

ONE-WAY CONCRETE JOIST CONSTRUCTION: STEEL LAP PAN FORMING SYSTEM

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INTRODUCTION

This type of construction has frequently utilized ready-made steel pan forms of standard sizes. Depths and spacings for one-way concrete joist construction were standardized in 1932 by the U.S. Department of Commerce on the basis of an industry study by a committee of Architects/Engineers, Contractors and Steel Form Suppliers. That early standard has since been replaced by ANSI/CRSI A48.1-1986 "Forms for One-Way Joist Construction," which establishes standard dimensions for one-way joist forms. Standard form widths are 20, 30, 40*, 53* and 66* inches, corresponding to structural modules ranging from 2 to 6 feet. Standard depths are 8, 10, 12, 14, 16, 18, 20, 22* and 24* inches. Not all depths are manufactured in each form width. Filler forms and tapered endforms are usually available locally to fit varying floor layouts and sizes. This type of construction is well established with a long record of successful use.

Joist construction was developed to reduce dead weight and reinforcement. As desired spans increase, the efficiency of solid slab construction is rapidly offset by the increase in the dead load. Joist construction enables the Architect/Engineer to provide the depth required for adequate stiffness and efficient utilization of the reinforcement without excessively high dead load/live load ratios. Standard size reusable forms make it possible to eliminate unnecessary dead weight with overall economy. Longer spans or relatively heavy loads can be accommodated by using tapered end forms which permit widening of the ribs in areas of high shear.

DESCRIPTION

One-way concrete joist construction provides a monolithic combination of regularly-spaced joists (ribs) and a thin slab of concrete cast in place to form an integral unit with the supporting beams, columns and walls. In one-way concrete joist construction, the joists are arranged in one direction between parallel supports. Joist rib widths vary from 4 to 6 inches. Standard endforms consist of square endforms. A tapered endform for a 2-foot module tapers from 20

to 16 inches wide in a distance of 36 inches. A tapered endform for a 3-foot module tapers from 30

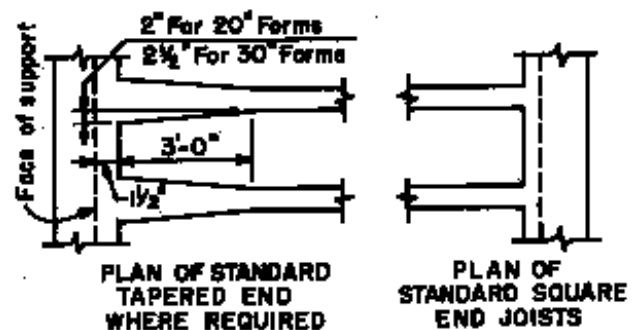


Figure 1 Tapered Endforms

to 25 inches (in some systems 26 inches) wide in a distance of 36 inches. See Figure 1.

Wide-module joist systems (also referred to as "skip-joist" systems) are defined as joist systems with a clear spacing between the ribs of more than 30 inches. Since this module, for application of the ACI Building Code, exceeds the rib spacing limit for standard joist construction (Section 8.11.3), wide-module joists become repetitive "T" beams and are subject to design requirements for such members.

Joist widths for wide-module joist systems vary from 6 to 8 inches. Standard forms for void spaces between ribs are 40, 53 or 66 inches wide and 12, 14, 16, 18, 20, 22 or 24 inches deep. Standard endforms consist of square endforms. Use of square end joist forms simplifies forming. Tapered endforms are generally not available for wide-module systems. See Table 1.

FORMWORK SELECTION CONSIDERATIONS

Maximum overall economy in concrete joist construction, as in any cast-in-place reinforced concrete design, is achieved by considering the relatively high cost of formwork and construction time versus material costs. Almost invariably overall economy is achieved by the maximum reuse of the same forms throughout the project, not only throughout each floor but also the same layout and

* For wide-module joists only.
1 inch = 25.4 millimeters

TABLE 1 Standard Dimensions of Forms for One-way Joist Construction¹

| System | Standard Forms | | Special Filler Forms ⁴ | |
|--------------------|--------------------|----------------------|-----------------------------------|----------------------|
| | Width ² | Depth ³ | Width ² | Depth ³ |
| 2I-00 | 20 | 8,10,12 | 10,15 | 8,10,12 |
| 3I-00 ⁵ | 30 | 8,10,12,14,16,20 | 10,15,20 | 8,10,12,14,16,20 |
| 4I-00 ⁶ | 40 | 12,14,16,18,20,22,24 | 20,30 | 12,14,16,18,20,22,24 |
| 5I-00 | 53 | 16,20 | — | — |
| 6I-00 | 66 | 14,16,20 | — | — |

