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RECOMMENDATIONS FOR CONCRETE FORMING KIT FOR THEATER OF OPERATI--ETC(U)
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construction engineering research laboratory

LEVEL II

TECHNICAL REPORT M-252
August 1978

(11) (12) 40 p.

RECOMMENDATIONS FOR CONCRETE FORMING KIT FOR THEATER OF OPERATIONS APPLICATIONS

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(7) Final technical rpt.,

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by
(10) L. I. Knab

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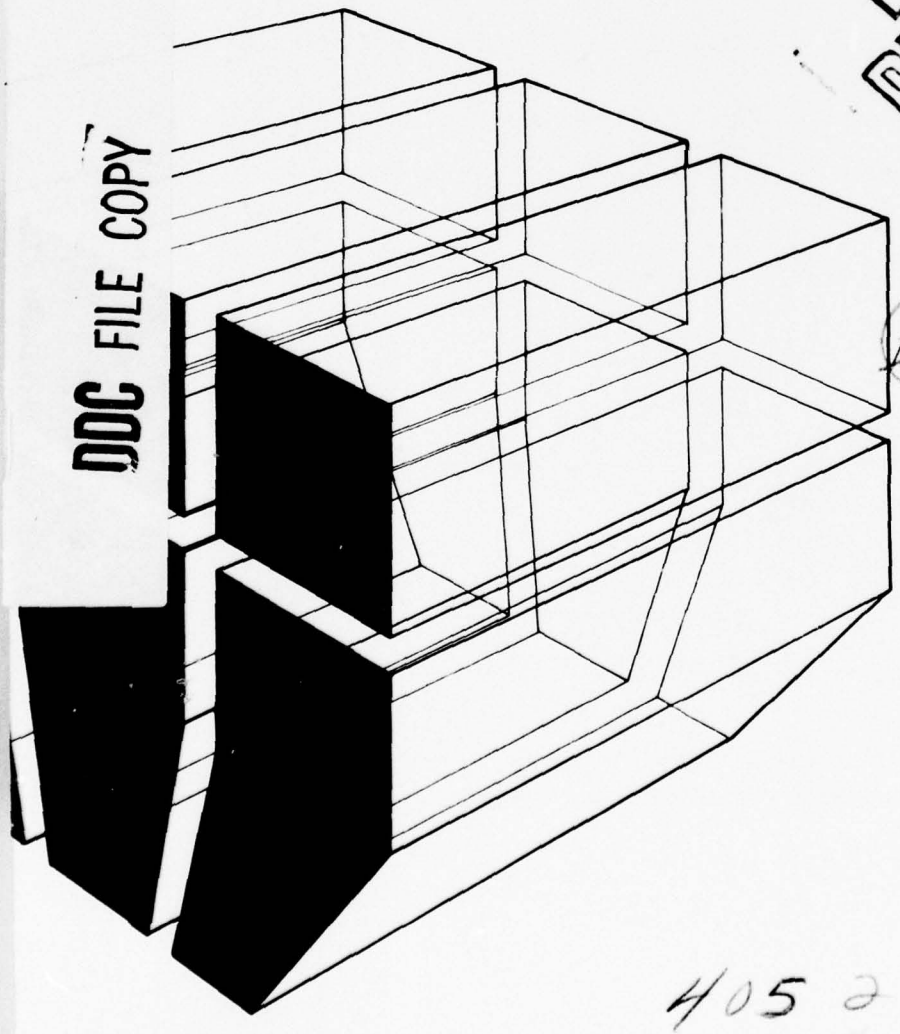

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: CERL-TR-M-252	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: RECOMMENDATIONS FOR CONCRETE FORMING KIT FOR THEATER OF OPERATIONS APPLICATIONS	5. TYPE OF REPORT & PERIOD COVERED: FINAL
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): L. I. Knab	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: CONSTRUCTION ENGINEERING RESEARCH LABORATORY, P.O. Box 4005, Champaign, IL 61820	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 4MS0MA00002
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: August 1978
	13. NUMBER OF PAGES: 38
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*	15. SECURITY CLASS. *(of this report)*: Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES
Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*
concrete forming
form-fastening systems
rebar

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This study recommends components to be included in a kit for concrete forming to be used in Theater of Operations construction. The kit will provide versatile materials and equipment for rapid construction of concrete formwork. Appropriate components are recommended for inclusion in the kit based on efficiency, cost, versatility, logistics, simplicity, and erection time. Specific recommendations are made for concrete form-fastening systems; rebar cutting, bending, support, tying, and splicing; curing compounds; form release agents; and air-entraining agents. The report provides a brief background and

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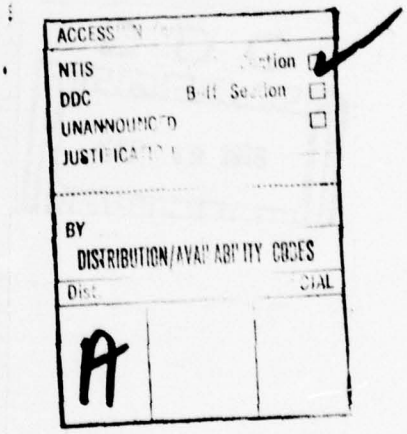
description of the rationale used to choose the components, as well as literature describing the items comprising the kit.

FOREWORD

This investigation was conducted by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL), for the Office of the Chief of Engineers under O&MA Project 4MS0MA00002, "Concrete Forming Kit for T.O. Construction."

Personnel directly concerned with the investigation were Dr. L. I. Knab and Dr. G. R. Williamson of CERL.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director. Dr. G. R. Williamson is Chief of EM.



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RECOMMENDATIONS FOR CONCRETE FORMING KIT FOR THEATER OF OPERATIONS APPLICATIONS

1 INTRODUCTION

Background

The design and construction of formwork and reinforcing steel as set forth in TM 5-742[1] do not take advantage of methods and equipment commonly available in civilian practice. Presently used methods of fabricating placement forms and methods for cutting, bending, supporting, and tying rebar are time-consuming and require close supervision to insure that the structure conforms to guide specifications.

Therefore, the Office of the Chief of Engineers has required that a kit be made available to engineer construction units which would contain commercially available, state-of-the-art components for rapidly erecting forms for building walls, headwalls, wing walls, splash pads, retaining walls, etc. The kit should also include components to provide for rapid cutting, bending, supporting, and tying of rebar.

Objective

The objective of this study is to recommend components for a concrete-forming kit to be used in the theater of operations (TO) that would provide materials and equipment for the rapid erection of concrete formwork and rapid cutting, bending, supporting, and tying of rebar.

Approach

Researchers identified the systems and materials most commonly used in the TO for form fastening; rebar cutting and bending; rebar support, tying, splicing, and column-forming aids; and form release agents, curing compounds, and air-entraining agents. On the basis of each system's advantages and disadvantages in terms of rapidity and economy, those considered to be most suitable for use in the TO were recommended.

[1] *Concrete and Masonry*, TM 5-742 (Department of the Army, 22 June 1970).

2 CONCRETE FORM-FASTENING SYSTEMS

Form-Fastening Systems

The following form-fastening requirements are based on the use of plywood or other wood sheathing as the vertical forming material. The vertical forming system is designed to meet these requirements.

1. Insure proper wall thickness and confine concrete without excessive deflection

2. Provide rapid concrete form erection and stripping

3. Accommodate a range of wall thicknesses (6 to 24 in. [150 to 600 mm]) typical of TO construction, including battered walls

4. Include a minimum of parts to provide ease of construction and training

5. Insure an economical construction

6. Provide for mobility

7. Be sufficiently compact for ease of shipment and transportation.

Form ties can have either tie action only, or both spreader and tie action. Some ties are expandable (left in concrete), and others are reusable. Systems are available in which part of the tie is expandable and part is reusable. The more common fastener systems are described briefly below.

Form Clamp or Button

This is a plain round rod secured by a clamp with a setscrew. Since the rod does not provide spreader action, a separate item must be installed for this purpose. The rod may be cut off or pulled out of concrete. Paper, plastic, or metal tubing can be placed over the rod so that it can be removed from the concrete easily.

Snap Tie

This is a steel rod with spreaders and breakbacks. Slotted, wedgeshaped pieces of steel called snap tie clamps or hairpins fit over the ends of the tie and clamp the forms together. Snap tie length varies with wall thickness. Snap ties remain in the concrete and their ends are snapped off.

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Coil Ties

These are two helical wire coils welded to opposite ends of two or four steel rods (called struts) to form the basic element or inner portion of the tie which remains in the concrete. Continuous threaded coil rod is then screwed into each helical wire coil. Use of plastic cones in the ends of the coil rod can provide spreader action.

She-Bolts

She-bolts consist of two waler rods, two nut washers, and one inner unit which remains in the concrete. The waler rods and inner units can be either National Course (NC), Acme, or Contour (coil) thread, or can be a combination of waler rod of one threading and an inner unit of another. The inner unit is generally deformed to prevent it from turning in green concrete. Special cones or continuous sleeves can provide spreader action. The inner unit changes length to change the wall's dimensions.

Taper Ties

Taper ties consist of one taper rod threaded at each end, generally either Acme cut thread or Contour (coil) thread. Two nut washers (usually of two different dimensions dependent on the size of the rod either before or after the taper) are used to fasten the ends of the tie. The ties are completely removed from the concrete when set up. A continuous sleeve, rather than taper ties, provides spreader action.

Continuous Threaded Rod

This consists of one continuous threaded rod (NC, Acme, or Contour [coil] threads) and two nut washers which serve as fasteners. A paper, plastic, or metal tube can be placed over the concrete contact portion to permit removal of the tie and to serve as a spreader. Complete removal of all types of tubes and grouting is recommended.

Single-Waler Forming Systems

Special metal brackets secure the wales and snap ties. No studs and few nails are required. Strongback (stiffbacks) are required at relatively large spacings and can be held by special brackets.

Tie Wire

Tie wires and wooden spacer blocks hold the forms together. This is one of the systems presently being used in the TO.

Comparison of Representative Systems

The advantages and disadvantages of the forming systems listed above as related to the TO form-fastening requirements are given in Table 1. These are based on an 8-ft- (2.4-m-) high wall with approximately 2000 sq ft (180 m^2) of form face.

Number of Operations and Cost of Systems

Since rapid, economical construction is extremely important in military engineering, a representative group of forming systems was chosen to compare how often they are used and how much they cost. Evaluation of each system was based on a rectangular enclosure, 16 ft (4.8 m) wide by 48 ft (14.4 m) long by 8 ft (2.4 m) high, with a 12-in. (300-mm) wall thickness. This wall has 1984 sq ft (179 m^2) of form face. The five systems examined are described below. All systems used 4-ft (1.2-m) by 8-ft (2.4-m) by 3/4-in.- (19-mm-) thick plywood sheets with the 8-ft (2.4-m) dimension vertical.

