LOAD DISTRIBUTION TESTS ON PRECAST PRESTRESSED HOLLOW-CORE SLAB CONSTRUCTION

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The only available authoritative source concerning the distribution of concentrated loads on a floor or roof construction composed of precast hollow-core slabs is ACI Standard 711-58, "Minimum Standard Requirements for Precast Concrete Floor and Roof Units." This ACI Standard has now been superceded by ACI 512-67, "Recommended Practice for Manufactured Reinforced Concrete Floor and Roof Units." However, prestressed concrete units and units whose length exceeds 35 ft. are not covered in ACI 512-67.

Because of this gap in the ACI Standards, it is common practice among hollow-core slab manufacturers to refer to ACI 711-58 for criteria concerning the load distribution of concentrated loads. ACI 711-58 states: "Where a hollow-core (closed section) system supports partition walls parallel to the unit, or where heavy concentrated loads are to be expected, such loads may be considered to be uniformly distributed over not more than three identical units on each side thereof but never over a greater total width than 0.4 of the clear span distance."

Since the width of precast hollow-core units has greatly increased since the writing of the provision for "three identical units on each side," it was felt that this provision would no longer be applicable. However, it was felt that a design width of 0.4 of the span was still an adequate conservative provision. Therefore, these tests were conducted to demonstrate the ability of grouted shear keys to transfer concentrated loads to adjacent slabs.

Two load distribution tests were devised, conducted and reported by The Flexicore Co., Inc. The tests were witnessed and test data recorded by a commercial testing laboratory.

TEST NO. 1—INTERIOR SLAB WITHOUT END BEARING

Description of construction. The 25 ft. 3 in. long by 14 ft. wide (7.7 by 4.3 m) test assembly consisted of seven 2 ft. (0.6 m) wide slabs; six were 25 ft. 3 in. (7.7 m) long and one was 22 ft. 8 in. (6.9 m) long. The center slab (Unit No. 4) was cut short at each end and had no bearing on the end supports (Fig. 1). Therefore, the only way load placed on the center slab could be carried was by load distribution through the

Test reports are presented which demonstrate the load transfer capabilities of hollow-core slabs with grouted shear keys in typical floor construction. Test panels contained interior slabs without end bearing and interior slabs with a large opening framed at mid-span. Deflection measurements verify full load distribution.

grouted shear key to adjacent slabs.

All test units were 8 in. (20 cm) deep, 24 in. (61 cm) wide with three 5⅞ in. (15 cm) dia. hollow cores, and they were designed in accordance with the ACI 318-71 Building Code. The four slabs adjacent to the center slab, Units 2, 3, 5 and 6, had a *d* of 5⅞ in. (15 cm) and a steel content of four ½ in. (13 cm) strands,

