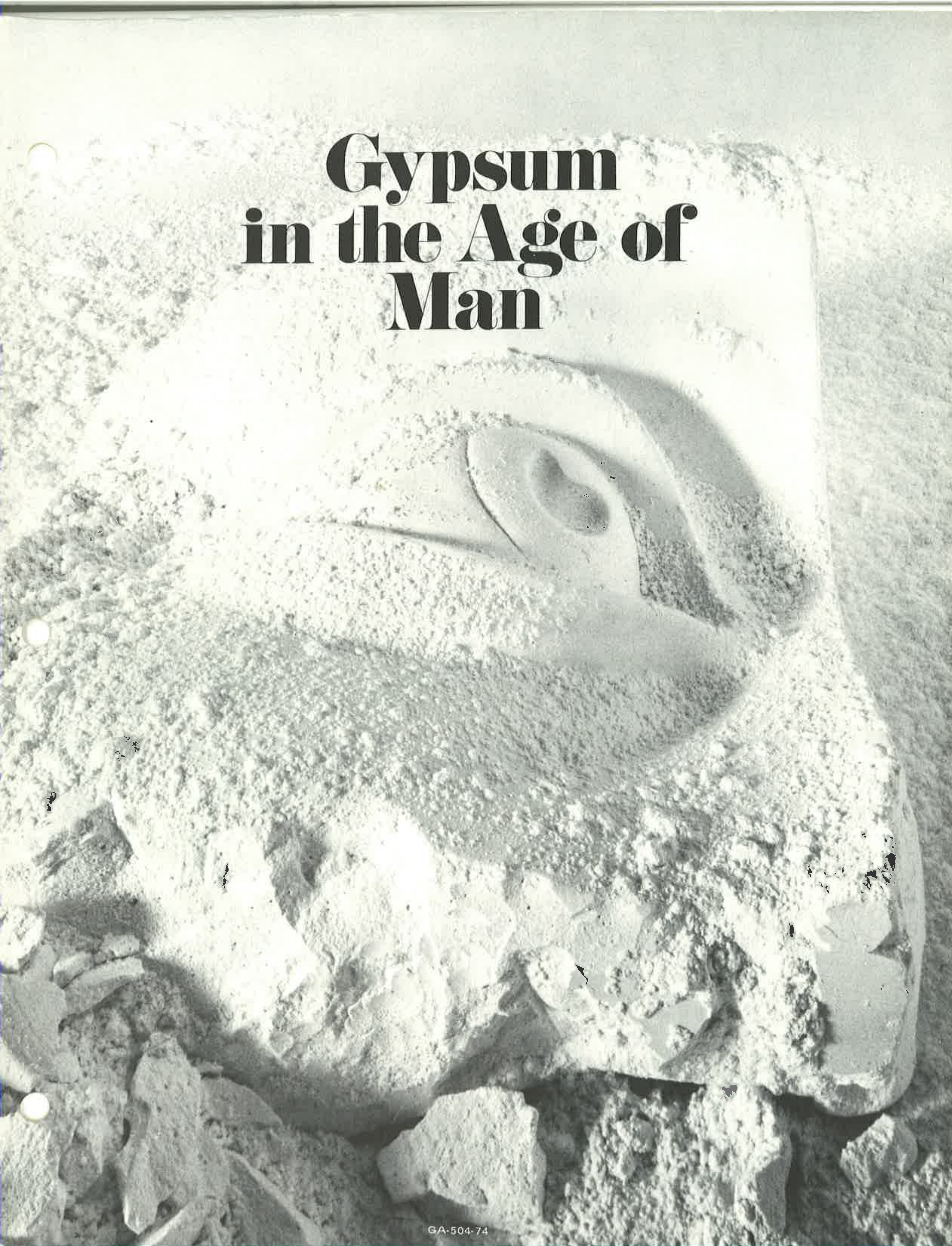
Gypsum in the Age of Man



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This publication offers a series of articles concerning the gypsum industry, its products, and their application to the building industry. It consists mainly of articles printed over the past few years in SOUTHERN BUILDING, the official publication of the Southern Building Code Congress. These informative articles are authored by individual experts from Gypsum Association member companies. They cover such subjects as fire resistance, sound control, innovative products and their use in today's building industry. It is the objective of this book to put all of these recent articles under one cover for easy reference by anyone who has an interest in gypsum products.

About the cover: More and more people are becoming increasingly aware of many and varied uses of gypsum in the building industry. Perhaps not so well known are the many ways gypsum has contributed to man's culture through the ages. Much of the world's masterful statuary has been carved from alabaster, a form of gypsum. Michelangelo's ceiling mural of the Sistine Chapel was painted on a gypsum base to assure its preservation as were most murals of the period. The Egyptians as far back as 3700 B.C. also used gypsum as a base to preserve the wall murals in their pyramids. Gypsum, in the age of man, has been an important contributor to culture as well as construction.

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The Gypsum Industry — Its Growth & Innovations

Nowhere in the annals of homebuilding has there ever been a more enthusiastically accepted construction innovation than gypsum drywall.

The rapid expansion in the use of gypsum drywall became possible after World War II when the demand for housing skyrocketed. Use of drywall for hastily built military barracks and other buildings during the war (when speed of construction was a prime factor) revealed the potential of drywall use on a large scale. This potential did not go unnoticed by the country's alert homebuilders.

During this period, use of temporary gypsum board siding and roof sheathing materials had spread to all sections of the country and overseas as the Seabees and other military constructors pioneered their use in the battle zones of the world.

The end of hostilities in Europe and the Far East brought a wave of returning servicemen and a tremendous market for new housing. Drywall provided some unique and much-needed qualities. No longer was it necessary to wait for the wet wall to cure for several weeks. The interior walls could be erected - ready for decoration in three or four days. Drywall was made from inexpensive, inexhaustible and readily available raw material, it was easily repaired, and could be used in conjunction with other building materials. It is not an exaggeration to say that without the development of the drywall industry, home building could not have grown to its present advanced level of high speed quality production.

Countless improvements have been made since that immediate post World War II period. Advanced products, sophisticated systems and modern techniques predominate in the industry today.

New products and systems are constantly being evolved by the gypsum manufacturers - many of them based on suggestions from mechanics and contractors in the field. Over the years when there has been a need for creative solutions to new problems faced by the rapidly expanding building industry, the gypsum manufacturer has been approached and usually come up with an answer.

Although it was the mid 1940's when gypsum drywall began a phenomenal rise to its present prominent position in the homebuilding field, gypsum had been used for many hundreds of years as a plaster by the architects, builders and artists of the world. It wasn't until nearly the end of the 19th century that a means was found to control its setting time and the way was paved for this ancient material to make its immense contribution to the unprecedented demand for living space necessitated by the expanding population and prosperous economy of the 20th century United States. Today, according to the Bureau of Mines, more than 18 million short tons of raw gypsum are mined annually and most of it is used in the building industry, including the gypsum wallboard interiors used in the overwhelming majority of today's homes.

A major milestone in the development of drywall was the perfection of effective joint finishing. Tapered edge wallboard permitted the joint to be concealed with tape and to be finished, providing a smooth, monolithic surface. Not to be overlooked is the contribution of Robert and Stanley Ames whose mechanical taping tools made possible the speedier covering of seams where the boards were joined.

Vinyl covered boards made their appearance in the late 1950's providing a wall system that required no additional decoration. The vinyl surface was even more damage-resistant than plain gypsum board. Another innovation of the late 40's and early 50's included the development of type X gypsum wallboard, with a specially treated glass-supplemented core which provided much greater fire resistance. Water resistant boards for use in areas exposed to extreme moisture conditions such as bathroom shower stalls where it functions as a base for ceramic, plastic, or metal tile; exterior soffit board for areas not exposed directly to the weather such as porch ceilings, covered walkways, eave overhangs, etc., and round edge gypsum board which effectively resists ridging at the joints made their appearance.

To counter the problem of nail popping, the G.W.B-54 type gypsum wallboard nail was especially designed and with its introduction this bothersome problem was substantially overcome. The subsequent introduction of steel stud construction and screw application of gypsum wallboard would provide an alternate solution.

Ridging, which still remained something of a problem, was finally minimized with the composite taper and round edge, plus two-step filling. This has almost completely eliminated ridging difficulties. Alleviation of the problems of ridging and nail popping were key factors in today's universal acceptance of gypsum board for interior surfaces, making it possible to provide a completely smooth, monolithic surface with drywall. When some inventive contractor in the field developed an effective method of covering curved surfaces with drywall (a task which previously could only be accomplished with metal lath and plaster) other contractors and builders were quick to adopt the method. It was now possible to provide a completely smooth, monolithic surface vertically anywhere. Drywall lent itself ideally to creative shaping of interior surfaces such as circular staircases, unusual ceiling treatment, irregular walls, etc.

Other key innovations which originated with the contractor in the field included: corner treatment where mechanical fasteners were omitted at interior angles in order to relieve stresses that might otherwise cause cracking and nail popping; studless partitions, consisting of layers of gypsum board attached together with joint or laminating compounds or other special adhesives; and resilient attachment methods whereby superior sound control was attained by mounting drywall on resilient channels or over sound deadening board to isolate it from the framing and decrease vibration. The use of resilient clips in multi-ply walls accomplished the same sound absorbing effect.

A simple but very effective way of increasing fire resistance was introduced involving the utilization of double layers of drywall applied on each side of a wall to make, in effect, a double wall.

While by the mid 1950's drywall was firmly established in the homebuilding market, not too much drywall was being used in high rise structures - including apartments. The drywall industry, having already accomplished so much in partnership with the homebuilder, next turned its attention to the high rise apartment building. Thus began the most extensive period of research and development in the drywall industry's history — a period of progress which today sees gypsum drywall accounting for approximately 90% of the total interior partitioning. The move into high rise construction brought the drywall contractor and builder increasingly into the use of systems.

In systems construction, performance is the key. The goal is better performance in less time for less cost — and was sought by contractor, builder, manufacturer, and owner occupants. It led to development of new and improved systems incorporating better essential characteristics such as fire resistance, sound control, durability, light weight, versatility, etc.

Another innovation important to the high rise apartment market, was the concept of membrane-fireproofing which utilized a thin shell of fireproofing around structural steel to protect it from fire. This membrane replaced heavier, more expensive systems, reducing the total steel requirements for the structure. Membrane-fireproofing systems were quickly approved by national code bodies.

Because of the rapid rise of drywall in the building field and its wide use throughout the industry, a standardization of products was soon established. Nationally recognized standards groups quickly established standards for gypsum products and related them to life and safety.

Steel studs were developed for the application of wallboard with special screws and permitted the economic installation of drywall partitions in high rise construction where noncombustible construction is required. As a matter of fact there are contractors today who feel the steel stud will eventually completely replace the wood stud in all constructions.

Of the numerous systems (partition, wall, ceiling) developed especially for use in high rise structures in recent years, one of the most revolutionary is the shaft-type wall, designed as a light weight replacement for masonry in the interior core areas of buildings for elevator shafts, electrical and mechanical enclosures and stairwells.

Because these shaft-type walls are put on from the outside of the shaft, elevator cars may be installed while the shaft is being erected. The fact that the men installing the wall do not have to work from a scaffold inside the shaft is a safety advantage and a decided psychological plus. They feel more comfortable and work better from the floor. This is also true in the case of stairwells and, in both instances, there is no cleanup necessary inside the shaft. Utility shafts are also enclosed quicker and easier. These shaft-type walls are approximately one-third the weight of the walls they replace (less steel, better sound, all weather, etc.)

Another recent addition to the drywall contractor's expanding library of systems available for use by today's builder is the radiant heat ceiling systems. These systems consist of special base factory or job site cable installation and nonshrinking fillers.

Sound control, difficult enough in single family units, becomes a really severe problem in high rise apartments. Recommendations made by the contractor in the field to the manufacturers have led to numerous systems designed to solve a variety of sound control problems.

Drywall proved to be highly efficient in sound attenuation. A close look at sample of systems using other products for sound control reveals that approximately 80% of them contain gypsum board.

The homebuilders and contractors have made long strides together and progressed a long way in the relatively short time since World War II. The gypsum drywall construction production has increased from 3 billion square feet a year to over 15 billion square feet. The tremendous accomplishments of all segments of the drywall industry can be appreciated in the fact that in Chicago alone the John Hancock Center (100 stories), the Standard Oil Building (80 stories) and the Sears Building (which on completion will be the tallest building in the world at 110 stories), have all specified a variety of drywall systems in their construction.

Thus, through continuing research and development, new gypsum products and systems are constantly being introduced at the same time those on the market are continually being improved.

Type "X" Wallboard, What it is, & Where & When It Originated

By C. E. Abbey

(Ed. Note: All the major gypsum wallboard manufacturers market one or more fire-retardant gypsum wallboards under their own trade-name. The term—Type "X"—is not the trade-name of any specific company's fire retardant gypsum wallboard. The following article is a concise history of the development of a particular Type "X" gypsum wallboard, by one company.)

In one or another of its present forms, gypsum is used in 90% of all buildings in the United States having finished interiors. Over 75% of all residential construction today utilizes gypsum wallboard. Most of the remaining residential units have gypsum lath and plaster. In commercial and institutional work where, historically, lath and plaster were widely used, there has been a strong movement in the past few years to gypsum wallboard assemblies.

When gypsum wallboard first appeared in the early years of this century, it was relatively crude, consisting of several layers of roofing felt spaced with thin layers of cast gypsum. Over the years, a great many improvements have been made to achieve a stronger, yet lower cost, high quality, fireproof building material, 4' wide with a highly calendered, smooth-face paper, strong back paper and tapered longitudinal edges to facilitate finishing of the joints between panels.

A major factor contributing to the rapid increase in gypsum wallboard interiors in the past 10 years, has been the development of a product with a core having greater fire resistance than conventional gypsum wallboard. In simple comparison, a 5/8" thick fire-rated board gives fire resistance in assemblies similar to the fire resistance of gypsum or metal lath and plaster which, for years, were considered as the only acceptable 1-hour fire resistive construction.

ASTM Standard C-36

The present ASTM Standard C-36 includes the definition of a product designated as "Type X" gypsum wallboard. It reads: "Type 'X' (special fire retardant) designated gypsum wallboard, complying with these specifications, is one that provides at least: (1) 1 hour fire retardant ratings for 5/8" thick; or (2) ¾ hour fire retardant ratings for ½" thick gypsum wallboard applied in single layer nailed application on each face of loadbearing wood framing members, when tested in accordance with the requirements of Methods of Fire Test of Building Constructions and Materials (ASTM Designation: E-119)". This is a refinement of the first definition for Type "X" which appeared in ASTM C-36, 1955.

Much of the following information on the development of Type "X" gypsum wallboard was obtained by reviewing the U. S. Patents issued on gypsum and related materials in the past 20 years; by studying the Underwriters' Laboratories "Building Materials List" from 1945 to the present; by checking the literature on gypsum wallboard products of the various manufacturers, including their Sweets' Catalogue inserts, beginning in 1950.

Early History

In the early 1940's, chemists from the Bestwall division of Certain-teed Products Corporation began experimenting with various additives in the core of the gypsum wallboard in an effort to increase its fire resistance. Gypsum, by itself, or in combination with an aggregate, is a barrier to the passage of heat, fire and smoke for long periods of time, due to the chemical make-up of the material and its reactions under heat. Gypsum, or as it is technically known "hydrous calcium sulphate", is about 50% water, by volume, or about 20% water, by weight. When subjected to heat, the water of crystallization is separated from the calcium sulphate, changed into steam, and driven from the material. This requires heat at the surface and progressive action working from the surface exposed to the heat, back through the mass. As the water of crystallization is driven from the material, the material remains incombustible and offers good insulation to heat transfer. As shrinkage occurs, cracks develop because of the loss of half the material's volume. As the calcination proceeds through a gypsum wallboard, gypsum plaster, or gypsum block assembly, fissures commence to open up. These openings ultimately permit the passage of the fire and heat directly through the mass. If the material is in a ceiling installation, this would allow the material to drop.

Improvement of Wallboard

The primary reason for the success of metal lath and gypsum plaster assemblies as fire-proofing, was the ability of the metal lath to reinforce the calcined material, holding it in place for a longer period of time. At the same time, such installation prevented the cracks from becoming large enough to allow the passage of heat, smoke, and flame. It was the aim of the Bestwall-Certain-teed chemists to incorporate characteristics in gypsum board that might accomplish the same result.

This research led to experiments in adding various incombustible fibers to the gypsum core, including asbestos fibers, mineral wood, glass wool, and fiber glass strands. The first patent issued October 17, 1950 to Michael Croce (#2526066) of Bestwall was based on material filed originally in 1943. Fire tests on full scale wall panels at Underwriters' Laboratories resulted in the first listing of ½" special fire rated gypsum wallboard in 1946. This was the basis of the current Design #1—45-minuted, listed by UL. Further laboratory work improved the

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product, resulting in a board which, when used in the ceiling, gave equal fire protection. Experimentation involved addition to the core of various materials which expanded when exposed to heat. It was found that vermiculite of proper grade appeared to be the most suitable. The purpose of the vermiculite was to offset the shrinkage of the core under heat. Fire tests of a floor and ceiling assembly with ½" board incorporating the unexpanded vermiculate and the incombustible fibers, developed a 45 minute fire resistance rating equal to that developed in the wall.

This was a major step forward. Up until then a partition surfaced on both sides with ½" regular gypsum wallboard would provide 40 minutes fire resistance, and a wood joist and floor assembly with ½" regular gypsum board as the ceiling, only 25 minutes. A wood floor-and-ceiling assembly with no fire protection, tested by the Bureau of Standards, withheld the passage of fire and heat and sustained the load for 15 minutes. ½" regular board, as the ceiling protection to this assembly, increased the fire resistance to 25 minutes thereby adding 10 minutes fire endurance to the assembly. Now the ½" fire-rated board newly developed by Bestwall produced 45 minutes fire resistance, or added 30 minutes of protection to the assembly. **Three times** the protection offered previously by ½" gypsum wallboard!

Wallboard Production Control

At the time of the first test made at Underwriters' Laboratories, showing the improved fire resistance possible with the new special formulation in the core, there was a great deal of discussion as to how the production of such a product could be controlled to take care of variations in the amount (both maximum and minimum) of the special ingredients added to the core, variations in caliper of the board, and variations in the physical characteristics of gypsum from different deposits. Control is vital since gypsum wallboard is formed at speeds varying from 60 to 150 lineal feet (240 to 600 square feet) per minute for a ½" thick board.

Before Underwriters' would agree to listing the product, a series of full-scale tests were made to show the variations in the fire resistance possible with the minimums and maximums of ingredients, both as contemplated by patent descriptions and by manufacturing limitations. Also, checks were made to determine the consistency of fire resistance within the normal variation of the mechanical proportioning equipment customarily used in board manufacture. Furthermore, based on Underwriters' knowledge of the characteristics of gypsum from various deposits, tests were made of board produced from various grades of ore. As a result of this early work, Underwriters' wrote their first "Manual of Procedure" which was to be their guide to check samples of material taken out of production runs or from dealer stocks, and also to check plant production of the special board. With refinements this has continued to be the basis for UL Listing and Labeling of all Type "X" gypsum wallboards.

Chemists continued to improve the core formulations to increase the performance of the board. This led to Patent #2,681,863 by Michael Croce and Clarence G. Shuttleworth, issued in June 1954. It was based on original applications made in July 1951, and representing the primary development insofar as the practical use of glass fibers in gypsum was concerned. It had been found from experiments that, while several incombustible fibers would perform satisfactorily to attain fire resistance of the product, all but one resulted in production difficulties.

The first test developing a 1-hour fire resistive wall assembly in a single layer application was of a 5/8" board with asbestos fibers and unexpanded vermiculite in the core. In the production of this material, due to the affinity of asbestos for water, there was difficulty in drying the board properly in the kilns. As a result, too much moisture remained in the wallboard and this created problems when shipments were made to northern destinations during below freezing weather.

Introduction of Glass Fibers

Many types of glass fibers were checked before chemists found a satisfactory one. This one consisted of drawn, textile glass fibers formed into strands with a water-soluble binder. The binder was strong enough to hold the fibers together in the glass fiber manufacturing process during which the filaments were gathered into strands and rovings. When the strands were cut into short pieces and agitated in a wet plaster slurry, the binder softened and permitted the individual filaments to separate and disperse rapidly throughout the mix.

Further Laboratory studies led to the third Patent #2,744,022 having to do with the use of additives in "Plaster Compositions and Products", issued again to Michael Croce, and Clarence G. Shuttleworth in May 1956.

During the early years of 1950, the Certain-teed Products Corporation was the only company producing a special fire-rated gypsum wallboard product, which it sold under the trade-name "Bestwall Firestop". "Firestop" was tested and proved, first in a wall assembly over wood studs, then beneath a wood floor and ceiling assembly, later over steel studs, and finally beneath steel bar joists, all in single layer application for 1-hour fire resistance.

When this product was introduced, the Gypsum Industry was not entirely convinced of its usefulness. Other gypsum manufacturers wanted to do their own experimentation and testing, and did not at that time take advantage of Certain-teed's development work. However, building officials and architects welcomed Firestop, as it enabled them to maintain 1-hour fire resistive requirements with a wider choice of assemblies, 5/8" Bestwall Firestop with its proven performance in full scale, official Underwriters' Laboratories fire tests, and the manufacture of the board under UL Re-examination Service, was accepted and approved under the West Coast Uniform Building Code in 1951 (first Research Report #296, September 1951). By 1955, there was acceptance in over 250 major cities throughout the United States. As the importance of Firestop developed, other gypsum manufacturers began to market competitive materials. However, in view of the acceptance of Bestwall Firestop, these manufacturers found it advisable to have their products also officially fire tested at Underwriters' Laboratories. Through the years, other first test facilities including those of Ohio State University, University of California (Berkeley), and the Fire Prevention Research Center (Gardena, California) have been used.

The U.L. Label

The Underwriters' Laboratories annual publication "Building Materials List," issued each January, indicates that Certain-teed Products Corporation was the only manufacturer listed for a special fire-rated gypsum wallboard as late as 1952. It was 1953 before any other manufacturer's fire-rated gypsum wallboard appeared in these Listings. As a result of several manufacturers producing a special fire-rated board, Underwriters' insisted these manufacturers take Label Service. In consultation with the Bestwall officials, it was agreed that they would also use Label Service. Since that time, all the special fire-rated gypsum wallboards have been made under Underwriters' Label Service and carry an identifying mark, generally a "Manifest" or "Label" on the twin mounting (end bundling) tape.

Just what does the UL Label mean on Type "X" gypsum wallboard? Underwriters' conduct a fire test on an assembly with a specific material, on the basis that the manufacturer will subscribe to Inspection Service and will properly label the product. Underwriters' Laboratories say in effect—the material when applied as listed will give the protection developed in the test. The manufacturer has the right **not** to so label the product. However, if the product is not labeled, Underwriters' will say nothing of the product and its value for fire protection. On the other hand, by subscribing to Inspection Service, and manufacturing and shipping the material with the UL Label and Listing, the manufacturer gives assurance to the purchaser that it conforms to the rigid specifications set for the material on which the official fire test was made. Underwriters' Laboratories make periodic unannounced checks of manufacturing facilities, check material in process, in stock in the plant, and also check material purchased on the open market. Consequently, the UL Label Service gives the end user protection against changes in the product, which may adversely affect its fire resistive performance.

