APPLICATION OF DESIGN PRINCIPLES IN PRACTICE

by J.C. Perreault

Webster defines the word "detail" as a "small or unimportant part," but a construction detail is not unimportant. Rather it is of extreme importance. It should not be small. On the contrary, it should be big, easy to read and easy to understand.

A good or bad detail will often make the difference between a good or bad installation. Building designers should bear in mind that those who actually build the buildings usually have no design background. They should not be forced to guess the designer's intention, or to play the role of designer, but should only be expected to build carefully, as detailed. That is why a detail must be precise, easy to understand and practicable. There should be no guess-work; if a problem arises in understanding the function or purpose of any item or specification or if a detail does not appear to be good practice, it should be queried. If a detail appears to be impossible to build, no attempt should be made to build it.

Attention to detail in design and construction is of prime importance if air tightness is to be achieved. In this regard one single thing will make a detail a success or a failure. This is the presence of holes. Indeed, in the investigation of many building problems an appropriate saying would be "cherchez le trou" (look for the hole). In practically all cases it will work.

Many examples of building problems directly resulting from openings or holes can be documented. In a certain hotel, for example, water appeared at the ceiling line of many bathroom walls, badly staining them. As usual, the first call went to the roofer, but because the problem occurred in mid-winter it could not be blamed on a roof leak. Because there were no windows in the bathrooms the window installer could not be blamed either. The leakage was eventually traced (by putting dye in the toilet water) to holes in the soil pipes. The pipes had inadvertently been placed in the wall directly behind the location chosen for the installation of the towel racks. In drilling holes in the walls to install the racks, the workman in many instances also drilled holes into the soil pipes, providing the paths for leakage.

Another example of "cherchez le trou" involved a shopping centre that had an outside pedestrian area beneath a large roof overhang (Figure 1*). Water dripping out of openings, intended originally to serve as air vents for the soffit space, did not concern the management except that the water froze on the sidewalk, forming patches of ice that were hazardous to the customers. The first proposed solution to the problem was simply

*Figures are presented at the end of these Proceedings.

to install heating cables in the sidewalk to prevent the water from freezing, but it was decided to try to find out what was causing the drips.

The overhang was formed by extending the corrugated steel roof deck over a concrete block wall. The soffit space was enclosed by the roof deck on top, by the block wall that separated the soffit space from the building, by precast concrete panels on the other three sides, and on the bottom by stucco applied to mesh, which was suspended by wires that passed through holes in the flutes of the corrugated deck.

In the soffit space it was found that frost, in some places to a depth of 1 1/2 in. (38 mm), had formed on the concrete panels, the steel truss members and the suspension wires. Large masses of ice were also present, apparently formed from water melted from the frost, which had run down the panel surface and had frozen into ice near the air vents. When the temperature in the soffit space became warm enough, the ice melted and the water-dripping problem began.

At first it was thought that the holes that caused the problem, by allowing warm moist air to move from the building to the soffit space where the water vapour condensed on cold surfaces, were those provided by the flutes of the roof deck, which formed openings between the top of the block wall and the underside of the deck. Although the drawing of the detail of this area called for these spaces to be filled, the material specified, glass wool insulation, did not provide an air seal, but served merely to filter the air passing through. It was replaced by polyurethane foam, and caulking was applied to any opening that could be found, but even after this had been done ice continued to form in the soffit space, and the water-dripping problem continued.

Another path for air leakage was eventually discovered, this being the space in the upper flutes of the deck. Air leakage by way of these flutes was possible because of holes drilled in the flutes to take the wires of the suspended soffit (Figure 1). Water formed by the condensation of water vapour collected in the flutes, and when its level reached that of the holes it flowed out and down the wires, many of which were coated with ice.

The air tightness of a building can be predicted from a study of the detailed drawings, which usually reveal openings in the enclosure, particularly when corrugated roof decks are used, whose spaces are difficult to seal. In fact on many drawings their sealing is not even specified. The detailed drawings also often reveal areas where it is impossible to install an air or vapour barrier; it is appropriate that designers use a dotted line to represent a vapour barrier because in practice it is usually incomplete or full of holes.

When things go wrong in a building, a good place to start the "cherchez le trou" technique is at the window heads, where many pieces of metal usually penetrate the wall, making it difficult, if not impossible, to install an air barrier. Another common source of trouble is the wall above a suspended ceiling, from which the vapour barrier and insulation are frequently omitted, thus allowing air leakage to take place through this part of the wall.

Insulation and vapour barriers are the two most misunderstood items in construction today. Many builders and designers apparently do not know exactly what these two things are supposed to do. Sometimes designers get carried away and provide two vapour barriers on the same element, but they never seem to be able to connect the vapour barrier of one element with that of another element.

