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CONCRETE CONSTRUCTION

The World of Concrete

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For Lindblad Construction, this project was a new high in low-heat concrete placement

Constructing a Mat Slab

By Joe Nasvik

After 56 years, the coal-fired power plant was worn out and obsolete. Corn Products International, Westchester, Ill., built the boilers and generators in late 1948 to provide steam and electricity for its manufacturing plant in Bedford Park, Ill. To replace this resource, Corn Products is now building a state-of-the-art power plant that will burn high-sulfur Illinois coal and meet all current emissions requirements. The State of Illinois provided funding for this purpose. The new plant will cost $97 million and be completed in 2006. Guy Buchner, the engineering manager for Corn Products, says the new facility will include a "1.1-million-pound-per-hour, 100-megawatt, circulating fluidized bed boiler." A byproduct of the boiler will be high-grade fly ash, which Corn Products plans to sell—hopefully to the concrete industry.

Above: This 4½-foot-thick mat slab will support a coal-fired generation plant with a boiler weighing more than 6 million pounds. Right: The precision location of anchor bolts was one of the most important elements of this project (see Fig. 1, p. 3). Lindblad placed "mud mats" to hardware for holding the anchor bolts in position during placement. Notice the steel mesh on top of the rebar, making it safer for workers to move around while concrete was being placed.

Corn Products decided to serve as its own general contractor, signing the contracts for each subcontractor involved in the project. It retained ESI of Tennessee in Kennesaw, Ga., to engineer the project and to serve as the construction and start-up manager. Besides Lindblad Construction's ability to perform the concrete work, Corn Products wanted its expertise at setting anchor bolts with high tolerance requirements and the company's commitment to jobsite safety. Lindblad's experience modification rate (EMR) of 0.73 and its previous year OSHA Recordable Frequency Rate of 0.0 was very important to Corn Products.

The boiler for the project will weigh more than 6 million pounds, and most of the weight will be suspended from the top steel so that its thermal expansion won't affect the slab. The total dead weight that will rest on this slab will be over 12 million pounds. To support this, engineers designed a 4½-foot-thick reinforced mat slab. Because of the complexity of the mat geometry and loadings, Corn products asked Ambitech Engineering Corporation of Downers Grove, Ill., to verify the design using PCAMats and STAAD software. Mark Stadalsky, Lindblad's vice president, notes that ironworkers placed 805,000 pounds of #10 steel reinforcing bars, generally spaced at 10 inches, but with the more highly stressed areas at 5-inch centers. The slab covered 22,800 square feet and required 3819 cubic yards of concrete coming from three different yards. It took 79 ready-mix trucks to keep up with the schedule.

Mass concrete

ACI 116 defines mass concrete as "any large volume of cast-in-place concrete with dimensions large enough to require that measures be taken to cope with the generation of heat and attendant volume change to minimize cracking." The heat generated by the hydration of cementitious materials causes temperatures in the center of a slab to be much higher than at its surfaces. This temperature gradient is the critical thing to remember about mass concrete since it can cause thermal cracking that would compromise the structural strength of the slab.

For practical purposes, according to PCA's *Design and Control of Concrete Mixtures*, (Kosmatka, Kerkhoff, and Panarese, Portland Cement Association, 2002) slabs and footings more than 3 feet thick qualify as mass concrete. Thermal cracking in mat slabs can be managed by the type and amount of cement used, by adding pozzolans, by increasing the amount of reinforcing steel, by reducing the delivered temperature of the ready-mixed concrete, by using a concrete with a low thermal expansion aggregate (such as limestone or granite), and by increasing the size of the aggregate. On the jobsite, covering a placement with insulated curing blankets reduces the rate of cooling at the concrete surface, helping to keep the temperature differential within acceptable limits. So, even with no danger of freezing, insulating blankets will often be used on a thick mat slab.

Given the 4½-foot thickness of the slab for this project, a mass concrete mix design with a low heat of hydration was needed in order to avoid thermal cracking. John Gajda, a principal engineer for Construction Technology Laboratories (CTL), Skokie, Ill., says that concrete temperatures for mass concrete placements shouldn't exceed 160° F. Additionally, based on a simple rule of thumb, the temperature differential between the center of a placement and the exterior surfaces shouldn't exceed 35° F to 56° F, depending on the aggregate used in the mix. In the development of the concrete mix design for this project, Gary Hall, who does quality control for Prairie Materials, Bridgeview, Ill., says it designed the mix not to exceed 130° F.

The mix used contained the following ingredients:

Cementitious, including slag	450 pounds
Sand	1450 pounds
#67 limestone (¾ inch)	1825 pounds
Water	24.85 gallons
Superplasticizer	Variable rates*
Water reducer	Variable rates
Air entrainment	5½±1½%
Slump	5±1%
Design strength, 28 days	4000 psi

*The water/cementitious ratio will remain the same. An increase in slump is provided by an increase in the superplasticizer.