When Bestwall Firestop is specified, it is only necessary for the Building Official, Owner, Architect, or Contractor, to examine the installation before it is decorated to make certain that the proper board has been used and that it has been correctly applied. To quickly identify the fire rated gypsum wallboard pioneered by Certain-teed, face marking was adopted for Firestop in 1951 and Bestwall Firestop is still face marked down the center of the sheet every few feet with '5/8" Firestop' or '½" Firestop'.

The cost of UL Inspection and Label Service, which insured that the product meets minimum standards and if properly installed, will give the fire protection specified and is absorbed by the manufacturer. The other testing organizations mentioned, are well equipped and properly staffed to make fire tests equal to those made at Underwriters' Laboratories. None of them, however, do more than test and make a report on the assembly as tested with the materials furnished. There is no follow-up inspection to insure continuation of the performance in the future. Hence, when Building Code authorities approve materials in assemblies based on such acceptable fire tests, they rely completely upon the character and reputation of the Manufacturer involved to assure them that the product continues to equal that tested. The UL Inspection and Label Service gives that continuing assurance!

Increases in Fire-Ratings

In 1956 the Bestwall Gypsum Company was formed to take over the Gypsum operations of Certain-teed. Bestwall has continued to test additional assemblies with 5/8" Bestwall Firestop. These tests proved 2 and 3 hour fire resistive partition assemblies. Later, up to 2-hour fire resistive floor and ceiling assemblies with single layer applications, 2 and 3-hour column fireproofing, and other assemblies with metal framing, were tested successfully.

In 1962 and 1963, in further Laboratory tests, in an effort to improve fire resistance, Bestwall made sufficient changes in formulation within the scope of the patent claims to require Underwriters' to revise the "Manual of Procedure" on Firestop Bestwall literature and Underwriters' Laboratories "Building Materials List" (latest edition) demonstrate that Bestwall continues to manufacture only **one** fire rated gypsum wallboard, Firestop, ½" or 5/8" thick, all of the improved type.

Going back again to the historical development of Type "X" wallboard, in all of the many patents which were reviewed and considered, there is one other issued to J. G. Jackson in August 1947, which mentioned fiber glass, reinforced gypsum wallboard. Based on work filed in 1941, it was covered by U.S. Patent #2,425,883. Comparison of the claims of the several patents which have been referred to, would indicate the Jackson patent covered a different principle in the use of glass fiber reinforcement, directed primarily to Portland cement construction, but broadened to include gypsum. The Jackson patent mentions the use of "concentrated reinforcement embedded therein" and reinforcing comprising "a consolidated group of fine glass filaments bonded together into a substantial rigid bar by a bonding medium which is substantially inelastic". The Jackson patent does not appear to describe use of textile glass fibers individually dispersed throughout a gypsum mass. The patents issued to the Croce-Shuttleworth team refer to glass fiber filaments individually dispersed throughout the product.

Certain-teed and Bestwall's literature has continually stressed the character of the core of Firestop as "thermally stabilized". Unexpanded vermiculite particles are well distributed in the core and expand on the application of heat, counter-balancing the shrinkage of the gypsum which occurs as it loses its water of crystallization, thus providing a core which is dimensionally stable under the action of fire. Glass fibers, well dispersed throughout the core, serve as a reinforcing network holding the wallboard core together.

License Agreements

Bestwall offers license agreements under its patents to other gypsum manufacturers. A number of companies have taken license agreements and make their product to the Bestwall's Firestop formulation. Underwriters' Laboratories Listing has been extended to their products after they have met the performance standards set for Firestop.

After several gypsum manufacturers had a fire rated board on the market with proven performance in several standard assemblies, the Gypsum Association began to push for Industry standards that would be acceptable to Building Code officials, Testing Organizations, and Manufacturers.

In 1955, ASTM Committee C-11 Gypsum finally added the new type gypsum board in ASTM Standard C-36 on Gypsum Wallboard referring to it as 'Type "X" '. The definition, as further refined, was given at the start of this article. The definition in C-36 is the basis on which Industry approvals of Type "X" Board are requested. Effort has been made to establish that all Type "X" gypsum wallboards are equal and that performances developed with one are applicable to the others. Bestwall takes the position that a product with a "thermally stabilized" core has important characteristics not found in some other Type "X" gypsum wallboards.

In addition to its United States Patents, Bestwall has obtained patent coverage in foreign countries including Canada, England, and Germany.

U.L. Recognizes Other Type "X" Brands

Underwriters' Listing for some of the gypsum manufacturers indicate other types of special fire rated boards are being marketed.

In addition to proving the fire resistance of numerous assemblies, many years ago, Bestwall Gypsum Company ran Official Tests in Underwriters' Tunnel Furnace developing Flame Spread ratings of 10 to 15 for both ivory face paper and gray back paper. Underwriters' have extended this to the paper for the special product used as a gypsum base for Bestwall's thin plaster veneer, and sold under the Trade-name Firestop Dens-Cote Gypsum Base.

As further proof of the advantages of Firestop and to give the contractors and building owners low cost constructions, Bestwall sponsored specific fire tests as outlined by Underwriters' in 1962, proving it was not necessary to cover joints between sheets of Firestop gypsum wallboard to develop the fire resistive ratings of the various assemblies, either wall or ceiling. No Firestop assemblies fire tested since 1961 have had the joints treated. This provides the lowest cost assemblies which may either be finished with tape and compound for smooth surface, or left unfinished and covered with veneer finish, acoustical tile, or whatever else may be desired.

The proving of the Fire ratings possible with assemblies using Firestop and the availability of Type "X" gypsum wallboard from all manufacturers has led to a great increase in the use of gypsum wallboard in multi-story dwellings, and in institutional, commercial, and industrial buildings which formerly used other materials to provide the fire resistance required by Building Codes and Fire Insurance Rating Bureaus. The Bestwall Gypsum Company, which developed the **original** Type "X" fire rated gypsum wallboard, has been first to prove most of the assemblies involving this material. There are likely to be additional assemblies proven by Bestwall as time goes on, including additional ratings with ½" Firestop.

Fire and Sound - A Challenge to the Industry

By Rodney G. Buergin

Gypsumboard in its many forms has moved from single family houses into all types of buildings where it is performing multiple functions. The gypsum industry faced many challenges on invading an expanding market. Systems were developed and tested to meet code and occupancy requirements for permanent and movable partitions and walls including elevator shaft and stairwell enclosures, floor-ceiling and roof-ceiling systems, column and beam protection, etc. These systems provide fire protection up to four hours and sound isolation values as high as 60 STC along with structurally sound surfaces suitable for all types of finishes.

Industrialized construction presents another challenge to the gypsum industry. One section of the industrialized construction industry is devoted to the production of modular or three dimensional housing units. Like the conventional or "stick" builder the producers of modular housing operate under one or more of the three regional codes: the Southern Building Code Congress (SBCC); Building Officials and Code Administrators (BOCA) and the International Conference of Building Officials (ICBO).

In addition they must comply with state codes, variations of the regional codes and numerous local codes and regulations. Producers providing units for Operation Breakthrough must meet the requirements of the Guide Criteria. The market area for one producing plant may involve compliance with as many as 50 or more codes. Standardization in materials and methods is one key to success for the modular producer. Designing his units to meet the most stringent codes in his market area may cost the producer many dollars per unit that must be passed on to the homeowner.

Intra-dwelling partitions pose no unusual problems. The various systems and their attendant fire and sound ratings utilized in conventional on-site construction can and are being used in the plant-built modules. The problem lies in the design and testing of inter-dwelling walls to meet the various code requirements and the interpretation of these requirements.

The question of what constitutes a fire wall or party wall must be resolved if industrialized housing systems are to develop to their full potential. It is impracticable and expensive to erect masonry fire walls between modules. The fire wall, or a portion thereof, is normally a part of the exterior wall of a factory built unit. Many codes recognize the combined fire endurance rating of two opposing walls, usually separated by a small air space that is properly fire stopped. Some codes recognize only that portion between combustible elements while others insist on free standing walls between modules. Penetrations are not permitted by some codes whereas they are permitted by others provided the fire endurance requirements of the wall are satisfied.

Fire endurance tests on walls and partitions, whether they be single or double walls, are conducted in a single lintel test frame. In a test of a load-bearing double wall the entire load of the double wall is transferred to the wall away from the fire when the exposed wall is no longer capable of carrying a load. When this occurs the membrane on the back of the exposed wall may stay in place offering some protection to the second wall. In a building fire this exposed wall would collapse and would no longer protect the second wall. In a single lintel test the second wall is now double loaded which may or may not accelerate its failure. In any event, the single lintel test does not represent actual construction conditions in modular construction or in any type of construction where the walls support separate loads. Some codes require that each portion of the double load-bearing wall maintain its structural integrity for a stipulated period of time regardless of temperature transmission.

A split or double lintel was installed in a wall test frame by National Gypsum Company to simulate conditions in modular double wall construction. Each wall in a double lintel test is loaded to its design load. When the exposed wall fails under its load it collapses and falls into the test furnace exposing the second wall, carrying only its design load, to the fire. Limited tests conducted to date, in National Gypsum Company's test facilities, indicate a difference in the performance of double walls in a single versus a double lintel test frame. Additional tests must be conducted before definite conclusions can be reached. Where the walls are nonload-bearing it makes no difference if the lintel is single or double.

Floor-ceiling construction in modular construction are posing still another challenge. In conventional job site constructions, floor and ceiling membranes are usually attached to common joists forming a horizontal separation between occupancies or between stories of the same occupancy. This may be true of some modular structures but more often the ceiling construction forms the top of one module and the floor assembly the bottom of another module.

A design load is applied to the floor-ceiling assembly in a fire test. In a unitized construction the effects of this applied load are transmitted to the protective ceiling membrane. Where the floor assembly is separated from the ceiling assembly, except perhaps at their perimeters, this applied load has little effect on the ceiling framing and its protective membrane. The ceiling membrane in this type construction is normally supported by framing members somewhat smaller than those used in a single frame floor-ceiling assem-

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bly. There is usually an air space between the framing members of the two assemblies. The combination of smaller framing members and the air separation between the assemblies are sufficient to alter the behavior of this type structure in a fire test as compared to that of a conventional assembly.

New technology in materials and their application, framing methods, etc. are being introduced by modular construction producers in their efforts to produce good housing at a reasonable cost. These materials and methods of construction need to be tested to prove their performance. The gypsum industry is working with these producers developing new methods of finishing gypsum board joints, application specifications, providing physical data and developing or modifying test methods.

Airborne and impact noises are well under control in most modular floor-ceiling assemblies because of the physical separations and other treatments of these areas. Intra-dwelling partitions perform like these in conventional on-site constructions. The acoustical behavior of party walls, however, needs some attention. Laboratory and field tests are often required to substantiate the performance of partition, walls and floor-ceiling assemblies.

Before proceeding with a discussion of laboratory vs. field STC values it should be made clear that the sound transmission loss of a partition is a physical property of the partition and should be the same no matter where the partition is built and tested. The differences that do occur in the transmission loss values of a partition when it is tested at several locations are caused by differences in the test environment (i.e. size of source and receiving rooms, size and edge restraint of the partition, amount of sound diffusion in the test rooms, and to a lesser degree the type of test equipment and competence of the operator).

The test standard used in the laboratory to measure the sound transmission loss of a partition is ASTM Test Method E90-70. This standard has been written for use only in the laboratory. To this extent it is very restrictive in specifying the environment in which a partition must be tested. However, there still are some differences between laboratories in STL values when identical partitions are tested. These differences are for the most part small and inconsequential.

On the other hand the test standard (ASTM E336-71) used in the field to determine the sound transmission loss of a partition is not very restrictive in specifying the environment in which a partition must be tested. Since a partition can be installed between any two pair of rooms and can vary greatly in size, this test standard cannot mandate the test environment. All a test standard, such as E336-71, can do is to describe the desirable test environment to aid in the selection of a partition to test in the field. If it is impossible, which is usually the case, to select an ideal environment, then compromises must be made. When compromises are made, then limitations must be imposed. If room volumes or partition size is too small, then low frequency transmission loss values cannot be determined. If rooms have too much sound absorbing material in them, certain corrections have to be made to the measured results. The list goes on for other shortcomings in the test environment.

A novice not knowledgeable in the field test standard or architectural acoustics can easily miss an important test environment criteria which could lead to erroneous results. For example, let's assume the volume of the receiving or source room next to the test partition is 960 cu. ft. (10 ft. x 12 ft. x 8 ft.). According to E336-71 the transmission loss value at 125 Hz. cannot be measured. The room is so small that the concept of transmission loss loses meaning at this frequency. If the transmission loss cannot be measured at this frequency, then an STC value cannot be assigned to this partition. Another example of where one could get substantially different STC values between a partition tested in the laboratory and one in the field is where the test partition extends beyond the confines of the receiving or source room. This type of situation would be encountered when a partition of a modular housing unit were tested. The test wall is usually the entire side of a modular unit. The test partition between the source and receiving room would be only a fraction of the total wall. In this case, the acoustic coupling between the two adjacent walls of two modular units would be different from the coupling between two similar walls in a laboratory where the test wall ends at the perimeter of the test chambers. The test results at the lower frequencies would be higher for the field situation. A double wall which consistently develops an STC of 40-41 in the laboratory, a wall which is excellent at the higher frequencies but severely limited at the low frequencies, developed 50-51 when tested in the field. For the reasons given this cannot truly be reported as an STC value. For most use conditions it is a highly acceptable sound barrier except where low frequency sound is generated such as the bass in a stereo set.

There are several other instances where there could be differences between field and laboratory STC values for the same partition. In some instances the field STC value could be higher or lower depending on frequency locations. It is impossible to state that the laboratory STC value will always be higher than the field STC values.

The preceding discussion has assumed that there were no leaks or flanking paths in the field test environment. If there are, then they must be eliminated or the field test values will always be lower than the laboratory results. Extensive laboratory and field testing must be accomplished to arrive at acceptable requirements.

Summary

Fire and sound test results and some of the details of test procedures and methods used in conventional stick built structures may not be entirely applicable to all elements of modular construction. In some instances these units may be borderline or under-designed but in others, the producers are compelled to over-design their assemblies to obtain approvals. Both conditions can be costly—in dollars to the producer and consumer or in dissatisfaction to the consumer which reflects back to the producer. It is apparent that more standardization in code requirements are necessary if industrialized constructions are to grow at the anticipated rate. Code officials, producers of industrialized construction, the gypsum industry, etc. must work together to meet the challenge.

Lath and Plaster and Wallboard Construction

By J. K. Hovind

GYPSUM LATH and plaster or gypsum wallboard are found somewhere in practically every habitable structure—from the one-family residence to the high-rise commercial building.

This wide use is explained by the properties and capabilities of these building materials. Because of their gypsum base, these products can provide long-lasting performance to meet standards of structural adequacy and, when fire protection is required, high levels of fire resistance.

However, the presence alone of gypsum products in building construction is no guarantee of structural adequacy or fire resistance. To comply with building codes—and so derive full benefit from these materials—proper installation and application are vitally essential.

The base concern of building inspectors when considering construction containing gypsum products is: *Are these materials properly installed and applied?*

STRUCTURAL ADEQUACY

When we speak of "structural adequacy" we are, in other words, talking about good, sound construction. To insure this, at least minimum standards, as set forth by the industry, should be maintained.

Compliance with American Standards Association specifications (A.42.1-1964: Gypsum Plaster; A.42.4-1955: Interior Lathing and Furring; A.97.1-1958: Gypsum Wallboard Finishes) will assure that minimum standard construction standards have been followed.

I am sure that all building officials are familiar with lath and plaster and wallboard. This knowledge, coupled with the extensive coverage provided by published standards, eliminates the need for lengthy discussion about gypsum products with regard to structural adequacy.

A brief rundown of certain basic requirements, however, is in order.

1. *Framing and Spacing*

Building inspectors can evaluate wood-stud, wood-joist, and steel-joist construction in terms of adequate framing and proper spacing by using industry tables for reference. In the case of various lightweight steel furring channels and steel studs of many different configurations, great reliance must be placed on manufacturers' technical data. This data should be requested from the builder or architect.

2. *Type of Lath or Wallboard*

Inspectors must make sure that the proper type of lath or wallboard is used with the selected framing spacing. There are exceptions, to be sure; however, the following is normally true:

Metal Lath	*Framing*
Diamond Mesh	16 in. o.c.
Flat Rib	19 in. o.c.
3/8 in. Rib	24 in. o.c.
Sheet Lath	24 in. o.c.
Gypsum Lath	*Framing*
3/8 in. Gypsum Lath	16 in. o.c.
1/2 in. Gypsum Lath	24 in. o.c.
Gypsum Wallboard	*Framing*
3/8 in. Gypsum Wallboard	16 in. o.c. single layer 24 in. o.c. double layer on walls
1/2 in. and 5/8 in. Wallboard	24 in. o.c. single and double layer

3. *Suitable Attachment*

In the case of metal lath, the proper type and spacing of wire ties, clips or nails is essential to sound construction. Metal lath is normally installed to the framing with side and end laps.

Gypsum lath is applied with ends always supported by the framing itself or by special clips. Be sure that the required number of fasteners are used and that screw heads, nails or staples are tight to the lath but do not cut into the paper surface.

When gypsum wallboard is used, check fasteners for proper length and spacing.

4. *Plaster Application*

When the building inspector is confronted with plaster construction he should bear in mind two factors:

(1) aggregate ratio, and

(2) thickness

The aggregate ratio should not vary from that specified by the plaster producer. This ratio is usually noted on the bags. With mill-mixed plaster, aggregate is not usually added on the job. Thickness of the applied plaster should be no less than industry minimums, including the finish coat. As a rule, the thickness of applied plaster should be:

1/2 in. over gypsum lath

5/8 in. over metal lath

5/8 in. over masonry (nonmonolithic concrete)

1/8 in.–3/8 in. over monolithic concrete

To sum up, the checks for structural adequacy, when dealing with gypsum plaster and/or wallboard, should include:

(1) adequate framing and proper spacing

(2) proper type of wallboard or lath for selected framing and spacing

(3) suitable attachment of lath or wallboard to framing

(4) correct aggregate ratio of plaster and standard applied thickness

FIRE PROTECTION

The cornerstone of all building codes—and foremost responsibility of building officials—is *public safety.*

In terms of fire protection, gypsum building products and *public safety* are closely allied.

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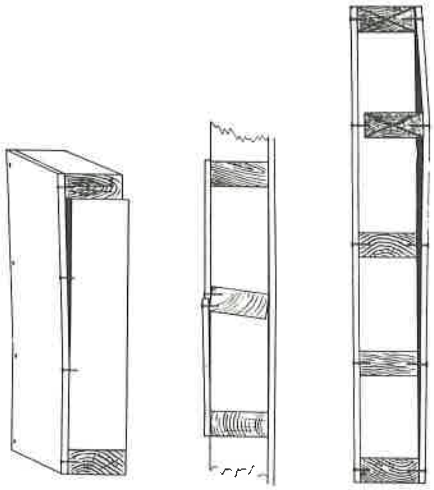

UN-EVEN TOP PLATE | TWISTED STUD | STUD NOT ALIGNED

COMMON CAUSES of "nail-pops" are uneven top plate, studs not aligned and twisted studs. Others are use of framing lumber with excessive moisture content and failure of mechanic to hold board snugly to framing while nailing.

Because of the fire-resistant properties of gypsum materials, they can be used to good advantage wherever fire protection is a chief consideration—most frequently in high-rise or other commercial structures for column, beam, floor-and-ceiling or partition fire proofing.

To insure top performance of gypsum building materials in terms of fire resistance, it is imperative that these materials be properly applied in the proper systems. It cannot be overstressed that individual construction details are critical when it comes to attaining a given, necessary fire rating.

For example, to achieve a specific fire rating, an assembly may require perlite or vermuculite aggregated plaster over perforated gypsum lath. The substitution of sand as the aggregate or use of plain gypsum lath would reduce the fire-resistant capabilities of that particular assembly. Likewise, a fire rating achieved by using a certain thickness of type "X" gypsum wallboard with a special core will not be equalled with the same thickness of regular wallboard.

Of course, logical variations from a tested construction can be permitted, such as the use of lightweight aggregated plaster in an assembly that employed sanded plaster under fire-test conditions. Or the plenum depth of a floor-and-ceiling assembly might be increased without impairing its fire-resistance potential.

In the main, however, fire-resistance assemblies should conform to those that have been proven under test conditions. This is the surest way to meet fire-rating requirements.

In addition to fire-resistive assemblies covered in the building code, there are many excellent sources of fire test information available. These would include the new booklet "Fire Resistance Ratings" of the American Insurance Association (formerly the National Board of Fire underwriters), "Fire Prevention Handbook" of the National Fire Protection Association and the Underwriters' Laboratories "Building Materials List." There are also authoritative trade association publications, such as the "Fire Resistance Design Data" booklet by the Gypsum Association and the bulletin "Fire Resistance Ratings" from the Metal Lath Association.

These publications do not cover proprietary systems, however, in which manufacturers' special products are employed. In such cases, the building official must rely on information supplied by the producer or on approvals granted by the parent code office.

In capsule form, when fire resistance is involved:

(1) be sure that the assembly specified will provide the fire resistance required;

(2) become familiar with the required construction details;

(3) be sure that specified materials are being properly used;

(4) when in doubt, require proof.

Why Partitions Crack in High Rise Buildings

By H. Omson

Extensive cracking of partitions occurs in many high-rise structures throughout the United States. A research study of this phenomenon, made by Wiss, Janney, Elstner & Associates, Consulting Engineers of Des Plaines, Illinois, shows the primary cause of two predominant types of partition cracking to be directly related to structural movement. This movement results from cracking of the structural frame, differential expansion of columns, or deflection of the flat-plate floor slabs. Floor slab deflection has become more pronounced with the advent of floor systems that use wedged-in-place partition systems such as those found in flat-plate type buildings.

Two basic types of cracking patterns have been identified. Type A is found primarily in the upper floors of high-rise buildings where exterior columns are exposed. This type of partition cracking is a racking stress caused by a differential temperature movement of structural elements that surround and support the partition. Type B cracking, generally found near the center of a partition, appears to be the result of flexural tension in which the wall panel tries to conform to the deflected floor. All available evidence reveals that nonloadbearing partitions specified in high-rise construction—with flat-plate floor slabs, exposed exterior columns, or both—may be subjected to tremendous loads.

