A SunCam online continuing education course

Shoring and Reshoring Fundamentals

by

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SHORING AND RESHORING FUNDAMENTALS

Because it has such a significant impact on schedule and material movements, it is important for everyone involved in the construction of concrete buildings to understand basic concepts of shoring and reshoring, and the purpose and importance of each. This course will provide the reader with the fundamental concepts of shoring, reshoring, backshoring, and construction methods that can affect the design of the same. It will include basic definitions, the differences between shoring, reshoring, and backshoring; and an overview of some important considerations for anyone involved in construction.

DEFINITIONS

Backshores: "Shores left in place or shores placed snugly under a concrete slab or structural member after the original formwork and shores have been removed from a small area, without allowing the entire slab or member to deflect or support its self-weight and construction loads." (*ACI 347R-14*, page 3).

Formwork: "Total system of support for freshly placed concrete, including the mold or sheathing that contacts the concrete as well as supporting members, hardware, and necessary bracing." (*ACI 347R-14*, page 3). See Appendix A for examples of formwork and shoring systems.

Engineered Lumber: A wood product that has been fabricated to certain structural specifications. Laminated Veneer Lumber (LVL) is an example of engineered lumber.

Lacing: Lacing is used to decrease the unbraced length of a shore to increase the capacity. Lacing is typically used in timber framing, but can be used in other types of shoring or reshoring systems.

Mud-Sills: Lumber used to support a shore that would otherwise sit on soil. Mud-sills distribute the shore load across an area big enough not to exceed the allowable soil bearing pressure.

Pour Strip: A section of concrete slab left open to control shrinkage and elastic shortening. It can also be used to provide access to post-tensioning cables. After a prescribed time, the pour strip is closed by pouring the remaining slab.

Shore: "Vertical or inclined support member or braced frame designed to carry the weight of the formwork, concrete, and construction loads." (*ACI 347R-14*, page 3). Shores can be single post shores, sectional shoring towers, truss tables, or another proprietary system. See Appendix A for examples of different types of shores.

Reshores: "Shores placed snugly under a stripped concrete slab or other structural member after the original forms and shores have been removed from a full bay, requiring the new slab or structural member to deflect and support its own weight and existing construction loads to be applied before installation of the reshores." (*ACI 347R-14*, page 3).

Runners or Joists: Horizontal formwork members placed directly below form facing material. Runners are supported by stringers (also called main beams). Runners can be timber, steel, or aluminum.

Stringers or Main Beams: Horizontal formwork members that support runners (also called joists). Stringers are supported by shores. Stringers can be timber, steel, or aluminum.

Stripping: Slang term used for removal of shores, reshores, or backshores. Also called shore removal.

X-Bracing: Members added to shores in an "X" pattern to resist lateral loads imposed by construction operations. X-Bracing can be timber, steel, or aluminum.

WHAT'S THE DIFFERENCE?

It would be difficult to start a discussion on shoring and reshoring fundamentals without giving clarification to the differences between shoring and reshoring.

Many times, contract document general notes will use the terms shoring and reshoring interchangeably. This can lead to confusion when setting a construction schedule.

Shoring supports the concreting operations which include not only the placing and finishing of the concrete but the reinforcing installation and trades that install sleeves, block outs, electrical components, and other items prior to concrete placement. Shoring is removed once the concrete floor has gained adequate strength and, where applicable, the appropriate post-tensioning has been applied.

Reshoring is installed under floors that have been stripped of shoring. Reshoring is utilized to distribute construction loads among several levels or to grade in order that the cast floors will not become overloaded and overstressed.

LOAD PATHS

It is important to distinguish between shoring and reshoring as it directly effects the sequence of construction. In a multi-level concrete building, the floor being constructed should not be poured until all shoring and reshoring is in place and has been inspected by a qualified person. At the time of the pour, the loads are distributed through the in-place floors to reshores below. If the recently cast floor will not self-support and the reshores are stripped, then the construction loads will be transferred directly to cast floors that may not have the capacity to support the added weight. Therefore, it is important to cast, cure, and tension (where applicable) the floor being constructed, then strip the shoring out before removing reshoring.

The shoring and reshoring designer should be cognizant of the post-tensioning specifications and criteria for shoring and reshoring removal. There are many options for a post-tensioned floor; for example, the floor may be designed such that it will not support itself and the design live loads until full post-tensioning has been applied. There are other times when a floor is designed to undergo staged stressing, where only partial tensioning is applied, and the floor will support its self-weight plus a reduced design load. Reshoring designs should account for the actual capacity of the floor during construction operations.

