



USG Presents: Gypsum Cavity Shaft Wall Systems: The Standard for Life Safety in Low-, Mid- and High-Rise Construction

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WITH THE ADVENT OF HIGH-RISE CONSTRUCTION, VERTICAL SHAFT WALL

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Use the learning objectives below to focus your study as you read **Gypsum Cavity Shaft Wall Systems: The Standard for Life Safety in Low-, Mid- and High-Rise Construction**.

To earn one AIA/CES Learning Unit including one hour of health safety welfare credit, answer the questions on page 201, then follow the reporting instructions on page 252 or use the Continuing Education self report form located at architecturalrecord.com.

Learning Objectives:

At the end of this article you will be able to:

- Understand the essential performance and design criteria used to select and specify cavity shaft walls;
- Know how gypsum drywall shaft walls perform and install;
- Create gypsum drywall shaft wall design specifications optimized for abuse resistance and moisture control.

systems have become a critical element underlying successful building design. These walls, which house elevators, stairwells and mechanical utilities, enable safe occupant egress and ensure the reliable flow of air, water, heating, cooling and other essential utilities throughout a building.

From a life safety standpoint, shaft walls are the most important walls in any building. In the event of a fire, shaft walls ensure that occupants have a means to exit the building (via stairwells) and that firefighters can access the building (via elevators and stairwells). In addition, the type of shaft wall constructed and its location impacts the

amount of usable space in a building. Lastly, by including abuse-resistant design into shaft wall specifications, these walls can positively affect building life cycle costs.

To properly specify shaft walls for low-, mid- and high-rise construction, architects must know the types of systems available, as well as the performance and installation attributes of each. Based on this knowledge, architects can then select – and specify – the system that best meets specific project life safety and structural performance requirements.

A Brief History

Prior to the advent of high-rise construction, the traditional materials of choice for shaft walls included masonry, structural clay tile and gypsum tile. In 1931, for example, the architectural firm of Shreve, Lamb and Harmon specified masonry shaft walls for the Empire State Building, which is considered by many to be the first modern high rise. In that same year, Graham, Anderson, Probst and White selected gypsum tiles for the construction of the 4-million-square-foot Merchandise Mart in Chicago.

However, as buildings reached farther into the skies, the search for lighter, more elastic shaft wall systems became a priority. Traditional hard and brittle materials, such as structural clay and gypsum tiles, limited the design capabilities of shafts in modern high-rises and placed constraints on the finished spaces within those buildings. In response to these needs, gypsum panel shaft wall systems were introduced in the 1960s. The first project to use these gypsum panel systems was a small office building in Los Angeles. This application was followed by a gypsum panel installation on the Central National Bank Building (designed by Charles Luckman and Associates) in Cleveland, and then at the U.S. Steel



Gypsum drywall shaft systems are now considered the standard for low-, mid- and high-rise construction.

Building (designed by Harrison Abramovitz and Abbe) in Pittsburgh.

Based upon these early efforts, designers today have much more flexibility in both cavity shaft wall material selection and system design. Material choices now include poured-in-place concrete, masonry, gypsum plaster, metal stud drywall or specially designed gypsum drywall shaft wall systems. Given certain design parameters for the shafts and the end

use of the structure, any of these may be appropriate for a given building. (See *Shaft Wall Performance Comparisons* table included in the additional online reading materials.) But determining which system is best for a specific structure requires careful research.

Selecting the Right System

The shaft wall selection process begins with a review of the key performance and design criteria that the walls will be expected to meet. While life safety is the overriding concern for all applications, specifiers should identify and prioritize the additional system attributes that best meet the remaining performance criteria and the other needs of the client. Following are some of the more important factors to consider.

Life Safety – This is the most important consideration for all projects. The life safety attributes of a shaft wall system protect building occupants, support the interests of the client and help manage the designer’s risk. As such, the fire endurance of the system (one to four hours) should be verified by an independent testing agency such as Underwriters Laboratories (UL), and the primary system components (such as gypsum panels) should be classified by the same agency. Only thoroughly tested systems can ensure long-term performance of the shaft wall itself and key interfaces such as elevator doors, fire dampers and stairwells.

Wall Thickness – The thickness of the shaft wall impacts the square footage of usable/leaseable floor space. Gypsum shaft walls are usually the thinnest systems available and thus deliver the maximum usable floor space.

