91

ADVANCED FORMWORK

FOR

PILE DRIVERS

BRIDGE BUILDERS

The Northern California
Pile Drivers
J.A.T.C

NORTHERN CALIFORNIA PILE DRIVERS J. A. T. C.

Pile Driver – Bridge Builder

Course of Instruction

Year	Quarter	Hours	Code	Title
1	1	36	78	Safety, First Aid & C.P.R.
	1	36	79	The Apprentice & The Trade, Math, Methods of Cutting and Burning
	2	36	80	Pile Driving Technologies: Tools, Equipment, Materials, & Rigging
	3	36	81	Concrete & Formwork
	4	36	82	Welding I • Fillet (1F, 2F, 3F, 4F)
2	1	36	83	Pile Driving – Land & Water (Introduction)
	2	36	84	Welding II • Plate (1G, 2G)
	3	36	85	Pile Driving – Land & Water (Advanced)
	4	36	86	Wharfage & Marine Structures
3	1	36	87	Cranes & Welding III • (3G,4G)
	2	36	88	Structural Blueprints & Layout Instruments (Introduction)
	3	36	89	Intro To Modern Bridge Building Methods & Advanced Structural Blueprints
	4	36	90	Falsework & Heavy Timber Framing
4	1	36	91	Advance Formwork & Shoring for Pile Driving & Bridge Building
	2	36	92	Welding IV • 3G & 4G Certification
	3	36	93	Dive Tending & Sub–Sea Technologies
	4	36	94	Welding V • Pipe (2G, 5G, 6G)

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J.A.T.C

By: J. McNamee

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CARPENTERS 46 NORTHERN CALIFORNIA COUNTIES

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(In cooperation with the Northern California Pile Drivers JATC)

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Graphic Design By:
Jim McNamee

Graphics & Typography By:
Daneen Pate, Lenore LaRocca

UNIT 91 – ADVANCED FORMWORK

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CLASS MATERIALS

Pile Driver Apprenticeship Class
NORTHERN CALIFORNIA PILE DRIVERS J.A.T.C.

UNIT 91 – ADVANCED FORMWORK & SHORING FOR PILE DRIVING & BRIDGE BUILDING

The information below details the books, supplies and tools needed to participate in and complete this scheduled apprenticeship class.

➪ YOUR BOOKS & CERTAIN REQUIRED ITEMS MAY BE PURCHASED AT:

Carpenters Apprenticeship Training Center
2350 Santa Rita Rd., Pleasanton, CA
☎ (415) 462–9644

Mondays Only:
8:30 A.M. – 10:30 A.M.

➪ THE FOLLOWING BOOKS ARE REQUIRED TO COMPLETE ASSIGNMENTS:

1. *Supported Beams and Slabs*, American Concrete Institute (ACI), 1989 ($7.50*)

(*Approximate cost of book)

➪ YOU ARE REQUIRED TO BRING THE FOLLOWING TOOLS/SUPPLIES TO CLASS:

*1.	Safety Glasses (OSHA Approved)	11.	Plumb Bob
2.	Hard Hat, Work Boots & Clothes	12.	Carpenter Pencil
3.	Long–Sleeved Shirt	13.	8 point Cross –Cut Saw
4.	Pocket Tape (16 ′ long min.)	14.	24″ – 30″ Stripping Bar
5.	22 oz. Rip Claw Hammer	15.	"Cats Paw" Nail Puller
6.	24″ – 30″ Level	16.	8″ Side–Cutter Pliers
7.	Tri–Square/Combination Square	17.	12″ Adjustable (Crescent) Wrench
8.	Framing Square	18.	Carpenter's Locking Tool Box
9.	Chalk Box w/Chalk	19.	Carpenters Coveralls (bib) and/or...
10.	String Line	20.	Nail Bags w/2 Pouches

(* Available in Training Center Book Store...Monday Mornings only)

➪ WEAR CLOTHING THAT YOU WEAR TO WORK:

For your personal safety : tank tops or sleeveless shirts, shorts or cut–off pants, and soft topped or soft soled shoes are **not** permitted while attending classes. **Safety glasses are required** during all manipulative lessons.

PILE DRIVER - APPRENTICE TOOL LIST*

Minimum of tools required before dispatch as Pile Driver should include:

1. 20 or 22 oz. Straight Claw Hammer
2. Pocket Tape (16' long minimum)
3. 12" Adjustable Wrench
4. 8" Lineman's Pliers (side cutters)
5. Lumber Crayon/Keel/Carpenters Pencil
6. Pair Leather Palm Gloves
7. Rigging belt with appropriate tool holders or pouches similar to the following:
   - Spud Wrench or Wrench Holder
   - Hammer Holder
   - Tape Holder
   - Pliers Keeper
   - Nail Pouch
   - Utility Pouch

Optional tools for dispatch as Pile Driver:

1. Pair Bib Overalls (i.e. Carhartt™ or equal), may replace rigging belt
2. Fold-back Knife - "Buck™ " style, lock back
3. 12" Adjustable spud Wrench, may replace 12" adjustable wrench & bull pin
4. Torch Tip Cleaner
5. Torch Striker
6. Pair Rubber Rain Boots

Minimum of tools required before dispatch as Bridge Builder, Pile Driver/Framer, or Dock-Builder should include:

1. Tool Box
2. 8-Point Crosscut Saw
3. Framing Square
4. 24"-30" Level
5. Pocket Tape (16' long minimum)
6. 22 oz. Framing Hammer
7. 24"-30" Stripping Bar
8. Carpenters Bib Overalls or Carpenters Apron with leather pouch
9. 12" Adjustable Wrench
10. 8" Linemans Pliers (side cutters)
11. Carpenters Pencil
12. Chalk box with White Chalk
13. 100' (minimum) String Line
14. Cat's Paw Nail Puller
15. Combination Square

Optional tools for dispatch as Bridge Builder/Framer:

1. Set of Wood Chisels - ½", ¾", and 1 ½"
2. 100' Tape
3. 3/8" Ratchet-Socket Set
4. Hacksaw
5. Set Screwdrivers
6. Pair Pliers
7. Framing Axe
8. Pea Shooter
9. 5/16" Allen Wrench (for air drill chucks)
10. Slick (if available)
11. Adze (if available)

Minimum of tools required before dispatch as Welder:

1. Welding Hood (to fit Hard Hat) w/#10 Lens
2. Safety Glasses (OSHA Certified)
3. Welding Jacket or Cape Sleeves
4. Welding gloves (All Leather, Long Gauntlet)
5. Chipping Hammer
6. Wire Brush
7. Vice Grips (#11)
8. 12" Adjustable Wrench
9. Burning Goggles w/#5 Lens
10. Torch Striker
11. Torch Tip Cleaner
12. Tape Measure (20' long minimum)

Optional tools for dispatch as Welder:

1. Torch Tip Nips
2. 12" Layout Square
3. Bevel Square
4. Tri-Square or Combination Square
5. 24" Level
6. Torpedo Level
7. Wrap-Around (4" x 48")
8. Chalk Box with White Chalk

Failure on the part of the apprentice to obtain these required tools could result in:

1. A delay in wage re-rates until requirements are met.
2. Possible job termination for failure to supply proper hand tools.

*You are encouraged to purchase one (1) tool a week to spread out the cost. Tools required for specific classes (listed in class notice) are **mandatory** and must be in your possession.

Opeiu-3-afl-cio-211/llr Revised 10/11/11 JMc/rh

Form 139-PD

PILE DRIVERS GRADING AND EVALUATION SCHEDULE

Grading

A uniform weighing system will be used as follows:

1. Class Participation and Attitude **5%**
2. Topic Quizzes **30%**
3. Manipulative Lessons **35%**
4. Final Exam **30%**

Assignment of grades will be as follows:

A = 100% – 92

B = 91 – 81

C = 80 – 73

D = 72 – 68

F = Less than 68%

Assignment of numerical evaluations will be as follows:

0 = Unsatisfactory

1 = Below Average

2 = Average

3 = Above Average

4 = Outstanding

5 = Excellent/Superior

Dot (•) Demerits valued at minus two (–2) points each will be assessed as follows:

17 = Repeating an unexcused class absence

17 = 4+ hours/week missed (+ repeat class)

10 = Unacceptable Brotherhood conduct

2 = Failure to make effort to perform

2 = Disruptive behavior

1 = Every 15 minutes of late arrival

Criteria for Evaluation

5. Safety
6. Accuracy
7. Following Directions
8. Fitting and Fastening
9. Speed
10. Plan Reading
11. Terminology
12. House Keeping

UNIT 91 – ADVANCED FORMWORK FOR PILE DRIVING & BRIDGE BUILDING

SEQUENCE OF INSTRUCTION

BOOKS: The following books will be required to complete this class:

1. ***Supported Beams and Slabs***, American Concrete Institute (ACI), 1989 ($7.50*)

(*Approximate cost of book)

TOOLS: The following tools and/or equipment will be required to complete the class:

*1.	Safety Glasses (OSHA Approved)	11.	Plumb Bob
2.	Hard Hat, Work Boots & Clothes	12.	Carpenter Pencil
3.	Long–Sleeved Shirt	13.	8 point Cross –Cut Saw
4.	Pocket Tape (16 ′ long min.)	14.	24″ – 30″ Stripping Bar
5.	22 oz. Rip Claw Hammer	15.	"Cats Paw" Nail Puller
6.	24″ – 30″ Level	16.	8″ Side–Cutter Pliers
7.	Tri–Square/Combination Square	17.	12″ Adjustable (Crescent) Wrench
8.	Framing Square	18.	Carpenter's Locking Tool Box
9.	Chalk Box w/Chalk	19.	Carpenters Coveralls (bib) and/or...
10.	String Line	20.	Nail Bags w/2 Pouches

(* Available in Training Center Book Store...Monday Mornings Only.)

A/V's: The following presentations will be featured during this weeks class.

None

FIRST DAY (MONDAY) — **Homework to be completed for Tuesday**

TEXT/RESOURCE	ASSIGNMENT
1) 91 – Advanced Formwork (Student Text)	Read Chapters 1 & 2. Complete Study Guides 1 & 2. Be Prepared for Chapter Tests 1 & 2.

8:00 a.m Registration – Orientation , Form A, Rules & Regulations, Student Conduct.
8:15 a.m. Course Objectives.
8:30 a.m. Pre–Test "91" Administer & Correct.
9:00 a.m. Unit 91 – Project Mobilization
10:00 a.m. **UNIT 91 PROJECT**
U. S. Coast Guard Signal Station – a C.I.P. Concrete Marine Structure

12:00 noon LUNCH
12:30 p.m. **Project** (Con't)
4:15 p.m. Clean up and receive study assignments.
4:30 p.m. DISMISSAL

SECOND DAY (TUESDAY)

Homework to be completed for Wednesday

TEXT/RESOURCE	ASSIGNMENT
1) 91 – Advanced Formwork (Student Text)	Read Chapters 3 & 4. Complete Study Guides 3 & 4. Be Prepared for Chapter Tests 3 & 4.

8:00 a.m. Roll Call
8:05 a.m. Review Study Guides Chapters 1, 2.
8:30 a.m. Administer Chapter Tests 1, 2 & correct
9:00 a.m. **Project** (Con't)
12:00 noon LUNCH
12:30 p.m. **Project** (Con't)
4:15 p.m. Clean up and receive study assignments.
4:30 p.m. DISMISSAL

THIRD DAY (WEDNESDAY)

Homework to be completed for Thursday

TEXT/RESOURCE	ASSIGNMENT
1) 91 – Advanced Formwork (Student Text)	Read Chapter 5. Complete Study Guide 5. Be Prepared for Chapter Test 5.

8:00 a.m. Roll Call
8:00 a.m. Review Study Guides Chapters 3, 4.
8:30 a.m. Administer Chapter Tests 3, 4 & correct
9:00 a.m. **Project** (Con't)
12:00 noon LUNCH
12:30 p.m. **Project** (Con't)
4:15 p.m. Clean up and receive study assignments.
4:30 p.m. DISMISSAL

FOURTH DAY (THURSDAY)

Homework to be completed for Friday

TEXT/RESOURCE	ASSIGNMENT
1) Supported Beams and Slabs, (ACI)	Read Chapters 5, 7, 8. Review Appendix A & Appendix B. Review for **Unit 91 – Final Exam**

8:00	a.m.	Roll Call
8:00	a.m.	Review Study Guides Chapter 5.
8:30	a.m.	Administer Chapter Tests 5 & correct
9:00	a.m.	**Project** (Con't)
12:00	noon	LUNCH
12:30	p.m.	**Project** (Con't)
4:15	p.m.	Clean up and receive study assignments.
4:30	p.m.	DISMISSAL

FIFTH DAY (FRIDAY)

No Assignments

8:00	a.m.	Roll Call
8:05	a.m.	E.D.D. Claim Processing
8:30	a.m.	**Project Demobilization**
10:45	a.m.	Review for **Unit 91 – Final Examination**
11:00	a.m.	**Administer Unit 91 – Final Examination**
12:00	noon	DISMISSAL

COURSE OBJECTIVES:

Upon the completion of this Unit, the student should be able to demonstrate knowledge of advanced formwork in correlation to the placement of concrete for more intricate structures. In addition, the student should have developed an ability for efficient problem solving and improvising rapid solutions to formbuilding in an industry that demands high production. Also, the student should have developed an awareness that formwork, in application, is often non–typical or variable from job to job and that a certain amount of ingenuity and creativity needs to be used to get the job done.

SPECIFIC OBJECTIVES:

Upon completion of this Unit the student should be able to:

1. Understand the basic specifications of lumber used in concrete formwork.
2. Understand the basic specifications of form facings used in concrete formwork.
3. Understand the basic hardware and fasteners used in concrete formwork.
4. Know the characteristics of footing, slab, curb, wall, column, beam, and girder forms in concrete construction.
5. Construct and erect typical as well as intricate concrete formwork to acceptable industry standards.

PRE–TEST

This quiz is designed to focus attention on the unit of instruction to be studied during this week. The questions are used as a means of testing for previously gained knowledge and to identify subject matter to be learned.

TRUE OR FALSE: Circle the ***(T)*** or ***(F)*** in front of the numbered statement to indicate that you believe the question to be true (correct) or false (incorrect).

T	F	1.	Form Detailing often involves transferring the mental image of the forms to drawings or sketches so they can be interpreted by the Pile Driver or Bridge Builder to build the forms.
T	F	2.	Form Detailing makes it possible to anticipate problems in constructing, erecting and stripping concrete forms.
T	F	3.	A device called a "batter board" is often used to locate concrete forms accurately on the job site.
T	F	4.	A batter board composed of three (3) stakes, two (2) ledger boards and two (2) anti–sway braces can be used for a building corner.
T	F	5.	Batter boards are placed on the building line.
T	F	6.	String lines are attached to the batter board ledgers to locate the exact building line of the structure.
T	F	7.	Plywood is generally not used for architectural concrete forms.
T	F	8.	Redwood is a good material for architectural form work.
T	F	9.	Mudsills provide bearing and nailing for girders, joists and blocking.
T	F	10.	The type of footing and foundation needed for a structure has little to do with the soil conditions upon which they rest.
T	F	11.	A "slab on grade" concrete construction pour means that the footings, foundation and floor are poured simultaneously (monolithically) rather than poured separately.
T	F	12.	Slab on grade pours always requires an inside form as well as an outside form.
T	F	13.	Detail drawings for the footings and foundation must be in accordance with the plans and specifications.
T	F	14.	In a concrete slab the effect of climate change is controlled by a device called an expansion joint.

T	F	15.	Expansion joint material can be a tarred felt strip as used in sidewalks and concrete floor slabs.
T	F	16.	A cubic yard of concrete contains 27 cubic feet.
T	F	17.	A cubic yard of concrete will form a slab of 85 square feet when placed 4″ thick.
T	F	18.	Plyform is a special plywood manufactured for concrete forms.
T	F	19.	0.037 is one 27th of a cubic yard.
T	F	20.	Concrete is always referred to as being "placed" not "poured."
T	F	21.	The aggregates in concrete tend to separate in a free–fall situation of 6′ or more.
T	F	22.	After adding water to a concrete mix it should be placed within $1–\frac{1}{2}$ hours.
T	F	23.	Concrete columns do not require reinforcing steel.
T	F	24.	Reinforcing steel is usually placed in the wall forms after the erection of the outside form.
T	F	25.	When aligning a wall form, always start at the middle of the wall and work toward each end.
T	F	26.	The line and block method of alignment is used to align wall forms.
T	F	27.	When using a plumb bob to align a wall, care must be exercised to compensate for "Magnetic North."
T	F	28.	Walers are wall alignment devices.
T	F	29.	Walers usually are installed in pairs.
T	F	30.	A single wall form, due to reduced load pressure, will require only half as much bracing as double wall form.
T	F	31.	Forms for beams and girders must be well supported by shores before the concrete is poured.
T	F	32.	A heavy beam that supports other smaller beams which are framed into it is called a girder.
T	F	33.	Tilt–up construction is the erection of pre–cast wall sections to form a building.

T F 34. Tilt–up panels may be joined together by casting concrete columns between them.

T F 35. The first consideration in the design of concrete forms is the load the form structure must support.

T F 36. Exterior plywood is bonded with water–resistant glue.

T F 37. Plywood is used the "strong way" when face grain is parallel to the span.

T F 38. The first step in aligning the outside wall form is to tighten the snap ties.

T F 39. Concrete made with normal–weight aggregates weighs about 150 pounds per cubic foot.

T F 40. In a tied column, the vertical reinforcing bars are tied together with stirrups.

ADVANCED FORMWORK FOR

PILE DRIVERS

BRIDGE BUILDERS

The Northern California
Pile Drivers
J.A.T.C

- ..... Chapter 1 – Formwork Lumber
- ..... Chapter 2 – Formwork Facings
- ..... Chapter 3 – Formwork Hardware and Fasteners
- ..... Chapter 4 – Prefabricated Forms
- ..... Chapter 5 – Building and Erecting Formwork

Chapter 1 – Formwork Lumber

This topic is planned to provide answer to the following questions:

- What are the basic types of lumber used in concrete formwork?
- What are the basic sizes of lumber used in concrete formwork?
- What are some of the specifications of lumber used in concrete formwork?
- What is "Stress Graded" lumber?

LUMBER

Practically all formwork jobs, regardless of the varied or exotic form materials that may be used, require some lumber. Any lumber that is straight and structurally strong and sound may be used for formwork, although the wide distribution and abundance of softwoods make them generally most economical for all types of formwork. The softwoods are usually lighter in weight and are easier to work, though not all species are truly softer than the so–called hardwoods. Hardwood caps and wedges may be introduced where additional strength across grain is needed.

Partially seasoned stock is preferred for formwork, since fully dried lumber swells excessively when it becomes wet, and green timber will dry out and warp during hot weather, causing difficulties of alignment and uneven surface. Old and new boards should not be used together in the same panel if uniform finish is important. Although final choice of wood for forming will depend on the local market, the following brief description of some of the commonly used woods may be of value.

KINDS OF LUMBER

Southern yellow pine and Douglas fir, sometimes called Oregon pine, are widely used in structural concrete forms, and are equally suitable for architectural concrete. They are easily worked and are the strongest in the softwood group. Both hold nails well and are durable. They are used for sheathing, studs, and wales, and Douglas fir is sometimes used for milled wood forms. Douglas fir is appreciably lighter in weight and a little softer than southern pine. Southern yellow pine has moderately large shrinkage, but stays in place well when properly seasoned. The choice between the two should be primarily one of the cost, as the differences between them are generally small.