System A

System A (see Figure 1) is a wire tie system (#9 wire) employing a design of 600 psf (2940 kg/m^2) with a safe tie working load of 1000 lb (400 kg). The components are plywood sheathing, 2- by 4-in. (50- by 100-mm) studs on 12-in. (300-mm) c/c,* 4- by 4-in. (100- by 100-mm) wales on 32-in. (800-mm) c/c, with ties spaced at 12 by 16 in. (300 by 400 mm).

System B

System B (see Figure 1) is a typical snap tie system that uses a design of 750 psf (3675 kg/m^2) with a safe tie load of 3000 lb (1200 kg). The components of the system are plywood sheathing, horizontal** 2- by 4-in. (50- by 100-mm) "studs" on 12-in. (300-mm) c/c, vertical** double 2- by 4-in. (50-by 100-mm) "wales" on 24-in. (500-mm) c/c, and button-end snap ties and pressed steel "hairpins" spaced at 24 by 24 in. (600 by 600 mm).

System C

System C (see Figure 1) is the Symons Speed Bracket System, a single-waler forming system. A design of 750 psf (3675 kg/m^2) with a safe snap tie working load of 3000 lb (1200 kg) and a tie spacing of 16 by 24 in. (400 by 600 mm) is used. The components of the system are plywood sheathing, 2- by 4-in. (50- by 100-mm) wales on 16-in. (406 mm) c/c, and vertical double 2- by 4-in. (50- by 100-mm) stiffbacks on 96-in. (2400-mm) c/c.

*Center to center

**"Studs" are next to plywood, and "wales" are placed on the outside; the term "stud" usually refers to a vertical member, and "wale" to a horizontal member. Here, their directions are reversed.

Table 1
Advantages and Disadvantages of Forming Systems

System	Advantages	Disadvantages
Form Clamp	Versatile with respect to wall thickness and shape (e.g., battered wall) Economical Part of rod reusable	Need wooden spacers or metal sleeves for spreader action No breakback Inconsistency in tightening ties (may overload a tie) Holding power of tie questionable Ties not completely reusable (even if paper tubing used, end of tie will be kinked) Cannot be ganged effectively Need to patch holes
Snap Tie	Reasonably rapid Economical Has spreader action	Need proper length tie for each wall thickness and lumber dimensions (can weld ties to proper wall thickness) Tie expendable Pour rate is limited (could use stronger snap tie, but breakoff is more difficult)
Coil Ties	High strength Can be readily ganged Coil rod reusable Uses lumber to greatest advantage (can put tie where it is needed) Versatile pour rate Threads and working parts not likely to jam Has spreader action	Only versatile for wall thickness in increments of approximately ±2 in. (51 mm) (e.g., 8 to 12 in. [203 to 306 mm]) but could use a variety of piece sizes. Coil piece expendable
She-Bolts	High strength Can reuse outer bolts Can be ganged Uses lumber to greatest advantage Versatile pour rate	Only versatile for wall thickness in increments of approximately ±1 in. (25 mm) (e.g., 10 to 12 in. [250 to 306 mm]), but could use a variety of inner piece sizes. Threads and working pieces can become jammed Inner piece expendable Spreader action difficult to obtain.
Taper Ties	High strength Reasonably versatile with respect to wall thickness (minimum of about 3 sizes required for 6 to 24 in. [150 to 600 mm] span) Tie reusable Uses lumber to greatest advantage Versatile pour rate Can be ganged	Patch holes (if required) If bent, difficult to bend back to proper shape Spreader action difficult to obtain.
Continuous Threaded Rod	Versatile with respect to wall thickness and shape Uses lumber efficiently Versatile pour rate Tie reusable Tie is tough; if bent, it can rebend to proper shape Threads and working parts are not likely to jam; it is easy to thread	Need wooden spacers or metal sleeves for spreader action Metal sleeve is expendable Patch holes (if required)
Single-Waler Forming Systems	Rapid Can provide significant lumber savings Fewer nails needed	Need proper length tie for each wall thickness (can weld to proper length) Many ties are needed Difficult or impossible to gang
Tie Wire	Versatile with respect to wall thickness and shape Economical	Very slow Strength not predictable Cumbersome to use Difficult or impossible to gang

System D

System D is a ¾-in. (19-mm) diameter continuous threaded coil rod system, using a design load of 750 psf (3675 kg/m^2) with a tie working load of 9000 lb (3600 kg). The components of the system are plywood sheathing, ¾-in. (19-mm) diameter continuous threaded rod spaced at 36 by 48 in. (900 by 1200 mm), nutwashers, vertical 2- by 6-in. (50- by 150-mm) studs approximately 12 in. (300 mm) c/c, and horizontal double 2- by 10- in. (50- by 250-mm) wales at 36 in. (900 mm) c/c. Thin wall metal conduit (1 in. [25 mm] nominal diameter) provides spreader action, insures proper wall thickness, and permits easy removal and reuse of the threaded rod ties. System D and its ganging details are shown in Figure 2.

System E

System E is ½-in. (13-mm) diameter continuous threaded coil rod system employing a design load of 1000 psf (4900 kg/m^2) with a tie working load of 6000 lb (2400 kg). The components of this system are plywood sheathing, ½-in. (13-mm) diameter continuous threaded rod ties spaced at 24 by 24 in. (600 by 600 mm), nutwashers, 2- by 4-in. (50- by 100-mm) studs on 12-in. (300-mm) c/c, and double 2- by 4-in. (50- by 100-mm) wales on 24-in. (600-mm) c/c. Thin wall metal conduit (¾ in. [19 mm] nominal diameter) provides spreader action, insures proper wall thickness, and permits easy removal and reuse of continuous threaded rod. System E is identical to System B, except that the snap ties and hairpins of System B are replaced by continuous threaded rod, flat washers and lagnuts, and metal conduit (over the wall portion of the tie rod).

The "Number of Operations" analyses are shown in Tables 2 through 6 and the "Materials Cost" analyses are shown in Tables 7 through 11. In the "Number of Operations" analyses, the "2" in the "number of operations" column for plywood in Table 2 reflects the fact that the plywood must be put up and taken down for each setup. The "2" operations for nails represent one operation to drive the nail in and one to take it out. In System B (Table 3), the three operations for ties (one setup) indicate that one operation is required to put the tie in and two operations are required to break them off (one on each side of wall). The numbers of operations should be considered as estimates.

The number of setups indicates the number of times that the forms are erected and stripped. For example, three setups indicate three erections and three strippings. The three setups were chosen to indicate reuse trends in terms of number of operations and cost.

The various operations can be weighted, based on a common basis of time; however, sufficient information is not available to do this. Instead, the operations which require two workers, such as nailing and cutting and most lumber operations, are distinguished from the remaining one-person operations. These are shown in the "Number of Men Required" column in Tables 2 through 6. The differentiation between one- and two-person operations is, at best, only an approximation. The use of a two-person operation is meant to account for the fact that lumber-moving and -handling is often considerably more time-consuming than non-lumber operations, such as many tie operations.

Table 12 shows the one- and two-person operations and totals for Systems A through E. Included is the number of operations per square foot of form face (based on 1984 sq ft [179 m^2] per pour). Table 12 also shows the "Adjusted Totals," which are obtained by doubling the number of two-person operations and adding that amount to the number of one-person operations. The "Normalized" results are found by dividing by the smallest "Totals" (or "Adjusted Totals"). The "Totals" represent actual numbers of operations. The "Adjusted Totals" do not represent actual numbers of operations, but rather reflect the result of weighting the two-person operations by a factor of two.

The "Material Cost" analyses are based on the current prices (or estimated prices) of materials only. Material cost totals are shown in Table 13.

System Discussion

Table 13 shows a "Criteria Summary" for Systems A through E. Based on this information, Systems B, C, and E offer the greatest potential for TO use.

One of the major drawbacks of Systems B and C is that the snap ties must be fabricated by field welding. The availablility and cost of the welding equipment (about 100 amps capacity required), the quality of the field weld, and the loss in tie strength resulting from the weld (about 15 to 20 percent) must be investigated further, although contractors have welded snap tie ends in the past.

Although the number of operations and cost for System E are greater than for System B, System E is considerably more versatile, because System B requires field welding, cannot be easily modified to accommodate a full liquid head of concrete, and cannot make as efficient use of lumber.

