AN INNOVATIVE PRECAST CONCRETE FLOOR PANEL SYSTEM

Mohamed A. Mahgoub, **PhD, PE,** Associate Professor, and Director of Concrete Industry Management (CIM) Program, New Jersey Institute of Technology, University Heights, Newark, NJ 07102-1982

Ken Baur, Senior Project Manager, Northeast Precast, Millville, NJ 08332

ABSTRACT

There is a great need for a durable precast concrete floor structure that is lighter, stronger and more energy efficient, and one that can be manufactured in variable sizes. Nowhere is this need greater than in areas devastated by storms, particularly in New Jersey's rebuilding efforts after Superstorm Sandy. A new concrete floor plank system offers many advantages for post-disaster rebuilding efforts. Test results compare the system's greater strength and durability compared with other building materials. The new patented floor system is similar in design to a double-tee panel. However, it is shallower in depth and has four longitudinal stems per piece instead of two. The new system uses prestressed strands in the stems, and mild reinforcement in the deck.

Keywords: Precast, Prestressed, Concrete Floor, Floor Plank, Panel System

INTRODUCTION

Building floors are usually constructed of wood, composite decking, joist systems, some proprietary CIP concrete systems, and precast double tees, in addition to hollow-core plank. These planks are made of precast prestressed concrete components and are typically used as structural floor or roof deck systems in single and multi-story buildings. To reduce the weight of the slab and provide a more efficient product, the planks are cast with continuous voids that run along the length of the panel. High strength prestressing strands are cast into the planks for added strength. A hollow core plank has a top and bottom flanges along the length of the panel. These flanges along with the prestressing slabs create an exceptionally strong structural component that can be used to cover longer spans. Hollow core planks are typically manufactured in fixed widths, typically 4 feet, and in long lengths, 500 feet, then cut to the required length depending on the project requirements.

The hollow core planks are relatively heavy and this would add to the floor loading and can affect the number of planks that can be shipped per truck. Thus there is a need for a precast concrete floor structure that is lighter in weight and can be manufactured in different widths and lengths.

NEW PRECAST FLOOR SYSTEM

A new precast floor system has been invented and was recently patented. It is an improved precast prestressed concrete floor structure system that is lighter in weight (these units are roughly half the weight of hollow core). The new patented floor system is shown in Figure 1. This floor panel is similar in design to a double-tee panel. However, it is shallower in depth and has four longitudinal stems per piece instead of two. The new system uses prestressed strands in the stems, and mild reinforcement in the deck. The innovative units make it easy to run mechanical systems between and through the stems. They are also fully insulated.

DETAILS OF THE NEW SYSTEM

The innovative precast concrete floor panel consists of a top concrete sheet or deck supported by a number of parallel, spaced-apart, longitudinal concrete stems that extend along the span of the floor. The deck is also supported by two transverse concrete end blocks, with 2 inch minimum thickness at each end, that formed with and protruding from the deck as shown in Figure 1. The end blocks extend along the width of the floor. They are made of solid concrete to form a continuous bearing surface for mounting the floor panel on top of wall members, and to support wall members mounted on top of the floor panel. They also enable stacking of the floor panels for storage or transportation. Each end block has an opening along the panel width to enable post-tensioning the floor system after installation on the bearing walls. This helps distributing wind, seismic, or any other lateral forces to the bearing walls. The concrete stems are extended between the concrete end blocks and are spaced apart from one another 2 feet center-to-center.

Each stem has a depth of 6 to 16 inches and a width of 2 to 15 inches depending on the load applied on the floor. There is approximately1 to 2 inch thick mold expanded polystyrene formed insulation attached to the bottom of the floor panel system. This insulation extends around the stems, the bottom portion of the deck, and the inside portion of the end blocks between the stems. The insulation provides thermal resistance and reduces noise transmittal in the finished floor panel. A metal wall stud is attached to the insulation at the bottom of each stem which can be used for attachment of drywall or other finishing materials. An optional light-weight, non-structural leveling coat can be applied to the deck upper surface.

Each building floor in is to be formed using a number of floor panels side-by-side. These panels are should be mechanically connected to each other along their respective longitudinal sides. These connectors are to be welded together by weld joints once the panels are in place. The metal connectors enable wind, seismic or any other lateral forces to be distributed among the floor panels. Vertical holes or channels may be cut in or pre-cast through the floor panel for passage of plumbing, electrical lines or any other required utilities.