Weight – The lighter the shaft wall, the less dead load on the structure. Gypsum drywall shaft systems offer benefits here as well. They are the lightest-weight systems available.

Elasticity – Elasticity accommodates structural dynamics such as building sway, drift and floor movement, as well as the cyclical nature of loading from elevators and seismic events. Elastic and ductile shaft walls are normally preferable to stiff and brittle walls.

Abuse Resistance – Abuse-resistant shaft walls stand up to everyday damage and thereby reduce life cycle costs. The abuse-resistance of gypsum drywall shaft walls can be enhanced through the use of special abuse-resistant panels, surface coatings and/or veneer plaster finishes.

Speed of Installation – Faster-installing systems help streamline scheduling and support good design and project management practices. Again, gypsum drywall shaft systems offer significant benefits in this area. They install quickly and allow construction from one side only (the floor side). This eliminates the need for scaffolding within the shaft and helps create a safer working environment.

By evaluating and ranking the relative importance of each of these factors, specifiers are able to zero in on the particular type of shaft wall system that best

meets the life safety and performance needs of the building, as well as other design and aesthetic priorities established by the client.

Gypsum Shaft Walls

Since their introduction nearly 40 years ago, gypsum drywall shaft systems have offered architects a highly attractive combination of performance and installation benefits. As such, they are considered the preferred choice for most applications. The systems are lightweight.

A two-hour fire-rated gypsum wall weighs only 9 pounds per square foot. They are thin. A two-hour fire-rated wall is only 3 1/2 inches thick. They also install more quickly and economically than “wet” shaft walls, such as masonry. Gypsum panel shaft walls are completed early in the construction process and finished later, along with other interior partitions. Most importantly, the systems have undergone extensive independent testing for fire, sound and structural performance.

The most widely used gypsum shaft wall system consists of only five components. They are:

- Gypsum Liner Panels – 1-inch-thick and 24 inches wide, with double-beveled edges
- Gypsum Panels – 5/8-inch-thick Type X or 1/2-inch-thick Type C core
- Steel C-H Stud – 2 1/2, 4 and 6 inches deep, 25, 22 or 20 gauge
- Steel J-runners – 2 1/2, 4, and 6 inches deep, 24 or 20 gauge (J-runners may also be used as starter studs.)
- Steel E-stud – 2 1/2, 4 and 6 inches deep, 25, 22 or 20 gauge

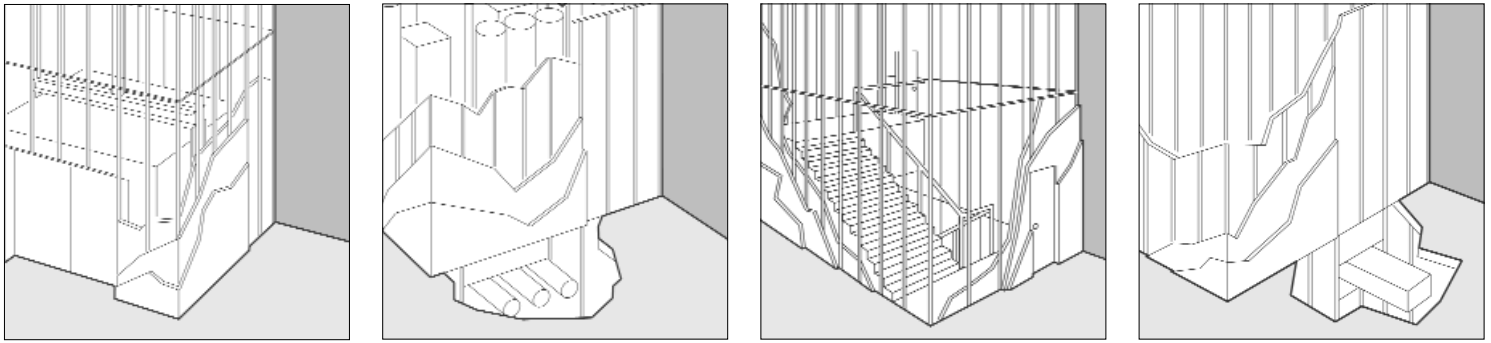
Substitutions for any of these components are not advisable without a thorough evaluation by the architect. Substitution is typically outside the scope of independent system evaluation and therefore is not endorsed by system manufacturers.

