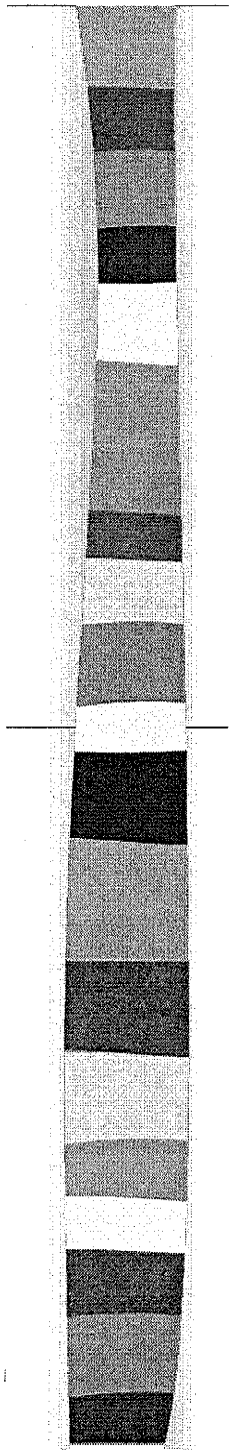
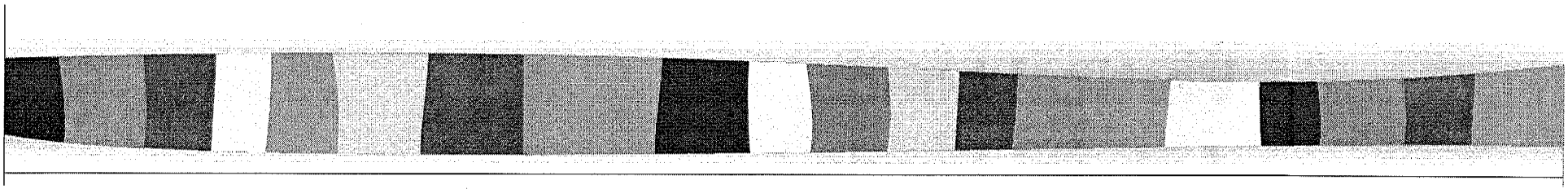


STRUCUTRAL AND OTHER REQUIREMENTS OF HOUSEHOLD SHELTERS

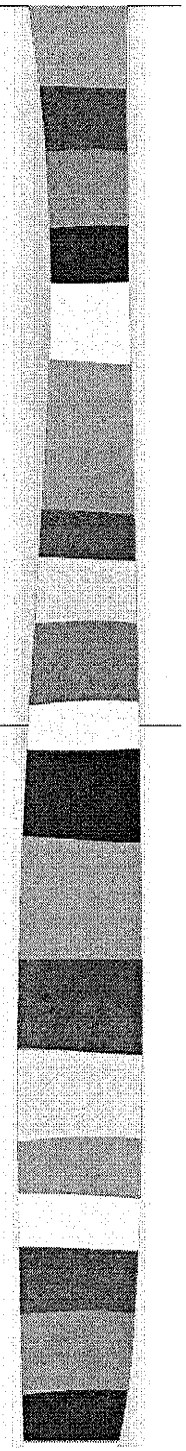
Building and Construction Authority



- **STRUCTURAL REQUIREMENTS**
- **VENTILATION SLEEVES**
- **HS DOOR**

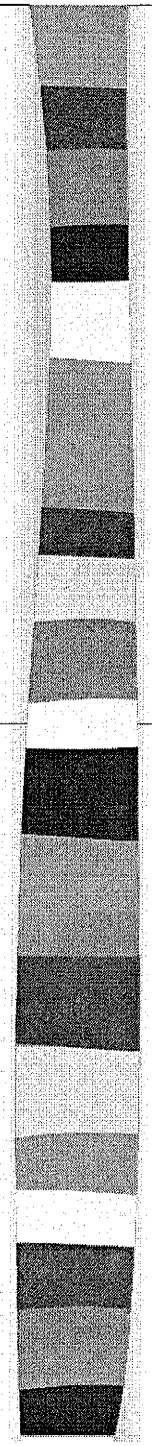


STRUCTURAL REQUIREMENTS



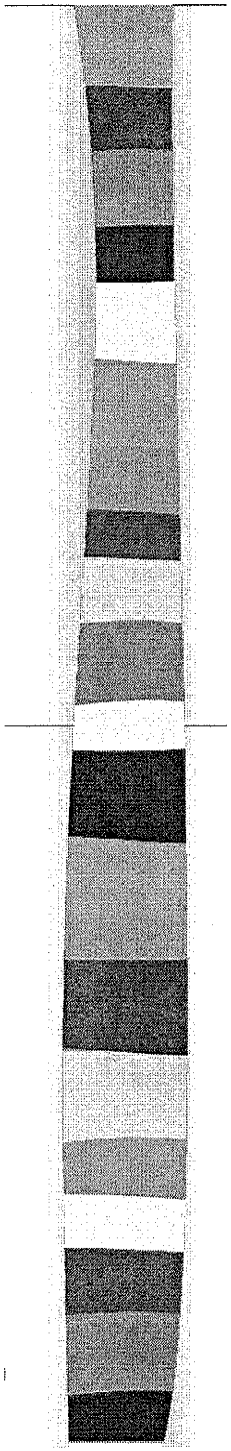
General

- **Structural design of HS Tower shall take into account**
  - **Vertical Loads**
  - **Lateral Loads**
- **HS Tower shall be designed**
  - **For maximum degrees of redundancy**
  - **Against weapon effects**



Material

- **Concrete**
  - Minimum Grade 30
  - Pre-stressed Concrete NOT permitted
- **Steel Reinforcement**
  - Main Reinforcements
  - Welded Steel Fabric Mess: 460 N/mm^2
  - Shear Links: 250 N/mm^2



Analysis

- **General**
  - Walls of HS Tower shall carry their loads directly to the foundations
  - HS Tower can be supported by transfer structure
- **Structural System**
  - HS/NS shall form a continuous structural HS Tower

Beam Supported on HS wall

The end of the beam that is supported on HS wall shall be designed and detailed as "simply support". This requirement shall only apply to HS in non-landed houses.