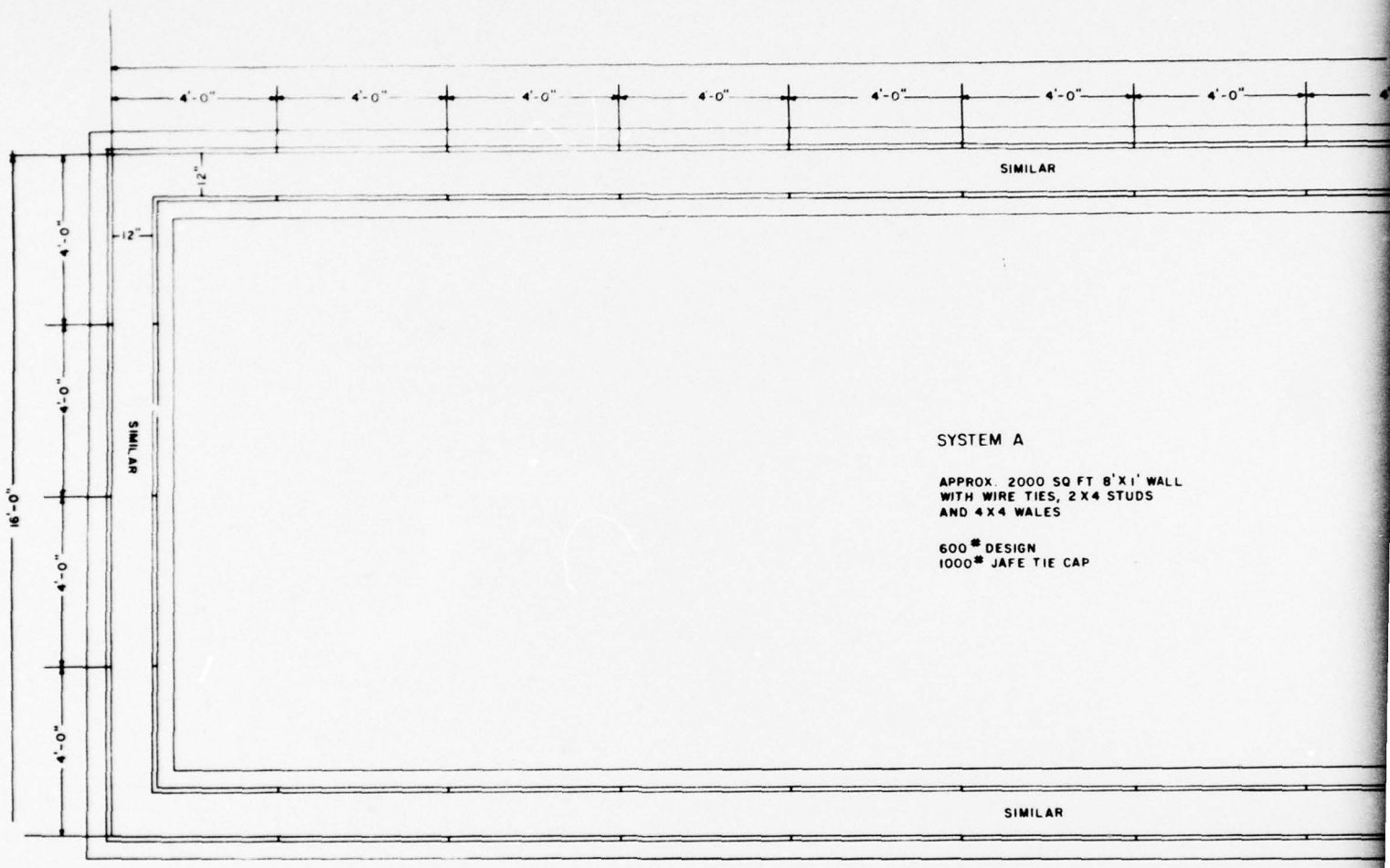
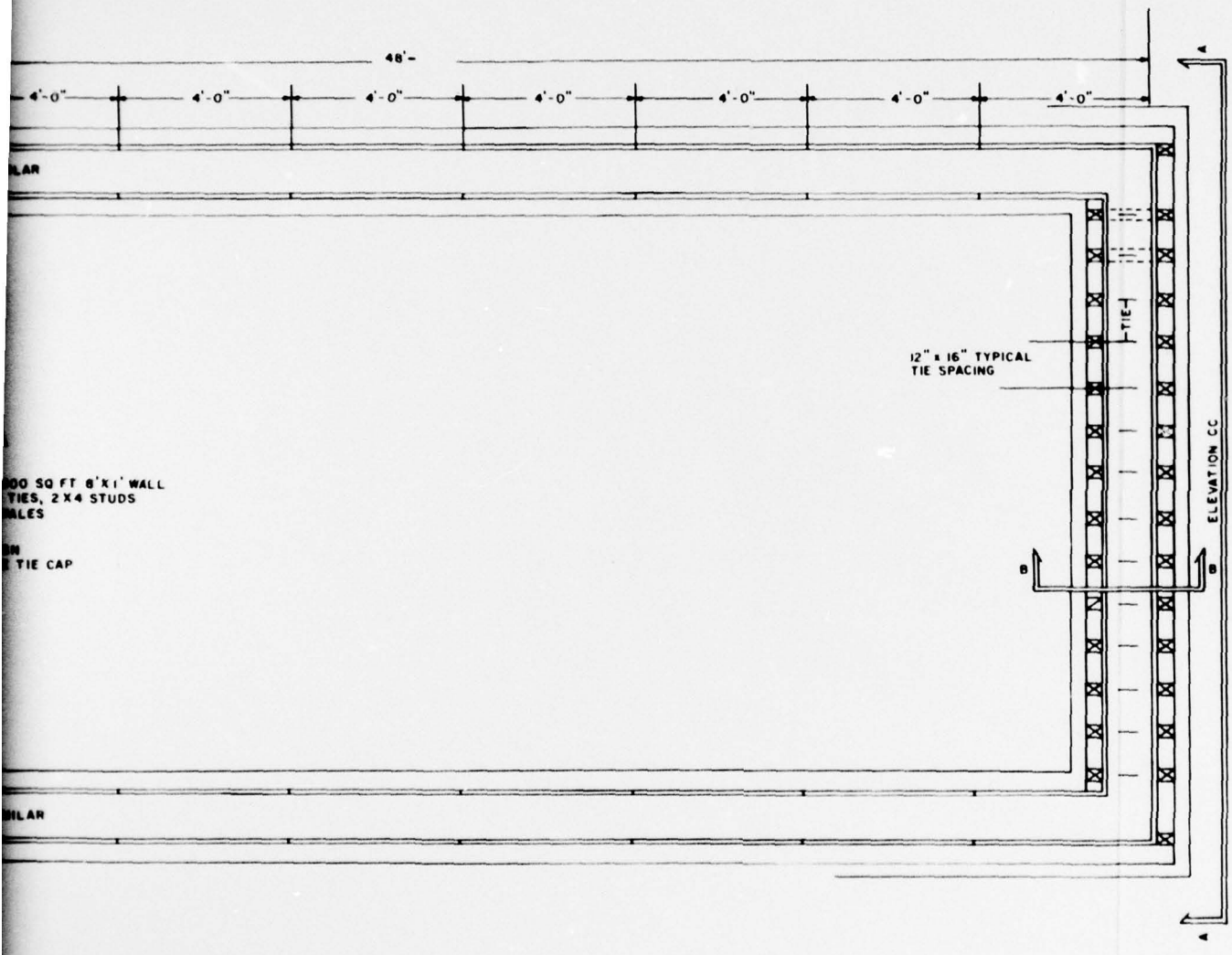


Figure 1. Systems A, B, and C.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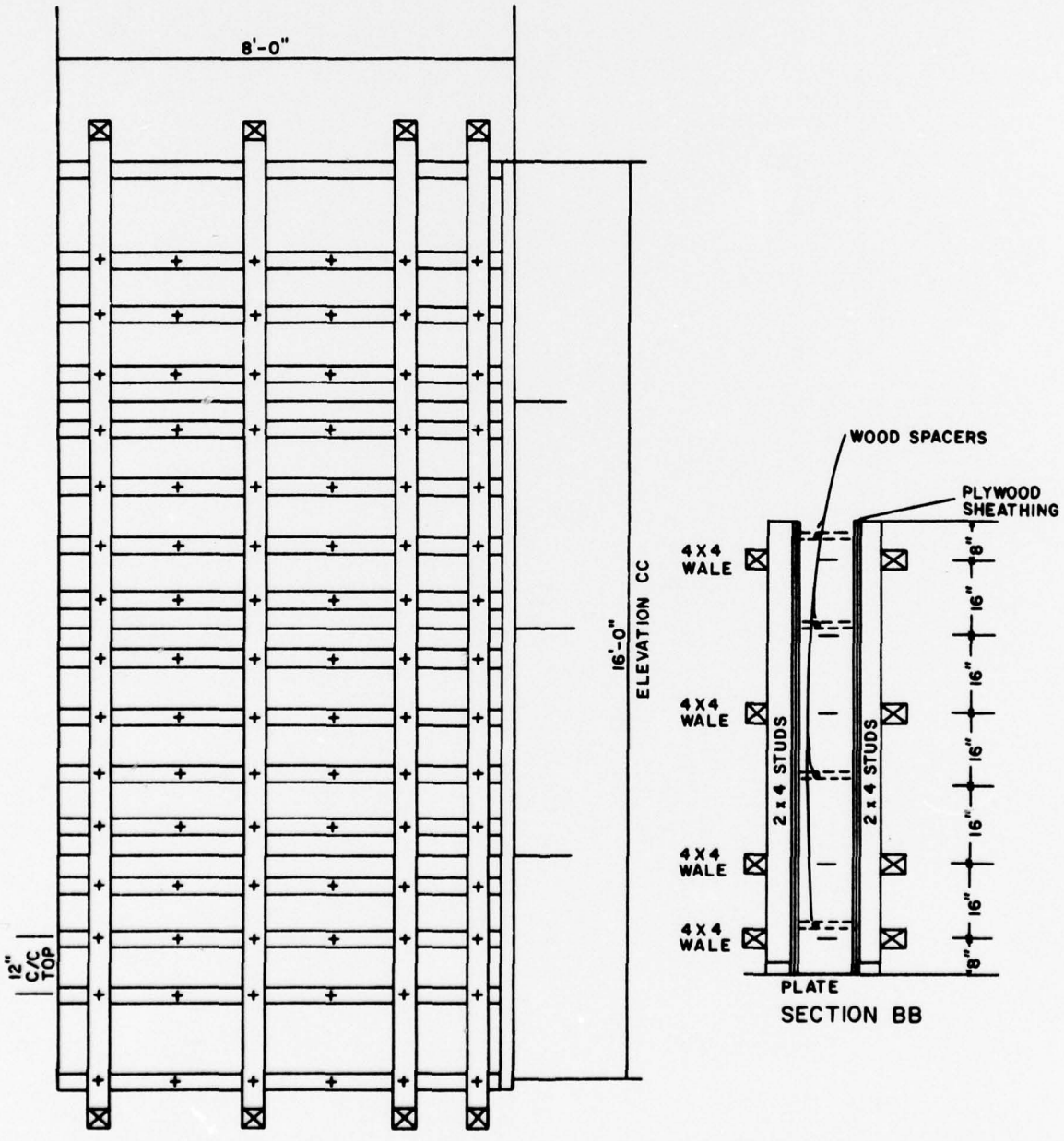