Installation of the gypsum shaft system is handled as follows:

1. J-runners are attached to the concrete floor and to the structure above. Attachment is accomplished using a power-driven fastener of a known pull-out and shear capacity.
2. An E-stud is vertically attached along one side of the terminating wall or structural element. In cross-section, the E-stud, in fact, looks like an “E,” and is designed to receive a 1-inch-thick, 2-foot-wide gypsum liner panel. (J-runners can be used as an alternative to E-studs.)
3. A gypsum liner panel is placed into the top and bottom of the J-runners and fitted into the E-stud. Because no fasteners or adhesives are required, the application moves quickly. (When using J-runners instead of E-studs, attachment screws are required.)
4. A C-H-stud is then placed over the free edge of the liner panel and the next panel is positioned within the J-runners and inserted into the “H” portion of the stud. The C-H-stud provides a tight friction fit along the entire length of the panel to eliminate rattles when in service. Again, no fasteners or adhesives are needed. Like the E-stud, the C-H-stud derives its name from its cross-section profile. The “C” section of the stud forms a cavity that can hold insulation, as well as plumbing and electrical lines. It has 1-inch-diameter holes located 16 inches from each end to accommodate horizontal conduit runs. The “H” portion of the stud features vertical slots to minimize heat transfer through the stud.



Gypsum shaft walls (seen here from inside the cavity) are the thinnest and lightest-weight shaft walls available.



Cut-away views of various gypsum shaft wall systems: an elevator shaft, a mechanical shaft, a stairwell and an air return shaft.

5. The installation continues progressively. Each succeeding liner panel is fitted with a C-H-stud and the next liner panel is inserted until the full length of the wall is reached. The wall is completed by fitting the final gypsum liner panel into another E-stud or J-runner attached to the intersecting construction.
6. After the gypsum liner panels are installed, one or more layers of $5/8$ - or $1/2$ -inch-thick Type X or Type C core gypsum wallboard panels are screw-attached to the front of the “C” section of the studs. The face panels are finished using standard wallboard joint compound and tape, then primed and painted. For enhanced abuse resistance and a more monolithic look, Type X or Type C veneer plaster base panels finished with veneer plaster can be used in place of the gypsum wallboard.

Design Parameters

The first definitive design parameters for shaft wall systems were developed more than 30 years ago by the structural engineering firm of Skilling, Helle, Christiansen and Robertson, working in association with Minoru Yamasaki and Associates and Emory Roth & Sons. Their study was prompted by a reported shaft wall failure in a prominent New York City office building. (A similar shaft wall failure had also been reported in a Cleveland building.)

The study revealed that the walls in the New York office building had failed due to elevator cyclic loading. As elevators move through a building, they create a piston-type action that induces alternating positive and negative loads in the shaft walls.

Based on these findings, Skilling, Helle, Christiansen and Robertson established the following criteria:

1. The shaft wall system should be capable of being built from one side only.
2. The assembly must obtain a two-hour fire endurance rating.
3. The assembly should have a minimum STC (Sound Transmission Classification) of 40.
4. The maximum dead load of the partition should be 15 pounds per square foot.
5. The shaft wall must withstand a 7.5 psf loading while limiting deflection to $L/240$.
6. The shaft wall must withstand an instantaneous load of 25 psf without structural failure.
7. The assembly must be cycled through its maximum deflection without failure for 1 million cycles.
8. The assembly must be airtight.

Gypsum cavity shaft wall assemblies meet all of these design requirements. They have been designed and tested using accepted engineering practices with deflection criteria of $L/120$, $L/240$ and $L/360$ clear partition heights. Limiting height tables account for flexural and shear forces, and a wide range of product and installation combinations is available to meet performance requirements.