Shielded NS wall/columns

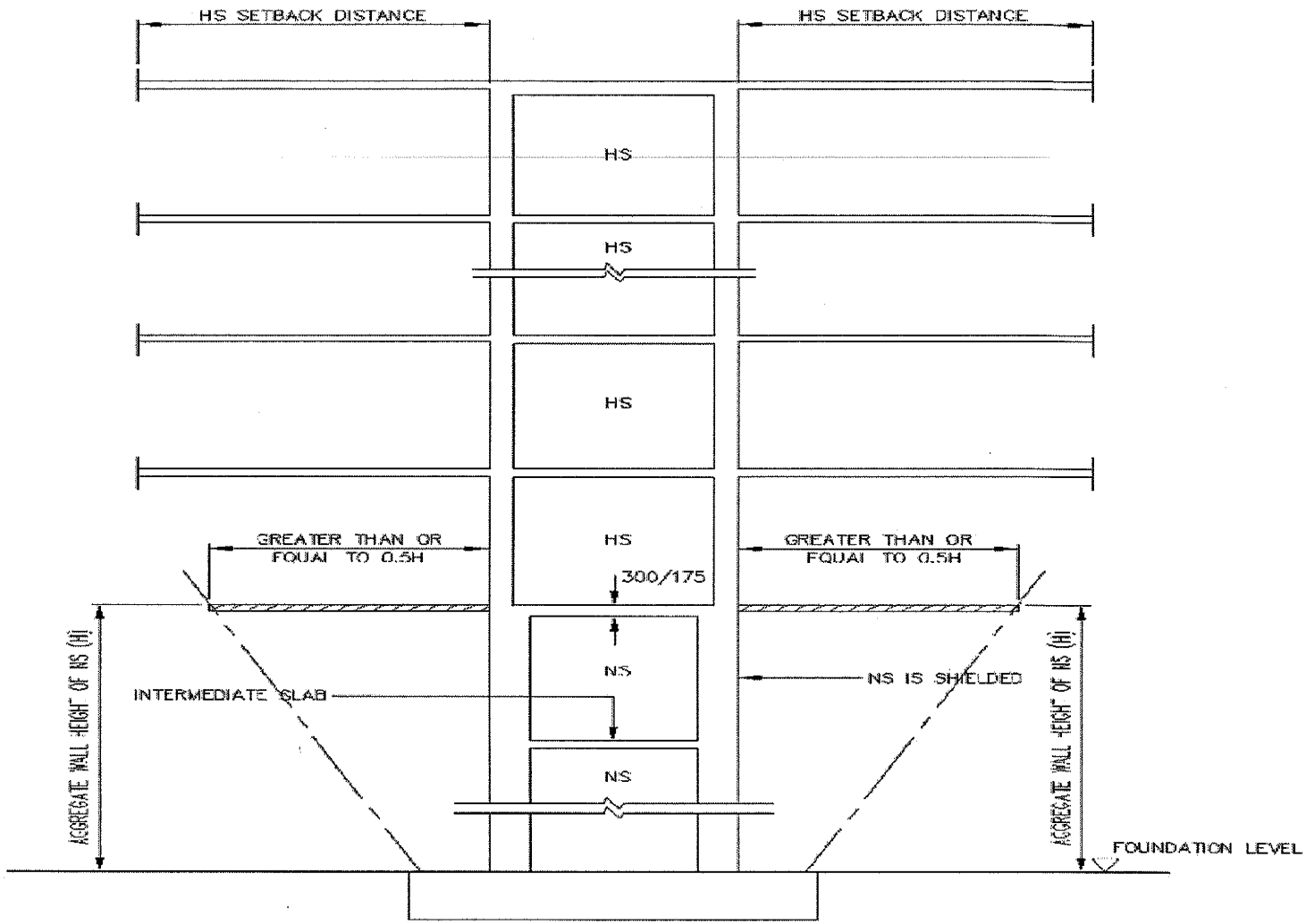


FIGURE 3.3.2.1 SHIELDED NS WALLS AND/OR NS COLUMNS

Shielded Transfer Structure

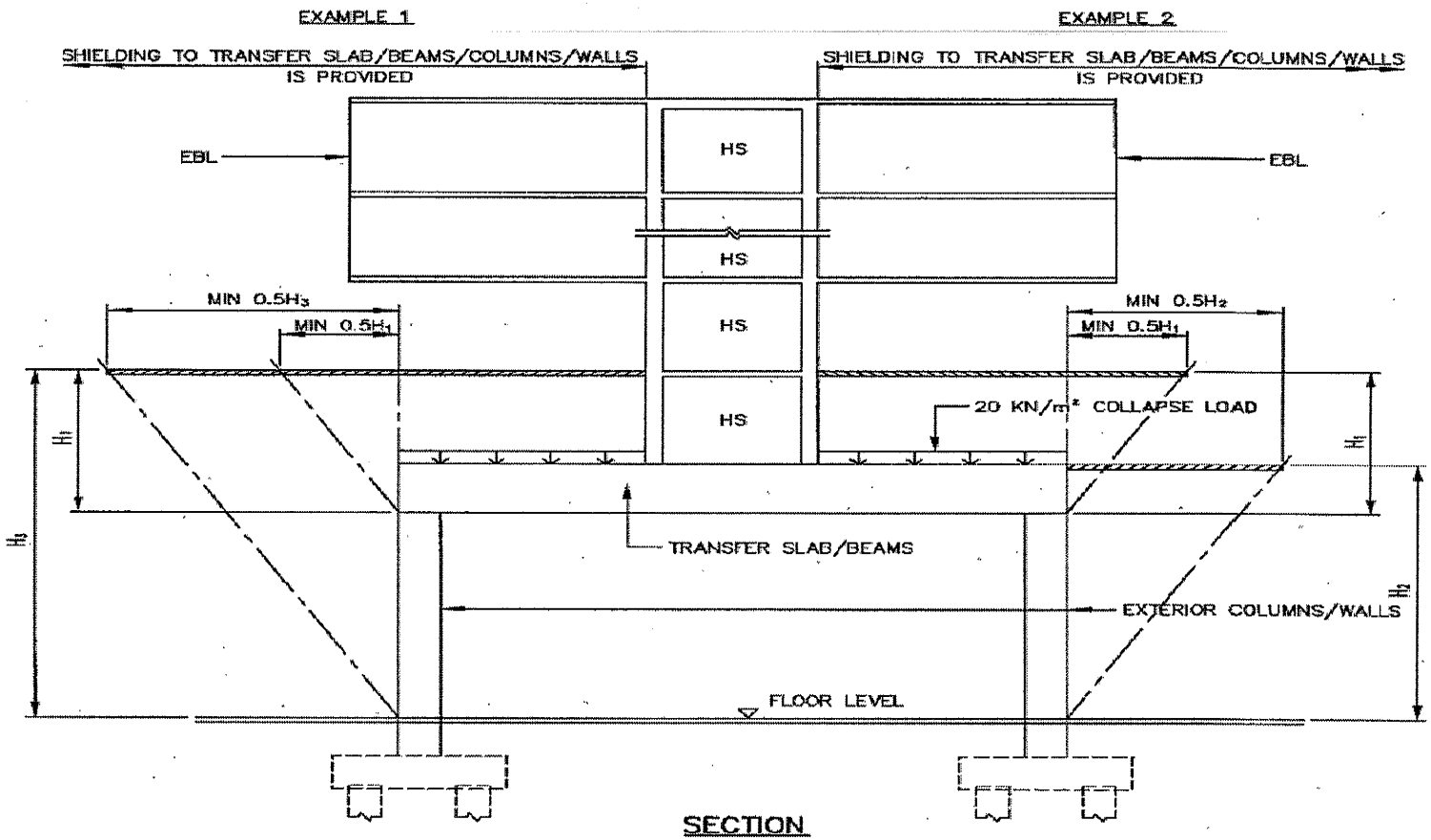


FIGURE 3.3.5.2(a) SHIELDED TRANSFER SYSTEM THAT SUPPORTS HS TOWER

Unshielded Transfer Structure

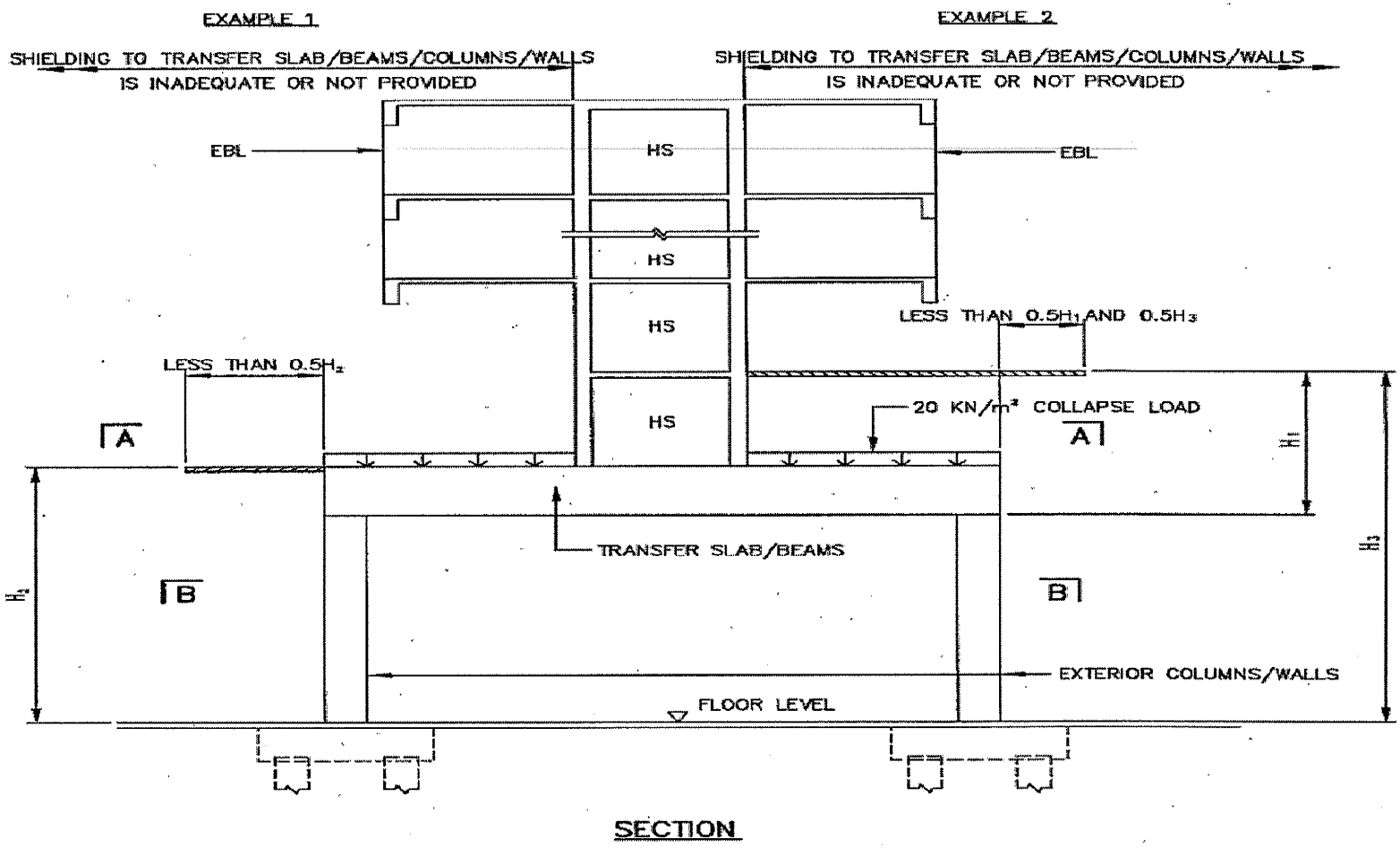


FIGURE 3.3.5.3 UNSHIELDED TRANSFER SYSTEM THAT SUPPORTS HS TOWER
(UNSHIELDED SLAB/BEAM OR/AND COLUMNS/WALLS)

