ARCHITECTURAL DETAILING FOR EARTHQUAKE MOVEMENT

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In the design of the six buildings for the Wellington Teachers' College+ an attempt was made to devise details which would avoid the imposing of distortion stresses on non-structural infill elements, resulting from deflections of the concrete structural frame during earthquakes.

Most of the buildings are based on a repetitive structural bay 16 ft. wide by 24 ft. deep, with 12 ft. storey heights. In-situ concrete columns carrying beams on the 16 ft. span form a simple longitudinal frame system, supporting continuous runs of precast prestressed double-T floor planks on the 24 ft. transverse span, with an in-situ concrete topping slab. Transverse beams are confined to the 8 ft. wide 'corridor' bays, as a spine. The buildings are generally of two and three storeys, with the soffit of the T-planks exposed internally as ceilings and with timber roof framing supported on steel ceiling beams.

Seismic forces are resisted by frame action in the column-to-beam junctions without shear walls. The design was started under N.Z.S.S.95 and the seismic coefficient adopted was 0.1g, i.e. Public Building standard at that time. In addition beams were checked to ensure that their strength in shear exceeded their ultimate strength in flexure and the frame was detailed to ensure satisfactory ductility.

The structural system is relatively light, such that maximum elastic inter-storey deflection was calculated to be 0.255", equal to .00177 storey height. In designing infill walling elements, $\frac{3}{8}$" to $\frac{1}{2}$" was assumed for movement of the structure. (Actual movement capability is generally greater than this). It was desirable that the detailing of fixings and junctions for exterior wall elements and interior partitions should allow for movements of this magnitude,

(a) to minimise the hazard to people, inside or outside the buildings, of dislodged elements; and

(b) to avoid secondary damage to infill materials, or reduce it to acceptable levels, bearing in mind economic considerations of first cost as well as repair costs.

Provision for movement was therefore incorporated in four main aspects of the detail design:

+ Wellington Teachers' College: Architects: Toomath & Wilson Consulting Structural Engineers: Hollings & Ferner.