The walls have been tested (per ASTM E119) to achieve fire ratings of one to four hours. The UL design numbers for the most commonly specified fire-rated gypsum shaft wall systems are:

- One-hour system: UL Design Numbers U415 and U469
- Two-hour system: UL Design Numbers U 415, U438 and U467
- Two-hour system (alternate): UL Design Number U492

- Three-hour system: UL Design Number U415
- Four-hour system: UL Design Number U415

In terms of sound transmission performance, gypsum assemblies using $2\frac{1}{2}$ -inch studs have been tested to achieve an STC of 39. The rating can be increased to 47 by adding a 1-inch-thick layer of sound attenuation fire blankets (SAFB) within the partition cavity, while an STC of 52 can be achieved by using 4-inch studs with 3 inches of SAFB.

When it comes to pressure loading, it is important to differentiate between intermittent and constant load tables when reviewing manufacturers' limiting heights tables. These tables evaluate the various combinations of gypsum panel thicknesses and layers with stud gauge and depth. Because the gypsum panels and steel studs behave compositely, the relative stiffness of the system is greater than the stud properties of the C-H-stud alone.

The intermittent load table is appropriate when designing an elevator shaft. If the shaft is to be used for HVAC and there is no sheet metal ductwork (e.g. the gypsum will serve as the duct liner) the constant load table should be used. This differentiation is important because AISI (the American Iron and Steel Institute) allows engineers to reduce the stress by one-third if the loading is considered intermittent. This reduction is not allowed for mechanical heating and cooling shaft walls where the pressure is constant.

It should also be noted that while codes require specifiers to assume a 5-pound per square foot uniform load for interior partitions, this may not be sufficient for elevator shaft walls, where loading is a function of the speed of the elevator and the number of elevators per shaft. (See *Recommended Elevator Shaft Pressure Load* table included in the additional online reading materials.)

These criteria are among the factors that define essential gypsum shaft wall performance. However, additional criteria such as life cycle costs and security considerations continue to shape how well the shaft walls function within the building as a whole. (See page 200 for more information about abuse resistance.)

Specification Guidelines

Following are a number of key issues that need to be considered when creating gypsum shaft wall specifications:

1. Design the system to meet anticipated elevator shaft pressures. Pressures will vary depending on the speed of the elevators and the number of elevators per shaft.
2. Maximum partition heights are determined by intermittent air pressure loads and allowable deflections. The applied pressure load is selected based on the elevator cab speed and the number of elevators per shaft. Specifiers should consider three factors to determine maximum partition heights:
 - **Bending Stress** – the unit force exerted that will break or distort the stud;
 - **End Reaction Shear** – determined by the amount of force applied to the stud that will bend or shear the J-runner or cripple the stud;
 - **Deflection** – determined by the amount of bending under a load that a wall can experience without exceeding a prescribed ratio related to partition height.
3. An important, but often neglected, design consideration is the interface of the elevator shaft wall and the B-labeled elevator doorframes. Be sure that

the cavity shaft wall system has been tested by UL with the elevator door and frames that will be installed in the building. Not all systems have been evaluated for this critical juncture, and there are some specific details that should be followed.

4. Bear in mind that not all shaft wall steel studs are the same. Airtight, rattle-free performance requires a C-H-stud, which provides continuous edge support along the full length of the 1-inch-thick liner panels. Some studs have tabs that provide only intermittent support and may bend or break during installation.
5. To provide the safest possible cavity shaft wall construction, carefully review the manufacturer's limiting height data.
6. Oscillating height testing is another key consideration. Manufacturer oscillation testing has demonstrated that J-runners at the top and bottom of the shaft wall should be at least 24 gauge to withstand the positive and negative pressures created by the elevators. Lesser-strength J-runners can fatigue and may be subject to fastener failure and fracturing. Look for specific test data up to at least 1 million cycles to ensure overall system longevity.
7. When designing mechanical shaft walls, give careful consideration to ductwork penetrations. If not designed properly, these penetrations may negate the wall's fire endurance rating. Typically, a fire damper in the ductwork itself is sufficient; however, make sure the damper is compatible with the type of wall specified and that both the wall and the damper have been evaluated under actual fire testing.
8. Typically, shaft wall installation closely follows the erection of the superstructure. This is done to provide a safety barrier around the shaft openings and speed the installation. Unfortunately this is sometimes done prior to completion of the exterior envelope. This exposes all building materials to moisture, which can lead to a variety of adverse conditions. To ensure proper performance, it is vitally important to control moisture on a project. (More information on moisture control is included in the required additional reading materials.)
9. Shaft walls with elevator door frames in them should be a minimum of 5 inches thick to accommodate the boxes for call buttons, position indicators and fireman's access keys.
10. Where shaft walls enclose elevator and unlined return air vents, and intermittent pressures are expected, sealant is recommended at intersections with floors, ceilings, columns, ducts, etc. to seal peripheries and penetrations to minimize whistling and dirt accumulation due to air movement.
11. If the gypsum shaft wall is intended to enclose a mechanical shaft and there will be no sheet metal ductwork, the system should be designed with the following performance provisions:
 - The gypsum board surface temperature should not exceed 125 degrees F.
 - Air stream dew point temperatures should be maintained below gypsum board surface temperatures.
 - The assembly should be designed to withstand sustained design uniform air pressure loads not exceeding 10 psf. Start-up surges should be no greater than 1½ times the design static load.
 - Separate approved liners should be installed in areas subject to continuous moisture overspray, condensation or air stream temperature exceeding 125 degrees F.
 - Appropriate sealants should be used to ensure airtight construction.

