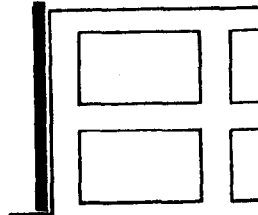


## EXTERIOR WALLS

### INTRODUCTION



The exterior wall performs several diverse functions simultaneously: when load-bearing, it provides physical support for the structure; it exists as the principal barrier between interior and exterior space and their frequently widely-differing environments; and its exterior surface and configuration constitute much of the public image of the building it encloses.

Subject to various structurally-induced stresses and strains, constantly exposed to the elements and to public scrutiny, the exterior wall subsystem is one of the most difficult to design for continuing, satisfactory performance over the life of the building. Exterior windows and doors further complicate design, detailing and construction. Despite these complications, failures of this subsystem are infrequent.

The examination of the exterior wall, in the context of the 'Buildings In Use' Study, is confined to the investigation of performance in the areas of durability, weathertightness and appearance, and to attributes which affect performance in those areas. There are numerous generic materials commonly used in this subsystem, and the findings are discussed separately under the following materials-oriented categories: brick and concrete masonry; in-situ concrete; and curtain walls and other openings.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Their exterior walls were examined to determine what, if any, movement had occurred since completion of the structures, and how well the materials and systems used had weathered. The 'fit' between individual components within the various wall systems was also examined quite closely.

Equipment used in examining and testing of the exterior walls included: a plumb line, to check for wall deflection; a small rule calibrated to 1/64 inch, to measure the width and depth of cracks; a measuring tape, to determine the length of walls and cracks in them; and a camera, to record instances of deterioration.

For a more detailed description of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974.

A comparison of the measures and observations was made with existing standards to determine the quality of performance.

SUMMARY OF PERFORMANCE

	<b>P</b>	<b>R</b>	<b>S</b>	<b>M</b>
<b>EXTERIOR MASONRY</b>				
Structural Stability	O	⊙	NA	O
Thermal Stability	O	⊙	NA	O
Other Stabilities	O	⊙	NA	O
Air-Moisture Penetration	O	O	NA	⊙
Stain/Discoloration	⊙	O	NA	O
Deterioration	O	O	NA	O

BUILDINGS IN USE STUDY

EXTERIOR WALLS

	A-3			
EXTERIOR CONCRETE				
Stability	NA	NA	O	NA
Air-Moisture Penetration	NA	NA	O	NA
Stain/Discoloration	NA	NA	O	NA
Deterioration/Delamination	NA	NA	O	NA
CURTAIN WALLS				
Structural-Thermal Stability	O	O	O	O
Air-Moisture Penetration	O	O	⊗	⊗
Stain/Discoloration	O	O	O	O
SUMMARY OF FINDINGS Deterioration/Delamination	O	O	O	O

Brick masonry exterior walls with block back-up were used extensively in three of the four schools studied. The difference in the specifications of these similar products, their storage conditions and their detailing and construction all influence performance during the useful life of the subsystem. Problems (below 85% performance level) were found at the Richards School. Conditions which bear watching were found at Mt. Healthy. The Parkside School was generally satisfactory (85-95%).

Movement and attendant minor cracking due to a number of factors-- structural loading, thermal expansion/contraction and shrinkage-- were found at numerous locations at the Richards School. However, only a few of these cracks due to movement cause more than aesthetic problems. Some minor movement due to thermal expansion is also taking place at one or two locations at

Mt. Healthy. At certain locations at Mt. Healthy School the brickwork is very badly fitted. Future deterioration is probable at these locations and only time will tell, in this relatively new facility, whether real problems will emerge. The Parkside School, aside from minor areas of efflorescence, is in excellent condition.

The concrete exterior walls of the Smith School perform satisfactorily in all respects. Though extensive staining and discoloration is present and would, under normal circumstances, affect aesthetics, the intention of the architect was to allow, possibly even encourage, such occurrences. Thus, what in a normal context would be judged unsatisfactory is acceptable, even desirable, under these circumstances.

Performance of the Cor-ten curtain wall at the Smith School is satisfactory based on the same criteria used in judging the concrete exterior wall at that school.

The performance of door and window openings of the exterior wall in all schools is generally good. The doors at the Richards School are ill-fitted and do allow some air and moisture infiltration.

In all buildings studied children have dug caulking out of window framing. Caulking is rubbery and fun to throw.

Routine maintenance is necessary on the ramps of the Smith School. After some 5 years of exposure the paint is chalking and in some cases flaking (this has just been repainted!). Polyurethane insulation, sprayed on the undersides of exposed slabs is undergoing deterioration and is flaking and falling off in places.

## DETAILS OF FINDINGS

## EXTERIOR MASONRY

## EXTERIOR MASONRY WALLS/STABILITY, STRUCTURAL LOADS (Fig. A.5)

Results: Performance was satisfactory at the Parkside and Mt. Healthy Schools. Performance at the Richards School was at the 75-85% level due to cracking evident under major roof truss supports in the multipurpose room.

Probable cause: Richards School. Probably due to actually higher loads than allowable under original design conditions or to expansion of restrained truss.