California redwood is used to some extent for structural concrete forms and is an excellent material for many uses. It is not recommended for architectural concrete work, however, because of its tendency to stain the concrete. Even for studs and wales, redwood is not suitable as the stain may drip onto an exposed surface when the wood is wet.

LUMBER FINISH AND SIZES

Lumber which has been surfaced in a planing machine to attain smoothness of surface and uniformity of size is called "dressed" lumber. The surfacing may be on one side (S1S), two sides (S2S), two edges (S2E), a combination of sides and edges (S1S1E, S1S2E, S2S1E) or on all four sides (S4S). Dressed lumber is generally used for formwork, because it is

easier to handle and work, but rough sawn boards and timbers may be used in bracing and shoring, or as a form surfacing material to secure a special texture effect in the finished concrete.

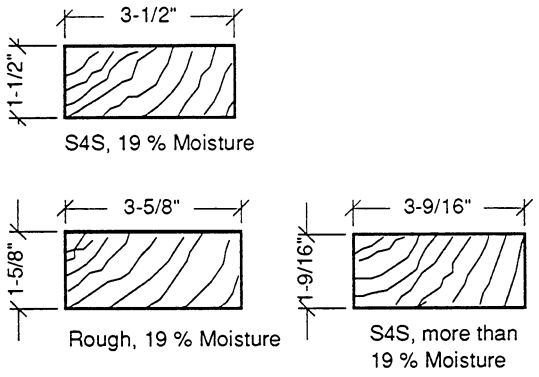


Fig. 1–1 Specified actual size of a 2x4 for different moisture content and finishes

Minimum sizes of both rough and dressed lumber are specified in the American Softwood Lumber Standard, PS 20–70. Lumber is commonly referred to by its nominal size, which at one time was the same as the rough sawn measurements. However, under PS 20–70 adopted in 1970, dimensions were changed in an attempt to equate green and dry lumber (see Fig. 1–1). Minimum sizes for green lumber are selected so that as moisture is lost it becomes the same size as dry lumber. Rough lumber is now generally required to be $^1/_8$ in. thicker and $^1/_8$ in. wider than its finished counterpart.

Fig. 1–2 shows actual dimensions and cross section properties of American Standard lumber at 19 percent moisture content. Actual, not nominal, sizes must always be used for design. Values of Fig. 1–2 can be safely used with either dry or green lumber.

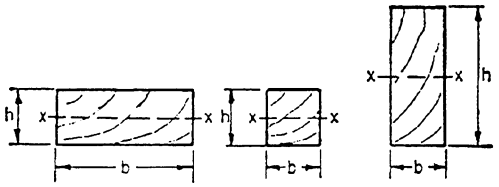
The length of lumber ordered, when this can be specified, should be such that it can be used to the best advantage with little waste. The most common lengths commercially available range up to 20–24 ft. in even–numbered increments of 2 ft. Sheathing can be ordered in random lengths, as it generally has to be cut, and short pieces can be worked in. Joists, studs, posts, beam bottoms, and other members where exact dimensions are required should be ordered in the nearest commercial length which equals or is a multiple of the span or height required. Floor joists, for example, which are to span 5 ft. 6 in. can be ordered in 12 ft. lengths for the least waste . Care in specifying lengths cuts down on the number of short ends that are wasted.

Quantities of lumber are generally spoken of in terms of board feet, or feet board measure, variously abbreviated as bd. ft., ft. bm, or fbm. The board foot is a measure of quantity, *based on nominal dimensions*, equal to 144 cu. in. or a board 1 ft. square and 1 in. thick. These units are used in estimating and paying for formwork lumber.

STRESS GRADING AND WORKING STRESSES

Stress–graded lumber provides material of designated and assured strength so that formwork structures can be designed to safely carry anticipated loads. Detailed requirements which lumber must meet to qualify for a stress grade are published by various manufacturers' associations in conformance with the American Softwood Lumber Standard, PS 20–70. Because of regional differences in grading practices and strength characteristics of different species, the grade

FORMWORK FOR CONCRETE



Based on data supplied by the National Forest Products Association
X — X = neutral axis

Nominal size in inches, $b \times h$	American Standard size in inches, $b \times h$ S4S* 19% maximum moisture	Area of section $A = bh$, sq in.		Moment of inertia, in.⁴ $I = \frac{bh^3}{12}$		Section modulus, in.³ $S = \frac{bh^2}{6}$		Board feet per linear foot of piece	Approximate weight, lb per linear ft, for use in form design†
		Rough	S4S	Rough	S4S	Rough	S4S		
4x1	3½x¾	3.17	2.62	0.20	0.12	0.46	0.33	⅓	0.7
6x1	5½x¾	4.92	4.12	0.31	0.19	0.72	0.52	½	1.1
8x1	7¼x¾	6.45	5.44	0.41	0.25	0.94	0.68	⅔	1.5
10x1	9¼x¾	8.20	6.94	0.52	0.32	1.20	0.87	⅚	1.9
12x1	11¼x¾	9.95	8.44	0.63	0.39	1.45	1.05	1	2.3
4x1¼	3½x1	4.08	3.50	0.43	0.29	0.76	0.58	5/12	1.0
6x1¼	5½x1	6.33	5.50	0.68	0.46	1.19	0.92	⅝	1.5
8x1¼	7¼x1	8.30	7.25	0.87	0.60	1.56	1.21	⅚	2.0
10x1¼	9¼x1	10.55	9.25	1.11	0.77	1.98	1.54	1 5/12	2.6
12x1¼	11¼x1	12.80	11.25	1.35	0.94	2.40	1.87	1¼	3.1
4x1½	3½x1½	4.98	4.37	0.78	0.57	1.14	0.91	½	1.2
6x1½	5½x1½	7.73	6.87	1.22	0.89	1.77	1.43	¾	1.9
8x1½	7¼x1½	10.14	9.06	1.60	1.18	2.32	1.89	1	2.5
10x1½	9¼x1½	12.89	11.56	2.03	1.50	2.95	2.41	1¼	3.2
12x1½	11¼x1½	15.64	14.06	2.46	1.83	3.58	2.93	1½	3.9
4x2	3½x1½	5.89	5.25	1.30	0.98	1.60	1.31	⅔	1.5
6x2	5½x1½	9.14	8.25	2.01	1.55	2.48	2.06	1	2.3
8x2	7¼x1½	11.98	10.87	2.64	2.04	3.25	2.72	1⅓	3.0
10x2	9¼x1½	15.23	13.87	3.35	2.60	4.13	3.47	1⅔	3.9
12x2	11¼x1½	18.48	16.87	4.07	3.16	5.01	4.21	2	4.7
2x4	1½x3½	5.89	5.25	6.45	5.36	3.56	3.06	⅔	1.5
2x6	1½x5½	9.14	8.25	24.10	20.80	8.57	7.56	1	2.3
2x8	1½x7¼	11.98	10.87	54.32	47.63	14.73	13.14	1⅓	3.0
2x10	1½x9¼	15.23	13.87	111.58	98.93	23.80	21.39	1⅔	3.9
2x12	1½x11¼	18.48	16.87	199.31	177.97	35.04	31.64	2	4.7
3x4	2½x3½	9.52	8.75	10.42	8.93	5.75	5.10	1	2.4
3x6	2½x5½	14.77	13.75	38.93	34.66	13.84	12.60	1⅓	3.8
3x8	2½x7¼	19.36	18.12	87.74	79.39	23.80	21.90	2	5.0
3x10	2½x9¼	24.61	23.12	180.24	164.89	38.15	35.65	2½	6.4
3x12	2½x11¼	29.86	28.12	321.96	296.63	56.61	52.73	3	7.8
4x4	3½x3½	13.14	12.25	14.39	12.50	7.91	7.15	1⅓	3.4
4x6	3½x5½	20.39	19.25	55.76	48.53	19.12	17.65	2	5.3
4x8	3½x7¼	26.73	25.38	121.17	111.15	32.86	30.66	2⅔	7.0
4x10	3½x9¼	33.98	32.38	248.91	230.84	53.10	49.91	3⅓	9.0
6x3	5½x2½	14.77	13.75	8.48	7.16	6.46	5.73	1⅓	3.8
6x4	5½x3½	20.39	19.25	22.33	19.65	12.32	11.23	2	5.3
6x6	5½x5½	31.64	30.25	83.43	76.26	29.66	27.73	3	8.4
6x8	5½x7½	42.89	41.25	207.81	193.36	54.51	51.56	4	11.5
8x8	7½x7½	58.14	56.25	281.69	263.67	73.89	70.31	5⅓	15.6

* Rough dry sizes are ⅛ in. larger, both dimensions.
† Based on a unit weight value of 40 lb per cu ft. Actual weights vary depending on species and moisture content. At 15 percent moisture content, the unit weight of coastal region Douglas fir is 34 lb per cu ft, and that of Southern pine ranges between 36 and 44 lb per cu ft. The other species commonly used for formwork in North America weigh less.

Fig. 1–2 Properties of American Standard board, plank, dimension, and timber sizes commonly used for form construction

designation alone is not a sufficient indicator of lumber quality for the user.

The allowable unit stresses for stress–grade lumber and comprehensive recommendations for their engineering application are summarized in the "National Design Specification for Wood Construction." The factor of safety represented in these allowable stresses is about 2½. To be sure that stress grades are obtained, check the lumber for proper grade mark, grade stamp, or certification of quality by a recognized, competent grading and inspection agency.

Because allowable stresses depend on so many factors including the species of wood, grade, size of cross section, moisture content,

and duration of loading, it is impossible to recommend a single set of working stresses for formwork design. Fig. 1–3, showing the range of stresses assigned to several pieces of wood, plus stress values for construction grade and No. 2 lumber 4 in. and less in thickness and in width, gives an idea of the wood strengths available. Values of Fig. 1–3 are stresses recommended for normal duration of loading (continuous throughout 90 percent of the life of the structure) using wood with a moisture content no more than 19 percent (partially seasoned). According to the definitions of PS 20–70, wood with 19 percent or less moisture is *dry*, all other is *green*. For green lumber or lumber wet during use, such as form sheathing, allowable stresses must be decreased as indicated at the bottom of Fig. 1–3. Since wood possesses the ability to absorb large overloads for short periods, adjustments for duration of loading are also provided.

REPRESENTATIVE WORKING STRESS VALUES (PSI) FOR LUMBER AT 19 PERCENT MOISTURE CONTENT, CONTINUING OR PROLONGED REUSE

Derived from National Design Specification for Wood Construction and from recommendations of American Plywood Association

PROPERTIES / SPECIES AND GRADE	Extreme fiber bending †	Compression ⊥ to grain	Compression ∥ to grain	Horizontal shear ‡	Modulus of elasticity
EASTERN SPRUCE					
Range, all grades	200-1785	255	425-1200		1,100,000-1,400,000
No. 2, 4x4 and smaller	1050	255	700	105	1,200,000
Constr., 4x4 and smaller	775	255	800		1,100,000
SOUTHERN PINE					
Range, all grades	275-2600	405-475	575-2000		1,400,000-1,800,000
No. 2, 4x4 and smaller	1250	405	975	135	1,600,000
Constr., 4x4 and smaller	1050	405	1100		1,400,000
DOUGLAS FIR-LARCH					
Range, all grades	275-2450	385-455	600-1850		1,500,000-1,900,000
No. 2, 4x4 and smaller	1450	385	1000	140	1,700,000
Constr., 4x4 and smaller	1050	385	1150		1,500,000
CALIFORNIA REDWOOD					
Range, all grades	225-2300	270-425	500-2150		900,000-1,400,000
No. 2, 4x4 and smaller	1400	425	1100	120	1,250,000
Constr., 4x4 and smaller	825	270	925		900,000
HEM-FIR					
Range, all grades	225-1650	245	500-1300		1,200,000-1,500,000
No. 2, 4x4 and smaller	1150	245	825	110	1,400,000
Constr., 4x4 and smaller	825	245	925		1,200,000
ADJUSTMENT FOR MOISTURE CONTENT GREATER THAN 19 PERCENT: Use percentage shown (also applies to wood used wet)	86 **	67	70	97 §	97 **
INCREASE FOR LOAD DURATION OF 7 DAYS OR LESS, permitted for lumber and plywood	25%	25%	25%	25%	0
PLYWOOD SHEATHING USED WET, Plyform B-B, Class I (Grade stress level S-2)	1545*	(Bearing on face) 210	— —	57†† *	1,500,000§§

† Under appropriate conditions, as described in the text, repetitive-member stresses 15 percent higher may be used for normal duration of load.
‡ Based on Sec. 3.4.4.2 of NDS (Reference 4-3).
§ For redwood use 94 percent; for southern pine use 90 percent.
** For redwood and southern pine, use 80 percent of bending stress, 93 percent of *E*.
†† Value for rolling shear in plane of the plies; check for rolling shear should be made according to formula on p. 6-7
* Includes the experience factor of 1.3 recommended by the American Plywood Association.
§§ May be increased 10 percent if shear deflection is computed separately.

Fig. 1–3 Representative working stress values (psi) for lumber at 19% moisture content

CHAPTER 1 ~ FORMWORK LUMBER

STUDY GUIDE

INSTRUCTIONS: Determine the correct word for each numbered blank in the sentence and write it in the blank space provided.

1. Any lumber that is [1]_____ and structurally strong and sound may be used for formwork, although the wide distribution and abundance of [2]_____ make them generally most [3]_____ for all types of formwork.

2. [4]_____ and [5]_____ boards should not be used together in the same panel if [6]_____ finish is important.

3. Douglas fir is appreciably [7]_____ in weight and a little [8]_____ than southern pine.

4. Lumber which has been [9]_____ in a planing machine to attain [10]_____ of surface and [11]_____ of size is called [12]_____ lumber.

5. Minimum sizes for [13]_____ lumber are selected so that as [14]_____ is lost it becomes the same [15]_____ as dry lumber.

6. The [16]_____ foot is a measure of [17]_____, *based on nominal dimensions,* equal to 144 cu. in. or a board 1 ft. square and 1 in. thick.

7. To be sure that [18]_____ grades are obtained, check the lumber for proper grade [19]_____, grade [20]_____, or certification of [21]_____ by a recognized competent grading and inspection agency.

8. According to the definitions of PS 20–70, wood with [22]_____ percent of less moisture is [23]_____, all other is [24]_____.

NOTES:

Chapter 2 – Formwork Facings

This topic is planned to provide answer to the following questions:

- What are the basic types of plywoods used in concrete formwork?
- What is the basic structure and grades of plywood?
- What are some of the structural specifications of plywood?
- What are some of the alternative facing materials used in concrete formwork?

PLYWOOD

Plywood is widely used as a facing for job built forms and pre–fabricated form panel systems. Relatively large sheets of plywood save labor in form building, and the correspondingly large areas of joint–free concrete reduce the cost of finishing and rubbing exposed surfaces. Improved production standards, along with waterproof glues, have largely overcome the earlier objections that plywood would delaminate when in recurrent or prolonged contact with wet concrete. With proper care and treatment of form surfaces and panel edges, many reuses are possible with plywood sheathing.

CONSTRUCTION

Plywood is a flat panel made of a number of thin sheets of wood. A single sheet in the panel may be referred to as a *ply*, but United States Standards also use the term *layer*. A layer may consist of a single ply or it may be two or more plies laminated together with their grain direction parallel. U.S. plywood is built up of an odd number of layers with the grain of adjacent layers perpendicular. The layers or plies are dried and joined under pressure with glues that make the joints as strong or stronger than the wood itself. Alternating direction of the grain of adjoining layers equalizes strains and thus minimizes shrinkage and warping of the plywood panels. Generally the grain direction of the outer layers is parallel to the long dimension of the panel.

In the United States, commercial and industrial plywood which is used for concrete forms is manufactured from several species of wood, including Douglas fir, western larch and hemlock, redwood, and various species of pine, spruce, fir and cedar. Since 1974, the product standard has also permitted use of maple, birch, beech, and other hardwood species.

Imported hardwood plywoods have recently gained acceptance in the United States for formwork where maximum reuse is desired. Their higher cost is offset to some extent by high strength and durability. For example, birch plywood from Finland may have recommended bending stresses in the range of 2500 to 3500 psi, and a modulus of elasticity 1,800,000 psi or greater (based on effective cross section).

SIZES AVAILABLE

The $^1/_2$, $^5/_8$, and $^3/_4$ in. thicknesses of plywood in 4x8 ft. sheets are most commonly used for formwork, with sheets of $^1/_4$ in. plywood frequently used as form liners. A greater range of thicknesses is obtainable when needed (See Fig. 2–1). In addition to the standard 4x8 ft. sheet, 5 ft. widths, and lengths ranging from 5 to 10 ft. are often

Sanded plywood, net thickness, in.	Minimum number of layers	Effective thickness for shear all grades, using exterior glue	12-in. width, used with face grain parallel to span				12-in. width, used with face grain perpendicular to span				Approximate weight, lb	
			Area for tension and compression (in.²)	Moment of inertia I (in.⁴)	Effective section modulus S (in.³)	Rolling shear constant Ib/Q (in.²)	Area for tension and compression (in.²)	Moment of inertia I (in.⁴)	Effective section modulus S (in.³)	Rolling shear constant Ib/Q (in.²)	4x8-ft sheet	per sq ft
¼	3	0.267	0.996	0.008	0.059	2.010	0.348	0.001	0.009	2.019	26	0.8
⅜	3	0.288	1.307	0.027	0.125	3.088	0.626	0.002	0.023	3.510	35	1.1
½	3	0.425	1.947	0.077	0.236	4.466	1.409	0.009	0.087	3.099	48	1.5
⅝	5	0.550	2.475	0.129	0.339	5.824	1.528	0.027	0.164	3.119	58	1.8
¾	5	0.568	2.884	0.197	0.412	7.121	2.084	0.063	0.285	4.079	70	2.2
⅞	5	0.586	2.942	0.278	0.515	8.182	2.841	0.122	0.470	5.078	83	2.6
1	5	0.817	3.721	0.423	0.664	8.882	3.163	0.185	0.591	7.031	96	3.0
1⅛	5	0.836	3.854	0.548	0.820	9.883	3.180	0.271	0.744	8.428	106	3.3

*Use listed S value in bending calculations, and use I only in deflection calculations. Properties shown, taken from the December 1983 edition of Referene 4-5, can be used for all sanded Group 1 plywoods. If B-B concrete fonn grade of plywood is used, slightly higher values from Reference 4-9 can be used for design.

Fig. 2–1 Effective section properties for plywood (12–in. widths) face piies of different species from inner plies*

available from stock. Some contractors cut the 5 ft. width to $2^1/_2$x10 ft. panels, which are easier for one man to handle than the 4 ft width. Fig. 2–1 shows the weight of 4x8 ft. panels of various thicknesses, as well as the weight per sq. ft. Remember when detailing forms that manufacturing tolerances for length and width of plywood panels are +0.0 and $-^1/_{16}$ in.

TYPES AND GRADES

Construction and industrial plywood is made in two types, *interior* and *exterior*; exterior type is bonded with waterproof glue, and the interior type is bonded with water–resistant glue. Both types may be used for formwork, but the exterior type is preferred where reuse is desired. Within each type, panels are made up of several grades of veneer ranging from A to D (interior) or A to C (exterior) depending on the freedom of the surface from knots and other defects. Grade B–B commonly used for formwork has both faces of B–grade veneer, which is a smoothly sanded solid–surface sheet with repair plugs and small, tight knots permitted.

