CANADA

BUILDING NOTE

JOINTS BETWEEN PREFABRICATED COMPONENTS

by

G. K. Garden

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Building components, large or small, must be assembled to produce the whole building with each component having a joint between it and each adjoining component. This is true in both conventional and prefabricated construction. The major differences between these methods of construction are that the larger the component, the greater is the differential movement at the joint and considerably less lineal footage of joint. The joint is normally the weakest link and the success of building with prefabricated components depends on the success of the joints.

The elements that can be prefabricated are so diversified that the functional requirements of joints are many, with special features for each classification. In view of the complexity, this paper will be confined to a discussion of the joints most commonly producing problems - those in the exterior enclosure of a building.

These joints must be so designed as to be inexpensive and easy to fabricate and assemble; be not easily damaged during handling and erection, and should allow for removal of an individual component. They should also present a good appearance. Materials used to fulfil the joint functions and requirements must be durable, and afford long life and low maintenance costs. It is also desirable that a joint be designed in such a way that manufacturing and installation inaccuracies do not seriously affect its success.

Joints in an exterior closure of a building must permit the joining of components to transmit loads as necessary, compensate for differential movements, tolerances, and clearances, and perform the functions of the wall. Joints between external wall panels, irrespective of their many other requirements and functions, must permit differential movements between panels and yet prevent rain penetration and resist air leakage and heat loss. A successful joint need not be a matter of luck, it can be achieved by good design based on a thorough rational analysis.

The magnitude and nature of differential movements between components being joined must be determined. It will seldom be possible to make a precise determination but reasonable accuracy can be gained. Differential movements

can be classified either as structural or those originating within the component due to dimensional instability of materials. Movements in joints take many forms which are most easily explained by considering the nature of stress which would occur in a jointing material. These stresses are longitudinal shear, transverse shear, tension, compression and both tension and compression by bending due to rotation of components about the joint or about an axis perpendicular to the plane of the components.

Major differential movements caused by accidental structural settlements can seldom be compensated for by joints between components and should never occur with today's engineering technology. Anticipated settlement should be controlled by major control joints not by cladding joints. Sway in tall buildings, deflection of beams to which components are anchored, creep in concrete columns, creep deflections and temperature variation in the structural frame will all cause differential movements between panels, the magnitude of which can and must be determined.

Irreversible dimensional changes in components are caused by curing shrinkage, post-hydration, carbonation, creep, etc., whereas reversible movements are mainly due to load variations and temperature and moisture changes. In order to gain an appreciation of the dimensional changes due to temperature or moisture, it is essential that a thermal analysis of the proposed wall be made. With knowledge of the range of temperature variation and the coefficients of thermal expansion for the various materials, the magnitude of differential movements and panel warpage can be determined as well as the dimensional changes of the component. In both composite and homogeneous panels, differential expansion that occurs between the inside and outside faces will exert forces striving to bend the unit. In analyzing a joint some consideration should be given to the fact that the components are seldom fabricated or installed at either of the extreme temperatures, consequently the joint will be opened or closed by temperature fluctuations from the width existing when the joint is made.

The magnitude of movements due to changes in moisture content is not so easily determined since values for dimensional changes with respect to moisture content changes are not available for all materials and those that are, are not readily available due to the lack of appreciation for this subject. Relative humidity is a ratio of the actual vapour pressure of the air to the saturated vapour pressure and the saturation vapour pressure is lowered by a lowering of temperature. Thus an appreciation of the relative humidity change caused by a temperature gradient can be gained from the thermal analysis of the wall. It can be stated that, exclusive of direct

wetting, the moisture content of materials increases with an increase in relative humidity which produces an expansion in the material. Conversely, a decrease in relative humidity will cause a shrinkage in the material.

Compression and tension stresses can obviously develop in a joint by thermal or moisture changes. Transverse shear can occur from panel warpage or deflections due to wind loads. Longitudinal shear can occur where panel joints do not make a four-way intersection or where panels are hung between mullions which in turn are hung from spandrel beams which deflect. With an appreciation of the magnitude of differential movements caused by structural movements and dimensional instability of materials and knowing the range of extensibility of joint sealing materials, the designer can determine the minimum satisfactory width of joint and the sealant or gasket necessary to prevent failure.

Tolerances between structure and components are normally compensated for by a three-way adjustable anchorage and by sufficient width, overlap, or interlock of joint members. The width of the joint required to compensate for the instability of materials will normally be sufficient to allow slight variations to take up those small dimensions not resolved by the anchorage.

Air leakage can be minimized by a tortuous configuration of the joint but is best stopped by a positive seal from component to component by a gasket or bead of sealant. With field applied gaskets and sealants, small imperfections occur or will in time develop permitting minute air leakages which will normally not be a problem if water does not come in contact with them. Air leakage from the interior of the building can be serious because in cold weather it is normally accompanied by condensation within the wall, resulting in water in the joint with the risk of accumulation and damage.

Thermal bridges can seldom be completely overcome, but it is important to provide sufficient resistance to heat flow so that interior surfaces can be kept warm enough to prevent surface condensation.

Rain leakage can be prevented by a complete and positive seal throughout the entire length of all joints but absolute perfection is essential. The required perfection is difficult to achieve because of inaccuracies in job site workmanship. Even more difficult is the maintenance of a perfect seal over a reasonable period of time due to the constant flexing, stressing, and aging of the jointing materials. A rational analysis of joint design, requires an examination of the mechanism of rain penetration. From this one finds that leakage can be easily controlled except where an air pressure difference forces water through a crack that

is bridged by water. If the control of rain penetration can be separated from the plane of air pressure drop, the force necessary to produce leakage will no longer exist. This can readily be accomplished by permitting the air pressures both inside and outside the crack to equalize. This is achieved by providing an air space behind the face of the joint with sufficient opening to the face.