Load paths are important, not only between floors, but also at the upper-most constructed floor. Shoring should be removed in a sequence that accounts for the load path of the building without adding excessive load to the remaining shores. For example, the shoring designer may specify that shores supporting girders should be stripped before those supporting beams, which should be stripped before shores supporting slabs. In this case, if a slab is stripped before its supporting beam, the load from the slab will transfer to the beam, which has not deflected and been allowed to carry its weight and tributary area. The shores under the beam will pick up that extra load and will experience localized overloading. This can damage the shores as well as overstress the floors below. Different buildings and structure types will have different stripping sequences, so it is important for the shoring designer to communicate to the contractor an appropriate stripping sequence for the specific project.

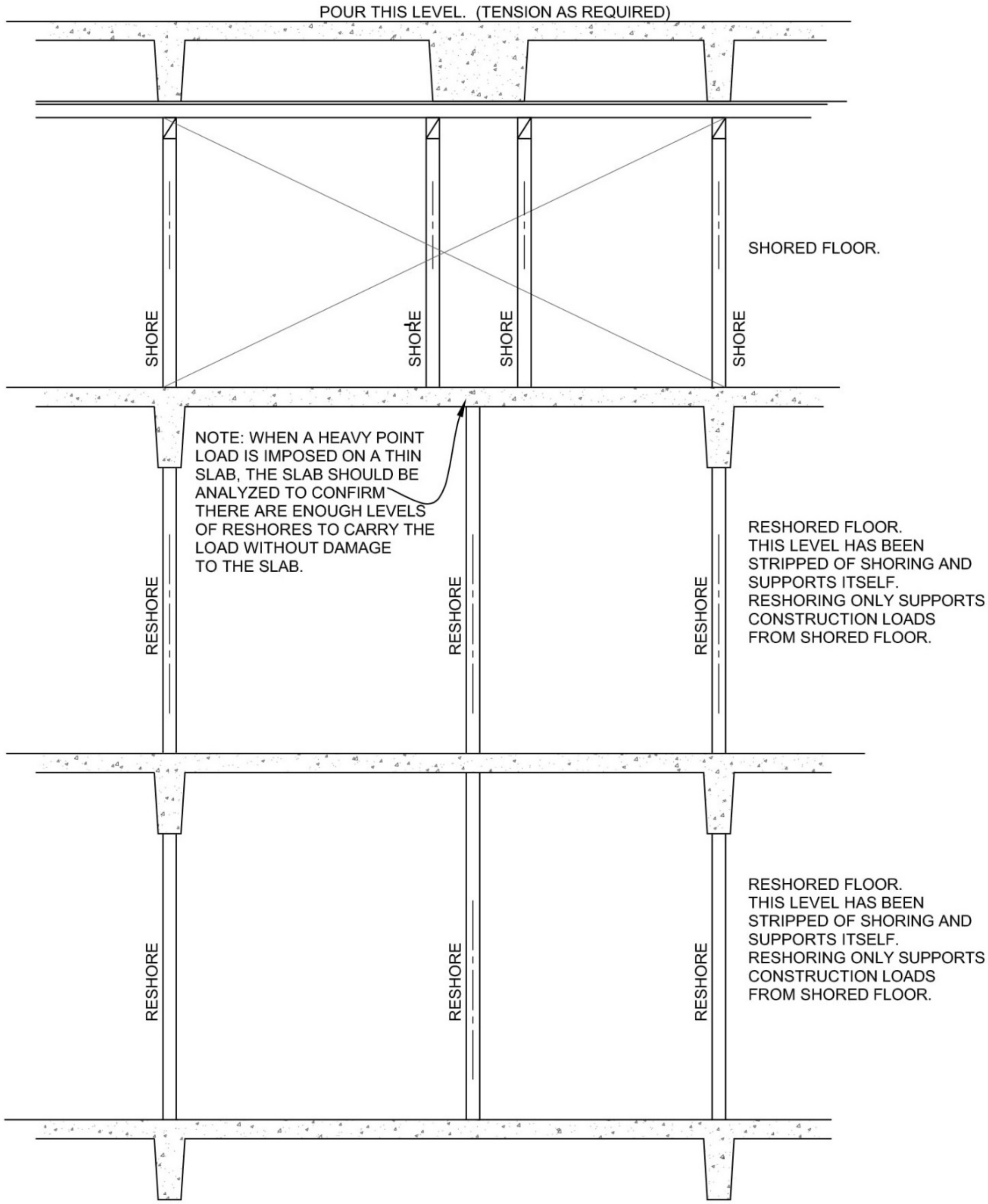

Figure 1. Sample riser diagram indicating shored and reshored floors. Note that, in a full reshore design, the reshore spacing and layout would be indicated in both plan and sectional views for best clarity.

Figure 2: Parking deck under construction with 1 level of shores and 2 levels of reshores extending to slab on grade. Note the horizontal lacing on the bottom level of reshores used to increase the capacity of the reshores.