Historically, investigators of partition and ceiling cracking have concluded that the partition cracking was caused by one or more of the following:

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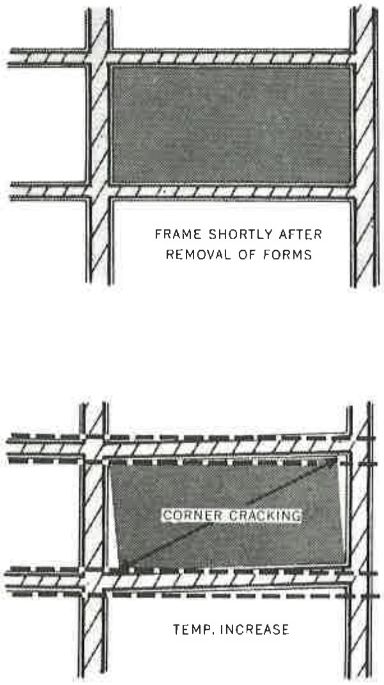
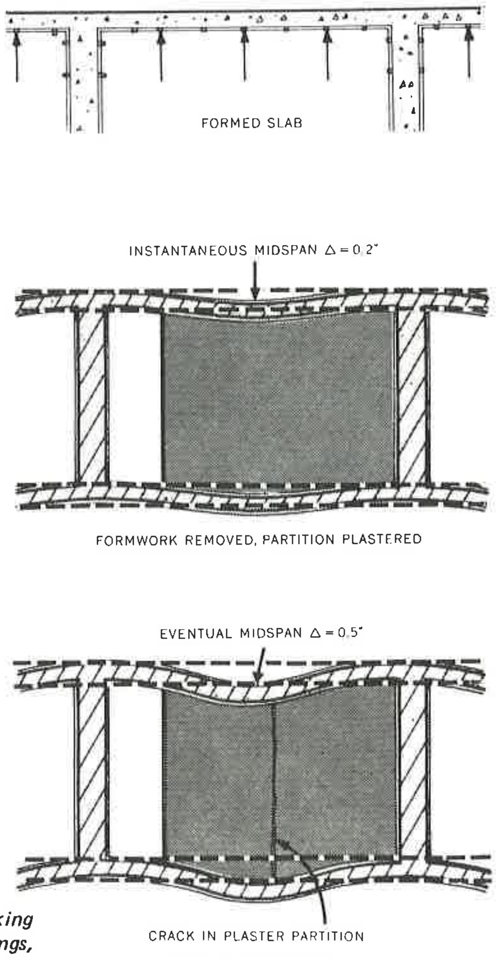
(continued)



TYPE A CRACKING
FIGURE 1



TYPE B CRACKING
FIGURE 2

Several phenomena contribute to cracking of plaster partitions in high-rise buildings, but main cause is movement of the structural frame.

- Shrinkage restraint in the materials, or movement in the base or frame that supports the surface materials
- Differential foundation settlement
- Quality of materials
- Seismic forces
- Movement of structural framework

However, it is now believed that the last cause—movement of the structural framework—is the chief culprit in cracking panels at midspan (type B) and at the corners (type A). Studies of mode's and actual structures support this theory.

Evaulation of recent problems in high-rise buildings reveals that restrained shrinkage is not usually a primary cause of partition cracking. Type A cracking is usually confined to the upper floors, with the intensity of the cracking pattern increasing floor by floor. Since temperature and humidity conditions are usually uniform throughout the building, shrinkage problems are not restricted to the upper floors. Moreover, the cracking patterns are typical of a racking distortion. The partition is racked and distorted as the surrounding frame moves from a rectangular shape to that of a parallelogram.

Type B cracking is usually found throughout the structure. However, type B is characterized by vertical cracks that start at the base with a wide gap, gradually decrease in magnitude, and then disappear as they move vertically toward the ceiling. Shrinkage cracks would normally be uniform; and they can also be repaired. Type B cracks do not stabilize, because they continue to recur even though repaired three or four times in a 12-month period.

Differential foundation settlement can be eliminated as a source of either type A or type B. Cracking from this source would neither be confined to the upper floors, as in type A, nor dispersed throughout the structure, as in type B, because it would be concentrated in the area where structural elements have settled. Seismic forces can also be eliminated as a source of the problem. Neither type A or type B is similar to those produced by these forces.

There are two reasons why quality of materials is not often assumed as the culprit. First, the problem of cracking is too closely associated with a particular building type, regardless of partition type. And, second, the problem is geographically much too widespread. This leaves structural movement as the primary cause. Structural movement may be caused by wind, temperature variation, force of gravity, value change in the framework elements, or cold flow of materials. Wind should not be dismissed as a factor, but it is not likely to be the primary cause of type A, nor is it likely to have anything to do with type B.

Type A cracking is almost exclusively associated with buildings that have exterior columns, shear walls, and spandrel beams either partly or completely exposed to outside temperatures. The inside beams are not subjected to great temperature changes; the exterior columns, however, are exposed to a wide range of temperatures that cause an appreciable movement in the members.

According to E. E. Ellwood, Director, Architect Service, United States Gypsum Company, the free movement in a 30-story building with 300-ft-high steel or concrete columns exposed to a 100° F temperature change can be calculated as follows:

$\blacktriangle = 0.000006 \times L^{x} (T\text{-}To)$

$\blacktriangle = 0.000006 \times (300 \times 12) \times 100 = 2.16$ in.

Where ▲ = free expansion; L = column length in in.; (T-To) = change in temperature, degrees F.

Ellwood points out, however, that the total movement will probably be no more than 30 per cent of this amount because of the stiffness of the frame and degree of the column exposure. As the outside column, which is exposed to temperature variations, moves up and down with respect to the inside column, cracks and gaps can be expected in two corners of partitions that connect the columns. Evidence of perimeter crushing will show up in the two opposite corners. In other words, the partition connected to the column is forced to become a shear wall for which it is not designed. Partitions parallel to the outside walls are usually unaffected.

Type B cracking is usually caused by floor deflection that increases for some time, due to creep or cold flow of the slab. It may amount to two-and-a-half times the initial dead-load deflection.

During the design stages, architects should anticipate the structural movement in the frame and deflection in the floor system. All available data reveals that exposed concrete columns and shear walls can be safely used in structures from 6 to 10 stories high without creating excessive stresses on most nonload-bearing partitions. Beyond these limitations, a control joint must be provided at the periphery of the partition. These control joints must compensate for the movement as well as maintaining the required fire protection and sound isolation.

It is economically unsound to develop nonload-bearing partitions that would resist the stresses imposed by movement of the structural frame. Architects and engineers should be aware of this problem, and compensate for it in design. Moreover, manufacturers must continue their research into adequate control joints in order to develop partition walls that can accommodate building movements without sacrificing current economies.

World's Tallest Apartment Building Selected for Gypsum Association Test Program

Lake Point Tower in Chicago is the site of an extensive study being conducted by the Gypsum Association to develop an understanding of partition movement.

This single tower skyscraper is 70 stories high, rising to a height of 645 feet, making it the world's tallest reinforced concrete building, as well as the world's highest apartment structure. When completed, 900 luxury-type apartments will be included, ranging from efficiency to three bedroom suites. Over a hundred tenants now inhabit the lower floor apartments, while construction continues above.

Partitions selected for the Gypsum Association study are located on four consecutive floors, 48th through 51st. Party walls—those between apartments—have been selected for the tests. Most of the test partitions are located in the west wing of Lake Point Tower, since the greatest extremes in temperature are found there. At least one partition on each floor located in northeast and south wings will also be measured.

Racking, slab deflection and thermal movements are all being measured in this field test program, according to Mr. Henry Omson, Technical Director for the Gypsum Association. The partition types selected for study are described briefly as follows:

1. Gypsum Drywall with provisions for relief of stresses.
2. Gypsum Drywall without provision for relief of stresses.
3. Gypsum Veneer Plaster (thin coat plaster over a gypsum base) with provisions for relief of stresses.
4. Gypsum Veneer Plaster (thin coat plaster over a gypsum base) without provisions for relief of stresses.

Each of the above methods of constructing partitions is located on a separate test floor. On each test floor, two column-to-column partitions and three column-to-shear wall partitions are being tested.

Measurements are being made each month of the slab deflections at the test partitions. However, since these partitions were erected about 100 days after the floor slabs were cast, the initial slab deflections upon removal of the forms are not being included in the program. The maximum slab deflection recorded is approximately 0.17 in. to date, with each test floor exhibiting similar patterns.

In cross-section, Lake Point Tower resembles a three-leaf clover. All walls are curved and each apartment has nearly all-glass outer walls with dramatic views.

All party-walls and corridors were constructed of gypsum and attained a two hour fire rating and 50 STC sound rating throughout the building. This was achieved by using one layer of half-inch thick Type "X" wallboard over a layer of five-eights inch thick Type "X" wallboard on both sides of one- and five-eights inch metal studs.

Lake Point Tower is located at Lake Shore Drive and Grand Avenue in Chicago. Bordered on the east by Lake Michigan and the west by the north end of Chicago's Loop, the Tower is ideally located near the heart of the business and entertainment center of the city. The skyscraper features a circular drive and heated walk-ways, and a heated four-level parking facility. The third level has the following features: a private two-acre park with the outdoor swimming pool, reflecting pond with waterfall, landscaped walkways, a council ring and a putting green.

With the selection of Lake Point Tower for its structural test program, the Gypsum Association anticipates to gather meaningful data that will be useful in predicting movement of partitions in other types of high-rise buildings.

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Gypsum Research

As with all competitive industries, the research personnel of the gypsum manufacturers guard their latest product developments until time for marketing. However, it is known that exciting projects and movements are afoot in all the gypsum research centers.

Future development for gypsum currently being considered in the laboratory include a study of casting gypsum to form entire walls of houses. This may be accomplished by combining several technical developments to extend the areas in which gypsum may be used. By using a special calcining process, an unusually high-strength gypsum can be produced.

This extra-strong gypsum can be mixed with water and cast, forming a full-size wall. Because of its rapid set and early strength gain, this cast wall could be moved into place a short time after the pouring operation. Special means of water-proofing the wall show promise for good exterior performance. A similar technique can be followed with floors which can be cast in place using the high-strength gypsum and the waterproofing technique.

A poll of leaders in the wallboard business gives this picture of the industry's future:

- Exterior gypsum board walls, both load- and nonload-bearing.
- Elimination of nailing and taping. Board will be glued to the studs (using new adhesives with greater bonding strength than present methods) either in the factory or job site, depending on degree of prefabrication.
- Prefabrication of gypsum board in panels as big as an entire wall.

Recent years have shown great progress in technical research, in manufacture, and in refinement of the selling approach and distribution of gypsum products. Progress means changes, but the industry is not undertaking changes through guesswork. Thorough studies and attention to product development have been the keys to the success of gypsum as a building material. The ultimate objectives of everyone in the industry is a better product for better construction.

This unique material called gypsum is so versatile that its continued use in all types of construction is inevitable.

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New Building Clothes

Condensed from an article published by the National Gypsum Co., Buffalo, N.Y.

A building's design may incorporate the most unique structural elements, difficult and intricate foundation and mechanical systems, but the exterior walls are what is viewed and accepted by the owners, occupants and public alike.

An interesting comparison can be made between exterior walls of a building and the clothing of a person. Functionally, they play a similar role. They both provide the physical comfort ingredients, such as the ability to help maintain uniform temperature; the ability to keep out the rain, wind or snow; and yet be light in weight and, therefore, comfortable to the "frame".

Exterior walls, like clothing, should have the characteristics of flexibility of design in order that the designer-architect may freely express himself. Walls, like good clothing, should be selected by applying good judgment, considering appearance, need and total cost including maintenance.

The building official will ask, "and what about safety?" The disastrous results of wearing a paper swimming suit into a pool certainly should not be repeated in building design. The pool spectators might enjoy the view, in the case of the former, but this would hardly be true of witnessing the collapse of a building's walls, in the latter instance.

One of the recent developments in the building products industry is the use of light gauge steel stud curtain wall. These systems incorporate fire resistiveness, ability of walls to resist design wind loads, give excellent acoustical control, are light in weight and are relatively low in total cost.

The components which make up these systems have been available for some time, but a research systems approach was needed to create the new assemblies. Testing results show these assemblies to have one or two hour fire resistive ratings, they can develop up to a 53 STC sound rating and are able to resist the highest wind loads.

These nonload-bearing curtain type exterior walls are normally made on the job. The heart of the systems are steel studs ranging from 16 to 25 gauge. This "shape" configuration to be used in a given system depends

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largely on the fastening system. The "C" shaped screw type (dry wall) stud provides wide flanges for applying interior and exterior surfaces with self drilling-tapping screws. The delta shaped flanged nailing stud provides a method for nailing whereas the heavier gauge hollow stud provides a number for clipping or wire tying the surfaces.

The stud members provide a cavity within the wall system which will accommodate practically any type and quantity of insulation material. Service and utility lines can also be run through the cavity created by the studs.

Structurally, the stud members provide stiffness to the wall assembly. A fully completed wall assembly can function similarly to a stressed skin panel, with optimum stiffness as a function of surface materials and type of surface fastening being used.

The wall surfaces may be either wet or dry construction. Exterior stucco may be applied over a stud-lath framework providing an incombustible surface. Brick or stone veneer or ceramic tile may also be applied over a properly sheathed and/or lathed stud surface.

Exterior faced **dry systems** may incorporate such materials as mineral fibered (asbestos) panels. Interior finishes, of course, would be either gypsum lath and plaster or gypsum wallboard to match the finished material of this interior partitions.

This short report merely attempts to bring to the attention of the building official a new basic concept in the "clothing" of America's buildings. Details, specifications, limitation and list information will be supplied upon request.

Partitions That are Here today, There Tomorrow

By J. H. Bacon

Have you ever wished you could completely change your entire office to better meet today's business needs? Not just shifting desks, etc., but rearranging space by changing the location of the walls. If you are in an older building, chances are this would mean a major remodeling job involving the removal of permanent partitions, a messy and expensive job to say the least. To avoid this problem in new construction and provide future flexibility in remodeling work, business is turning to movable partitions . . . the partitions that are here today, there tomorrow.

Movable partitions in various forms have been around for many years, but up until a few years ago, they were quite utilitarian, quite expensive, not very attractive, and generally used as space dividers within an office defined by permanent wall systems. All this has changed.

Increased demand for flexibility in office layout has brought new pressures to upgrade movable partitions to meet performance criteria primarily met until now only by permanent systems. The use of pre-finished paneling with more colorful surfaces and durable materials has helped to offset the sterile, utilitarian image commonly associated with movables.

Inclusion of gypsum panels has provided movable partitions with the opportunity to give a low cost fire protection and thus meet building code requirements in new areas such as corridors and party walls, which were previously out-of-bounds. Also contributing to their growth has been the excellent sound ratings attributed to several types of movable partitions. One final factor is the narrowing gap between the cost of permanent and movable systems.

There are four basic forms of movable partitions: integrated, post and panel, runner and slide, and concealed stud.

Integrated

Integrated systems presently compose the bulk of the movable partition business and are custom fabricated to meet job requirements. They are usually composed of steel panels and accessories and are generally regarded as being the most expensive form of movable partitioning.

Post and Panel

Post and panel systems are easily recognizable by their modular appearance established with aluminum or steel posts or battens which are used to connect the solid or semi-solid panels. The P & P systems offer a wide variety of panel types and finishes ranging from prefinished plywood and pressure laminates to asbestos and gypsum panels which may or may not be prefinished. Very few of these systems offer fire protection which can be an important limiting factor in their selection for use throughout a building.

Runner and Slide

Runner and Slide Systems are very often used where economy is paramount and movability is of minor importance. Gypsum wallboard in the form of three-ply laminated panels is commonly used in the runner and slide systems to form progressive tongue and groove paneling. The use of low-cost gypsum board and the absence of trim components such as battens makes this a very price-competitive system; however, the mobility factor is rather poor.

Concealed Stud

The last of the four systems is the concealed stud movable partition. These are composed of steel studs, usually light gauge screw type but sometimes nailable, which are used in conjunction with gypsum paneling or a similar panel material which are held in place with battens.

All four types of partitions are available in the four basic partition heights: ceiling, cornice, bankscreen, and rail. In the case of integrated systems, this may be a specific height

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for any given type, whereas in the case of job fabricated partitions such as the concealed stud systems, the height may vary to suit a particular purpose. All of these partitions can incorporate glazing, be it translucent or transparent. Each system may have its strong points in any given height.

The search for partitions that lend themselves to relocation, exhibit pleasing appearance and design flexibility, and require little maintenance, has not been easy. The complicating factor has been that of cost. The construction industry is experiencing a problem of trying to offer better performance for less money in a time of rising costs. One system meeting all the criteria including that of cost has been the concealed stud system. Spun off from the now widely accepted drywall systems which center themselves around lightweight framing materials, these systems can offer more for less when compared to many of their forerunners in the movable partition field.

Pleasing aesthetics have been achieved at a reasonable cost by using vinyl-clad gypsum wallboard panels which offer great durability and a tremendous range in finishes including woodgrains which provide expensive-looking decors without an increase in cost above more subdued finishes. Of great advantage is the fact that these panels qualify as being noncombustible under the definition of the Southern Standard Building Code and American Insurance Association (formerly National Board of Fire Underwriters). This opens the door for their use in commercial construction.

To maintain modular appearances which tie the ceiling system and the partitions to a particular modular office layout, various width prefinished panels are being made available. The National Gypsum Company has introduced 30" wide Durasan vinyl-clad gypsum wallboard for use in its Contempo-Wall Demountable Partition System so as to meet the demand for systems lending themselves to the 5' (60") module which is becoming increasingly popular in office design. The system calls for the installation of the 30" wide 5/8" panels over 2½" screw studs spaced 30" o.c. Aluminum battens are placed over each panel joint. Fire endurance, sound transmission loss, and rigidity testing has shown this to be very acceptable for use in commercial construction. As in the case of the 4' modular Contempo-Wall System the company offers, there is a complete range in partition heights and glazing details.

Sound transmission loss for concealed stud systems is comparable to that of similar type permanent drywall steel stud partitions and is easily varied to meet particular job requirements. The addition of mineral wool or Fiberglas to the stud cavity is very common and causes a substantial increase in sound control on this type of partition. Often, the insulation also may be used to create a favorable moderate cost combination which provides fire endurance and increased sound control while reducing the thickness of the paneling required.

Most important in terms of performance criteria, at least for the building official, is the fire protection provided by concealed stud movable partitions. A broad range in fire-rated assemblies is available in this type of movable partitioning. Some require the use of 5/8" Type X gypsum wallboard, while others require only ½" Type X panels. Some require special battens and batten spacing and many call for the use of mineral wool. While creating the opportunity to vary design and hold down costs, the myriad of assemblies can pose a problem to building inspectors. This problem is easily resolved by requesting published data from the partition manufacturer either in the form of technical literature which carefully details the rated assembly or a copy of the fire endurance test. In some instances, test reports may not be available at the time a company begins promotion of a system, because of the time required to write and publish the report. In such instances, the testing laboratory will usually supply details directly to a building official at the request of the manufacturer. As stated earlier, most vinyl-covered gypsum wallboard is considered to be noncombustible.

The very nature of concealed stud type movable partitions makes them easy to inspect. Utility inspection is facilitated by leaving the paneling off one side of the partition until after the inspection is completed. Fire-rated panel material is easily verified by markings on the back of the panels and on bundling tapes; other materials and assembly methods are, of course, self evident. The similarity between these movable systems and permanent lightweight drywall systems makes it relatively simple for an inspector to become familiar with the assemblies which, of course, helps to minimize inspection time and increase his efficiency.

Perhaps the only major problem the building official may face with the onrush of movable partitions is to get the office address fast enough, in light of his busy schedule. With a movable partition, you can't be sure that today's address will be the same tomorrow.

Water Resistant Gypsum Backing Board for Bath, Shower & Laundry

By V. H. Noble

Some six years ago, water-resistant gypsum board was introduced as a base for ceramic tile in bathrooms, shower stalls and laundries. Once accepted by the ceramic tile trade, building officials and insuring agencies, it soon became the most popular ceramic tile base used for those applications. Today most of the gypsum board companies supply a water-resistant type board meeting ASTM C-630-68T.

First used mainly in wood frame,

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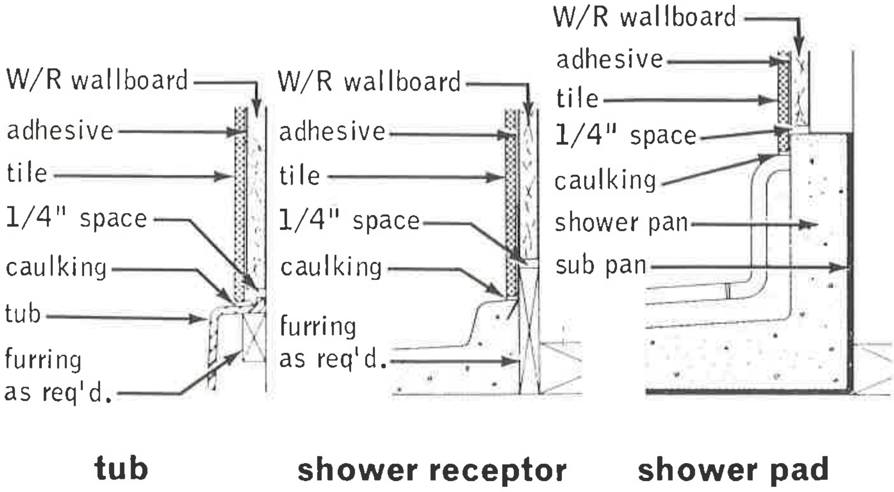

single-family houses, contractors soon began to install this water-resistant product in garden apartments and motels.

Its success and popularity quickly spread to high-rise apartments, dormitories, hospitals and schools and most recently it has been used for toilet rooms in core areas of major high-rise office buildings.

Manufacturers of water-resistant gypsum board have carefully developed details and specifications for installing water-resistant gypsum board to assure satisfactory performance. Following are some widely accepted "DO'S AND DONT'S" for your consideration.

In wood frame construction, DO see that the carpentry contractor has made proper provisions in his framing for the support of soap dishes, grab bars, towel racks, etc.

DO see that the tub lip or shower pan receptor is not set out beyond the face of the water-resistant board to allow the ceramic tile to pass over the lip to the tub or receptor shoulder (see details).

DON'T let the board touch the lip of the tub or receptor. Leave at least ¼ inch space (again see details) between the board and the tub lip. Preferably this should be a paper edge of the board with application horizontal. If for any reason the cut edge of board must be installed above the tub lip. DO be sure that it is sealed with a recommended sealer or waterproof tape.

DO be sure that all cutouts for soap dishes, faucets and shower heads are neatly made and that the cut edges are properly sealed with sealer or waterproof tape.

DON'T permit the spotting of nails or screwheads or taping of joints with regular taping compound within the area to which ceramic tile will be applied. DO apply sealant over all nails and screw heads and cut edges of the board within the area to be tiled.

DO tape joints and spot nails of the board above the tile line prior to painting.

When installing over metal framing, DO be sure anchorage is provided for fixtures such as toilet partitions, grab bars, hooks and so forth before you apply the water-resistant board.

Whether wood or metal, no framing should exceed 16 inches on center. With metal studs, particularly in office building toilets, it is common practice to install the water-resistant board vertically. In this case, the end of the board must be sealed prior to the installation.

In apartment houses, dormitories, hospitals, hotels and motels where the board is erected to metal studs around tubs and showers, the installation should be horizontal with the paper sealed edge held a minimum of ¼ inch above the tub or shower receptor lip.

For ceramic tile 5/16 inch or less in thickness the water-resistant board should be fastened with nails 8 inches on center or to metal or wood with screws 12 inches on center. In those rare cases where the design provides for thicker and heavier tile the fastener spacing should be reduced to 4 inches for nails and 8 inches for screws, and in this case blocking between studs should be provided 1 inch to 2 inches above tub or receptor lip and mid height.

Following the proper installation procedures, the next step is up to the tiling contractor. If he complies with ANSI Standard A136.1—1967 and installs his ceramic tile in accordance with ANSI Standard A108.1—1968, a long, enduring, trouble-free job will result.

Metal Studs in Wood Framed Construction

By Jim Manderbach

The use of steel studding in new home construction was a unique and perhaps startling sight when viewed by the prospective home buyer during the late 1960's. The use of steel studding rather than wood will surely find its place in the 1970's as an ordinary, common-place alternate type of construction to the good old 2 x 4.