1. Fixings of pre-cast cladding panels.

2. Cladding panel joints at columns.

3. Fixings of window frames to structure.

4. Interior partition fixings.

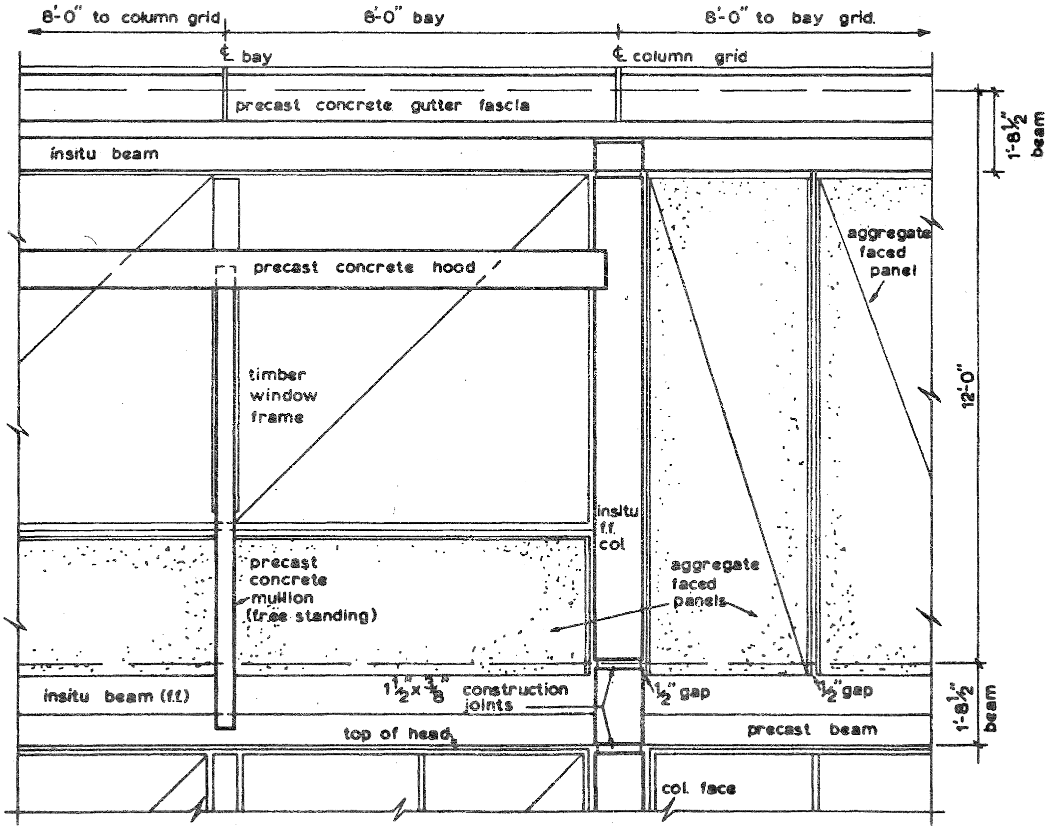


Fig. 1. TYPICAL PART BAY ELEVATION.

In general the provisions adopted are relatively simple and unsophisticated, invention being tempered by budget factors. Most of the details are based on sliding pockets and/or resilient members, to accommodate the anticipated degree of movement while ensuring positive location of the infill elements within the structure.

In simple terms, the structural frame was regarded as a flexible skeleton and the infill elements as rigid planes firmly fixed to the floor slabs on which they stand. Consequently, each bay of infill elements is sufficiently separted from the structure at sides and top to allow movement of the main frame, without imposing stresses on the wall elements.

Detailing therefore becomes a process of devising practical means to hold elements in their proper position, to retain weather tightness in external joints, and to allow infillings to remain undistorted rectangular planes while the structure moves alongside and above them.

1. Fixings of precast cladding panels

The 4" thick basalt-faced concrete exterior wall panels are basically of two types, either full-height panels 4'0" wide by 10'3" high between floor beams or spandrel panels 7'6" wide by 3'0" high below window areas. (fig. 1). All are firmly secured at the floor slab by two steel angle cleats, fixed by bolts to the slab and into sockets cast in the panel backs. The fixing hole in the upper leg of these cleats is slotted, to eventually allow sideways rocking of the panels to relieve strain if the separation distance from the structural frame is overcome in a very strong earthquake.

