USG Presents:

Design Techniques for Controlling Movement Stress in Partitions and Ceilings

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Buildings are subject to a wide range of forces that affect structural integrity. Some forces are obvious and easily identified. Hurricanes, tornadoes and seismic events, for instance, are examples of extreme forces that can severely impact building structure and create distress to building sub-elements such as partitions and ceilings.

Other forces are more subtle, but over time, they may be just as damaging to partitions and ceilings. Variations in temperature and moisture conditions, for example, can exert a significant force on a building's structural integrity, leading to (among other problems) cracking and other symptoms of distress in partitions and ceilings.

Cracking is the distress mode most often associated with plaster and drywall membranes. It is defined as a break or fissure originating on the surface of, or within the membrane, and is due to one primary cause – movement stress. More specifically, cracking results from a concentration of stresses that in magnitude exceed the maximum strain capacity of the material. The stress is relieved in the form of a break or crack.

Whether the stress movement stems from dimensional changes due to varying temperature or moisture conditions or from external forces that directly affect the membrane such as impact or vibration, structural movement can be controlled through a variety of design techniques. Perimeter relief and slip connections, for example, are used to reduce the transfer of stress from the structure to the building sub-elements. Integral stress relief can also be achieved through the use of expansion joints, control joints and construction joints.

Flat Plate Construction Stress

Flat plate concrete construction, which constitutes a large portion of residential high-rise buildings, is subject to two types of stress movement: racking and slab deflection.

Racking of the building frame is especially likely on the upper floors of the building and where exterior columns are exposed to major changes in temperature. As structural elements are exposed to racking stress, the partitions that they surround and support are distressed, typically leading to diagonal cracking in the partition face. In effect, the partition is forced to function as a shear wall, though it has insufficient strength to resist shear wall forces (Figure 1).

Another type of movement relates to deflection of the slab, which in flat plate construction increases for some time after the installation due to plastic creep of the concrete. Partition cracking from this type of movement results from flexural tension as the wall panel tries to follow the deflection of the structural floor (Figure 2).

While cracking resulting from flexural tension will decrease and diminish over time as the deflection process stabilizes, cracks due to racking are seasonally affected by thermal expansion and contraction, since the stress reverses with prolonged changes in outside temperature.

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Use the learning objectives below to focus your study as you read **Design Techniques for Controlling Movement Stress in Partitions and Ceilings**. To earn one AIA/CES Learning Unit including one hour of health safety welfare credit, answer the questions on page 189, then follow the reporting instructions on page 244 or use the Continuing Education self report form located at *architecturalrecord.com*.

Learning Objectives:

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

- Control structural movement through design.
- Know proper installation techniques for control joints.
- Understand how drywall corner edge cracking can be minimized and how cracked plaster walls and ceilings can be repaired.

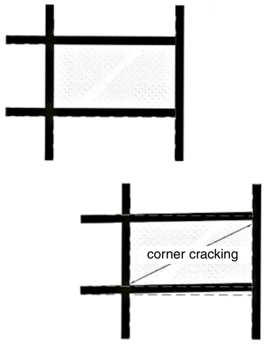

Figure 1. Frame movement can cause racking cracks in partitions.

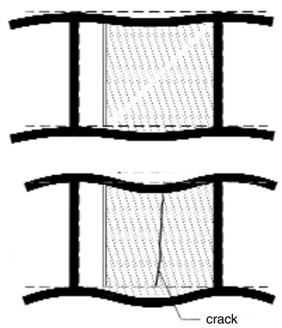

Figure 2. Slab deflection can also cause partition cracking.

Design Considerations

Design professionals can calculate the amount of anticipated movement required to cause racking stresses. Similarly, the amount of anticipated slab deflection can be calculated based on the initial dead load, with compensating partition and ceiling details providing for an amount ranging from two to five times the initial dead load deflection.

When designing partition and ceiling assemblies with perimeter relief or control joints, architects should bear in mind the following general considerations:

- Distress problems are usually most serious when partitions are tightly connected to the structural frame, or when partition membranes are abutted to the structure rather than supported by a suspension system.
- In high-rise buildings (more than eight stories), a relief joint must be incorporated at the periphery of the partition to allow for sufficient vertical movement to meet the anticipated stress conditions.
- Initial and creep deflection can be reduced with a stiffer floor system or with a pan-joist structure and a suspended ceiling. For flat plate construction, perimeter relief and/or control joints should be used to compensate for deflection of the floor and ceiling.