In the choice and application of material for building, care must be taken to ensure that one specified material or installation does not destroy or interfere with other specified items. Sometimes two materials, seemingly good in themselves, when combined together can harm the other. In a certain building, for example, foil-covered insulation was specified to be glued to the back of precast wall cladding, a difficult installation job because of all the precast anchors, sway braces and furring channels that the insulation had to be cut around and sealed to. But in addition, the specification called for wet concrete to be poured against the aluminum foil, to cover precast anchors and provide fire separation between floors. The product data sheet for the insulation, however, clearly indicated that: (1) the material backing the foil contains water soluble salts, and if it becomes wet these salts have a corrosive action on the foil; (2) the foil, when placed in contact with wet plaster or mortar, will corrode. In spite of these warnings, however, both specification and drawing for the foil's application in this instance called for wet cement to be poured against it.

An interesting case of problems arising from air leakage involved one of the first high-rise buildings built on the rain-screen principle in Alberta. An account of this building and its performance, prepared by G.O. Handegord for a DBR Building Science Seminar,† referred to the construction and the problem as follows:

> "The wall consists of an inner wythe of 8-in. (200 mm) thick common brick together with cast-in-place reinforced concrete spandrel beams. Expanded polystyrene insulation, 1 in. (25 mm) thick, was installed on the exterior with spot applied asphalt adhesive."

> "The outer rain screen is a 4-in. (100 mm) thick precast concrete panel 18 in. (460 mm) long and approximately 5 ft (1.5 m) wide suspended to create an air space 1 in. (25 mm) wide between its inner face and the outer face of the insulation. The space is open to the outside at the bottom above

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† DBR Audio-Visual Presentations No. 12A and 12B, Feburary 1972. Presented at the Building Science Seminar "Walls, Windows, and Roofs," October 1971.

the window head and connected to the outside at the top by means of a special aluminum sill. The spandrel beams provide the air vapour barrier above the suspended ceiling and a polyethylene film acts in this capacity over furring on the inside of the masonry wall. The furring provides a means for securing the metal induction units and supporting the vapour barrier."

"In the early spring of the building's first year of occupancy, the outside temperature rose to a sudden and unusual high of 40°F (5°C) under sunny conditions. A series of icicles formed along the bottom edge of the precast panels on every floor and on every orientation except the south."

"It was eventually concluded that the primary source of moisture causing the icicles was that which had found its way into the inner wythe during the period of winter construction. The problem has not recurred to our knowledge, thus tentatively confirming the analysis. The situation prompted additional comments by those concerned as an example of the effectiveness of the system in allowing the escape of moisture which might ordinarily be trapped inside the wall to cause serious problems."

"Further observations by the designers indicated that some of the board insulation had become detached from the inner wythe as evidenced at the opening above window heads. The problem was remedied by the installation of small wedges between the precast panel and insulation. It is a credit to the designers that these difficulties have been reported by them in the literature for the benefit of others and the improvement of design technology."

The problem, however, did not stop; icicle formations, not as large as the first, showed up from time to time and the problem has required the expenditure of $50,000 in investigation and remedial work. The owner found it more and more costly to maintain heating and cooling operation and something had to be done to reduce air leakage and revamp the insulation.

In applying the "cherchez le trou" technique to this building, a source of air leakage was found where the anchors for the precast panels were located above and below windows, and at the corners of the building. The openings around the anchors were not sealed, permitting air leakage to take place, with the resultant condensation and icicle formation.

As is evident by the variety of buildings that are completed daily in Canada, there is no lack of creative genius and ingenuity on the part of designers and builders within the construction industry, but there seems to be a lack of understanding of the design process by builders. Much would be gained by the builders and owners if they tried to understand the design process. The architect's lot is not an easy one, even if one discounts the frustrations attendant on being an adjudicator, financial adviser, decorating consultant, and guardian of culture and aesthetics. His job is not made easier by the proliferation of new and inadequately understood methods and materials, and a quickened pace of construction. The successful performance of the building depends on his ability to choose the right material or system.

Just as builders must try to understand the designer's job, so must the designer realize that putting up a modern structure is also a formidable task. The construction superintendent spends a third of his time pushing papers and answering the phone. If he has to spend half of his remaining time figuring out how to build a particular detail and once it is done, he has to spend the other half of his time around a conference table trying to explain why he did it that way or why it doesn't work then he will not be able to do what he is good at doing, which is putting up the building.

The problems resulting from the faulty design and construction of buildings, and the need for joint action by designers and builders to overcome them, have been well summarized in the following words prepared by M.C. Baker for a DBR Building Science Seminar¶ which are worth repeating as a summary of this account of the application of design principles in practice:

> "In this age of unprecedented technological expertise, it should be possible to predict performance. The construction industry, however, appears to be plagued by an ever increasing amount of extremely poor performance, including buildings that leak, stream with condensation, overheat in summer or whose appearance is marred by streaking, discoloration, and material break-down on the exterior. It is obviously necessary to get back to scientific principles in the design and construction of enclosures for building. All details must be examined to ensure the continuity of air and vapour barriers, and the construction must be carried out in a manner that achieves this continuity. There is no doubt that the present unsatisfactory performance of many buildings, and building elements, can be overcome by a concerted team effort on the part of designers and builders."

¶ DBR Audio-Visual Presentation No. 11, February 1972. Presented at the Building Science Seminar "Walls, Windows, and Roofs," October 1971.