Discussion: There is a long vertical stepcrack emanating from each of the lowest spanning trusses of the multipurpose room. The cracking is long (over 10' is typical), visible but minor (1/16" or less). Due to the age of the building one can assume that this structural adaptation has been completed and that further consequences will not occur. There are no problems other than aesthetic directly related to this phenomenon, however, there are more serious indirect effects (see roofs). The probable cause of this phenomenon is an excessive loading on this lowest truss due to water trapped in the drainage valley directly above it. Other possible causes are: bearing seat improperly specified or installed; transfer of some loading from upper trusses to this one and; high stresses caused by thermal expansion and the restrained nature of these trusses (see Roof P. B-5).

## EXTERIOR MASONRY WALLS/THERMAL STABILITY (Fig. A.6)

Results: Performance was satisfactory at the Parkside School. Some minor accommodation in the exterior wall at Mt. Healthy has taken place. The performance was below the 75% level at the Richards School. Expansion of roof truss over the multipurpose room causes wall movement which, in turn, causes moisture infiltration.

Probable cause: Lack of provision for the expansion of a long span truss.

Discussion: Mt. Healthy. At two locations the exterior wall is continued out of the building for some distance and that portion is exposed to the elements on both sides. The varying rates of expansion of the two portions of wall which are continuous implies some accommodation, since there is no expansion joint between the two portions. Some hairline cracking has occurred, however, this should be the extent of accommodation due to the use of horizontal reinforcement in the walls. This reinforcement should adequately absorb all thermal stress and minimize movement of the wall which otherwise would have caused major problems.

At the Richards School, a number of problems due to thermal movement have occurred. The first concerns the roof trusses spanning the multipurpose room. These 54 foot trusses are restrained at their ends causing wall movement and real leakage problems as described in the 'Roof' section of this report (See P. B-7).

Two other minor, but easily visible effects have occurred due to thermal expansion/contraction. These are primarily of academic interest because they are primarily aesthetic problems and visible primarily to researchers.

The long (78 feet) north-south wall forming the eastern end of the school has expanded and cracked the two perpendicular walls at their common T-joint. This cracking, while easily visible is minor and is only an aesthetic problem. This long wall, while designed without an expansion joint is broken up by entrance doors and an air intake grill. Notwithstanding these potential places which could have provided relief from expansion the wall did expand (fig. A.6)

At the west end of the school there are two wings with 84 foot masonry walls perpendicular to the main body of the building. Though an expansion joint is provided at this juncture there is easily visible, though functionally harmless, cracking at this T-joint. Though we have not dissected this area we believe a logical explanation is an incorrectly constructed joint which

allows a rigid connection at the point and in essence not allowing proper expansion.

EXTERIOR MASONRY WALL/STABILITY (OTHER) (Fig. A.8)

Results: In certain classrooms adjacent to 'stub' corridors there is a constant, though minor, cracking at the caulked joint of the two walls.

Probable cause: The two walls are probably 'tied' at this T juncture and since no expansion joint is provided the exterior wall has moved causing a slight separation.

Discussion: Though visible (1/16"-1/64") these cracks are not functionally detrimental. Properly recaulked and painted they would probably not reoccur.

EXTERIOR MASONRY WALL/AIR-MOISTURE PENETRATION

Results: The varied phenomena noted in the previous sections have not resulted in air and moisture infiltration.

Probable cause: Not applicable.

Discussion: Not applicable.

EXTERIOR MASONRY WALL/STAIN AND DISCOLORATION

Results: Performance levels of exterior masonry walls were satisfactory in this regard at all schools except Parkside where some efflorescence has occurred.

Probable cause: Dissolved salts in the brick (or sometimes mortar) leaching out on to the surface.

Discussion: This is not an infrequently found condition. Though correctly specified and installed, efflorescence of masonry exterior wall may still occur. Knowledge of the quality control of the manufacturer and the use of a 'hard' brick which is more resistant to moisture penetration would

help to reduce the probability occurrence of this white staining on the brick's surface, but not necessarily prevent it.

EXTERIOR MASONRY WALL/DETERIORATION

Results: Performance was satisfactory at all schools.

Probable cause: Not applicable

Discussion: Not applicable

EXTERIOR CONCRETE

EXTERIOR CONCRETE: STABILITY (ALL ASPECTS)

Results: Performance was satisfactory.

Probable cause: Not applicable

Discussion: Not applicable

EXTERIOR CONCRETE: AIR AND MOISTURE PENETRATION

Results: Performance was satisfactory.

Probable cause: Not applicable

Discussion: Not applicable

EXTERIOR CONCRETE: STAIN AND DISCOLORATION

Results: Performance was satisfactory.

Probable cause: Not applicable

Discussion: Smith School. As mentioned in the Summary of Performance staining of the in situ concrete would not hinder performance--not even aesthetic performance, and indeed staining of the concrete is extensive due to the initial rusting of the Cor-ten steel.



## EXTERIOR CONCRETE: DETERIORATION/DELAMINATION

Results: At the Smith School there are one or two individual instances of serious deterioration of the exterior concrete surfaces which should be corrected.

Probable cause: The overall low, or 'brutal' quality of the finish as specified by the architect has resulted in a few places in which performance is affected.

Discussion: A low quality of finish for the in situ concrete is acceptable, even encouraged, in this building for reasons mentioned previously. Thus, patches, spalling, honeycombing and formwork markings are plentiful and acceptable. However, at the exit ramp leading from the 3rd and 4th grade levels the concrete supports have 'lost' enough material to cause exposure of the reinforcement, perceptible movement of the bearing plate and some displacement in the ramp itself. Over time this will become serious and we recommend correction as soon as possible.