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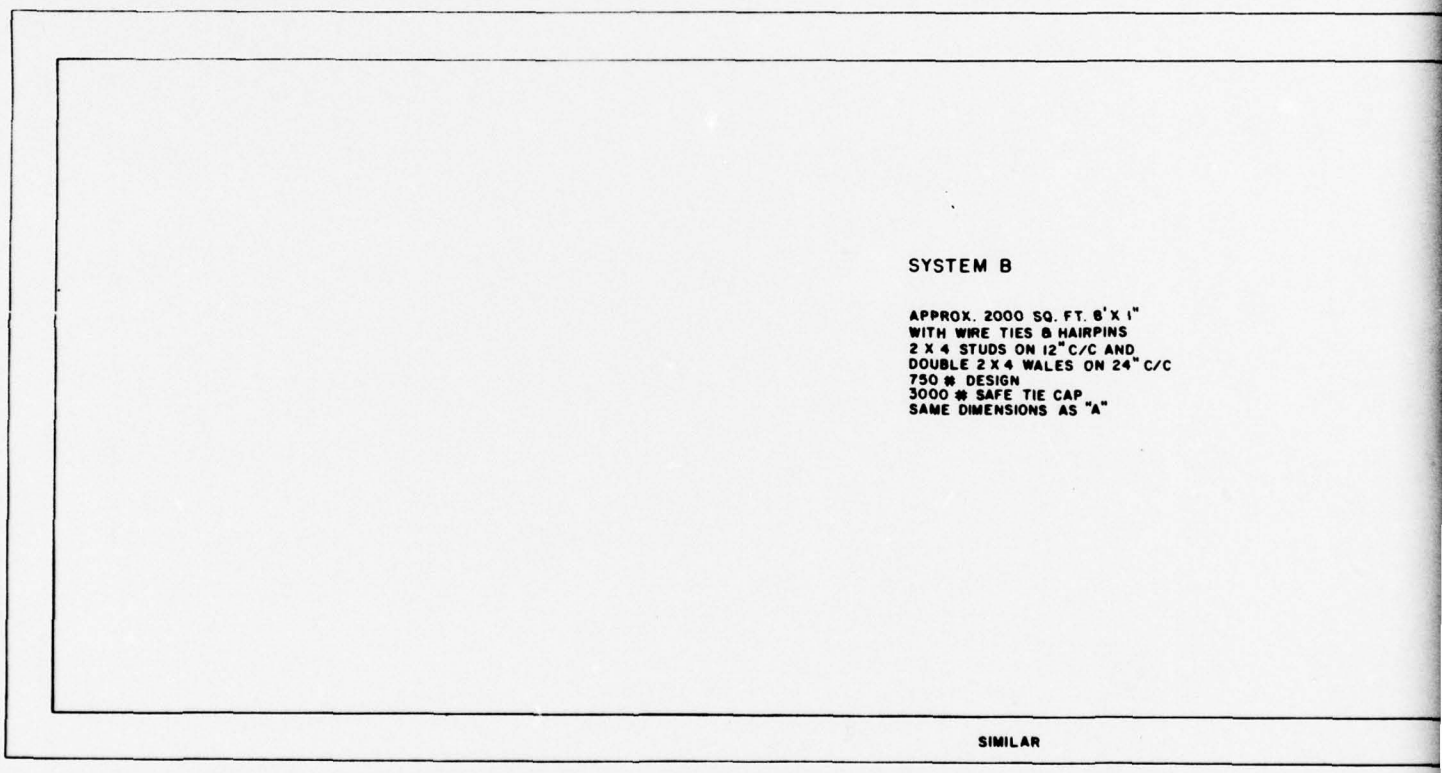

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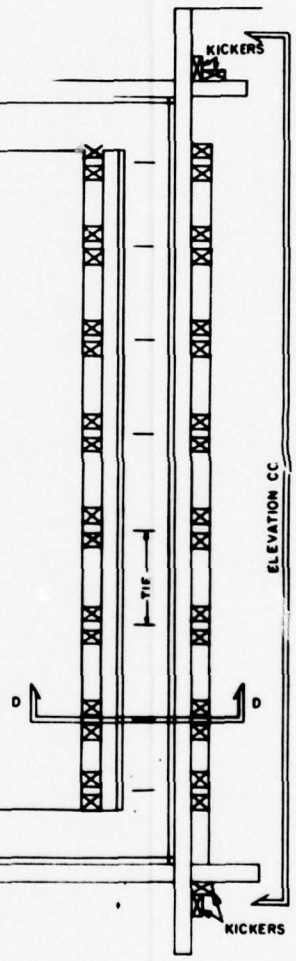

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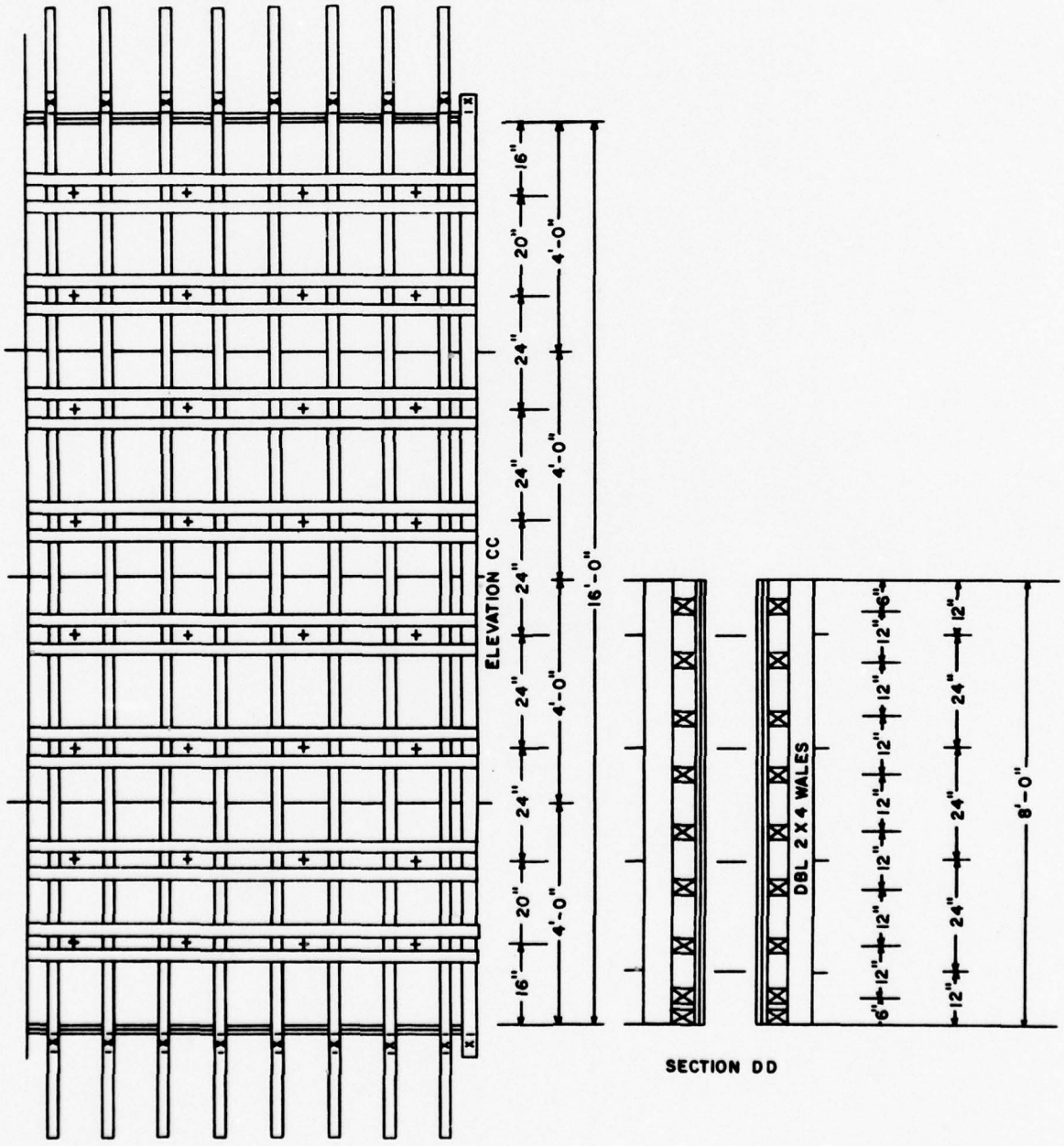

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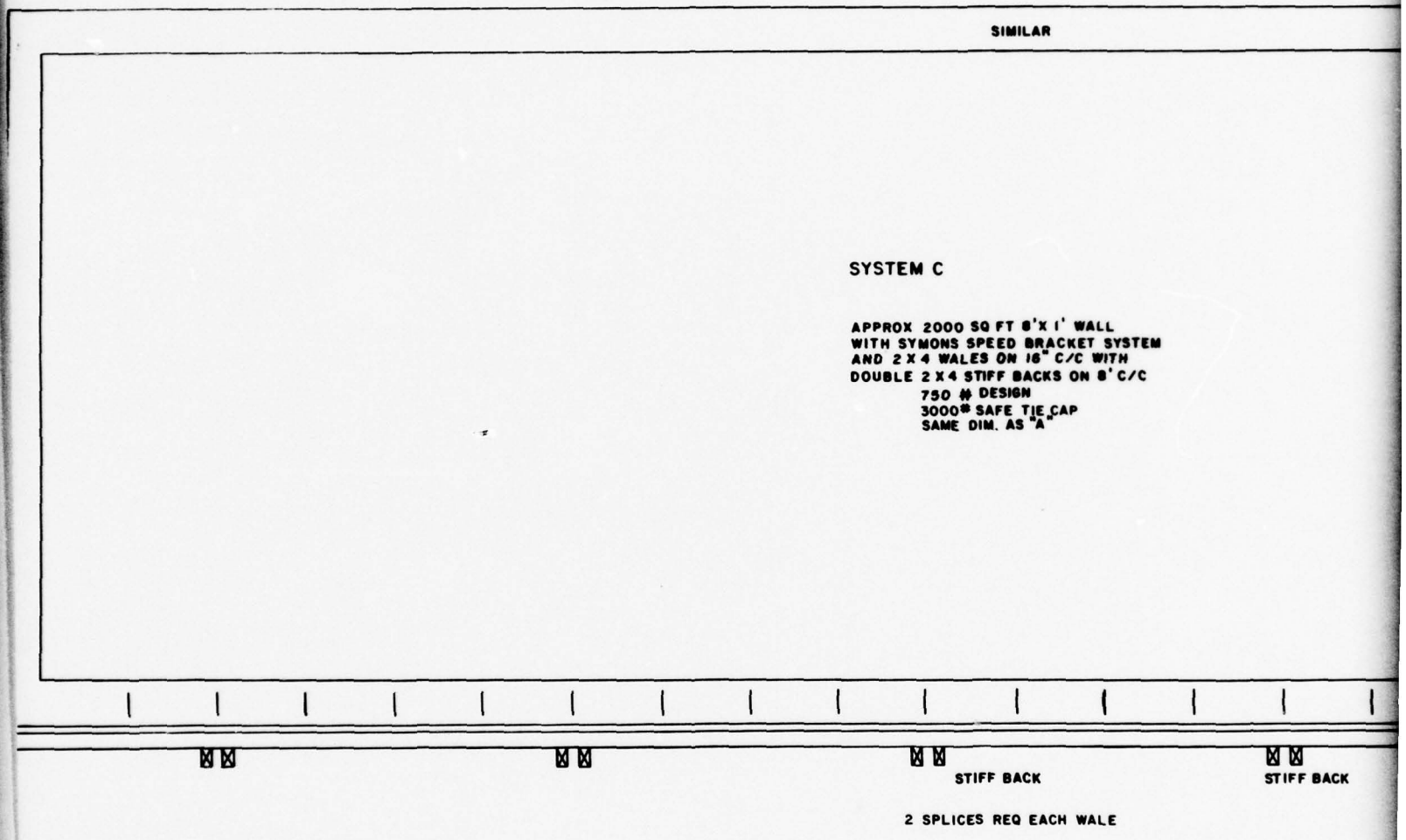