Unshielded Transfer Structure

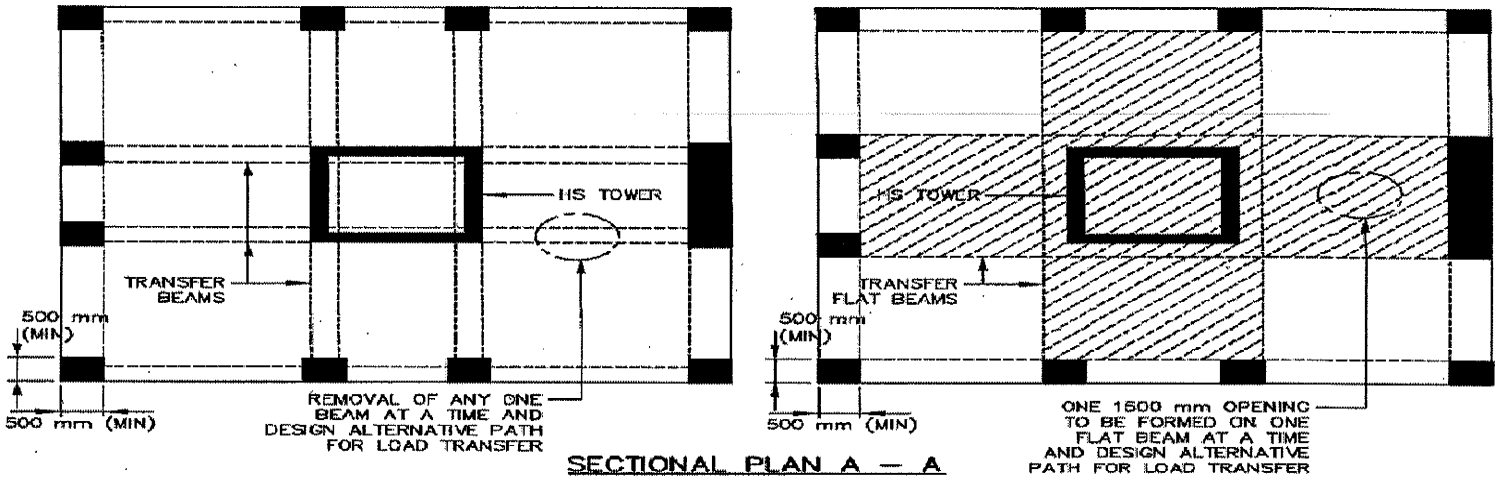


FIGURE 3.3.5.3a (i) UNSHIELDED TRANSFER BEAMS

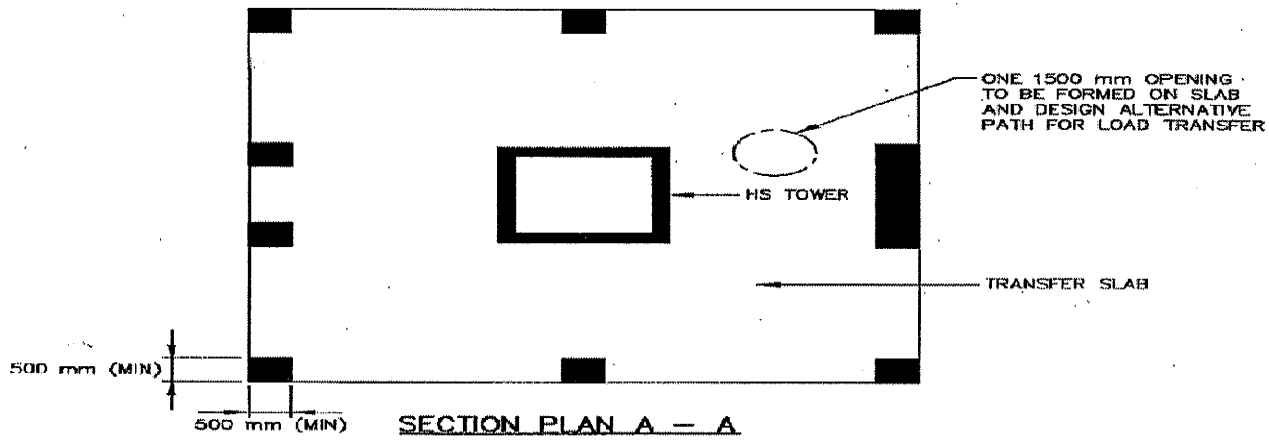
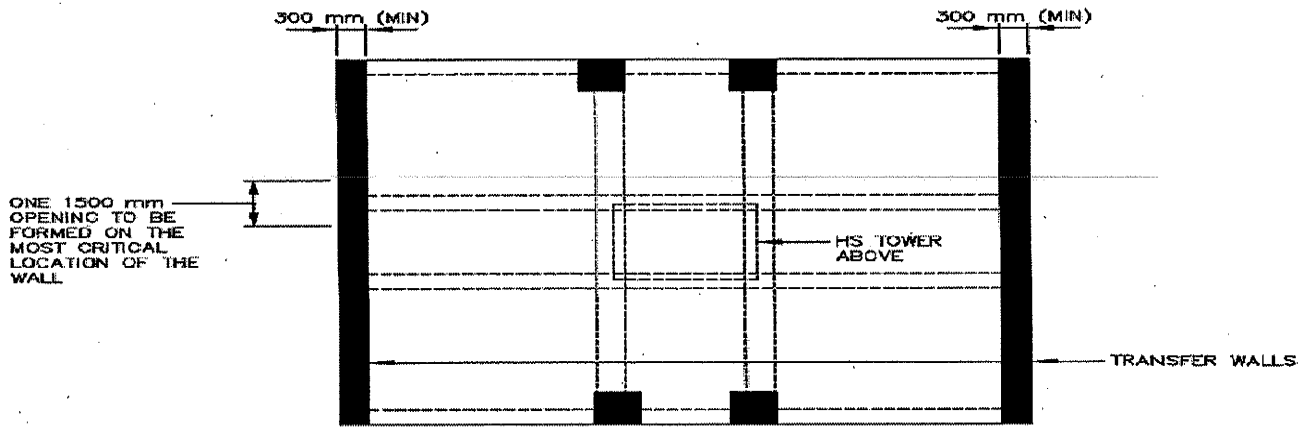


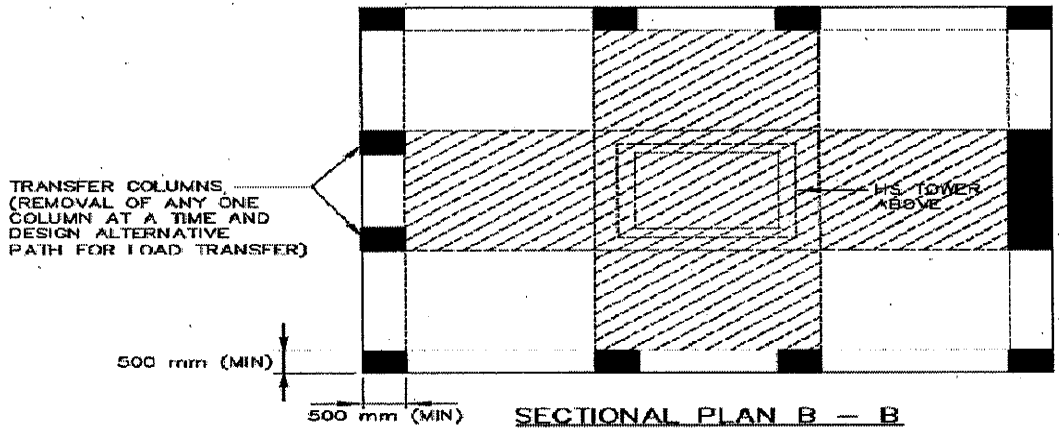
FIGURE 3.3.5.3a (ii) UNSHIELDED TRANSFER SLAB

Unshielded Transfer Structure



SECTIONAL PLAN B – B

FIGURE 3.3.5.3b (i) UNSHIELDED TRANSFER WALLS



SECTIONAL PLAN B – B

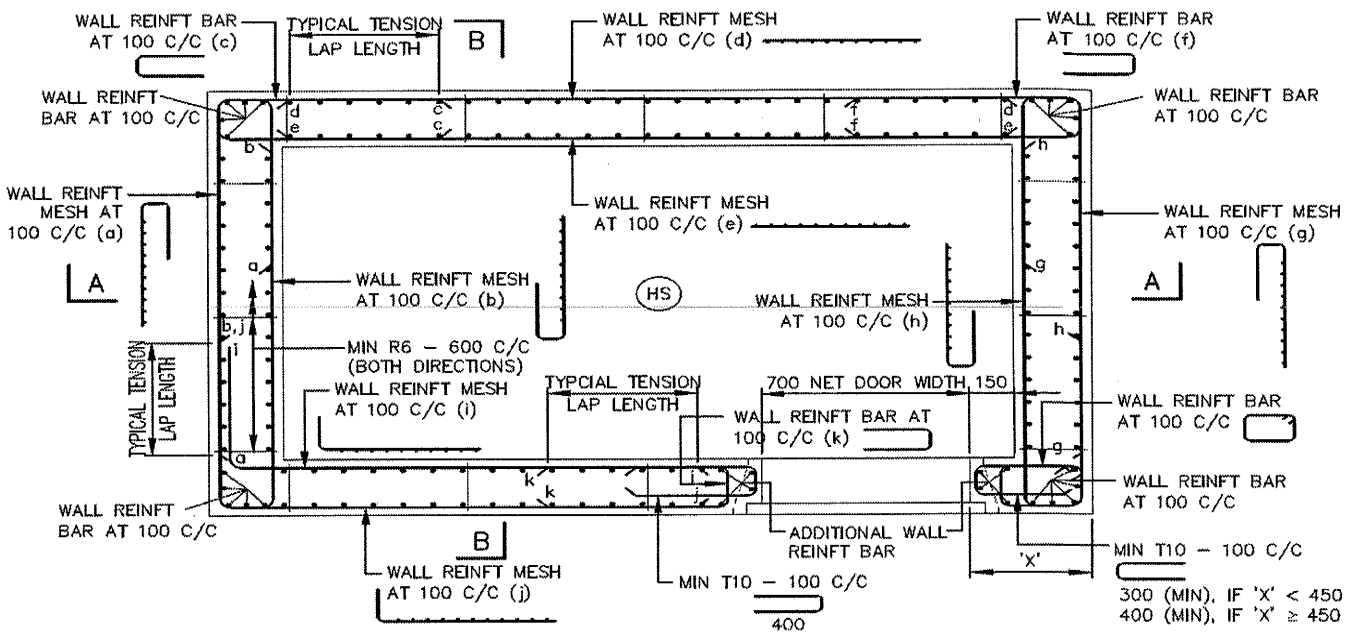
FIGURE 3.3.5.3b (ii) UNSHIELDED TRANSFER COLUMNS