ADVANTAGES OF THE NEW SYSTEM

There are several advantages of the new floor system. It is approximately half weight compared to hollowcore plank system. This lighter weight allows more panels to be transported to the construction site. Also, due to lighter weight, this system can be easily tilted when shipped allowing more space. The new panel system can be manufactured in different widths, up to 14 feet (a typical piece is 8 feet wide). The new panel system is cheaper compared to other floor systems. It is also flood and seismic resistant. The thickness of the top deck can be as thin as 1 inch. The new system was tested under several types of loading (distributed and concentrated) to analyze its performance and the results were promising. This system can also help reduce heat loss in a home. That’s a bottom line consideration that has long-term financial benefits for a homeowner.

THE NEW FLOOR SYSTEM IN CONSTRUCTION

This system has been already used in a couple of buildings at some New Jersey shore hard hit areas after Hurricane Sandy in October 2012. With many coastal areas of East United States taking the full brunt of Hurricane Sandy’s damaging effects, precast concrete panels provide a dry, warm, damp-resistant, and exceptionally energy-efficient system for a home. Figures 2, 3 and 4 show the use of the new floor system during construction.

Fig. 1 New Precast floor panel system

Fig. 2 The floor panels placed side by side on a bearing wall.

Fig. 3 One side of the floor panel mounted on top of bearing wall.

Fig. 4 The new precast floor panel system in place.

LOAD TESTING OF PRECAST CONCRETE PLANK

The following load test was performed in July 2012 in Millville, NJ. This test was done to analyze the performance of a floor plank system under loading. Shown in Figure 1, the plank is similar in design to a double-tee, but is very shallow and has 4 stems instead of 2. It uses prestressed strands in the stems, and mild reinforcing in the 1 1/8” thick flange.

Fig. 5 Load testing overview

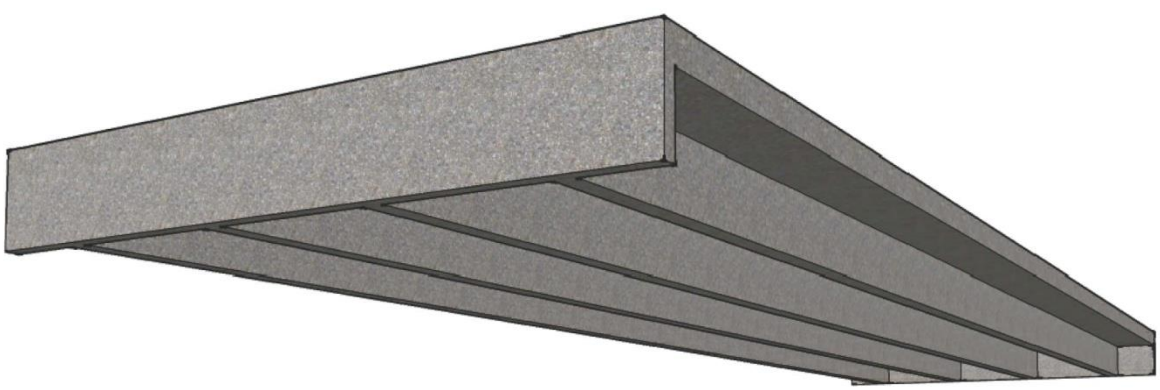


Fig. 6 Eight foot wide prestressed plank

A typical piece is 8 feet wide. The last 2 inches on each end are solid concrete for a continuous bearing surface. For the purposes of this test, a smaller representative section was chosen. Two planks with the cross section shown in Figure 2 were cast, in 26'-1"lengths.

