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# Precast Concrete Walls – Problems with Conventional Design

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## Please note



Concrete is an excellent building material and precast concrete is a quality, factory-produced product that gives great scope to the designer of a wall with respect to form, texture and colour. The total wall system consists, however, of more than precast concrete, and difficulties will arise, as with an assembly of any building materials, if the total wall design is not based on sound scientific principles.

The philosophy underlying the present method of assembling precast concrete walls is that the concrete panels, together with the joints between them, form the real wall, which can be made both rain- and air-tight. Insulation and an internal finish are then added, very often without proper analysis of their effect on the other components of the wall. It is the purpose of this Digest to describe some of the problems that this type of construction has produced and to show that, unless the underlying faulty concept of wall design is corrected, it is not reasonable to expect that present practice will be able to prevent them.

**Some Problems**

Of all problems, the presence of water inside a building is reported most frequently. Water dripping from ceilings or running down walls is not tolerated for long without protest, and in some cases it will cause a disruption of activities. Water on the inside surface of a wall does not cause so great a disruption but in both cases there can be a severe deterioration of the appearance of walls, ceilings, and floor coverings, or the contents of the room.

Condensation on windows and window frames is a similar problem but, because the immediate cause is more obvious, it does not provoke the same protest as does water that emerges mysteriously from wall panels or through ceilings. Some designs accept it as inevitable, and drainage gutters are provided. Unfortunately, however, these do not always work satisfactorily as the drain hole often becomes plugged with frost or dirt, or an inward air pressure prevents the water from draining away.

A less obvious, but more serious, form of deterioration is the corrosion of the metal connections that hold the precast panels onto the structure of a building. Should one panel break loose, all other panels would be suspect and the remedial work required would be very costly. Only one connection failure has been reported to the Division, but other connections have been seen to be wet or very rusty after comparatively short periods of service. It should be pointed out that a failure can result not only from the removal of metal by corrosion, but also from expansive forces set up by the products of corrosion, which have a much greater volume than the parent metal. These forces can pull inserts out of a panel, as occurred in the one example reported to DBR.

Glass breakage is reported quite frequently as a mysterious problem that appears to have no connection with the use of precast panels. In fact, the problem is one that is accentuated by the basic layout of the total wall system.

Loads can be transferred onto wall panels that were not designed to be load-bearing if inadequate clearance is allowed to accommodate not only the movements that take place but also the variations in the size of the panels within the manufacturing tolerance. In particular, allowance must be made for the shortening of a concrete structural frame and the deflection of horizontal spanning members (**CBD 54**) under the action of elastic stress, drying shrinkage, and creep under sustained load. Transfer of load in this manner can lead to displacement of the panel or to cracking and spalling.

Sandwich-type panels, with the insulation located between two leaves of concrete, have many advantages but they present special difficulties. The two leaves of concrete will be subjected to different conditions and so will have different expansions and contractions. Should they be rigidly connected there is a possibility that the connectors will be sheared off or that the panel will crack or become bowed. Cold winter temperatures would make the exterior leaf contract in relation to the interior one, thus making the panel concave on the outside. From examination of panels in service this does not appear to be the critical factor, since all that had bowed were concave on the inside and there were more cracks in the inner leaf than in the outer. It would seem, therefore, that drying shrinkage of the inner leaf is of greater importance in causing this problem than temperature difference.

Deterioration of appearance is often associated with many of the foregoing problems but this is not the principal cause for concern. Some problems are mainly concerned, however, with aesthetics, and since precast concrete panels are often used to create a beautiful building it is important to avoid situations that will mar this beauty.

Rain water and condensate within the wall are inherently "soft" and thus are able to dissolve lime from cement. Following further reactions involving carbon dioxide, a deposit of insoluble calcium carbonate is left as the water evaporates. The water also tends to become alkaline as it runs over the surface of the concrete, and should it flow over a window there is a danger that the glass will be etched.