## CURTAIN WALLS

## CURTAIN WALLS: STABILITY (STRUCTURAL/THERMAL)

Results: Performance levels were satisfactory in this regard at all schools.

Probable cause: Not applicable

Discussion: Not applicable

## CURTAIN WALLS: AIR/MOISTURE PENETRATION (Fig. A.9)

Results: Performance levels were marginally acceptable at most facilities studied (85%). Severe weather and windblown rain does cause instances of water infiltration but these occurrences are infrequent. The fit of the exterior doors at Richards is not tight enough to prevent air infiltration--this is correctable. At the Smith School water flowing down grooves in the metal wrapped sloping ramps has penetrated through the seal at the lower ends

of the ramps and has entered the building. This has been corrected. Probable cause: The original detailing, weathering and the removal of caulking by students have all contributed to deteriorated performance.

Discussion: The level of performance required of this subsystem does not permit air and water infiltration even during severe weather. Thus even the minimal occurrences of problems which were found constitute a lower level of performance. At the Richards School this is a problem in a few classrooms. The original exterior doors were 'hollow core' type, failed, and were replaced with solid core exterior doors, some of which may need refitting and weather protection.

At the Smith School the detail at the lower end of the sloped ramps is extremely difficult to solve with the use of the corrugated steel exteriors. The water races down the valleys of the corrugated metal exterior and is directed with some force at the joint with the curtain wall which could not perform adequately. The original detail has been modified with silicone caulk which seems to be performing adequately. It should be noted that the working drawings examined used the corrugated steel wound around the ramp which would have simplified the detail. The ramps were built with the metal corrugations running longitudinally.

At Mount Healthy recaulking is now taking place. The original material used on the industrial sash is dry and coming loose allowing water to enter.

#### CURTAIN WALLS: STAINING/DISCOLORATION

Results: Performance levels were satisfactory at all buildings examined except at Smith where extensive chalking of the painted steel ramp siding is evident.

Probable cause: Weathering.

Discussion: Chalking is a normal result of weathering of a painted surface. The ramps need repainting.

NOTE: They have just been repainted (1974).

#### CURTAIN WALLS: DETERIORATION/DELAMINATION

Results: The removal of caulking from window frames is present at the Smith, Parkside and Mount Healthy Schools. Normal deterioration of the wooden window frames is present at Richards. The original exterior hollow core doors at the Richards School deteriorated within one year of occupancy and were replaced with solid core doors. With these exceptions, performance levels were satisfactory. The galvanized industrial sash glazing at Mount Healthy is beginning to rust in spots. This is being repainted as a preventive measure.

Probable cause: Kids dig out caulking from around windows. Weathering has caused deterioration of Richards frames.

Discussion: The removal of caulking by kids at three of the facilities is surprising. Subsequently we noted similar situations at elementary schools in other localities. We are no longer surprised by this phenomenon. Covering the caulking with a metal strip, which has been used at the Smith School is effective in preventing occurrences, as is the use of hard or preformed gasketing such as a neoprene gasket or an elastomeric sealant such as polysulfide or silicone. Caulking materials which are easily removed and fun to throw or which have 'play' potential should not be used.