The steel framed home is not an entirely new subject. The first house utilizing a rigid framework of steel that we know of was constructed in 1962. Studs fabricated from galvanized sheet steel for partitions and exterior walls were easily inserted into retaining channels which had been fastened to floor and ceiling and the

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(continued)

collateral material applied to the studding. The result was a California Ranch style home of some 2,600 square feet floor area which was steel framed, architecturally compatible with the surrounding neighborhood and, most importantly, built at lower cost than were the other nearby luxury homes.

In 1969 severe lumber shortages and escalating prices of what little lumber there was, plus high demand for housing construction, plus a shortage of drywall carpenters skilled in the application of gypsum wallboard to wood studs, forced the further development of new methods of construction of interior partitions.

Light gauge, nonload-bearing steel studs and gypsum wallboard used in conjunction with truss roof construction were found to offer the solution. Steel prices did not have the wild fluctuations of wood studs. An adequate manufacturing capacity was available. Apprentice labor was more easily and rapidly trained to handle the erection of steel studding and acceptable application of wallboard to steel than to wood.

Commercial and high-rise construction has successfully utilized light gauge steel studs and gypsum wallboard in noncombustible nonload-bearing construction for about eight years. Manufacturing facilities for light gauge members is adequate for any project requirements. The volume is substantial, business remains highly competitive, and costs are not subject to pressures of volume, weather or season.

Screw-on studs and track are roll-formed from 0.22 inch (nominal 25 gauge) steel, conforming to ASTM A446 Grade A. Full galvanizing by the hot dip method appears to offer superior protection against rust and corrosion in service and storage over the electro-galvanizing method. Galvanizing by one method or the other is mandatory.

Roll forming uses a progressive series of precision forming-roll dies arranged to shape strip metal. The initial machine set up of the roll dies is checked for quality of the finished part, the machine is then "locked up" and a consistent standard of quality is assured during production. Utilizing a roll of continuous strip steel of approximately 2,500 lineal feet, roll forming permits high volume manufacturing to specifications with minimum tolerances.

Quality standards are maintained by frequent inspections at critical check points—by the operator during production—by the foreman when finished parts move to inventory—by the shipping foreman when shipments are prepared. Fabricating plants have earned an enviable record for high quality.

Studs and track are available in widths of 1-5/8, 2½, 3¼, 3-5/8, 4 and 6 inches. Utility holes are provided for both plumbing and wiring, thereby eliminating the need for costly hole drilling. Studs are manufactured in lengths to accommodate ceiling heights up to 18 feet. Stud spacing can be 16 inch or 24 inch on centers, (refer to Chart C). Additional heights, where required, may be achieved by using a heavier stud, manufactured from 20 gauge (.0396") steel.

Steel studs are not affected by moisture content, nor will they warp, buckle or shrink. Once established in correct plane they stay in place. The metal-screwed-into-metal holding power of the fasteners, a self-drilling, self-tapping power driven screw, eliminates the age old problem of nail pops. The specially designed head of the screw compresses the face paper of the wallboard and provides for proper fastener concealment with joint cement. Rust-proof, rot-proof, termite proof, they form a framing that will give a lifetime of satisfactory service to the owner.

A wide range of systems is available for fire resistive ratings. The simplest, a one hour NLB partition, is the 1-5/8 in screw-on stud with one layer of 5/8 inch type X gypsum wallboard applied to each side with screws. An equally good selection is available for sound control problems. To point out the differences, the foregoing assembly provides an STC rating of 39, compared to a standard wood framing partition of 36 STC.

Usable floor area in the modern home is as important as rentable space is in commercial or high-rise construction. In one home of 1,150 square feet, an additional 30 square feet of living space was provided by the two inch difference in wall width gained by using a 1-5/8 inch steel stud in the 180 lineal feet of interior partitions in lieu of the standard 3-5/8 inch stud.

Wood truss construction permits the interior walls to be nonload-bearing. The higher cost of truss over conventional construction is offset substantially when combined with the advantages of steel studs and drywall. The quality and type of construction used in the truss must be good. The drywall ceiling should be installed first. This way the entire ceiling may be finished without interruption, utilizing maximum sizes of wallboard and thereby reducing the number of joints to be finished. In addition, the stresses on the trusses will be uniform and problems of stocking the job are greatly reduced.

All interior partitions can be framed with steel studs and track. Track fastening must not exceed 24 inches on centers. The studs are positioned vertically in floor and ceiling track. Fastening of studs to track is

TABLE NO. 1—ALLOWABLE INTERIOR PARTITION HEIGHTS BASED ON WALLBOARD AND NO. 25 GAUGE STUDS ACTING AS A COMPOSITE SECTION[1] [2]

STUD SPACING (In Inches)	FACING ON EACH SIDE	STUD DEPTH (In Inches)					
		1⅝"	2½"	3¼"	3⅝"	4"	6"
		Height in Feet and Inches					
16	½"— one-ply	11'0"	14' 8"	17'10"	19'5"	20'8"	18'10"
24	½"— one-ply	10'0"	13' 5"	16' 0"	17'3"	18'5"	17' 8"
24	½"— one-ply	12'4"	15'10"	18' 3"	19'5"	20'8"	19' 0"

[1] The tabulated stud heights are based on 25 gauge steel studs and installed in conformance with Gypsum Association specifications for installation of screw type steel framing members to receive gypsumboard.
[2] Gypsumboard product must have a minimum thickness of ½" and may be applied vertically or horizontally.

Chart C.

not required except at partition corners, terminals or at door and window locations. Double studding is recommended at door jambs. Headers are made of track sections and attached to the framing. In partitions exceeding 10 feet in height the rigidity of the framing may be increased by insertion of a stiffening channel spanning two full length studs on each side of the opening.

Application of ½ inch gypsum wallboard is recommended in conventional housing, with one inch self-drilling screws 12 inches on centers for single layer application. The same precautions for the installation of gypsum wallboard to wood apply for installation to steel.

Steel studs and other framing systems are compatible. Snap-in-place steel door frames are available or rough door frames constructed of conventional 2 x 4 wood can be finished in the manner now used in most construction. Electrical and plumbing installations are approached from a slightly different manner. For plumbing, all of the work is done prior to construction of the partitions except the installation of plumbing fixtures. No need to try and fit the plumbing within a six inch wall. Simply build a chase wall of two parallel rows of 1-5/8 inch studs and wallboard to the width required. Electrical wiring is most easily handled over-the-ceiling or under-the-floor runs rather than trying to make long pulls through the studs.

Bath, tub and shower areas are easily handled. Full size panels of gypsum wallboard with specially treated moisture resistant gypsum core and face paper (WR board) is recommended for use to provide a permanent backing for ceramic, metal or plastic tile. The wallboard is applied horizontally and screw attached to the steel studs spaced not over 16 inches on centers. A ¼ inch clearance between the paper bound edge of wallboard and tub or receptor pan must be left. Water-proof adhesives and sealers conforming to manufacturers' standards are required for attachment of tile.

Where a drop ceiling is desired, the construction can be of the same screw-on studs in lieu of wood. Backing strips of steel or wood for cabinets and wall fixtures are easily installed. The base can be conventional wood or rubber base.

Will this new concept in residential housing obsolete wood as a building member? Perhaps not, but the case for steel studs is strong; they are functional, they are noncombustible, the finished product appears conventional, except walls are more straight and true and they can be decorated in current fashion. The systems are easy to design, they are easy to construct, they are easy to inspect, and steel studs meet all of the requirements of modern construction.

Electric Radiant Heat Ceiling Systems

By J. H. Bacon

Radiant heat ceilings in one form or another have been around for many years. Both hydronic and electrical systems have been offered; the latter being far the most popular. Radiant ceilings offer all the advantages commonly attributed to other electrical heating systems and in addition offer extremely even heat distribution and are completely unseen and silent.

Giving impetus to the growth of electric heat is the fact that electrical heating rates overall are declining, whereas the cost of fossil fuels such as gas and oil is increasing. The popularity of electric heat with consumers has helped to fan the demand for electric heat in new construction and in conversions. Apartment builders are impressed with the low maintenance costs.

Electric Heat and Air Conditioning reported in their "13th Annual Market Analysis on Electric Heating" that nearly 10% of the homes and apartments in the U. S. in 1968 were heated electrically. The survey states that 3.4 million installations, 680,520 annually, are expected in the period 1970-75. The latter half of the 1970's are projected to average 981,940 units annually according to this report.

This volume of demand will surely be felt in areas never before considered electric heat markets. Even in those areas traditionally considered good electric heat markets new equipment will appear and many new contractors will surely be attracted to this market. Building code officials will find it necessary to be well versed in the various systems to be competent in their inspection. This article will direct its comments to the resistance ceiling systems which revolve around gypsum products and presently constitute about one-fifth of the total electric heat installations in the U. S.

Electric Radiant heat ceiling systems may be completely fabricated on the job and take the form of plaster over cable or cable sandwiched between drywall, or they may be factory fabricated. In either case, the finished ceiling heats the room using a combination of radiation and convection. Radiation from the cables or resistive sheet in the ceiling becomes heat only when it strikes an object. The best way to describe this is to compare it to the sun's heat. Convection plays a major role as these objects heat the air in contact with them. Convection currents begin to distribute heat to areas not directly exposed to radiation from the ceiling. It is this phenomena that explains why our legs don't get cold under a table in a room heated by a radiant heat ceiling. The net effect of a carefully designed and installed system is a temperature differential as little as 2°F. within the room! With individual

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(continued)

room control it is easy to see why this is the ultimate in comfort heating systems.

To enjoy all the advantages of electric heat and assure continued customer satisfaction, careful planning is most important. Probably no residential heating system receives as careful planning as an electric radiant ceiling system. Attention must be paid to the computation of heat loss for each room and the proper amount of resistance heating cable or panels installed. Often a plan layout is made to be certain heat is supplied in the proper areas.

Heat loss calculations are often supplied to the contractor by utilities. In other cases, equipment manufacturers or the contractor will compute these figures. These calculations are based upon the heat loss through the walls, floor, and ceiling of the structure at a given design temperature differential (DTD). This figure is computed by subtracting the outside design temperature from the desired indoor temperature. The outside design temperature is taken from the records of the local weather bureau. Usually the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Guide is used as a reference to obtain this figure. The lowest recorded temperature during the past 13 years is used. This figure is then multiplied by the "U" value for a given section of the particular assembly which is then multiplied by the total area of the assembly. The sum of the calculations for walls, ceilings, floors, etc. then constitute the total heat loss. This figure in BTU's is then converted to watts to obtain the required capacity of the heating equipment. A 10% safety factor is often added on.

Selection of adequate insulation is very important if comfortable, economical operation is expected. The additional cost of proper insulation will be partially returned immediately in the form of smaller capacity heating installation and eventually more than offset by operation economies. The utilities often specify insulation requirements as they are the ones who suffer when consumers experience high operating costs. In some instances they may even insist on inspecting the installation prior to approving its connection to their lines. The National Electrical Manufacturers Association (NEMA) and the Electric Heat Association have established standards for proper insulation. Briefly, these are R-24 or R-19 in ceilings, R-11 for sidewalls, and R-13 for floors. Simply stated in terms of glass fiber insulation, these become 6"-3"-3". Obviously, the thicker the better, but under no circumstances should less be used than that recommended either by those associations or the local utility.

Moisture control is important. A good vapor barrier such as polyethylene vinyl film applied on the warm side of the wall, floors, and ceilings provides good humidity control and also cuts down on infiltration which affects the economy of operation. Because electric heat consumes no oxygen it is not necessary nor is it desirable to provide as much ventilation. Poly film applied to the framing members after batt insulation is installed assures the tightest practical construction. Whether or not poly is applied to ceiling joists above the radiant ceiling appears to be controversial. Some people believe the warm surface of the ceiling together with proper attic ventilation negates the need for the vapor barrier on the ceiling. Others believe ventilation is usually not sufficient to draw off moisture properly. At any rate, most everyone agrees ventilation fans should be provided in excessive moisture areas such as baths and kitchens to avoid undue moisture build-up. In general, a range of 40%-50% relative humidity is desirable for maximum comfort.

Installation of the ceiling system requires placing the heat in areas of greatest heat loss. This means that the heat is concentrated towards the outside walls. Most radiant heat systems give off about 15 watts or about 51 BTU's per square foot of ceiling surface. This provides a low level of heat which covers about 80% of the ceiling in cold climates. While providing very gentle even heat, this may not be intense enough to properly offset concentrated losses such as those experienced by sliding glass patio doors. This situation is best handled by installing a drop-in high intensity floor heater which will "wash" the window with warm air and curb drafts. These units are connected to the same thermostat used to control the ceiling; thus forming a total comfort system. Another potential problem area is in bathrooms. Experience has shown a need for higher than normal design temperatures required quickly for short durations. Being a low intensity system, most ceiling systems are not well suited for this type of operation. The solution may be a wall panel, high intensity ceiling panel, or better, the heat/light/fan combination. The latter satisfies the need for quick response to meet heat requirements and provides the bonus of ventilation to remove excess moisture and also supplements lighting needs for the tub area.

Cable heat installations begin with the installation of gypsum lath or a drywall base layer. The base layer is applied horizontally to the joists and may be 3/8" or greater in thickness on joists spaced 16" o.c. and ½" or thicker on joists spaced 24" o.c. Veneer plaster systems require the use of joint reinforcing mesh which is applied over all the joints prior to cable installation.

Resistance cables are applied using staples recommended by the cable manufacturer. Wires must be run parallel to the joists and are generally spaced 2"-3" apart. Staples should be spaced 16" apart at maximum. Under no circumstances should cables be spaced closer than 1½" apart. To avoid penetration of the cable by nails used in the application of the face layer of gypsum board in drywall construction, cables should not run closer than 1¼" from the center of each joist. This provides a clear nailing channel of 2½" along each joist. Cables should cross joists 4"-6" from the wall. The National Electrical Code requires that cables come no closer than 8" from openings in the ceiling, such as those provided for ceiling fixtures. Resistance cables should not be installed above soffits, partitions or in closets or other closed location. The code does allow one cable to cross partitions to get heat into adjacent areas such as in the case of a bath-dressing room combination.

Base plaster is then applied over the cables in the case of a veneer plaster system. The "scratch" coat is then rodded to a depth of about 1/16" over the cables. Finish coat plaster may be applied as soon as the base is set.

Drywall systems require a nonshrinking filler material to completely encompass cables. If the filler does not provide complete contact between the face and base panels, air pockets will be formed. Air is an excellent insulator and where air space exists between layers and around cables, the efficiency of the system will drop. Heat may build-up around cables, too, as a result of this insulation and cause deterioration of the cables which may eventually cause burnout of the system. To avoid this, fillers of the hardening type are recommended. These experience very little shrinkage as opposed to normal joint compounds and laminating adhesives.

To complete the drywall system a face layer of gypsum board is immediately applied over the filler. This layer may be applied either parallel or perpendicular to the base layer. In either case, base and face layer joints should be offset at least 10". Nail within 2" of the walls and drive the next nail at least 8" away from the wall to avoid the cable return where it crosses the joist.

Either system should not be operated until thoroughly dry. With plaster systems it is important to maintain uniform temperatures of between 55°F. and 70°F. during and after installation to prevent thermal shock which can cause cracking. The Gypsum Association recommends drywall installations dry a minimum of one week under good drying conditions and two weeks under poor conditions before activating the systems.

The past decade has seen the introduction of prefabricated ceiling heat systems utilizing gypsum board together with various forms of heating elements. One system utilizes resistance cable embedded in 5/8" gypsum board whereas the other is composed of a resistance sheet factory laminated between a base layer of 3/8" gypsum board and a 1/4" face layer of gypsum board. Both offer the advantage of simplifying the installation of radiant heat ceiling systems by eliminating on-site cable installation and time consuming lamination. The shortage and expense of skilled labor coupled with the growing demand for electric heat have made these products ideal for today's market.

Planning the installation of these systems is similar to that required for other radiant heat ceiling systems. Layout becomes more important because of the prefab nature of the system. Both systems offer various models to provide a variety of wattages and panel sizes. The operating voltage for both is 240 volts, although lesser voltage, 230 and 208 for example, can be used at considerably reduced efficiency. Each gives off approximately 15 watts or 51 BTU's per square foot in heating areas. After determining the heat loss for a particular area, the optimum combination of panels is determined to offset the heat loss and fit into the area. The remaining ceiling area not covered by heating panels is finished with conventional 5/8" drywall.

Installation of either system is fast and quite simple. The cable embedded system manufactured by National Gypsum Company is called Panelectric and is applied just as regular gypsum wallboard is installed using conventional fasteners and drywall tools. Trim areas are provided in several panels to accommodate fixtures and vary panel size. Nail lines are marked on the face of panels together with trim areas to avoid puncturing heating cables. The second product is manufactured by Georgia-Pacific and is known simply as G-P Radiant Heat Panels. These are applied using insulated nails driven through the resistance sheet. With the exception of the clearly marked electrode areas these panels can be nailed anywhere in the field of the board. Holes may be cut in the field in this system. When this is done, the panel is rendered non-heating for the full width of the panel on either side of the hole.

Both systems may be finished and decorated in the normal manner used for conventional drywall. Once applied to the ceiling and connected to a thermostat using non-heated leads connected to each panel, either system can be operated to provide heat during the remainder of construction. The systems should be turned off while taping and decorating as the warm panel will alter the working characteristics of the joint compound and decorating materials.

Electrical work concerning cables and panels is covered in Article 424 of the National Electrical Code. Either line or low voltage thermostats are used. Which type of control is used depends on several factors including the installed wattage, accuracy of control desired, and, of course, economics. The low voltage units require a transformer and relay and are, therefore, more expensive. Double pole units are usually required in buildings such as apartments where the panel box is not directly accessible to the electrician. Branch circuits are usually 20 or 30 ampere. In the case of ceiling cable the electrician handles the connections to branch circuits when the cable is installed. Panel systems may be connected by the electrician as the panels are applied or after the drywaller has hung them all. This depends upon the access he has to the nonheating leads.

The introduction of the prefab gypsum heating panels is expected to take an increasing share of the conventional cable heat business as the demand for electric heat continues to grow and labor costs escalate. From the inspectors viewpoint these systems are a boon because they offer very little room for error on the part of the installer and provide the high degree of quality control available only in factory processed products.

Adhesives . . .
Today's Miracle Fasteners

By James R. Dowling

The use of adhesives goes back thousands of years. The first adhesives were natural gums and waxes such as rosin, rubber, shellac and beeswax. The earliest adhesives were animal and casein glues for attaching ornamental veneers to wood surfaces and those used by the Egyptians to make furniture.

Since we will be discussing the use of adhesives in the lamination of gypsum wallboard, it is interesting to note that one of the first recorded uses of gypsum was also by the Egyptians. The interior surfaces of all the pyramids are plastered with gypsum.

Up until the late 1930's the only adhesives in common use were animal, casein and vegetable glues and natural resins. After the synthetic plastics resins were developed and became available around 1935, new uses were found for almost all industries.

The terms **adhesive** and **glue** once were considered synonymous, but the term glue now implies a sticky substance, whereas many adhesives are not sticky.

Adhesives may be broadly classified into two main groups: organic and inorganic. The organic materials are subdivided into those of animal origin, vegetable origin and synthetic origin.

A more useful classification is based on the chemical nature of the adhesive:

(1) protein or protein derivatives.
(2) starch, cellulose, or gums and their derivatives.
(3) thermoplastic synthetic resins.
(4) thermosetting synthetic resins.
(5) natural resins and bitumens.
(6) natural and synthetic rubbers.
(7) inorganic adhesives.

The protein and protein derivative adhesives include those made from casein and soybean proteins and also the important groups of glues made from hides, bones, etc.

Adhesive made from materials such as starch and vegetable gums are water soluble and are used for bonding paper, postage stamps and similar items.

Thermoplastic synthetic resin adhesives comprise a variety of polymerized materials such as polyvinyl acetate, polyvinyl butyral and other polyvinyl resins and are used in making tapes, safety glass, shoe cements and for bonding foils, metals, woods, rubber, paper and so forth. Thermosetting synthetic resin adhesives comprise a variety of phenol-formaldehyde urea-aldehyde, melamine-aldehyde as well as other condensation-polymerization materials and also are used in bonding similar materials.

The adhesives of the natural resin and bitumen group include those made from asphalts, shellac, resin and its esters. They are used in the bonding materials such as minerals and linoleum.

There are many different rubber adhesives. Some are simply solutions of rubber latex, rubber, or synthetic and modified rubbers in a solvent. Others consist of caseins or synthetic resins. Their application range from bonding flexible materials such as paper, textiles, leather and rubber to rigid materials such as metals and plastics.

The important inorganic adhesives comprise the following: sodium silicate principally used for corrugated paper and other paper products; plaster of paris for ceramic and similar products; litharge-glycerin for joints in plumbing fixtures; and portland cement for bonding mineral aggregates.

The term cement is often used as a synonym for adhesive, however, a cement is a particular kind of adhesive. It consists of any material that can be prepared in a plastic form which hardens to bond together various solid surfaces.

Adhesives are formulated to do particular jobs. They can solve a multitude of construction problems. One very popular use is in the application of gypsum wallboard to wood and metal structural members in both wall and ceiling assemblies. At present, the growth of adhesively attached gypsum wallboard is 15% annually. As we learn more about adhesives, we can expect the market to expand proportionately through the 1970's.

By definition, adhesives are substances which can hold materials together by surface attachment. This phenomenon of uniting one material to another is called "bond." The bond strength is the unit-load required to cause failure of an adhesive assembly, with failure in or near the plane of bond. The cohesive strength of a substance is defined as the force needed to cause failure within the substance itself. The load applied can be expressed as tensile, shear, cleavage or peel.

Since the chemical or physical processes of adhesion are not completely understood, technology tends to be experimental rather than theoretical. We can define certain properties and strengths of adhesives, but the most complex question to the adhesive chemist is, "What makes it stick?" We know how, but not why.

Today there are three theories: the principles of absorption, diffusion and electrostatic. Until we know "why," we can only continue to define the properties and the causes of failure.

Failure is defined as a yield in either the adhesive itself or the adherend. The adherends in gypsum drywall applications are the stud and the drywall. A yield within the adherend is not considered an adhesive failure but rather it is a failure of the adherend.

The three most common causes of failure are: (1) Improper choice of adhesive. (2) Improper preparation of the surfaces, and (3) Improper applica-

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tion of the adhesive itself.

The remarkable properties and versatile applications of adhesives suggest that they can do nearly all things under nearly all conditions. However, adhesives vary not only in initial and ultimate strength but also in life expectancy. Each is designed by the manufacturer to do a specific job. For example, one adhesive resists a force of only a fraction of an ounce before failure while another can resist the force of several tons.

In the application of gypsum wallboards we are mainly concerned with two forms of adhesive, mastic and dry powder. The mastics are produced to a particular premixed formula and come ready for use. Technically, they could be classified as natural and synthetic rubbers. The dry powders also are produced to particular formulas but must be mixed with water at the job site. Technically, they would be classified under protein and protein derivatives.

Mastic adhesives come in both solvent and water-base formulas and are recommended for attaching wallboard to wood or metal framing members. The basic difference between the two depends on the applications for which they are intended.