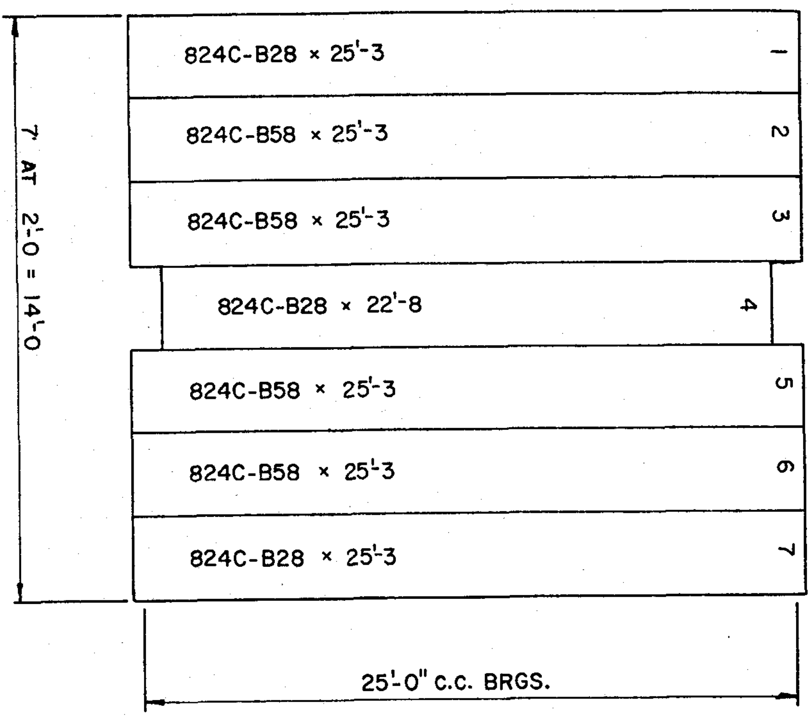

Fig. 1. Layout of hollow-core slabs for Test No. 1

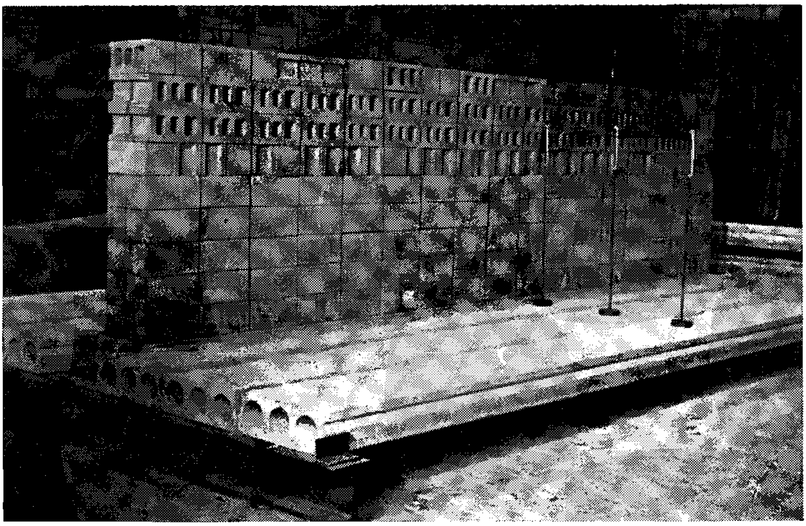

Fig. 2. Test assembly with center slab loaded

250 ksi grade (17,577 kg/cm²). These slabs have a theoretical superimposed load capacity of 144 psf (700 kg/m²) on a 25 ft. (7.6 m) span.

The two outside slabs, Units 1 and 7, were designed for a safe superimposed load of 55 psf (270 kg/m²) and were not designed to carry any additional distributed load from the center slab. These two units and the center unit contained two ⅜ in. (9.5 mm) and two 5/16 in. (7.9 mm) strands.

Test assembly. The slabs were supported on two steel beams which created an effective span of 25 ft. (7.6 m) ctr. to ctr. of bearings. Each end of the two outer slabs was restrained from lateral movement by a 4-in. (10 cm) angle bolted to the steel beam (see Fig. 2). During the construction of the test assembly, wood blocking was used to support the center slab until the grout had been placed between all units and allowed to harden.

Test procedure. Concentrated and uniform loading was accomplished using concrete blocks with sufficient spacing between blocks so that no arching of the load would occur. The average weight per block was 43.5 lb. (19.7 kg). Vertical deflection measurements were made on the supported units at mid-span. Sightings were made using a surveyor's level on rules attached to vertical stands (see Fig. 2). Deflection readings, accurate to 1/32 of an inch (0.8 mm) were made at various increments of loadings, after 17 hours under load, and immediately after removal of the applied load.

Test data and results. 6×12 in. (15×31 cm) test cylinders, which represented the concrete used in the slabs and the grout used in the shear keys, were given curing identical with that applied to the materials in

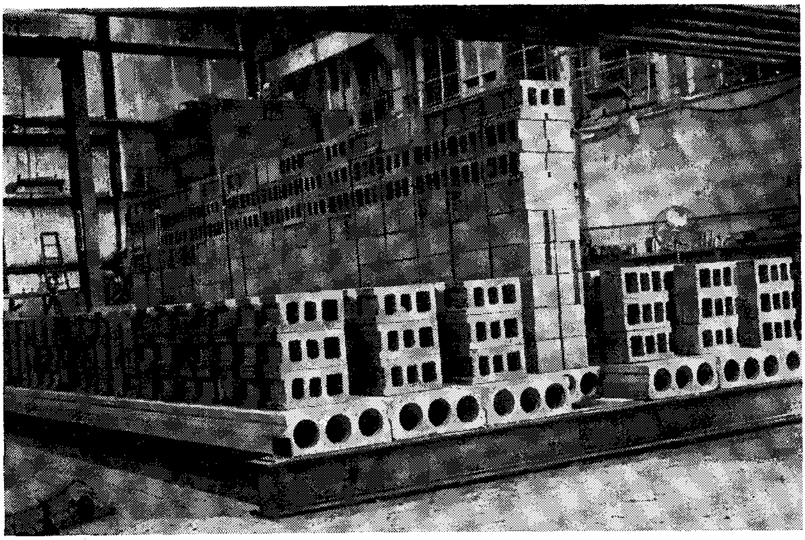

Fig. 3. Test assembly under full load

the test assembly. The average measured 28-day compressive strengths were:

