The Dry Floor — A New Approach to High Rise Apartment Buildings

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TISHMAN RESEARCH CORPORATION has been studying new construction approaches to residential high rise building in connection with the parent company's desire, as owner-builders, to provide more value in what it builds; to help trim costs for other interests whom they serve as a consultant or owner's representative; and as part of a team directed by the School of Architecture of Pratt Institute seeking cost reduction methods for low income high rise housing—under HHFA and Ford Foundation grants. Regardless of the auspices, there is a common objective—to decrease costs without sacrificing or by enhancing value.

Although the studies and development activity are not quite complete, presented here is a particular approach to the building's structural system which is believed to have sufficient promise to warrant attention now. It is hoped that it will inspire others and provide a basis to expand thereon. It has already sparked sufficient enthusiasm so that it is planned for use in a high rise project in Philadelphia during 1967.

A large portion of the high rise apartment construction today is flat plate reinforced concrete. When a designer is asked why he chooses flat plate he invariably states that it is more economical; offers optimum flexibility of space layout, and permits the least height per story. When asked what he and his client do not like about flat plate construction, but tolerate, the designer will likely comment in the following areas:

Structure Borne Sound—Varying degrees of structure borne noise transmitted through the integral frame is evident in almost every concrete building. Isolation of such noise is almost a universal problem which the architect lives with.

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Noise Transmission—Noise transmission through floors generally is greater than through walls. Whereas attainment of a 50 STC (Sound Transmission Coefficient) in party walls is relatively simple, e.g., 8 in. concrete walls or multi-layered gypsum, it is not possible with the relatively thin concrete floors now specified.

Impact Noise—Noise from people moving in and about apartments, as well as the movement of objects, is a problem, especially in low income housing, in kitchens and other areas where carpeting is not widely used.

Interior Partition Cracking—The bane of a landlord is the callback to patch and repair cracks on interior plaster or gypsum board walls. This is not only a costly problem for the owner, but has created a problem for the gypsum building products industry who have gone to great lengths to show designers how to take precautions to minimize the condition. Yet many builders ignore them because of increased costs involved. The gypsum companies point out that structural movement stresses partitions and in order to avoid cracking or failure, the partition requires compensation for wind loads, temperature loads, and deflection of floor slabs. The latter, in particular, is a problem in flat plate high rise buildings. The deflection of floor slabs, particularly creep deflection, places partitions in tension as the floor deflects and the partition is loaded by deflection from the slab or structure above. They point out that relief from stresses can be accomplished by not tying the portions into the structure, particularly at columns and ceilings.

The ideal solution, therefore, is to eliminate all stresses through control joints at the periphery of partitions, and in long runs of partitions at a spacing not to exceed 20 ft on center. The degree of isolation required in flat plate construction is particularly high.

Seasonal Limitations—In winter conditions, rare is the job that does not slip because of cold weather limitations with concrete and other "wet" materials.

Labor-Material Balance—With field costs rising more quickly than factory costs, long term economics dictate the desirability of having less field man-hours to do a given job. This has been difficult to achieve with current construction methods.

With the above in mind, we asked ourselves what opportunities steel frame construction might offer to help solve these problems, as well as how to put it in a more realistic competition with flat plate concrete. We concluded that the first thing we must do was to eliminate or minimize wet construction.

We had already studied what opportunities precast concrete construction might offer and found them limited. Intuitively, we suspected dry construction might lead us down the road we were seeking. The key to this objective was the development of a "dry" floor system. Figure 1 shows the floor system that finally evolved from these studies.

By use of an incombustible precast metal-edged gypsum plank, as manufactured by the United States Gypsum Company, we were able to erect quickly and easily over steel joists, 4 ft on center, a high strength reinforced deck ready for application of a flooring system. The gypsum planks are laid dry, without grout, by interlocking tongue and groove metal edges. To develop shear diaphragm resistance, the plank units were attached to the joists by welding. Clip attachments were considered, but were not suitable because of a tendency to squeak, become loose, and not provide adequate stiffness. Tack welding (on the groove edge of the plank at each steel joist intersection) with a short arc, lightweight gun with automatic wire feed appears to be the best approach.

At the top surface of the plank a welded construction of the metal edged joists was necessary. Welding about 4 ft on center will give the floor adequate strength to carry wind loads between braced rows of columns. The painted carbon steel has been shown to be compatible with the weld and the metal edging of the plank. We have found that Microwire equipment appears to do the job best.

Gypsum plank has been used reliably for roof decks for a long time, and there are reports of its use as flooring, particularly in other countries. The plank system will span up to at least 4 ft under normal apartment house loads. Each plank component, 2 in. thick, 15 in. wide and 10 ft long weighs 10.5 lbs per sq ft and is reinforced with 16 ga. galvanized wire mat.

Laboratory and field tests were run on this gypsum plank floor construction with a floating raft overlay. The results of these tests follow.