TYPES OF SHORES AND RESHORES

Shores and reshores can be made of: wood, steel, or aluminum. The simplified method will be discussed later in this course and can be used with any of these materials. Sometimes it is necessary to use different shore or reshore materials on a floor. For example, if there is a clear height of 26’ in one bay and a clear height of 10’ in another bay; timber single post shores may be a good option for the 10’ bay, but sectional steel shoring or steel post shores may be needed at the high areas instead of single post timber shores for the extra capacity they would provide at taller heights. Different reshore materials generally should not be used within a bay, however, because they can compress different amounts and the stiffer materials may take more of the load.

Figure 3. Timber runners, timber stringers, timber shores. Shoring is nearly completed and getting close to being decked with sheathing. B-B Plyform is commonly used as a sheathing material in this type of construction.

Figure 4. Timber formwork and shores using adjustable shore clamps.

Figure 5. Proprietary shoring system. Proprietary systems commonly use steel or aluminum members and may also use timber for the horizontal members.

RESHORING BY THE SIMPLIFIED METHOD

Reshores are commonly designed by the simplified method as set forth in ACI 347.2R-17. There are 5 basic assumptions in the simplified method:

1. *Construction loads are assumed to be distributed uniformly across the floor*. There are some shoring systems that can support large areas of pour loads and impose only a few large point loads on a reshored floor. The reshore designer should be aware of point loads on thin slabs and should analyze the slab for that condition.
2. *Slab on grade is considered to be rigid*. Because of the rigidity of the slab on grade, pour loads distributed to reshores extending to slab on grade will transfer load directly to the slab on grade (or mud sills) and soil on which it bears. Because the reshores transfer load directly to grade, it is assumed the reshored floors do not accept any construction load.

3. *Reshores are assumed to be infinitely stiff*. If the reshores are infinitely stiff, loading several interconnected levels will allow them to deflect equally. Likewise, if the reshores are infinitely stiff, the reshores extending to grade will collect the construction loads and not allow the floor to assist in supporting the load. (See assumption 2.)
4. *Elevated slabs connected by reshores will deflect equally*. This assumes that each interconnected floor will carry an equal amount of the construction loads. This is not necessarily true in a situation where one floor may have a higher design capacity or is a stiffer floor than the typical levels (such as a plaza or amenities level). When a high capacity floor is present, the designer should be aware that the floor will carry more than an equal share of the load.
5. *Deflection is elastic*. As construction loads are applied and released, deflection in the floor behaves elastically. In elastic deflection, a member will deflect under load but recovers once the load is removed.

CONSTRUCTION LOADS

Construction loads are those loads imposed on a structure, shoring, and reshoring system by construction operations. These loads include, but are not limited to: wet concrete, rebar, plumbing, mechanical, electrical, embeds, finishing equipment, forms, and placing personnel. Construction live loads are reducible in certain situations (see ASCE 37).

DESIGN LOADS

Design loads are those for which the final structure is designed. These loads include, but are not limited to: live loads, partition loads, sprinkler systems, furniture, mechanical equipment, superimposed dead loads, etc.

In reshoring design, the design loads of a structure are used to determine the amount of construction load each floor will carry.

The reshoring designer should check to see if the engineer of record has taken live load reductions on the slabs, joists, beams, and girders. The designer should be aware of which code was used as different codes have different reduction criteria. The designer should also be cognizant that there are 2 different ways of calculating live load reductions and should find out which method was used as the two different methods can result in 2 drastically different live load capacities.

HOW RESHORING AFFECTS THE CONSTRUCTION SCHEDULE

Many multi-story concrete buildings can be built with 2 levels of reshoring. But there are other times when 2 levels of reshoring are not adequate. In those cases, the contractor needs to know in advance that the construction schedule will be affected by additional levels of reshores that may impede or completely cut off access to lower floors by other trades.

One simple way of making a preliminary determination of the number of levels of reshores required is to divide the construction load by the design live load of the in-place floors. Note that, even in a preliminary design, the design capacity should consider design load reductions.

This simplified calculation can give the contractor a very good estimate of how many floors of reshores are required for scheduling purposes, but should not be considered a final design. An experienced reshore designer will consider all construction loads, load paths, redundancy, type and material of reshores used, locations of shores and reshores, as well as the construction sequence.

Figure 6. An example of a high rise that required more than 2 levels of reshores due to a non-typical thick slab at the roof.

Example: A parking garage is designed for 40 PSF live load plus 5 PSF superimposed dead load. It has been determined that the live loads in the parking garage are not reducible, so the total floor capacity is 45 PSF.

The floors consist of 8" two-way flat plates, the total construction load will be 160 PSF.

Slab: 150x8/12 = 100 PSF.
Construction Dead Load: 10 PSF. (Construction dead load includes the weight of formwork.)
Construction Live Load: 50 PSF.*

*Reductions in construction live loads are allowed per *ASCE 37 Design Loads on Structures During Construction*, but that discussion is beyond the scope of this course.

Make a preliminary determination for the number of levels of reshores required.

Solution: construction load/floor capacity = 160 PSF / 45 = 3.6. Therefore, 4 interconnected slabs are required to distribute the load. This converts to 1 level of shores and 3 levels of reshores.