Reinforcement Amounts

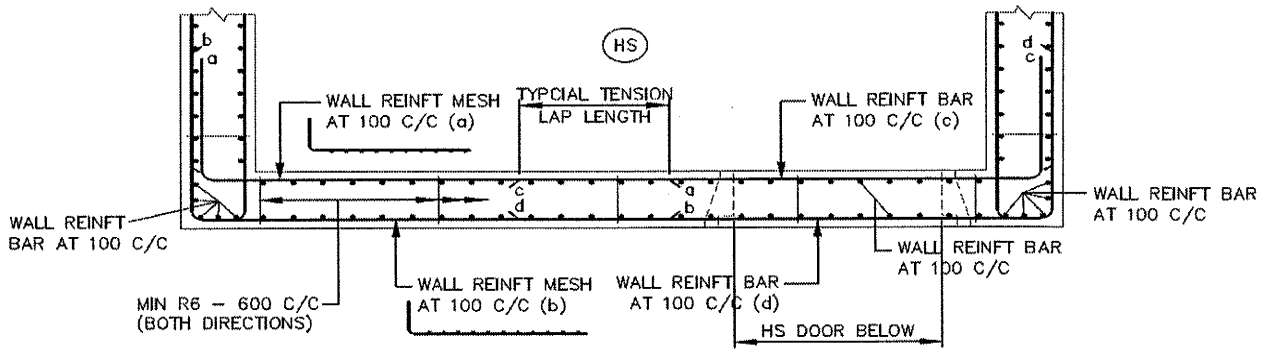
- **Amount of Reinforcement**
  - **HS/NS Wall Reinforcements: Table 3.4.2**

HS Clear Height (mm)	Reinforcements at both internal and external faces of wall (both directions)	Shear Links (both directions)
$2400 \leq Ht \leq 3000$	T10 – 100	R6 – 600
$3000 < Ht \leq 3900$	T13 – 100	R6 – 600

PLAN OF HS



PLAN OF HS WALL AT DOOR OPENING

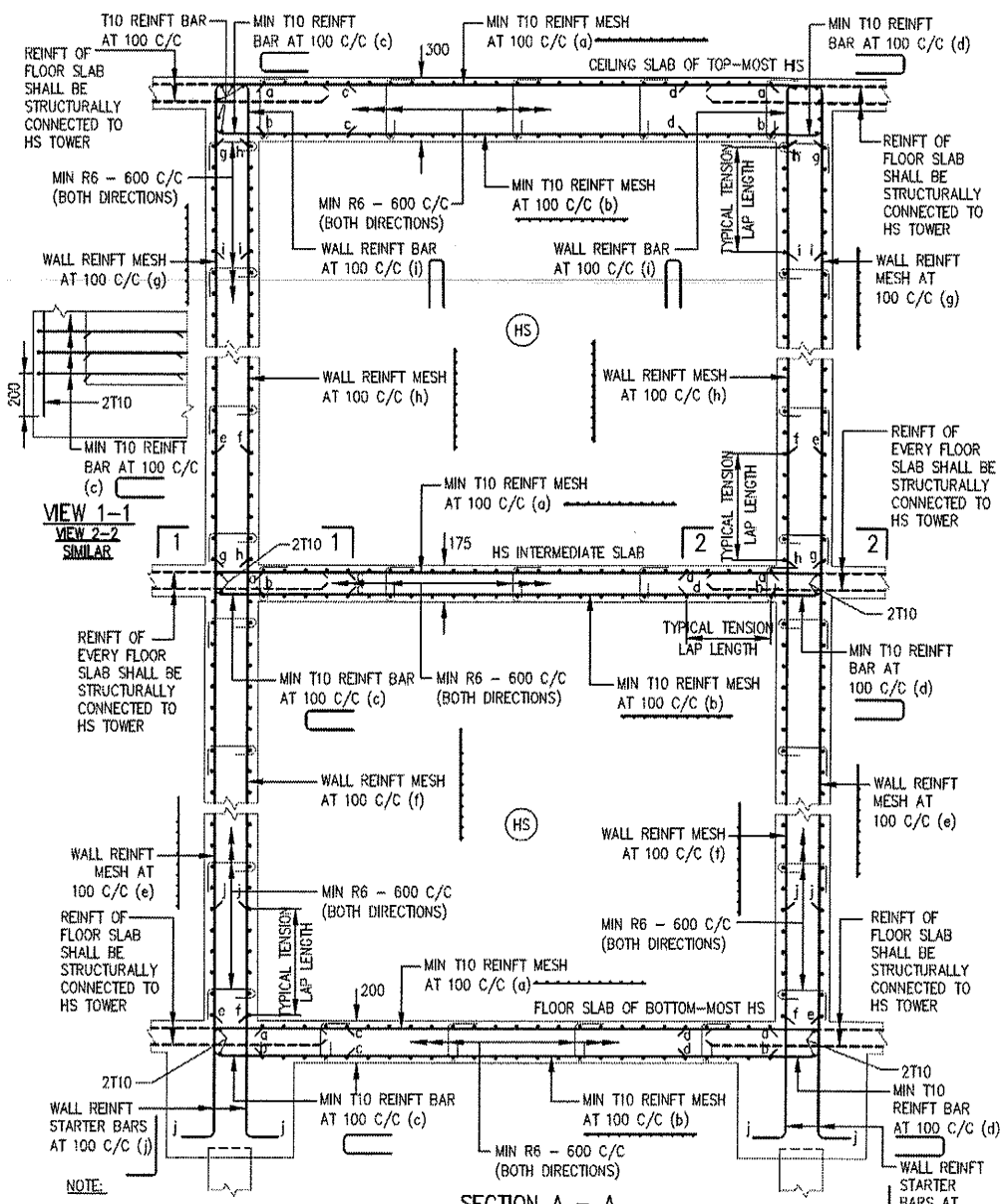


PLAN OF HS WALL ABOVE DOOR OPENING

NOTE:

1. WALL REINFORCEMENT REFER TO TABLE 3.4.2.1(a) FOR LANDED DEVELOPMENT OR TABLE 3.4.2.1(b) FOR NON–LANDED DEVELOPMENT
2. TENSION LAP LENGTH AND TENSION ANCHORAGE LENGTH TO BE 37 TIMES THE DIAMETER OF THE REINFORCEMENT BAR
3. MIN CONCRETE GRADE = 30 N/mm²

TYPICAL DETAILS OF HS SLABS AND WALLS



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1. WALL REINFORCEMENT REFER TO TABLE 3.4.2.1(a) FOR LANDED DEVELOPMENT OR TABLE 3.4.2.1(b) FOR NON-LANDED DEVELOPMENT
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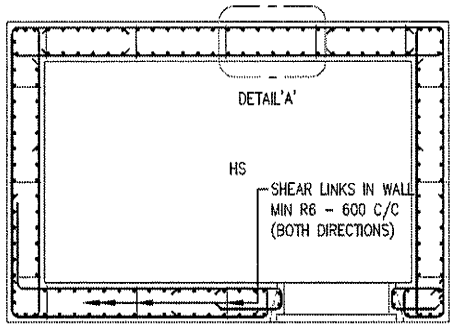
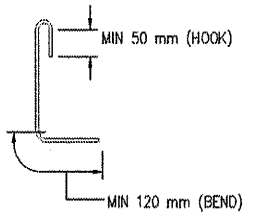
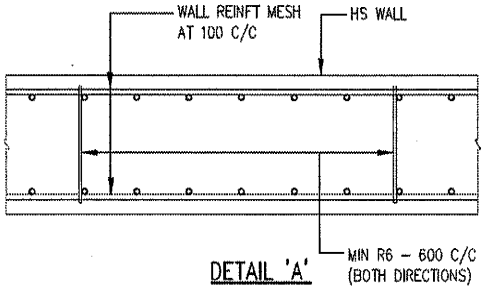
DETAILS OF SHEAR LINKS IN HS SLABS AND WALLS



PLAN OF HS SHOWING
SHEAR LINKS ARRANGEMENT



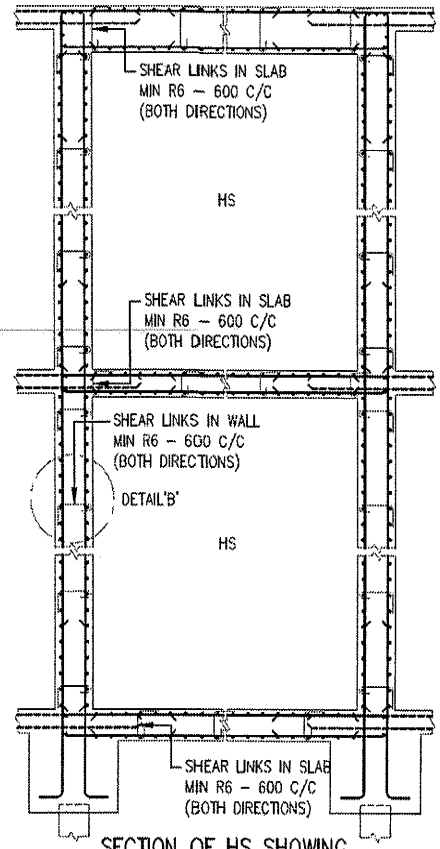
MINIMUM HOOK AND BEND
ALLOWANCE FOR SHEAR LINKS (R6)



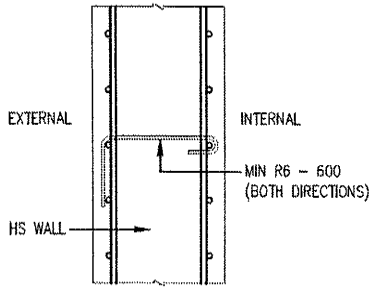
DETAIL 'A'

NOTE:

1. WALL REINFORCEMENT REFER TO TABLE 3.4.2.1(a) FOR LANDED DEVELOPMENT OR TABLE 3.4.2.1(b) FOR NON-LANDED DEVELOPMENT
2. TENSION LAP LENGTH AND TENSION ANCHORAGE LENGTH TO BE 37 TIMES THE DIAMETER OF THE REINFORCEMENT BAR
3. MIN CONCRETE GRADE = 30 N/mm²
4. THE HOOK AND THE BEND OF R6 LINKS MUST BE TIED TO OUTERMOST REINFORCEMENT BARS OF HS WALL WHERE THE HOOK MUST ALWAYS BE PLACED NEAR TO INTERNAL FACE OF HS WALL.