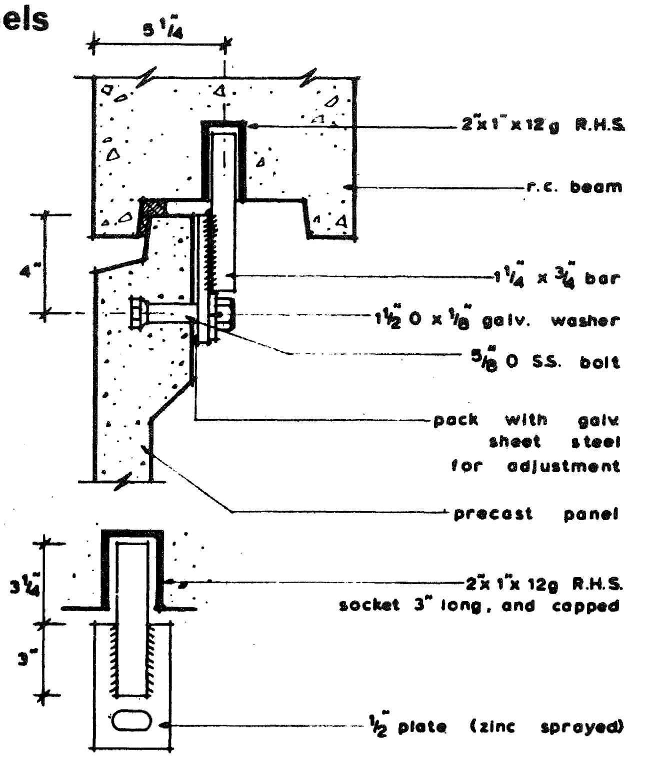


Fig. 2 HEAD OF PRECAST PANELS

The top of each full height panel is attached by a pair of fixings to the soffit of the floor edge beam, each consisting of a $1\frac{1}{4}$" x $\frac{3}{4}$" steel bar bolted to the back of the panel and projecting vertically to engage in a 2" x 1" steel tube socket cast in to the beam (fig. 2). Side clearances within the tube allow for displacement of the beam by approximately $\frac{3}{8}$" each way, while the closer fit in the fore-and-aft direction serves to locate the panels. A compressed strip of bituminous foam plastic seals the joint of panel to beam, while allowing movement to occur.

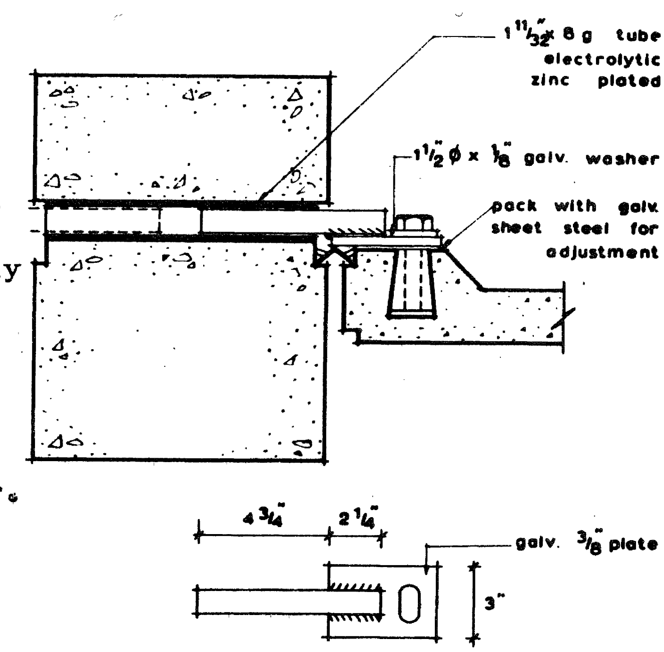


Fig 3 JAMB OF SPANDREL PANELS

The upper corners of spandrel panels abutting columns have a single fixing which similarly provides for a sliding action. In this case a 1" diam. rod is bolted to the panel back and projects horizontally into a $1\frac{1}{4}$" diam. tube which passes through the column (fig. 3). Panels on both sides of a column share the same tube which thus allows sideways deflections of the column.