Solvent-base adhesives provide a more controlled vehicle evaporation in damp or cold weather. They may be used with foil-backed insulating wallboards and similar predecorated products. However, caution should be taken to prevent the adhesive from coming in contact with the vinyl-surfaced wallboards.

Water-base adhesives eliminate the hazards of solvent-base adhesives. Water-base adhesives may be used in the same applications as the solvent-base products but in addition also are recommended for applying wallboard to wallboard, wallboard to polystyrene or urethane rigid foam insulation, monolithic concrete, concrete block and wood fiber sound deadening board. Both generally are available in one-quart cartridges and five gallon cans. Both are pumpable. About two to three gallons are required to apply 1,000 sq. ft. of gypsum wallboard.

When the solvent-base adhesives are used, adequate ventilation should be provided during use to remove fumes emitted from the volatile agents in the adhesive. Normal precautions (for flammable material) should be used regarding proximity to fire, sparks or smoking.

The advantages of the adhesive, nail or screw-on method of fastening gypsum wallboard overcome the problems of twisted studs and misaligned framing. They provide a pliable gap-filling bridge between the wallboard and distorted framing and readily are compressed at protruding members.

Adhesives are applied easily and quickly with common tools. Because of their superior strength, they provide a stronger assembly. Tests show that adhesives provide up to 100% more tensile strength (pull-off) and 50% more shear strength.

On walls, adhesives eliminate all field fasteners and up to 75% of all fasteners that cause problems when lumber shrinks or distorts. With age, adhesives remain flexible and maintain proper bond to absorb the stresses caused by structural movement.

Dry powder adhesives are formulated from a casein (phosphoprotein) base. They are recommended for laminating wallboard to wallboard, wallboard to gypsum studs or ribs and sound deadening board. In addition, similar formulations are used for joint treatment, back blocking, spackling, patching and repairing cracks. They are not recommended for use on wood or wood fiber products.

The casein powder adhesive products through constant improvement have long predominated the drywall industry. They are relatively inexpensive as compared to the mastic type and are usually packaged in 25 lb. bags. Coverage varies with application techniques, however, one bag will cover approximately 500 sq. ft. of gypsum wallboard. Although casein compounds are generally compatible with each other the intermixing of compounds which have been formulated for different applications is not recommended.

All of the dry powder adhesives are pumpable and can be either machine or hand applied. Caution should be exercised to prevent freezing, however, satisfactory results can be achieved.

The advantages of the dry powder adhesives used in laminated systems include excellent bond which provides greater strength, higher resistance to fire and sound transmission, high resistance to cracking, less possibility of fastener imperfections and joint ridging. In addition, they are easily mixed at the job site and have smooth working qualities.

It is not possible to review all of the many applications of adhesive construction in one short article. Instead we have tried to provide you with a basic understanding of the various adhesives that are available and their uses including those that pertain to the gypsum industry.

The development of adhesives over the past 10 years has been phenomenal. The current domestic consumption of adhesives is estimated at between 2 and 3 billion pounds per year and this figure continues to grow annually. Because of the tremendous demand for housing in the 1970's new and advanced building techniques will have to be employed and the use of adhesives will play an even greater role in the construction industry.

Sky's the Limit for Gypsum Slim Line Shaft Wall

By James R. Dowling

Gypsum drywall shafts are replacing conventional masonry and plaster walls, once the only methods of enclosing high-rise elevators, stairwells and other vertical shafts. As is often the case with a new product, process or system, the drywall shaft wall system was created to eliminate a specific problem. And, as so often happens in the construction industry, the elimination of the problem is but one benefit of the new development.

Historically, the core area partitions of multi-story buildings have been of heavy masonry weighing 20 to 45 pounds per square foot, followed by lath and plaster assemblies weighing 15 to 20 pounds per square foot. Now we have drywall shaft wall assemblies weighing only 10 to 13 pounds per square foot being used in the core area of high-rise structures.

The core area of the high-rise structure is the working backbone of the building and is complicated by the following considerations.

1. The traffic pattern within the building requiring corridors, elevators and stair towers.
2. Service areas, such as toilets, mail handling equipment, janitor's closets.
3. Heating, cooling and ventilating supply and return shafts and their accompanying duct work.
4. Facilities for electrical power and communication lines.
5. The water supply and waste lines to service the plumbing facilities.

This trend of gypsum drywall construction in the core area is not revolutionary but rather the natural result of finding a better answer to a problem and in this case the adaption of products and systems already being used for other partitions in the structure.

The concept for these new drywall assemblies capable of being erected from the slab or floor side around shafts came from the structural engineers designing the twin 110 story towers of the World Trade Center currently under construction in New York City.

Together with the Port of New York Authority, the engineers, architects, consulting general contractor and the United States Gypsum Company used a team-approach to solve the 4 million square foot shaft wall problem. In addition to the 2 hour fire resistance rating, it was determined that seven significant needs would have to be satisfied for the system to be accepted.

1. Resist lateral loading of 7½ and 15 psf air pressures.
2. Deflection not to exceed L/240 of the partition height under design load.
3. Dead load of partition not to exceed 15 psf.
4. STC rating about 38.
5. No evidence of severe failure through fatigue by any component after a partition was cycled one million times through its maximum allowable deflection.
6. Construction to permit the system to be built from one side only.
7. Accommodate 16 foot floor to floor heights.

What evolved from these requirements were shaft wall systems having top and bottom tracks of galvanized steel with vertical steel members spaced either 24", 16" or 12" on center in a gauge to meet the above design criteria for the vertical span, and supporting the gypsum liner or plank and to which the face layers of gypsum wallboard are screw attached.

In comparing these new lightweight drywall shaft assemblies with the conventional systems let us examine the advantages and disadvantages. In the case of masonry the elevator shaft cannot be completed and cars cannot be installed until the masonry operation is finished.

With the drywall system, the installation of the elevators can be done in conjunction with the core walls. The core wall is installed from the exterior side of the shaft while the masonry installation normally is done from a suspended scaffold inside. The same is true for the stairwells. Normally these areas would be congested with a lot of scaffolding and mountains of rubble created by the masonry trades.

The drywall shaft installation requires no scaffolding in either area thus allowing unobstructed use of these important traffic avenues by the other trades. Where it is desirable to get man hoists in operation early, the shafts can be enclosed with the studs and liner boards in lieu of temporary enclosures.

Clean up is simply a sweeping operation with no clean up required within the shaft.

Mechanical shafts, and particularly piping shafts which are required to be left open on one side for inspection and testing are more easily and quickly enclosed.

Special problems that arise on mechanical equipment floors such as unusual heights up to 25 feet, high pressure loadings, or large penetrations can all be handled in the design and detailing of these new systems.

For walls buried in shafts it is desirable and practical to finish them while the mechanics are in the shafts. With the alternate use of gypsum wallboard batten strips in lieu of conventional joint treatment, this work can be completed regardless of the temperature unlike plaster or masonry which must be stopped at freezing temperatures or be provided with temporary heat.

Each of these advantages are significant in increasing job efficiency and reducing cost. By utilizing them in a properly scheduled construction program in the core area a highly favor-

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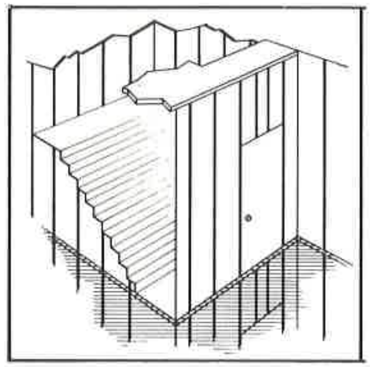
able effect on the total construction budget will be achieved.

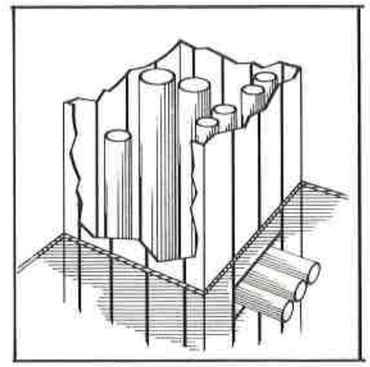
Before the World Trade Center Towers were ready for the shaft wall installation these new drywall systems were used on many other high-rise buildings.

Some of these buildings are the United States Steel Building in Pittsburgh (Harrison & Abramovitz & Abbe), The Tishman Airport center in Los Angeles (Welton Becket & Assoc.), 1010 Common Building, New Orleans (Skidmore, Owings & Merrill), 111 East Wacker Drive, Chicago (Mies van der Rohe & Associates), Central National Bank in Cleveland (Charles Luckman & Associates), and No. 1 Perimeter Center, Atlanta (Sidney R. Barrett).

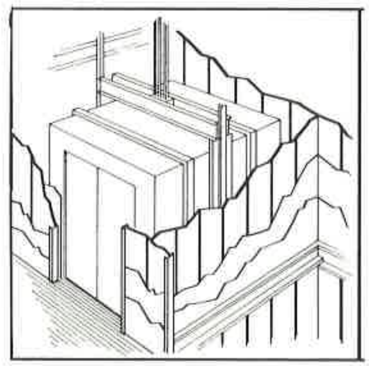
Many others in the process of construction today utilizing the drywall shaft wall systems, include the IDS Center in Minneapolis, the Shell Oil Building in New Orleans, the First National Bank in Portland, the Westwood Center, Los Angeles, and the Coastal States Life Insurance Building, Atlanta.



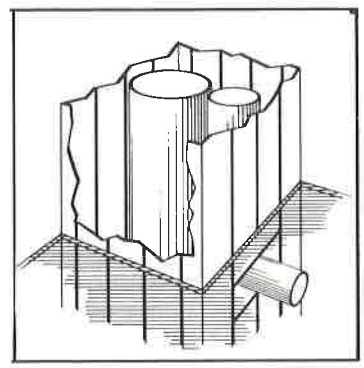
stair wells



mechanical shafts



elevator shafts



air ducts

Veneer Plaster Systems

By Robert L. Keeler

Until recent years, widely accepted thicknesses for plaster ranged from one-half to three-quarters of an inch. Anything less was simply sub-standard and, it was thought, would not provide that solid, monolithic property which had made plastered walls the mark of quality construction for decades, if not for centuries.

Now, with more advanced systems technology, plaster applied to thicknesses of one-eighth inch or less has gained widespread industry acceptance. It is true that over the last 30 years some tradesmen had experimented with 3-coat work totaling one-quarter inch thickness, but they met with dubious success. Under some job conditions, the basecoat dried before it set, producing a plaster lacking the strength to withstand the stresses of even minor building movement without cracking.

It was not until the inroads of gypsum wallboard, which threatened the future of plaster and plastering, that productive efforts were made by lath and plaster interests to remain competitive through development of veneer plaster systems.

The challenge was essentially one of time—speed of application. In the late 1950's several small Southern mixing plants that manufactured mill-mixed finishes began experimenting with veneer plasters. They found their first use in Florida and a few other Southern areas. Veneer systems came to be regarded as the great opportunity for plasterers to bring their cost per square yard into line with drywall.

Early in the 1960's, various manufacturers in the gypsum industry picked up the challenge and moved on two main fronts: the plaster base and the plasters. The first was quickly solved by "wallboard size" gypsum lath instead of the familiar, but slower to hang, 16 inch x 48 inch lath. This transition was made by facing a typically 4 foot wide board machine product with a more highly absorbent lath paper. Developed for use on this base, the new plasters were formulated to give rapid set and high strength that would perform satisfactorily when applied at a typical overall thickness of three-thirty-seconds of an inch to one-eighth inch.

With the introduction of metal framing and screw application of plaster base, veneer plaster, which had been developed for residential construction and wood framing, now had great potential in commercial construction. Systems were developed which included veneer plaster application over concrete, masonry block, electrical radiant heat cables, rigid foam insulation, "two inch solids" and shaft walls. Two basic plaster systems were introduced: One coat and two coat. The latter consists of a basecoat, applied and allowed to set, over which a separate finish coat is applied direct

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(continued)

to the base and worked to a smooth or textured finish in a single operation.

Veneer plaster combines many of the best features of drywall with those of standard plaster construction, resulting in these advantages or benefits:

1) It has sound and fire ratings at least equal to drywall, and in some systems, the sound ratings are better than standard lath and plaster.

2) Rapid installation reduces overall construction time. An entire area can be completed in one day. Compared with regular plaster, drying time is reduced by a week to ten days.

3) It provides a tough surface and the appearance of a regular plaster at a lower cost.

4) Also the system provides good resistance to cracking, impact, abrasion failure and nail popping.

Veneer plaster can be used in most systems to obtain the same fire rating as obtained with drywall. The system is installed in the same manner as drywall, except that a gypsum base for veneer plaster of the same thickness and same type core is used instead of gypsum wallboard.

The same fasteners such as nails, screws or laminating compound used in the drywall system are applied using the same techniques, spacing, and size. The veneer plaster is then applied according to manufacturer's specifications.

In high-rise construction, one and two hour fire ratings are often required for partitions and two or three hour ratings for elevator shafts. On columns, the rating can vary from two to four hours. Ceilings usually require a two hour rating. All can now be achieved by veneer plaster systems.

Gypsum Board in Exterior Locations is Research Result

By Howard L. Weightman

Gypsum board products manufactured today include a wide range of properties and performance characteristics. Each product is designed specifically to provide properties peculiar to the intended application.

Thirty years ago, gypsum board was quite limited as to end use applications because technology to build in a variety of physical properties was not available. The gypsum industry has since applied new technologies and innovations to provide the construction industry with a family of gypsum board products incorporating multiple physical properties.

For example, gypsum boards developed specifically for application in exterior locations include gypsum sheathing, fire barrier gypsum board and soffit board. Each product is manufactured to provide physical properties required for the intended end use.

Gypsum sheathing is used as an underlayment for a variety of exterior finish materials, including wood siding, masonry veneer, cement asbestos or wood shingles, Portland cement stucco, etc. The properties designed into gypsum sheathing include fire resistance, weather protection, water repellancy, vapor permeability, structural strength and long term protection for framing members.

Standard Grades

Two standard grades of gypsum sheathing are produced: plain and core-treated. Core-treated sheathing is produced to resist absorption of water in the core and should be specified for use in high rainfall climate areas.

The 5/8" type X gypsum sheathing is also available where additional fire resistive ratings are desired. For example, this application provides required fire protection in townhouse and other multi-family construction.

Material cost for gypsum sheathing is low, often as little as 50 percent of other sheathing materials. Waste is minimal since lengths to accommodate the structural design are used to avoid scrap. Large, four foot wide sheets applied vertically eliminate the need for diagonal bracing, thereby reducing framing cost. Also, the large sheets can be applied quickly with fewer nails or staples than are required by other sheathings. An average home can be sheathed in approximately eight man-hours.

Gypsum sheathing should not be used as a nailing base. Exterior materials applied over gypsum sheathing must be fastened through the gypsum sheathing directly into the structural framing members. Gypsum sheathing is not designed for use as a siding to be decorated with a finish coating.

As Fire Barrier

Fire barrier gypsum board is designed for use as an underlayment in roofing systems. This product was developed by the gypsum industry to provide improved fire protection for residential and light commercial buildings. Fire barrier gypsum is installed on the top surface of roof rafters beneath conventional roofing systems.

The gypsum board thereby protects the structural members and retards the spread of fire even though the source of fire is from burning brands landing on the roof from burning adjoining buidings or underbrush and will contain a fire started within the building. This added protection is especially valuable where fire fighting service could be delayed; in any areas where flame-spreading winds are strong, or for any structure where combustible roofing materials are used.

Fire barrier gypsum board is manufactured with a special Type X fire-retardant gypsum core and the paper surfaces are water-resistive for protection during job application prior to installation of the roof membrane. Flame-spread rating of fire barrier gypsum board is less than 25 when tested in accordance with ASTM Method E 84.

Type X Core

Fire barrier gypsum board is nailed

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with the long edges across rafters spaced up to 24 inches on center. At least one 4d common or 1-3/8 inch long gypsum wallboard nail is used at each rafter for every board. Either plywood or spaced sheathing (1" by 4" stripping) is installed over the fire barrier gypsum board in the conventional manner. Nails a half inch longer than usual are used to apply the plywood or sheating for attachment of the roofing system.

Soffit Board

Soffit board is a new gypsum board development. This product is intended for use under eaves, carports, porches and covered walkways. Since soffit board is used as a "ceiling" in exterior locations, it must remain rigid and resist sagging in spite of high humidity exposure conditions.

Several manufacturers have developed proprietary gypsum boards for this use. In any case, the gypsum soffit board must be protected from direct exposure to weather by proper use of drips, moldings, water stops or casings around the perimeter of the gypsum board. Ventilation above applied soffit board is essential to prevent long term job problems. Manufacturer's recommended joint treatment and finish decoration should also be followed for good performance of the gypsum soffit board system.

The future prospect of using gypsum board as an exterior siding or exterior wall is promising. A wide range of physical properties are being incorporated into gypsum board products today. Many of these properties were dreams a few short years ago. Further sophistication of technical achievements may well provide the capability of manufacturing a truly exterior gypsum wall system.

Exterior Gypsum Wallboard

By E. J. Salamon

The acceptance of wallboard as a replacement for plaster has been a long uphill battle. Builders and architects were rather hesitant to be the first to make the change. The gypsum industry, backed by extensive research and development, stood ready when new products were needed. The history of the gypsum industry shows a willingness to invest its resources when the need for new gypsum products was recognized.

Back in the 1940's the need for an exterior gypsumboard became apparent. The forerunner of today's exterior wallboard was a gypsum sheating made as a tongue and groove product of black paper and regular core. After drying, the paper on each side of the board was subjected to a water repellent treatment. This was a costly process because of the double handling of board. As a result, a new method (developed in 1947) was devised using asphalt and wax emulsion to waterproof the core, plus a special paper which had water-repellent characteristics. This idea led to the recent development of a water-resistant gypsumboard which had a treated core similar to sheathing but with mildew-and-water-repellent face and back papers.

Gypsum sheathing has many exterior uses. It is used as a sheathing for brick veneer, cement-asbestos shingles and other siding materials.

A first cousin to gypsum sheathing is a recent development which is used as a fire barrier under different roofing materials and is known as Fire-Fighter gypsumboard.

As the production capacity in the gypsum industry increased, possible new uses for gypsum wallboard were being explored. For a long time plywood was used in soffits and outdoor porches. As building construction costs rose, a call for a more economical material was made. The gypsum industry, responding to the call, began further developments resulting in another new gypsumboard product. There are several patents for exterior soffit gypsumboard. These generally deal with chemical additives which make the gypsumboard more impervious to water vapor and moisture. The prime requisite of a gypsumboard to be used for soffits is that it should be rigid after exposure to high humidity. The gypsumboard used for soffit application should be ½" thick and exhibit no sag for a period of 48 hours at 90°F. and 90% RH when spaced on framing members 24" on center. Gypsumboard, as with many grades of plywood, must be reasonably protected from the elements. However, caution must be exercised that the gypsum wallboard in soffit areas be totally protected from the elements.

Some of the gypsumboard manufactured specifically for soffit application is chemically treated to attain vapor impermeability. Industry members, as a result of this breakthrough, have been working closely with exterior coating producers to develop another special gypsumboard which, when properly coated, can be used as a finished siding. Exterior joint compounds have been developed to complement this new innovative siding.

This new siding system utilizes a 5/8" type X gypsumboard with a treated core and mildew and water repellent paper over which an acrylic type paint is applied. The application method generally is: first finish the joints with an exterior taping compound, followed by a primer and then a heavy bodied finish coat applied at a rate of 25 sq. ft. to a gallon. This finish coat is generally pressure spray-applied to give a textured appearance. When dried and cured the result is a tough surface which resists weathering. Many houses on the West Coast are being finished in this manner.

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The Role of the Gypsum Manufacturer in Industrialized Housing

By D. L. Magnusen

The role of the gypsum manufacturer in industrialized housing can be that of merely a material supplier or it may extend well beyond that. As a manufacturer constantly seeking new markets for his materials, it is natural that he work with the pioneers and innovators in this rapidly growing industry towards new and more efficient uses of gypsum and realted products.

Gypsum products and systems are of primary interest to housing manufacturers because of their universal acceptance as interior finish materials and their unique fire resistive and protective properties. However, the finishing systems and the methods of achieving fire protection developed over the years for conventional construction do not necessarily lend themselves to the construction practices and design of sectional and modular housing units.

The industrialization of housing generates a host of problems peculiar to that industry alone. Problems have included specialized means of achieving required fire resistive ratings and sound isolation; developing speed of erection and speed of interior finishing; providing structural integrity through basic design and construction details that will permit handling and shipping without appreciable damage to the unit.

It is to the mutual interest of the industry and its suppliers as well as society itself that these problems be resolved in an acceptable manner as expeditiously as possible. Much attention has been focused in recent years on the hope placed upon industrialized housing to produce suitable homes in the quantities required to meet current, let alone forecasted, needs. We are told that conventional construction cannot cope with the demand; that the solution lies in the automation of assembly lines.

But successfully automated construction cannot accept the methods and procedures of another age anymore than the automobile industry could continue to use products and adaptations from the buggy industry. Entirely new construction ideas and technologies must evolve.

To date, most of the use of gypsum products in industrialized housing has pretty well paralleled their use in conventional construction, mainly since this is what is known and also this is what has been available. Evolution has started as might be expected with some special sizes and special formulations of existing products.

From a gypsum manufacturer's standpoint, one of the pressing needs has been that of development of a more rapid means of finishing of gypsumboard joints. Several manufacturers have developed and marketed systems intended to answer the need. U. S. Gypsum's answer is that of a very high strength, quick setting joint compound strong enough in itself to preclude the need for tape. It is compatible with certain paints that permit it to be painted as soon as it sets, before it has had time to dry. The system reduces to hours what previously had required days, thereby enabling producers to increase their production. Tests show that its use in fire rated assemblies does not sacrifice performance.

As the industry moves more towards incombustible construction, a trend we can expect for multi-family housing, needs for systems currently unavailable will develop. An example of such a need would be a light weight floor construction of dry materials that could be used in conjunction with ceiling systems. USG, anticipating this need, is developing such a system; a combination of a thick, high density gypsumboard to serve as a floor underlayment over a corrugated or ribbed steel deck. Elimination of hundreds of pounds of dead weight and elimination of curing time should be significant gains to the producer. Elimination of a wet process would, of course, be of significant help in avoiding moisture problems during storage periods.

Another need will be that of establishing new means of determing fire resistance of column fire protection. In module housing, steel frame construction will not have the same meaning as in conventional construction. Several housing manufacturers are already building modules that are contained within a steel framework which, when connected together, form columns of bundled square tubing at the corners of the modules, providing capability of being stacked to form medium-rise apartments and hotels. Columns are a composite of comparatively small sections, concealed within a wall formed by the two abutting modules. The columns may be unique in yet another way; failure of the column of one unit, in at least one system, will not endanger the safety of adjacent units or those above. Conventional column fire protection systems obviously will not serve this type of construction. Solutions have been handled on an individual basis generally by the gypsum manufacturer and modular manufacturer consulting on a rational approach and then seeking approval of the governing code body.

The trend in code requirements is away from material specification in preference for performance specifications. Yet in many areas there still exist arbitrary material specifications. One of those which frequently confronts the industrialized housing industry is that of the masonry fire wall. Masonry construction, of course, does not lend itself to industrialized housing. Even in conventional construction, requirements for masonry walls can cause serious delays to completion. Since the masonry is intended to

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provide fire protection, the fire protection desired is what should be specified rather than the masonry. Comparable fire protection can be provided by designed systems in a number of ways and still be compatible with the industrialized housing concept. In some areas substitute fire resistive constructions of a specified period are accepted; in others they are not. Gypsum manufacturers are working with housing manufacturers to gain acceptance of more compatible design but here again such work is on a job-to-job or area basis.