Grout = 2800 psi (197 kg/cm^2)
Slabs = 4650 psi (327 kg/cm^2)

When the wood supports under the center slab were removed, Units 1, 2 and 3 deflected 1/32 in. (0.8 mm), whereas Units 5, 6 and 7 showed no measurable deflection. Load deflection measurements are given in Table 1 and the test assembly under full load is shown in Fig. 3.

The center slab was subjected to a superimposed load of 588 plf (880 kg/m)—equivalent to a 10 ft. (3.0 m) high, 12 in. (31 cm) block wall at 59 psf (290 kg/m^2)—in addition to the slab dead load of 114 plf (170 kg/m). This results in a 351 plf (520 kg/m) distribution to the adjacent slabs through the shear keys.

As evidenced by the measured deflections on the six unloaded slabs, the grouted shear keys transferred the applied load to these units without any signs of distress in the shear keys and provided fairly uniform load distribution over the entire 14 ft. (4.3 m) wide test assembly.

The six unloaded slabs were then subjected to a uniform load, while the load remained on the center slab. The measured deflections, as given in Table 1, again indicate relatively consistent distribution of these uniform and concentrated loads throughout the entire 14 ft. (4.3 m) width. Units 2, 3, 5 and 6 theoretically were carrying $351 \div 4 = 88$ psf (430 kg/m^2) plus $18{,}880 \div 12 \times 25 = 63$ psf (310 kg/m^2) for a total load of 151 psf (740 kg/m^2), whereas the design capacity of these units was 144 psf (700 kg/m^2). Units 1 and 7 were carrying 63 psf (310 kg/m^2), whereas their design capacity was 55 psf (270 kg/m^2).

Observations. Deflection data seem

Table 1. Deflection measurements for Test No. 1

Applied loading		Deflection in 1/32 in.					
Blocks	Load at each increment lb.	Slab units 1	2	3	5	6	7
0	0	0	0	0	0	0	0
Center slab only 2 rows—3 high	4,440	2	2	2	3	3	2
Center slab only 2 rows—6 high	8,880	4	5	5	5	5	4
Center slab only 2 rows—9 high	13,330*	6	7	8	7	7	6
Total load on panel Adjacent slabs 3 high—spaced 1 ft. on centers	32,130	17	19	20	19	18	17
Same—17 hours elapsed time	32,130	20	21	22	21	20	19
All blocks removed	0	4	4	4	4	4	3

*588 lb. per lin. ft.

to indicate that the concentrated load on the center slab was distributed to the total assembly width of 14 ft. (4.3 m). Under these conditions, the load distribution would amount to $351 \div 6 = 59$ psf (290 kg/m^2) plus the uniform load of 63 psf (310 kg/m^2) for a total uniform load of 122 psf (600 kg/m^2) on all the supported units. This load is less than the rated capacity for Units 2, 3, 5 and 6, and more than the rated capacity for Units 1 and 7. Further, the panel width of 14 ft. (4.3 m) is 0.56 of the clear span, a ratio greater than permitted in ACI 711-58. Therefore, the load distribution procedure of ACI 711-58, which specifies a maximum panel width of 0.4 of the span, or the distributed load to be carried by units within a width of 0.4 of the clear span distance, is a conservative design procedure.

After the total load was applied to the panel, the steel restraining angles, which represented the restraining effect of additional slabs in typical floor construction, were removed. There was no evidence of any vertical or lateral movement. From this, it was concluded that such a panel could be contained not only within the width of a long series of slabs in each direction but also at the end of a series of slabs, or could be a small, separate panel by itself.

It is not anticipated that shrinkage of the grout in the grout key would cause inferior behavior in comparison with the above results had the test been conducted at a later age. The width of the grout joint at the widest point is only slightly over an inch. Assuming a free shrinkage coefficient of 0.001 in./in., this would produce a crack of 0.001 in. (0.03 mm) which would be of no concern.