NOTES

- All dimensions are in inches, except the module designations.
- Width is the horizontal clear distance, between two consecutive joists, measured at the bottom of the joists.
- Depth is the vertical distance, measured between two consecutive joists, from the underside of the concrete slab to the bottom of the joists.
- Special filler forms may be available only in limited quantities. Availability should be investigated before specifying these forms.
- Tapered endforms are available for the one-way 3I-00 module. These forms are 30 inches wide at one end and 25 inches wide at the other end, and they are 36 inches long. Standard depths of these forms are 8, 10, 12, 14, 16, and 20 inches.
- Tapered endforms are available for the one-way 4I-00 module. These forms are 40 inches wide at one end and 34 inches wide at the other end, and they are 36 inches long. Standard depths of these forms are 12, 14, 16, 18, 20, 22, and 24 inches. These forms are generally available only on the West Coast.

size of forms for all levels of the structure.

The use of the lap-type steel one-way pan system is probably one of the most efficient methods of reinforced concrete construction ever devised in terms of spans and applied loads versus volume of concrete and weight of reinforcing steel. A steel lap pan system has one major drawback: typically it can produce no better than a Class 'C' finish.

Sectional steel pan forms can adjust to varying site conditions without extensive detailing and fabricating of special shapes. The Architect/Engineer is allowed great freedom in varying joist widths for accommodating concentrated loads by slightly adjusting the center-to-center spacing of the ribs. Clearing blockouts, drops and other interferences is accomplished by workers simply starting and stopping pan runs as required. Steel pan forms are a proper forming system to consider when evaluating design choices because they provide inherently stiff floor systems for the volume of concrete and reinforcing steel, and the forms are economical to obtain and erect when concrete esthetics are not a concern.

Project specifications are often vague with reference to laps and single one-piece voids. The Architect/Engineer's expectations are generally different from those of the Contractor. The Contractor should be very sensitive to the Class of finish for which the pan forms are intended. Lap pans are generally inappropriate for exposed work. The Architect/Engineer's attention should be focused on the end product results during pre-construction meetings as to the finish that these forms are and are not capable of producing. For instance, when pans are lapped, both the joist width and slab thickness vary slightly. ACI 117 tolerances for joists and slabs are +3/8, -1/4 inch in width and thickness (Section 4.4.1). The Contractor needs to ensure that the erection of the formwork is performed with a reasonable degree of accuracy. Finally, the Architect/Engineer may want to recognize the

challenges with this type of forming and specify a joist width one inch larger than required by design. While it is usually better to cast an onsite mockup section, it may be more practical and prudent to have the Architect/Engineer and Owner participate in a site visit to a structure of similar construction and application to measure both esthetics and performance.

FABRICATION AND ERECTION

The typical lap pan is a 16-gauge or a 14-gauge piece of sheet metal, 3 feet long, bent into one of three traditional shapes (see Figure 2) with varying flange widths dependent on style and Supplier. Both ends are open. A chalkline on the deck or soffit form should be used to align the pans. End caps are placed first and work proceeds toward the center of the member from both ends, overlapping the pans until proper closure is achieved. Flanged pans are nailed into position. After the pans are tightly in place, they should be oiled before other trades proceed with their work. See Figure 3.

The normal procedure for setting pans is to set the end caps first, nailed to the deck form on the line where the coffer begins. A long section of pan is first placed over the end cap. Then, through pre-punched matching holes in the top flange of the end cap and the top surface of the pan section, nails are dropped in to form a bond between the form sections. It is not uncommon to see small machine screws or center pin rivets used. However, form stripping procedures need to be considered with these types of fasteners. This connecting procedure also assists in preventing the end cap from collapsing inward under the pressure of concrete placing. The pan section is then nailed in place and a free standing steel or wood diaphragm (internal brace) is inserted into the form (suggested spacing is 18 inches on center under normal concrete placing conditions and should include the lap point between pans) and nailed in

place. The next pan section is then installed, reasonably lapping (1 to 5 inches) the previous section and the previous procedure is repeated until the coffer is completely formed. It should be noted that all pans may require diaphragms to resist lateral pressures. However, 14-gauge pans with a depth of 16 inches or greater should always be installed with internal bracing. The soffits of all steel pans should be strengthened with some type of permanently attached internal brace, the most common of which is a welded sheet metal angle at least of the same gauge as the body of the pan. Because the steel lap pan system is characterized by offsets, fins and