Plywood grades and types are defined in commercial standards for the manufacture of plywoods established by the U.S. Department of Commerce. These same standards also provide that plywood labeled as concrete form grade shall be edge sealed and mill oiled. Mill oiling does not eliminate the need for oiling or coating on the job, but mill oiled plywood gives better service than that which is job–treated only. Edge sealing provides protection against moisture, which may cause swelling and deterioration of the wood layers even though the glue itself is waterproof. Resealing the edges and tie holes after a number of uses, or sealing freshly cut edges, helps prolong the life of the forms. Some

form coatings now on the market require an unoiled base; if the use of such a coating is planned, it is important to specify unoiled plywood. Various grades of plywood may be found to suit different forming needs, but mill oiling and edge sealing are standard practice only for the grades specifically designated for formwork.

Wherever plywood of known structural properties is required, as is generally the case for formwork, it is a good practice to specify panels carrying the mark of an approved inspection and testing agency, which indicates type and grade, species of veneer, and conformance with applicable standards. If there is any doubt as to quality of plywood purchased, a certification of type and grade may be requested.

OVERLAID PLYWOOD

Overlaid plywood is exterior type (waterproof glue) produced the same as other plywood, but with the addition of resin–impregnated fiber faces permanently fused under heat and pressure on one or both sides. It may be either *high density* or *medium density* as described below. Overlaid plywood is also referred to as plastic coated, but it should be carefully distinguished from plywood which is coated or treated by the user with various plastic compounds.

Translucent or opaque overlays blank out the pattern of grain or knots, and consequently these overlaid plywoods are used where smoothest, grainless surfaces are desirable. Up to 200 reuses in formwork have been reported for high–density form grade overlaid plywood, and decreases requirements for release agent. Some of the high density overlay surfaces may be used untreated, but light application of release agent usually prolongs their service life. Since the exact nature of the overlay may vary from manufacturer to manufacturer, the producer's instructions should be followed with regard to oiling or treating overlaid plywood.

High Density – The surfacing of high density overlaid (HDO) plywood is hard and smooth. The overlay, which may be on one or both sides, consists of a cellulose fiber sheet or sheets having no less than 45 percent phenolic or other resin solids, based on weight of fiber and resin, exclusive of glue.

Medium Density – The resin impregnated facing on one or both surfaces of medium density overlaid (MDO) plywood consists of cellulose–fiber sheet in which not less than 17 to 22 percent by weight of the laminate is a thermostatting phenolic or other type of resin. Medium density overlaid plywood is less resistant to abrasion and water penetration than the HDO. General purpose MDO plywood is not recommended for forms, but good service can be expected from MDO products designed and designated for formwork. Using a release agent suggested by the manufacturer is particularly important with MDO.

Special Overlays – In addition to the resin impregnated overlays defined in PS 1–74, some U.S. manufacturers have produced plywood form panels overlaid with other materials such as formica, epoxy resin, and glass–fiber–reinforced plastics. Probably the most expensive and durable are the panels surfaced on one or both sides with a heat–fused and pressure molded layer of glass–fi-

ber–reinforced plastic, of the order of 0.025 to 0.05 in. thick.

TEXTURED SURFACES

A number of textures such as deep, wide striations or realistic wood grain are available in both interior and exterior type plywood panels. The pattern or design on the plywood is reproduced on the concrete to provide one–way or vari–directional patterns for exposed concrete surfaces. The result is functional as well as decorative; textured surfaces may have a marked reduction in light reflection and glare, important in highway structures. The use of textured form panels also cuts down on the otherwise necessary sack and rub finishing, although it is more difficult to match where patching is required. Standard panels and pre–cut squares can be arranged as desired when the forms are constructed, and designers can originate patterns without expensive special forming. Fewer reuses of textured panels are generally obtained than with conventional surfaces.

STRENGTH PROPERTIES

Working stresses for plywood are based on the strength properties and basic stresses for wood as determined by the U.S. Forest Products Laboratory. Recommended working stresses for plywood form sheathing included in Fig. 1–2 along with working stresses for lumber are for the most commonly used formwork grade of plywood.

Plywood sheathing acts as a beam, but the plies whose grain runs perpendicular to the span contribute little to the bending strength and stiffness of the panel. Fig. 2–1 gives the effective section properties for various thicknesses of plywood for two cases—face plies parallel to span of beam and face plies perpendicular to beam span. For a given thickness of plywood panel, I and S are larger when the face grain is parallel to the span of the beam, and this is referred to as using plywood the "strong way." Conversely, plywood with its face grain perpendicular to beam span is said to be used the "weak way." See Fig. 2–2.

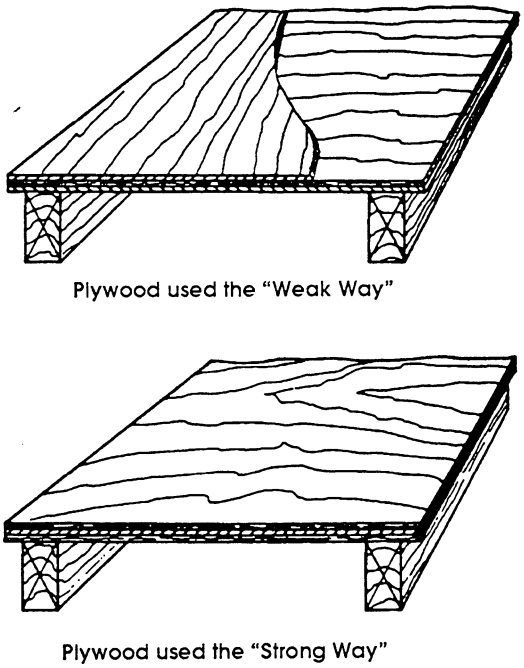


Fig. 2–2 Structural plywood (5–layer) used the "weak way (top) and the "strong way" (bottom).

BENDING PLYWOOD TO CURVED SURFACES

Simple curves with radii not less than 24 in. can readily be made in plywood form sheathing. Fig. 2–3 shows minimum bending

radii for several thicknesses of panel. Note that shorter radius curves can be obtained when plywood is bent across the grain.

These radii apply for mill run panels carefully bent. Select pieces with clear, straight grain can be bent to smaller radii.

Panel thickness, in.	Curved across grain	Curved parallel to grain
¼	24 in.	5 ft
⅜	36 in.	8 ft
½	6 ft	12 ft
⅝	8 ft	16 ft
¾	12 ft	20 ft

* Based on information in Reference 4-8.

*Fig. 2–3 Minimum bending radii for plywood panels bent dry**

Shorter radii than those tabulated may often be developed by wetting and steaming, but this should be done only with exterior type plywood made with waterproof glue. Checking and grain rise may be more prominent with this method.

Best results in bending are obtained when a continuous rounded backing is used, but this may not be required for larger radius curves. In applications where there is abrupt curvature, secure the panel to the shorter radius first. In critical bends, two thin panels often work better than one thick one.

Thick plywood, like solid timber, may also be bent by saw kerfing the inside of the curve. To get a smooth curve the saw cut should not go through the last two plies next to the face. Space kerfs so that at the correct radius the cuts will just close up. The finer the saw, therefore, the narrower will be the space on either side of the cut and the smoother the corresponding curve.

OTHER FRAMING AND FACING MATERIALS

Tempered Hardboard

Hardboard is a board material manufactured from refined or partly refined wood fibers, felted into a panel having a density of more than 30 lb per cu. ft. under controlled combinations of consolidating pressure, heat, and moisture. Both standard and tempered hardboard are produced, but the latter is preferred for formwork. Tempering is the supplemental operation of impregnating the hardboard with materials such as drying oils which are stabilized by baking or other heating after impregnation. Tempered hardboard has improved strength properties, lower rate of water absorption, and improved abrasion resistance.

The special grade of hardboard once manufactured for forming applications is no longer available. Ordinarily tempered hardboard, although capable of producing smooth surfaces, has limited reuse potential. If uncoated hardboard is used for forming purposes, a resin–based parting compound is recommended as a sealer to keep moisture from the concrete out of the board.

Used primarily as a form liner or form facing material, hardboard is not a structural material like plywood and lumber and therefore should be applied to a supporting backing of 4 in. or wider lumber as accompanying details show. Adjoining hardboard sheets should not be tightly butted. To prevent buckling, joints about the width of a dime are usually left between abutting edges.

Sheets 4 ft. wide are available in lengths from 4 to 16 ft., but the 4x8 ft. panel is the common standard size. The 1/4 in. thickness recommended for formwork weighs 1.4 psf. Large sheets cut down the number of seams and thereby reduce finishing costs.

STEEL

Steel has long been an important material for the fabrication of special–purpose forms; all steel panel systems for general building construction have been successfully fabricated and used; and steel framing and bracing are important in the construction of many wood and plywood panel systems. Patented steel pan and dome components for slab forming as well as various stay–in–place steel forms are standard construction items, and horizontal and vertical shores of steel are widely used today.

With reasonable care steel form framing members will last indefinitely and hence to be suitable for many reuses; their selection may be determined on the basis of cost comparisons, or a contractor who has some steel sections on hand may adapt his form design to make use of them. At times steel members do a job that is impossible with other materials; their relatively longer spans make possible considerable saving in materials and labor that would otherwise go into intermediate supports.

Magnesium

Magnesium has found rather limited use for forming concrete, although its lightness, favorable strength–weight ratio, and freedom from rust discoloration suggest that additional formwork applications could be developed if and when relative material costs become more favorable.

Aluminum

Pure aluminum is attacked chemically by wet concrete, but a number of aluminum alloys have proved successful in resisting corrosion both from concrete and from the atmosphere. Use of aluminum for forming and shoring applications has been increasing because higher initial material cost can be offset by reduced handling costs and longer service life. Lighter weight aluminum formwork components produce forming units larger than practical with other materials. For example, welded aluminum basement forms can be made 50 percent wider than conventional framed plywood panels and yet weight about the same. Aluminum truss supports for flying forms make it possible to move 80 ft. lengths of deck form at one time.

Cast aluminum alloy molds are available for making ornamental concrete products and have been used in manufacture of concrete blocks. Cast aluminum wall forms are made with an integral pattern to reproduce brick texture on the finished concrete wall. Tubular aluminum has been used for form bracing, and recently scaffold–type shoring frames of aluminum were introduced. Also available in aluminum are horizontal shoring beams and a pan forming system for slabs.

Glass–Fiber–Reinforced Plastic

Glass–fiber–reinforced plastic forms are popularly described both as plastic forms and fiber glass forms, but neither abbreviated term is completely correct. They are truly a combination of materials, up to about one–third being glass fiber. Such forms have

found increasing use because they are strong and lightweight, capable of producing high quality concrete surfaces, and generally last through numerous reuses. They can be readily fabricated to complex or nonstandard shapes with little capital investment. Form linings of glass fiber reinforced plastic are made in standard and custom profiles serving much the same purpose as the plastic liners discussed later, but frequently good for more reuses.

Glass reinforced plastic is one of the few materials which can be easily molded into shape, yet have a high quality finish. A seamless surface with little limitation of size or shape is possible. Where greater stiffness is required, wood or metal members are added, with layers of the fiber glass reinforced plastic coated over them to hold them in place. Complete encasement of a lightweight core material such as balsa wood results in a sandwich construction of considerable strength suitable for forming warped surfaces.

Fabric Forms

Fabric bags, mats, and tubes have been effectively used as forms under special construction conditions. Burlap sacks, 6 inches in diameter and 24 inches long, are the basis of a stacked–bag type of construction used for one and two–story buildings. The bags are filled with dry concrete mix, then stacked up like block; the wall is reinforced by short bars driven through several layers of sacks. The sacks may be dipped in water before stacking or wet down with a hose after being placed in the wall.

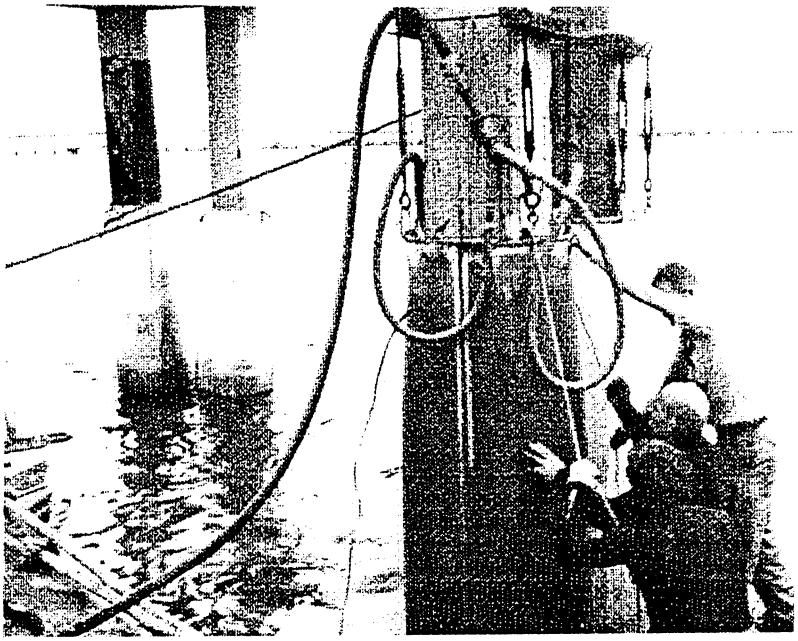


Fig. 2–4 Typical wood pile repair using fabric form to contain pumped–in concrete.

Larger bags of less permeable, synthetic fabrics are pumped full of concrete at the point where they are assembled into dikes, retaining walls, and embankments, cofferdams and other structures. Double–walled fabric mats, pumped full of concrete or mortar, are used for concrete revetments along the shores of lakes and inland waterways. Weep holes for relief of hydrostatic uplift may be incorporated into the fabric during the weaving process, and spaced openings may be provided to allow growth of vegetation. These heavy fabric forms are particularly suited for marine concrete and wood pile repair (see Fig. 2–4) and underwater construction, but also have proved economical for certain dry–land installations. Several aspects of fabric forming, including special weaving of some of the fabrics, are patented.

CHAPTER 2 ~ FORMWORK FACING

STUDY GUIDE

INSTRUCTIONS: Determine the correct word for each numbered blank in the sentence and write it in the blank space provided.

1. U.S. plywood is built up of an [1]_____ number of layers with the [2]_____ of adjacent layers [3]_____.

2. Construction and industrial plywood is made in [4]_____ types, and [5]_____ and [6]_____; exterior type is bonded with [7]_____ glue, and the interior type is bonded with [8]_____ glue.

3. [9]_____ sealing provides protection against [10]_____,which may cause [11]_____ deterioration of the wood layers even though the glue itself is waterproof.

4. Overlaid plywood is also referred to as [12]_____ coated, but it should be carefully distinguished from plywood which is [13]_____ or treated by the user with various [14]_____ compounds.

5. *High Density* – The surfacing of high density overlaid [15]_____ plywood is [15]_____ and [16]_____.

6. The pattern or design on the plywood is reproduced on the [17]_____ to provide one–way or vari–directional [18]_____ for exposed concrete surfaces.

7. Conversely, plywood with its face grain [19]_____ to beam span is said to be used the [20]_____.

8. Best results in [22]_____ are obtained when a continuous rounded [23]_____is used, but this may not be required for larger radius curves.

9. Ordinarily [24]_____ hardboard, although capable of producing [25]_____ surfaces, has limited [26]_____ potential.

10. With reasonable care, [27]_____ steel form framing members will last [28]_____ and hence be suitable for many [29]_____.

11. Use of aluminum for [30]_____ and [31]_____ applications has been increasing because higher initial [32]_____ cost can be offset by reduced [33]_____ costs and longer [34]_____ life.

12. Such forms have found [35]_____ use because they are [36]_____ and lightweight, capable of producing [37]_____ quality concrete surfaces, and generally last through numerous [38]_____.

13. Larger bags of less permeable, [39]_____ synthetic fabrics are pumped full of concrete at the point where they are assembled into [40]_____, [41]_____ and [42]_____, [43]_____ and other [44]_____.

This topic is planned to provide answer to the following questions:

- What are the basic types of hardware and fasteners used in concrete formwork?
- What are the applications of various hardware and fasteners in concrete formwork?
- What are the strength characteristics of various hardware and fasteners?

NAILS

Nails and spikes are the most common mechanical fastening used in construction and wood formwork and bracing, and their proper use contributes much to economy and quality of the work. Forms must be substantial and their component parts held together securely, but the use of too large or too many nails should be avoided. The labor required for fabrication, erection, and stripping of forms will be reduced by holding the number of nails to a safe minimum, and by selecting the best types of nails for differing formwork requirements.

Nails and spikes are available in a wide assortment of lengths, wire diameter (gage), kind of head, and kind of point; shanks may be smooth bright, cement coated, barbed, etched, galvanized, etc. Regardless of these several variables, wire nails and the shorter spikes have become standardized in "penny" (*d*) lengths through usage, while the longer spikes are measured inches. The nominal length is customarily measured from under the head to the tip of the point. Measurements of several types and sizes of nails are shown in Fig. 3–2, and Fig. 3–1 shows the actual size of several 16*d* nails.

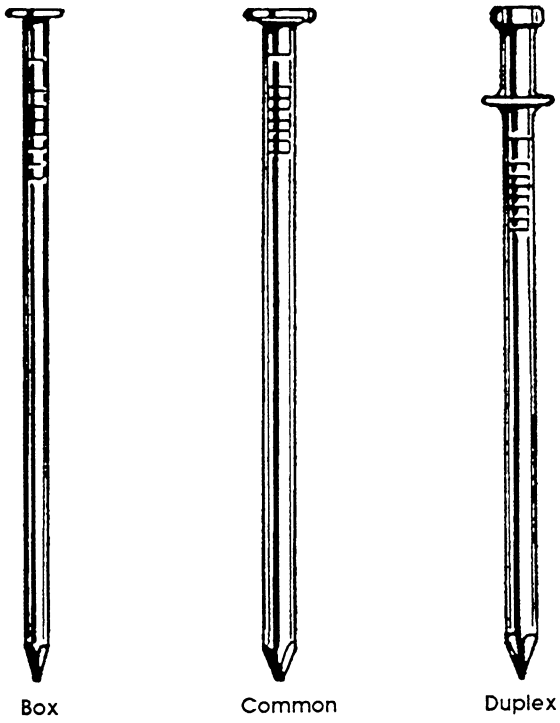


Fig. 3–1 Actual sizes of 16–penny (d) nails

Double Headed and Common Nails

Double headed nails (duplex) are a must for nailing kickers, blocks, braces, and reinforcing for wales—anywhere that that considerable holding power is required, and at the same time nails must be removed readily when forms are stripped. Double headed nails can be pulled easily and quickly with a claw hammer or stripping bar without bruising or otherwise damaging the lumber.

Size	COMMON NAILS Flat head, diamond point				SMOOTH BOX NAILS Large flat head, diamond point				DOUBLE HEAD NAILS Diamond point, double head			
	Length,* in.	Gage No.	Diameter, in. Head	Nail	Length, * in.	Gage No.	Diameter, in. Head	Nail	Length under lower head, in.	Gage No.	Diameter of Head, in.	Distance between heads, in.
2*d*	1	15	0.172	0.072	1	15½	0.188	0.067	–	–	–	–
3*d*	1¼	14	0.203	0.080	1¼	14½	0.219	0.076	–	–	–	–
4*d*	1½	12½	0.250	0.099	1½	14	0.219	0.080	–	–	–	–
5*d*	1¾	12½	0.250	0.099	1¾	14	0.219	0.080	–	–	–	–
6*d*	2	11½	0.266	0.113	2	12½	0.266	0.099	1¾	11½	0.113	0.250
7*d*	2¼	11½	0.266	0.113	2¼	12½	0.266	0.099	–	–	–	–
8*d*	2½	10¼	0.281	0.131	2½	11½	0.297	0.113	2¼	10¼	0.131	0.250
9*d*	2¾	10¼	0.281	0.131	2¾	11½	0.297	0.113	–	–	–	–
10*d*	3	9	0.313	0.148	3	10½	0.313	0.128	2¾	9	0.148	0.313
12*d*	3¼	9	0.313	0.148	3¼	10½	0.313	0.128	–	–	–	–
16*d*	3½	8	0.344	0.162	3½	10	0.344	0.135	3	8	0.162	0.375
20*d*	4	6	0.406	0.192	4	9	0.375	0.148	3½	6	0.192	0.375
30*d*	4½	5	0.438	0.207	4½	9	0.375	0.148	4	5	0.207	0.438
40*d*	5	4	0.469	0.225	5	8	0.406	0.162	–	–	–	–
50*d*	5½	3	0.500	0.244	–	–	–	–	–	–	–	–
60*d*	6	2	0.531	0.263	–	–	–	–	–	–	–	–

* Length from underside of head to tip of point.