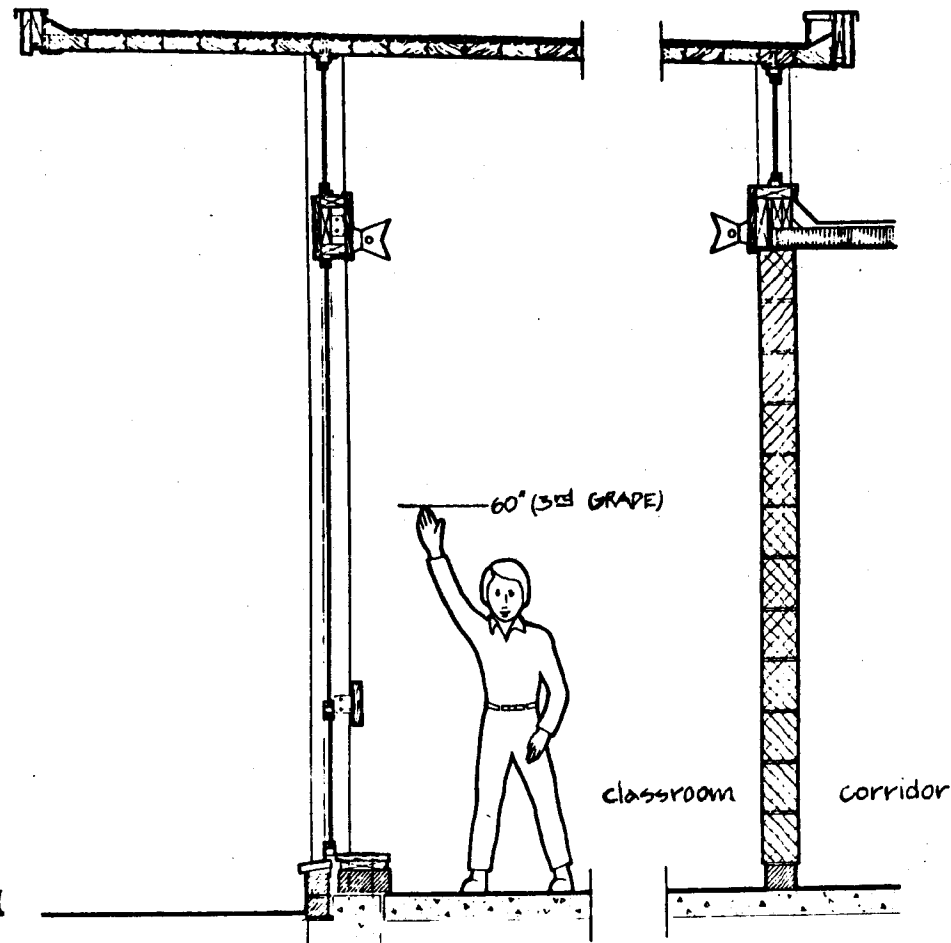


fig. A.1  
PARKSIDE SCHOOL/SECTION