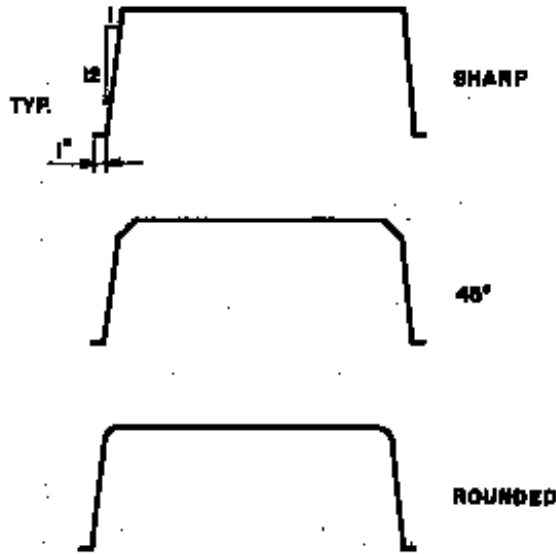


Figure 2 Lap Pan Shapes

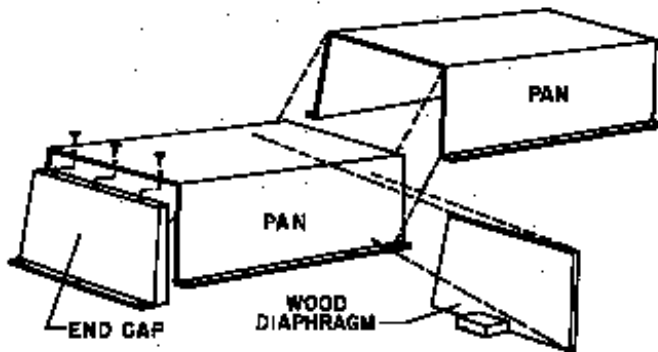


Figure 3 Setting Lap Pans

protrusions as well as chips and dings that result from the removal of the pan sections, the contract documents should include guidance and information on acceptable tolerances for formed surfaces.

It should be pointed out that care must be taken with the installation of any embedded items or mechanical inserts or fixtures. If the attachment of these items is not considered in relationship to the stripping of these forms they may act as anchors preventing the removal of the pan forms. Therefore, it is recommended that only center pin soft rivets be used. The center pin of the rivet will remain exposed

on the underside of the pan form and can be removed prior to stripping. This will allow the body of the rivet to close as the pan is stripped, permitting the easy removal of the forms.

TOLERANCES

Tolerance guidance can be found in several ACI standards and reports. ACI 117, "Standard Tolerances for Concrete Construction and Materials"; ACI 301, "Specifications for Structural Concrete"; and ACI 347R, "Guide to Formwork for Concrete," provide information on finished surfaces, but do not address pan joist surfaces specifically. ACI 117 and ACI 347R limit offsets and other irregularities based on "Class" of surface finish. See Table 2. The ACI 117 standard might be regarded as the most authoritative. The mandatory specification checklist in ACI 117 requires the Architect/Engineer to designate the intended Class of surface finish and thereby establish the tolerance for form offsets. ACI 301 addresses the finishing of formed surfaces in Chapter 2 and differentiates between rough form finishes (those not exposed to public view) and smooth finishes (exposed to public view). ACI 301 requires: "Patch tie holes and defects. Remove all fins completely." for smooth formed finishes, but permits up to 1/4 inch fins for rough finishes. As a default, Article 5.3.3.5 of ACI 301 calls for the finish to be based on exposure to public view where

| Type of Irregularity | Class of Surface Finish | | | |
|----------------------|-------------------------|-----|-----|---|
| | A | B | C | D |
| Gradual (ACI 347R) | 1/8 | 1/4 | 1/2 | 1 |
| Abrupt (ACI 117) | 1/8 | 1/4 | 1/2 | 1 |
| (ACI 347R) | 1/8 | 1/4 | 1/4 | 1 |

Class A: For surfaces prominently exposed to public view where appearance is of special importance.
 Class B: Coarse-textured concrete-formed surfaces intended to receive plaster, stucco, or wainscoting.
 Class C: General standard for permanently exposed surfaces where other finishes are not specified.
 Class D: Minimum-quality surface where roughness is not objectionable, usually applied where surfaces will be concealed.

surface finish is not designated in the contract documents.

TABLE 2 Surface Finish Class

ACI Committee 347 notes that revisions of the 347R report are in progress to change the limit for abrupt offsets within Class C finish to 1/2 inch, consistent with ACI 117. Although ACI 347R cautions against using pry bars directly against concrete to remove formwork, this is common practice in many areas of the country.

CONCLUSION

Surface irregularities should be expected in pan joist construction. It is difficult to patch surface spalls successfully. The patch may be more noticeable

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than the spall. The continuing use of the steel lap pan joist form system remains a proven and excellent method of forming site cast reinforced concrete floor systems in non-critically exposed applications.

REFERENCES

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3. "Specifications for Structural Concrete (ACI 301-96)", American Concrete Institute.
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5. "Building Code Requirements for Structural Concrete (ACI 318-95) and Commentary (ACI 318R-95)", American Concrete Institute.



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