It is usually more difficult to control rain penetration at vertical joints than at horizontal joints. It can readily be seen from examination of Figure 1 that when bridged with water the slightest failure of the seal at the outside face of the wall will allow rain to penetrate. By moving the seal to the back of the joint there will be a chamber of air at a pressure equal to that on the face of the building and water is not forced back to the air seal. The only way it can get to the air seal is by the kinetic energy of the drop or by the action of gravity and surface irregularities. It might be useful to mention at this point that rain water on the face of a building tends to accumulate in vertical irregularities and further modifications in detail are necessary. A loose-fitting batten will prevent water entry by kinetic energy but may permit the vertical flow of water in the joint due to water accumulation to become so great that it reaches the air seal. The introduction of a loose-fitting baffle in the joint will be more successful in controlling both these problems as well as permitting the air pressures on both sides of the joint to equalize. Vertical irregularities on the surface will minimize the volume of water that accumulates at the face of the joint.

It should be restated that, providing the air seal does not get wet, minor air leakages will not be accompanied by rain penetration.

This principle of rain penetration control has been studied by the Norwegian Building Research Institute, originally with respect to window leakage but it has been extended to all problems of rain penetration. It is being generally accepted throughout Europe and is proving very successful. There are of course a few refining considerations but the essential principles have been outlined. It should be pointed out, however, that the rain penetration control provided by a shingled wall has been appreciated for hundreds of years and is the simplest expression of this principle. The success of masonry cavity walls is also explained to some extent by this principle.

Joints between components will always be of concern but a thorough rational analysis can lead to complete success.

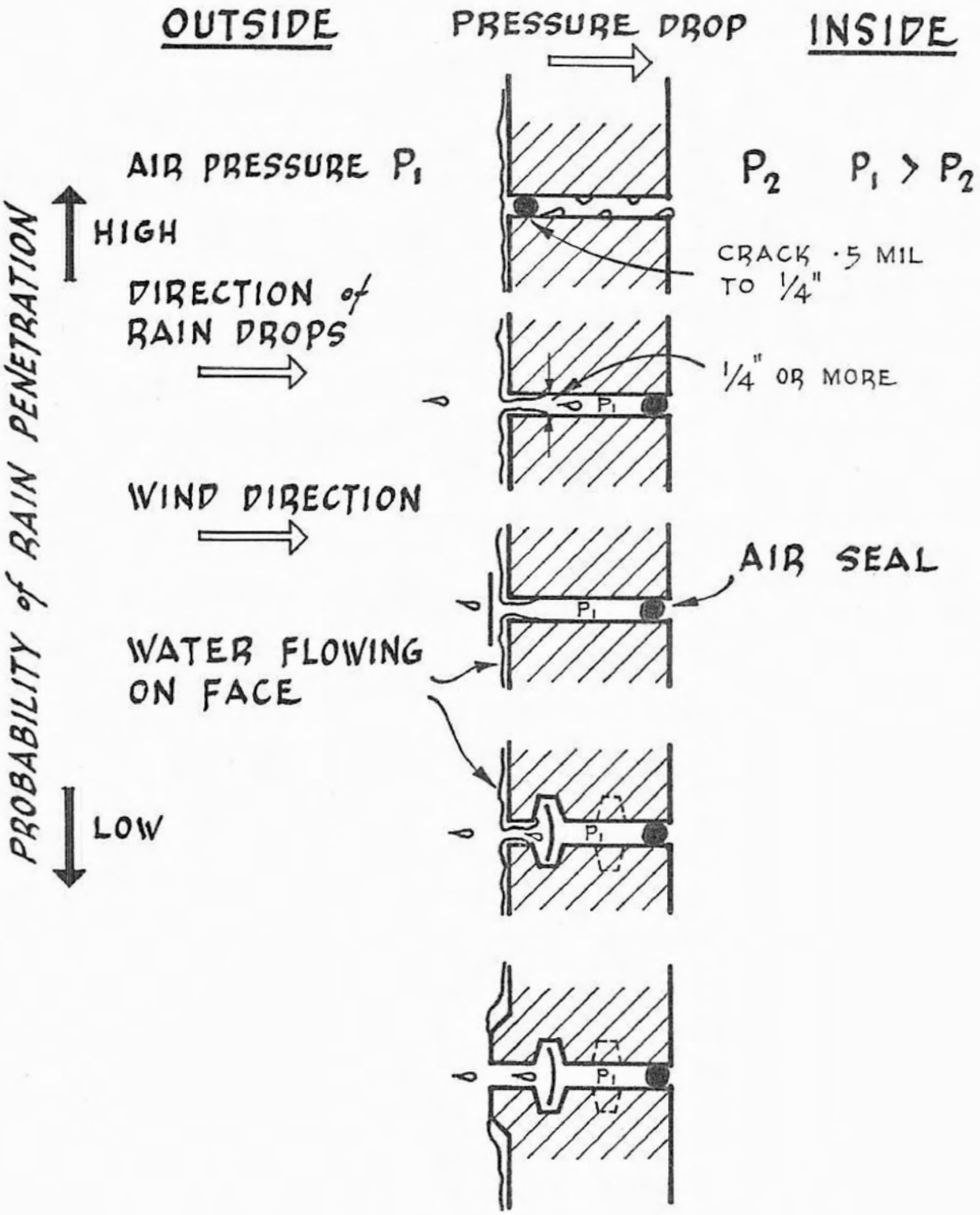

FIGURE 1 VERTICAL JOINTS