**The Causes**

Such a recital of problems with walls incorporating precast concrete panels might appear to suggest that this material is not considered suitable for use in buildings. On the contrary, it must be emphasized that precast concrete is an extremely versatile material that can be used to great effect on a wide variety of buildings. Nevertheless, it is pertinent to examine problems that have arisen in order to determine their causes. If the factors involved could be controlled by changes in the methods of design and construction, then the material could be used more satisfactorily and fewer problems would be encountered.

Two factors lie at the root of most of the problems: water in its various forms, and temperature differences. Either singly or in conjunction these agents of destruction conspire to undo the efforts of the design and construction team. It is necessary, therefore, to ascertain why walls, as made at present, fail to control or allow for them satisfactorily.

Considering the control of water first there are two possible sources of moisture - rain and vapour in the air. Water introduced during construction by wet operations on site or retained in components fabricated off the site is usually converted into water vapour as the materials dry.

It can, therefore, be treated as a special temporary problem of high humidity within the building.

*Rain Penetration.* The problem of rain penetration and the methods whereby it can be controlled have been described in **CBD 40**. It was pointed out that for rain to penetrate the wall there must be water on the wall, a hole through which it can pass, and a force to move it inward. It was concluded that the greatest success in combatting rain penetration was achieved by controlling all of the four forces that cause it - momentum of the raindrop, capillarity, gravity, and air pressure. With a dense, uncracked, precast concrete panel on the outside, all four forces can be controlled. The panel itself will not permit the passage of rain and the problem is largely confined to the joints between panels and between the panels and other wall components, such as windows.

It is possible to devise suitable joints for these locations, although there are special difficulties mainly related to the thermal conditions to which the panel is subjected. As it is insulated on the inside, a panel will be colder in winter and warmer in summer than would be the case if it were not insulated. As this leads to increased expansion and contraction, the sealant materials or gaskets are subjected to greater strains. Alternatively, the joint width must be increased to allow for the deformation while keeping the strain constant. With a wider joint more sealant is required, there is a greater risk of the sealant's sagging, and, in some cases, it is not acceptable aesthetically. Furthermore, the final portion of the extension takes place when the temperatures are lowest and the sealant or gasket is coldest, and so, stiffest. Thus it can be seen that although joints can be devised to meet the principles set out in **CBD 40**, there may be some question as to whether, as the sealant materials deteriorate with the passage of time, they will retain their ability to control both rain and air leakage.

The foregoing discussion presupposes that the panel is not cracked. If it is cracked, the situation can be changed considerably. Some hairline cracking of concrete panels is not uncommon and such cracks are usually accepted provided they do not exceed 0.005 in. in width on the exterior face or 0.01 in. on the interior face. The large movement of panels under temperature variations must be allowed for by the way in which they are fastened to the structural frame. If this is not done satisfactorily then the cracks could open further or additional ones be induced. Once there is a crack through a panel, capillarity, gravity, or air pressure can move water into the wall and the principal defence against rain penetration has been breached.

*Vapour Movement.* Water vapour in the air within a building can move outwards through the wall by two methods - transportation by air currents, or diffusion through the wall material. Of the two, the former is by far the more important, as has already been stressed in **CBD 72**. The mechanisms causing the pressure differential through the wall have been discussed in **CBD 23**. If air that contains water vapour moves from a warm to a cold location, there is a danger that it will be cooled to below its dew-point and deposit water vapour by condensation (**CBD 1**). For this to occur, the air need not pass right through the wall. It can enter it, be cooled by contact with the colder parts of the wall, and return by convection to the inside of the building. In order to stop this convective air flow, either an air barrier is required on the warm side of the insulation or there must be no air spaces in which it can occur. The precast panel is on the cold side of the insulation and thus can control through-wall leakage only. The interior finish of a wall is seldom applied in the form of a continuous air-tight shield, and would be difficult to make air-tight because of the various pipes, ducts and electrical conduits that pass through it and the inspection panels that may be required in it. Thus, there is no effective air barrier to control convective air flow unless the insulation itself can form one or be applied so as to eliminate all air spaces.

