PARTITION CRACKING: SOLVING ITS MYSTERIES

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An analysis of high-rise partition problems

Each advance in construction technology brings with it new problems. A notable example is the high-rise building. The use of flat-plate concrete construction and exposed exterior columns has provided vertical growth of buildings economically and efficiently, but has created new problems that only recently have become well understood.

Not only have significant strides been made in the engineering aspects of building, but the development and improvement of building materials have also expanded structural and architectural capabilities of the industry at the same time. The architectural result of these technological and material advancements has been that more and more volume can be enclosed with less and less material. Regardless of design concept, this can only lead to buildings of less mass and consequently less overall stiffness.

Where land cost or other considerations have dictated against free lateral expansion of urban buildings, growth has become vertical. For many years, the need for vertical growth was confined to central business sections of the cities, and high-rise construction consisted chiefly of office buildings. But transportation problems and high land costs produced economic pressures that have made it necessary to expand residential buildings vertically, too.

As a result, designers and developers have refined their techniques, architecturally and structurally, to produce more economical structures without compromising safety. One such reinforced concrete design is popularly known as the “flat plate,” in which the underside of a concrete structural slab can be used as the ceiling.

Problems Plague the Flat Plate

As is true with many innovations, the dramatic development of the flat plate in building construction brought with it a whole new series of problems. The most elusive of these, and the subject of this article, is partition cracking.

The primary causes of partition cracking as related to the structural frame are racking, in which the rectangular shape of the partition is forced into a parallelogram shape, and flexural tension cracking, in which structural force is applied near the center of a partition. The cracking pattern caused by racking is referred to as Type A Cracking (Fig. 1) in this article, and that caused by flexural tension is Type B Cracking (Fig. 2).

Because of a general lack of understanding of the mechanics involved, these two types of cracking are often confused with each other and with other unrelated causes of cracking of partitions. Thus, it is first necessary to discuss the mechanics of the causes, the differences between the two types of cracking, and the
characteristics of other types of cracking before we can determine how to solve the problem.

How, Why and Where Does Cracking Occur?

Sometimes non-structural elements in a building suffer as a consequence of utilizing structural advances to derive economies. For example, roofing and insulating materials, floor coverings, ceilings, curtain walls and partitions frequently experience unusual new problems, not only because the structural elements are less rigid, but because of economizing on these non-structural elements as well. Partitions are a prime example. Particularly in high-rise apartments, extensive partition cracking has occurred with increasing frequency (where suitable detailing was not provided.)

The pattern of cracking caused by structural movement depends in part on the physical properties of the partition, as well as the method of framing it. If the interaction between partitions and building framing is not well thought out, loads can be transmitted to the partition as a result of movement of the structural frame. When we evaluate cracking problems in non-structural building materials, such as those used in partitions, many factors must be considered. Table 1 lists these factors as they relate to the susceptibility of various materials to crack in structural movement situations.

The Type A (racking pattern) is found primarily in the upper floors of high-rise buildings, usually if exterior columns are exposed. This kind of partition distress results from racking of the structural elements that surround and support the partition. The racking is caused by thermally induced expansion or contraction and drying of the concrete structural frame.

The Type B pattern, which is predominant near the center of a partition span, is the result of flexural tension as the wall panel tries to follow the deflection of the structural (slab) floor and/or ceiling.

Tensile Cracking is Not the Problem

Let’s consider the sources of tensile cracking. Most investigations have concluded that cracking in partitions and ceilings results from shrinkage restraint in the material or to movement in the base or frame which supports the surface material (e.g. studs masonry, etc.). This source of cracking has been thoroughly studied and documented.

However, restrained shrinkage in partitions is not a primary cause of the distress which occasionally is encountered, and which is discussed in this article. In the first place, Type A (racking) Cracking is usually found in the upper floors of a high-rise structure, with the intensity of the cracking increasing floor by floor toward the top. Conversely, shrinkage problems would not be restricted to the upper floors since it can be assumed that temperature and humidity conditions are fairly uniform throughout the building.

Furthermore, shrinkage cracking displays its own typical pattern which is dissimilar to Type A Cracking. The stress pattern in Figs. 1 and 3 clearly show that the partition is racked and distorted as the surrounding frame moves from a rectangular shape into that of a parallelogram.

Restrained shrinkage cracking differs from Type B Cracking as well, although since Type B usually displays distress throughout the building, it may lead one to suspect that Type B Cracking is caused by shrinkage. However, Type B Cracking is characterized by vertical cracks which start at the base of the partition with a wide gap and gradually decrease in intensity, disappearing as they move toward the top of the partition (Fig. 4).

Shrinkage cracks will normally be uniform in width and intensity from floor to ceiling. Shrinkage cracks also can be repaired satisfactorily, prior to decorating. However, the Type B Crack does not stabilize for some period of time after decorating. Even though it is repaired three or four times in a 12-month period after construction, the crack recurs and continues to widen at the base, increasing in intensity and length, until the deflection in the structural slab has stabilized.

Differential foundation settlement can also be eliminated as a possible source of either Type B or Type A Cracking. Cracking from this source would not be confined to upper floors as Type A is. Nor would it be evenly dispersed through the structure as
shrinkage cracks. Instead, it would be concentrated in the vicinity of the elements that have settled.

Seismic forces can also be eliminated as a cause, since the pattern of cracking produced by these forces (Fig. 5), whether from earthquake or vibration, is not similar to either type of cracking.