Conclusion

Because gypsum shaft walls enable designers to meet all key performance, design and installation criteria more effectively than competing systems, they are now considered the standard for low-, mid- and high-rise construction. Gypsum systems not only enabled the construction of ultra-high-rise buildings such as the Sears Tower in Chicago and the Petronis Towers in Kuala Lumpur, Malaysia, but they also provide a superior combination of benefits for low- and mid-rise construction.

No matter what the application, gypsum shaft walls are required to meet a complex range of performance and design functions. As such, architects must account for multiple variables in the specification process. With this in mind, designers are well advised to work with manufacturers that offer the most extensive testing data and technical support services. Doing so will minimize the risk for all parties involved and ensure long-term performance. ■

Designing for Gypsum Board Abuse Resistance

Within the last decade, gypsum board manufacturers have focused a great deal of research on understanding the nature of abuse that gypsum partitions may face during day-to-day service life.

This analysis has led to an understanding that there are three distinct components of abuse resistance. They are:

- **Surface Damage** – This encompasses abrasion or incidental indentation of the partition face from high traffic under normal use.
- **Penetration** – This is defined as penetration through the facing material into the stud cavity resulting from the impact of a blunt object (such as a kick or a hammer blow) or from a sharp object (such as a screwdriver or a knife). It also includes a blow from a softer object that covers a large surface area of the wall. When penetrated, systems without a stud cavity tend to undergo failure of the entire partition.
- **Security** – This is a breach of the entire assembly from either forced entry or ballistics.

To aid architects in determining which gypsum panel designs best meet these various abuse-resistance conditions, the following abuse categories have been developed:

- **Category One (Light Duty)** – A basic upgrade of standard drywall that provides improved resistance to incidental surface and impact damage.
- **Category Two (Moderate Duty)** – Ideal for areas such as multifamily stairwells and retail corridors that require an upgraded resistance to incidental surface and impact damage.
- **Category Three (Heavy Duty)** – Ideal for freight elevator walls and other areas that require resistance to heavy surface and impact damage.
- **Category Four (Extreme Duty)** – For even stronger protection against heavy surface and impact damage.
- **Category Five (Security)** – For protection against forced entry and ballistics.

For a typical office building, the shaft wall design may require a category one or two level of abuse resistance. Hospitals and other institutional facilities may require heavy to extreme abuse resistance (categories three or four). And where security is a consideration, category five abuse resistance may be required. One such building, the Broward County Judicial Center, in Broward County, Fla., was designed by Michael Schiff & Associates in the early 1990s with shaft walls made from high-strength solid plaster. As security in building design continues to grow in importance, wall security testing recently promulgated by the U.S. Department of State (ST-STD-01.01 and ST-STD-01.02) may be of particular interest.

One Cautionary Note:

When designing shaft walls for abuse resistance or for any other secondary consideration, life safety considerations should never be compromised. Independently verified system performance always comes first.

Click for Additional Required Reading

As part of this CES learning activity, you are required to read some additional material. Some of the test questions below will relate to the additional reading material. Go to www.architecturalrecord.com/CONTEDUC/ConteducC.asp to access the material online. To obtain a faxed copy, contact Marty Duffy at 312-606-5781 or mduffy@usg.com.