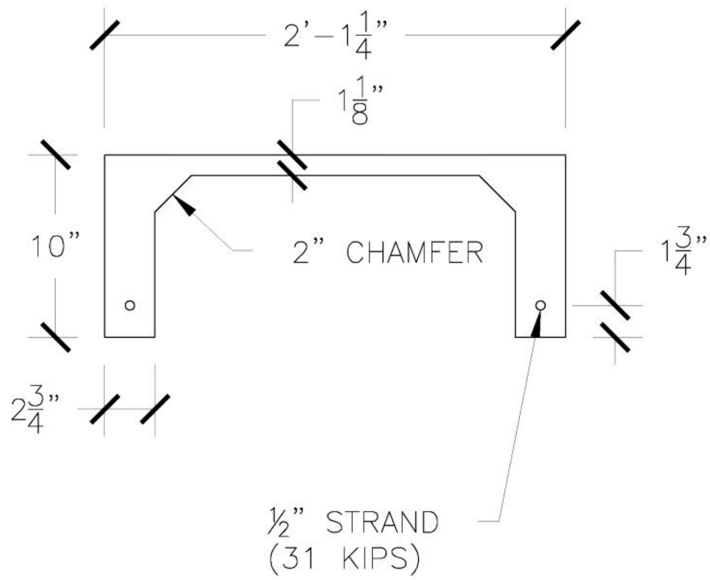


Fig. 7 Section of test plank

The planks were cast on July 5, 2012, and had reached a compressive strength of 7000 psi after 2 weeks, when the planks were initially loaded, and a compressive strength of 7600 psi after 3 weeks, when the planks were loaded to failure. Each stem had a ½" dia. strand stressed to 31 kips. The flange reinforcing consisted of 2'-0" long #3 bars at 18" O.C. For the test, two planks were placed side by side and a 2" topping was poured over them, so that the actual plank tested had the section shown in Figure 8. The topping was 2" thick at the center of the plank, and thicker towards the ends, due to the plank's camber.

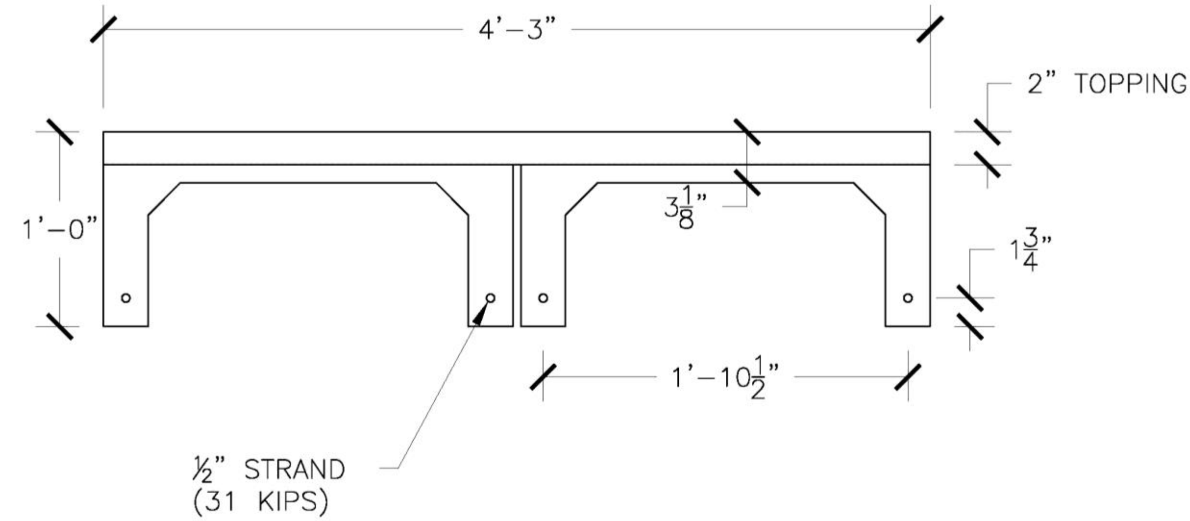


Fig. 8 Section of test planks with topping

To set up the test, the topped planks were raised onto concrete blocks, and supported 3 ½" inches in from each end to leave a span of 25'-6". The schematic in Figure 9 shows the setup. The ends were supported by 2 ¾" wide urethane bearing pads, with one bearing pad at each stem, as shown in Figure 10.