Control Joints

Control joints are time-proven means for accommodating stress relief. When designing with control joints, architects need to analyze the structure and determine when, where and which type of control joint will deliver the desired performance. Several options are available.

Expansion joints (also referred to as building control joints) prevent structural cracks due to building movement resulting from a variety of factors, including the structural materials (concrete, steel, etc.), the length of the structure, area temperature variations, foundation conditions and occupancy. Expansion joints extend entirely through the footing, foundations and superstructure of a building. They consist of a complete frame separated with a space between the structural members. They are filled or bridged with a compressible and resilient material, and they include a suitable joint closure on the outer face.

Expansion joints are needed:

- Where a long narrow structure abuts a rigid mass;
- At the ends of a low structure between two heavy masses and at intervals of approximately 150 feet;
- When a new building adjoins an existing building;
- In freestanding buildings at intervals of approximately 200 feet;
- When interior and exterior temperature differentials are extreme (for example, a cold storage building).

Construction joints are horizontal or vertical features introduced into the building design to conform with material limitations such as the amount of concrete that can be poured in a day's operation, the size of the selected component or panels, aesthetics and other considerations. Generally, these joints are located at ledges or other architectural features such as window jambs, heads and sills.

Control joints/perimeter relief joints are used to limit cracking in partitions and ceilings. Control joints are located within the face of a partition or ceiling, while perimeter relief joints (also called slip joints) are located at perimeters. Control joints are effective in limiting cracking due to tensile or compressive movement in a membrane resulting from thermal, hygrometric and structural effects. Perimeter or slip joints are necessary at perimeter interfacings to control shear movement when flat plate construction is employed.

Proper installation of control joints in wall and ceiling membranes requires breaking the lath or gypsum panels behind the control joint. On ceilings, the framing at control joint locations should be broken. In partitions, separate studs should be installed on each side of the control joint, and the runner track should be separated at the joint location. (Figures 3, 4, 5 and 6 detail suggested locations for perimeter relief and control joints.)

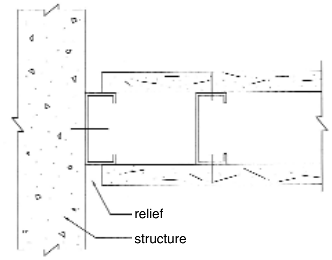

Figure 3. Perimeter relief at junction of partition and structural wall.

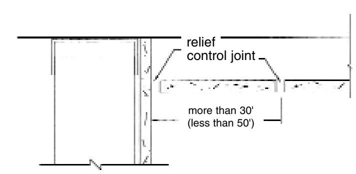

Figure 4. Perimeter relief of large ceiling space.

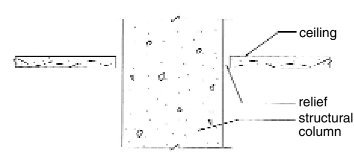

Figure 5. Perimeter relief of ceiling at structural column penetration.

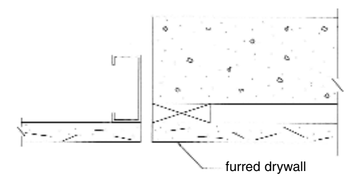

Figure 6. Control joint at junction of drywall partition and masonry.

The use and location of partition and ceiling control joints is the responsibility of the design professional. Generally speaking, control joints should be used:

- Where a partition, furring or column fireproofing abuts a structural element (except for a floor) or dissimilar wall or ceiling;
- Where a ceiling or soffit abuts a structural element, dissimilar wall or partition, or other vertical penetration;
- Where construction changes within the plane of the partition or ceiling;
- Where a partition or furring run exceeds 30 feet;
- Where ceiling dimensions exceed 50 feet in either direction with perimeter relief, or 30 feet without relief;
- Where exterior soffits and ceilings exceed 30 feet in either direction;
- Where wings of L-, U-, and T-shaped ceiling areas are joined;

(See Figures 7, 8, 9 and 10 for typical perimeter relief and control joint details.) Following are some additional design considerations regarding the use and placement of control joints:

- While ceiling-height door frames may be used as vertical control joints in partitions, frames of lesser height require control joints extending to the ceiling structure from both corners of the top of the frame.
- Control joints in ceilings should be located to intersect column penetrations, light fixtures and air diffusers that can impose stresses on the ceiling membrane.
- Experience has shown that to relieve stresses in portland cement-stucco surfaces, control joints should be spaced no greater than 10 feet.
- The ratio of length to width in ceiling membranes should be in the range of 1:1. For example, a Portland cement plaster ceiling formed of 10- by 10-foot panels (100 square feet) is considerably less prone to cracking than a soffit measuring 2 by 50 feet (100 square feet).
- A control joint in a partition should extend through a bulkhead/soffit condition with the same consideration for separation of the membrane and framing.

TYPICAL PERIMETER RELIEF AND CONTROL JOINT DETAILS

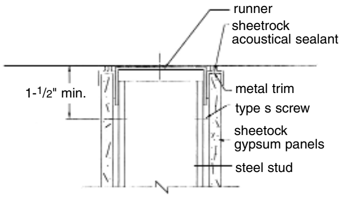

Figure 7. Perimeter relief of partition at structural ceiling.

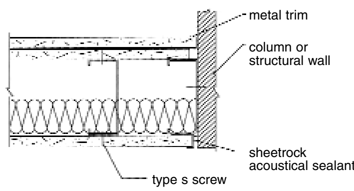

Figure 8. Perimeter relief of partition at structural wall or column.

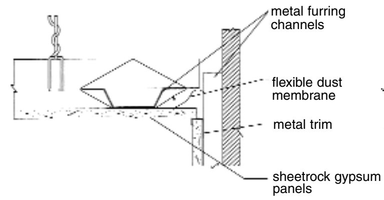

Figure 9. Perimeter relief of suspended ceiling at exterior wall.

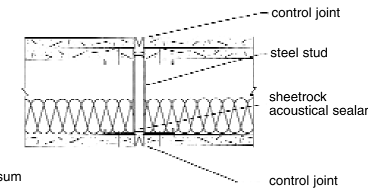

Figure 10. Control joints in the face of a drywall partition accommodate lateral expansion or contraction of up to 1/4 inch.

Fire-Rated Considerations

The introduction of a control joint into a partition or ceiling membrane that is part of a fire-rated assembly necessarily creates an opening for flame and temperature transmission. For gypsum drywall ceilings Underwriters Laboratories (UL) provides generic details for maximum one-hour floor/ceiling assemblies in the G500 and L500 series. Since typical fire tests of floor/ceiling assemblies incorporate an end joint backed with a continuous gypsum strip, the detailing for control joints in ceiling membranes for higher ratings should be acceptable to a code jurisdiction.

For gypsum partitions, details have been tested at an independent fire test facility on a two-hour partition using gypsum panel strips as back-up members in one case and mineral fiber insulation in another. The details are considered pertinent to one-hour assemblies as well (Figures 11 and 12). The development of special details to satisfy head of wall conditions is a relatively new consideration for design professionals and must be factored into the overall design as required by local codes.

FIRE-RATED PARTITION CONTROL JOINT DETAILS

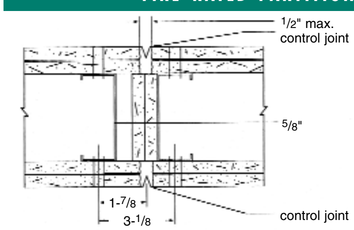

Figure 11. A two-hour fire-rated steel stud partition.

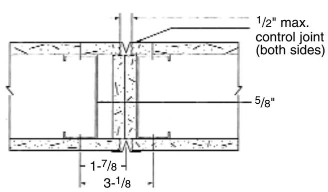

Figure 12. A one-hour fire-rated steel stud partition.

Wood Framing Considerations

In wood frame construction, the basic framing material– wood, which is subject to lumber shrinkage – is often the root cause of distress in a gypsum membrane. Gypsum surfaces do not react like wood in response to moisture changes, and thus may buckle or crack when firmly anchored across the flat grain of wide dimensional lumber. The gypsum surface should either “float” over the wood or a control joint mechanism should be provided.