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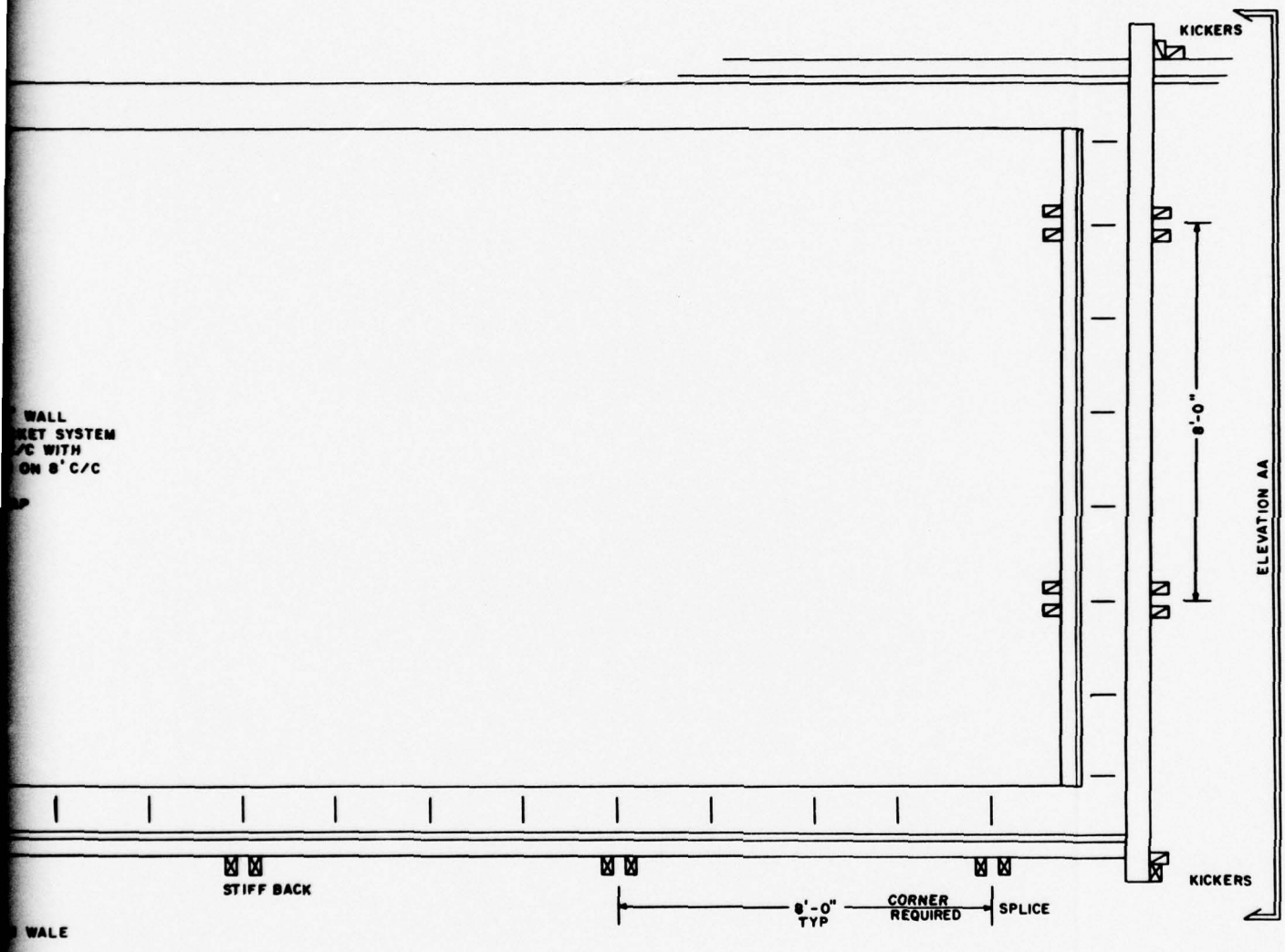

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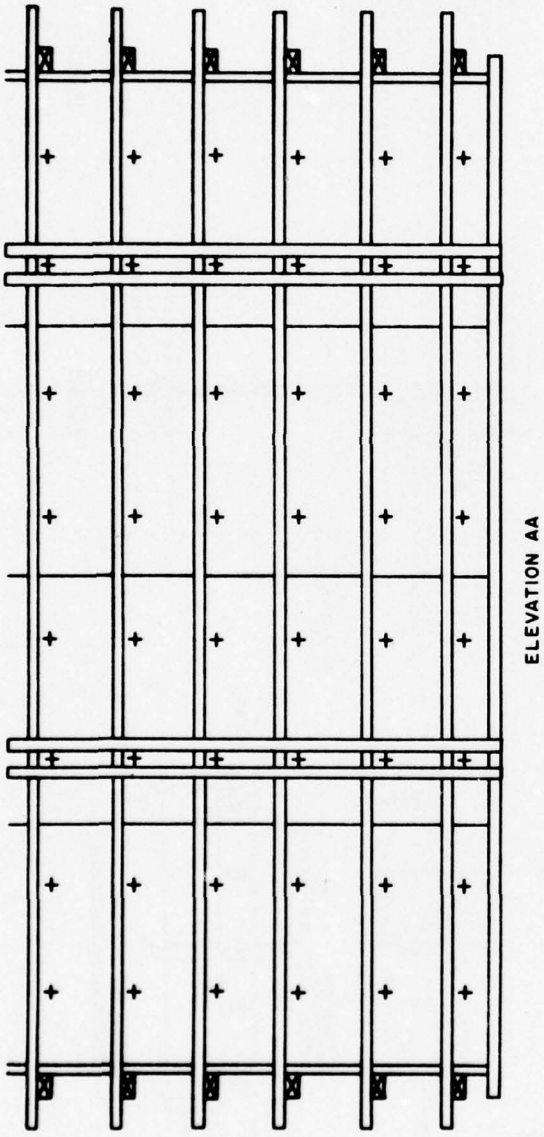

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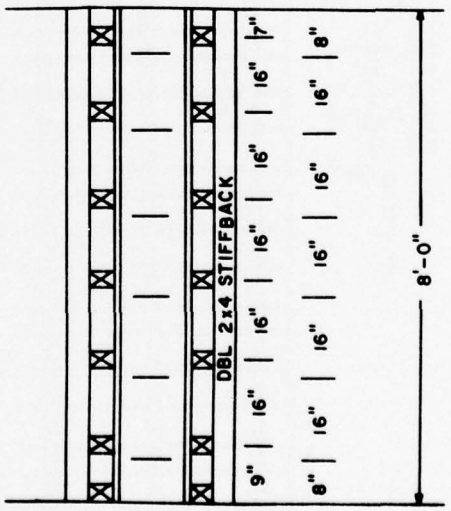

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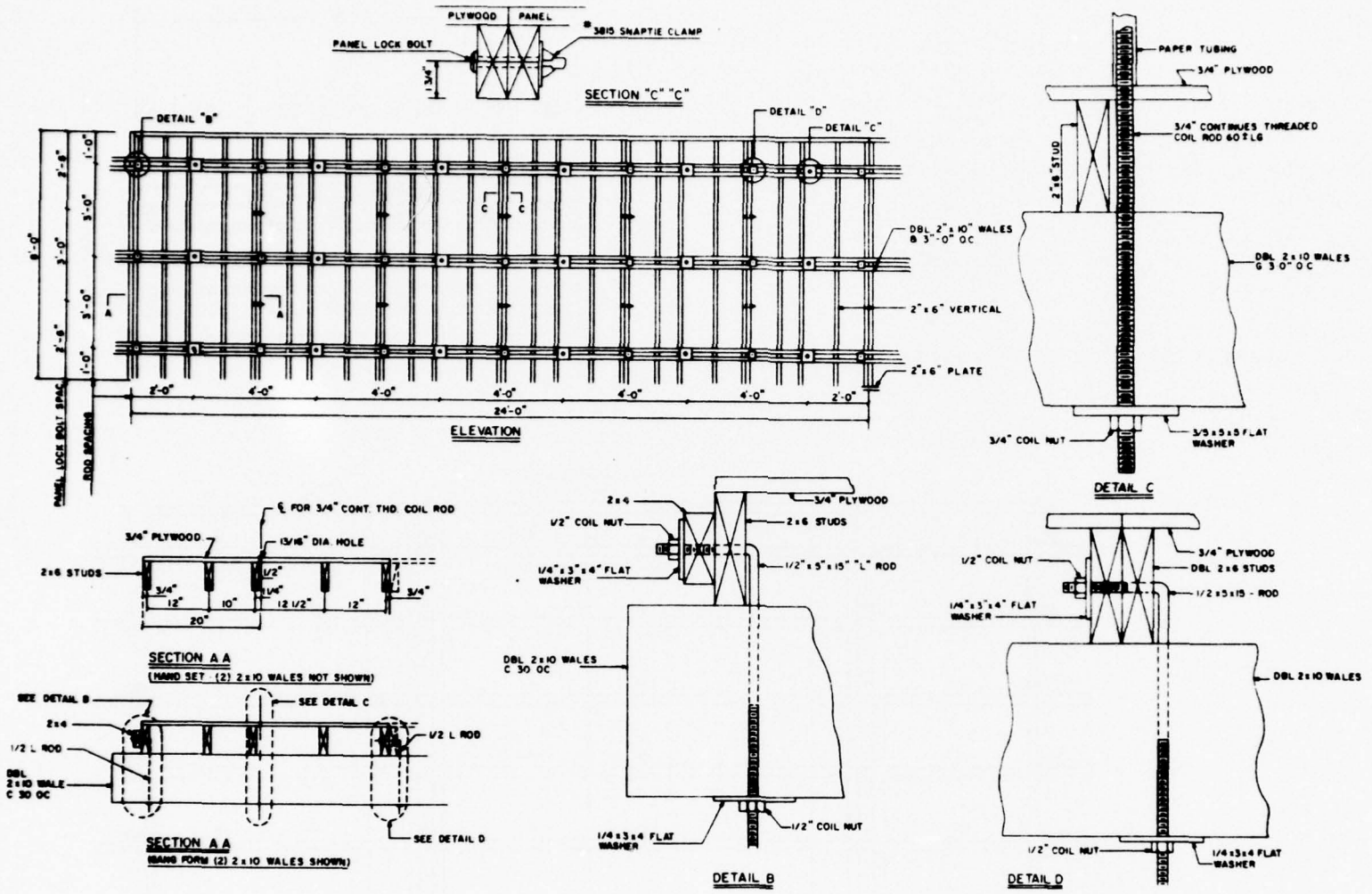

Figure 2. System D.