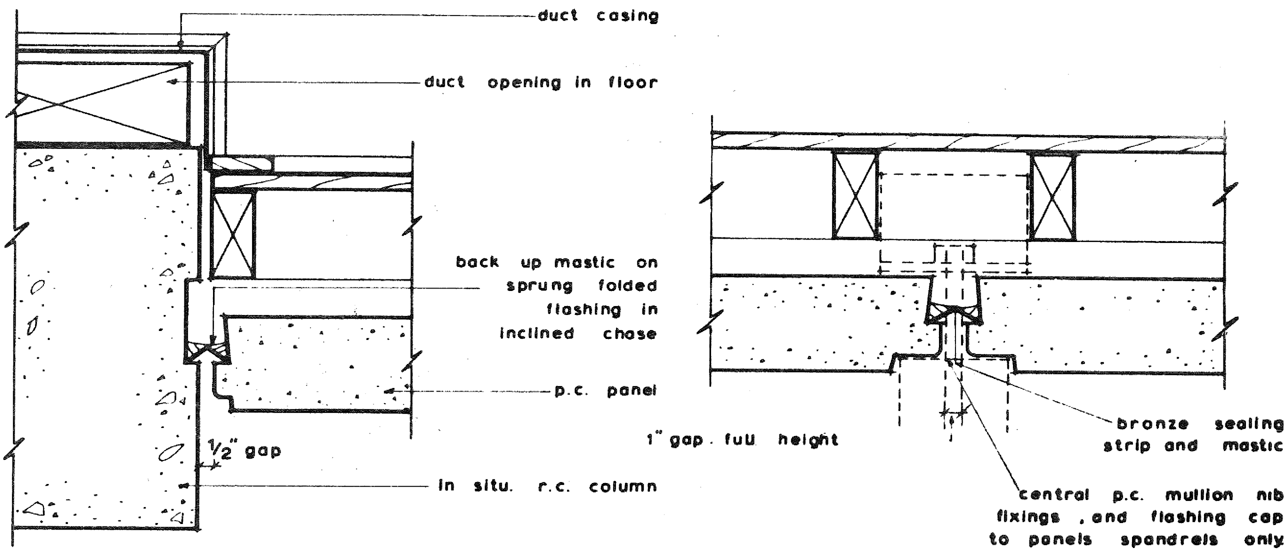


Fig. 4 CLADDING PANEL JOINTS

For all panel fixings stainless steel bolts were used, and all steel components are galvanised. The fixings are designed to resist a force of 1.0g.

2. Cladding panel joints at columns

Vertical joints between panel and column sides and between panels themselves are gapped a minimum of ½" to allow relative movements (fig. 4). The gap is bridged by 35 swg phosphor bronze strips, folded to a V shape, which serve as the primary weathering and take up earthquake movements by spring action. The strips are so prebent as to require a minimum ½" compression for insertion from the back of the panels into rebates formed in the column sides and panel edges. Secondary weathering and draught proofing is achieved by backing runs of butyl mastic, protected from weather deterioration by the permanent metal flashing strip.

On the job, once a crude but effective jig had been devised to compress the flashing lengths for insertion, no particular difficulties were encountered with the installation and fixings of the whole cladding system.

3. Fixings of window frames to structure

As longitudinal movements of the structural frame up to ⅜" in each story height were anticipated, means had to be adopted to avoid racking of the timber window frames. The joinery frames are 7'3" square, two per bay with a 6" separation at mid-bay which provides tolerance for accurate placement against columns. The sills are fixed, as normally, to a 4" stud wall framing which lies behind the spandrel precast panels.

The jambs, however, stand 1¼" clear of the column sides (fig. 5) and are located by