Thus the role of the gypsum manufacturer includes that of a consultant, to aid in the design of housing that can be effectively produced in quantity by modern factory production methods and yet provide the aesthetics, structural integrity, and safety of conventionally constructed housing. Much of this work is repetitive from location to location as varying code requirements are met plus being duplicated by coincident efforts of several gypsum manufacturers. Conversely, one would imagine that the efforts of code officials are being widely duplicated and repeated as groups in many areas are faced with the same requests from several sources.

The trend towards the statewide code to govern factory-built housing that twenty or more states have already adopted should prove to be a very significant step towards developing uniformity of requirement and intent as it affects the industry. These codes are designed to regulate factory built housing uniformly within a state and hopefully there will be a high degree of uniformity among state codes with reciprocity between states.

However, such codes cannot hope to continually remain on an up-to-date basis, constantly reviewing and evaluating all new developments of a rapidly changing industry. Such a realization would indicate the need for a group representing code bodies that would have the function of evaluating proposed construction and manufacturing practices on a continual basis and serve as an advisory board to the model codes and in turn to the states. This would have the effect of a central clearing house, avoiding duplication of independent effort plus keeping interested code officials apprised of developments in product and procedure including valued commentaries.

Stress Relief of Gypsum Product Components for Industrialized Housing

By J. J. Gafford

Industrialized Housing, Manufactured Housing, Modular/Sectional Construction, select any name you wish; regardless of what you call it, the idea of homes, town houses or apartments being built in a factory is here to stay. This concept is not totally new, though there are some revolutionary new ideas being conceived and incorporated. Where does it differ from conventional construction insofar as the performance demands of materials and systems are concerned? Let's take a quick look at "stick" building.

The greatest stress to which materials are submitted in on-site construction (short of earthquake, hurricane or tornado) is when the materials are "dumped" from the delivery trucks. Individual pieces of building materials are bent and buckled for a short period, then are allowed to recover. In manufactured housing, however, the stresses are somewhat different both in-plant and over the road, and as a result they must be studied somewhat differently.

In manufactured housing we do not have the "dumping" problem of the "stick" builder, but we have a number of times both within the plants as well as over the road when the whole wall or portion of a house or apartment may be racked, vibrated and twisted. For example, in the plant, depending upon the degree of sophistication the plant has for unit handling, a prefabricated wall section can be twisted, warped and buckled just taking if from the fabrication table or bed. Further, it can go through similar stresses again during placement on the floor unit. As the unit is moved and loaded, additional stresses can be set up. The type of trailer or carrier can be the source of other problems related to stress as the unit is loaded, transported and set into place. Improper tie-down on the carrier, road vibration and even twisting stresses are part of the reason a unit may arrive in less than satisfactory condition.

In the case of gypsum wallboard and plaster products, special studies have been made and systems developed to alleviate some of these problems. For example, where does the stress generally show up? Can this be eliminated by design changes? Will a different method of loading and transporting correct the problem? What can be done? The problems will show up as cracks or ragged tears usually found above and below the corners of large windows, over the corners of doors, corners and ceilings and wall junctures. Correction of in-plant handling methods, loading and transporting systems can reduce the likelihood of excessive stresses on these critical areas, but this is not the complete answer.

The best results are achieved when we combine several ideas, all aimed at eliminating cracks or breaks which

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(continued)

could deface the gypsum material. A structurally overdesigned unit is not the answer because the cost would be prohibitive and it would not stop vibration. The answers today are being found in design changes and the inclusion of either stress relief joints or systems having joint and surface treatments of a type to create a marriage which will produce the resilience to absorb the shock without permitting the surface to be distressed or broken.

Now, let's take a brief look at certain techniques which have been successful in elimination of the problem:

Wall Corners: (Inside corners as found at extreme corners of unit)

The use of the "floating angle" technique of applying gypsum wallboard.

The changing of materials, for example, painted gypsum wallboard or plaster on one wall and then paneling on the adjoining wall installed over gypsum backer board and with a "dry" corner joint, the joint trimmed with conventional wood molding.

The use of "dry" corner by terminating either the gypsum wallboard or plaster on each wall surface at the corner and not carrying them around the corner in the conventional manner. These surfaces can be terminated at the corner with cornerbead or "U" beads.

Wall/Ceiling:

The same systems as mentioned under "Wall Corners" can be used plus the installation of a ceiling molding over a "dry" joint juncture.

Windows and Door Areas: (small windows are generally no problem)

These areas should first have the gypsum wallboard installed with joints falling on the studs at the four corners of the windows and above the doors. This will tend to isolate the area wherein problems are most frequent.

There are several methods which can be used to create stress relief joints that will reduce the difficulties encountered.

1. Install the one piece relief joint which is basically a "V" shaped member with nailing flanges and with a resilient material adhered in the crotch of the "V".

2. Install two corner boards with a 1/16" space between each and insert a string in the void which is pulled out when the joint system has been installed and is still in a pliable state.

3. Consult some of the gypsum manufacturers who have been studying methods of creating extra strong joints and then covering the entire surface with a resilient coating. These systems are capable of allowing the gypsum to break or crack without any distress being visible through the coating.

The one principal point which should not be overlooked is that the manufactured housing industry can enjoy the beauty, fire resistance and sound conditioning benefits of economical gypsum products with the reassured knowledge that the gypsum industry is dealing with the problem in a manner which will result in an acceptable product in the market place.

Finishing of Masonry Walls and Partitions

By: Richard M. Glazier

The finishing of masonry walls and partitions has always presented problems to the construction industry. The most usual and conventional way was to apply wood furring strips to the masonry and then nail on gypsum wallboard or gypsum lath as a base for plaster.

The use of wood furring strips has had limitations as they introduce combustible wood into the structure; and changes in temperature and humidity, especially below grade, could be the cause of cracked plaster or joint deformities and nail pops if drywall construction were used.

These problems were compounded with the introduction of rigid plastic foam insulation and as methods had to be developed for finishing over the foam insulation as well as finishing directly to the masonry.

The National Gypsum Company, as well as other building material manufacturers have been researching this problem and have developed products and systems to minimize the problem and to create sound wall surfaces ready for any type of decoration. These systems have been adequately field tested and proven under actual conditions and are now being accepted as standard construction and are acceptable under most building codes.

We would like first to cover the subject of attachment of gypsum wallboard directly to masonry. The word "masonry" as used in this article includes monolithic concrete and masonry block walls.

There are now a number of steel furring members readily available and adaptable for the application of gypsum wallboard over masonry.

The steel furring members may be positioned either vertically or horizontally. The spacing of the steel furring channels should be in accordance with American Standards Association Standard A97.1. The walls to be furred should be nominally plane so that a minimum of shimming will be required.

The first of the steel furring members recommended is the screw furring channel. This is a "hat" shaped section approximately 7/8" thick and 2¾" wide by 10' lengths. This is secured by concrete stub nails or other suitable fasteners normally through alternate flanges of the channel. The wallboard is applied with self-drilling drywall screws. There are a number of screw furring channels of various types and manufacture on the market today.

Another type is the nailable chan-

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nel which is ideal for use when power is not available on the job, thus precluding screw attachment of section approximately 7/8" thick with 1" wide face flange forming a continuous inverted "V" to tightly grip ratchet nails. It is secured to the masonry with Nail-Tite Clips which are attached to the masonry with concrete stub nails or power fasteners. The gypsum wallboard is then attached with ratchet nails of appropriate length.

In addition to the mechanical application methods, the adhesive application of gypsum board is recommended. There are a number of adhesives on the market for this use. Basically, they fall into the following three categories:

1. Joint Compound (an adhesive used for concealing joints in drywall construction).
2. Reclaimed Rubber Base Adhesive.
3. Modified Contact Adhesive.

In an adhesive application, the adhesive is generally applied to the back of the gypsum wallboard and then the gypsum wallboard is positioned against the masonry.

When the joint compound adhesive is used, it is normally applied in 3/8" wide by ½" high beads spaced 12" apart or in "daubs" 2" to 2½" in diameter and ½" thick approximately 16" apart in both directions to the back of the gypsum wallboard. After positioning, the board must be held in position until the adhesive is dry using temporary bracing. The drying period is a minimum of 24 hours under normal drying conditions.

When reclaimed rubber base adhesive is used, the adhesive is applied in a 3/8" diameter bead spaced 16" o.c. The gypsum board is positioned and temporarily braced until the adhesive is dry.

With a modified contact adhesive, a 3/8" diameter bead is applied 16" o.c. The board is positioned against the masonry and then pulled away for a minute or two to allow the solvents to flash off after which it is again firmly pressed against the masonry and impacted to firmly bond it to the masonry partition or wall. Temporary nailing or bracing is needed only to prevent it from "slipping" down the partition during drying. This can be accomplished by wedges at the floor line forcing the board tight against the ceiling or temporary nails at floor or ceiling line.

Illustration No. 1

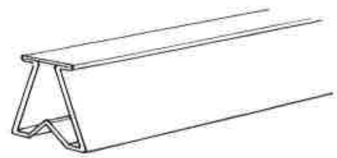

Illustration No. 2

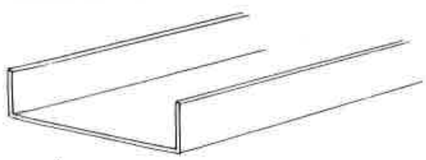

Illustration No. 3

Veneer plaster base board as a base for veneer plaster may be substituted for regular gypsum wallboard in any of these constructions. In most instances gypsum lath may also be substituted for the gypsum wallboard as a base for conventional gypsum plastering.

Cautions or Limitations

1. The attachment of gypsum wallboard to masonry is recommended for interior partitions or for above grade exterior walls where the masonry is waterproofed. Although not normally recommended, below grade on exterior walls may be used if the walls are completely waterproofed and not subject to excessive dampness.

2. The masonry surface must be monolithic concrete, aggregate block or brick and must be clean, dry, and plane.

3. When the lamination method is used, consider application of the wall board proir to applying the ceiling wallboard. This is recommended in case temporary nailing or bracing is required at the ceiling line.

4. Room temperatures of 55 to 70 degrees must be maintained in cold weather during the application of the board and until adhesive is thoroughly dry.

5. Wallboard application should be in accordance with ASA Standard A 97.1—Gypsum Wallboard Finishes.

6. Drywall screws should be type "S" bugle head self drilling 1" length.

Application of Gypsum Wallboard to Foam Applied over Masonry

There are a number of recommended methods of applying gypsum wallboard over Rigid Foam Insulation. Generally, our recommendation is for application to friable types of Rigid Foam Insulation only. Rigid foams of this type are: Isotropic Urethane, such as Gold Bond Therma-Thange or extruded polystyrenes, such as Styrofoam Expanded Bead Polystyrene, such as beadboard cannot be recommended.

The only recommended method for applying wallboard to "beadboards" is by a straight mechanical application to furring strips as follows:

Apply screw furring channels to the masonry spaced as required for the wallboard per ASA A 97.1. This method, of course, can also be used with friable types of rigid foams if desired.

The rigid foam plastic insulation is placed against the screw furring channel and attached with one screw approximately in the center of each piece of foam to hold it temporarily.

The proper thickness of gypsum wallboard is then placed over the foam with the long edges of the wallboard at right angles to the furring and screw attached with screw of sufficient length to pass through the wallboard, the foam and into the screw furring channel without touching the masonry.

The application of friable types of Rigid Foam Insulation to waterproof masonry should be in accordance with the foam manufacturer's specifications.

In general, gypsum wallboard may be laminated to the rigid foam (Polyurethane and Extruded Polystyrene) in the same manner and using the same adhesives as recommended for laminating to masonry. Certain types of modified contact adhesives may react adversely on polystyrene, so a check with the manufacturer of the polystyrene is recommended. Any of the adhesives recommended previously for attachment of gypsum board directly to masonry may be used for attachment of wallboard to polyurethane, such as Gold Bond Therma-Thane.

A very practical method of attach-

(continued)

ing not only the wallboard to the foam but also attaching the foam to the masonry can be accomplished with the use of the new Gold Bond Foam Furring Channel. In this application the Therma-Thane or Extruded Polystyrene of the desired thickness is temporarily attached to the masonry with daubs of Gold Bond Drywall Adhesive approximately 3/8" by 1" approximately every 24". The foam furring channel is then positioned either horizontally or vertically. The foam furring channel legs are pressed into the foam so that the web of the foam furring channel is flush with the surface of the foam.

The channel is now securely fastened to the masonry with concrete stub nails or power fasteners spaced not over 24" apart driven through the center of the channel. Usually a fastener penetration of ½" into the masonry is adequate. The fastener head is "dimpled" slightly below the surface of the channel.

The wallboard is then applied with the long edges at right angles to the furring channel with drywall screws in the conventional manner.

All of these methods of applying gypsum wallboard or gypsum base for veneer plaster or lath have the advantages of:

1. Eliminating combustible wood furring.
2. Speeding application.
3. Assuring a satisfactorily finished wall.

Laminated Construction with Gypsum Board Yields Multiple Benefits

By T. R. Godfrey

There is no finer way to build walls and ceiling than the application of laminated or double layers of wallboard. The most common method is the installation of two layers of gypsum board on each side of interior partitions, on joists and on the interior side of exterior walls.

Generally, the face layer in double layer construction is laminated to the base layer, using drywall adhesives or a special type wallboard joint treatment compound. On walls, no fasteners are needed in the field of the face layer board. The perimeters of the panels are nail or screw attached, and these are covered by tape or molding.

On ceilings, only one nail or screw per joist per panel is needed in the field. The minimal use of nails eliminates the possibility of nail-popping, the single most troublesome problem in drywall construction. The base or inner layer is, of course, nailed to the framing member. (See Figure 1.)

Another advantage to the double thickness is that an extremely strong wall results. The greater mass and the multi-lies of paper produces a wall that is extremely resistant to severe damage. Fire and sound resistance are both substantially increased due to the added mass.

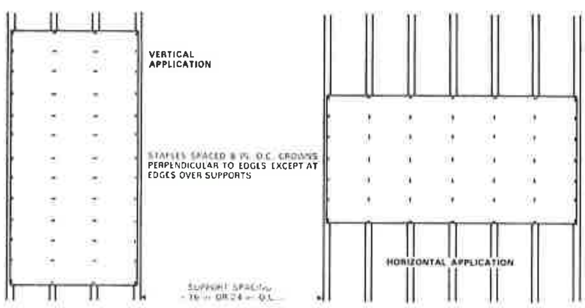

Figure 1: Staples are driven with crowns perpendicular to gypsumboard edges except where edges fall along supporting members.

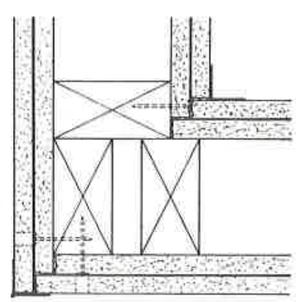

Figure 2: Floating angle construction for multiply systems has overlapping side of base ply only nailed at interior corner.

Higher priced homes and apartments throughout the South, as well as in other areas, are requiring a laminated gypsum board system because of the advantages mentioned.

Gypsum board adds strength and fire resistance to a wall when applied as a base for paneling or other finishes. The wallboard (usually a backing type board) is 3/8 inches to a half inch thick and is nailed to the framing. The finishing material can then be adhesively applied or nailed to the gypsum backer. (See Figure 2.)

An excellent method builders are using to obtain better sound ratings in quality homes is unequal thicknesses of wallboard on interior partitions. The gypsum industry produces special quarter inch thick Sound Deadening Backing Board that, combined with a face layer of a half to five-eighths of an inch thick is engineered to greatly reduce sound transmission.

Another laminated gypsum board partition finding favor with home and apartment builders is the 2 inch solid system. Construction consists of laminating a layer of half inch board to each side of a one inch gypsum core board. The resulting wall is free standing and is placed between wood or metal floor and ceiling tracks. The

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total thickness of only two inches can mean extra room in closets or rooms where walls are nonload-bearing.

When applying multiple layers of gypsum wallboard, the base layer can be erected using staples, nails or screws. Joints in the face layer should be offset from those in the base ply by at least 10 inches. Both layers of board may be applied either horizontally or vertically. For best finished results the face layer should be adhesive applied, thus eliminating most fasteners. However, nails or screws are frequently used on the face layer. Staples are to be used only on the base layer. (See chart for fastener spacings.)

BASE-PLY FASTENER SPACING ON WOOD FRAMING[1]

	NAIL SPACING		SCREW SPACING		STAPLE SPACING	
Location	Laminated Face Ply	Nailed Face Ply	Laminated Face Ply[2]	Screwed Face Ply	Laminated Face Ply	Nailed or Screwed Face Ply
Walls	8 in. o.c.	16 in. o.c.	16 in. o.c.	24 in. o.c.	7 in. o.c.	16 in. o.c.
Ceilings	7 in. o.c.	16 in. o.c.	16 in. o.c.	24 in. o.c.	7 in. o.c.	16 in. o.c.

[1] Fastener size and spacing for applying sound deadening boards vary for different fire and sound-rated constructions. The manufacturer's recommendations should be followed.
[2] 12 in. o.c. for both ceilings and walls when supports are spaced 24 in. o.c.

The Fire Resistance of Gypsum . . .

Although fire is one of mankind's most faithful servants, it becomes a dreaded menace when uncontrolled. As a safeguard, early Roman rulers prescribed death to a builder who failed to provide fireproof surfaces for walls and ceilings. In spite of this, Rome burned.

Our modern cities of today require by law a degree of fire protection, but in spite of these provisions about 10,000 people die annually, and about $500 million of real property is lost each year as a result of fires in the United States. Yet, only when a catastrophe occurs which takes many lives do we realize and evaluate the importance of fire protection—then it's too late.

Great strides have been made against this demon menace, particularly with respect to the strategic use of fire-resistant materials in building construction. Millions of dollars have been spent in fire protection research to provide techniques by which fire safety can be built into structures by the proper use of fire-resistant materials.

The term fire-resistant, by definition, means resistance to burning or supporting combustion. But the exclusive use of fire-resistant materials in buildings does not necessarily imply that they are fire safe or have sufficient fire-resistive qualities. For example, metals that are used structurally to carry loads are generally fireproof because they will not burn, but when subjected to intense heat they lose strength, fail to carry the intended load, and collapse. Similarly, wood used in building construction, when subjected to sufficient heat, will ignite even though not in direct contact with fire and cause a collapse.

So these structural elements require protection against fire, and the technique of the fire protection engineer is to interpose a material that is not only fire-proof but one which will prevent the rapid transfer of heat so that the structural members will not be endangered for a certain period of time. It should be noted that relatively few fire-resistant materials possess the insulating qualities necessary to restrain rapid and excessive heat flow. Gypsum is one of these rare materials, for not only is it fire-resistant, but it possesses a phenomenal characteristic that literally repels fire by virtue of the fact that it provides its own "sprinkler system." Gypsum is a rock, a mineral of unusual composition. Although hard and stone-like, it is capable of releasing water to the extent of about half its volume. It is known as hydrous calcium sulphate, and although the water is not in liquid form, it is ever present and ready to be released when attacked by fire. This is the composition of the gypsum used in fire-protective walls and ceilings.

This crystaline mass of gypsum may be likened to a solid block of ice. If the intense heat from a blowtorch is played on one face of the block the ice melts. Yet, one may safely hold his hand on the opposite side of the block, because the temperature there will remain at 32° F. until the heat from the torch has melted all the way through the ice. Even though the ice thickness is only ¼ in., it will not transmit the intense heat until completely melted.

Similarly, the water in crystaline gypsum dissipates the intense heat of fire. As the surface is heated to 212° F., the boiling point of water, the crystaline water "melts out" from the gypsum and quickly becomes steam which repels the fire and dissipates the heat. With continued application of the intense heat, more water of crystalization is released, but the process is slow and requires intense heat. As water leaves the gypsum mass, a white chalky material remains on the surface to further insulate against the flame. After about 15 minutes of exposure to intense heat of fire, the crystallized

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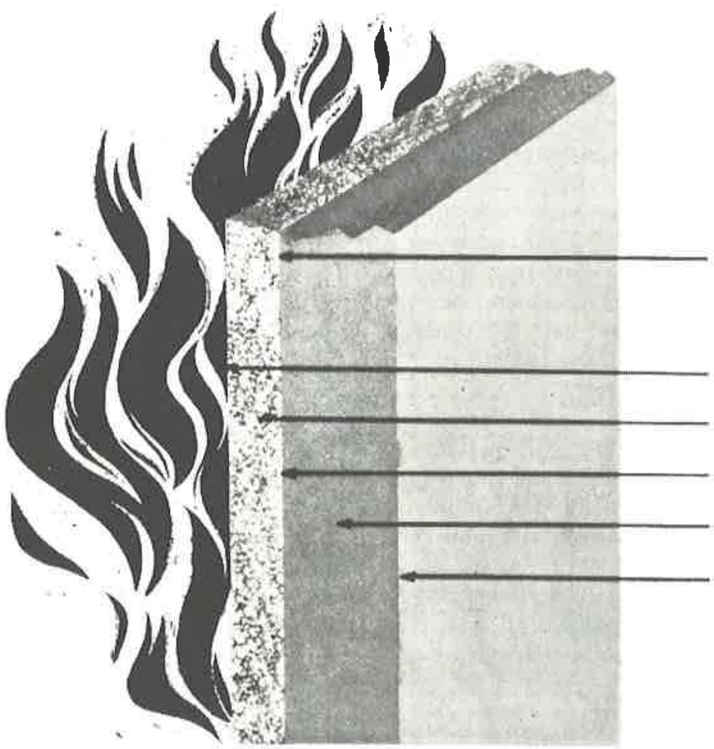
water will be released to a depth of approximately ¼ in. Following the phenomenon described for melting ice, the temperature immediately behind the ¼ in. depth cannot greatly exceed 212° F., because the combined water in the gypsum would boil at that temperature. After 30 minutes of fire exposure, the water in the gypsum will be released to a depth of about ½ in. Similarly, the temperature at a depth of 5/8 in. will not, theoretically, exceed 212° F. This process of calcination is extremely slow.

Consider the protection that this phenomenon provides for wood and steel used in building construction. It is significant that wood will ignite and burn at temperatures of about 350°-450° F. Steel begins to lose its strength at about 850° F. When we consider that many fires are of sufficient intensity to melt glass, plumbing fixtures, faucets and so forth, we must realize the great necessity for protecting wood and steel framing members against this extreme heat. Gypsum protects these vital load-carrying elements against temperatures greatly exceeding 212° F. until all water contained in the gypsum, about half its total volume, has been driven off.

Fire protection engineers, through long experience and research, are able to predict the fire intensity to be expected in buildings of a given type and occupancy. As a result, they have established standards for fire resistance for such buildings which assure reasonable safety to the occupants and adequate protection for the structural integrity of the building. They know that a one-hour fire-resistive partition will not pass flame or smoke or permit excessive heat transfer for one hour. Based upon these facts, building codes require specific fire-resistive values for building construction depending entirely upon the anticipated hazards.