The inside face of a precast panel is not usually finished to a high degree of smoothness and it is not uncommon for air spaces to be formed between the insulation and the back of the panel. Many of these spaces will be connected one with the other and with the inside of the building. Because of difficulty in applying insulation to the panel where it is opposite the structure, it is sometimes specified that the structure be insulated before the panel is erected, and that for the remainder of the area the insulation be applied to the panel after erection. Not only is it difficult to make a good air seal at the point of changeover, but relative movements between the two will open a crack at this point. This crack leads directly to the air space between the back of the cold concrete panel and the insulation that has been applied to the structure.

Thus in many instances there are a number of air passages either leading right through the wall or connecting with spaces on the cold side of the insulation. Airflow outward from the building into the wall in winter may deposit considerable quantities of water in the wall. This water runs down the back of the panel to emerge at the outside face of the wall or runs through various passages through the insulation and emerges at the inside face of the wall. On the inside, it runs down the wall or collects above suspended ceilings to cause the problems so often reported. On the outside, it forms icicles, leaves calcium carbonate stains, or etches the window glass.

Water vapour that moves by diffusion through the wall material is not normally a serious problem, since the rate of water movement by this mechanism is slow. Considerable time would be required to move a significant amount of water and few buildings are located where adverse weather conditions on the outside persist long enough for troubles to develop. Nevertheless it is desirable to analyse the vapour diffusion characteristics of a wall and assess the need for a vapour barrier in relation to the amount of water which may collect and also in relation to its potential to harm the wall (**CBD 57**). Dense concrete in the thicknesses normally used for precast panels, i.e., 3 in. or more, has a high resistance to vapour diffusion. In conformity with the principles set out in **CBD 57**, it should be used on the high vapour pressure side of the insulation.

*Thermal Conditions.* Items connected to a cold panel will have the same temperature as the panel at their point of contact, modified only insofar as the item concerned can feed heat into the panel and so raise its temperature locally. In view of the massive proportions of the panel and the high conductivity of dense concrete, it is easy for heat fed into the panel to flow away. As the panel is the structural element of the wall, items mounted on it do not have a compensatory easy path for heat to flow into them and so they tend to be cold.

Window frames are such items. They are cooled by contact with the cold concrete panel and in turn cool the edge of the window glass. The centre of the pane of glass may be warmer for various reasons. The higher thermal resistance of a multiple glazed window will keep the inner pane warm; heat supplied by the building heating system can have a similar effect, even with single glazing; and heat-absorbing glass will be warmed by the sun. Thus, a situation is produced in which the edge of the glass is colder than the centre and so is in tension. If the temperature difference is great enough, the glass will break. The cold frame and edge of the glass will, in any case, suffer from condensation.

The connections that hold the panel onto the structure will also be cooled at their outer end by contact with the panel. They, however, must be connected at their inner end to substantial elements of the building structure that provide a means to supply them with heat. Even so, they will be colder than the air inside the building. As there are often passages through which this air can enter the wall, condensation may take place on the connection. Rain leakage through defects in the panel or its joints can also wet the connections. Since the basic layout of the wall is predicated on the idea that the panel system forms a continuous air barrier, it is not possible to introduce outside air to the inside face of the panel to dry the connection. Thus, there is a general increase in the time of wetness, leading to more rapid corrosion.

### Conclusion

Precast concrete panels have great potential for walls of modern buildings. The designer must appreciate, however, that the total wall assembly must be designed as a unit to separate the internal and external conditions. In particular, the present practice of using a precast panel as both the structural unit of the wall and the external facade, with insulation on its inside face, increases the temperature range to which the panel and those items connected to it are subjected. This makes the task of achieving effective and continuing control of both air leakage and rain penetration more difficult and aggravates problems associated with thermal conditions.

A subsequent Digest will discuss a philosophy of wall design that overcomes these difficulties.