PHOTOS: LINDBLAD CONSTRUCTION

Anchor bolt placement

Lindblad Construction is known for its attention to detail and accurate placement of anchor bolts. The owner considered accurate anchor bolt placement to be a vital part of the contract. Before installing the reinforcement, workers marked the location of all the anchor bolts on the subgrade. Next, they cast "mud mats" over those spots and under the angle support locations (see photo, left). Lindblad's two onsite superintendents then verified the precise location for each anchor bolt assembly on the mud mats.

Each anchor location included four anchor bolts mounted in a steel frame. Workers mounted the frames to the mud mats with concrete anchors. The angle supports were then attached to hold each assembly securely in place. Ironworkers created a clear space between the anchor assemblies and the reinforcement to insure that there would be no movement during concrete placement. A total of 264 bolts were set in this manner. After the anchor bolts were set and secured, surveyors checked each anchor bolt and verified that all of them were in the proper location.

Forming trench drains

To anchor trench drain forms, Lindblad used a procedure similar to that used to position the anchor bolts. Workers again placed concrete mud beds on the subgrade under the drains and attached angle iron to them with concrete anchors. Angled supports were also used. As shown in the photo, vertical form panels secured to the angle iron formed the walls of the drain, but the drain floors were left open. Stadalsky said that they were concerned that the buoyant forces of the concrete against the bottom forms would float the drains out of position. As a result, they planned to bush-hammer some concrete and place an overlay cement topping to provide pitch to the drains in each trench.

Placing concrete

A private weather service provided information about weather conditions. Ambient temperatures were around 32° F when concrete placement started (concrete temperatures were approximately 50° F). Placement started at midnight on a Saturday, and finishing was completed at 10 p.m. on Sunday evening. Windy conditions prompted Lindblad to spray a vapor retarder during placement to reduce the effect of surface drying. The slab was covered with polyethylene sheeting and wrapped with insulated curing blankets the following morning, and this was kept in place for a week. Because of the low heat of hydration, concrete temperatures didn't reach 85° F on the surface until the following Tuesday evening. There were no internal sensors placed in the slab so its core temperature isn't known.

One unusual aspect of this job is that the mat slab was pitched to trench drains everywhere, so power screeds couldn't be used for the placement, except in small areas. Workers placed pipe screeds at the high points in the slab and hand-struck the concrete. Because of the many pitches, finishing machines weren't useful either. All finishing was done by hand with finishers working from knee boards. The finished surface was broom finished.

Lindblad decided to use three Putzmeister Telebelts with maximum reaches of 105 feet to place the concrete, based on past experience with the equipment. Its goal was to place 9 cubic yards of concrete every 3 to 4 minutes from each belt. One ready-mix truck arrived on the jobsite every minute. A fourth Telebelt was kept onsite as an

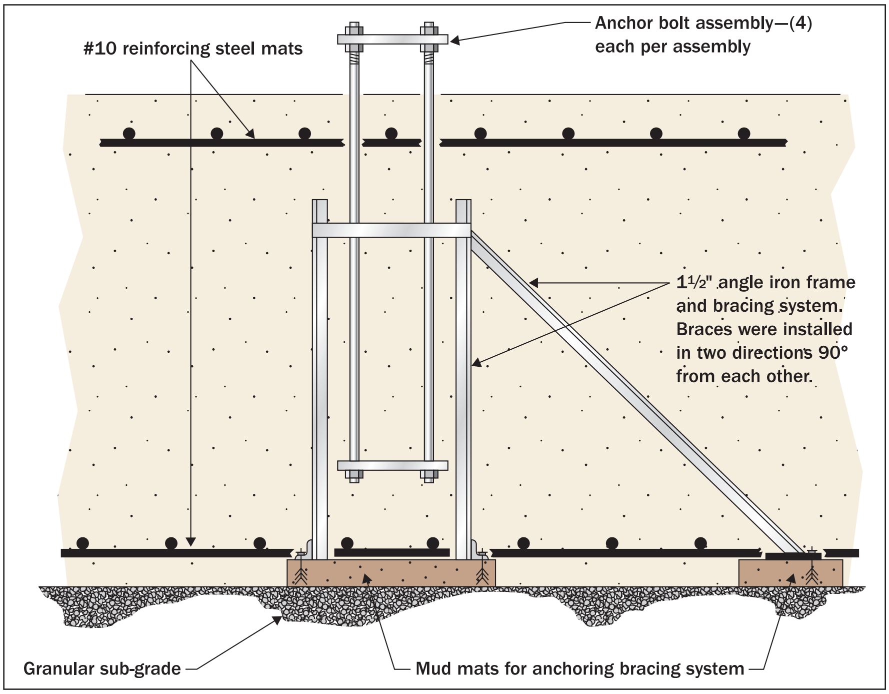

Fig. 1. Anchor Bolt Assembly Anchoring System. The anchor bolts were secured to "mud mats" placed in the subgrade. Angle irons placed at angles and secured to mud mats fixed the anchor bolts in proper position.