Wood shrinkage is greatest in the direction of the annular growth rings (tangentially). It is less across the rings (radially) and is minimized even further along the grain (Figure 13). Using lumber in which the bearing is across the grain presents the potential for damaging shrinkage. In fact, a major contributor to wall surface damage in cathedral type installations is western or platform framing, which uses dimensional lumber up to 2 by 14 inches for floor joists at intermediate floor locations.

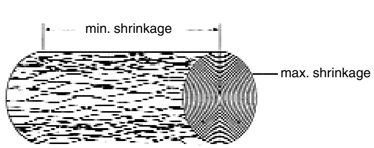

Figure 13. Wood shrinkage is greatest in the direction of the annular growth rings (tangentially), and is less across the rings (radially).

Platform framing shrinkage can be addressed through the use of resilient channels on the wood frame studs and by spanning the gypsum panels across the wood member (Figure 14). Another option is to use a control joint at the bottom edge of the top and first floor studs, which positions the joint where the greatest amount of shrinkage and dimensional change needs to be absorbed (Figure 15). The gypsum panels are then applied horizontally with a 1/4-inch separation between panels at the control joint location. The bottom gypsum panel is applied with its top edge aligned with the bottom of the top plates. One-quarter inch shims placed on the top edge provide the proper spacing. The upper gypsum panel is not nailed below the level of the toe plate allowing the edge to float over the header joist. The control joint can be finished with a manufacturer accessory or with wood molding, applied so as not to restrict movement of the gypsum panel above the joint.

USING RESILIENT CHANNELS WITH PLATFORM FRAMING

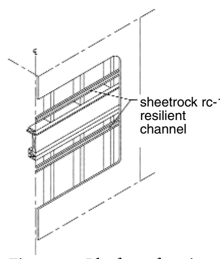

Figure 14. Platform framing with a resilient channel.

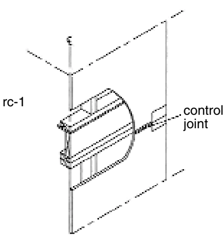

Figure 15. Platform framing with a control joint.

Seismic Considerations

In areas of earthquake activity, structures are designed and constructed to resist the lateral forces induced by seismic disturbances. Per the Uniform Building Code, drywall and gypsum plaster membrane ceilings do not require lateral bracing when they are braced by walls or partitions spaced a maximum of 50 feet apart. Where walls do not brace the ceiling, independent bracing, as designed by a structural engineer, is required. Light fixtures need to be supported independently of the ceiling runners.

While direct-hung suspended acoustical ceilings are not subject to the same stresses as continuous membranes, they are affected by seismic forces. Damage is often exhibited by battered and collapsed ceiling edges at walls and partitions, and the dropping of light fixtures. The common type of lateral bracing for suspended ceilings consists of diagonal (45 degree) wires connected between the ceiling runners and/or tees and the floor or roof structure above. The spacing of the diagonal braces is a function of the lateral force produced by the ceiling, lights, partition, etc., the load capacity of the wires and their connection to the ceiling system members and the structure above. The load brought into the brace points is a horizontal force and the wire braces are tension diagonals, resulting in a vertical uplift component to be resolved. This is usually satisfied with a vertical compression strut.

Various organizations offer additional design reports and recommendations on partitions and ceiling design under seismic conditions. The Gypsum Association addresses the issue through its Seismic Bracing of Steel Stud/Gypsum Board Partitions – Design Tables (GA-350). The California-based Drywall Information Trust Fund offers an Evaluation Report (ER-4071) on the topic. And the Ceilings and Interior Systems Construction Association (CISCA) offers reference materials on seismic criteria for acoustical ceiling systems.

In the end, controlling stress movement within a building structure requires both good design practices and proper installation techniques. The architect is responsible for understanding movement within the structure and creating the details for perimeter relief and slip connections, as well expansion joints, control joints and construction joints. When these details are designed correctly – and installed properly – movement can be effectively controlled within any structure.

Minimizing Corner Bead Cracking

Washington D.C.'s National Research Council Uses the Latest in Corner Bead Technology

Paper faced metal drywall bead is applied with joint compound instead of mechanical fasteners. It doesn't fasten directly to framing like conventional nail-on bead.

When Centex Construction completed the new headquarters building for the National Research Council in downtown Washington, D.C., in June 2002, it proved to be a fitting showcase for the work being done by the council. Founded by the National Academy of Sciences in 1916, the council's mission is to associate the broad community of science and technology, to further knowledge and to advise the federal government, the public and the scientific and engineering communities.