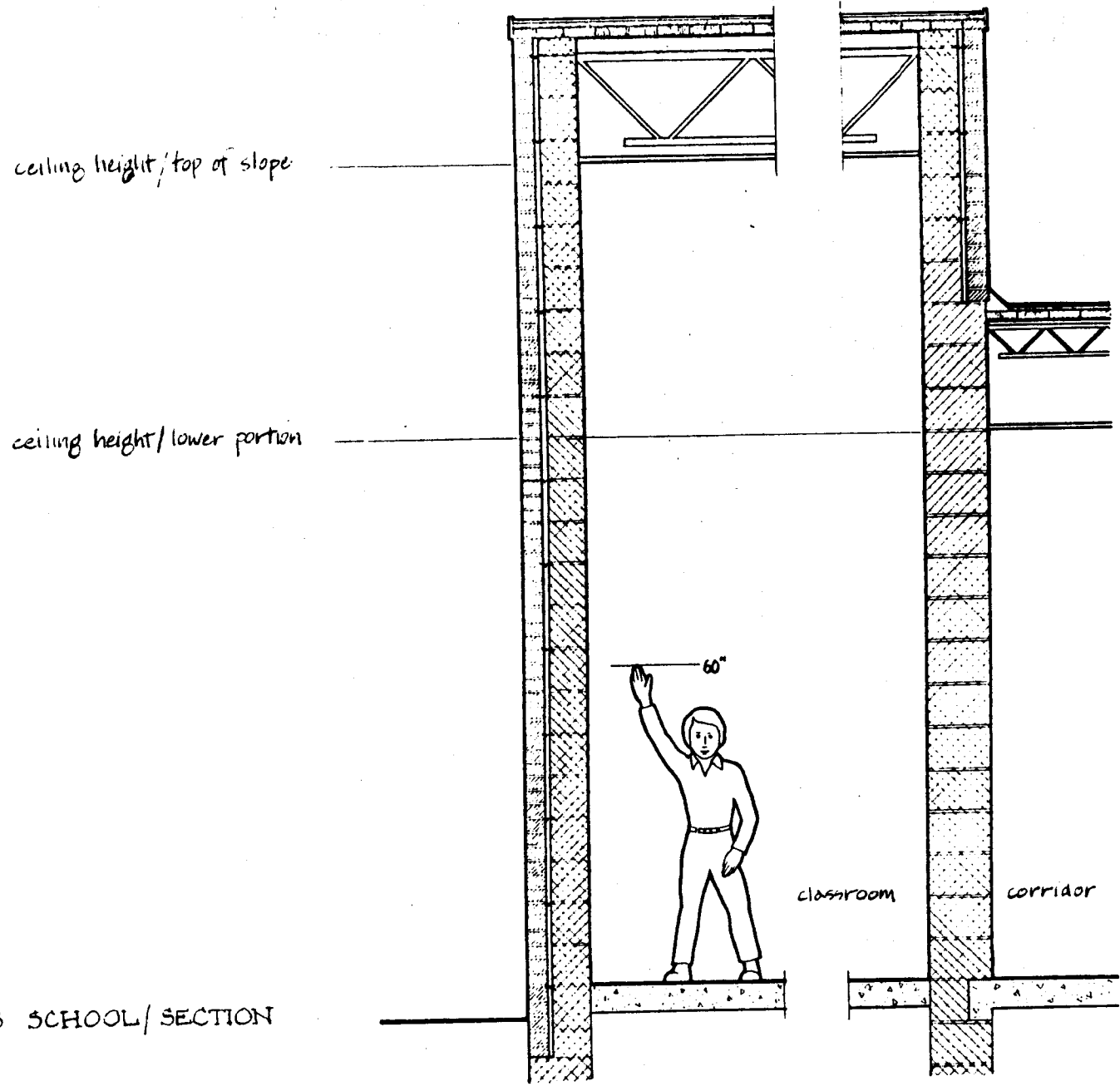


fig. A.2  
RICHARDS SCHOOL / SECTION

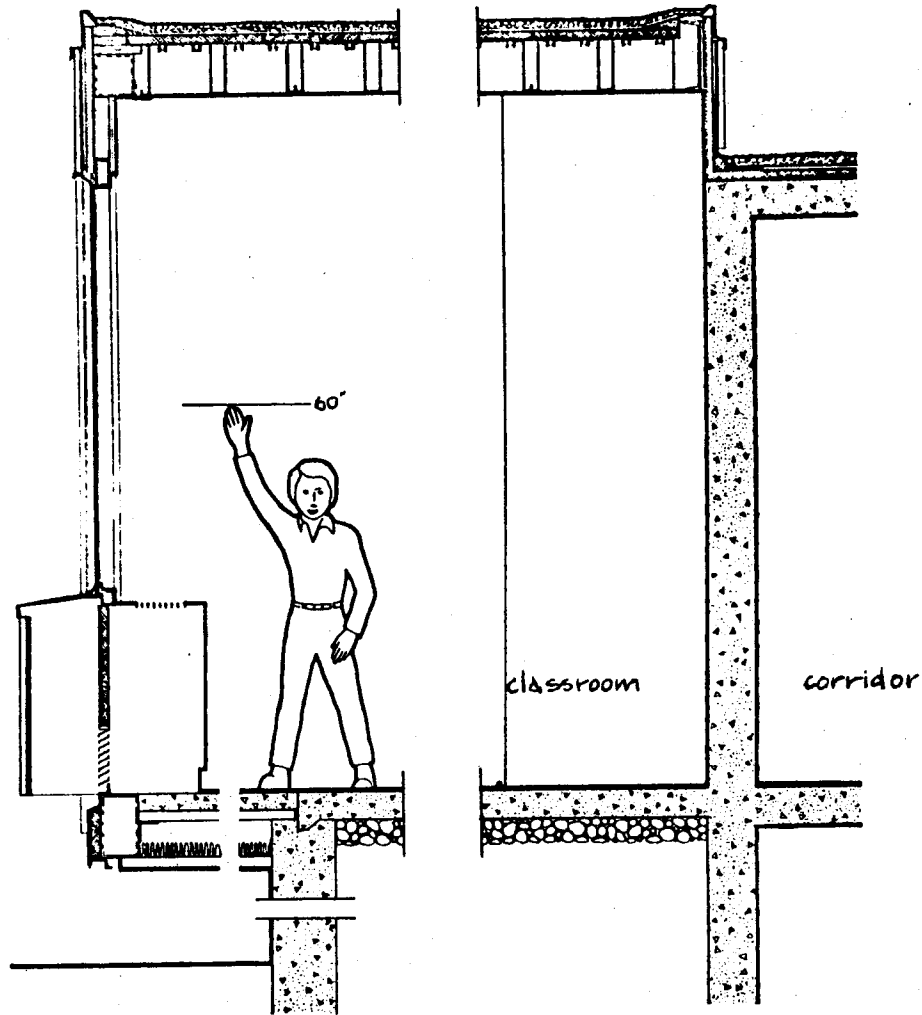