If shores and reshores are in place, it is not acceptable to take them out even for "just a little while" without prior approval from the reshore designer in order for other trades to get to the area. If loaded reshores are removed, the load has to go somewhere. Because loads are generally transferred to the stiffest member, the load will transfer to the concrete floor and the floor may become overstressed, which can lead to cracking or even total failure. If adjacent reshores try to pick up the load, they may be overloaded and possibly ruined. Catastrophic failure of the structure is also possible. If notified, the reshore designer can account for alternate load paths and, in some cases, may be able to move reshores.

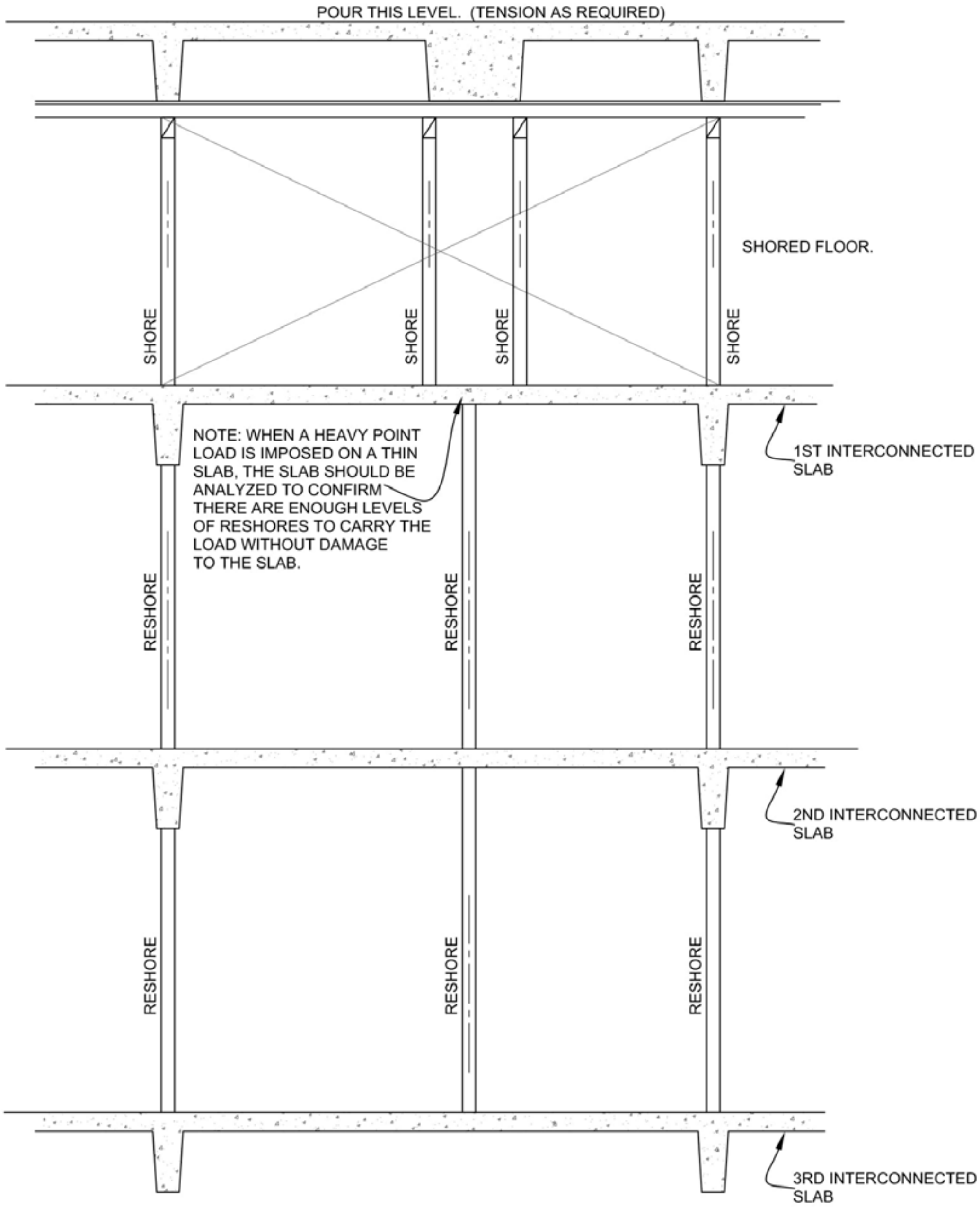

Figure 7. A sample riser diagram illustrating 3 interconnected slabs; 1 level of shoring and 2 levels of reshoring.

POST-TENSIONING EFFECTS ON RESHORES

Reshoring design is intimately related to load paths. In order to be an effective reshore designer, one must have a complete understanding of how loads are transferred throughout a structure. One major, but often over-looked, item affecting load paths is post-tensioning operations. While the exact method of calculating the actual post-tensioning forces are beyond the scope of this course, the general concept is important and will be discussed here.