Fig. 3-2 Nail sizes and measurements

The size depends on the material to be nailed and the load to be carried. A spike with removable head now available from form hardware manufacturers may be used where loads are heavy.

Common nails are used in assembly of form panels and other components for multiple use, or wherever nails need not be removed in stripping. Their holding power makes them relatively difficult to remove, and their heads leave a more noticeable impression in the concrete than some of the special purpose nails.

Nails for Attaching Sheathing or Liners

For attaching sheathing or lining materials to studs, nails whose heads leave the smallest impression on the finished concrete are generally desired. For built–in–place forms, *box* nails are desirable because the shank is thinner than that of common nails and will pull loose more readily. The size needed depends on the thickness of the sheathing.

For nominal 1 in. sheathing or $^5/_8$ in. and thicker plywood, 6*d* nails are recommended. For panel forms common nails of this size are better because such forms must withstand considerable racking and abuse.

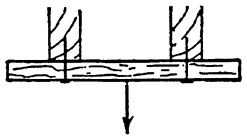
Where fiberboard or thin plywood liners are to be attached over sheathing, small nails with thin flat heads such as 3*d* blue shingle nails are desirable. The heads of these nails leave a very faint impression in the concrete, and the small diameter shank pulls out of the sheathing material easily without pulling the head through the lining material.

HOLDING POWER OF NAILS

The diameter, penetration, surface condition, and metal strength are considerations in determining both the lateral and withdrawal strength of nails and spikes. A further variable is the specific gravity of the species of wood into which the nail or spike is driven.

Nail joints are generally stronger when the nails are driven into the side grain (perpen-

Fig. 3–3 Allowable Withdrawal Loads For Common Nails And Spikes



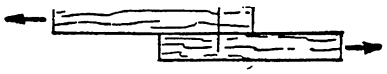
Allowable withdrawal loads, lb per in. of penetration of nail or spike into member receiving the point, for common wire nails and spikes driven into the side grain of various softwoods

Species of wood	SIZE OF NAIL, *d*									SIZE OF SPIKE, *d*										
	6	8	10	12	16	20	30	40	50	60	10	12	16	20	30	40	50	60	5/16"	3/8"
Redwood (open grain)	13	15	17	17	19	22	24	26	28	30	22	22	24	28	28	30	33	33	36	43
Balsam fir and Eastern white pine	14	16	18	18	20	24	25	28	30	32	24	24	25	28	30	32	35	35	38	46
Idaho white pine	16	18	21	21	23	27	29	31	34	37	27	27	29	31	34	37	40	40	44	52
Redwood (close grain); pine: red, ponderosa-sugar; and Hem-Fir	18	21	23	23	25	30	33	35	38	41	30	30	33	35	38	41	45	45	49	59
Eastern spruce	19	22	25	25	27	32	35	38	41	44	32	32	35	38	41	44	47	47	52	63
Lodgepole pine	20	23	26	26	29	34	37	40	43	47	34	34	37	40	43	47	50	50	55	66
Mountain hemlock	24	27	31	31	34	40	43	47	51	55	40	40	43	47	51	55	59	59	65	78
Douglas Fir-Larch	29	34	38	38	42	49	53	58	63	67	49	49	53	58	63	67	73	73	80	96
Southern pine	35	41	46	46	50	59	64	70	76	81	59	59	64	70	76	81	88	89	97	116

* Data reproduced through courtesy of National Forest Products Association.

NOTES: 1. The above values are for nails driven into partially seasoned or wet wood which will remain wet, or dry wood which will remain dry. If the nail or spike is driven into unseasoned wood which will subsequently season under load, the allowable load is ¼ of the tabular value.
2. Nails and spikes should not be loaded in withdrawal from end grain.
3. The allowable withdrawal load for nails in toenailed joints is ⅔ of the tabular value.

Fig. 3–4 Allowable Lateral Loads For Common Nails And Spikes



Allowable lateral loads, lb, for common wire nails and spikes driven into the side grain of various softwoods

Species of wood	SIZE OF NAIL, *d*									SIZE OF SPIKE, *d*										
	6	8	10	12	16	20	30	40	50	60	10	12	16	20	30	40	50	60	5/16"	3/8"
Redwood (open grain) Cedar: western, northern white Fir, balsam Spruce: Engelmann Pine: Eastern white, Western white, Idaho white	41	51	61	61	70	91	102	115	130	146	91	91	102	115	130	146	163	163	188	248
Pine: lodgepole, northern, red, ponderosa, sugar Redwood (close grain) Hemlock: mountain and Eastern Spruce: Eastern and Sitka	51	64	77	77	88	114	127	144	163	182	114	114	127	144	163	182	203	203	235	310
Douglas Fir-Larch Southern pine	63	78	94	94	108	139	155	176	199	223	139	139	155	176	199	223	248	248	288	379

* Data reproduced through courtesy of National Forest Products Association.

NOTES: 1. The above values are based on the assumption that the nail or spike penetrates the piece receiving the point for a distance not less than 14 diameters for species in the first group; not less than 13 diameters for species in the second group; and not less than 11 diameters for species in the third group. When penetration is less than that specified, the allowable load may be determined by straight line interpolation between zero and the tabulated load, except that penetration must not be less than one-third of that specified.
2. The allowable lateral loads for nails or spikes driven into end grain are ⅔ of the tabular values.
3. If the nail or spike is driven into partially seasoned wood that will remain wet, or into dry wood that will be wet in service, the allowable load is 75 percent of the tabular values.
4. If metal side plates are used, the allowable loads can be increased 25 percent.

dicular to the wood fibers) instead of into the end grain of the wood. The joint is also stronger if it uses the lateral resistance rather than direct withdrawal resistance of the nail. Lumber design specifications recommend against loading in direct withdrawal from the side grain of wood, and prohibit loading in direct withdrawal from end grain.

Comparisons of holding power may be made for softwoods with Fig. 3–3 and Fig. 3–4, which show recommended design values for common nailed joints subject to withdrawal and lateral loads, respectively. Values tabulated are for one nail. When more than one nail is used, the load carrying capacity of the joint is the sum of the values of the

individual nails used. These values are for normal loading and are subject to 25 percent increase for short term loading (less than 7 days duration of maximum load).

It is not good practice to place nails in long rows in a tension splice. The end distance and edge distance should be such that objectionable splitting does not occur. No definite distances have been established, but the following may serve as a guide:

- Minimum end distance—13 to 20 times nail diameter, at loaded end;
- Minimum spacing—12 to 15 times nail diameter in direction of load;
- 5 times nail diameter perpendicular to load direction.

Many form designers have observed that in practice nails can carry considerably larger loads than those shown in Fig. 3–3 and 3–4. This is not surprising since substantial factors of safety against deflection or collapse have been provided for in determining allowable loads. The ultimate withdrawal loads are nearly six times the values given in Fig. 3–3.

Toenailing and Clinching

Since withdrawal resistance of nails and spikes driven into end grain is quite low, connections of this type should be avoided. This makes toenailing an important technique for form construction. Toenailing, used in place of end nailing, provides a joint that is equivalent to two–thirds of the allowable withdrawal resistance and five–sixths of the lateral load capacity of nails and spikes driven perpendicular and entirely through the side grain of the wood. Best results are obtained when the toenails are started at one–third the length of the nail from the end of the piece with the nail driven at an angle of approximately 30° to the face of the piece in which it is started.

Because of the need to disassemble formwork readily, clinched joints are frequently not practical, but where feasible, clinching can increase loads carried by the joint by 50 percent or more.

Cement Coated Nails

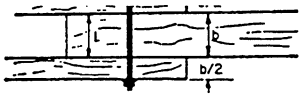
The so–called cement coated nails have some obvious advantages for certain types of formwork construction, since a properly applied coating may double the resistance to withdrawal of nails immediately after they are driven into the softer woods. Different techniques of applying the coating as well as different ingredients in the coating make it impossible to predict the exact improvement in withdrawal resistance. The increase in withdrawal resistance is not permanent but drops off about half after a month or so.

Nails in Plywood

Nailing characteristics of plywood are much the same as those of solid wood, except that plywood's greater resistance to splitting when nails are driven near the edge is a definite advantage. The resistance to withdrawal of nails in plywood is 10 to 30 percent less than that of solid wood of the same thickness, because the fiber distortion is less uniform than in solid wood. Direction of the grain of face ply has little influence on the withdrawal resistance along the end or edge of a piece of plywood.

BOLTS, LAG SCREWS, AND OTHER CONNECTORS

Bolts and lag screws are common joint fasteners for heavier formwork construction, and Fig. 3–5 showing the strength of such joints has been included. For other information on other more specialized connectors such as the split ring and toothed assemblies, refer to technical literature on timber design.



member. For adjustment of load values for other conditions, see p. 4-24

‖ indicates load applied parallel to grain of wood

⊥ indicates load applied perpendicular to grain of wood

Length of bolt in main member, in.	Bolt dia., in.	DOUGLAS FIR-LARCH (Dense) SOUTHERN PINE (Dense)		CALIFORNIA REDWOOD (Close grain), DOUGLAS FIR-LARCH, SOUTHERN PINE SOUTHERN CYPRESS		DOUGLAS FIR, South		EASTERN HEMLOCK-TAMARACK, CALIFORNIA REDWOOD (Open grain), HEM-FIR WESTERN HEMLOCK		MOUNTAIN HEMLOCK, WESTERN CEDARS, NORTHERN PINE		SPRUCE-PINE-FIR, SITKA SPRUCE, YELLOW POPLAR, IDAHO WHITE PINE, EASTERN SPRUCE, LODGEPOLE PINE		RED PINE, WESTERN WHITE PINE, PONDEROSA PINE-SUGAR PINE, EASTERN WHITE PINE, BALSAM FIR, IDAHO WHITE PINE		EASTERN COTTON-WOOD, ENGELMANN SPRUCE-ALPINE FIR, NORTHERN WHITE CEDAR	
		‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain	‖ grain	⊥ grain
1½	½	1100	500	940	430	870	370	800	280	750	300	680	280	630	190	530	210
	⅝	1380	570	1180	490	1090	420	1000	310	930	340	850	320	790	210	660	230
	¾	1660	630	1420	540	1310	470	1200	350	1120	370	1020	350	950	240	800	260
	⅞	1940	700	1660	600	1530	520	1400	380	1310	410	1190	390	1110	260	930	290
	1	2220	760	1890	650	1750	570	1600	420	1490	450	1360	420	1260	290	1060	310
2	½	1370	670	1170	570	1080	500	1040	370	990	400	900	370	840	250	700	280
	⅝	1820	760	1550	650	1440	560	1330	410	1240	450	1130	420	1050	290	890	310
	¾	2210	840	1890	720	1740	630	1600	460	1490	500	1360	470	1260	320	1060	350
	⅞	2580	930	2200	790	2040	690	1870	510	1740	550	1580	520	1480	350	1240	380
	1	2960	1010	2520	870	2330	750	2130	550	1990	600	1810	560	1690	380	1420	420
2½	½	1480	840	1260	720	1170	620	1180	460	1190	500	1080	470	1010	320	840	340
	⅝	2140	950	1820	810	1690	710	1620	520	1550	560	1410	530	1310	360	1100	390
	¾	2710	1060	2310	900	2140	790	1990	580	1870	620	1700	590	1580	400	1330	430
	⅞	3210	1160	2740	990	2530	860	2330	630	2180	690	1980	650	1840	440	1550	480
	1	3680	1270	3150	1080	2910	940	2670	690	2490	750	2260	700	2110	480	1770	520
3	½	1490	1010	1270	860	1180	750	1210	550	1280	590	1160	560	1080	380	910	410
	⅝	2290	1140	1960	970	1810	850	1810	620	1800	670	1640	630	1530	430	1280	470
	¾	3080	1270	2630	1080	2430	940	2340	690	2230	750	2030	700	1890	480	1590	520
	⅞	3770	1390	3220	1190	2980	1040	2790	760	2610	820	2380	780	2210	520	1860	570
	1	4390	1620	3750	1300	3460	1130	3200	830	2990	900	2710	850	2530	570	2120	620
3½	½	1490	1140	1270	980	1180	870	1210	640	1280	690	1160	650	1080	440	910	480
	⅝	2320	1330	1980	1130	1830	990	1890	730	1970	780	1790	740	1670	500	1400	550
	¾	3280	1480	2800	1260	2590	1100	2580	810	2540	870	2310	820	2150	560	1800	610
	⅞	4190	1630	3580	1390	3300	1210	3180	890	3030	960	2760	900	2570	610	2160	670
	1	5000	1770	4270	1520	3950	1320	3710	970	3480	1050	3170	990	2950	670	2480	730
4	½	1490	1180	1270	1010	1180	960	1210	700	1280	790	1160	750	1080	500	910	550
	⅝	2330	1510	1990	1290	1840	1130	1890	830	2000	900	1820	840	1690	570	1420	620
	¾	3340	1690	2850	1440	2630	1260	2690	920	2770	1000	2520	940	2340	630	1970	690
	⅞	4450	1860	3800	1590	3510	1380	3480	1020	3400	1100	3090	1030	2880	700	2420	760
	1	5470	2030	4670	1730	4320	1510	4150	1110	3960	1200	3600	1130	3360	760	2820	830
4½	⅝	2330	1640	1990	1400	1840	1270	1890	930	2000	1010	1810	950	1690	640	1420	700
	¾	3350	1900	2860	1620	2650	1410	2730	1040	2850	1120	2610	1060	2440	710	2050	780
	⅞	4530	2090	3870	1790	3580	1560	3690	1140	3700	1240	3350	1160	3130	790	2630	860
	1	5770	2280	4930	1950	4560	1700	4500	1250	4380	1350	3980	1270	3710	860	3120	940
	1¼	7980	2670	6820	2280	6300	1980	5940	1460	5590	1580	5080	1490	4740	1000	3980	1100
5½	⅝	2330	1650	1990	1410	1840	1380	1900	1010	1990	1190	1810	1110	1690	750	1420	820
	¾	3350	2200	2860	1880	2640	1720	2730	1270	2870	1370	2610	1290	2430	870	2040	950
	⅞	4570	2530	3900	2180	3600	1990	3720	1490	3920	1510	3560	1420	3320	960	2790	1050
	1	5930	2790	5070	2390	4680	2090	4820	1520	4930	1650	4550	1550	4240	1030	3560	1150
	1¼	8940	3200	7640	2790	7060	2430	6840	1780	6730	1930	6110	1820	5700	1230	4780	1340
7½	⅝	2330	1480	1990	1260	1840	1290	1890	950	2000	1150	1820	1090	1690	730	1420	800
	¾	3350	2130	2860	1820	2640	1800	2730	1320	2880	1590	2620	1500	2440	1010	2050	1110
	⅞	4560	2840	3890	2430	3600	2360	3720	1730	3910	2010	3550	1900	3310	1280	2780	1400
	1	5950	3550	5080	3030	4700	2800	4850	2060	5110	2250	4650	2110	4330	1430	3640	1560
	1¼	9310	4450	7950	3800	7350	3310	7580	2430	7990	2630	7260	2480	6770	1670	5680	1830
9½	⅝	3350	1920	2860	1640	2640	1700	2720	1250	2870	1520	2610	1430	2430	970	2040	1060
	¾	4570	2660	3900	2270	3610	2260	3720	1660	3910	2010	3560	1900	3320	1280	2780	1400
	1	5950	3460	5080	2960	4700	2900	4850	2130	5110	2360	4650	2410	4330	1630	3640	1780
	1¼	9300	5210	7950	4450	7340	4140	7570	3040	7980	3330	7250	3140	6750	2120	5680	2320
	1½	13410	6480	11460	5530	10590	4830	10910	3540	11520	3830	10470	3610	9760	2440	8190	2660
11½	⅞	4560	1980	3900	2060	3600	2170	3700	1590	3930	1940	3570	1820	3330	1230	2790	1350
	1	5950	3240	5080	2770	4690	2780	4860	2040	5120	2490	4650	2340	4330	1580	3640	1730
	1¼	9300	5110	7950	4360	7340	4270	7570	3130	7970	3750	7240	3530	6750	2080	5670	2610
	1½	13410	7200	11450	6150	10580	5740	10880	4210	11470	4640	10430	4370	9720	2950	8160	3230
13½	1	5980	2410	5100	2530	4710	2680	4850	1970	5130	2410	4670	2270	4350	1530	3650	1680
	1¼	9300	4890	7950	4160	7340	4130	7590	3030	7990	3680	7270	3460	6770	2340	5690	2560
	1½	13400	7070	11450	6040	10580	5920	10930	4340	11510	5150	10460	4850	9750	3280	8190	3580

* Data reproduced through courtesy of National Forest Products Association.

Fig. 3–5 Allowable Loads (LBS) On One Bolt Loaded At Both Ends For Various Species Of Wood

TIES

A concrete form tie is a tensile unit adapted to holding concrete forms secure against the lateral pressure of unhardened concrete. Twisted wire and band iron were once the chief tying materials, but because of low strength and the labor of assembly and installation, they are today considered

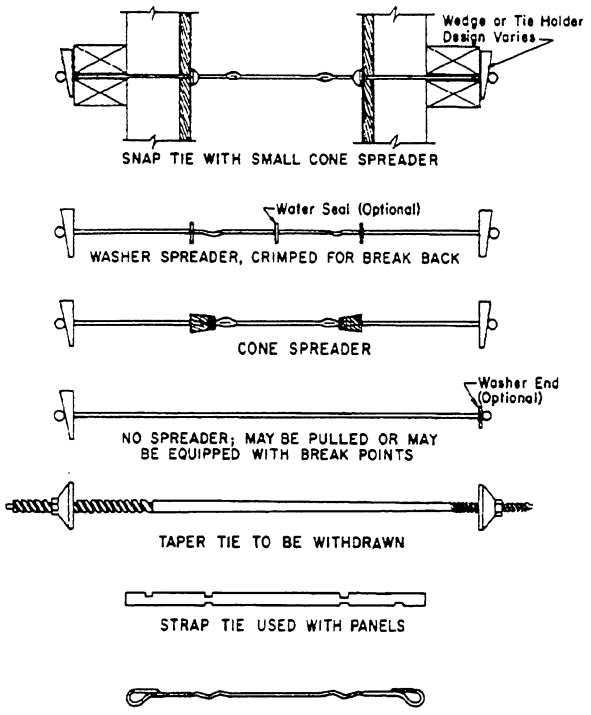


Fig. 3–6 Some commonly available single member ties

acceptable only for the simplest structure. A wide variety of ready–made ties with safe load ratings ranging from 1000 lb. to more than 50,00 lb. have gained general acceptance. They consist of an internal tension unit and an external holding device, and are manufactured in two basic types:

Continuous single member, in which the retaining unit is a single piece, and a specially designed holding device is added for engaging the tensile unit against the exterior of the form. These ties may be rod, band, channel, or angle in cross section, and may be cut to length on the job or completely pre–fabricated (see Fig. 3–6, Fig. 3–7).