fig. A.3  
SMITH SCHOOL/ SECTION

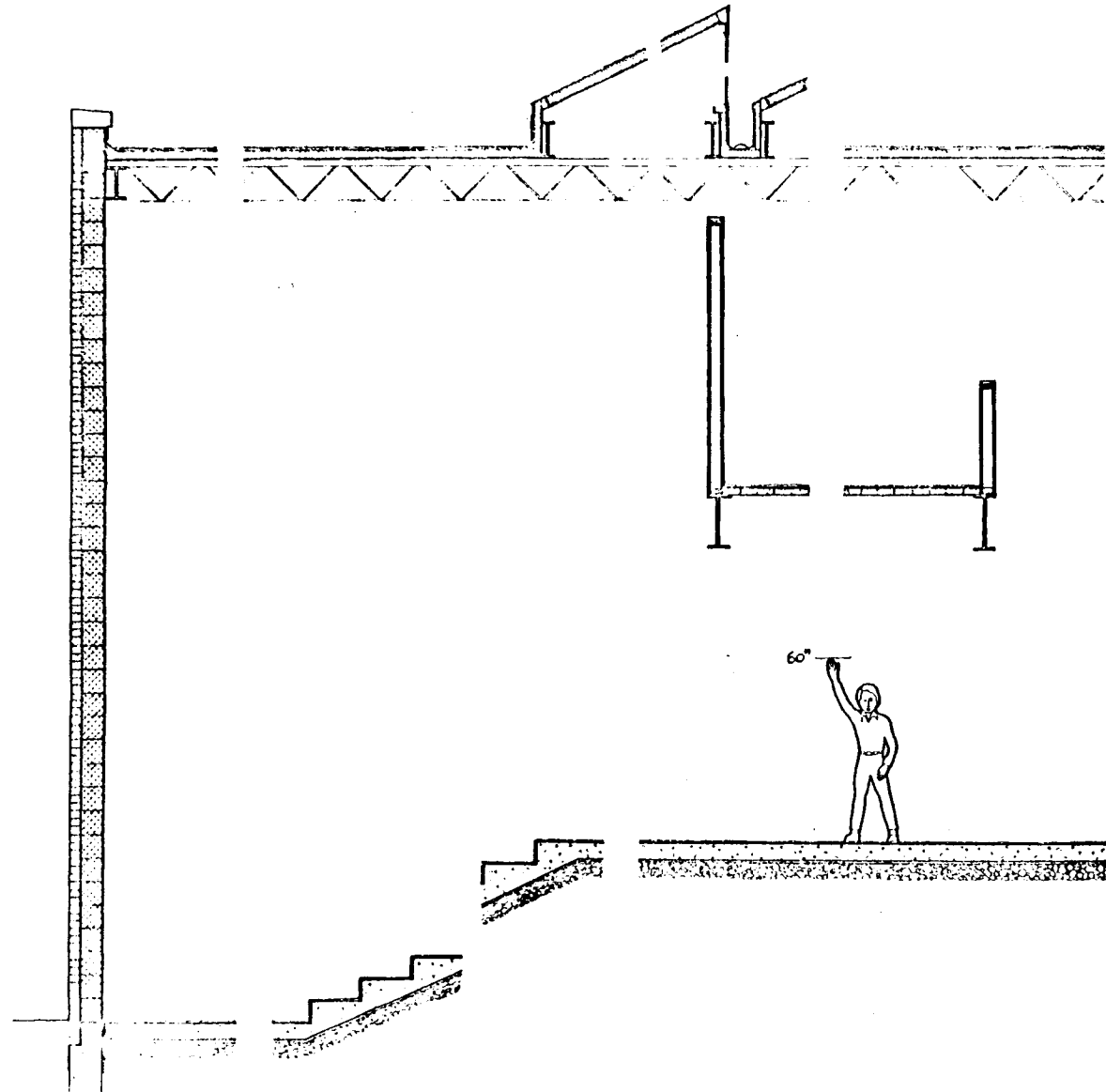


fig. A.4  