Table 2
Number of Operations – System A
Tie Wire and Wooden Spacers
(Metric Conversion Factors: 1 ft = .3 m; 1 in. = 25.4 mm)

Description	No. Personnel Req'd	No. Pcs.	No. Opers., 1 Setup	Total Opers., 1 Setup	Sub-Total	No. Opers., 3 Setups	Total Opers., 3 Setups	Sub-Total
Plywood (4 ft by 8 ft by 3/4 in. sheet)	2	64	2	128		6	384	
Holes	1	1344	1	1344		1	1344	
Nails (7/corner)	2	56	2	112		6	336	
Cuts	2	8	1	8	1592	1	8	2072
Lumber								
2 by 4 in. plate (16 ft long)	2	16	2	32		6	96	
Nails (5/Pc)	2	80	2	160		6	480	
2 by 4 studs (8 ft long)	2	256	2	512		6	1536	
Nails (top and bottom)	2	512	2	1024		6	3072	
4 by 4 in. wales (16 ft long)	2	64	2	128		6	384	
Nails (16/corner)	1	64	2	128		6	384	
Spacers (1 by 2 by 12 in.)	2	480	3	1440		9	4320	
Cut Offs (plate and wale)	2	56	1	56	3480	1	56	10328
Hardware								
Ties and twisting	*	672	5	3360	3360	15	10080	10080
					8432			22480

*Three operations require two people.
Two operations require one person.

Table 3
Number of Operations – System B
Snap Ties with Hair Pins
(Metric Conversion Factors: 1 ft = .3 m; 1 in. = 25.4 mm)

Description	No. Personnel Req'd	No. Pcs.	No. Opers., 1 Setup	Total Opers., 1 Setup	Sub-Total	No. Opers., 3 Setups	Total Opers., 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in. sheet)	2	64	2	128		6	384	
Holes	1	512	1	512		1	512	
Nails (7/corner)	2	56	2	112		6	336	
Cuts	2	8	1	8	760	1	8	1240
Lumber								
2 by 4 in. plate (16 ft long)	2	16	2	32		6	96	
Nails (5/Pc)	2	80	2	160		6	480	
2 by 4 in. studs (16 ft long)	2	128	2	256		6	768	
Nails (top and bottom)	2	256	2	512		6	1536	
Nails (corners)	1	128	2	256		6	768	
2 by 4 in. wales (8 ft long)	2	256	2	512		6	1536	
2 by 4 in. kickers (8 ft long)	2	8	2	16		6	48	
Nails	2	128	2	256		6	768	
Cuts (plate and studs)	2	72	1	72	2072	1	72	6072
Hardware								
Ties	*	256	3	768		9	2304	
Hair pins	1	512	2	1024		6	3072	
Weld (tie ends)	1	256	3**	768	2560	9	2304	7680
					5392			14992

*One operation requires two people (feed tie through).
Two operations require one person (breakoffs).
**Cut tie wire, position tie ends, weld.

Table 4
Number of Operations – System C
Single-Waler System (Symons Speed Bracket)
(Metric Conversion Factors: 1 ft = .3 m; 1 in. = 25.4 mm)

Description	No. Personnel Req'd	No. Pcs.	No. Opers., 1 Setup	Total Opers., 1 Setup	Sub-Total	No. Opers., 3 Setups	Total Opers., 3 Setups	Sub-Total
Plywood	2	64	2	128		6	384	
Holes	1	768	1	768		1	768	
Nails (7/corner)	2	56	2	112		6	336	
Cuts	2	8	1	8	1016	1	8	1496
Lumber								
2 by 4 in. plates (16 ft long)	2	16	2	32		6	96	
Nails (5/Pc)	2	80	2	160		6	480	
2 by 4 in. wales (16 ft long)	1	96	2	192		6	576	
No nails				–			–	
Splices (2 by 4 to 8 ft long)	1	24	2	48		6	144	
Corner splices (2 by 4 to 8 ft long)	1	24	2	48		6	144	
Stiffbacks (dbl 2 by 4 to 8 ft long)	1	64	2	128		6	384	
No nails				–			–	
Kickers (2 by 4 to 8 ft long)	2	8	2	16		6	48	
Nails	2	128	2	256		6	768	
Cuts (plate)	2	8	1	8	888	1	8	2648
Hardware								
Ties	1	384	3	1152		9	3456	
Waler brackets	1	768	2	1536		6	4608	
Stiffback brackets	1	192	2	384		6	1152	
Weld (ties)	1	384	3	1152	4224	9	3456	12672
					6128			16816

Table 5
Number of Operations – System D
3/4-in.-Diameter Continuous Threaded Coil Rod*
(Metric Conversion Factors: 1 ft = .3m; 1 in. = 25.4 mm)

Description	No. Personnel Req'd	No. Pcs.	No. Opers., 1 Setup	Total Opers., 1 Setup	Sub-Total	No. Opers., 3 Setups	Total Opers., 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in.)	2	64	2	128		6	384	
Holes	1	192	1	192		1	192	
Nails (7/corner)	2	56	2	112		6	336	
Cuts	2	8	1	8	440	1	8	920
Lumber								
2 by 6 in. studs (8 ft long)	2	384	2	768		6	2304	
Nails (3/stud)	2	1152	2	2304		6	6912	
Cuts	2	64	1	64		1	64	
2 by 10 in. wales (16 ft long)	2	96	2	192		6	576	
Nails (3 every 4 ft–spacer block–dbl-wale)	2	576	2	1152		6	3456	
Nails (24/corner–wale splices)	1	96	2	192		6	576	
Cuts (wales–corners and splices)	2	96	1	96		1	96	
2 by 6 in. kickers+ (8 ft long)	2	8	2	16		6	48	
Nails	2	128	2	256	5040	6	768	14800
Hardware								
Ties	**	96	2	192		6	576	
Flat washers	1	192	2	384		6	1152	
Lagnuts	1	192	2	384		6	1152	
Metal conduit (this wall steel, 1 in. diameter)	1	96	2	192	1152	6	576	3456
					6632			19176

*Hole patching not included as operation.

**One operation requires two people (feed tie through; one operation requires one person (pull tie out).

+External ties (instead of kickers) may be necessary at corners.

Table 6
Number of Operations – System E
1/2-in.-Diameter Continuous Threaded Coil Rod*
(Metric Conversion Factors: 1 ft = .3m; 1 in. = 25.4 mm)

Description	No. Personnel Req'd	No. Pcs.	Total No. Opers., 1 Setup	Opers., 1 Setup	Sub-Total	No. Opers., 3 Setups	Total Opers., 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in. sheet)	2	64	2	128		6	384	
Holes	1	512	1	512		1	512	
Nails (7/corner)	2	56	2	112		6	336	
Cuts	2	8	1	8	760	1	8	1240
Lumber								
2 by 4 in. plate (16 ft long)	2	16	2	32		6	96	
Nails (5/Pc)	2	80	2	160		6	480	
2 by 4 in. studs (16 ft long)	2	128	2	256		6	768	
Nails (top and bottom)	2	256	2	512		6	1536	
Nails (corners)	1	128	2	256		6	768	
2 by 4 in. wales (8 ft long)	2	256	2	512		6	1536	
2 by 4 in. kickers (8 ft long)	2	8	2	16		6	48	
Nails	2	128	2	256		6	768	
Cuts (plate and studs)	2	72	1	72	2072	1	72	6072
Hardware								
Ties	**	256	2	512		6	1536	
Flat washers	1	512	2	1024		6	3072	
Lagnuts	1	512	2	1024		6	3072	
Metal conduit (thin wall steel, 3/4 in. diameter)	1	256	2	512	3072	6	1536	9216
					5904			16528

*Hole patching not included as operation.
**One operation requires two people (feed tie through).
Two operations require one person (pull tie out).

Table 7
Materials Cost
System A – Tie Wire and Wooden Spacers
(Metric Conversion Factors: 1 ft = .3 m: 1 in. = 25.4 mm)

Description	Unit	Cost ($) Per Unit	Quantity of Units, 1 Setup	Total Cost, 1 Setup	Sub-Total	Quantity of Units, 3 Setups	Total Cost, 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in.)	Sheet	9.19	64	588.16	588.16	64	588.16	588.16
Lumber								
2 by 4 in. plate (16 ft long)	lin ft	0.158	256	40.45		256	40.45	
2 by 4 in. studs (8 ft long)	lin ft	0.158	2048	323.58		2048	323.58	
4 by 4 in. wales (16 ft long)	lin ft	0.507	1024	519.17		1024	519.17	
Spacers (1 by 2 by 12 in.)	lin ft	0.05	480	24.00	907.20	480	24.00	907.20
Hardware								
Ties	Each	0.03	672	20.16	20.16	2016	60.48	60.48
					1515.52			1555.84

Table 8
Materials Cost
System B – Snap Ties With Hairpins
(Metric Conversion Factors: 1 ft = .3 m: 1 in. = 25.4 mm)

Description	Unit	Cost ($) Per Unit	Quantity of Units, 1 Setup	Total Cost, 1 Setup	Sub-Total	Quantity of Units, 3 Setups	Total Cost, 3 Setups	Sub-Total
Plywood (4 by 8 ft by 4 in.)	Sheet	9.19	64	588.16	588.16	64	588.16	588.16
Lumber								
2 by 4 in. plate (16 ft long)	lin ft	0.158	256	40.45		256	40.45	
2 by 4 in. studs (16 ft long)	lin ft	0.158	2048	323.58		2048	323.58	
2 by 4 in. wales-dbl (8 ft long)	lin ft	0.158	2048	323.58		2048	323.58	
2 by 4 in. kickers (8 ft long)	lin ft	0.158	64	10.11	697.72	64	10.11	697.72
Hardware								
Ties	Each	0.14	256	35.84		768	107.52	
Hairpins	Each	0.25	512	128.00		512	128.00	
Weld (tie ends)	Each	0.10	256	25.60	189.44	768	76.80	312.32
					1475.32			1598.20

Table 9
Materials Cost
System C – Single-Waler System (Symons Speed Bracket)
(Metric Conversion Factors: 1 ft = .3 m: 1 in. = 25.4 mm)