For these reasons, gypsum in its many forms has been widely tested for its fire protective values to provide the varying degrees of fire-resistive ratings as required by building codes. Most of these fire-resistive ratings for assemblies using gypsum products are listed by the National Bureau of Standards and the National Board of Fire Underwriters. The results so published are generally used by building code administrators to determine compliance with standards of fire protection as required by their building codes.



How Gypsum Retards Heat Transmission

TWO-HOUR EXPOSURE

Vertical line represents plane of calcination at depth of about 2″. Temperature never greatly exceeds 212°F. behind plane of calcination.

Temperature of exposed surface = 1900°F.

Temperature 1″ from exposed face = 950°F.

Temperature 2″ from exposed face = 220°F.

Temperature 4″ from exposed face = 180°F.

Temperature at back surface = 130°F.

(Data from Underwriters' Laboratories, Inc.)

A Logical Approach to Fire Control in High Rise Buildings

By J. D. Shull

Since evacuation and fire extinguishing present considerably greater problems in high-rise buildings than in those less than about 75 feet high, numerous articles have been written about various aspects of high-rise fires. This is an attempt to consolidate the major problems involved, and to suggest logical solutions for each problem, since, unfortunately, we will never completely eliminate fires in high-rise buildings (or any other buildings).

In the vast majority of cases, fires are caused by people careless in disposal of combustibles or hot objects; careless in maintenance of electrical equipment; arsonists, etc. Regardless of the method of ignition, people are the primary cause, and there is no way we will ever keep people from starting fires.

Since we cannot prevent fires from starting, what can be done to minimize loss of life and property in high-rise buildings?

After having read much of what has been written on the subject, it appears that there are five major areas of concern when a fire breaks out in a tall building. Listed in chronological order during a fire, these are: (1) detection, (2) containment, (3) evacuation, (4) access by fire fighters and (5) extinguishment. Even though all five areas of concern are tied together, we will cover each separately and propose solutions for each.

Detection

A number of detection devices are readily available on the market that are automatically activated by heat, smoke or other products of combustion. Placement of these devices is extremely important for early detection of fire. It is suggested that location of detectors be determined in conjunction with local fire experts (fire protection engineers, the local fire chief, the state fire marshall or an insurance expert). The building design, particularly vent and partition layout, are of utmost importance when locating detectors.

Another important factor to be taken into consideration is location of alarms. Again, we must consider the "people problem." Panic is very easily created, particularly in high density personnel areas (such as offices). It is, therefore, suggested that alarms be sounded (1) only in the immediate area of the fire, (2) at a monitored central building location on the first floor or basement (to be discussed later) and (3) at the nearest fire station.

Detecting devices must be maintained at a high level of efficiency. Many of them are "fail safe" in that they become more sensitive with time. However, this could then become a "cry wolf" situation if a number of false alarms are forthcoming. It is, therefore, suggested that detection devices be maintained and inspected by the fire department or insurance inspector regularly, the same as fire extinguishers found in industrial establishments.

Containment

Containment is normally thought of as containment of fire. ASTM Test Method E119 provides criteria for the containment of fire only. However, more people are killed from inhalation of smoke and the products of combustion in fires than from the flames themselves. Therefore, discussion of containment of smoke and the products of combustion is necessary alongside discussion of containment of fire.

Fire spreads by burning through partitions or ceilings and doors; through ducts; by breaking windows and spreading on the outside of buildings, and by burning through suspended ceilings and spreading through plenums where partitions do not go slab to slab. However, products of combustion can also spread around partition and door perimeters and can become much more wide-spread by passage through air ducts and plenums.

Ideally, fires could be confined in small compartments with rated slab to slab partitions, floor-ceiling systems and doors. Each compartment could have a separate duct system with fire dampers and each exterior wall could be fire rated with no windows. However, this utopian design is about as practical as expecting teenagers to always hang up their clothes.

A practical solution may be to design for fire load (combustibles per square foot or floor area). Agreed, it is not always known what the fire load will be on a given floor of a given building, but the intended type of occupancy is usually known. It is also known, within limits, what the anticipated fire load might be for a given type of occupancy. Therefore, fire load can be reasonably well defined before the building design is finalized.

By designing compartment size based on fire load, partition, ceiling and door fire ratings could be varied depending on the amount of anticipated combustibles. As a sidelight to this thought, for architects and owners, sound ratings could be varied at the same time to accommodate different occupancies. Also, by caulking for sound barrier, products of combustion would be contained to a much greater degree.

Evacuation

As stated, people usually panic when a fire alarm sounds. Therefore, it is desirable for only those people in the immediate area of the fire to be advised at once. Assuming the wall and ceiling surface is such that the flames will not spread rapidly, time is available to evacuate the remainder of the fire floor and adjacent floors.

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It is suggested that this be done by a calm voice over a public address system with instructions for evacuation. As mentioned previously, the alarm should sound at a central monitor, such as a central telephone switchboard or a lobby guard station. The message would then be relayed to the affected area.

Fire stairs should be available at widely separated points to prevent all escape routes from being blocked. Stairs should also be separated from elevators. Sufficient area should be available on stair landings to accommodate a large percentage of people on the floor. Fire doors should be gasketted to prevent smoke from entering and should have automatic doors. Positive pressure should also be provided in stairways to minimize smoke.

It is also suggested that the fire stairs always be used to evacuate people, leaving the elevators for the fire fighters.

Access by Fire Fighters

Fire fighters must have rapid access to the fire. As soon as the alarm is sounded, the lobby of the building should be cleared as much as possible. The most rapid access to fire on the upper floors is by elevator. Therefore, elevators must remain operable and not be deactivated by heat sensitive devices or by smoke that breaks the electronic light sensor.

Emergency power sources should also be provided. The exit from elevators must also be protected from the fire and products of combustion with fire walls and gasketted fire doors. This will enable the fire fighters to exit the elevator and bring equipment into play before they are in direct contact with the fire.

Since fire fighting equipment is difficult to transport in high-rise buildings, it should be available throughout the building. It is suggested that fire fighting equipment rooms be established and that they be maintained and inspected by the local fire department.

Stand pipes for hose connections should be available at strategic locations on each floor. These stand pipes should be located such that it will not be necessary for hoses to go through fire door openings. Thus, they should be located in corridors, not in stair wells or elevator enclosures.

Extinguishment

The faster a fire is extinguished, the fewer problems will be encountered with the other areas of concern. Therefore, automatic sprinkler systems should be provided. Here again, design should be based on fire load and occupancy and the system maintained by qualified experts. It is also suggested that the systems be designed such that they cannot be shut off or tampered with by arsonists.

Most fires are small when they start and, consequently, could be extinguished by a layman. However, most inexperienced people will not use a high pressure fire hose as provided in most buildings. Therefore, it is suggested that the high pressure hose be stored in the fire fighting equipment room for use on the stand pipes.

Small garden type hose with spray nozzles should be provided at strategic locations for use by laymen. These hoses could be connected to regular water lines with relatively low pressure and could be used to extinguish many fires before they become catastrophes.

Summary

It is impossible to prevent fires from starting. With this premise, the most effective way to control fires in high-rise buildings is by a combination of all the factors mentioned rather than any single method. No area can be sacrificed in favor of another to minimize destruction of property or, more important, loss of life.

There are many aspects of high-rise fires that are not covered here (dissipation of smoke and heat, control of combustibles, etc., etc.). No generalization can be made as to the best answer for any phase of fire prevention and control. Design must be on an individual building basis, since each building has its own unique set of circumstances where fire control is concerned. It is, therefore, the purpose of this article not to answer all the questions, but to promote objective thinking by those involved with building design, construction and control of fires.

Structural Membrane Protection with Gypsum Wallboard

By J. J. Gafford

For many years now the use of gypsum as a fire protection medium has been well known and accepted in Building Code and insurance circles. Walls and partitions as well as ceilings have long been protected by gypsum wallboard. Fire protection of columns and beams on the other hand, has often been accomplished with either plaster or concrete.

This use of plaster or concrete in a building to protect columns and beams, when the bulk of the job is being done with gypsum wallboard, tends to complicate the job. In many cases it necessitates a second trade being brought into the picture and further, in the case of concrete, it adds tremendously to the over-all weight.

On the other hand most building codes and insurance regulating agencies permit the use of "membrane" fireproofing of ceilings. Use of this technique as opposed to the ceiling plus independent beam protection, can offer substantial weight savings. According to the American Insurance Association and most building codes this continuous ceiling protection or ceiling membrane method may include protection of structural members as well, provided the ceiling rating is the same as that required for the structural members. They will also allow the ceiling membrane to be furred down under structural members provided the

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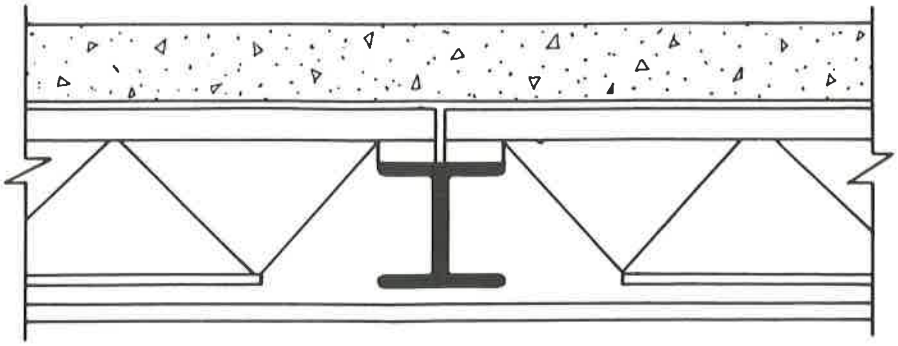

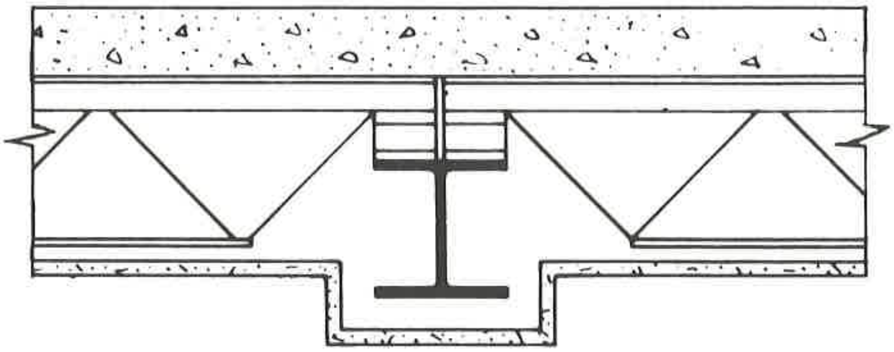

required drop does not exceed 6 inches. If the drop is more than 6 inches, it is recommended that the gypsum lath and plaster protective membrane extend from the ceiling to the floor above.

Below are two examples of membrane fireproofing, each protecting steel beams. The second sketch depicts the ceiling furred down and around the structural member.

Underwriters' Laboratories, Incorporated have tested several systems (for example, UL Designs 254-2 and 255-2) utilizing gypsum wallboard exclusively to protect beams. Beams and bar joists were also successfully tested (for example, UL Designs 94-2 and 82-3). All utilized the ceiling membrane technique. In using this technique care should be taken to see that no combustibles are present in the plenum space.

The encasement of columns is a simple enough task with gypsum wallboard. The fire ratings available range from 1 to 4 hours. In the more sophisticated 2, 3 and 4 hour areas, Underwriters' Laboratories, Inc. have tested a number of systems including the following:

2 hour protection
UL Designs 10-2, 5-2, and 8-2
(all with columns of 10 WF 49) and
20-2 (heavy column 14 WF 228)

3 hour protection
UL Designs 14-3 and 20-3
(Tested with 10 WF 49 columns) and 39-3 (heavy column 14 WF 228)

4 hour protection
UL Designs 26-4 and 34-4
(Tested with 10 WF 49 columns)

These tests prove that fire protection with gypsum wallboard is effective for the whole job; columns and beams as well as walls, partitions and ceilings.

Gypsum Association Program to Evaluate the Combination of Gypsum Wallboard and Prefinished Paneling

By C. W. Lehnert

Gypsum wallboard and prefinished plywood paneling are well known wall surfacing materials. Their economy and versatility enables them to be specified for a broad range of structural and aesthetic requirements in both residential and commercial construction. Occasionally gypsum wallboard and plywood paneling are used in combination with the gypsum wallboard as the inner or base layer and the plywood paneling as the outer of face layer. There are advantages to be gained by using these products in combination, but there has never been data published to confirm these advantages. The Gypsum Association recently embarked on a test program to compare the performance of the combination of gypsum board and plywood paneling over wood stud framing to the same construction with only the plywood paneling. Tests were made to evaluate sound transmission, structural integrity, and fire resistance. The three basic panels tested were:

Panel #1—Wood stud framing faced with one layer of ¼" prefinished birch plywood on each side.

Panel #2—Wood stud framing faced with one layer of 3/8" gypsum backer board and one layer of ¼" prefinished birch plywood on each side.

Panel #3—Wood stud framing faced with one layer of ½" gypsum backer board and one layer of ¼" prefinished birch plywood on each side.

The framing consisted of 2 x 4 wood studs 16" o.c. In panel #1 the plywood paneling was vertically applied to both sides. It was attached with ribbons of mastic adhesive on

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each stud and with 3d finish nails 12" o.c. around the perimeter and two nails in the center of the panel. In panel #2 and #3 the 3/8" and ½" gypsum board were vertically applied using 4d and 5d nails respectively 16" o.c. The plywood paneling was then applied over the gypsum board with joints staggered. Ribbons of mastic adhesive were spaced 16" o.c. vertically between the two layers. Finish nails (4d for panel #2 and 5d for panel #3) were used 12" o.c. around the perimeter with two at the mid point of each panel. The only variation in construction for the tests was the size of the specimens tested.

Each test was conducted by a member company of the Gypsum Association and certified by an independent testing laboratory. A summary of the results are as follows:

Construction	Panel #1 ¼" birch paneling	Panel #2 ¼" birch paneling and ⅜" gypsum board	Panel #3 ¼" birch paneling and ½" gypsum board
Sound Transmission			
ASTM E-90-66T	28 STC	40 STC	40 STC
ASTM E-90-61T*	28 STC	39 STC	39 STC
Resistance to Racking (Avg. load to failure)	2,156 lbs.	4,544 lbs.	5,723 lbs.
Resistance to Impact (Avg. height of the drop at failure)	26"	82"	82"
Resistance to Fire (Time required to burn through the exposed surface)	8¼ minutes	42 minutes	73+ minutes

* For comparison with tests using the older ASTM standard.

Details of the individual tests were:

Sound Transmission

The sound transmission tests were conducted in accordance with ASTM E-90-66T. A 14' wide by 9' high partition with a single bottom plate, double top plate, and 2 x 4 fire blocking at mid height was tested.

Resistance to Impact

The impact tests were conducted in accordance with ASTM E-72-68. Four foot by eight foot partition specimens were constructed using two interim 2 x 4 studs, two exterior 1 x 4 studs, and a single top and bottom plate. This test essentially consists of dropping a sand bag weighing 60 lbs. through a known height and onto the center of the specimen. The resulting deflection and set were measured and failure was judged to have occurred when the damage was nonrepairable.

Resistance to Racking

The racking tests were also conducted by the method in ASTM E-72-68. Eight foot by eight foot partition specimens were tested with a double top plate, single bottom plate, and double separated corner posts as indicated in the method. The test basically consists of the bottom held immovable while a horizontal load is applied at a point diagonally opposite the immovable corner. The force was applied and deflection measurements were taken at 200 lb. increments through the first 3,000 lbs. Measurements were taken at 500 lb. increments thereafter.

Fire Resistance

The specimen size for the fire resistance tests was 39½" x 63". This was the size of the furnace opening. The specimens were exposed to the time/temperature curve specified in ASTM E-119. Thermocouples were placed inside the furance on the unexposed face of the studs at mid height, in the stud cavity, and on the unexposed surface. Failure was determined when the fire broke through the unexposed surface.

Safety and Silence

These tests results dramatically show the added fire protection that gypsum wallboard underlayment will give. Equally dramatic is the gypsum wallboard ability to provide increased sound control, which will be greatly appreciated by those in adjoining rooms. And last but not least is the substantial increase in strength that will be achieved with the addition of gypsum wallboard as a substrate. This increased strength means a sounder, safer and longer lasting wall.

Should Building Codes Regulate Sound Control?

In designing and constructing buildings, whether they be industrial, commercial or residential types, the efforts of architects, designers, contractors, material suppliers, and building code authorities are pointed in the direction of creating a structure with a controlled environment for the occupants.

In developing this controlled environment, several major functions are provided for as follows:

1. Shelter—provides protection

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from the elements.
2. Structural adequacy.
3. Fire resistance.
4. Healthfulness.
   a. Heating
   b. Cooling
   c. Lighting
   d. Ventilation
   e. Privacy from noise
5. Space—functional requirements.
6. Esthetics.

In past years, considerable evolution has occurred in providing all of the above functions in modern construction with the exception of privacy from noise. Five years ago if we had asked the question, "Should building codes regulate sound control?" the answer would have been, "Of course not." Since that time, efforts to reduce building costs and to use thinner, lighter weight materials, coupled with the advent of more noise making equipment such as air conditioning, electrical and mechanical equipment, TV, Hi-Fi, and stereo, have resulted in buildings which are noisy, contributing to the discomfort of tenants. Since this problem has become more pronounced, the public, architects, building and code officials are now concerned with the control of noise, and the use of noise suppression systems are becoming more and more important in designing and constructing buildings. In addition, as a result of law suits, high vacancies in substandard buildings, and quick obsolescence of some rental properties, a general ground swell is occurring in support of regulations for sound control. The medical profession is showing mounting concern for excessive noise and its effect on the health and well being of individuals. Lending agencies such as large insurance companies, insuring agencies such as the Federal Housing Administration, building officials in several of our smaller cities and of our largest city, New York, have already adopted or are in the process of adopting sound control regulations.

Today, instead of asking the question, *"Should* building codes regulate sound control?" it might be more timely to ask, *"How* can building codes regulate sound control?"

In order to answer this question, we should examine the structure of our building codes and what is required in order to include regulations in a new area such as sound control.

1. The scope and purpose of most building codes is to secure the beneficial interests of the public, which are safety, health and general welfare through structural strength, stability, sanitation, adequate lighting and ventilation, and the protection of life and property from fire and other hazards. From the beginning, the primary motivation of building codes has been concern for the safety of life from fire and structural hazards. In recent years, additional safeguards regulating thermal control, sanitation, light and ventilation, obsolescence, and the general welfare of the public have been introduced. Today, regulations for sound control are a logical extension of this concern for public well being. We already have laws and regulations needed to protect the public from excessive street noises, industrial noises, and the like.

2. A basic requirement for inclusion in any regulation is a standard method of testing or evaluation such as has been provided for fire, structural, electrical, etc. In the field of

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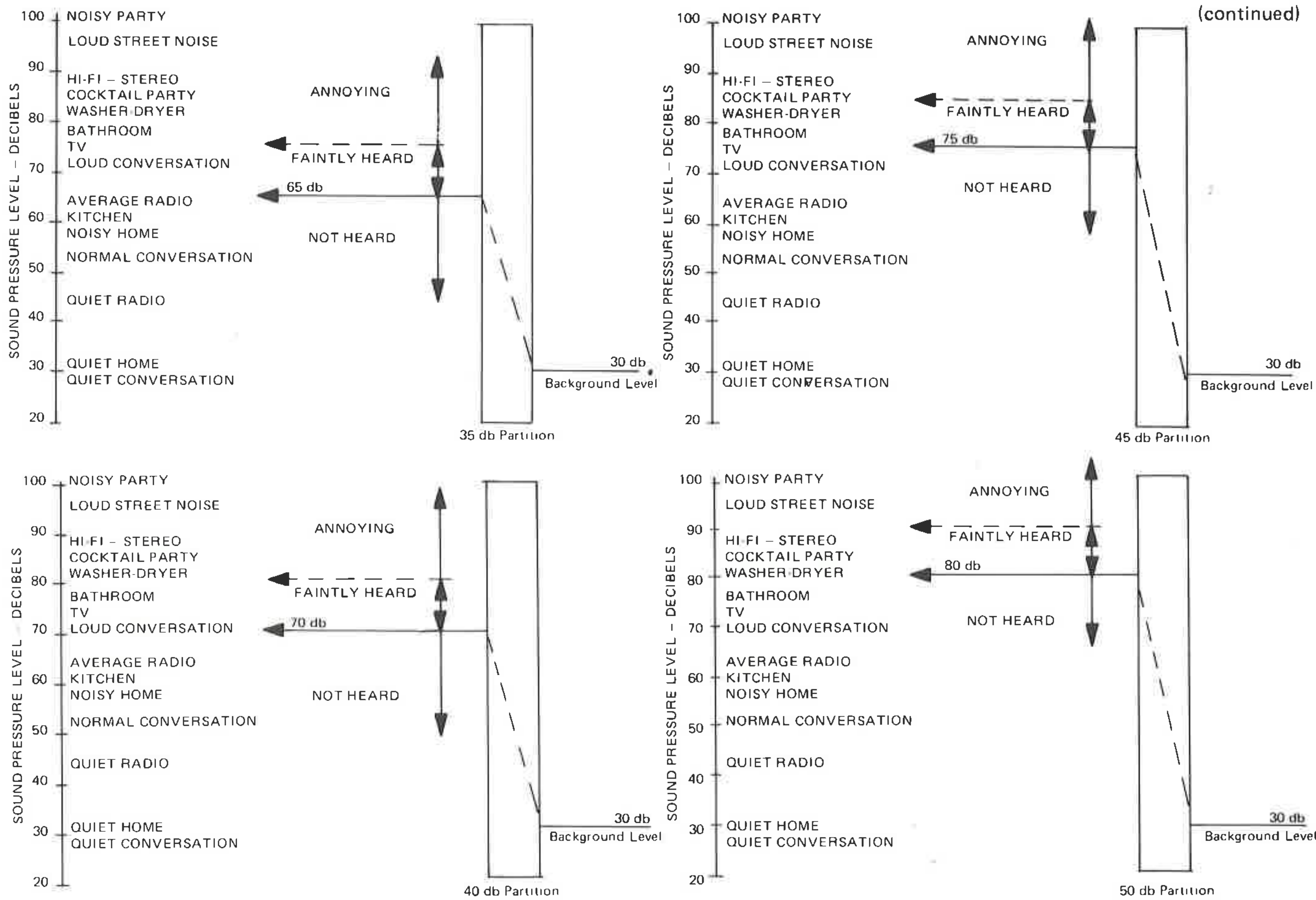
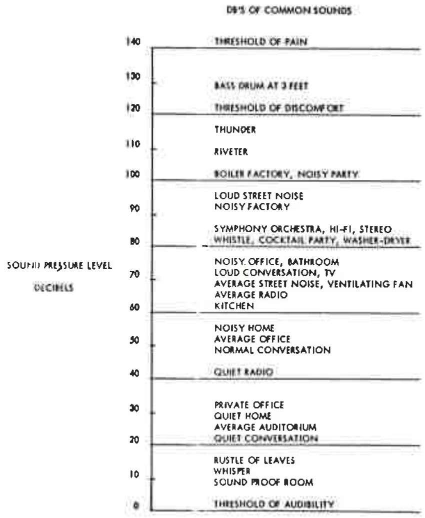
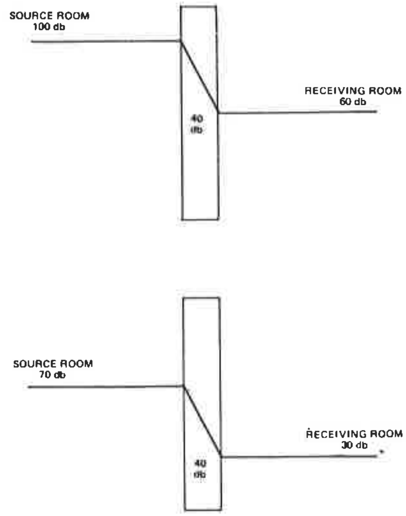


COMMON SOUNDS HEARD THROUGH VARIOUS PARTITIONS





SOUND TRANSMISSION LOSS OF PARTITION IS INDEPENDENT OF SOURCE ROOM SOUND PRESSURE LEVEL

sound control where we are particularly interested in the transmission of noise from one room to another through the walls, floors or ceilings in this area, there already have been established standard test methods. At present there are the ASTM Tentative Method of Testing E 90-61 T, "Tentative Recommended Practice for Laboratory Measurement of Airborne Sound Transmission Loss of Building Floors and Walls"; Acoustical Materials Association, "Tentative Methods Test AMA-I-II" covering the Airborne Sound Transmission Loss of Walls; and the International Organization for Standardization, "Field and Laboratory Measurements of Airborne Impact Sound Transmission," ISO Recommendation R 140-1960 (E). Considerable testing has been done in recent years according to these test methods and they could serve as the basis for regulation purposes.