MT. HEALTHY/SECTION

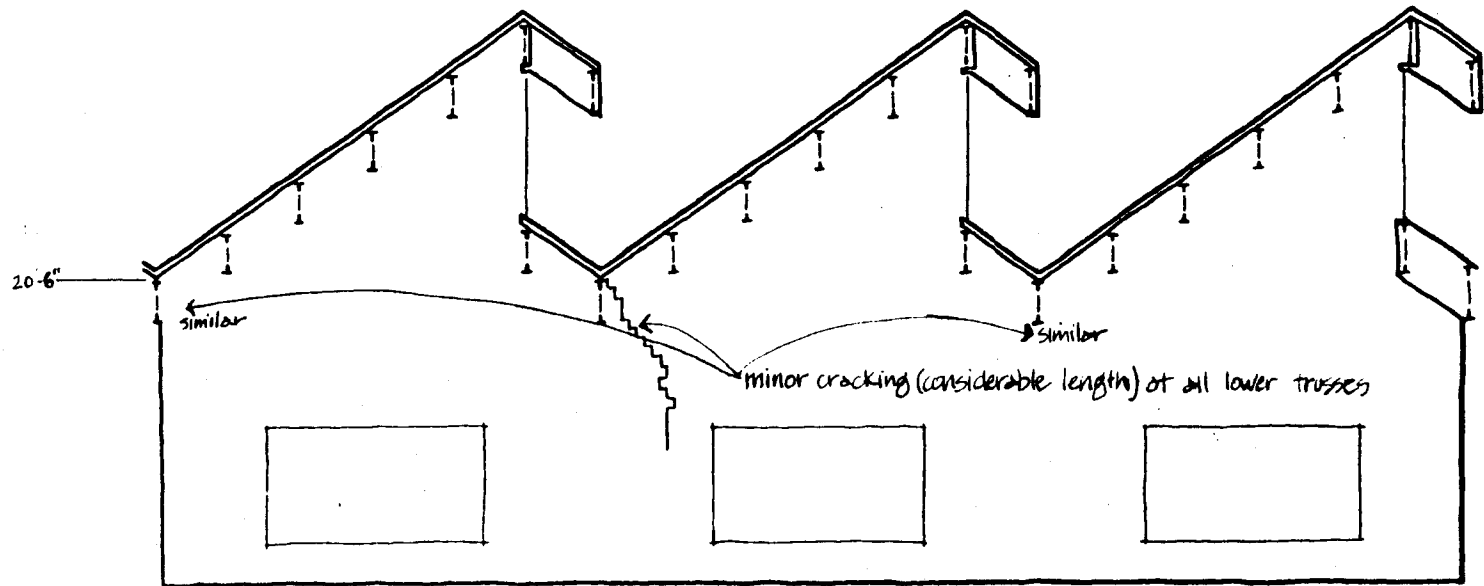
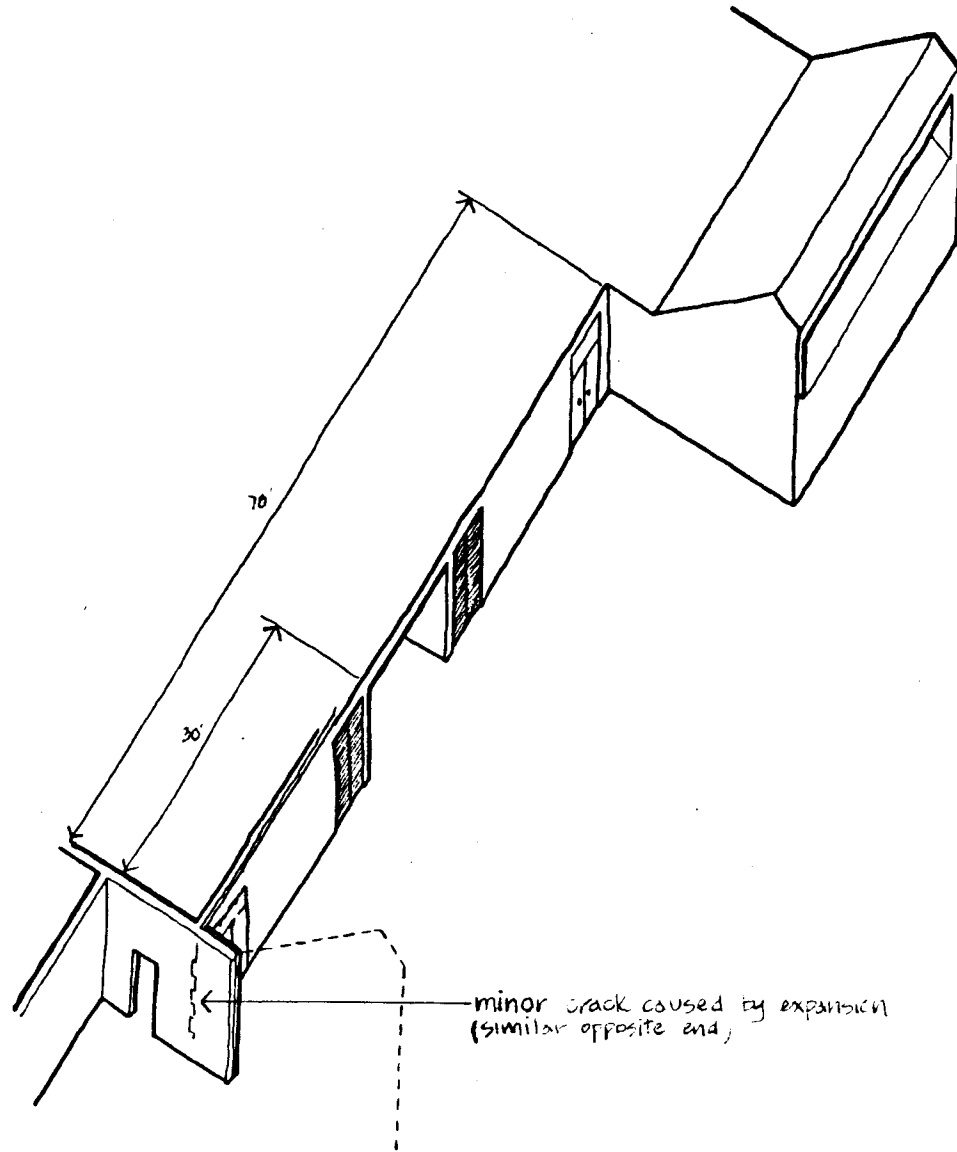