The 260,000-sq.-ft. project consists of 11 stories of unique, modern offices and a stunning atrium on the third floor that extends over 80 feet to a dramatic skylight in the ceiling. The Smith Group, a Washington D.C.-based architectural firm, designed the building in a grand style.

In a building dedicated to science and technology, it's fitting that a leading-edge drywall technology played a key role in the construction of the building's interior walls. Interiors subcontractor C.J. Coakley Co., Inc. managed to virtually eliminate any potential for corner-edge cracking – and the associated callbacks – in the building through the use of an innovative corner bead that offers the unique ability to "move" with drywall surfaces, providing the flexibility needed to withstand structural shifting and settling.

"This is one of the best technology breakthroughs in drywall finishing in a long time," said Michael Coakley, senior project manager and part owner. "We love it."

Coming from Coakley, that statement carries a lot of weight. His company has been completing interiors on some of the biggest and most prestigious projects in the Washington, D.C. area since 1962. Based in Falls Church, Virginia, C.J. Coakley's 480 employees handle approximately $35 million in interiors work annually. Over the past four decades, the company has completed drywall, plaster, fireproofing and acoustical ceiling applications on everything from Dulles International Airport to Fed Ex Field, from the Dirksen Federal Building to the Pentagon. C.J. Coakley has also completed hundreds of lesser-known commercial projects, including local hotels, hospitals, universities and shopping malls.

Paper faced metal bead applied over a gypsum board corner.

The corner bead that C.J. Coakley raves about is known as paper faced metal drywall corner bead. C.J. Coakley began using the product in 1998 during renovation work on the Pentagon.

"We had been using conventional metal clinch bead until that time," said Coakley. "But on the Pentagon project, we decided to try the paper faced metal product. It handled really well and we realized a cost savings. We've never turned back. We now use paper faced metal bead for a significant part of our drywall work."

So what's the attraction behind the product's performance? "For one, we don't find that we have to go through jobs fixing up damaged corner beads with this product," said Coakley.

The key to the product's performance lies in the fact that tape-on paper faced metal bead is not fastened directly to framing. Rather, it is attached to gypsum board corners using joint compound applied under the paper flanges that extend from the metal corners. This gives the product the flexibility to withstand cracking resulting from normal building movement. It also delivers superior strength and impact resistance.

Drywall corners treated with paper faced bead "float" with the gypsum board surface, providing the flexibility needed to withstand structural shifting and wood frame shrinkage without cracking.

"If you hit a paper faced metal corner, it won't crack all the way up and down the wall like conventional metal bead will," said Coakley. "The damage will only be at the point of impact. And it's much harder to damage because it's so much stronger."

Coakley also points out that the product installs more quickly than conventional metal clinched-on bead. It cuts easily with tin snips, and can be quickly applied using joint compound and either a 4- or 6-inch taping knife, a multiuse hopper and corner roller, or a mechanical angle applicator.

C.J. Coakley crews installed more than 90 boxes of paper faced metal drywall corner bead on the National Research Council building. To begin the application, workers generously applied ready-mixed joint compound to both sides of the corners, extending 2 inches wide on each side. Once cut to the desired length, the paper faced metal bead was aligned to the corner and pressed firmly along its length. Excess joint compound was then removed using a drywall knife. The paper faced metal bead was then finished with two coats of ready-mixed joint compound applied over the paper flanges.

Alternatively, the paper faced metal bead can be run through a gravity-fed hopper to spread a layer of joint compound over the inner surfaces of the paper flanges. The bead is applied to the corner and pressed into position using the roller tool. A mechanical angle applicator can also be used to apply joint compound directly to corners. The bead is then simply pressed in place and wiped clean with a rag or drywall knife.

"Although the paper faced metal bead costs a couple of cents more per foot than regular bead, you don't put as much mud on the walls when applying it, you don't have to hit it as many times and you eliminate one pass on the finishing," said Coakley. "So, the amount of material you are using and the actual finishing time is less. When you add those factors in, you're actually saving money."