3. Another requirement is that a standard method be established for reporting data that allows consistent comparison and setting of limits. In the field of sound control, the ASTM 90-61 T Standard spells out the Sound Transmission Class as a method of reporting airborne sound transmission loss data. This Sound Transmission Class system of rating data is being used almost universally in this country by all parties concerned in reporting their data. A limited amount of data is available on impact testing.

4. Normally, Code authorities require that acceptable, independent testing or evaluating agencies be available for obtaining appropriate test information. Here again there are several independent laboratories equipped to conduct tests according to the above testing standards.

There will be skeptics and purists and others who will argue that the "state of the art" is too young to be used in establishing regulations. This same argument has been used over and over again in all fields of testing and evaluation in the past. For example, fire resistive testing has been going through a constant evolution for many years and changes are still being made, while fire resistive regulations have been incorporated in building codes for many, many years.

In essence, the sum and substance of any building code is that, at any one time, it is a consensus of the latest available information and evaluation of a particular subject, and it is generally understood by all concerned that constant revision, updating and upgrading are necessary as the progress of the building industry continues.

Assuming at this point that sound control regulation is possible and desirable, what can the building official do in establishing sound control regulation?

1. *Preparedness*

In the past few years a considerable volume of excellent literature on sound control has been provided by building materials manufacturers, trade associations and others. In addition, several text books are available for reference and study. Tours and visits to a sound control laboratory can be arranged through manufacturers, testing agencies and educational institutions to witness actual tests in progress.

Training meetings conducted by the local building official groups at monthly meetings and with department personnel are important. Many manufacturers, associations, consultants and others have trained personnel available to assist in planning and conducting such meetings. From time to time, special training schools are held in certain parts of the country and key personnel could attend them.

The building of a library on sound control can easily be done since most of the literature on sound control is available at no charge or at a nominal cost.

2. *Formulating the Regulations*

Existing regulations such as those of the Federal Housing Administration, insurance companies, the New York City code proposal and European codes are available for review. Recognized authorities could be enlisted to prepare proper regulations.

Performance type requirements for the basic construction are feasible with present information. Additional requirements can be spelled out covering the use of plumbing, wiring, caulking, windows, doors, etc., as they affect the performance of the construction. Care should be taken in establishing requirements that are compatible with existing fire and structural requirements.

3. *Enforcement*

Enforcement of sound control regulations could begin with a check of all plans submitted to building department personnel such as is now done with structural, fire, electrical, etc. Compliance can be determined by a comparison of submitted data with established standards. In addition, laboratory test reports on the construction can be requested. In other cases, consulting various reference materials may be sufficient. Field inspection similar to that for structural, electrical and plumbing may be desirable.

The effect of establishing minimum standards and regulations, while not the ultimate, would certainly upgrade to a considerable degree the amount of privacy from noise that could be expected in multi-tenant structures built with no regulations at all.

If an enlightened, minimum standard regulation is established, it is logical to assume that the entire building industry will respond favorably as it has previously to other areas of regulation. In the past several years, millions of dollars have been spent by manufacturers, trade associations, testing laboratories and others to develop reliable and up-to-date test methods and test data on sound control; more will be spent for this purpose in the future. All of the resulting information is and will be available to the interested building official.

Finally, today one can say yes to the question, "Should building codes regulate sound control?" To the second question, "How can building codes regulate sound control?" it is clear that sufficient information is available to provide a good start and, as with everything new, considerable education, effort and time will be required to do the job properly.

New Gypsum "Sound" Ideas lead attack on Noise Pollution

Today's homebuyer or office tenant, already battling encroachment of spaghetti freeways and smog, now is focusing new attention on another problem—"noise pollution."

This is the word from Georgia-Pacific, one of the nation's major building material manufacturers and a leader in noise control studies. It reports that builders and their customers are beginning to rate noise as one of today's most threatening environmental banes.

Indoors the increase in electrical equipment, from air conditioning to disposers and other appliances has left few quiet niches for quiet concentration or relaxing.

Outside, the ever-mushrooming numbers of automobiles, jets, garbage trucks and power mowers have left few urban or suburban neighborhoods in peace and quiet.

Where Americans once accepted noises for the efficiency and comfort they represented, homeowners are no longer willing to tolerate them.

"Neither are we," reports O. E. Burch, G-P's gypsum technical services director.

"Noise abatement is of prime importance in our gypsum research and in our service to builders and architects. Accordingly, several exciting concepts in gypsum sound control materials and systems have been introduced in recent months. They can satisfactorily control sound without adding appreciably to construction cost," Burch explains.

One such sound control innovation is ¼ inch Incombustible Gypsum sound deadening board developed by G-P to help assure "quiet living" with effective fire control in virtually all types of construction.

Tests conducted at Underwriters' Laboratories and Ohio State University have shown the new Incombustible Gypsum sound deadening beard, with a standard face layer of G-P's ½ inch Type "XXX" Firestop gypsum wallboard, on metal or wood studs provides a one-hour fire rating and a Sound Transmission Class range from 45 to 54 in various assemblies.

The new board has a strong, glass-fiber-reinforced gypsum core and a specially absorbent face paper. It is made in easy-to-install 4 x 8 foot panels.

A major Incombustible sound deadening board case history is the 14-story Three Rivers apartment development nearing completion in Fort Wayne, Ind.

According to Burch, G-P gypsum division engineers worked with architects and contractors in developing a highly effective sound/fire barrier system that includes party wall construction of G-P ½ inch Firestop over the new economical and lightweight sound deadening board on metal studs. Tenants now moving into the first completed units already have complimented owners on the lack of disturbing noise, Burch adds.

Another current noise abatement system combining beauty, sound and fire control into one wall, hardwood plywood wall paneling was used over gypsum wallboard as part of the decorating program that also helped sell apartments.

This case history is Mansion House Center, an inspiring complex of three 28-story apartment towers with other low-rise buildings in St. Louis. It not only is a pace-setting case of imaginative use of both decorative and sound and fire control materials, but also points to a noise pollution control design that has captured interest of builders and architects nationally.

Mansion House wall systems, developed with the cooperation of G-P gypsum division technicians, include top and bottom gaskets for "floating" walls, staggered studs, insulation in stud pockets of party walls, staggered and insulated wall outlets to prevent transmission leaks through walls, and soundproofing of household equipment.

The walls alone have S.T.C. ratings from 50 to 55, Burch reports.

In the sound conditioning area should be included also the excellent fire and sound control properties of lath and plaster, he adds.

G-P markets large quantities of this material in improved forms such as timesaving Denscote veneer plaster, to contractors for use in schools, residential and commercial structures.

An intriguing current lath and plaster example is Point East, a $20 million-plus condominium community near Miami, Fla. It is described by

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industry experts as one of the largest condominium developments ever built with pinhole-perforated lath and plaster construction, utilizing some 5 million feet of G-P lath and 300,000 bags of G-P base plaster.

"Noise abatement is just as important as fire control in our research and in our service to architects and builders. To meet this end, Georgia-Pacific has just completed a new gypsum research and development laboratory near Portland, Ore. Two buildings house applied and basic research operations for fire and sound control development as well as R & D on new and improved gypsum products including board, plaster and joint systems," he concluded.

Laboratory Results vs. Field Program

By James R. Dowling

Acoustical privacy is fast becoming a major factor in tenant satisfaction in both apartment and office buildings. One of the major problems facing the construction industry today is to achieve a sound transmission loss duplication in the field equal to or even approaching the rating established by laboratory tests. As an example, a partition capable of 55 STC as determined by laboratory test will only achieve approximately 41 STC when normally built in the field. This is a drop of 14 db.

Why would this occur? Need it happen?

To answer these questions one must understand what occurs in "normal construction," how partitions are tested in the laboratory, and the detailing and construction adherence required on the project to avoid such a discrepancy. It can, however, be emphatically stated that it need not happen.

By normal construction we mean the usual job site practices and the typical architectural detailing so common today. A partition capable of 55 STC performances as tested in a laboratory will give a 50 STC performance in the field only if and when the construction and detailing for the actual construction is comparable to the assembly tested in the laboratory.

GARDEN TYPE APARTMENT CONSTRUCTION

Construction	STC comparison	
2" x 4" wood studs, 16" O.C., resilient channel one side, 3" insulation, single 5/8" wallboard on each side	Laboratory	50 to 54
	Select	45 to 49
	Normal	35 to 39
Staggered 2" x 3" wood studs on double plates, 2" insulation between stud in one row, single 5/8" on "out" sides	Laboratory	50 to 54
	Select	45 to 49
	Normal	35 to 39
Staggered 2" x 3" wood studs on double plates, 1/2" sound deadening board base; 5/8" both sides	Laboratory	50 to 54
	Select	45 to 49
	Normal	35 to 39

HIGH-RISE APARTMENT CONSTRUCTION

Construction	STC comparison	
1/2" wallboard, 1" coreboard, each side, 1 1/2" sound attenuation blanket in 3" cavity between coreboards	Laboratory	60
	Select	55 to 59
	Normal	45 to 49
3 5/8" metal studs—24" O.C. 5/8" wallboard, double layer 1 1/2" sound attenuation blanket, double 5/8" on each side	Laboratory	50 to 54
	Select	45 to 49
	Normal	40 to 44
2 1/2" metal studs, 1 1/2" blanket, sound attenuation blanket, double layer 1/2" each side	Laboratory	50 to 55
	Select	45 to 55
	Normal	40 to 44
2 1/2" metal studs, 1 1/2" blanket single layer 1/2" wallboard, one side; double layer other side	Laboratory	50 to 54
	Select	45 to 49
	Normal	40 to 44
2 1/2" metal studs, 2" sound blanket, double 5/8" plaster base, 1/8" veneer plaster finish both sides	Laboratory	50 to 54
	Select	45 to 49
	Normal	40 to 44
4" gypsum tile, 5/8" plaster one side, resilient clips, 3/8" plaster base and 1/2" plaster other side	Laboratory	50 to 54
	Select	45 to 49
	Normal	35 to 39
2 1/2" stud, plaster, resilient clips one side; 1 1/2" blanket	Laboratory	50 to 54
	Select	45 to 49
	Normal	35 to 39
Veneer plaster base over 1" coreboard, 2" sound attenuation blanket	Laboratory	50 to 54
	Select	45 to 49
	Normal	40 to 44

Modern acoustical laboratories have openings in the partition between the source room and the receiving room to accept wall panels at least 8' x 12' and up to 9' x 14'. In addition, the facility is so constructed that this opening constitutes the only important sound transmission path between the source room and the receiving room.

Thus the sound transmission class obtained on any partition construction tested fairly well represents the true capability of the construction and what might be expected in a field installation—provided it is installed on the job in exactly the same manner.

But the building structure in which the partition is being installed is not the same as the laboratory. It has flanking paths through the floor and ceiling, around the partition ends or through outlets built into the partition that are not the equal of those in the laboratory.

Other articles in this magazine discuss these flanking paths and how they should be treated.

When all factors are considered and

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treated, a close correlation will be found between the laboratory and a field test.

Several years ago USG retained an acoustical consultant and embarked on a two to three year field testing program to establish the relationship between laboratory data and performance in the field.

Because architects and builders both depend upon quoted STC ratings it is desirable that the subcontractor be able to translate these results into predictable field performance results. Our research on this program has proven that a partition can be built in three different ways on the job site. Each erection procedure produces a different acoustical value. These three methods are:

1. **NORMAL**

Both the building structure and the partitions between units are designed and built without any consideration for acoustical performance.

2. **SELECT**

The structure is again designed and built with no consideration for acoustical performance but the partitions are selected and built according to good acoustical details used in the laboratory test panel.

3. **PREDESIGN**

The building structure is designed and constructed with special acoustical attention to prevent structural flanking paths for sound and the partition designed and built with acoustical details used previously in the laboratory. This condition comes the closest to the laboratory results. The predesign concept requires that the architect retain a qualified acoustical consultant in the early preliminary stages of design.

In our tests with several different partition systems we found that there was a typical drop of about 14 db. from the laboratory data and the "normal" construction and approximately a 4 db. drop from the laboratory data to the "select" construction concept. The accompanying table lists various partition systems including drywall, thin wall plaster, lath and plaster, and gypsum block and plaster. These are not all that have been tested but they do provide a basis of comparison of accepted construction practices.

Although we have only scratched the surface of this subject, we are in a position to formulate some conclusions. Very important consideration must be given to the layout of the building and its intended use. FHA and other lending agencies, as well as a few building codes, now include acoustical standards keyed to land use intensity and the location of the partitions in relationship to other living units, corridors and service areas. It is noteworthy in this respect that sound attenuation between two rooms will be 4 db. less than the weakest element.

Cost is another factor and the architect should make preliminary investigations in this regard. Before making his final selection, and for budget figures, he should always consult the subcontractors in the local market since it is inevitable that costs will vary from market to market depending upon the availability of materials, market practices and particularly the size and type of structure.

Another factor that should be considered is instruction in the basics of sound control for field personnel. This would include construction supervisors, the subcontractors and in some cases the building official. There are various courses available and it is necessary for the field to catch up with sound technology.

The partitions between apartment units cost about one-half of 1% of the building's total cost and are responsible to a large part for the occupancy rate which directly affects the rental revenue.

Therefore, progressive architects, builders and owners have found that it makes good sense to retain an acoustical consultant to insure the field performance of the partitions selected will be equal to the results obtained in the laboratory.

"Mismatch" and "Decoupling" Provide High STC Ratings

By J. J. Gafford

Gypsum drywall partition systems with Sound Transmission Class ratings of 61 (wood studs) and 58 (metal studs), the highest ratings yet achieved with conventional construction, are now available. In addition, these new STC systems also provide one and two hour fire ratings.

The basic theory which permits such high STC systems is not totally new, but it has now been refined to a high degree. Laboratory tests have now substantiated the fact that gypsum wallboard, when incorporated into a partition or wall, vibrate at different rates, creating a condition called "mismatch." In effect, the variance in thickness in wallboard installed in the system develop friction. This friction, in turn, reduces the amount of sound energy which is transmitted from room to room by converting it to heat energy, thus dissipating it. Further studies revealed that the slight

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variances of density between the different thicknesses of the gypsum wallboard contributed to the new system's high efficiency. Lamination of face layers, the use of wide spacing of screws or nails and the use of resilient channels provide a "decoupling" method of attachment which requires fewer nails or fasteners than ordinary systems and aids sound attenuation.

The importance of the breakthrough in gypsum drywall partition systems is reflected in the industry's concern over the better control of sound transmission between partition walls in apartment houses, motels, hotels, and other high-rise buildings. The FHA recently issued new and more stringent regulations for sound control, and municipal codes throughout the country reflect the serious attention being paid to methods for better sound control.

The sound conditioning advances in the new systems can be appreciated when the 61 and 58 STCs are compared to an STC 50 which screens out even very loud speech. When the new systems are properly installed, they should make party walls almost impervious to not only day to day office and apartment noises such as typewriters, ringing of telephones, but to almost all mechanical, electrical and human sounds. In apartment buildings, for example, the unwanted noise of a stereo record player set at a high volume output would be effectively reduced by the new partition system and would pose no party wall transmission problem.

The new systems are much thinner than other fire rated, high performance STC systems. The systems measure 6½ to 7 or 8" wide, compared to 9¼ to over 18" wide for other systems. The thin wall design makes it possible to design for maximum usable space within a building. Installation of utility and other services within a standard stud framing is much simpler than working with heavy masonry partitions.

The new systems weigh approximately 12 pounds per square foot and are 150 to 170 pounds less per square foot than heavy masonry systems required for near or equal performance. The weight reduction reduces the need to add extra "footings" and steel required for the heavy masonry systems. To come within the range of the new 61 and 58 STC ratings before the design of the new systems, it was necessary to use either double studs, some type of heavy concrete construction, or double solid gypsum partitions. The new systems are much simpler to design and construct than the older ones.

While extremely high performance partitions with STCs of 58 and 61 are effective designs, their ultimate performance can be severely restricted—even to a point of not being effective—if associated construction and buildings details do not follow good practices involved in overall sound conditioning of a building. Among the factors that can control the end result of STC rated partition systems are badly designed floor/ceiling systems, ceiling systems, improperly installed electrical outlets, ducts, back to back medicine cabinets, pipes, conduits, improperly sealed doors and faulty workmanship. To provide good sound conditioning in a building, it takes the total coordinated effort of the owner, architect, contractors and occupants.

The Riverbank Acoustical Laboratories filed four reports on the new systems, two on wood studs—TL 68-286 (STC 59) and TL 69-117 (STC 61), and two on metal studs—TL 68-114 (STC 58) and TL 69-118 (STC 57). The differentials in performance show the effects of mismatch and minor mass increases or decreases once this high degree of sophistication is reached.

The test procedures used to verify the STC and fire ratings of the new partition systems were ASTM E90-66T, "Laboratory Measurements of Airborne Sound Transmission Loss of Building Floors and Walls"; ASTM E-119, "Methods of Tests for Fire Tests of Building Construction Materials"; and ASTM E84 "Surface Burning Characteristics of Building Materials".

Both systems were developed by the Celotex Technical Service Department and the Jim Walter Research Corporation. Celotex and the Research Corporation are subsidiaries of the Jim Walter Corporation. The Research and Development work behind the new systems was begun more than two years ago and represents a continuation of more than 40 years in the development of acoustical treatment systems by the Company.

Understanding the Terminology of Sound Control

By G. E. Burgeson

Terminology, as defined by Webster, means: "The technical or special terms or expressions used in a business, art, science, or special subject." There are a number of special terms and expressions which must be understood if one is to deal effectively with sound control as it applies to building construction, and sound control is certainly a special subject.

The following are some of the more widely used terms and their definitions:

ABSORPTION: Absorption is the capacity of a material or assembly of materials to reduce sound by providing a surface which will convert the sound energy waves into heat (energy). Fabric, such as carpeting, draperies, furniture covering and some wall covering "absorb" sound waves. Ceiling tile is manufactured specifically for this functional value. Resilient channels, incorporated into various gypsum

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systems, permit the surface to "move" and thereby absorb sound wave energy. Insulation materials placed in wall and floor/ceiling cavities also act to absorb sound.

ACOUSTICS: Acoustics is the term given to the "science of sound, its production, transmission and effects." When one speaks of the acoustics of a room, orchestra hall or theater, for example, reference is made to all the characteristics of sound within.

AIRBORNE NOISE: Airborne noise are those sounds which are radiated directly into the air and carried by or through the air until it becomes completely absorbed by the air. (Another example of absorption.)

ATTENUATION: The attenuation of any given barrier to noise is that barriers capacity to lower the amount of noise from its source to the backside of that barrier. A partition erected to divide space within a given room or space area has an attenuation factor which is denoted by its STC (sound transmission class) rating. Gypsum partitions will carry STC ratings from 35 to over 60, depending upon the assembly.

BACKGROUND NOISE: Normal or familiar sounds or noises are those created either by outdoor activity, such as street traffic, or indoor noises, such as air conditioning unit, furnace, refrigerator or other regularly used appliance. These noises are usually acceptable as part of the environment of the listener and are called background noises.

DECIBEL: This is the designation given the unit of measure of the relative loudness, level or intensity of sound. The higher the decibel (db) number, the louder the sound. (Zero (0) decibel is a sound, slightly below the faintest audible sound. Each additional decibel represents the next loudest sound which can be detected.

FLANKING PATHS: Where a wall or floor/ceiling construction permits noise to be transmitted along its surface, under, over or through any openings, a flanking path is created. The use of sealants which harden and subsequently crack, create flanking paths. Oversize cuts for electrical boxes, medicine cabinets back to back are also common causes of flanking noises.

FREQUENCY: A sound frequency is equal to the number of vibrations or waves emanated in cycles per second. The slower the vibrations, the lower the frequency. Speech has a range of 100 to 5,000 cps. The human ear, however, can recognize sounds within a much wider range. Most animals can hear sounds that have both a higher and lower frequency than man can distinguish. A dog, for example, can hear a "silent" dog whistle which has a frequency higher than man's ear can distinguish.

IMPACT NOISE RATING: Most floor/ceiling assemblies are assigned an impact noise rating (I.N.R.) which identifies the capacity of a given assembly to absorb or block a noise created by impact (foot steps, moving furniture, a shoe being dropped) as opposed to air-borne noise. Although these ratings now appear as plus or minus 0 ratings, a change is underway which will result in figures similar to those used to measure sound attenuation. The higher the I.N.R. rating, the "better" the assembly.

MASKING: A masking noise is one which is usually an acceptable noise and a part of the environment. The sound of an air conditioner, furnace fans, dishwasher and even low volume street noises are typical masking noises. One noise covers another.

NOISE: Usually, a sound becomes a noise when it is loud enough or unpleasant enough to be an undesirable nuisance. Even pleasant or otherwise acceptable sound becomes noise whenever it interferes with concentration, conversation, or other tasks to be performed.

REFLECTION: The return of sound not absorbed on contact with surfaces is called reflection or bounce-back. Sound, as with light, is subjected to reflection from certain surfaces. An echo is an example of sound reflection not being absorbed by the surface it strikes.

SOUND: A vibration in any elastic medium within the frequency range capable of producing the sensation of hearing, is called a sound. Those vibrations which are not within the frequency range of the sensation of hearing are not considered sound until they are increased or decreased into that frequency range.

SOUND CONDITIONED: A room or unit area which is specially constructed to control sounds from all sources is said to be sound conditioned. Until recently, only radio, TV, studios or music or lecture halls were said to be sound conditioned. Today, however, an apartment, an entire residence or an office can be considered to be sound conditioned if the proper construction is utilized.

SOUND PRESSURE LEVEL: The intensity or loudness of sound is measured in decibels. The greater the intensity of sound, the higher the decibel rating or sound pressure level (S.P.L.).

SOUND TRANSMISSION CLASS (STC): The ability to retard transmission of airborne sound by a wall or floor/ceiling is measured in an STC number or a narrow range of STC numbers. The higher the STC number(s) the more efficient the construction.

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