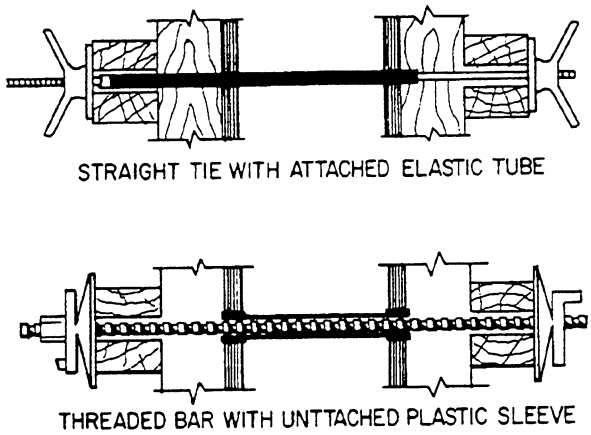


Fig. 3–7 Other single member ties w/sleeves to prevent bonding to concrete

Internal disconnecting type, in which the retaining unit has an inner part with threaded connections to removable external members which make up the rest of the tensile unit and have suitable devices for holding the external against the outside of the form (see Fig. 3–8).

These two types of tying devices are identified commercially by various descriptive names, such as form clamps, snap ties, he bolts, she bolts, wedge clamps, coil ties, and rod clamps. Except for taper ties, the continuous single member type is generally used for lighter loads, ranging up to about 5000 lb. safe load. The internal disconnect-

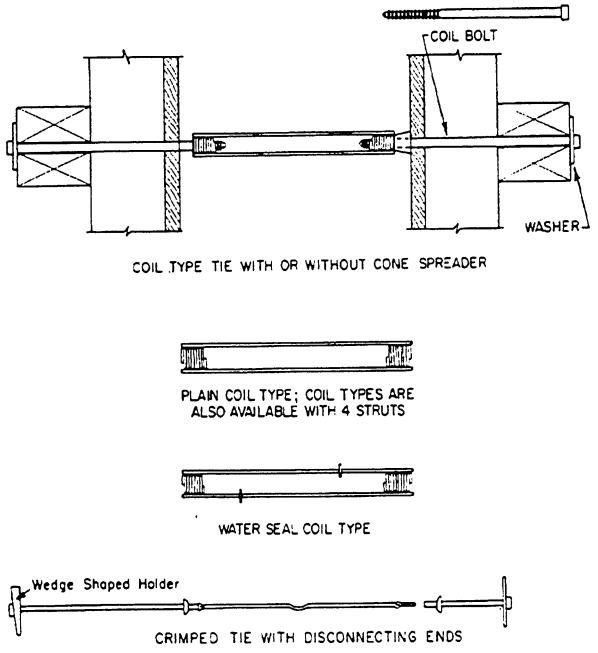


Fig. 3–8 Some common types of internal disconnecting ties

ing type of tie is available for light or medium loads but finds its greatest application under heavier construction loads (up to 70,000 lb.).

ACI Committee 346 now recommends that ties have a safety factor of 2 for all architectural concrete, for all formwork over 8 ft. in height, and for any conditions hazardous to life. For light formwork 8 ft. or less in height, where there is no danger to life, a safety factor of 1.5 may be used.

Effect of Tie on Finished Concrete Surface

Wherever the concrete surface is to be visible and appearance is important, the proper type of form tie or hanger which will not leave exposed metal at the concrete surface is essential. Architectural concrete specifications often require that no metal be left closer than $1^1/_2$ in. to the surface of the concrete. This requirement can generally be met with either type of tie. However, with the so–called snap tie there is the possibility that break–off will not occur at the specified depth in spite of the weakened tie section.

Where spreader ties are used for exposed work, the spreading device should be of a type that can easily be removed with a minimum of damage to the concrete and that leaves the smallest practicable hole for filling. Spreader cones of wood, plastic, or metal leave a uniform hole for patching. Plugs designed to fill tie cone holes are also available and can be color matched to the existing concrete finish (see Fig. 3–9). Some plastic spreader cones used with snap ties also permit breaking ties before the forms are stripped.

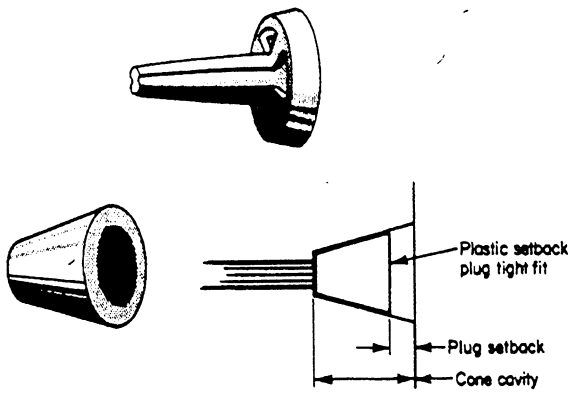


Fig. 3–9 Typical tie cone hole plugs

A good patch over the tie end, well bonded to adjacent concrete, is essential. If any moisture gets to the tie end, rust stains will

gradually appear on the surface of the concrete. Greater depth of breakback or threaded ends of internally disconnected tie units allow a better chance of bonding the patch which covers the tie, and also a greater factor of safety in case of spalling of the patch.

ANCHORS

Form anchors are devices used to secure formwork to previously placed concrete of

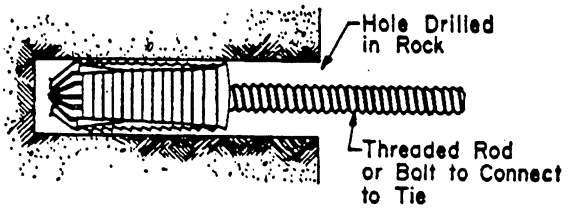


Fig. 3–10 One of several available concrete anchor types

adequate strength; they are normally embedded in concrete during placement. Anchors are also used to support forms by off–rock tying. There are two basic parts: the embedded anchoring device, whose design varies with the load to be carried and the strength of concrete in the structure; and the bolt or other external fastener which is removed after use, leaving a set back hole for grout patching (see Fig. 3–10, Fig. 3–11).

ACI Committee 347 recommends a safety factor of 2 or 3 form anchors, depending on job conditions under which they are to be used. Ultimate strength of anchoring devices in shear and tension is frequently given by manufacturers in sales literature, but their actual *holding power*, depends on the strength of the concrete in which they are embedded, the area of contact between concrete and anchor, and the depth of embedment.

Many form anchors are set in the relatively low strength concrete used for massive structures, and development of holding power may be limiting factor in early reuse of the cantilever forms which the anchors must support. Some manufacturers' strength data for their anchorage products are based on tests in actual concrete specimens at various low strength levels. Using data of this sort, and with estimated compressive strength of the concrete mix at early ages (3–7 days) tentative selections of anchoring devices needed for a given job can be made. Specific

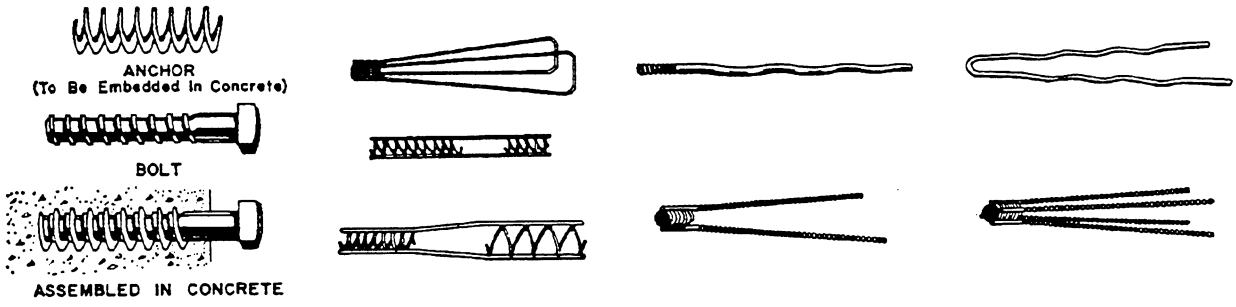


Fig. 3–11 Bolt type anchors can be used with a variety of embedments

selections for any large job should be field tested under actual summer and winter working conditions.

HANGERS

There are a number of ready–made devices for hanging forms from steel or precast concrete structural members; such as forming may be for the fireproofing required for the steel members, or for construction of a slab composite with beam framing.

A number of different designs are available in ready–made hangers (see Fig. 3–12). External holding devices are similar to those used for the rods. ACI Committee 3476 recommends a safety factor of 2 for these hanger assemblies. When checking manufacturers' safe load ratings note carefully whether suggested working load is given on a per leg basis or as the total capacity of the hanger. Also, remember that the two–sided hangers must be loaded equally on both sides of the supporting beam, or the hanger will not stay in the correct position.

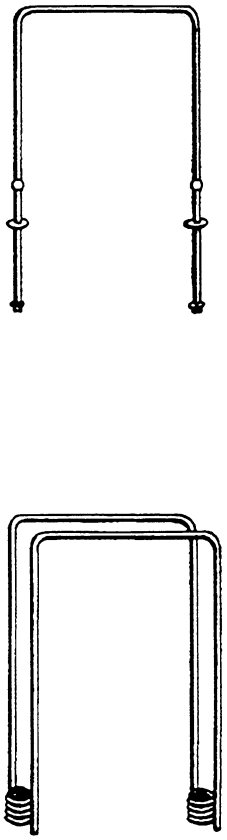


Fig. 3–12 A few of the many styles of form hangers available

COLUMN CLAMPS

Column clamps or yokes encircle column forms and hold them together securely, withstanding the lateral pressure of the freshly placed concrete. Individual parts of the column clamp may be loaded in bending or tension or a combination of the two, depending on details of assembly. Several designs are available in ready–made reusable column clamps that are adjustable to a range of column cross section dimensions. Certain clamping devices such as some of those shown in Fig. 3–13 are best adapted to shorter columns of small cross sections, while other heavier devices are suited to larger cross sections and the greater loads that may be imposed in concreting taller columns.

Fig. 3–13 shows a hinged bar column clamp typical of the heavier ones produced by several manufacturers. Two hinged units making up each clamp have all fastening hardware permanently attached; the two parts are laid in place around the column, lock castings are slid together, and the wedge is dropped into the proper slot and tightened with a hammer. Where column forms are tight in tight quarters , a single bar type, made

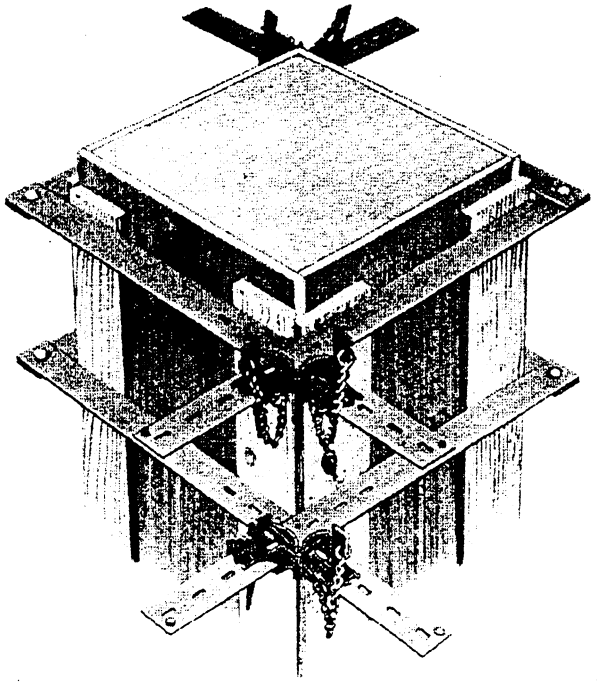


Fig. 3–13 Hinged bar column clamp typical of the heavier clamps

up of four straight members with attached hardware is used.

Clamps are the type shown in Fig. 3–13, or the single bar variation thereof, are available for column sides ranging from about 8 in. to 8 ft. The longer clamps have a thickened cross section at midspan or are reinforced with attached channels.

CHAPTER 3 ~ FORMWORK HARDWARE AND FASTENERS
STUDY GUIDE

INSTRUCTIONS: Determine the correct word for each numbered blank in the sentence and write it in the blank space provided.

1. Regardless of these several variables, wire [1]_____ and the shorter [2]_____ have become standardized in [3]_____ (*d*) lengths through usage, while the longer spikes are measured in [4]_____.

2. For built–in place forms, [5]_____ nails are desirable because the [6]_____ is thinner than that of [7]_____ nails and will pull loose more readily.

3. Nailed joints are generally [8]_____ when the nails are driven into the [9]_____ grain (perpendicular to the wood fibers) instead of into the [10]_____ grain of the wood.

4. Toenailing, used in place of end nailing, provides a joint that is equivalent to [11]_____ of the allowable withdrawal resistance and [12]_____ of the lateral load capacity of nails and spikes driven [13]_____ and entirely through the [14]_____ grain of the wood.

5. Twisted [15]_____ and [16]_____ iron were once the chief [17]_____ materials, but because of low strength and the labor assembly and installation, they are today considered acceptable only for the [18]_____ structures.

6. These [19]_____ types of tying devices identified commercially by various descriptive names, such as form clamps, [20]_____, he bolts, she bolts, wedge clamps, [21]_____, and rod clamps.

7. However, with the so–called [22]_____ there is the possibility that break–off will not occur at the specified [23]_____ in spite of the [24]_____ tie section.

8. There are [25] _____ basic parts: the [26]_____ anchoring device, whose design varies with the load to be carried and the strength of concrete in the structure; and the [27]_____ or other external fastener which is removed after use, leaving a set back [28]_____ for grout patching.

9. Column [29]_____ or yokes encircle column [30]_____ and hold them together securely, withstanding the [31]_____ pressure of the freshly placed concrete.

Chapter 4 – Prefabricated Forms

This topic is planned to provide answer to the following questions:

- What are the basic types of prefabricated forms used in concrete formwork?
- What are some applications of various prefabricated forms?
- What are some types of custom–made forms used in concrete formwork?

PREFABRICATED FORMS

Prefabricated forms and forming systems have become increasingly important to the contractor as a means of saving both materials and labor cost through the efficiency of mass production. Their flexibility in financing offers attractions to some contractors; the forms may be purchased outright, rented, or sometimes rented with an option to purchase. Manufacturers of the forming systems frequently provide engineering layouts at no additional cost or for a nominal charge. Supervision for erecting the forms may also be provided.

Prefabricated forms are most advantageous where numerous reuses are expected, and they are generally built with added durability to meet this anticipated reuse. However, there are some prefabricated forms such as the fiber tubes and void forms intended for a single use, which are destroyed or lost in construction.

Other prefabricated forms are built to stay in place as part of the finished structure.

Prefabricated forms may be considered in two groups:

1. *Ready–made forms.* This includes the modular panel systems that are made in relatively small, easily handled units that can be adapted to forming different structural members. Standardized forms suitable for only one kind of structural member, such as column forms or pans for concrete joist construction, are also part of this group.

2. *Custom–made forms.* This group includes special purpose forms built to order, such as tunnel forms, cantilever forms for dams, special forms for bridges, and many others. Although these forms may be made for a single job, they are often reused many times on that job.

PANEL FORMS AND FORMING SYSTEMS

Prefabricated panel forms are generally manufactured in modular sizes, with 2– and 4–ft. widths being the most common in heights ranging from 2 to 8 ft. Smaller filler and corner units are of varying sizes. Hardware and ties supplied with form panels vary with the different manufacturers. Ties are similar to those already described (Chapter 3), but are frequently fastened against the panel frame eliminating wales in low lift construction. Specialized patented hardware is a major component of many of the panel systems.

Although the many panel forming systems on the market today vary widely in details, there are four basic types:

1. *Unframed plywood panels,* sometimes backed by steel braces as shown in Fig. 4–1. Locking and tying hardware

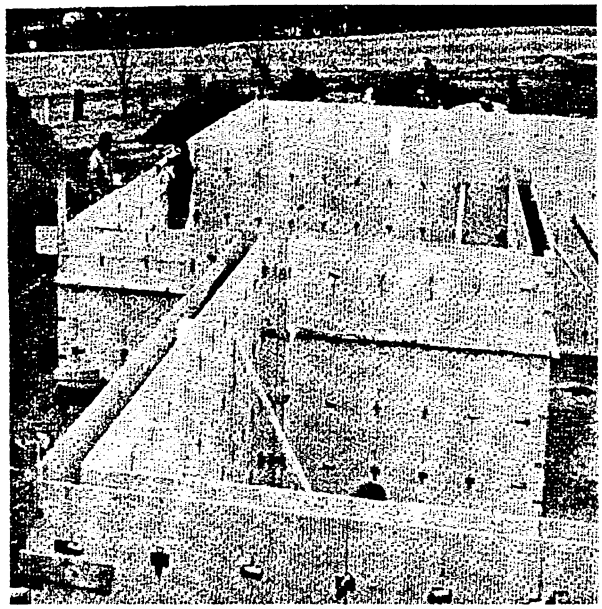


Fig. 4–1 Predrilled, unframed plywood panels

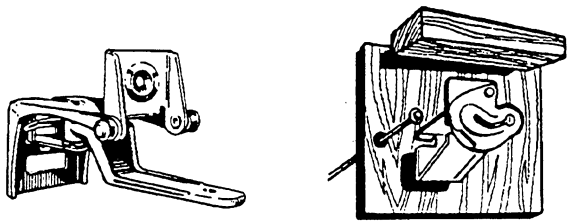


Fig. 4–2 Patented wall forming system bracket and tie

are the essential parts of the system, and the lock which holds ties frequently is part of the waler support (Fig. 4–2).

2. *All–metal panels*, metal plates supported by a metal frame. Available in both steel (Fig. 4–3) and aluminum.

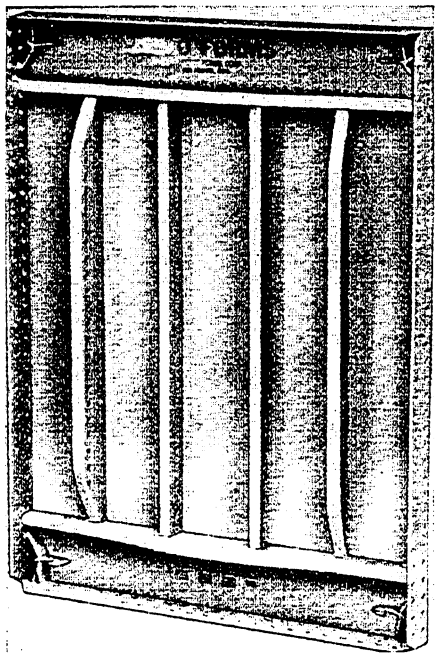


Fig. 4–3 All–metal panel form

3. *Plywood panels set in metal frame*, with or without metal bracing on the back (Fig. 4–4). Usually light enough to be set by manual labor.

4. *Heavier steel–framed panels*, suitable for greater pressures, faced with either wood or plywood sheathing. Suitable for greater loads, planned for crane handling, and often ganged together into larger units.

