same amount of lime
c. same amount of sand
d. twice as much sand

14. How many hours does it take the plaster scratch coat to set hard at 70° F?

a. 1 or 2
b. 2 to 3
c. 3 to 4
d. 4 to 5

15. What should be the minimum thickness in inches of the scratch coat of plaster?

a. ¼
b. ⅜
c. ½
d. ⅝

16. You have cut off a 2-inch piece from an end of an 8-inch common brick. What is the remaining portion of the brick called?

a. 6-inch bat
b. 4½-inch bat
c. ¾ bat
d. queen

17. What would you place above an opening in a brick wall to direct the moisture to the outside of the building?

a. coping
b. metal head flashing
c. metal tie
d. metal sill flashing

18. What type of brick would you use to build a structure that required the brick to have a breaking strength up to 20,000 pounds per square inch?

a. kentucky dark gray
b. kentucky red
c. illinois underburned
d. arkansas red

19. You are to build a non-load-bearing brick partition in the mess hall. What type of brick do you use?

a. fire brick
b. face
c. glazed
d. imitation brick

20. Where would you make a rowlock course of brick?

a. on top of a brick wall exposed to weather
b. on steel lintels over wall openings
c. on wooden lintels above windows
d. under window openings in brick buildings

21. Which of the following stones would you select for the facing of a structure?

a. limestone
c. sandstone
b. granite
d. slate

22. You are constructing a stone wall. Where do you place the bond stones (headers) in the wall?

a. in each 3 to 5 square feet
b. every 2 square feet
c. in each 6 to 10 square feet
d. each 8 square feet of foundation

23. Why do some stone walls develop rust stains?

a. oxidation of iron in the stone
b. incorrect mortar used in laying
c. too much mica and feldspar
d. wrong combination of clay and sand

24. How many coats of mortar are used in preparing a wall surface to be tiled?

a. 1
c. 3
b. 2
d. 4

25. Why are tile snapped into place when the floating method is used?

a. to test for imperfect tile
b. to set tile more firmly in plaster base
c. to remove surface impurities on base plaster
d. to expel air from back of tile

26. You have just completed laying a quarry-tile floor. What is the maximum number of hours that you can wait before grouting these tiles?

a. 6
c. 2
b. 3
d. 1

27. When it takes 8 ordinary brick to cover 1 square foot of wall surface, using ¼-inch mortar joints, how many brick do you need to construct a wall 30 feet long, 10 feet high and 12 inches wide?

a. 7200
c. 800
b. 6400
d. 567

28. You measure an area where you will pour a concrete slab, and find it is 674 cubic feet. How many cubic yards of concrete do you need, before allowing for loss or waste?

a. 25
c. 19
b. 20
d. 15

29. How many cubic yards of concrete are required for making a concrete slab 12 feet long, 12 feet wide, and 6 inches thick?

a. 1.5
c. 2.7
b. 2.0
d. 3.2

30. On what does the percentage of tile allowed for breakage depend?

a. distance traveled from source of supply
b. weight of the tile
c. skill of the mason placing the tile
d. size of the individual tile