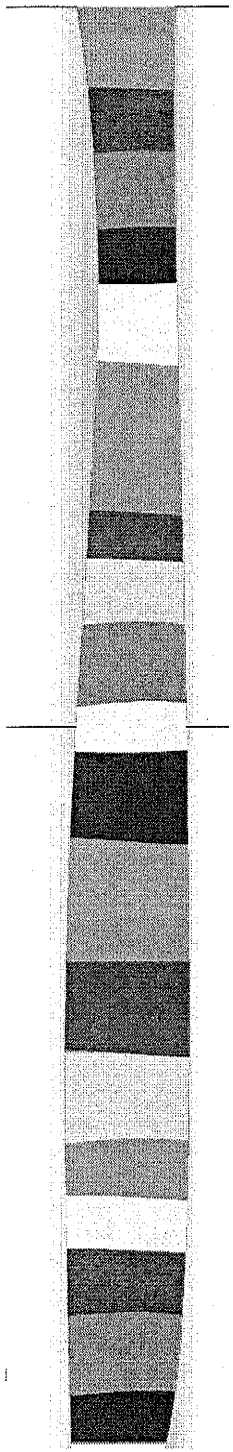
SECTION OF HS SHOWING
SHEAR LINKS ARRANGEMENT



DETAIL 'B'

Reinforcement Amounts

- **Amount of Reinforcement**
  - **Ceiling Slab outside tower above HS door**
    - **Minimum 125 mm thick**
    - **T10 - 100 mm c/c (both directions and both ways)**
  - **Floor Slab outside tower**
    - **Reinforcements of floor slab shall be structurally connected to the HS tower**
  - **HS Slab integrated with pile-cap/footing**
    - **> 500 mm, No shear links required**
    - **Main Reinforcement spacing < 200 mm c/c**

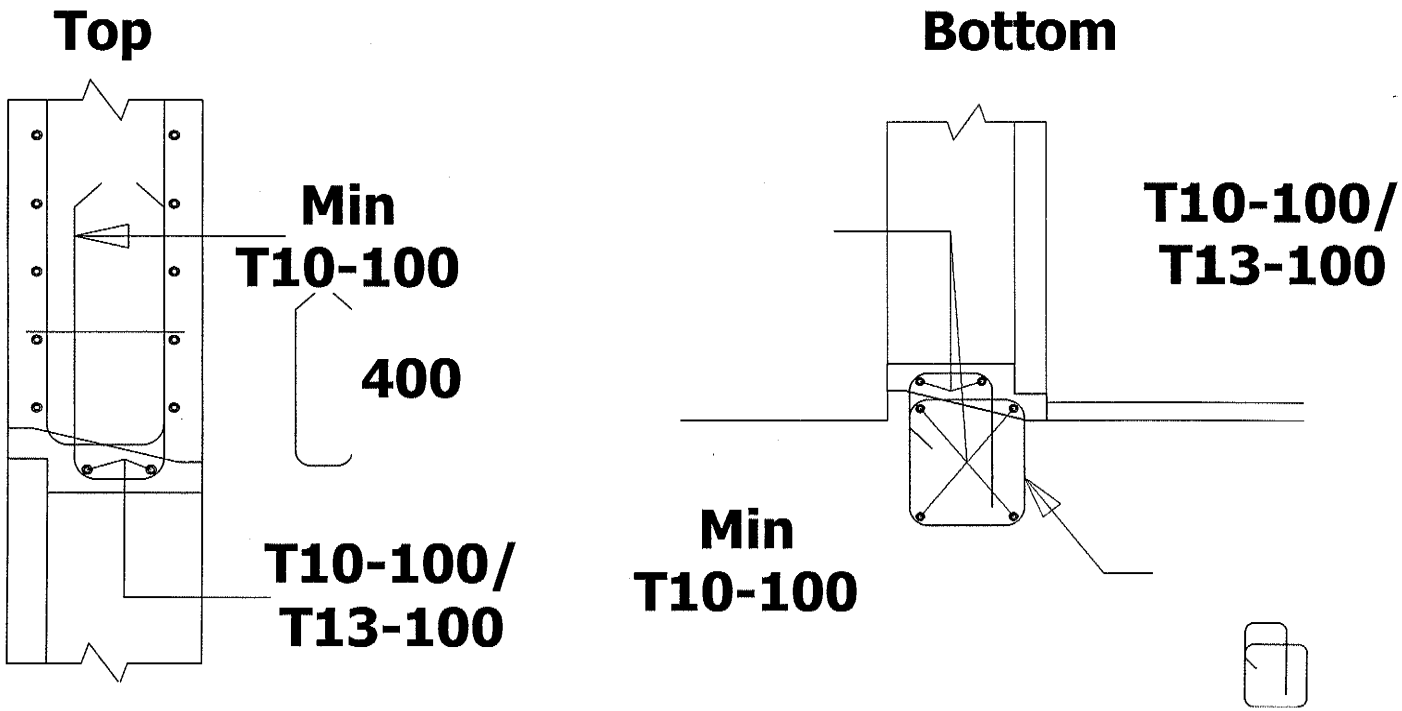


Detailing of HS Tower

- **Concrete Cover ≤ 40 mm**
- **Cast-in-Situ and Pre-cast Elements**
  - **Cast-in-Situ**
  - **Pre-cast HS Elements**
- **Joints**
  - **Construction Joints**
    - **Concrete Kicker ≤ 100 mm**
    - **HS walls shall be cast in 1 operation**
  - **Expansion/Contraction Joints not permitted**