A fully complete structure will usually transfer loads from the slabs to the beams to the girders to the columns then to the footings. A post-tensioned building will not transfer those loads until full post-tensioning has been applied; it is, therefore, imperative that the shoring and reshoring designer account for load transfers.

After a floor is poured, but before post-tensioning is applied, all wet concrete load is transferred to the shoring system as designed. The first step in tensioning a floor is usually to tension the slab. When the slab is tensioned, an upward force acts upon the midspan and transfers the load to the beam. At that stage of the stressing, the load is released from the slab shores and transferred to the shores supporting the beam. Because the beam has not been tensioned, it does not have its full capacity and, thus, is dependent upon the shores to carry the lesser of the tributary slab dead load or the post-tensioning forces.

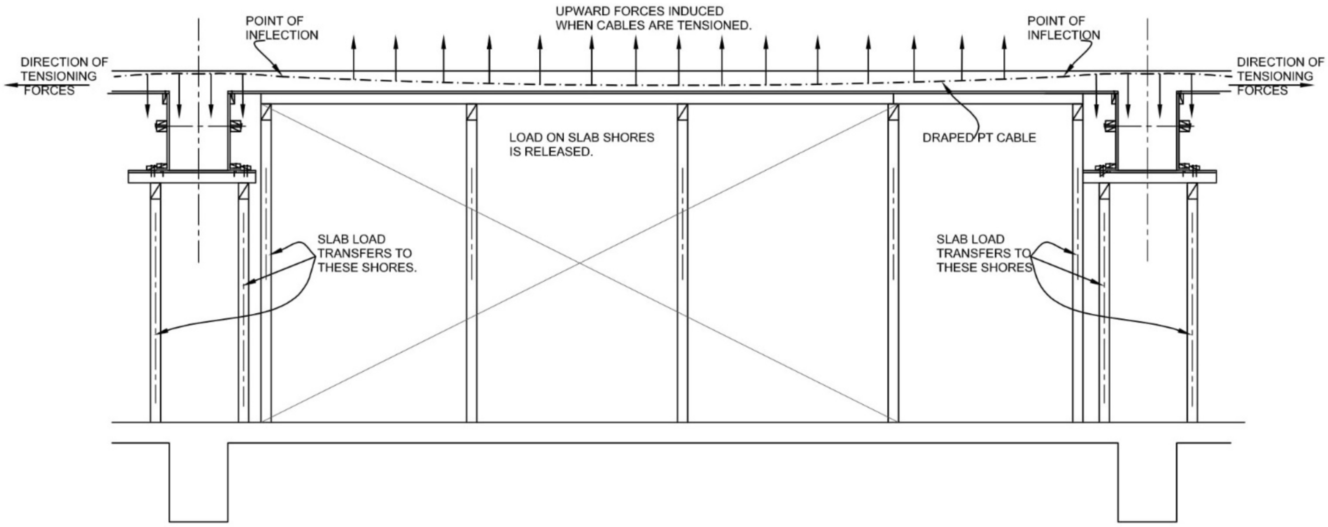

Figure 8. Schematic illustrating post-tensioning forces and resulting load paths.

Next, the beams are post-tensioned. At this stage, there is an upward force in the midspan of the beam which forces load to the girder. The shores under the beam are no longer loaded as the load is transferring to the girder as designed. At this point in the operation, significant point loads can be imposed on the intersection of the beam and girder. Because the girder has not yet been stressed, it cannot carry the tributary weight of the slab and beam. Therefore, shoring and reshoring must be adequate at the intersection location to carry the lesser of the tributary dead load or the post-tensioning forces (where no column is present). Depending on the type of construction and the tributary area, the resulting point load at this location can exceed 100,000 pounds and should not be neglected.

A simplified method of calculating the post-tensioning forces may be used if the designer prefers not to do a full post-tensioning analysis. In the simplified calculations, the dead load from the full tributary area can be calculated and applied in the same fashion as described in the previous paragraph.

Figure 9. Post-tensioning cables in the slab. Column forms and rebar cages for columns in the background.

BACKSHORES

Backshores are utilized when a floor cannot carry its own self-weight. Sometimes this is due to construction problems such as concrete not coming up to strength or post-tensioning cables not being stressed properly. Sometimes backshores are required by design, such as in the case of pour strips (also called closure strips). There are also times when a contractor will choose not to strip a floor and will let the shoring be used as backshoring due to scheduling and other considerations.

Backshores are installed in such a way that floors are not allowed to carry their own weight and, thus, the construction loads accumulate at each subsequent level. Backshores should be lined up as much as possible and/or the concrete slab analyzed to insure the offset loads can safely be distributed to the backshores below. See Figures 10 and 11.