fig. A.5  
RICHARDS SCHOOL / SECTION - MULTIPURPOSE ROOM



fig. A.6  
RICHARDS SCHOOL / EAST END



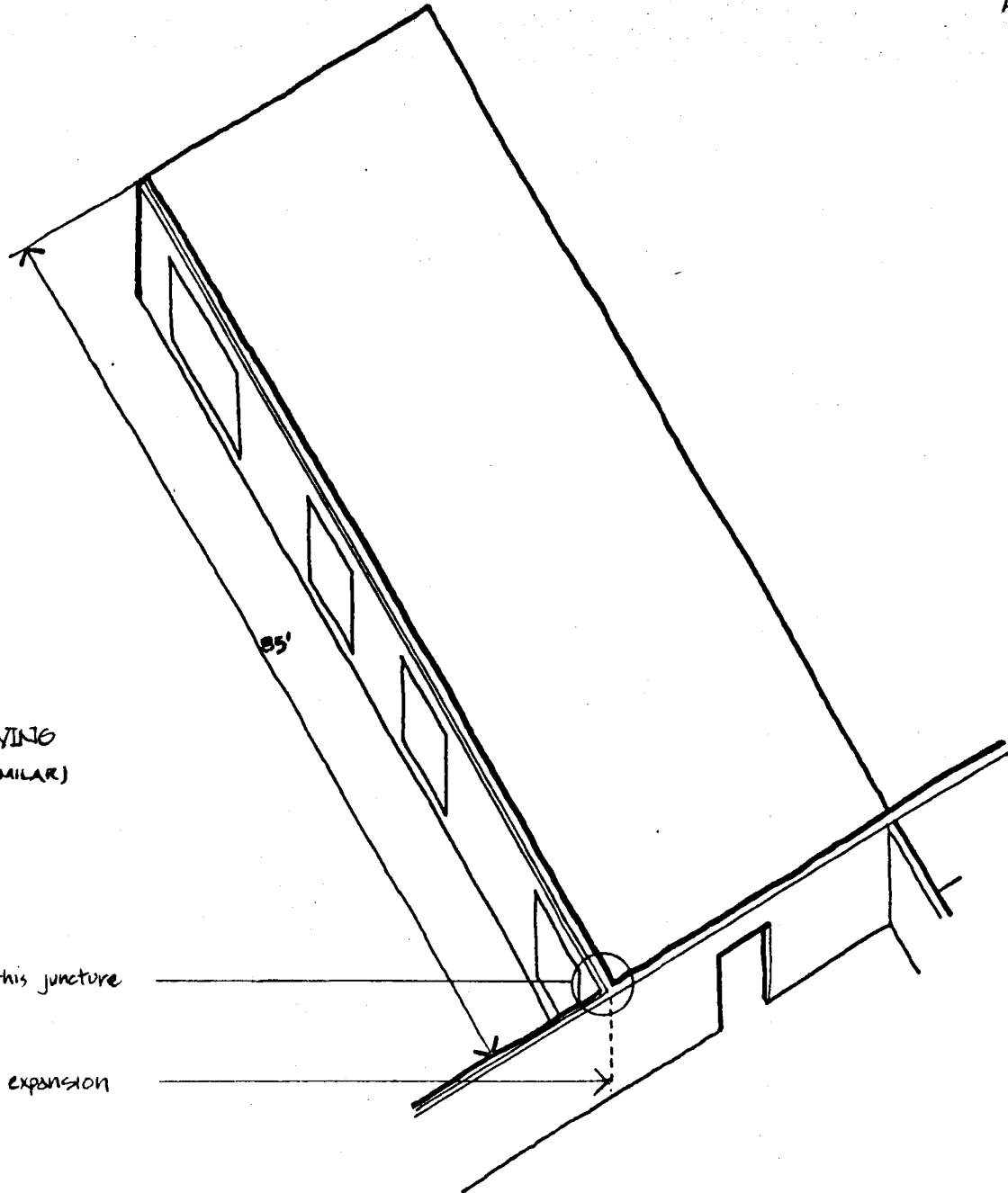


fig. A.7  
RICHARDS SCHOOL/NORTHWEST WING  
(SOUTHWEST WING SIMILAR)

expansion joint at this juncture

minor cracking caused by expansion

water running down sloped corrugations enters  
via weld line or sealant (corrected)

corrugated steel siding  
10 ga. steel gusset

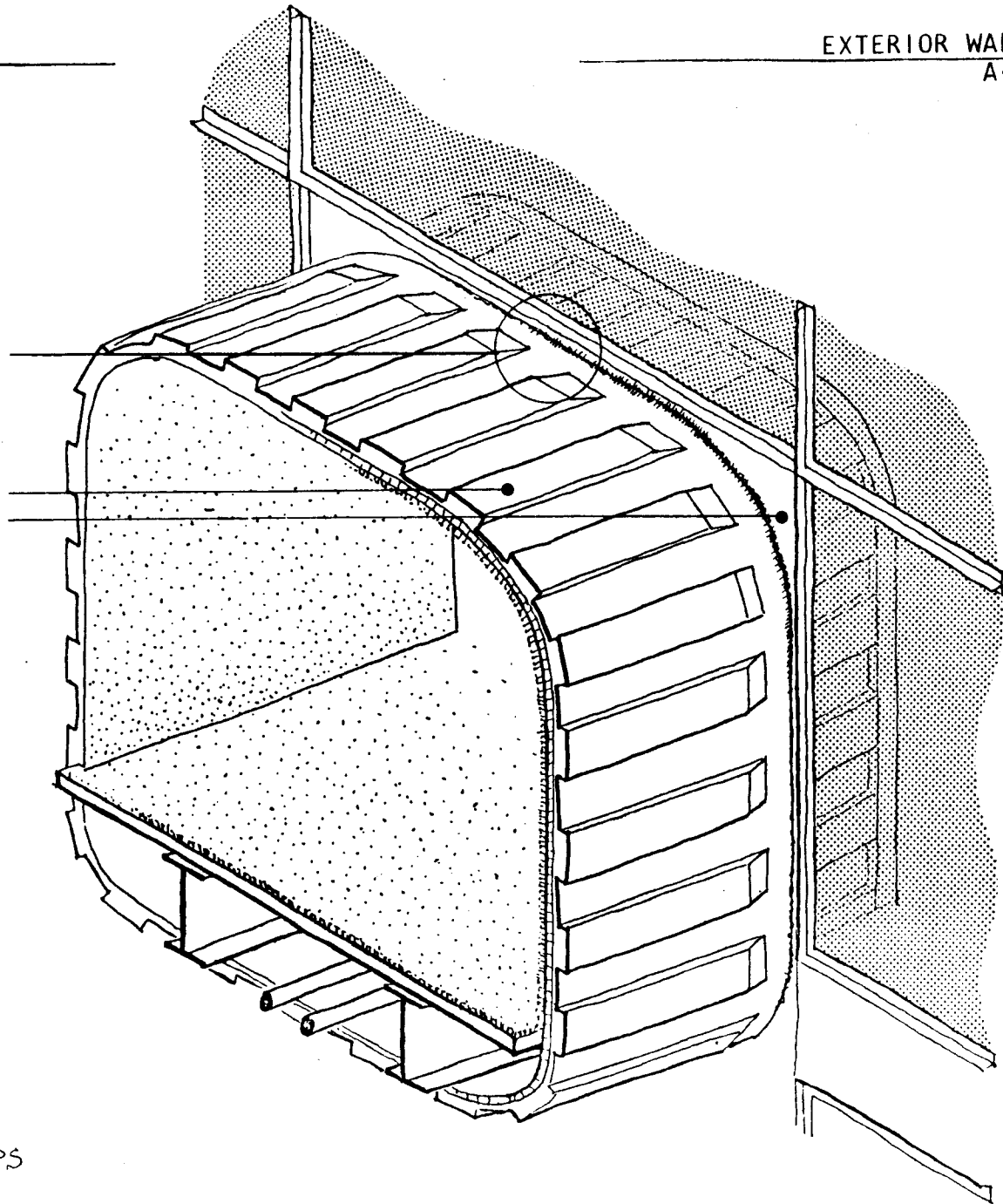


fig. A.8  
SMITH SCHOOL/SLOPED RAMPS