TEST NO. 2—TWO-SLAB OPENING

Description of construction. This 25 ft. 3 in. (7.7 m) long test assembly consisted of six 2 ft. (0.6 m) wide slabs, the center two of which were cut to form an opening 4 ft. wide by 5 ft. long (1.2 × 1.5 m) as shown in Fig. 4. A standard two-slab steel header supported the short slabs and, in combination with the grouted shear keys, distributed the concentrated load to the adjacent slabs (Fig. 5).

The full-span slabs have the same dimensions as those described in Test No. 1, with a safe superimposed load capacity of 144 psf (700 kg/m^2) or an ultimate moment capacity of 54.55 ft. kips (7.55 m-t) per unit. The center short slabs have a nominal amount of steel necessary to carry 43.5 psf (210 kg/m^2) loading

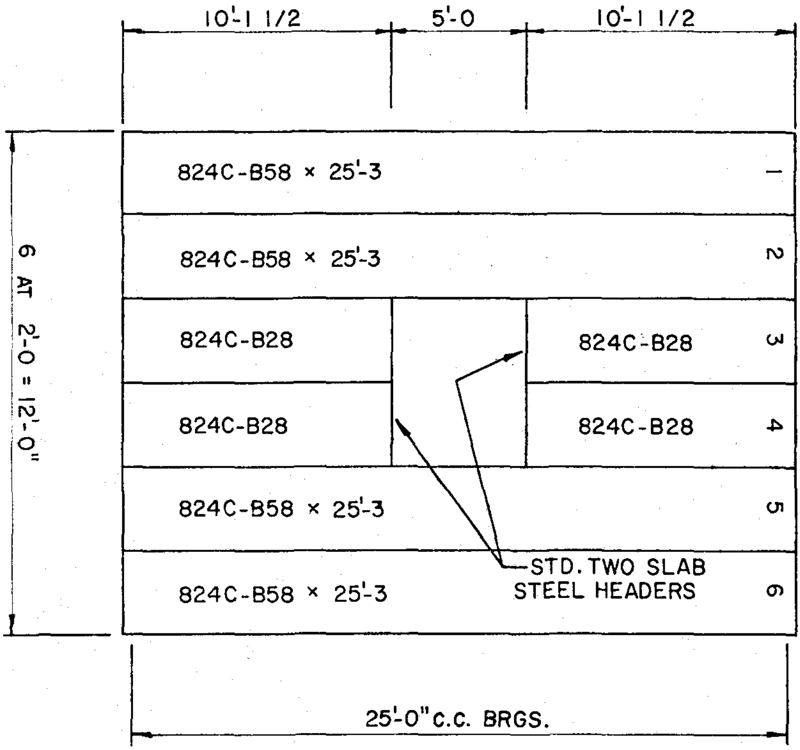

Fig. 4. Layout of hollow-core slabs for Test No. 2

Fig. 5. Test assembly with center opening

over their short span.

Test assembly. The slabs were supported on steel beams as in Test No. 1, with a 25 ft. (7.6 m) span ctr. to ctr. of bearings, and restrained from lateral movement by 4-in. (10 cm) angles. Wood blocking was used to support Units 3 and 4 until the grout in the shear keys had hardened.

Test procedure. A 4 × 6 ft. (1.2 × 1.8 m) wood platform was placed over the opening and loaded with concrete blocks so that a concentrated load was applied to the ends of the