Backshoring can have a significant impact on the construction schedule. There are steps that can be taken to eliminate the need for backshores or reduce the number of backshores required; however, that is beyond the scope of this course.

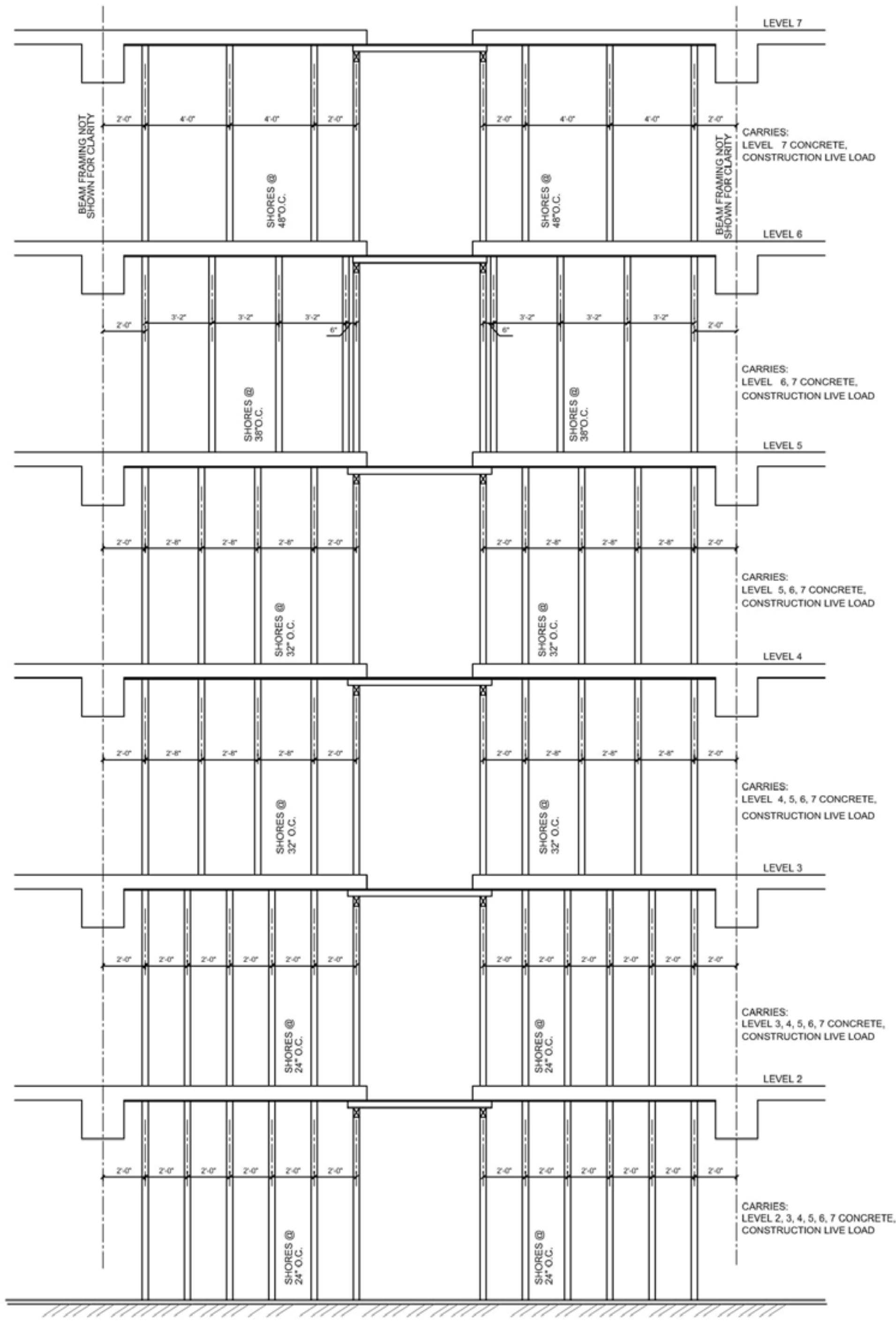

Figure 10. An example of backshoring when the floors cannot support their own weight and loads accumulate.

EFFECTS OF RESHORING ON ALL TRADES

As you can see, the reshoring of a concrete building can have an impact on all trades that follow the placement of the concrete structure. It is important for the contractor to plan in advance for distributing construction loads and coordinating the schedule – particularly when there is a very heavy floor, such as a plaza, amenity, or transfer level.

Figure 11. Timber backshores required due to pour strip.

EXPLANATION OF PUBLICATIONS AND COMMITTEES

Please note that this is by no means an exhaustive list of publications and committees pertaining to formwork, shoring, and reshoring; it is only intended to expand on some of the resources used for authoring this course.

American Concrete Institute (ACI) 347 Formwork for Concrete Committee: The 347 committee writes reports, guides, and manuals for formwork, shoring, and reshoring. The publications are intended for use by anyone in the industry including: engineers, designers, contractors, and inspectors.