Compared to the bare metal or plastic surfaces of conventional corner bead, the paper tape provides superior adhesion of joint compounds, textures and paints, ensuring a strong, smooth finish. "It goes on a lot straighter than the typical metal bead. When you install metal bead, you're crimping it on the surface and you inevitably kink the bead, and often, installers won't fill it in just right," said Coakley. "So if you have a bulkhead that you're running down a line, you'll see it run in and out. Whereas the paper faced metal bead will stay straight and true."

The paper faced metal bead's superior performance also minimizes—and sometimes eliminates—subsequent repairs.

Getting workers to try a new product is often the hardest part. "It's sometimes hard to get our guys to switch to a new product when they've been using an established product for a long time, even if the product is superior," said Coakley. "When we started this project, we gave our workers five boxes of traditional bead and five boxes of the paper faced metal drywall bead to use. Many of them initially went for the first box of traditional bead. Once the traditional beads were used up, the men were forced to use the paper bead. When we replaced the order for bead, the men went with paper faced bead. Once they tried the paper faced metal bead, they never went back. They had all become converts." ■

Click for Additional Required Reading

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

Learning Objectives

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- Control structural movement through design.
- Know proper installation techniques for control joints.
- Understand how drywall corner edge cracking can be minimized and how cracked plaster walls and ceilings can be repaired.

Instructions

Refer to the learning objectives above. Complete the questions below. Go to the self report form on page 244. Follow the reporting instructions, answer the test questions and submit the form. Or use the Continuing Education self report form on *Record's* website—*architecturalrecord.com*—to receive one AIA/CES Learning Unit including one hour of health safety welfare credit.

Questions

Q: 1. Which is seasonally affected by thermal expansion and contraction since the stress reverses with prolonged changes in outside temperature?
A: a. Cracks due to racking stress
b. Cracking resulting from flexural tension

Q: 2. The amount of anticipated slab deflection can be calculated based on the initial dead load, with compensating partition and ceiling details providing for an amount ranging from _______ times the initial dead load deflection.
A: a. One to three times
b. Two to five times
c. Five to seven times

Q: 3. Distress problems are usually most serious in which situations?
A: a. When partition membranes are supported by a suspension system
b. When partition membranes are abutted to the structure

Q: 4. Initial and creep deflection can be reduced with a stiffer floor system or with a pan-joist structure and suspended ceiling.
A: a. True
b. False

Q: 5. Expansion joints are needed in all situations except which?
A: a. When interior and exterior temperatures are extreme
b. When a new building adjoins an existing building
c. At the ends of a low structure between two heavy masses
d. At perimeter interfacings in flat plate construction

Q: 6. You generally find which control joints at ledges or other architectural features such as windows, jambs, heads and sills?:
A: a. Expansion joints
b. Construction joints
c. Perimeter relief joints
d. Slip joints

Q: 7. For the proper installation on ceilings, the framing at control joint locations should not be broken.
A: a. True
b. False

Q: 8. While ceiling-height door frames may be used as vertical control joints in partitions, frames of lesser height require:
A: a. A ratio of 1:1 for door height to width in ceiling membranes
b. Expansion joints extending through the footing, foundations, and ceiling.
c. Control joints extending to the ceiling structure from both corners of the top of the frame

Q: 9. Generally speaking, control joints should be used in all but which of the following:
A: a. Where a ceiling or soffit abuts a structural element, dissimilar wall or partition, or other vertical penetration
b. Where construction changes within the plane of the partition or ceiling
c. In any ceiling space less than 30 by 30 feet
d. Where wings of L, U, and T-shaped ceiling areas are joined

Q: 10. Gypsum surfaces may buckle or crack when:
A: a. Firmly anchored across the grain of lumbar
b. Provided with a control joint mechanism
c. They "float" over the wood
d. Used with resilient channels on the wood frame studs

Q: 11. Drywall and gypsum plaster membrane ceilings do not require lateral bracing when they are braced by walls or partitions spaced a maximum of 50 feet apart.
A: a. True
b. False

Q: 12. When the relative humidity increases from 13 percent to 90 percent, gypsum panels can expand at a rate of approximately:
A: a. 1/4 inch per 100 feet
b. 1/3 inch per 100 feet
c. 1/2 inch per 100 feet
d. 2/3 inch per 100 feet

Q: 13. Benefits of paper faced metal drywall corner bead include all but which:
A: a. Flexibility to withstand cracking
b. Costs less per foot than regular bead
c. Harder to damage
d. Installs more quickly