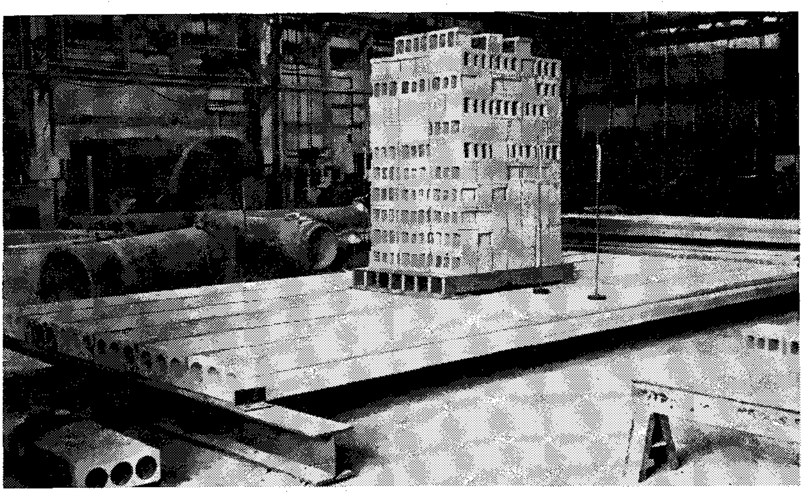

Fig. 6. Test assembly with concentrated loads at opening

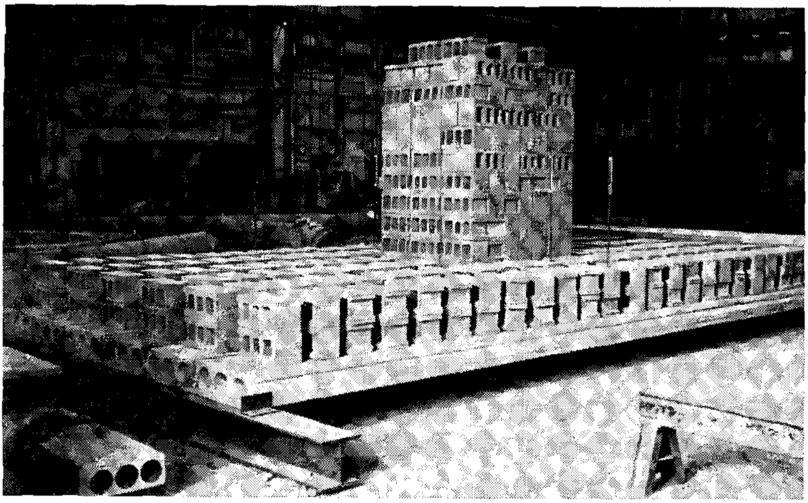

Fig. 7. Test assembly under full load

short slabs at the edges of the openings (see Fig. 6). Additional loading was accomplished by stacking blocks on the slabs as shown in Fig. 7.

Vertical deflection measurements were made on Units 1, 2, 5 and 6 in the same manner as Test No. 1 at various increments of loading, after 20 hours under full load, and immediately after removal of all load.

Test data and results. The initial deflections when the wood blocking was removed were 3/16 in. (4.8 mm) on Units 1 and 2, 7/32 in. (5.6 mm) on Unit 5 and 5/32 in. (4.0 mm) on Unit 6. The average measured 28-day compressive strengths were:

Grout = 3700 psi (260 kg/cm²)
Slabs = 4650 psi (327 kg/cm²)

Load deflection data are given in Table 2.

A total load of 9550 lb. (4340 kg) –representing a piece of machinery or equipment–was placed on the platform over the opening to create a line load at the ends of the opening. Distributing these concentrated loads equally to the adjacent slabs along with the uniform loads on the short slabs, plus the uniform superimposed load of 43.5 psf (210 kg/m²) on the adjacent slabs themselves, produced a theoretical ultimate design moment of 55.8 ft. kips (7.72 m-t) per unit which was larger than their ultimate moment capacity of 54.55 ft. kips (7.55 m-t).

No sign of distress was evident for the behavior of either the grouted keys or the slabs themselves during the test.

Observations. It may be seen from the measured deflection data, both when the adjacent slabs were unloaded and loaded, that fairly uniform load distribution occurs across the panel as assumed in the design.

After the total load was applied to the panel, the steel restraining an-

Table 2. Deflection measurements for Test No. 2

Applied loading		Deflection in 1/32 in.			
Blocks	Load at each increment	Slab units			
	lb.	1	2	5	6
0	0	0	0	0	0
On platform* 21 blocks—4 high	3,810	4	4	5	3
On platform 21 blocks—8 high	7,460	8	8	9	7
On platform 21 blocks—10 high + 6	9,550	11	11	12	10
72 added on center slabs	12,680	13	14	14	12
Total load on panel 192 added on adjacent slabs	21,030	20	21	22	20
Same—20 hours elapsed time	21,030	24	25	26	23
All blocks removed	0	6	6	7	5

*Platform weight = 155 lb.

gles were removed and there was no evidence of any vertical or lateral movement. Therefore, the same conclusions were reached as in Test No. 1, that the panel could act by itself, at the end of a series of slabs, or be contained within a series of slabs and still produce the same results. Similarly, it is not anticipated that shrinkage of the grout key would produce inferior behavior at a later age.

Discussion of this paper is invited. Please forward your comments to PCI Headquarters by March 1 to permit publication in the March-April 1972 issue of the PCI JOURNAL.