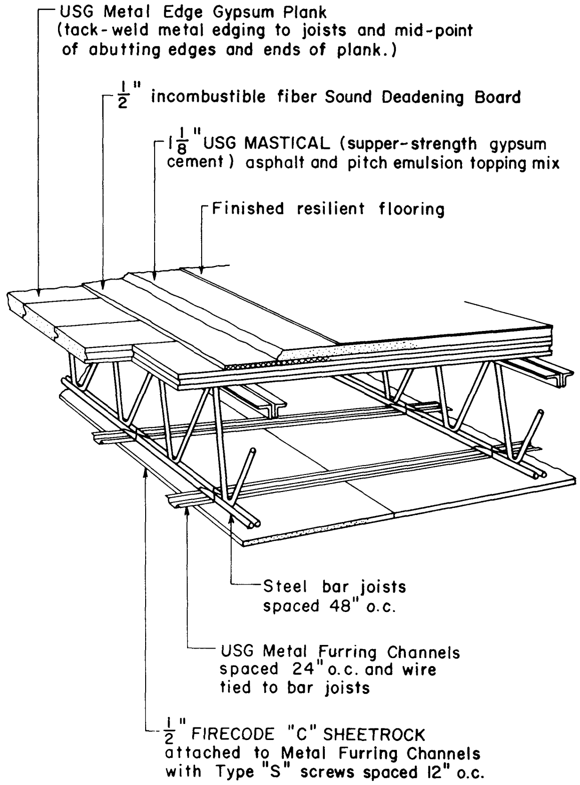

Figure 1

Fire Rating—At a test run at the Underwriters' Laboratory, the floor system achieved a 2½ hr rating. In a field fire test conducted by the National Bureau of Standards, where the fire substantially exceeded that of the ASTM time-temperature curve, causing the gypsum ceiling to fall off, the joists deflected several inches; but there was no real structural failure.

Noise Transmission—An STC of 49 was achieved. This permits an apartment design with total privacy at a recognized acceptable level. Further, the dry floor provides an opportunity to isolate the party wall from the floor, which is a preferred acoustical practice.

Impact Noise Transmission—An INR of +2 was achieved. This is above the minimum FHA recommendation. A plus impact rating, as reported, is not possible with even 12 in. of bare concrete.

Structure Borne Noise—History shows that steel framed structures generally do not have this problem.

Interior Partition Cracking—This condition is minimized or eliminated. Cracking, due to creep deflection of the floor slab, does not exist in steel construction as it does in concrete construction.