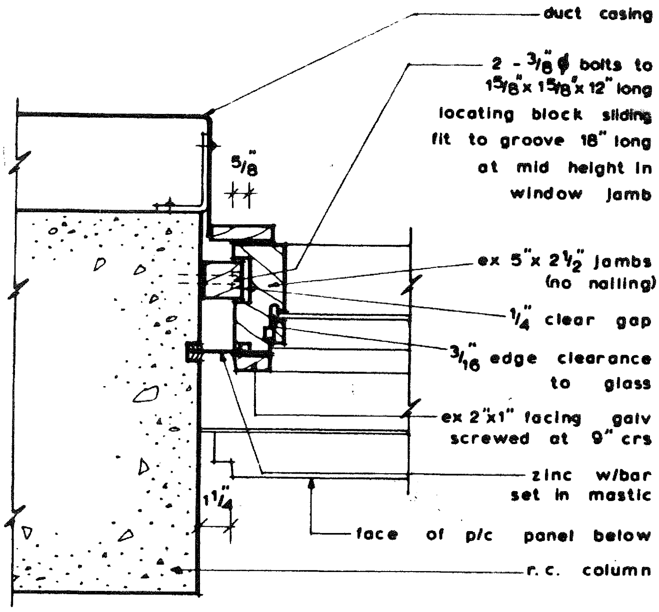


Fig. 5 WINDOW JAMB

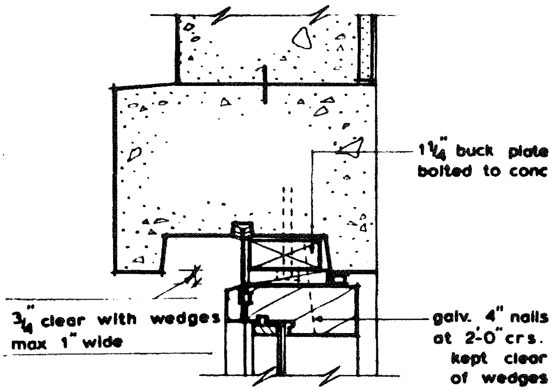


Fig. 6 WINDOW HEAD

a 12" long ex 2" x 2" block bolted to the column at mid-height of the window frame and engaging in a pocket rebated in the back of the jamb. A side overlap of $\frac{3}{8}$" together with a $\frac{1}{4}$" clearance at the back of the pocket, will allow free sideways movement of the column (in the order of $\frac{1}{4}$" at this height of 7 ft. above the floor).

The window head is kept $\frac{3}{4}$" below a timber fixing plate bolted to the beam soffit (fig. 6), the gap being bridged by 4" galvanised fixing nails which are expected to deflect when subjected to movement of the beam in opposition to the planar resistance of the joinery frame stiffened by glazing. (In execution construction tolerances tend to reduce this $\frac{3}{4}$" clearance, and a greater dimension appears desirable to ensure effectiveness of the detail).

In the fixings of jambs and heads, adequate holding power against wind forces had to be borne in mind, while retaining flexibility. A fairly severe exposure to the hurricane of April 1968 produced no dislodgement or leakage in the window frames.

As a further precaution against imposed stresses which could lead to breakage of glass, an edge clearance of 3/16" was specified around all panes of glass beaded into the frames.

Finally, the adoption of waterbar flashings fixed on the face of the frames, besides facilitating initial installation of frames and flashings, allows easy access for repair of the flashing system if a major earthquake exceeds its capacity to absorb movement.

4. Interior partition fixings

Interior partitions are generally of conventional 5" stud construction, lined with fibrous plaster sheeting, particle board or timber boarding, frequently in

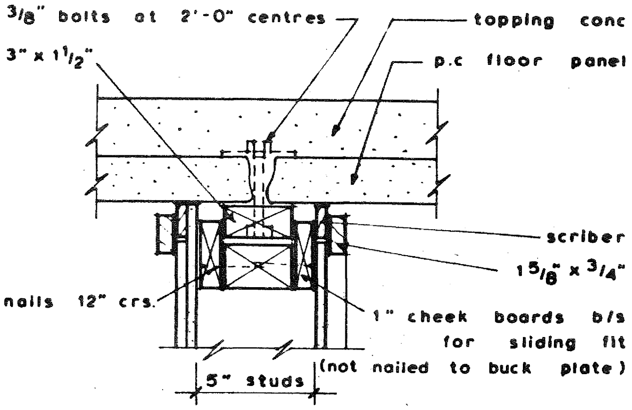


Fig. 7 PARTITION JUNCTION WITH CEILING

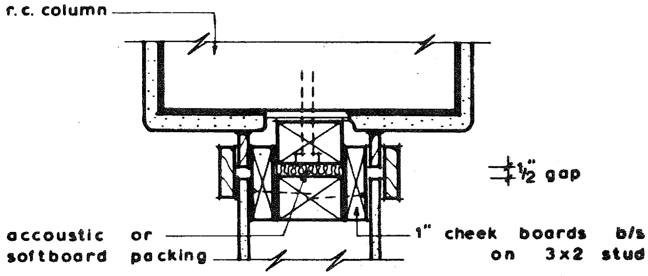


Fig. 8 PARTITION JUNCTION WITH COLUMN

multiple layers for effective sound reduction.