Although the panel systems were developed primarily for wall forming, many of them are adaptable to slab and column forming, and smaller ones have been successfully used in forming beams. The user should read carefully the manufacturers' data on these forms and select a system that is suited to his own job conditions. Some are obviously for light construction, while other form panels

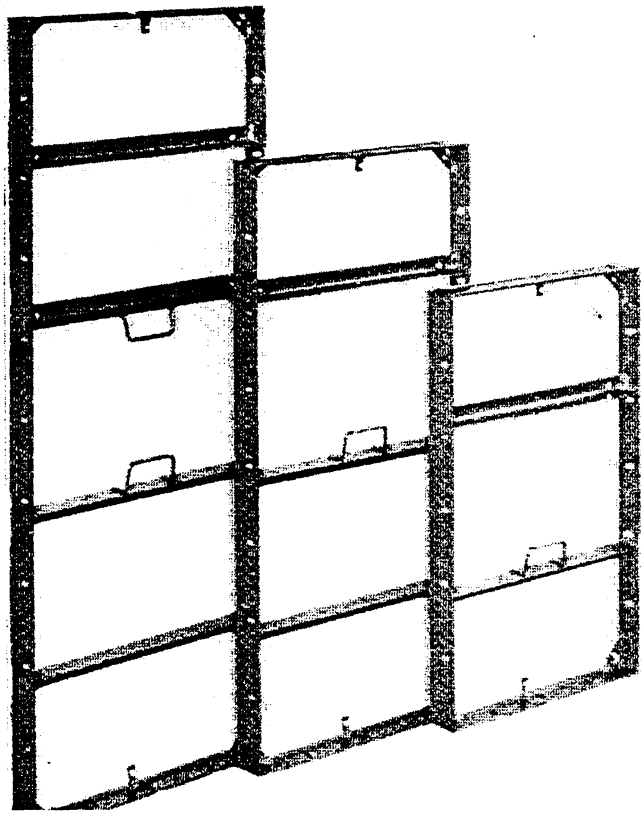


Fig. 4–4 Metal framed plywood panels

are so sturdy that they can be adapted for a variety of forming needs.

Prefabricated panels for Types 1 and 3 are most often used for general and light construction where walls range in height from 2 to 24 ft., with particular emphasis on walls ranging from 4 to 10 ft. "Prefab" forms are less frequently used on complicated walls such as curved or battered ones with corbels, but interesting applications for such jobs have been developed (Fig. 4–5 and Fig. 4–6).

On large jobs where cranes can work to advantage in handling forms, panel forms are "ganged," that is joined together with special hardware provided by the form manufacturer, to form a relatively large wall section. A crane erects, strips, and then moves this large unit to another location for reuse. This is advantageous for high walls where much labor is saved since it is a closed–cell material it does not absorb water during storage or concreting. The material does not

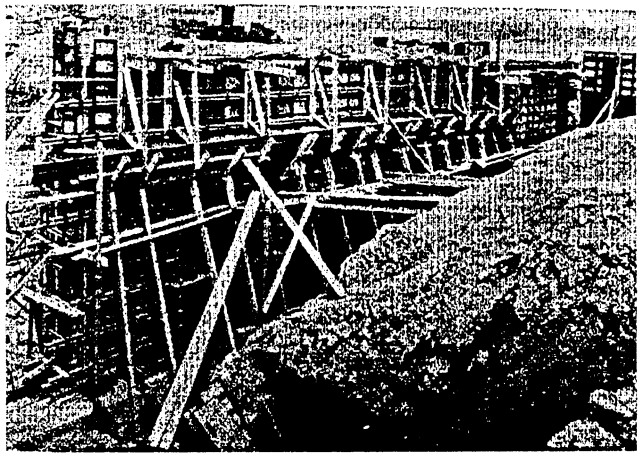
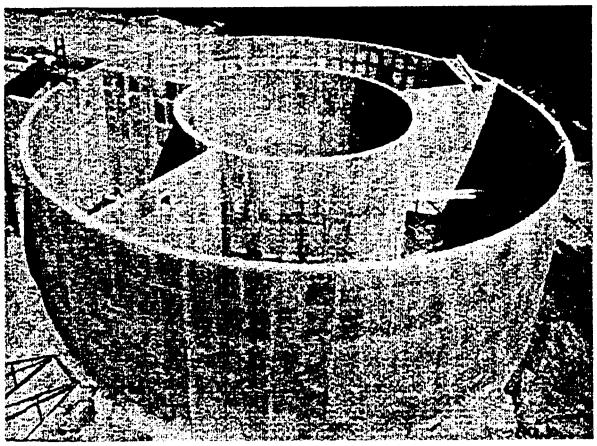


Fig. 4–6 Newly stripped 50–ft. diameter sewage treatment tank built with prefab forms

Fig. 4–5 Prefabricated forms used for 22–ft. bulkhead wall. (Note: walers and heavy bracing).



rot or decay, and can remain in the cavities. If it is necessary to leave the cavities hollow, the polystyrene can be burned out, dissolved with a solvent, or cut out.

COLUMN FORMS

Standard forms for round columns are available in both fiber and metal as complete units with no extra fastenings. The fiber tubes are single use items and require only a minimum of external bracing to keep them plumb. Also available are one–piece glass fiber reinforced plastic round column forms which bolt or clamp along a single joint. They are flexible enough to be sprung off the column after the concrete has hardened. Diameters range from 12 to 36 in.

The tubular fiber column form shown in Fig. 4–7 is available for columns ranging from 6 to 48 inches in diameter. Standard lengths available are 12 and 18 ft., but greater lengths may be ordered. One manufacturer reports that such forms have been successfully used for continuous placement of columns 40 ft. high. Fiber forms can be cut by saw to the exact length desired, and cut sections can be adapted to forming half–round, quarter–round, and obround columns and pilasters. They are also suitable for encasing steel pipe and other members with concrete. Where the form cannot be slipped over existing piling, piers, or posts that are to be encased, a special double walled version which can be cut for installation is suggested.

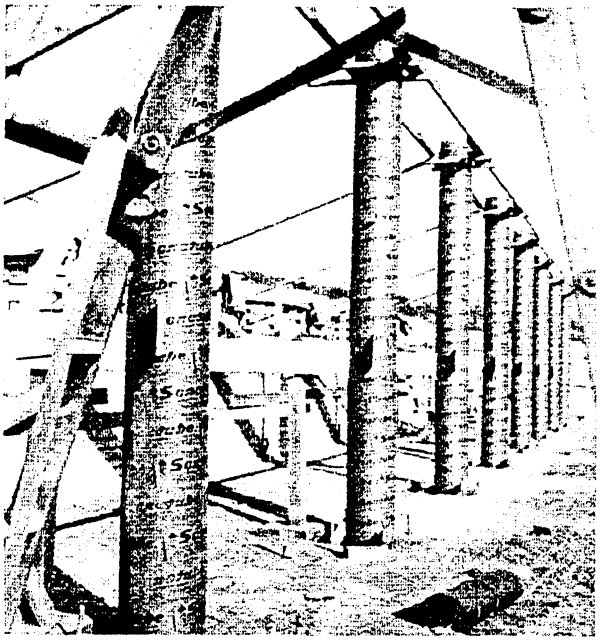


Fig. 4–7 Fiber tube column forms

The laminated fiber piles are spirally constructed and are available with was–impregnated inner and outer surface for weather and moisture protection. Where the columns are to be exposed, the inner surface is coated with polyethylene. If the appearance of the columns is critical, a so–called seamless type is available in which fiber piles nearest the inner surface are deckled or scarfed and overlapped to minimize the spiral gaps or seams on the column surface.

No clamps or ties are needed and no form oil is required; since there is no reuse, there is no cleanup. If these forms are left in place, they aid proper hydration of concrete without additional curing procedures. However, it is advisable to strip before placing any critical loads on the columns, in order to detect any voids which may have formed during placement, which would weaken the member.

The fiber tube form can be stripped by making two vertical cuts with a power saw and pulling the form off; or by making a vertical 12 in. cut in the tube with a linoleum

knife, then peeling spirally, using a broad bladed tool. With either method, care must be taken to prevent marring the column surface.

Adjustable steel forms for column capitals are made for use with these fiber forms. They are similar to the capital portion of the all–steel column forms and are generally a rental item.

Ready–made steel column forms for architectural prismatic columns, are assembled in sections, with necessary hardware being provided with the form. Bracing is built into the form so that no column clamps are required, and external bracing is needed only to keep the forms plumb during concreting. The capital is a standard part of the form, and can be adjusted to different depths and diameters. These forms are manufactured in diameters ranging from 14 in. to 10 ft., with vertical panels 1 to 10 ft. high. Some have an access ladder built into the form.

SPECIAL PURPOSE AND CUSTOM–MADE FORMS

A number of companies in the United States specialize in building forms for use by the contractor; such forms are built to order for special structures or special construction conditions where ready–made form components or job–built forms are not satisfactory. In many cases it is to the advantage of the contractor to get the service of these experts who not only design the form but may fabricate it in materials not easily handled by the contractor on the job or in his shop.

Due to the high cost of field labor, increasing use of custom forms has been noted in recent years. It is often economical to have a form custom built even though it may be used only four to six times. Although economy is a prime reason for using custom forms, dimensional integrity, speed, and safety are also important considerations.

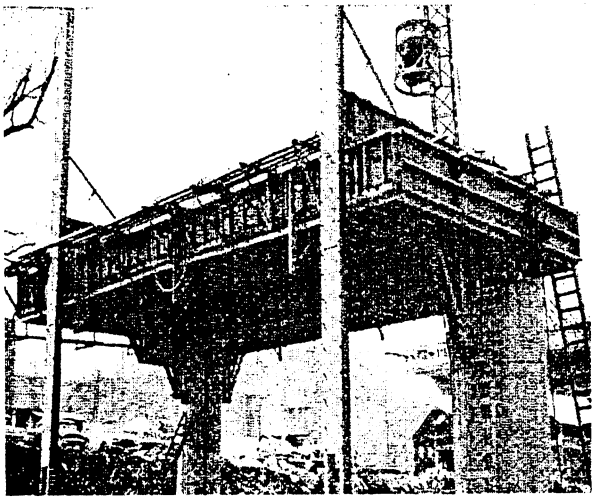


Fig. 4–8 This massive steel pier cap weighing 30 tons used custom–made forms

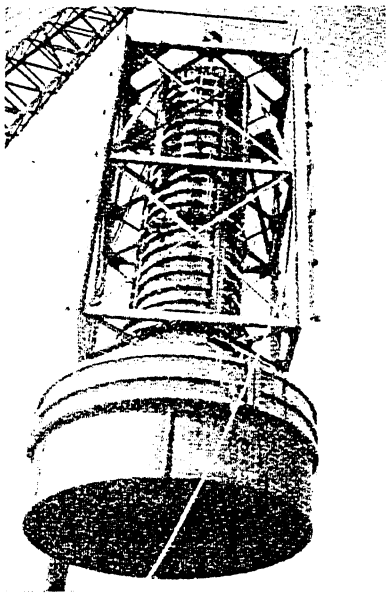


Fig. 4–9 Bottom structure and supporting frame structure for a custom–made watertight column caisson form

Various firms specialize in different types of formwork such as that needed for underground structures, mass concrete, bridge work, or architectural ornament. Many of these forms are for specialized construction techniques or are made of special materials and are shown here in Fig. 4–8 and Fig. 4–9.

HORIZONTAL SHORING

Adjustable beam, truss, or beam and truss combination members which support formwork over a clear span and eliminate intermediate vertical supports are referred to as *horizontal shoring*. Fixed length metal support beams (either I– or box–type) which span lengths of about 2 to 8 ft., replacing timber ledgers, are sometimes included in this category too. *Telescoping horizontal shores* are made up of lattice, plate, or box members, or a combination of these (see Fig. 4–10). Units support forms for spans of 6 to 30 ft., and have built–in adjustable camber. Allowable loads range up to about 600 lb. per lineal ft., depending on span. *Heavy duty horizontal shores*, of which perhaps the ultimate forms are trusses supporting flying form panels, carry loads ranging up to 1000 lb. per lineal ft. on spans as great as 70 or 80 ft.

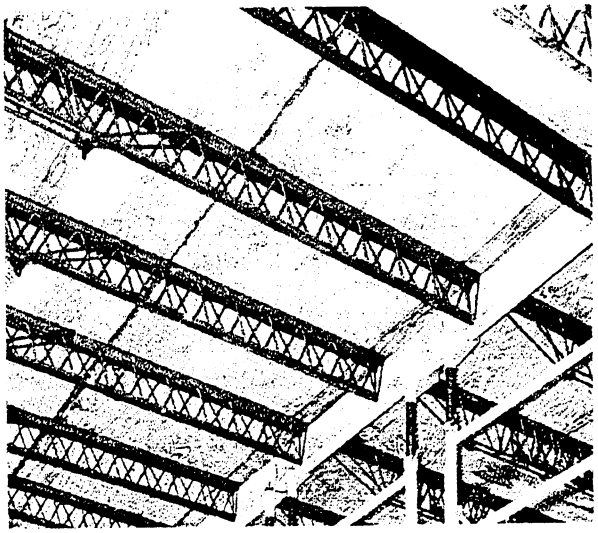


Fig. 4–10 Typical telescoping lattice–type horizontal shoring

CHAPTER 4 ~ PREFABRICATED FORMS

STUDY GUIDE

INSTRUCTIONS: Determine the correct word for each numbered blank in the sentence and write it in the blank space provided.

1. However, there are some [1]_____ forms such as the [2]_____ tubes and [3]_____ forms intended for a single use, which are [4]_____ or lost in construction.

2. Although these forms may be made for a [5]_____ job, they are often [6]_____ many times on that job.

3. On large jobs, where [7]_____ can work to advantage in handling forms, panel forms are [8]_____, that is joined together with special [9]_____ provided by the form manufacturer, to form a relatively large [10]_____ section.

4. If the [11]_____ of the columns is critical, a so–called [12]_____ type is available in which fiber piles nearest the inner surface are deckled or scarfed and overlapped to minimize the [13]_____ gaps or [14]_____ on the column surface.

5. Due to the high cost of field [15]_____, increasing use of [16]_____ forms has been noted in recent years.

6. *Telescoping horizontal* [17]_____ are made up of [18]_____, plate, or [19]_____ members, or a combination of these.

NOTES:

Chapter 5 – Building and Erecting Formwork

This topic is planned to provide answers to the following questions:

- What are the basic types of built formwork used in concrete construction?
- What are some of the fundamental methods used in building specific concrete formwork?
- What are some of the "tried and true" shoring methods used in formwork?

HOW FORMWORK IS BUILT and erected depends on many factors—the materials available or required, the type and cost of local labor supply, and demands on the job for accuracy and perfection of finish. For most formwork jobs there is no single correct building procedure; rather there are several workable alternatives, and a choice among them depends on cost comparisons as well as local preferences or customs. At times it may be preferable to handle the work in a way familiar to the available crews rather than try to train them for a new system.

The techniques presented in this chapter are not the only way to do a given job, but they do represent ideas that have wide current acceptance, or some that have proved particularly valuable to experienced form builders. In this section we will investigate various areas of form building as it is actually performed and discussion centers on various formwork components in most of the following divisions:

1. Footings
2. Slab on grade and paving
3. Walls
4. Columns
5. Slabs
6. Beam and girder forms
7. Shoring and scaffolding

FOOTINGS

The principal construction requirements for footings are sound concrete and correct position to match column and wall plans. Since appearance is rarely important because the footing is below grade, any old or used material that is sound may be used to build the forms. Sometimes fabricated forms are omitted entirely and concrete is cast directly against the excavation. When casting concrete against earth, it is frequently desirable to form the top 4 in. of the footing. In case of rain or water buildup, this makes it easier to keep water and slime out of the bottom of a completed or partially completed earth form.

To set the building line from the surveyor's stakes, batter boards are set up outside the limits of the excavation at a convenient location. A string or wire supported by the batter boards is then put in the plane of the building line as shown in Fig. 5–1.

Points below the string are located with a plumb bob. A convenient height should be selected for the batter boards (an even number of feet above or below some horizontal feature of the proposed structure

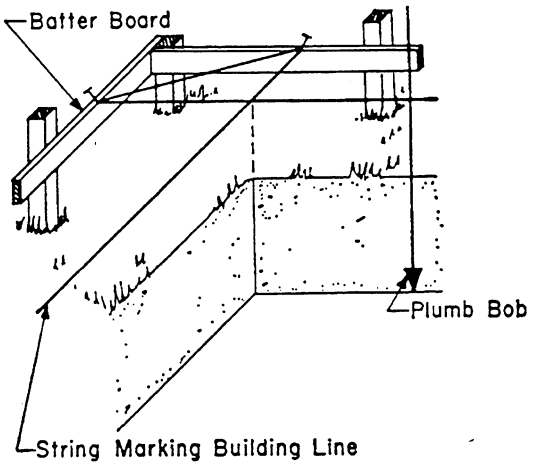


Fig. 5–1 A string line is supported by batter boards in the plane of the building line

such as the finished footing elevation) so they can be used for temporary bench marks.

Wall Footings

In good, cohesive soils that stand up well, all possible excavation down to the top of the footing is done with trencher, backhoe, or other digger, and the footing outline is cut by hand or by specialized mechanical equipment to the exact size. If the soil is porous or non–cohesive, the rough excavation proceeds to the bottom of the footing, and used planks, built up panels, prefabricated metal forms, or other available material can be used to form the sides of the footing. Since footings are generally shallow, lateral pressure from the fresh concrete is relatively small, and the required bracing is simple (Fig. 5–2).

The panels or planks for one side of the form are adjusted to line and grade and staked into position. After one side is set, the other side is aligned by spreaders and held in position by staked placed about every 6 ft. If the holding power of the stakes is poor because of ground conditions, sometimes earth can be used as a brace by simply backfilling around the forms although this is a disadvantage when forms are stripped. No ties are needed for shallow forms.

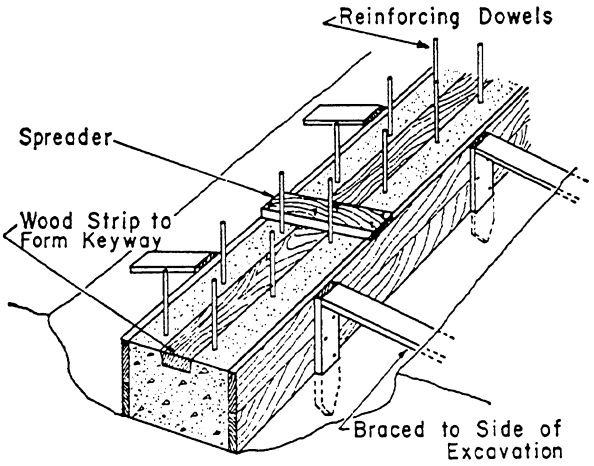


Fig. 5–2 Low footing form for wall can be stake braced

Deeper wall footings or grade beams (in non–cohesive soil) require more bracing or ties to withstand concrete pressure, and are constructed much like wall forms. Fig. 5–3 and Fig. 5–4 show construction of these deeper forms.

If the supporting ground for a wall footing slopes, the footing may be stepped longitudinally with formwork as shown in Fig. 5–5 and Fig. 5–6.

Column Footings

The forms for simple, rectangular column footings are bottomless boxes. They are constructed in four pieces, two end sections and two side sections. The end sections are built to the exact dimensions of the footing and the sides somewhat longer with vertical

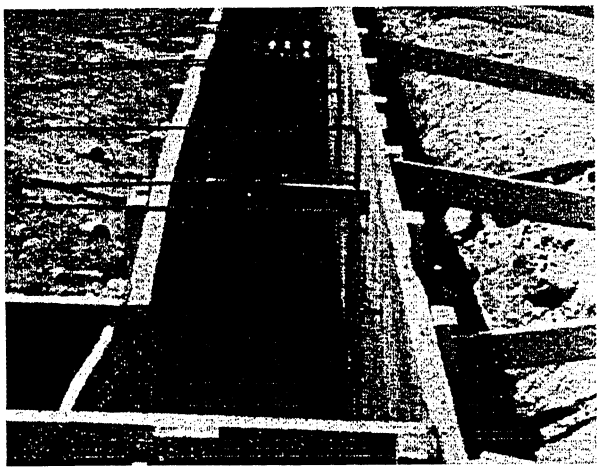


Fig. 5–3 Typical plank footing form is braced against the excavation

cleats to hold the ends as shown in Fig. 5–7. Ties prevent the sides of the box from bulging under concrete pressure, and no external bracing is needed. Since the correct concrete elevation can be marked with a nail, available planks should be used and no time wasted in ripping them to exact height.