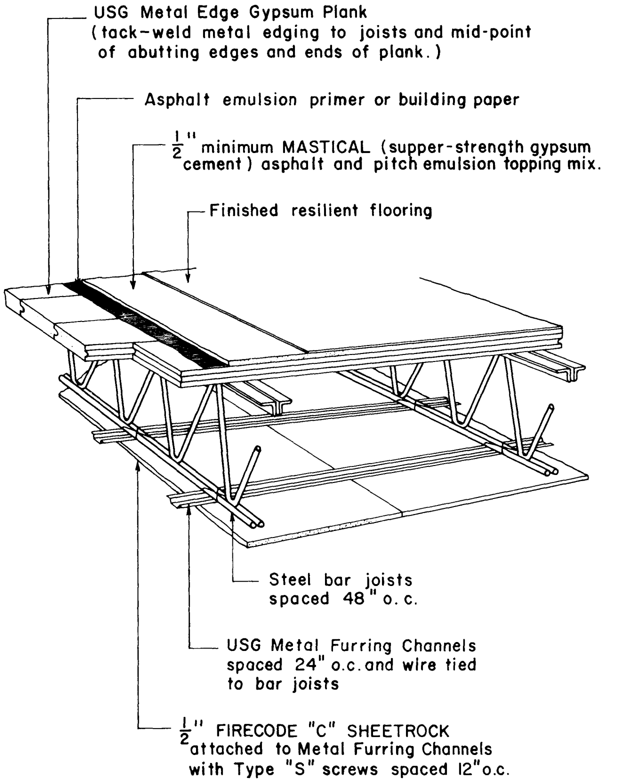

Figure 2

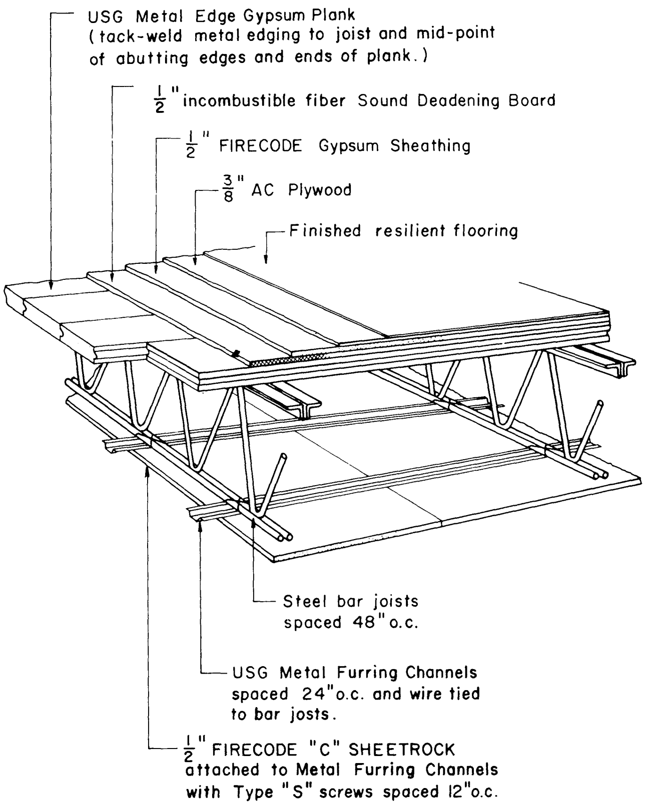

Figure 3

Scheduling—The dry floor may be installed immediately following the steel in all kinds of weather, and may be used immediately following installation. It is conceivable that the plank may be laid under the same contract as the steel erection, resulting in the normal single responsibility economies.

Labor-Material Balance—The ratio of field labor cost to material cost should decrease. Before a conclusive change may be established, several actual jobs will have to be analyzed.

Economics—The floor is light enough to result in savings in structural steel weight (under 7 lbs per sq ft including joists) and of such characteristics as to permit joist spacing to be increased from 2 ft to 4 ft.

The most economical overlay floor known at this time, to be used where impact noise transmission characteristics similar to that where flat plate construction is acceptable, consists of a gypsum mastic concrete (about ½ in. thick) such as U. S. Gypsum's MASTICAL-BT. (See Fig. 1.) Low shrinkage, high early strength, water resistance and trowelability characterize this product. Because this system sets up in a few hours it can be applied independent of the building sequence, i.e., it is not critical. Where minimum FHA noise impact recommendations are to be met, Mastical, about 1⅛-in. in thickness with an underlay such as Fiberglas Noise Stop Board may be effective. (See Fig. 2.)

Tests have shown that a floating floor raft consisting of a soft fibrous incombustible material such as Owens-Corning's Fiberglas Noise Stop Board with two hardboard layers to distribute load is effective. (See Fig. 3.) One acceptable construction for the top of the Fiberglas, consists of a layer of ½ in. gypsum sheathing plus a layer of plywood. (Staggered joints.) Tongue and groove plywood, or two layers of plywood, or perhaps particle board in place of plywood will also serve. Other soft incombustible materials being developed to compete with Fiberglas may be available soon.

Floating raft systems also work well with flat plate construction and must be placed over concrete floors to achieve minimum FHA noise impact recommendations.

When parquet or hardwood floors are used instead of resilient tile, the overlay floor may be simplified, the degree depending upon the characteristics of the wood flooring.

In order that we might make a realistic economic comparison of the proposed floor system with flat plate, where cost experience is well established, we used two actual steel building designs: one with a 20-story building using a wet floor (2½ in. concrete fill and finish on flexible centering) and one utilizing the gypsum plank dry floor.

Table 1
Comparative Costs—$/sq ft[a]

	Reinforced Concrete	Steel Frame[b]	
	Flat plate concrete. Including spray ceiling finish[c] directly on concrete	Gypsum plank dry floor. Joists 4 ft on center	Concrete floor on steel lath. Joists 2 ft on center
With impact noise requirement of INR-O minimum	3.68	3.10	3.38
Without impact noise requirements	3.25	2.91	2.95

[a] *Add to indicated figures, $0.11 for thin plaster plus paint finish.*
[b] *Including cost of fireproofing and premium for extra height.*
[c] *Finish is coating not usually painted.*

Table 2
Detail Costs—$/sq ft
Steel Frame—Joists 2 ft on Center
Concrete Floor on Steel Lath

2½ in. concrete fill and finish on steel lath	0.66
Bar joists	0.36
⅝ in. firecode gypsum board ceiling	0.40
Paint on ceiling	0.07
Structural steel	0.99
	2.48
Impact noise raft (¼ in. particle board; ⅜ in. fiberglas; ½ in. gypsum sheathing)	0.43
Fireproofing of steel and premium for extra building height	0.47
	3.38

Table 3
Detail Costs—$/sq ft
Steel Frame—Joists 4 ft on Center
Metal Edged Gypsum Plank

2 in. gypsum plank	0.55
Welding	0.08
Bar joists	0.21
⅝ in. firecode gypsum board ceiling	0.40
Paint on ceiling	0.07
Structural steel	0.93
½ in. U.S.G. mastical topping[a]	0.20
	2.44
Fiberglas for impact noise	0.13
Fireproofing of steel and premium for extra building height	0.47
	3.04

[a] *Add 0.06 when used with fiberglas as more topping needed.*

Table 1 shows a synopsis of a cost analysis. New York City costs were used. Although these absolute costs may not apply in other geographical areas or under unique market conditions, the relationship between the systems are fairly similar in other circumstances checked so far.

It is recognized that there are other floor system alternatives, for example, precast concrete hollow plank. These have been considered and none were felt to offer enough promise to compete with flat plate concrete.

Tables 2 and 3 show more detailed cost breakdowns for 4 ft and 2 ft joist spacing. The economics are encouraging and work is continuing to refine the system and obtain more engineering and economic data.