**Building Types Involved**

When construction difficulties are encountered, the first investigations usually center around quality of materials. It is very unlikely that the cracking problems under discussion here can be attributed to faulty materials. The problem is associated too closely with a particular building type—and too widespread geographically.

By process of elimination, we have thus reduced the probable source of cracking to movement of the structural framework. This movement may be brought about by wind, gravity or volume change in the framework elements. Although wind cannot be totally eliminated as a contributing factor, it is not likely to be the primary cause of Type A (racking) Cracking, and definitely not a cause of Type B. Type A Cracking is usually encountered in buildings that have exterior columns and/or spandrel beams either partly or completely exposed to outside temperature. Since the interior of the building maintains a fairly uniform temperature, interior columns and beams are not subject to much movement from temperature differentials. Exterior columns and beams, however, are subject to wide swings in temperature. Their free movement is restricted only by the restraint provided by the remainder of the structure. Frame restraint reduces the free movement in an amount dependent on stiffness, but total movement can still be appreciable.

Assuming a 30-story building has 300 lin. ft. of exposed column in steel or concrete, the free movement from a 100°F temperature change could be expressed this way:

\[
\text{Free expansion} = 0.000006 \times L \times (T - T_o)
\]

where:
- \( L \) is column length in inches,
- \( T - T_o \) is change in temperature in degrees F.

\[
= 0.000006 \times 300 \times (12) \times (100) = 2.16 \text{ in.}
\]

Because of the stiffness of the frame, the total movement is usually found to be less than half the amount calculated for free movement (Fig. 6). The amount can be approximated by proper structural analysis. As the out-

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Type B Crack (at right) is caused by sagging upper floor bearing directly on wall. Lower floor also deflected from wall due to creep in concrete, so pressure from above tries to bend partition like a beam. Flexural cracks are widest at bottom, run out as they move vertically.

Side column moves up and down with respect to the inside column, cracks, and gaps can be expected in two corners of any partition that frames against columns. Evidence of crushing will show up in the two opposite corners (Fig. 3). Diagonal cracks may

Vibration source, such as earthquake or blasting, causes this type of crack pattern.

Section of 30-story building shows effect of differences in indoor and outdoor temperatures. Right side shows how much differential movement could be expected in top floor-slab during winter; on left, movement during summer. Numerical values assume free movement of exposed exterior column due to temperature change. Actually, free movement is restricted by bending stiffness of frame, and actual movement will be considerably less.
also show up on the face of the partition if the edges are unusually well reinforced.

In other words, the partition is forced to become a shear wall, but does not have sufficient strength to resist much force. When cracking caused by movements in exterior columns does occur, partitions parallel to the outside walls are usually unaffected.

As stated before, Type B Cracking is a result of floor deflection. This deflection, particularly in flat-plate design, increases for some time after construction, due to creep. It may amount to 2½ times or more the initial dead-load deflection. The deflection continues at a decreasing rate until becoming reasonably stable.

Type B Cracks, therefore, usually can be repaired after a one to two-year period following completion. The problem should not recur to any serious extent. On the other hand, Type A (racking) Cracking cannot be repaired by filling the cracks, since the distress reverses with prolonged changes in outside temperature. A corner that is now being pulled apart can show signs of compression at other times.

### Integral Construction a serious Problem

Both types of cracking are illustrated in Figs. 7 and 8, the results of modest scale-model studies. In both cases, cracking appears most serious when partitions are tightly connected to the structural frame, rather than supported by some kind of suspension system. Type B Cracking, which is caused by sagging floors, is less likely when the wall connects to a suspended ceiling than when it is extended to the bottom of the structural floor. Type A (or racking) Cracks may still occur when suspended systems are employed, but their severity will be reduced.

### The Solution Appears

Now that the problem and likely causes have been discussed, we logically ask, “What can be done about it?” The most obvious answer is to take into consideration, during design stages, the anticipated structural movement in the frame and deflection in the floor system.

Based on experience, exposed concrete columns and shear walls can be safely used in structures from six to ten stories high (in most areas) without creating excessive stresses on most non-load-bearing partitions. Beyond these limitations, a control joint which allows sufficient movement must be provided at the periphery of the partition. A number of control joints can be detailed to do this, depending on the materials used in the partition construction and appearance considerations in the finished wall.

The design of this control joint must not only take into consideration the movement, but also must maintain the required fire protection and sound isolation of the partition.

Initial deflection and anticipated creep deflection can be calculated. This can be reduced with a stiffer floor system, or with pan-joint construction and a suspended ceiling. If the flat plate is used, consideration should be given to a stronger partition, with a
Fig. 7. In laboratory model of section through two bays of three-bay building (top), partitions are in direct contact with interior and exterior columns, ceiling and floor. Photo illustrates effect of moving exterior column up (note wedge) with respect to interior column. This simulates upper floors in tall building during summer. Type A Cracks are circled.

Fig. 8. Interior partition of model is loaded by thumb pressure on upper floor to simulate effect of sagging floor (bottom). A thin Type B Crack appears near center of wall (circled). Type B Cracks are typically much narrower than Type A Cracks and may be expected anywhere in building, not just in partitions at slabs of upper floors as with Type A.

control joint to compensate for deflection of floor and ceiling.

At the present time, it is not economically sound to develop non-load-bearing partitions that are capable of resisting stresses imposed by the structural frame under these conditions.

It seems the only sensible approach is to make architects and engineers aware of the problem so they can assess it properly beforehand, rather than blame materials afterwards. United States Gypsum has developed partition detailing that can accommodate the building movements, rather than resist them, and still maintain past economies.