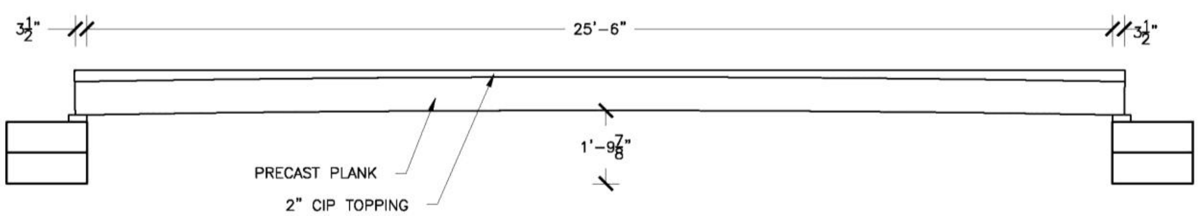


Fig. 9 Test setup with 25'-6" span

Fig. 10 Plank on urethane bearing pads

TESTING PROCEDURE

There were two stages of the testing procedure. In the first stage, the plank was loaded with the Ultimate Superimposed Design Load. The deflections due to this moment were noted immediately after loading, and again after 136 hours. Then, the plank was loaded with a point load in the center, which was increased until the plank failed. In this case, the test was stopped before catastrophic failure for safety reasons, but the plank had deflected more than 8 inches and large cracks had developed through the full depth of the plank.

For stage 1 of the test, the plank was loaded with the Ultimate Superimposed Design Load. This was determined to be 52 ft-kips, as shown in Appendix A. However, it should be noted that the 52 ft-kip load was scaled down from a plank with 5 stems, as shown in the calculations, because the original 8’ wide plank was to have 5 stems. With the current design of 4 stems, the moment should have been scaled back up to 65 ft-kips.

To apply a 52 ft-kip moment, the plank was loaded with precast blocks of sizes that were available at the plant. Because certain sizes were available, the locations necessary to achieve the correct moment were calculated, as shown in Appendix B. Using these locations, the 52 ft-kip load was applied to the plank, as shown in Figure 11.

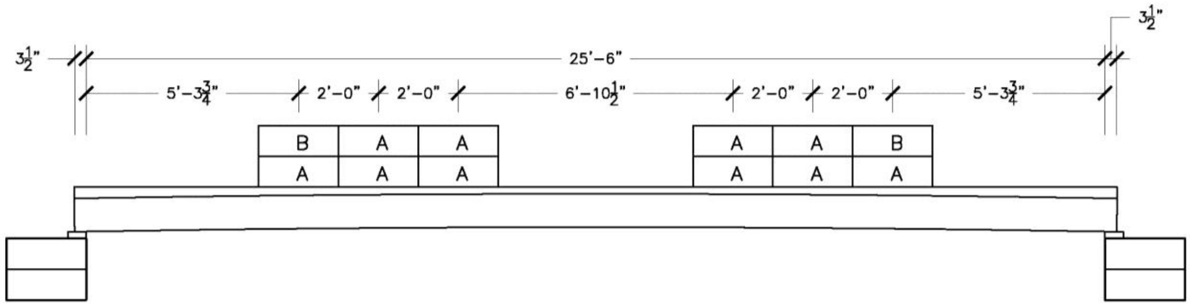


Fig. 11 Test setup with 52 ft-kip loading

The weights of the blocks used are shown in Table 1. Blocks C and D were used later to apply the point load in the middle of the span.

Table 1 Weights of blocks for applying loads

Block Type	**Weight (lbs)**	**Size**
Block A	1156	5' x 2' x 9 1/4"
Block B	1388	6' x 2' x 9 1/4"
Block C	1350	3' x 3' x 1'
Block D	675	3' x 3' x 6"

The deflection of the plank was measured after the Ultimate Design Load was applied. Then, a period of 136 hours passed, and deflection was measured again, as shown in Figure 12.

Fig. 12 **M**easuring deflection at mid-span of plank

At this point, loading to failure began. Blocks C and D were used as weights, and were loaded one by one at the mid-span of the plank. After each increment of weight was applied, deflection was measured again, the plank was inspected at mid-span for cracks, and the strands were checked at the end of the plank for slippage. The load was increased incrementally until there was a point load of 10.8 kips at mid-span, in addition to the 52 ft-kip load initially applied. At this point, the panel had deflected more than 8 inches with the last weight increase having increased the deflection by 3 inches. The panel was considered failed, and the weights were stacked up higher than could be reached safely with the test setup, so no more weight was applied. Final measurements were taken, and then the weights were taken off one by one. After all the point load at mid-span was removed, deflection was measured again to see to what extent the plank returned upwards. Deflection was again measured after the 52 ft-kip load was removed.

The steps of loading are summarized in Table 2, to be able to show which steps correspond to which loading configurations. Schematics of the loading steps are shown in Appendix C.