Description	Unit	Cost ($) Per Unit	Quantity of Units, 1 Setup	Total Cost, 1 Setup	Sub-Total	Quantity of Units, 3 Setups	Total Cost, 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in.)	Sheet	9.19	64	588.16	588.16	64	588.16	588.16
Lumber								
2 by 4 in. plate (16 ft long)	lin ft	0.158	256	40.45		256	40.45	
2 by 4 in. wales (16 ft long)	lin ft	0.158	1536	242.69		1536	242.69	
2 by 4 in. splices (8 ft long)	lin ft	0.158	384	60.67		384	60.67	
2 by 4 in. stiffbacks (8 ft long)	lin ft	0.158	512	80.90		512	80.90	
2 by 4 in. kickers	lin ft	0.158	64	10.11	434.82	64	10.11	434.82
Hardware								
Ties	Each	0.14	384	53.76		1152	161.28	
Weld (ties)	Each	0.10	384	38.40		1152	115.20	
Waler brackets	Each	1.25	768	960.00		768	960.00	
Stiffback brackets	Each	1.25	192	240.00	1292.16	192	240.00	1476.48
					2315.14			2499.46

Table 10
Materials Cost
System D – 3/4 in.- Diameter Continuous Threaded Coil Rod
(Metric Conversion Factors: 1 ft = .3 m: 1 in. = 25.4 mm)

Description	Unit	Cost ($) Per Unit	Quantity of Units, 1 Setup	Total Cost, 1 Setup	Sub-Total	Quantity of Units, 3 Setups	Total Cost, 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in.)	Sheet	9.19	64	588.16	588.16	64	588.16	588.16
Lumber								
2 by 6 in. studs (8 ft long)	lin ft	0.238	3072	731.14		3072	731.14	
2 by 6 in. kickers (8 ft long)	lin ft	0.238	64	15.23		64	15.23	
2 by 10 in. wales	lin ft	0.442	1536	678.91	1425.28	1536	678.91	1425.28
Hardware								
Ties (3/4 in. diameter by 61 in. long)	Each	2.34	96	224.64		96	224.64	
Flat washers (3/8 by 5 by 5 in.)	Each	0.90	192	172.80		192	172.80	
Lagnuts	Each	0.38	192	72.96		192	72.96	
Metal conduit	lin ft	0.20	96	19.20	489.60	288	57.60	528.00
					2503.04			2541.44

Table 11
Materials Cost
System E – 1/2-in.-Diameter Continuous Threaded Coil Rod
(Metric Conversion Factors: 1 ft = .3m; 1 in. = 25.4 mm)

Description	Unit	Cost ($) Per Unit	Quantity of Units, 1 Setup	Total Cost, 1 Setup	Sub-Total	Quantity of Units, 3 Setups	Total Cost, 3 Setups	Sub-Total
Plywood (4 by 8 ft by 3/4 in.)	Sheet	9.19	64	588.16	588.16	64	588.16	588.16
Lumber								
2 by 4 in. plate (16 ft long)	lin ft	0.158	256	40.45		256	40.45	
2 by 4 in. studs (16 ft long)	lin ft	0.158	2048	323.58		2048	323.58	
2 by 4 in. wales-dbl (8 ft long)	lin ft	0.158	2048	323.58		2048	323.58	
2 by 4 in. kickers (8 ft long)	lin ft	0.158	64	10.11	697.72	64	10.11	697.72
Hardware								
Ties (1/2-in.-diameter continuous threaded rod 45 in. long)	Each	1.01	256	258.40		256	258.40	
Lagnuts	Each	0.21	512	107.52		512	107.52	
Flat washers (1/4 by 3 by 4 in.)	Each	0.2425	512	124.16		512	124.16	
Metal conduit (3/4-in. nominal diameter)	lin ft	0.1166	256	29.85	519.93	768	89.55	579.63
					1805.81			1865.51

Table 12
Summary – Number of Operations

	ONE SETUP					THREE SETUPS				
System	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
One-Person Operations	2816	3072	5408	1440	3584	5760	8192	14688	3936	9728
No. Opers./Sq Ft	1.42	1.55	2.73	0.73	1.81	0.97	1.38	2.47	0.66	1.63
Two-Person Operations	5616	2320	720	5192	2320	16720	6800	2128	15240	6800
No. Opers./Sq Ft	2.83	1.17	0.36	2.62	1.17	2.81	1.14	0.36	2.56	1.14
Totals	8432	5392	6128	6632	5904	22480	14992	16816	19176	16528
No. Opers./Sq Ft	4.25	2.27	3.09	3.34	2.98	3.78	2.52	2.83	3.22	2.78
Normalized	1.56	1.00	1.14	1.23	1.10	1.50	1.00	1.12	1.28	1.10
Adjusted Totals	14048	7712	6848	11824	8224	39200	21792	18944	34416	23328
Normalized	2.05	1.13	1.00	1.73	1.20	2.07	1.15	1.00	1.82	1.23

1984 sq ft (179 m^2)/1 Setup
5952 sq ft (536 m^2)/3 Setups

Table 13
Criteria Summary

Criteria	Versatile Wall Thickness and Shape	Number of Operations for One Setup: Normalized Totals	Number of Operations for One Setup: Normalized Adjusted Totals	Material Cost (in Dollars): One Setup	Material Cost (in Dollars): Three Setups	Easily Ganged	Storage and Mobility	Easily Modified to Withstand Full Liquid Head
System								
A	Yes	1.56	2.05	1515.52	1555.84	No	Good – very good	No
B	Yes	1.00	1.13	1475.32	1598.20	Yes	Good	No
C	Yes	1.14	1.00	2315.14	2499.46	No	Good – very good	Yes
D	Yes	1.23	1.73	3928.32	3966.72	Yes	Fair – good	No
E	Yes	1.10	1.20	1805.81	1865.51	Yes	Good	Yes

Although System C can be erected and stripped rapidly, it cannot be ganged easily. System C requires 38 percent less 2-by-4 lumber than System E (2752 lin ft [826 m] were required in C versus 4416 lin ft [1325 m] in E); therefore, the reduction in volume and weight of 2-by-4 lumber to be handled is significant.

The number of pieces comprising the metal hardware of Systems C and E is approximately the same. System C is limited to 2-by-4 and 4-by-4 lumber (3 3/8 in. to 3 5/8 in. [84 to 90 mm]) and 5/8- or 3/4-in. (15- to 18-mm) plywood. The initial relatively high cost of the metal brackets in System C would be offset by the lumber savings. For example, the difference of 1664 lin ft (499 m) of 2-by-4 lumber is approximately $260, and the initial cost of the brackets is approximately $1200. Thus, the cost of the brackets could eventually be covered.

The overall versatility of System E with respect to wall thickness and shape, rate of pour, type of lumber, and efficient use of lumber is unmatched. System E can probably not be erected as rapidly as System C, as indicated by the total number of operations and the adjusted totals in Table 13. In addition, System C is a two-person operation, whereas System E is a three- to four-person operation. Another disadvantage of System E is that holes must be patched or plugged. The inside surface of the metal conduit may cause some bonding problems when it is patched. If necessary, the conduit surface can be made bondable (if it is not already bondable). Caulking the holes may be an alternative to patching.

The advantages and disadvantages of Systems C and E are summarized in Table 14.

Table 14
Advantages and Disadvantage of Systems C and E

System	Advantages	Disadvantages
C	Two-person operation	Welding of ties required
	Rapid	Not easily ganged
	Saves lumber	Restricted to 2-by-4 and 4-by-4 lumber and 5/8-in. and 3/4-in. plywood
	Order of operations not very important	
		Possible material shortage
E	Versatile with respect to:	Holes must be patched (if required)
	Wall thickness and shape	
	Rate of pour	Three- to four-person operation
	Lumber sizes	
	Efficient use of lumber	Order of operations important
	Ganging	

3 REBAR CUTTING AND BENDING

Reinforcing bars up to and including No. 8 bar (1 in. [25 mm] nominal diameter) must be cut and bent. The Willard Manufacturing Company manufactures a combined rebar cutter and bender called the Willard Cutter-Bender. This compact, portable hand tool weighs approximately 70 lb (28 kg) and bends all shapes of rebar up to and including 3/4-in. (18-mm) diameter (No. 6) bar. The Cutter-Bender also cuts all rebar up to and including a 5/8-in. (15-mm) diameter (No. 5) bar. It will also cut No. 6 mild rebar, but is not recommended for No. 6 rebar, which is not mild steel. The reproducibility of the bends produced by this cutter depends on the operator.

The Willard Cutter-Bender retails for approximately $120, including delivery. This cutter-bender has been on the market for more than 12 years and has been used by the Armed Forces. The product is listed with the Defense Supply Agency in Richmond, VA, as follows:

> Part Number—3/4 CAP 6 REBAR, ITEM NAME—Bender and Cutter, Bar, Hand Operated; FSN (Federal Stock Number) 3441-175-6213, MFR Code—24695

The American Peddinghaus Corporation sells a hand-operated hydraulic bender which can bend a bar having a diameter as large as 1 in. (25 mm) (a No. 8 bar). This bender is compact and portable and sells for approximately $232.

The Midland Products Company manufactures a mobile apparatus for field use that can cut and bend rebar. The unit is designated Series 4 and has the following characteristics:

- Cuts and bends bars through No. 11 for both 40 and 60 ksi/min yield
- Approximate dimensions: 7 ft long by 5 ft wide by 4.5 ft high (2.1 by 1.5 by 13.5 m)
- Gasoline engine: 18 Hp—$10,700
- Electric engine: 20 Hp—$10,500
- Total weight of unit—3300 lb (1320 kg)
- Axles, wheels, tires, etc., included in price; spiral ($1100) and stirrup ($310) bending attachments are extra.

4 REBAR SUPPORT, TYING, SPLICING, AND COLUMN-FORMING AIDS

Support and Tying

Rebar support systems require the supporting and tying of rebar (through No. 8) for TO slabs, footers, walls, columns, etc.

Support

Rebar support chairs and slab bolsters are standard items. Using slab bolsters to support rebar during slab construction may be quicker than using individual chairs; however, chairs are easier to use in certain applications, such as supporting footing steel. If the slab is on fill, gravel, or similar material, a slab bolster or chair with plate support may be advantageous; however, other supportive devices under the chairs and/or slab bolsters can be used, such as metal plate, etc. Since TO structures are assumed to have a 2- to 5-year design life, appearance is not a main concern. Therefore, the lowest priced chairs and bolsters should be used.

Tying

Hard twisters and bar ties which are precut and looped on both ends will enable rebar to be tied rapidly. Precut bar ties are available in a variety of sizes. Wire holders which a worker can wear on a belt and coils of tie wire are also available.

Combined Support and Tying

Gateway Building Products sells a "G-Loc Clip Chair," which is used to support and tie *bottom* steel in typical flat-slab, plate, and beam designs. Both 3/4-in. (18-mm) and 1-in. (25-mm) support height are provided and are limited to any combinations of two perpendicular No. 3, 4, or 5 bars.