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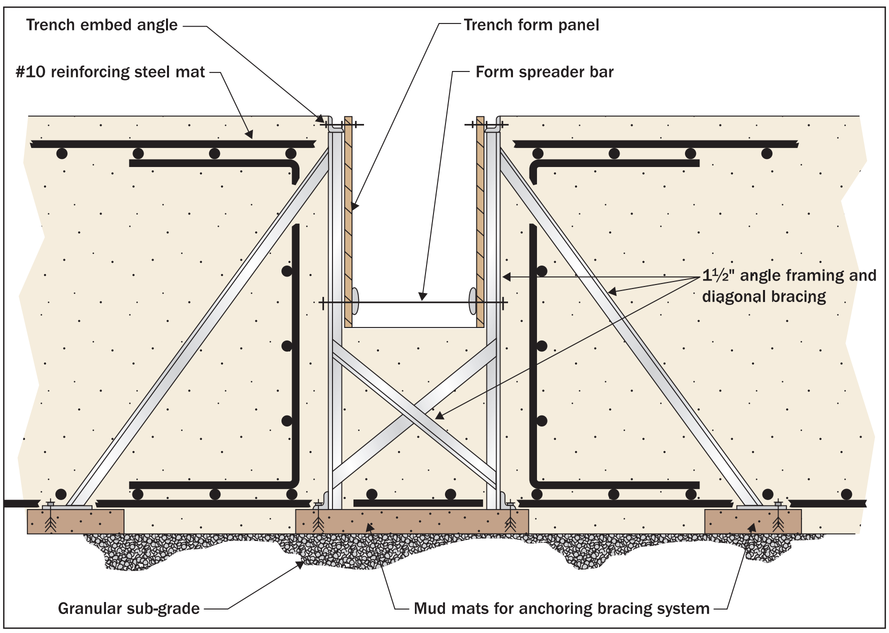

Fig. 2. Trench Forming and Bracing System. In order to avoid the possibility of "floating" the trench drain formwork, the bottom of the form was left open. By taking this precaution, Lindblad knew it would have to bush-hammer some of the bottom of the drain and establish proper pitch using overlay cements.

The entire surface of the slab was pitched to trench drains like the one shown here. As a result, much of the slab had to be "hand struck."

emergency standby unit just in case there was an equipment breakdown.

Lindblad placed the concrete at ambient temperatures just above freezing, and Stadalsky reports that it was 6 to 8 hours later before finishing could begin. It took 22 hours to complete the concrete placement and finishing process. Twenty-three finishers and 15 laborers completed the work without incident.

Safety

Corn Products and Lindblad both consider safety to be the most important part of the construction process. The construction site is located in a heavy industrial area with constant train traffic, truck deliveries, and storage areas for chemicals. Corn Products requires every worker and guest to watch a safety video before entering the project to learn the plant's safety requirements, including how to safely drive through the area. Lindblad set up a fund for this job to which Corn Products, Lindblad, and the excavation contractor all contributed. Cash rewards were given to workers who submitted the most innovative safety ideas. Lindblad calls its program the "Good Catch Recognition Program." Two recipients of this award were carpenters who suggested that a layer of 6x6-10-10 steel mesh be fastened to the top layer of rebar to create an easy walking surface for finishers and laborers during concrete placement—eliminating the possibility of injuring feet and ankles by stepping through the holes between rebar. Other cash prizes were raffled off to workers each week there wasn't a jobsite accident. In addition, for every 2 weeks that were accident free, the entire workforce was treated to a catered lunch on the jobsite. There were no accidents on this jobsite.

Planning and executing

The level of difficulty goes up when constructing mat slabs that qualify as mass concrete. "The devil is in the details," and, as you can see in the description of this job, planning and organization were critical to a positive outcome. Lindblad started its process by holding three key meetings with representatives from all of its vendors and subcontractors. In the first meeting they thought through the process from traffic control and conveyor placement to truck washout. At the second meeting, they drew plans marking the locations for everything based on the decisions of the first meeting, and they discussed back-up plans to cover possible problems. At the third meeting they met with the owners to present and finalize the plan.

The construction of the mat slab went very smoothly, and there are no cracks in the finished work. The next step in the construction process will be the installation of the boiler and the erection of the building around it. ■

Participants:

Owner and General Contractor: Corn Products International, Westchester, Ill.

Engineer and Construction Manager: ESI Inc. of Tennessee, Kennesaw, Ga.

Concrete Contractor: Lindblad Construction, Joliet, Ill.

Concrete Conveyor Contractor: Ruane Construction Inc, Frankfort, Ill.

Reinforcing Steel Contractor: Gateway Erectors, Burnham, Ill.

Ready-Mix Supplier: Prairie Materials Sales, Bridgeview, Ill.

Finishing concrete placement. Because the heat of hydration of the concrete mix was so low, finishers waited as long as 8 hours to begin finishing operations. Because of the pitches, the entire slab was finished by hand.

Compliments of:

PCA Portland Cement Association