Table 2 – Steps for loading test plank

Step	Description		
1	Plank with topping, 13 days after pouring		
2	Plank with 52 ft-kip loading		
3	With 52 ft-kip load, after 136 hours		
4	With 52 ft-kip load, and center point load of	1.350	kips
5	With 52 ft-kip load, and center point load of	2.700	kips
6	With 52 ft-kip load, and center point load of	4.050	kips
7	With 52 ft-kip load, and center point load of	4.725	kips
8	With 52 ft-kip load, and center point load of	5.400	kips
9	With 52 ft-kip load, and center point load of	6.075	kips
10	With 52 ft-kip load, and center point load of	6.750	kips
11	With 52 ft-kip load, and center point load of	7.425	kips
12	With 52 ft-kip load, and center point load of	8.100	kips
13	With 52 ft-kip load, and center point load of	8.775	kips
14	With 52 ft-kip load, and center point load of	9.450	kips
15	With 52 ft-kip load, and center point load of	10.125	kips
16	With 52 ft-kip load, and center point load of	10.800	kips
17	With 52 ft-kip load, after unloading center		
18	All loading removed		

RESULTS

The load and deflections at each step are shown in Table 3.

Table 3 Load and deflection data for test plank

Step	(Excluding Self-Weight)		Total Load (kip)	Deflection (in)	Camber (in)
	Moment (ft-kip)	Point Load (kip)			
1	0.0	0	0	0.00	1.38
2	52.0	0	14.336	0.69	0.69
3	52.0	0	14.336	1.06	0.31
4	60.6	1.350	15.686	1.13	0.25
5	69.2	2.700	17.036	1.19	0.19
6	77.8	4.050	18.386	1.38	0.00
7	82.1	4.725	19.061	1.56	-0.19
8	86.4	5.400	19.736	1.75	-0.38
9	90.7	6.075	20.411	2.00	-0.63
10	95.0	6.750	21.086	2.25	-0.88
11	99.3	7.425	21.761	2.56	-1.19
12	103.6	8.100	22.436	2.94	-1.56
13	107.9	8.775	23.111	3.31	-1.94
14	112.2	9.450	23.786	3.94	-2.56
15	116.5	10.125	24.461	4.94	-3.56
16	120.9	10.800	25.136	8.06	-6.69
17	0.0	0	14.336	5.38	-4.00
18	0.0	0	14.336	2.94	-1.56

The plank was monitored for cracks at each step. No cracks were noted until Step 6, when the plank was supporting the 52 ft-kip load and a 4.05 kip point load. At this point, three cracks were noted at mid-span, started at the bottom of the plank and going up about 6 inches. Two cracks were about 20” from the center of the plank, and the third crack was about 2” off of center. These cracks were emboldened with marker, and are shown in Figure 13.

Fig. 13 Cracking at mid-span after step 6

Further cracking was noted after step 8, where the point load had been increased to 5.4 kips at mid-span. At this point, cracks had formed at about every 8 inches, and extended from the bottom of the plank up to between 6 and 8 inches. This cracking is shown in Figure 14.

Fig. 14 Cracking at mid-span after step 8

Finally, the strands at the end of the plank were checked after each step of the test. There was no slippage noted in any of the 4 strands at any point in the test.

CONCLUSIONS

A new concrete floor plank system is produced. This system offers many advantages for post-disaster rebuilding efforts. The system was tested and test results compared the system's greater strength and durability with other building materials. The new patented floor system is lighter in weight and shallower in depth when compared to double-tee panel.

Appendix A

Determination of Ultimate Design Load

Design Loads:

Superimposed Live Load		**40 psf**
Dead Load,	Prestressed Slab:	33.4 psf
	2.5" Topping:	31.3 psf
Superimposed Dead Loads:		
	Finishing:	10 psf
	Interior Partitions:	10 psf
	Services:	10 psf
Total Superimposed Dead Load:		**30 psf**

Ultimate Superimposed Load to be placed during load test:

U = 1.2 D + 1.6 L

U = 1.2 (40 psf) + 1.6 (30 psf) = 100 psf

Two topped slabs to be tested, with four stems. Note that the normal width of these slabs to be 8' wide with 5 stems. The ultimate load required to be supported by an 8' slab is thus 8' x 100 psf = 800 psf.