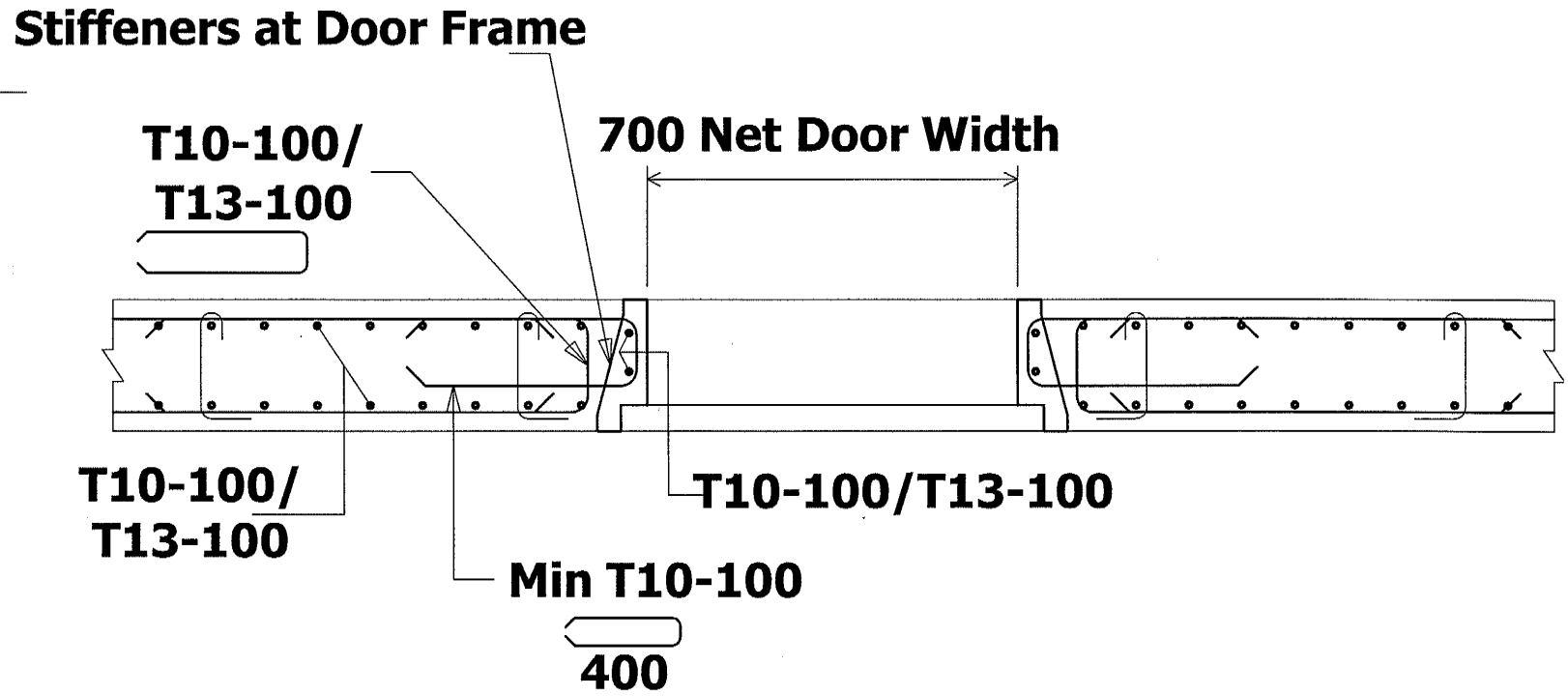
Detailing of HS

- **Details of HS Wall Reinforcement near HS Door - Fig 3.5.4(e)**



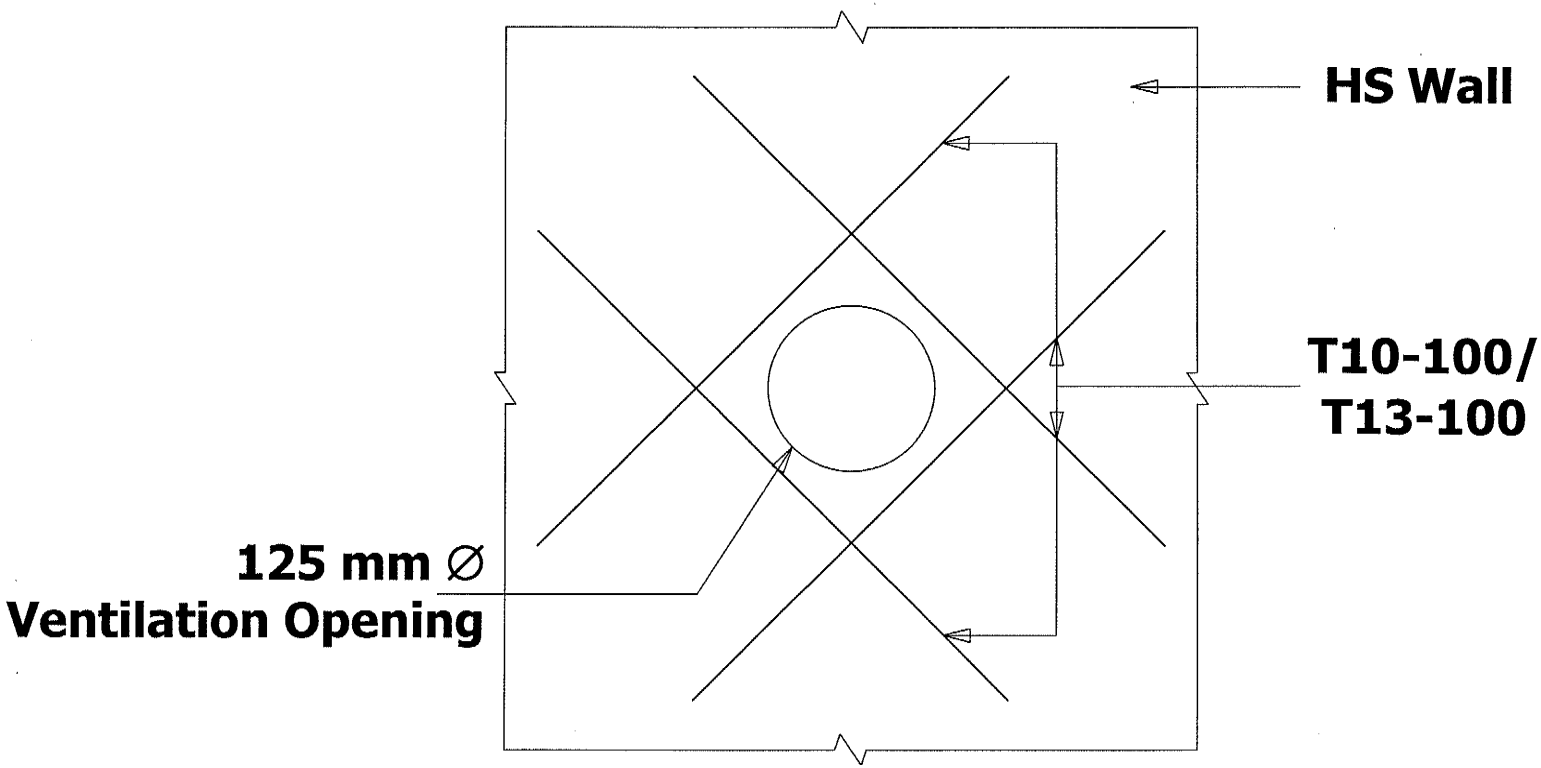
Detailing of HS

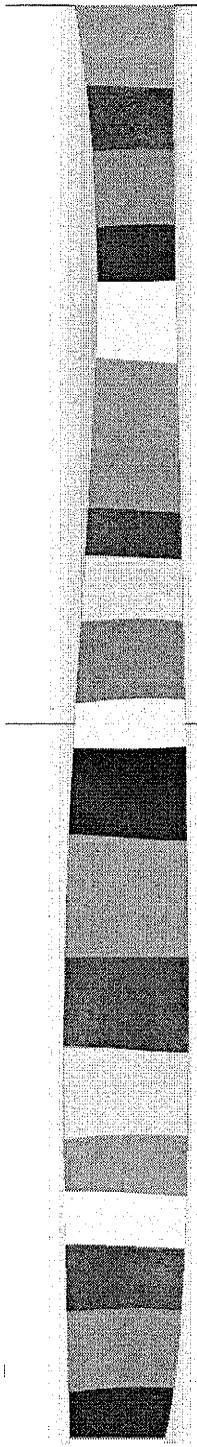
- **Plan of HS Wall Reinforcement Details near HS Door - Fig 3.5.4(g)**



Detailing of Ventilation Sleeve Openings

- **Typical Details of Trimmer Bars for Ventilation Sleeve - Fig 3.5.4(h)**

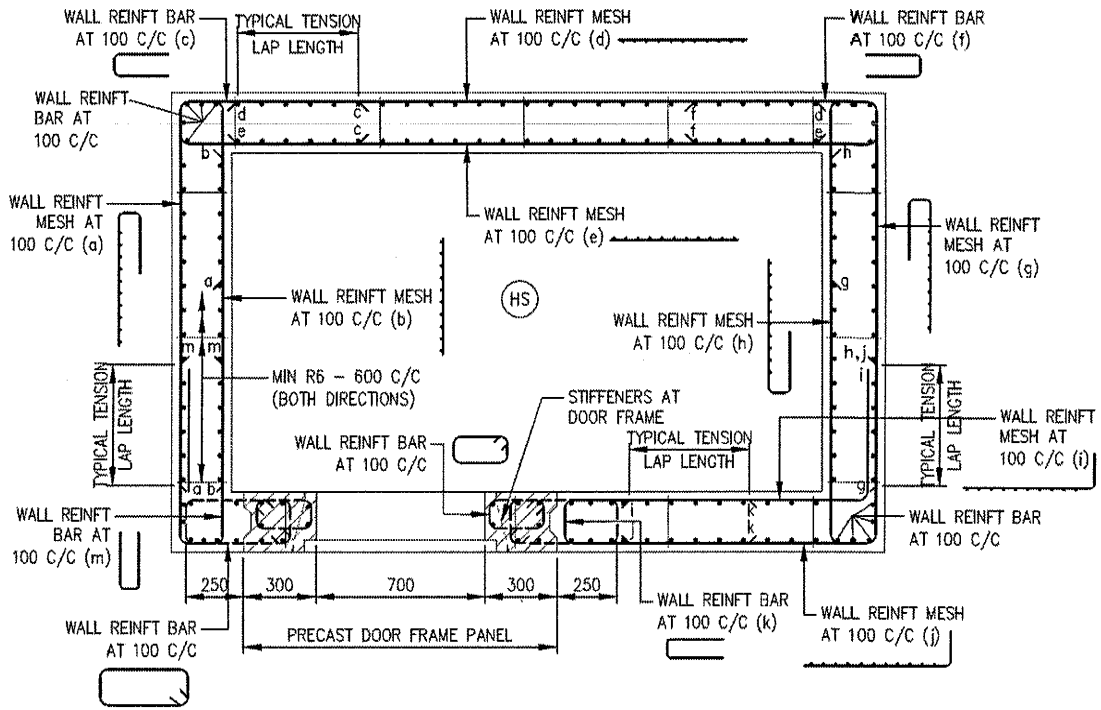




Precast HS Doorframe Panel

- Type 1
- Type 2
- Type 3

TYPE 1
HS PRECAST DOORFRAME



NOTE:

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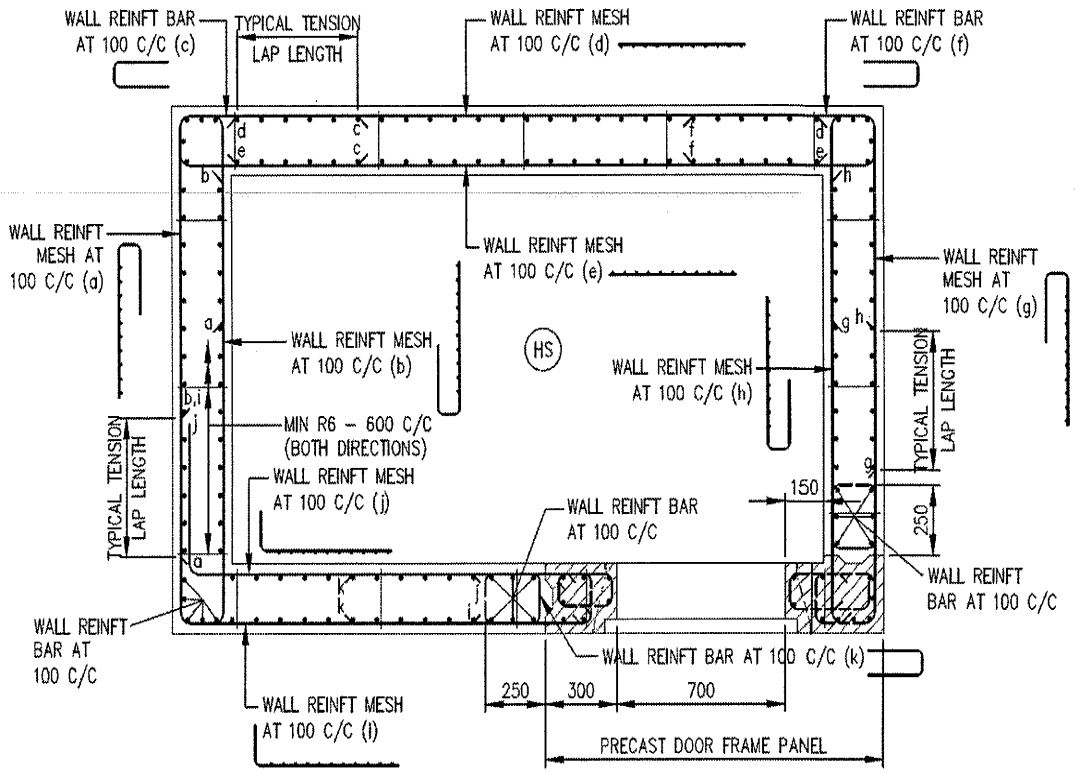
2. TENSION LAP LENGTH AND TENSION ANCHORAGE LENGTH TO BE 37 TIMES THE DIAMETER OF THE REINFORCEMENT BAR
3. MIN CONCRETE GRADE = 30 N/mm^2

TYPE 2
HS PRECAST DOORFRAME



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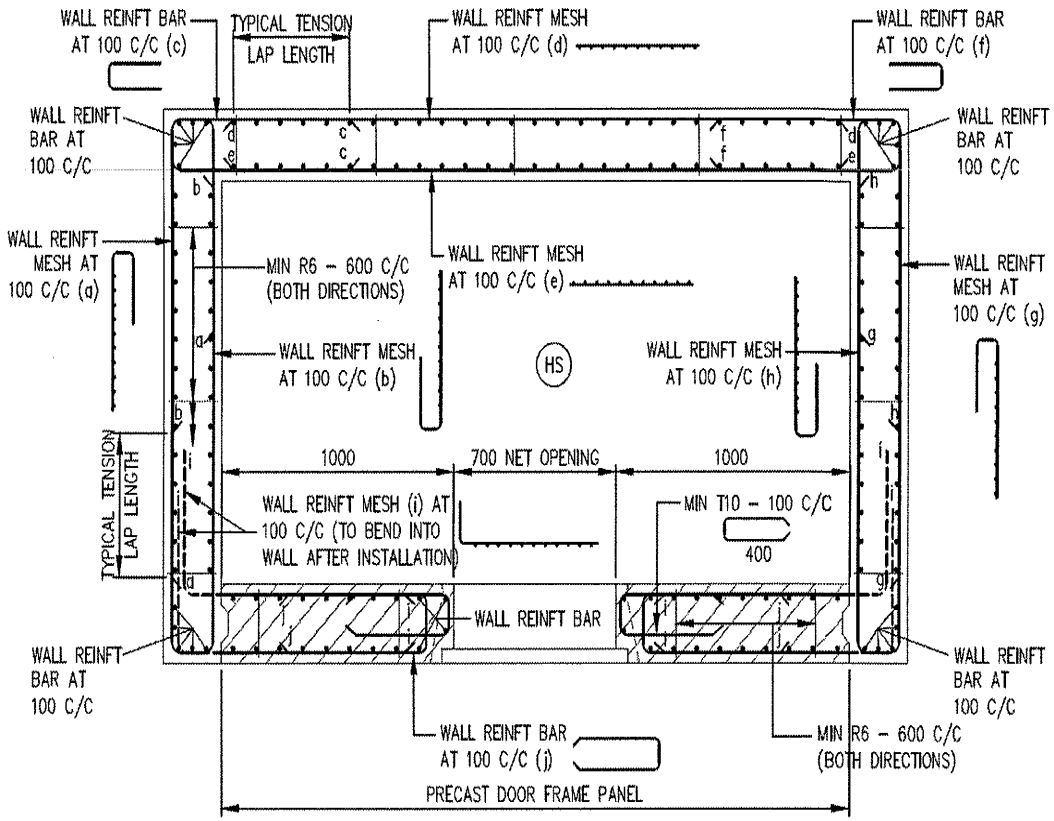
HS PRECAST DOORFRAME



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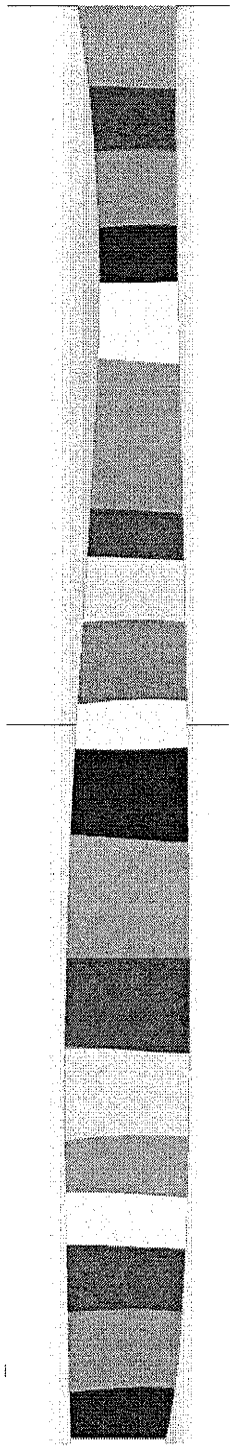
3. MIN CONCRETE GRADE = 30 N/mm^2

Penetration of Services

- **Electrical Services**
  - **Service Cables**
    - **That do not serve the HS directly shall not penetrate the walls/slabs of the HS**
    - **From the socket mounted on the external face of HS can be embedded in the HS walls/slabs**
  - **Embedded Sockets**
    - **≥ 300 mm apart measured between their clear edges**

Electrical Services

A maximum of four (4) numbers of 25 mm diameter conduits are allowed to be embedded within the HS walls for electrical cables serving fixtures in the HS



Penetration of Services

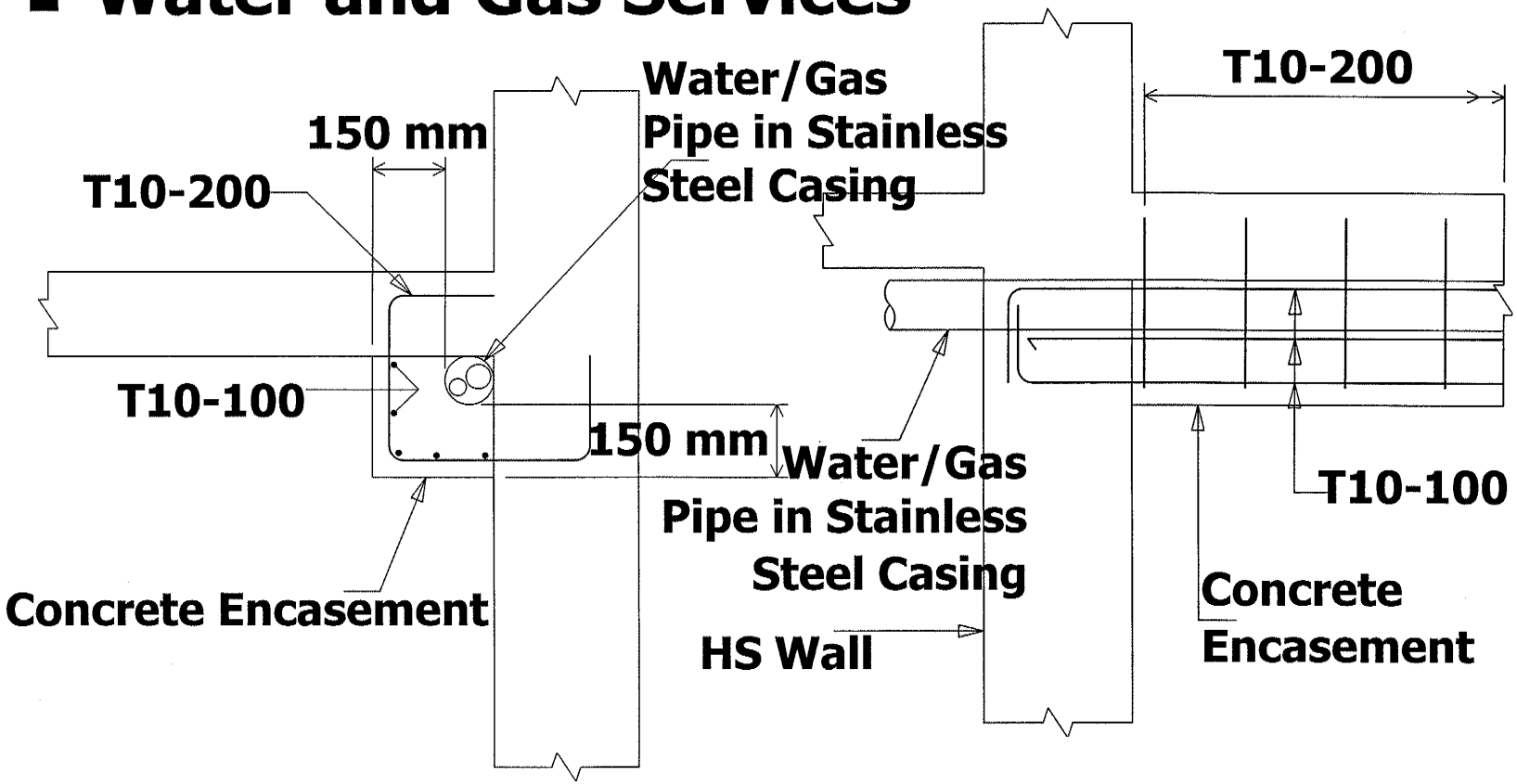
- **Electrical Services**
  - **For service conduits penetrating HS wall**
    - **Both ends of conduits to be fully sealed with approved sealing material of depth>100 mm**
  - **HS/NS shares common wall with Lift Core**
    - **Service Mounting to be stainless steel material**
    - **Anchor Bolts to be stainless steel material**
    - **Max Penetration of 75 mm, cast-in-place**
    - **Spacing>300 mm c/c**