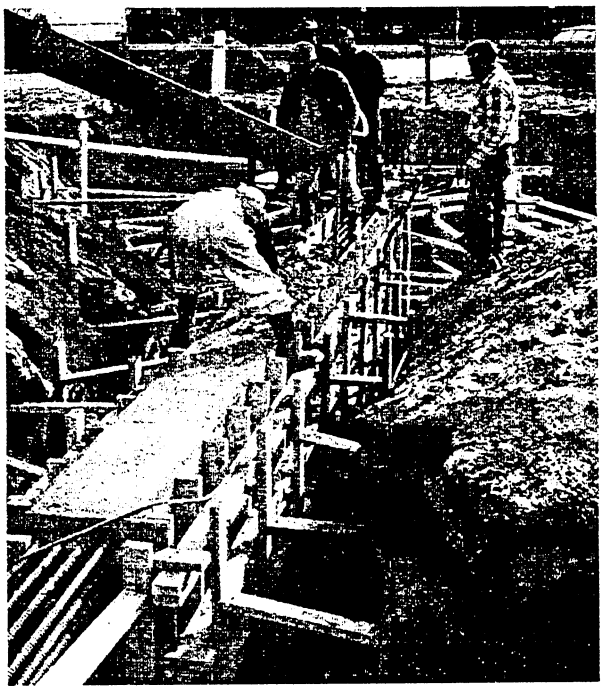


Fig. 5–4 Heavy tie–beam form with walers and ties

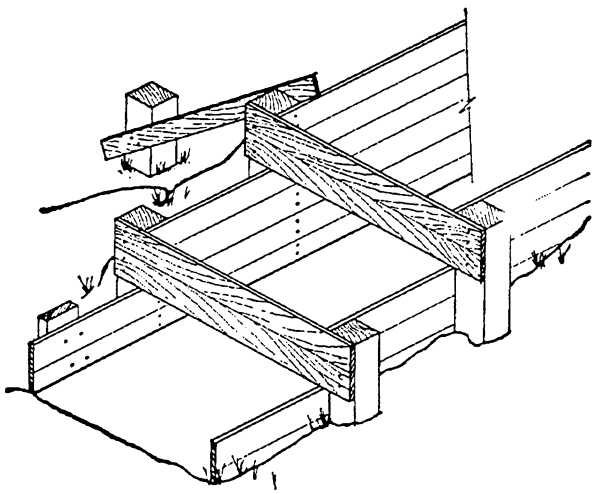


Fig. 5–5 Simple stepped footing

Stakes should be set to maintain the correct position of the form. A template for positioning dowels can be attached to the form box Fig. 5–7 .

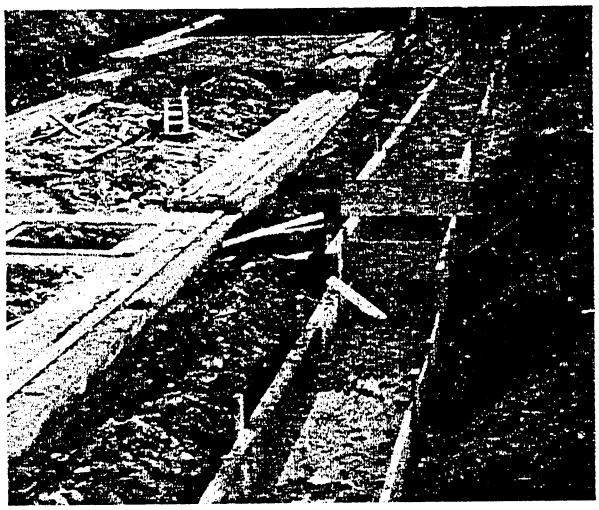


Fig. 5–6 Actual stepped footing

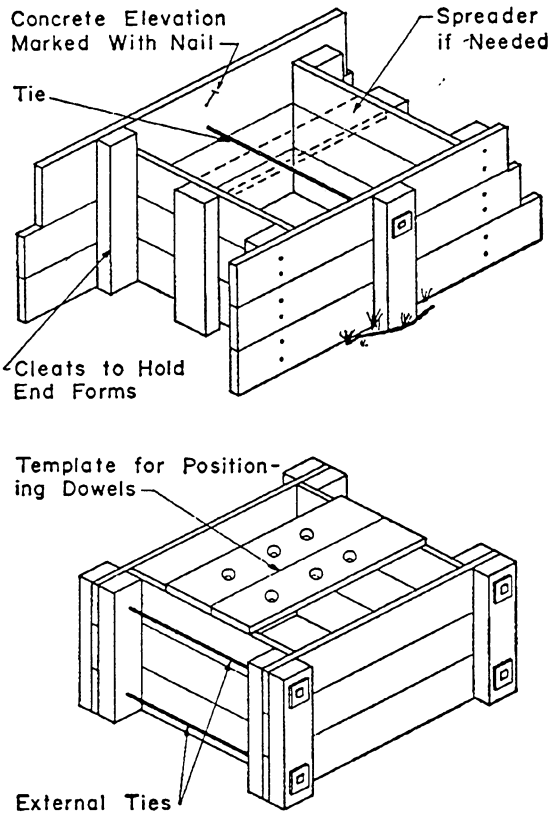


Fig. 5–7 Two methods of forming column footings

For small shallow column footings, the ties are sometimes omitted and diagonal wood braces are nailed across the top of the form box. Round footings may be formed with short lengths of the fiber tubing used to form round columns.

Stepped Column Footings

Stepped column footing forms are similar to flat footing forms but they are made in decreasing sizes and stacked one on top of the other to form a series of two or three pedestals or steps. If a stiff concrete of proper slump (about 2 in.) is used, or there is a short time between placing successive steps, the only difference from flat footing

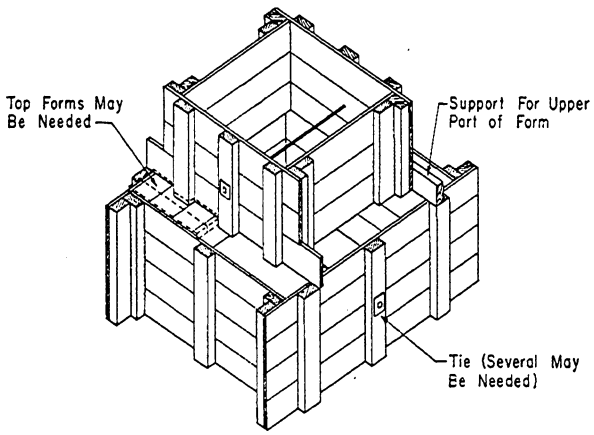


Fig. 5–8 Stepped footing form shows two methods of supporting upper box

forms is the method of support of the forms for the upper steps (Fig. 5–8).

If the entire footing is to be cast at one time with higher slump concrete, top forms for the space between the steps will be needed to keep the concrete from pushing out. When this area between the steps is covered, there is an upward pressure on the top forms and the whole assembly must be weighted or tied down to resist this uplift from the freshly placed concrete.

Combined Footing Forms

Combined or strap footings are used to transfer part of the load of one footing to another or to support two columns on a single footing. If two columns bear on one footing, the combined footing form is built in the same way as for flat or stepped footings. If the load of one footing is to be partly transferred to another, a strap or beam must be constructed between the two footings or pads.

If the beam or strap is to be cast after the pads, the beam forms are supported by the previous placement. If the footing is to be cast monolithically, its construction is much like that of the stepped footing. The boxes for the pad forms are built with a cutout for the beam if necessary. The beam forms are supported on timbers or blocks and the flat footing portions are covered and tied down like forms for stepped footings. The beam forms can be braced to the supporting timbers. A suggested method of forming a strap footing is shown in Fig. 5–9.

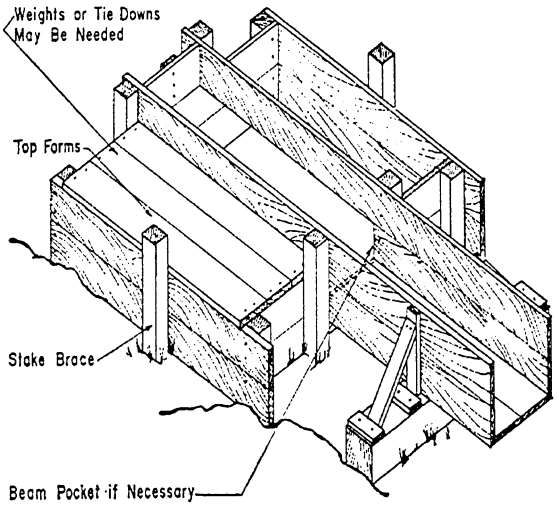


Fig. 5–9 One type of strap footing form for monolithic pour

Curb and Gutter Forms

The curb and gutter common in city street pacing are of various sizes and shapes, which may be formed in wood (Fig. 5–10), but like highway paving are much more commonly built with ready–made steel forms. The curb and gutter forms are lighter than the forms used for highway paving. Typical combined

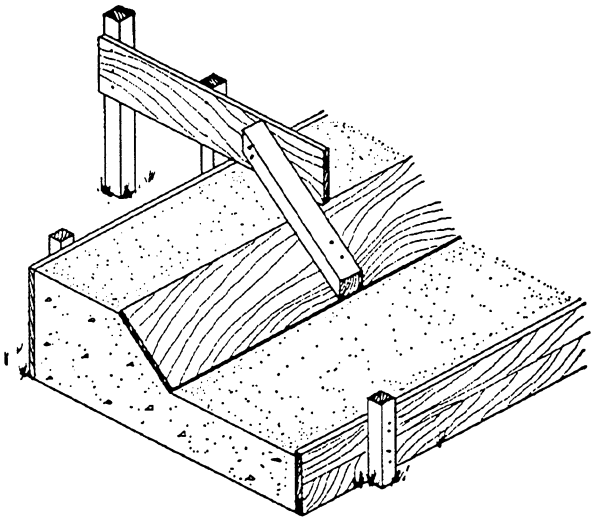


Fig. 5–10 One method of wood curb and gutter forming

curb and gutter form is shown in Fig. 5–11, and similar assemblies are available for casting curbs only in roll, batter, vertical and other shapes. Form manufacturers can also

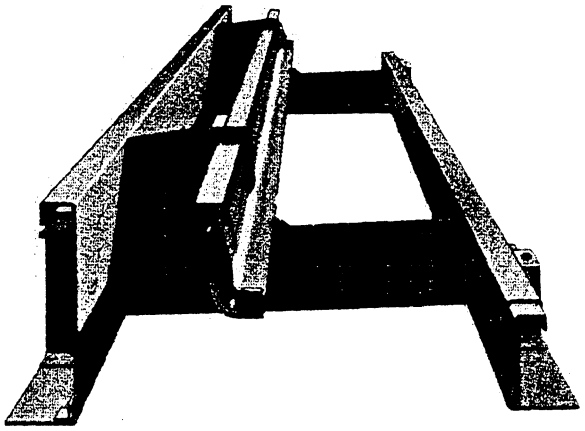


Fig. 5–11 Prefabricated metal curb and gutter form

supply a full line of comparable fixed radius and adjustable radius forms for curved curb and street work.

One common construction sequence is to place the curb and gutter as a unit using metal forms, then pave the roadway between with the already cast curb or curb and gutter serving as the edge form. In such a case, after the grade line has been set for the outside (back) curb form, the forms are set in position on the ground and a stake placed in each pocket. Stakes are driven when the form is precisely located; then the form can be raised on the stakes to correct elevation and wedges driven to lock the stakes. Then a second form member is loosely connected to the first, staked, raised to line, and locked.

When all the back forms are in, or after each form is locked up, the division plates are hooked into slots along the curb form at desired intervals, and then front forms (either gutter form or curb face form if only a simple curb is being cast) may be set. The free ends of division plates are hooked into the opposite front form, the forms squared up, and the stakes driven. The front form can then be raised to grade line and locked with the wedging device. This completes the sequence if only a curb is being cast.

WALL FORMS

Built-In-Place Forms

Wall forms are constructed from five basic parts: (1) sheathing to retain the concrete until it hardens; (2) studs which support the

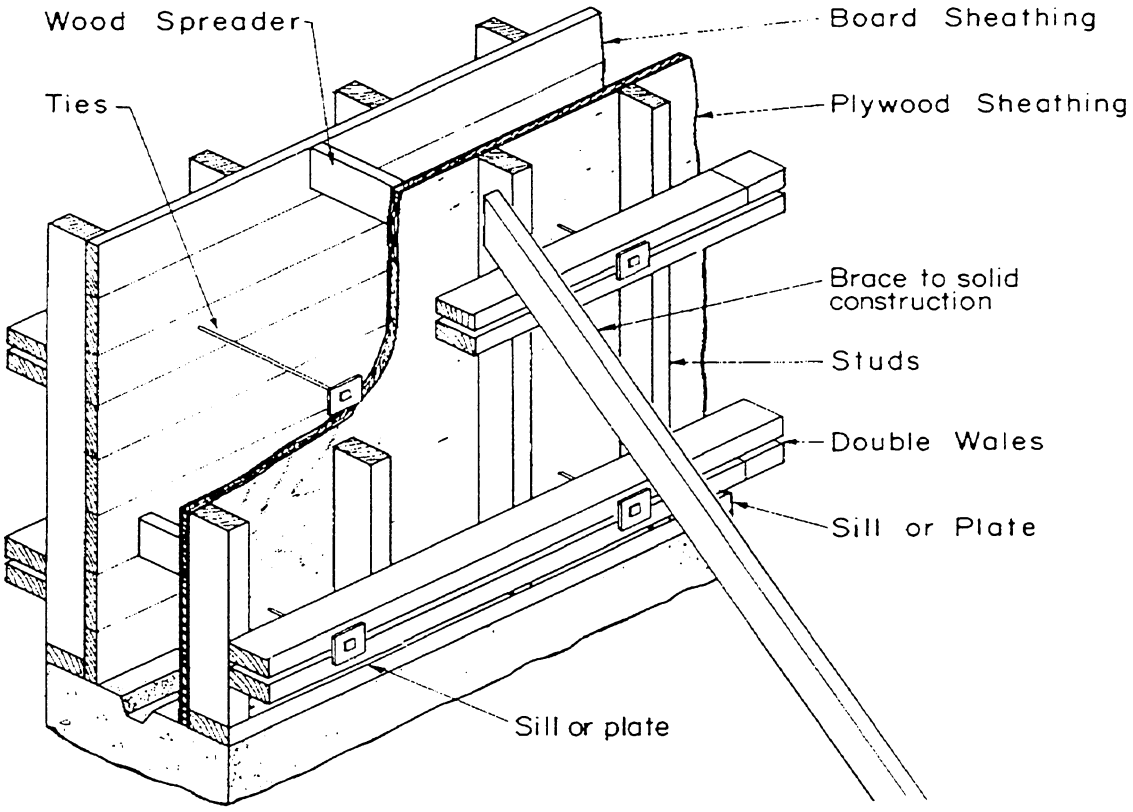


Fig. 5–12 Typical wall form with components identified

sheathing; (3) wales to support the studs and align the forms; (4) braces to hold the forms against construction and wind loads; and (5) separate spreaders and ties or tie–spreader units to hold the forms at the correct spacing under the pressure of the fresh concrete.

The first step in building a wall form is to attach a sill or ledger to the footing as a base for studs. The sill may be attached to preset anchors or stub–nailed to the concrete with specially hardened nails. Special care must be taken in aligning this strip because it will determine the line of the wall. It is set out from the proposed line of the wall a distance equal to the thickness of the sheathing.

After the starting plate or sill is in place, the studs are erected (Fig. 5–12). The bottom of each stud is toenailed to the sill and held vertical by temporary braces of 1x6 or other suitable stock. The stud spacing at the top of the form is held by temporary ribbons until the sheathing is placed. To save time and material, studs may be left extending above the top of the form rather than cutting them off evenly.

The next step is to attach sheathing to the studs. The bottom edge off the first sheathing board or plywood panel is set on the highest point on the foundation and leveled accurately to establish alignment for succeeding boards or panels. If the footing is uneven or stepped, the space between the first sheathing unit placed and the footing may be filled out with specially cut pieces to make a tight joint if appearance is important.

The sheathing for the remainder of the wall is nailed to the inside of the studs after the first unit has been aligned and attached. When nominal 1–in. sheathing lumber is used, it is usually nailed from the inside face with tow 6*d* or 8*d* nails at each stud. Plywood sheets $^5/_8$ in. and thicker are nailed with 6*d* nails at 12– to 16–in. intervals. Remember that the manufacturing tolerance for plywood sheets is +0 and $-^1/_{16}$ in. which may lead to significant accumulated error in long walls, unless properly adjusted for. When thin plywood and hardboard liners are nailed over the sheathing, small nails with thin flat heads such as 3*d* blue shingle nails are desirable.

Contractors who install ties as the sheathing is being placed, can notch the edge of a sheathing board that is at the required height so that holes through the sheathing are formed at the joint between sheathing boards. Otherwise, holes must be drilled in board sheathing after it is in place. Plywood panel sheathing is frequently predrilled. Tie holes must be located at the proper elevation so that the ties will thread through the wales when they are installed.

Wales may be installed as soon as the sheathing is in place or after the other face of the form has been built. Wales are attached to the outside of the studs and held in place by nails, clips, or brackets or patented devices. When wales are constructed of two members, this saves drilling for ties. Special hardware facilitates the use of single member wales. In long wales, the joints between members should be staggered. If double wales are used, there need be no transverse joint completely through the wale.

Permanent bracing can be installed after the wales are in place or as the form is plumbed. These braces extend from the wale to the ground or other solid support. If the brace is

designed to act in compression only, wedges may be used at the end to help in plumbing the forms.

If the braces are designed to act in tension only, they must be securely attached to the forms and tightly anchored at the other end. A cable is well adapted to this type of bracing. The cable length can be adjusted during the plumbing of the forms by a turnbuckle or other device.

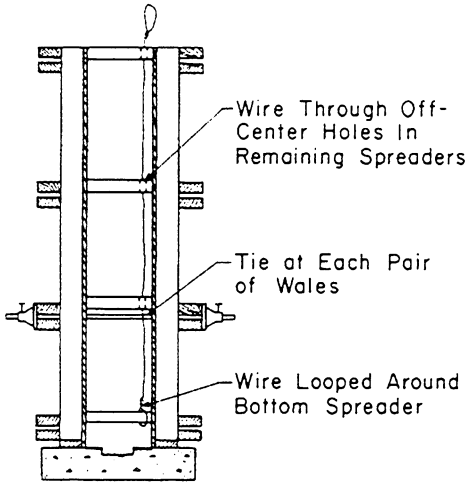


Fig. 5–13 Wire attached to bottom spreader and passing through upper ones for pulling spreaders as concrete rises

When the forms are braced on only one side, the braces must take both compression and tension. Therefore, special attention should be given to fastenings at each end of the brace. Proprietary devices are available for attaching the brace and adjusting its length after it has been installed.