SP-4. Formwork for Concrete: an ACI Manual. SP-4 is published by ACI and is currently on its 8th edition. It is one of the most comprehensive manuals on the market for descriptions of a variety of shoring, reshoring, and forming systems as well as design considerations.

SEI/ ASCE 37. Design Loads on Structures During Construction. This standard is published by the American Society of Civil Engineers (ASCE) in conjunction with the Structural Engineering Institute (SEI). It describes safety requirements, load combinations, and required construction loads in order to maintain structural integrity while a structure is under construction.

APPENDIX A

Figure 12. Example of sectional steel shoring towers used for reshoring a tall floor. Timber framing is used for the shored floor. (*Photo courtesy of Aluma Systems*.)

Figure 13. Example of sectional steel shoring towers with aluminum main beams and joists. (*Photo courtesy of Aluma Systems*.)

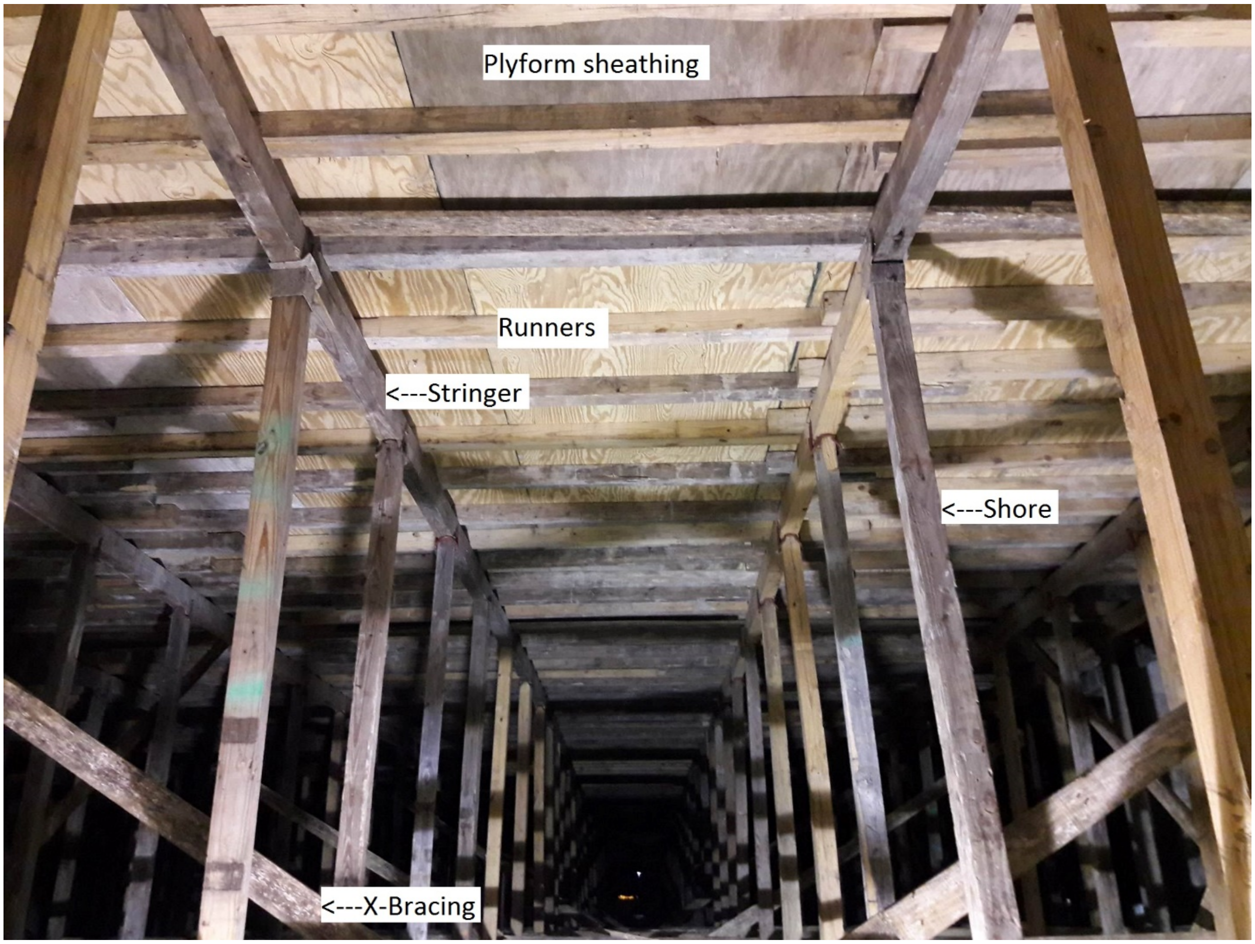

Figure 14: Timber shoring and plyform facing material.
(*Photo courtesy of Skyline Forming North Texas, Inc*.)