Adjusting this load for use of four stems rather than five:

800 plf / 5 stems = W / 4 stems

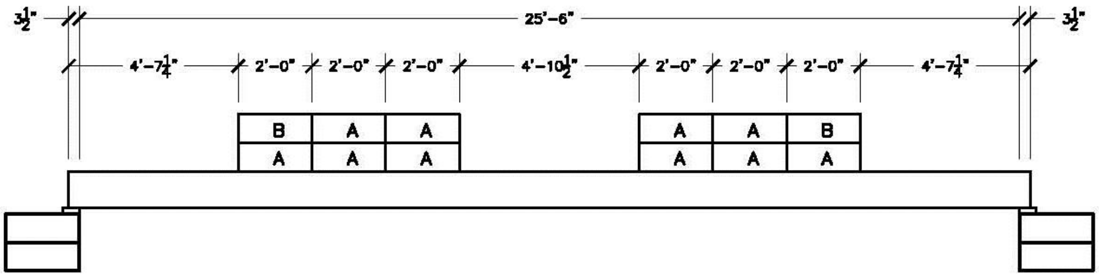
W = 640 plf Note that this will result in a slightly conservative approach since the width of the compression block is reduced.

Ultimate Superimposed moment generated by this load:

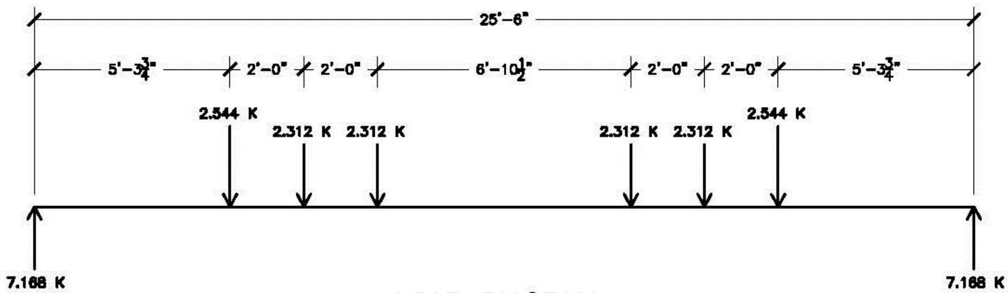
M_u = (.640 x 25.5' x 25.5') / 8 = 52.0 ft-kips

Appendix B

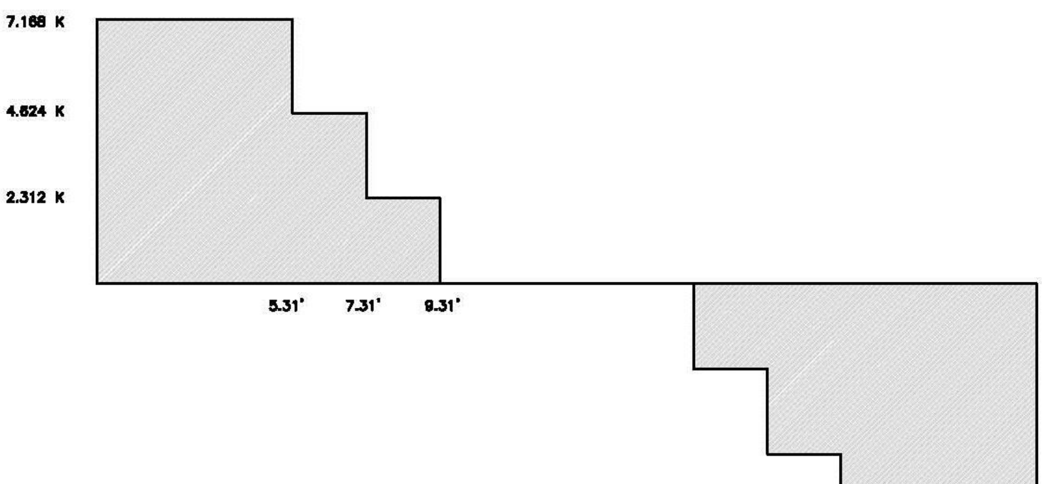
Determination of Loading Block Locations



ELEVATION DIAGRAM



LOAD DIAGRAM



SHEAR DIAGRAM

Area within the shear diagram =

7.168 K x 5.31' + 4.624 K x 2' + 2.312 K x 2' = 52 ft–kips

Appendix C

Loading Sequence