The Richmond Screw Anchor Company manufactures a "Special Bar Support/Spacers" system, which is designed according to customer specifications. The system, which is designed to support and accurately space various layers of rebar, will handle any combination of rebar sizes and heights (no tie wire is needed).

Splices

Clamps are available that join two compression reinforcing bars in perfect axial alignment, with the ends of the bars saw cut to 90° for full bearing. These clamps are to be used for *compression* steel only, and are used instead of welding or other mechanical techniques. (Gateway Building Products' "G-Loc Clamp" and other similar products are available.)

Erico Products, Inc., manufactures a product called "Cadweld," which can be used to splice both tension and compression rebar. An exothermic reaction is used to weld a metal sleeve, using a special filler over the rebar ends.

A product called "Stricon," manufactured by Slygab Co., can be used to splice both tension and compression rebar. "Stricon" is a mechanical ultimate strength splice, in which a preheated metal sleeve is placed over the rebar ends and squeezed over the deformations to form a splice. Generally, the compression-only splices are more economical and considerably easier to use than the tension-compression splices.

Column-Forming Aids

Steel column clamps for forming and squaring rectangular columns are a standard item. Steel strapping (commonly used in packaging) can also serve as a column form clamp. The steel strapping has the advantages of being lightweight, easily storable, and easily movable; however, a disadvantage is that the squareness of the column is not automatically insured. Based on overall versatility for rectangular columns, Signode recommends: Strap Size 3/4 × 0.031 Magnus (waxed); Seal No. 34HC; Tensioner No. T; Sealer (to crimp) No. SYC 3435, and a Cutter No. 2. Strapping dispensers afford convenience and should be considered.

Round column fiber-forming tubes such as those available from Gateway Building Products are also a standard column-forming method.

5 FORM RELEASE AGENTS, CURING COUMPOUNDS, AND AIR-ENTRAINING AGENTS

Form Release Agents

Form release agents are a standard item and are commonly used for construction formwork. Based on a premixed product, 55-gal (209-ℓ) drum quantities cost about $1.25/gal ($.33/ℓ). Neither freezing nor a short shelf life is a problem. Two products usually recommended are Symons Corporation's "Magic Kote" and Richmond Screw Anchor Company's "Rich Cote." A concentrated form is available from both companies. Both concentrates require No. 2 distilled, but either can use diesel fuel. The dilution ratio for both is 3:1

Curing Compounds

W. R. Meadows, Inc., markets an all-resin "AR-30" curing compound. Sika Chemical markets "ANTISOL," a clear, curing compound. The cost of each is approximately $1.75 to $2.25/gal ($.46 to $.59/ℓ) in 55-gal (209-ℓ) drum quantities. Neither a short shelf life nor freezing is a problem. The W. R. Meadows product comes in a concentrated form; the ratio of concentrate to mineral spirits is 1:1.

Air-Entraining Agents

Sika Chemical Co. markets "SIKA AER," an air-entraining agent which has an unlimited shelf life, but which should be discarded if it freezes. Sika also manufactures a double-strength concentrate.

W. R. Grace Co. markets the "DAREX AEA" air-entraining agent; if this product freezes, it can be thawed, stirred thoroughly, and used with no problems. The shelf life of this product is unlimited, and a concentrate is available.

The price of the air-entraining agents is approximately $1.50/gal ($.40/ℓ) based on 55-gal (209-ℓ) quantities.

6 CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that the systems listed below are most suitable for TO construction purposes. All the materials, equipment, and hardware proposed for use should be field-evaluated, preferably by an engineering construction group, for example, an Engineer Construction Battalion.

Concrete Form-Fastening Systems

Based on overall versatility, the ½-in. (12.5-mm) diameter continuous threaded coil rod system is recommended (see Figure 3).

For an 8-ft (2.4-m)- high wall that is 12 in. (300 mm) thick, and which has 1984 sq ft (179 m^2) of form face, the following quantities are required (wastage not included):

Ties—35 in. (875 mm) long, 256 required, minimum working load of 4800 lb (1920 kg) (6000 lb [2400 kg] is a typical working load)
Handle lagnuts to fit ties; 512 required
Flatwashers to fit ties and lagnuts; 512 required
Metal conduit of ¾-in. (18-mm) nominal diameter, thin-walled, 270 lin ft (81 m) (810 lin ft [243 m] for three pours)
Plywood in ¾-in. by 4-ft by 8-ft (18-mm by 1.2-m by 2.4-m) sheets; 64 sheets required
Lumber—4416 lin ft (1325 m) of 2-by-4
Plugging or caulking material to fill holes (if required)
Ganging hardware (if needed)

The single-waler system may work best to achieve rapid forming and savings in lumber cost and handling. The single-waler system, however, is not easily ganged, is restricted to 2-by-4 and 4-by-4 lumber, and requires field welding of ties.

Rebar Cutting and Bending

A small, portable, hand-operated, rebar cutter and bender (such as the Willard Cutter-Bender) is recommended for use in the TO. If there is sufficient need to cut and bend larger bar sizes (No. 7 and larger) a centrally located, portable, heavy-duty cutter and bender (such as Midland's equipment) is recommended. A bolt cutter for cutting small rebar is also recommended.

Rebar Support, Tying, and Splicing

Rebar support chairs and slab bolsters should be used. A percentage of the chairs and slab bolsters may have plate support.

Hand twisters and bar ties which are precut and looped at each end are recommended. Continuous tie wire is recommened for operations not covered by precut ties. Wire reels with coils of tie wire may be used for special applications.

Devices which support and tie rebar appear to be too specialized and are not recommended for use in the TO.

Depending on the availability of welding facilities and splicing methods, compression splices and/or tension-compression splices may be required.

Column-Forming Aids

Metal steel strapping is recommended for forming columns. Based on a 22- by 22-in. (550- by 550-mm) square column 12 ft (3.6 m) high and the Signode Corp. Design Guide (using a safety factor of 2), the following quantities are required.

Plywood—3 sheets of 7/8 in. by 4 ft by 8 ft (21 mm by 1.2 m by 2.4 m)

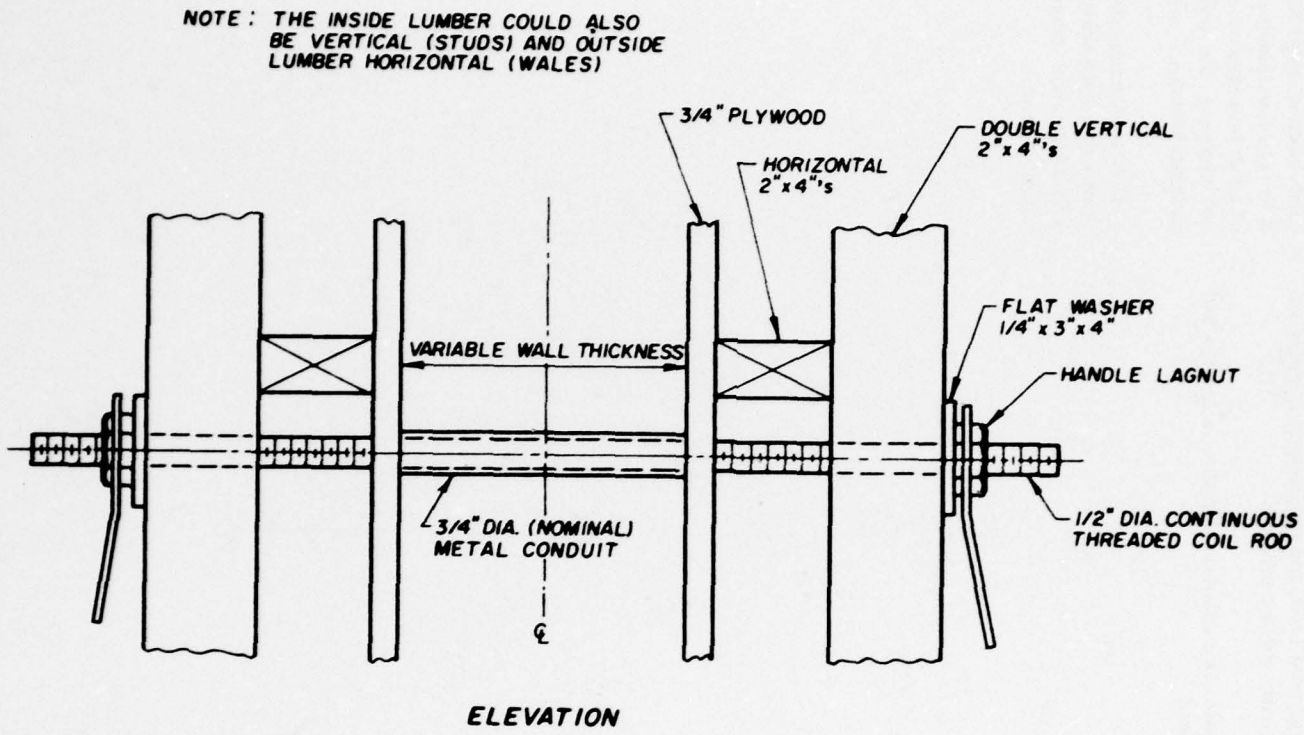

Figure 3. 1/2 in. (12.5-mm) continous threaded coil rod system.
(Metric Conversion Factor: 1 in. = 25.4 mm.)

Lumber—192 lin ft (58 m) of 2-by-4 and 48 lin ft (14 m) of 1- by 4-in. (25- by 100-mm) cleat

Metal Strapping—3/4 by 0.031 in. (18 by .8 mm) 138 lin ft, 12 seals. A tensioner, sealer, and cutter are required tools, and obtaining a strapping dispenser should be considered.

The above are minimum quantities; waste has not been included.

Form Release Agents, Curing Compounds, and Air-Entraining Agents

It is recommended that a form release agent be used; use of a curing compound is recommended for structural concrete only. Air entrainment is recommended if increased workability of the concrete is desired. Use of air entrainment to obtain freeze-thaw resistance is not necessary for walls, slabs, and other structural elements having a 2- to 5-year design life.

If it is economically feasible, products should be chosen that have unlimited shelf life, do not degrade with temperature extremes, and can be shipped in concentrated form.

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Recommendations for concrete forming kit for theater of operations applications.--Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from National Technical Information Service , 1978.
38 p. : ill. ; 37 cm. (Technical report - Construction Engineering Research Laboratory ; M-252)

1. Concrete construction--formwork. 2. U. S. Army-military construction operations. I. Title. II. Series: U.S. Construction Engineering Research Laboratory. Technical report ; M-252.