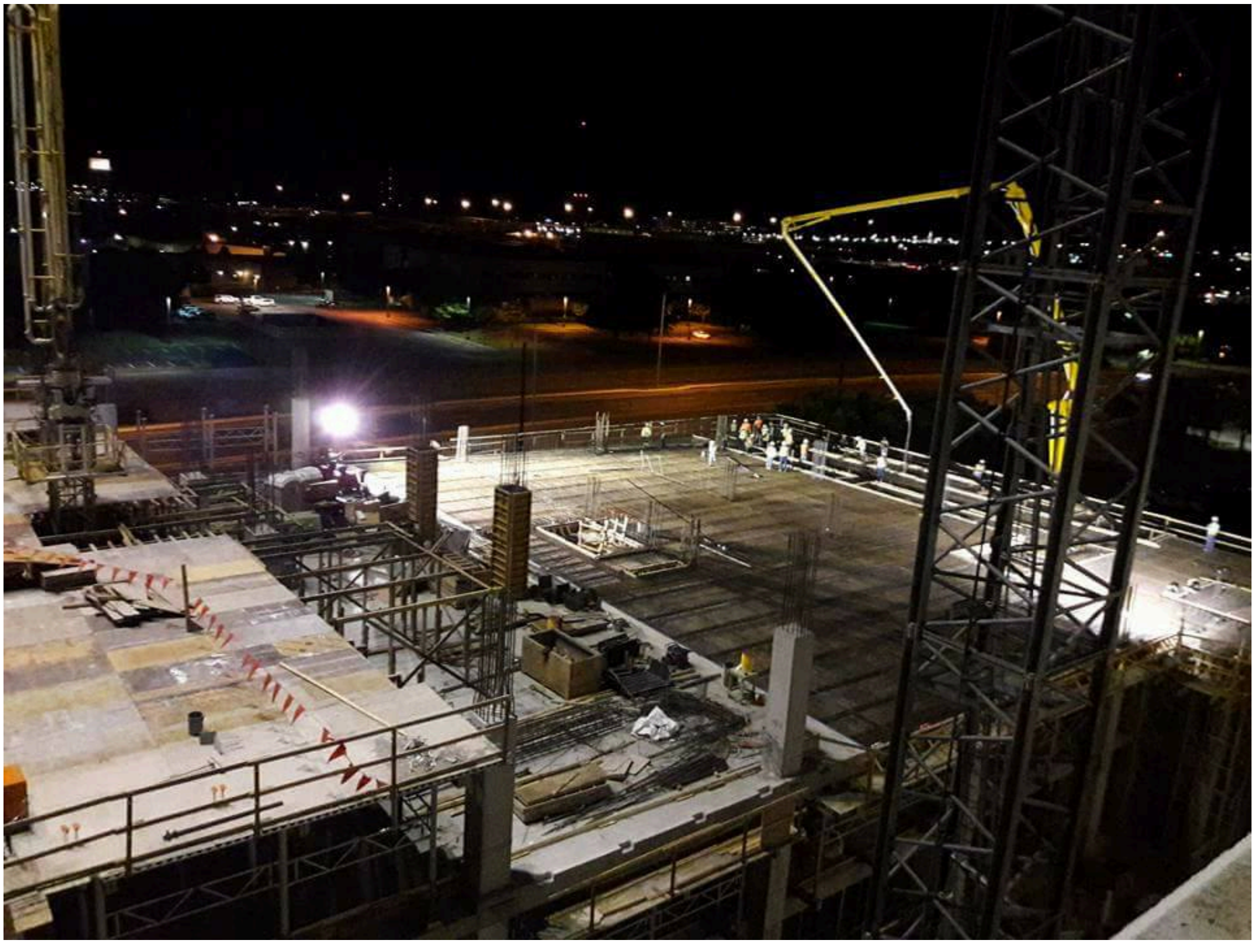

Figure 15: Night placing operations of cast in place concrete building.
(Photo courtesy of Skyline Forming North Texas, Inc.)

Figure 16: Steel truss tables, with aluminum joists (runners). This table was used as shoring, the floor is now self-supporting, and the truss table has been removed to allow for the floor to be reshored.
(*Photo courtesy of Bordner Engineering Services, LLC*.)

SOURCES AND FURTHER READING

ACI 347R-14. Guide to Formwork for Concrete. American Concrete Institute. July 2014.

ACI 347.2R-17. Guide for Shoring/Reshoring of Concrete Multistory Buildings. American Concrete Institute. January 2017

SP-4 (14). Formwork for Concrete: an ACI Manual. 8th Edition. American Concrete Institute. August 2014.

SEI/ASCE 37-02. Design Loads on Structures During Construction. American Society of Civil Engineers.

Bordner-Tanck, Mary. "Pour Strips and Constructability." *Structure Magazine* April 2014: pages 46-47.

Bordner, R.H. "Practical Design of Reshoring." Concrete International October 2002: pages 57-63.