Learning Objectives

At the end of this article you will be able to:

- Understand the essential performance and design criteria used to select and specify cavity shaft walls;
- Know how gypsum drywall shaft walls perform and install;
- Create gypsum drywall shaft wall design specifications optimized for abuse resistance and moisture control.

Instructions

Refer to the learning objectives above. Complete the questions below. Go to the self report form on page 252. Follow the reporting instructions, answer the test questions and submit the form. Or use the Continuing Education self report form on *Record's* website—architecturalrecord.com—to receive one AIA/CES Learning Unit including one hour of health safety welfare credit.

Questions

- Q:** 1. The type of shaft wall selected and its location impacts the amount of usable space in a building.
- A:** a. True
b. False
- Q:** 2. In comparing shaft wall performances, which has the lowest cost index?
- A:** a. Masonry
b. Poured-in-place concrete
c. Solid plaster
d. Gypsum panel
- Q:** 3. In comparing shaft wall performances, which has the fastest speed of erection?
- A:** a. Masonry
b. Poured-in-place concrete
c. Solid plaster
d. Gypsum panel
- Q:** 4. Which of the following components are NOT part of a gypsum shaft wall system?
- A:** a. Steel C-H-stud
b. Steel L-angles
c. Steel J-runners
d. Steel E-stud
- Q:** 5. Other commonly available materials may be substituted for the components of a tested gypsum shaft wall system.
- A:** a. True
b. False
- Q:** 6. During the installation of a gypsum shaft wall, what is the next step after a gypsum liner panel is inserted?
- A:** a. J-runners attached to the concrete floor and to the structure above
b. An E-stud is vertically attached along one side of the terminating wall
c. A C-H-stud is slid over the free edge of the liner panel
- Q:** 7. Insulation, plumbing and electrical lines can fit inside:
- A:** a. J-runners
b. C-H-studs
c. E-studs
d. The cavity between the gypsum liner panels and face layers
- Q:** 8. According to the design parameters set by Skilling, Helle, Christiansen, and Robertson, shaft walls should be capable of being built from one side only, obtain a two-hour fire rating and:
- A:** a. The shaft must be waterproof
b. Be oscillation-tested for one million cycles
c. Maximum height of an individual panel is 4 feet
- Q:** 9. When it comes to pressure loading, it is important to differentiate between intermittent and constant load tables when reviewing manufacturers' limiting heights tables.
- A:** a. True
b. False
- Q:** 10. For pressure loading, if the shaft is to be used for HVAC and there is no sheet metal ductwork, which table should be used?
- A:** a. Intermittent
b. Constant
- Q:** 11. The recommended elevator shaft pressure load for a single shaft enclosing two elevators moving at 1,000 – 1,800 ft./min. is:
- A:** a. 5.0 psf
b. 7.5 psf
c. 10.0 psf
d. 15.0 psf
- Q:** 12. In order to withstand the positive and negative pressures created by elevators, J-runners at the top and bottom of the shaft wall should be at least:
- A:** a. 12 gauge
b. 30 gauge
c. 24 gauge
d. 48 gauge
- Q:** 13. Which abuse category would best meet the abuse-resistance conditions in a shaft wall design for a freight elevator?
- A:** a. Category One (Light Duty)
b. Category Two (Moderate Duty)
c. Category Three (Heavy Duty)
d. Category Five (Security)

About USG

USG Corporation is a *Fortune 500* company with subsidiaries that are market leaders in their key product groups: gypsum wallboard, joint compound and related gypsum products; cement board; gypsum fiber panels; ceiling tile and grid; and building products distribution. The company received the 2001 AIA/CES Award for Excellence for its commitment to providing quality continuing education programs.

United States Gypsum Company, a subsidiary of USG Corporation, manufactures the SHEETROCK® Brand Cavity Shaft Wall System, the

most extensively tested and widely used gypsum shaft wall in the industry. The shaft walls provide fire resistance up to four hours and sound ratings up to 52 STC. They resist intermittent lateral loads up to 15 psf, and resist fatigue failure under cyclic lateral loading.

For technical advice relating to cavity shaft wall detailing and specifications, contact USG Corporation at P.O. Box 806278, Chicago, IL 60680-4124, call USG's Customer Service Department at 800-USG-4YOU or visit the company's Web site at www.usg.com.



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