Plumbing is the final operation in building a wall form. Ties are usually installed and all permanent bracing placed before plumbing begins so that the form will not need to be disturbed after it has been plumbed. Most bracing systems have devices for adjusting the braces to facilitate the plumbing operation. If the braces are non–adjustable, the form must be plumbed as the braces are installed. No time should be spent in plumbing both sides of wall forms because the second form to be built will be automatically plumbed from the first by the spreaders.

After the form for one side of the wall has been built and braced, work is begun on the second form. In many operations, steel is placed before the second form is built. If a man can work inside the forms, the second form is constructed at the first. If the wall is too thin for men to work inside the forms but is wide enough to swing a hammer, the carpenters can work from the outside over the top of the sheathing as it is placed. For thin walls, the second form can be constructed in an inclined position (or flat if there is enough space) and then titled into position.

When both forms have been erected, and reinforcement has been placed, the ties are

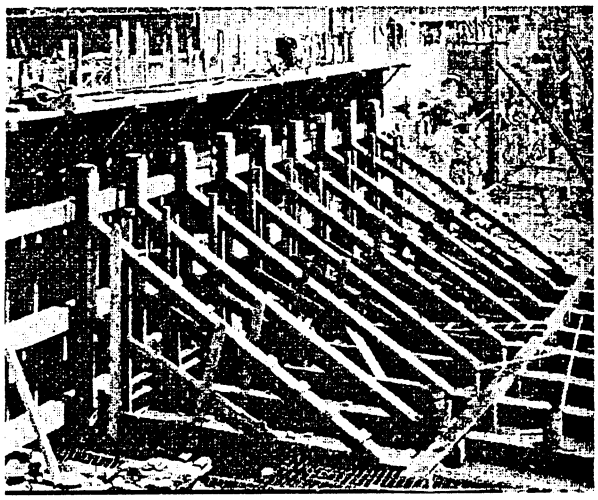


Fig. 5–14 When wall ties are impractical, heavy external form bracing must be used

tightened. If ties with spreading devices are not used, the forms must be held apart at the correct spacing with spreaders which can be removed as the concrete rises in the forms. A wire attached to the bottom spreader, running through all spreaders above, and anchored to the top of the forms will aid in their removal and avoid leaving any spreaders in as the concrete rises in the forms (Fig. 5–13).

Where through–the–wall tying is impossible, or prohibited by specifications, as is the case for some water retaining structures, external bracing must be provided to resist the lateral pressure of the fresh concrete (Fig. 5–14).

SQUARE CORNERS

Handling of wall forms at corners is a critical operation. Continuity of sheathing and wales is broken, making this a potential weak point in the formwork. Corners must be drawn tight to prevent concrete leakage. Leakage here is particularly objectionable as patching to a square edge is most difficult, and

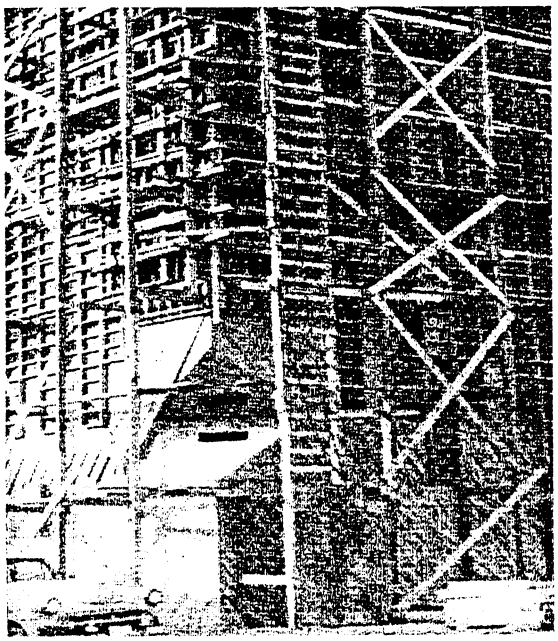


Fig. 5–15 Typical formwork corner using overlapping walers held by a vertical 4x4 block

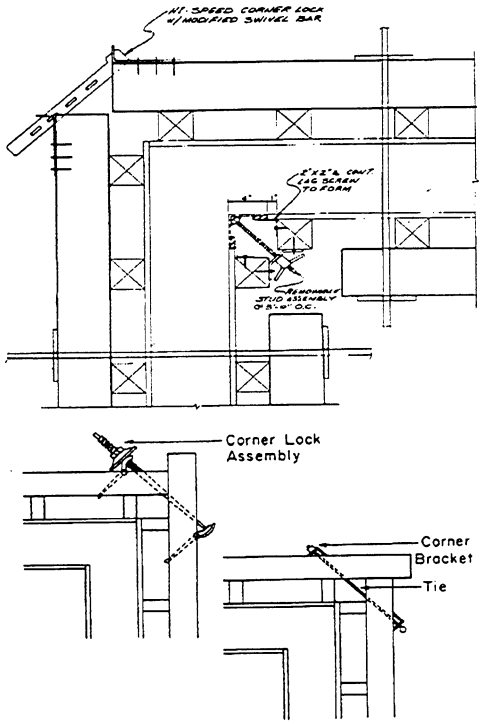


Fig. 5–16 Three types of corner tying devices

chipped, weathered, poorly patched corners are particularly noticeable. Lateral pressure of the concrete, which tends to open the corner joint must be resisted by ties or suitable connections between the wales of the wall forms on either side of the corner.

One method of making a tight corner is shown in Fig. 5–15. The wales overlap and two vertical 2x4 or 4x4 kick strips or blocks are provided at the intersection, against which the wales are wedged to tighten the corner. Another method of securing corners in formwork Fig. 5–16 uses a diagonal tie across the corner. Special corner clamps and ties are available from formwork hardware suppliers.

"Log cabin" corners are sometimes used. Alternate sheathing boards are brought beyond the corner, and vertical kick strips behind the interlaced sheathing boards prevent movement. This type of corner is much more difficult to build and strip than those shown.

CURVED WALLS AND ROUND CORNERS

Rounded corners or curved walls or radius greater than 4 ft. can be formed with plywood attached directly to studs. Horizontal sheathing boards can be used for curves with a radius of 18 to 20 ft. or larger, and vertical board sheathing is sometimes used for smaller radius curves. Rectangular prefabricated panels, with narrow or flexible fillers added, are often used on long radius curves. Short radius curves frequently require a smooth lining material backed up by narrow vertical members. Thickness of sheathing and details of construction vary with the radius of the curve. Several of the many forming methods are described in the following paragraphs.

Long Radius Curves

Long radius curves are easily formed with prefabricated panels, and special filler panels and accessories, as well as suggestions for erection, are available from panel manufacturers.

A typical detail of a form for a long radius curve, not less than 20 ft, using plywood sheathing, is shown in Fig. 5–17. The studs are vertical and are blocked out from yokes or frames which are spaced 4 to 6 ft. apart vertically. By staggering the frames to break joints, a full circle or any part can be held rigid. For the outside form it is necessary at the center of the frames and for a distance of two or three studs each way to tie the studs to the frames to prevent the spring of the

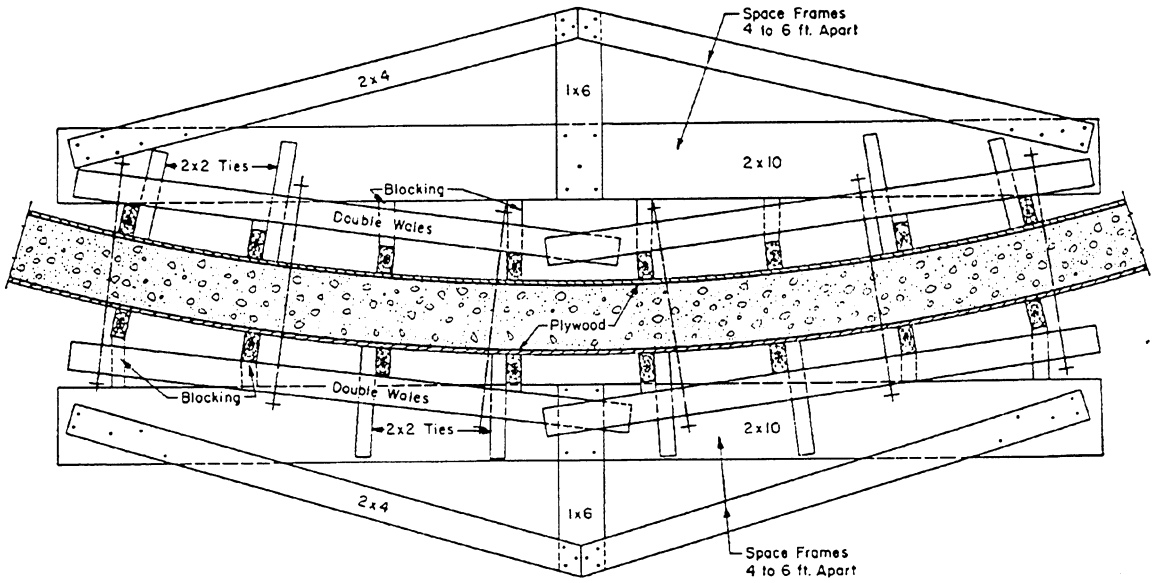


Fig. 5–17 Details of long radius curve formed with plywood sheathing

sheathing from pulling it away from the frames. For the inside form it is necessary to tie the studs at the outer ends of the frame instead of those at the center.

Long radius curves may be formed with horizontal board sheathing in much the same way straight wall forms are erected. After the wall line has been marked on the footing, a sill is nailed down to set the line for the studs. Since wales cannot be bent to the curvature of the wall, short sections are used to span four to six studs according to the curvature of the wall or curved wales may be constructed from standard lumber. With the former method, care must be take to assure the correct amount of blocking so a smooth curve will be formed after the ties are tightened. The installation of ties, external bracing, and plumbing of the form is similar to that for straight wall forms. More external bracing is required for this type of form than for normal straight walls because of the short wales.

Curved wall forms with vertical sheathing require curved horizontal ribs fabricated to support the sheathing. These ribs are usually cut from 8 in. or wider stock; they can be made of single or double segments.

Building curved wall forms in place with vertical sheathing is somewhat more difficult than the method of horizontal sheathing using vertical studs. The ribs must be set in place and held by vertical members and braces until the sheathing has been applied. After the sheathing has been applied, ties are inserted and vertical wales placed. Vertical sheathing is more frequently used to support the lining for short radius curves.

Short Radius Curves

Fig. 5–18 shows a short radius corner formed with hardboard or plywood lining. Yokes are cut to the required curvature from 2 in. stock and spaced about 30 in. apart. The yokes are

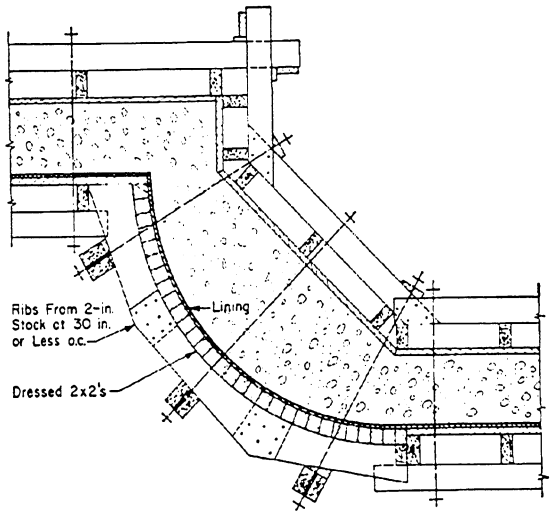


Fig. 5–18 Typical detail for small radius corner form using hardboard or plywood liner

sheathed with vertical 2x2 backing. Since the lining material will tend to spring back to its original flat shape, it must be nailed at 6 in. intervals in both directions.

Two thin sheets of form material may be used rather than one thick one because they can be bent to a smaller radius. Fig. 5–19 shows one way of using double plywood for corner forming. The corner sheathing is brought out beyond the spring line in order to form tight joints where it abuts the wall sheathing. The sheathing is supported by horizontal members cut to the curvature of the corner.

WALL OPENINGS

Small openings in walls can be formed by attaching rigid cellular plastic blockouts or

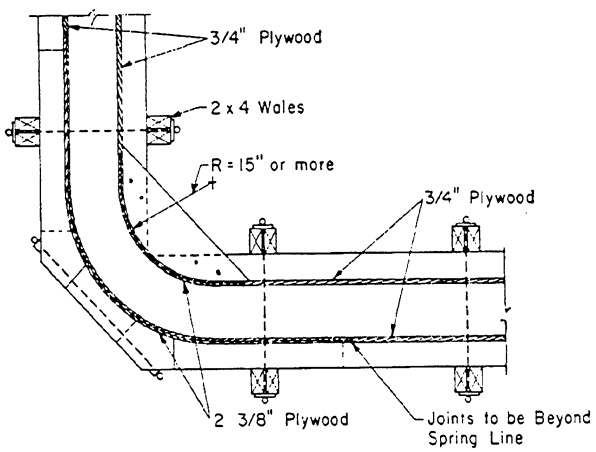


Fig. 5–19 Small radius corner formed with two thin sheets of plywood

box frames to the forms to block out the concrete. The box should be rigid or braced so that it will not deform from the pressure of the concrete. It should be lightly tied to the face of the form so the form can be stripped leaving the box in place in the hardened concrete. Kickers to resist the uplift action of the fresh concrete may be required.

JOINTS

Vertical Construction Joints

Vertical construction joints are formed with a bulkhead placed in the forms at the end of the proposed concrete placement. Since the reinforcing steel continues past the joint, some provision must be made to allow it to pass through the bulkhead. The bulkheads may be built up from short pieces, placed horizontally, cut so they will fit evenly between the two faces of the wall form. Vertical boards may also be used (Fig. 5–20). Reinforcement is passed through the bulkhead by notching the bulkhead boards at the desired steel (rebar) location.

The bulkhead resists the pressure of the fresh concrete by cleats nailed to the inside face of the forms, outside of the bulkhead sheathing. The short pieces forming the bulkhead are lightly attached to these cleats to hold them in place until the concrete is placed. The pressure of the concrete will hold them against the cleats. Keyways or waterstop materials are frequently attached to bulkhead forms as required by design specifications **(See Fig. 5–21)**.

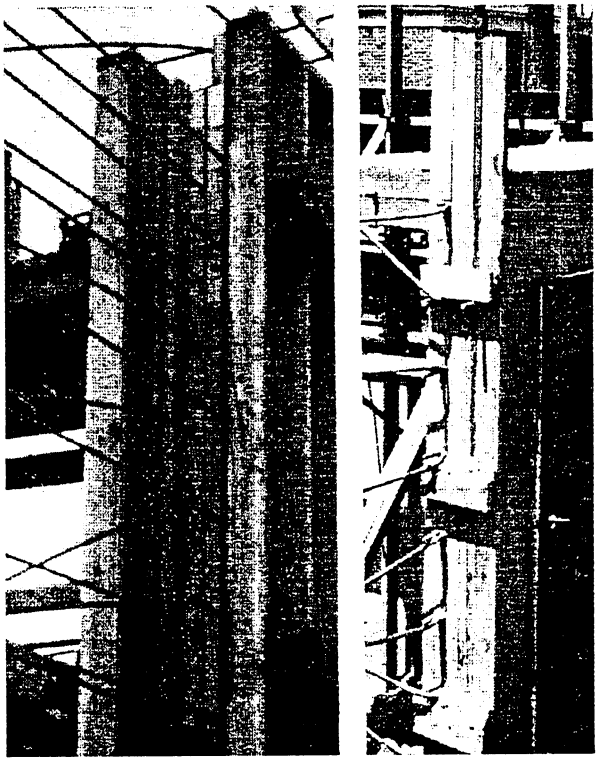


Fig. 5–20 Two types of bulkheads using short, horizontal boards (left) and long, vertical boards (right)

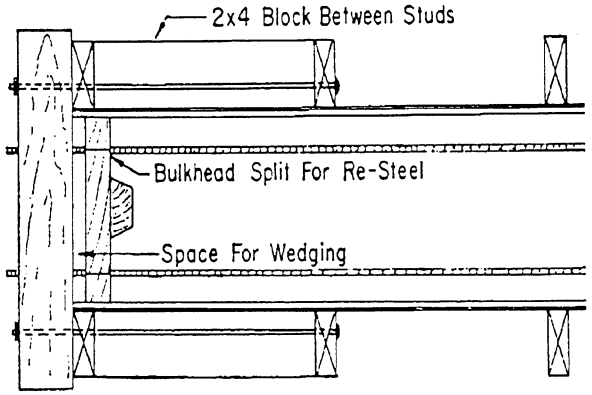


Fig. 5–21 One method of building a bulkhead with a strip for attaching keyway

Horizontal Construction Joints

The technique of forming high walls with lift forms (or climbing forms) is used where it is impractical to place them full height. When the first concrete lift is placed, ties or bolts are placed in the concrete near the top of the lift. After the concrete has hardened sufficiently, the forms are stripped and raised to the elevation of the next lift and supported on the previously placed bolts below.

A row of ties should be placed about 6 in. above the joint between the concrete lifts to prevent leakage. The bolts or ties in the previous lift support the weight of the form, but cannot be relied on to prevent a slight spreading of the forms at the joint. The form members connected to the bolts must be an integral part of the form panel. If the wales are securely attached to the form, they may be used to support the panel. Sometimes a timber ledger is attached to the bolts cast in the previous lift, and the studs of the form rest on it. Specially constructed strongbacks can also be used. Special brackets, attached to the previous lift by bolts, may also be used to support the forms.

CHAPTER 5 ~ BUILDING AND ERECTING FORMWORK

STUDY GUIDE

INSTRUCTIONS: Determine the correct word for each numbered blank in the sentence and write it in the blank space provided.

1. When casting concrete against [1]_____, it is frequently desirable to form the top [2]_____ of the footing.

2. Since footings are generally shallow, lateral [3]_____ from the fresh [4]_____ is relatively small, and the required bracing is simple.

3. Ties prevent the sides of the box from [5]_____ under concrete pressure, and no [6]_____ bracing is needed.

4. If the entire footing is to be cast at one time with [7]_____ slump concrete, top forms for the space between the [8]_____ will be needed to keep the concrete from [9]_____ out.

5. If the footing is to be cast [10]_____, its construction is much like that of the [11]_____ footing.

6. In such a case, after the grade [12]_____ has been set for the outside (back) curb form, the forms are set in position on the ground and a [13]_____, placed in each [14]_____.

7. The first step in building a wall form is to attach a [15]_____ or [16]_____ to the footing as a [17]_____ for studs.

8. Remember that the manufacturing tolerance for [17]_____ sheets is +0 and $-1/16$ in. which may lead to significant accumulated [18]_____ in long walls, unless properly [19]_____ for.

9. If the [20]_____ are designed to act in [21]_____ only, they must be securely attached to the [22]_____ and tightly [23]_____ at the other end.

10. No time should be spent in plumbing [24]_____ sides of wall forms because the second form to be built will be automatically [25]_____ from the first by the [26]_____.

11. Lateral pressure of the concrete, which tends to open the [27]_____ joint must be resisted by [28]_____ or suitable connections between the [29]_____ of the wall forms on either side of the corner.

12. The studs are [30]_____ and are blocked out from [31]_____ or frames which are spaced 4 to 6 ft. apart [32]_____.

13. [33]_____ thin sheets of form material may be used rather than one [34]_____ one because they can be [35]_____ to a smaller radius.

14. Small openings in walls can be formed by attaching rigid [36]_____ plastic blockouts or [37]_____ frames to the forms to block out the [38]_____.

15. Reinforcement is passed through the [39]_____ by [40]_____ the bulkhead [41]_____ at the desired steel (rebar) location.

NOTES:

UNIT 91

ADVANCED

FORMWORK

FOR

PILE DRIVERS

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