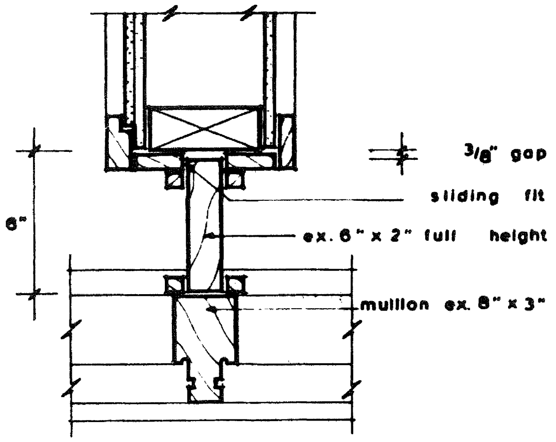
Transverse partitions, normally 23 ft. long and 11'6" high, can be located on any 4'0" module line, on which lines window mullions also occur. As the sheet linings result in a stiff diaphragm, a system of sliding joints was adopted at the ends and top of the partitions to allow independent movement of the structure in an earthquake.

Longitudinal partitions, however, occuring mainly at corridors on the line of the stiffer direction of the buildings, were fixed conventionally in this case as the cost of special details was not considered warranted. These partitions are of less height (10'0" under beams) and 15'0" in length - ideally, of course, they too should have sliding connections to the structure.

At the head of the transverse 5" partitions, the top plate is 3" x 2" flanked by upstanding 1" boards (fig. 7). A separate 3" x 1½" buck plate is fixed to the ceiling structure and lapped by the cheek boards, thus locating the partition laterally while allowing free sliding of the buck plate with the structure.

A similar device is adopted at the vertical junction of partitions with internal columns (fig. 8). At the intersection of two partitions, the end stud of the transverse wall is separated from dwangs in the longitudinal wall by ½" softboard packings, which can crush under load.

Where transverse partition abut window mullions, provision is made for lateral movements of the window wall by variants of the sliding principle. From co-ordination with other design requirements (blindboxes, column duct facings, ceiling margin continuity, etc.) the main partition framing stops short about 5" from the window frames. Bridging this



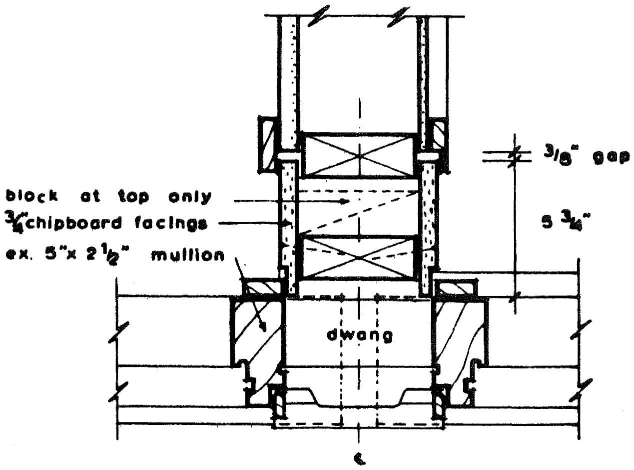


Fig.9 PARTITION JUNCTIONS AT WINDOWS

space are infill members (fig. 9), consisting of 6" x 2" uprights at single window mullions, and paired cheek facings on independent studs at doubled mullions.

In each case $\frac{3}{8}$" tilting movements either way of the window wall are accommodated by the lapping details of the members and adjacent trim, working within the $\frac{3}{8}$" clear gaps provided.

At exterior columns the partitions stop 4" from the back of the columns, the resulting space being enclosed as a duct of column width by sheet steel casings which themselves provide adequate resilience for deflection, as a result of their L - shaped form.

At the perimeter of all partitions abutting the concrete structure the finishing battens, cornices, architraves, etc. are held $\frac{1}{2}$" away from the adjoining structure, to provide a shadow margin which will mask the cracking or opening of joints, and absorb a degree of local crushing, while at the same time allowing the trim to be fixed without scribing to uneven surfaces.

Conclusion

The various details discussed above may serve to emphasise the close collaboration that is required between architect and engineer, in order to recognise and deal with the problems of secondary damage in relatively flexible structures. It is hoped that these details, though by no means a total solution, will provide this group of buildings with a greater degree of protection than usual, at nominal cost.