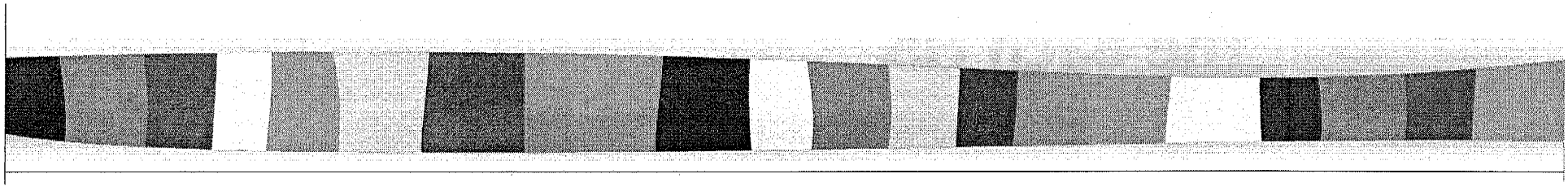
Penetration of Services

- **Water and Gas Services**
  - **Services pipes for water/gas are allowed to pass through the HS walls**
    - **Laid within stainless steel conduit encased by 150 mm RC all round – Fig 3.6.2**
    - **Joints in water/gas pipes or conduits shall be located outside the HS**
    - **Risers for water/gas service can be mounted on the external face of HS tower walls**

Penetration of Services

- **Water and Gas Services**

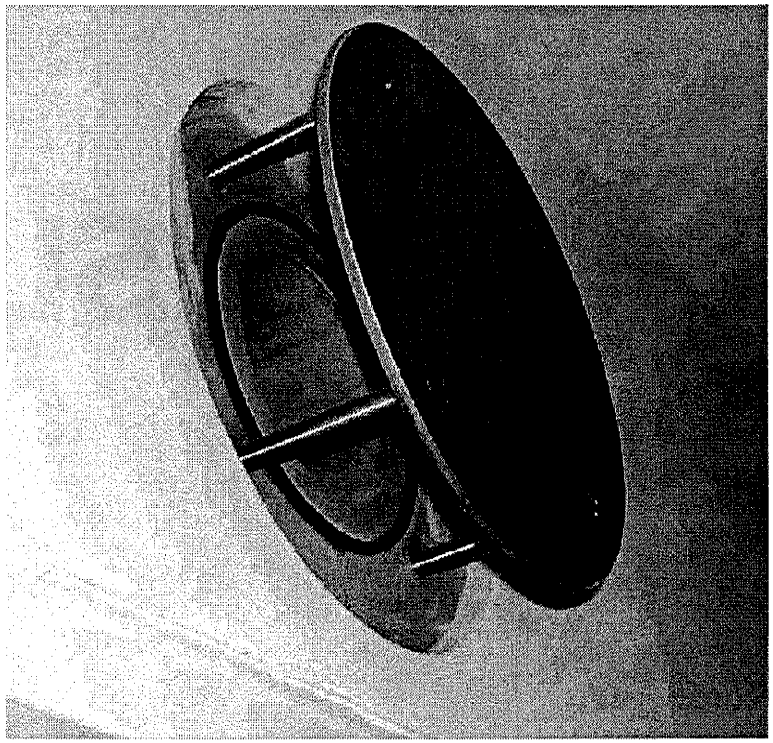




VENTILATION SLEEVES

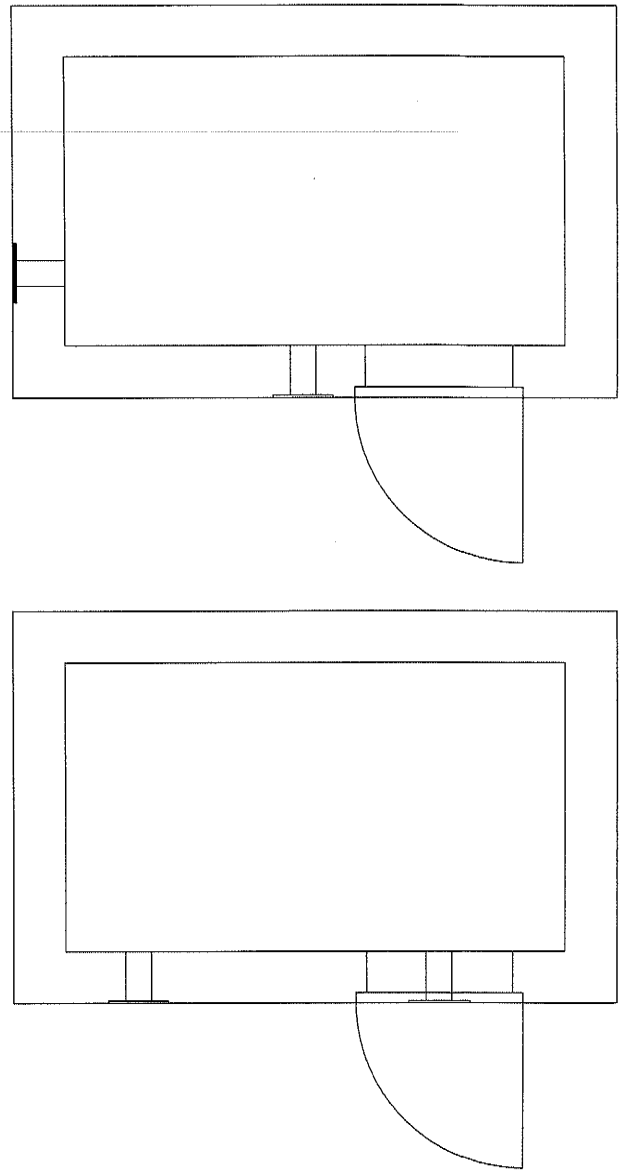
General

- **Two 125 mm diameter Ventilation Sleeves shall be cast into the wall/s of the each HS**



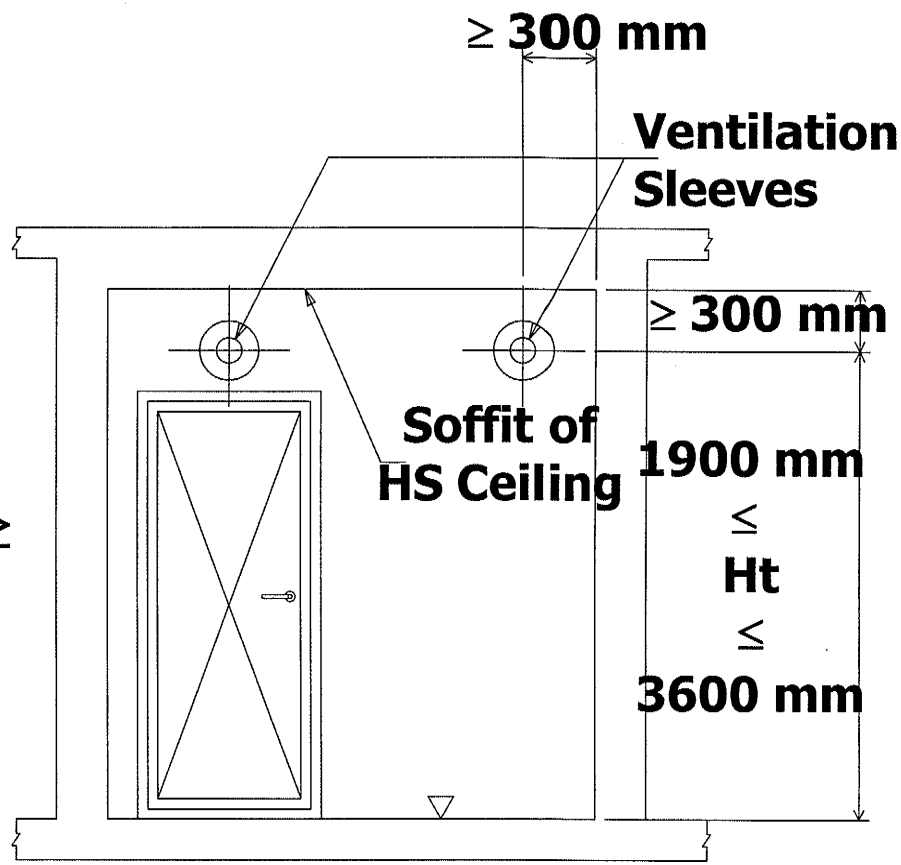
Position

- VS may be on
  - Different walls
  - Same wall of HS



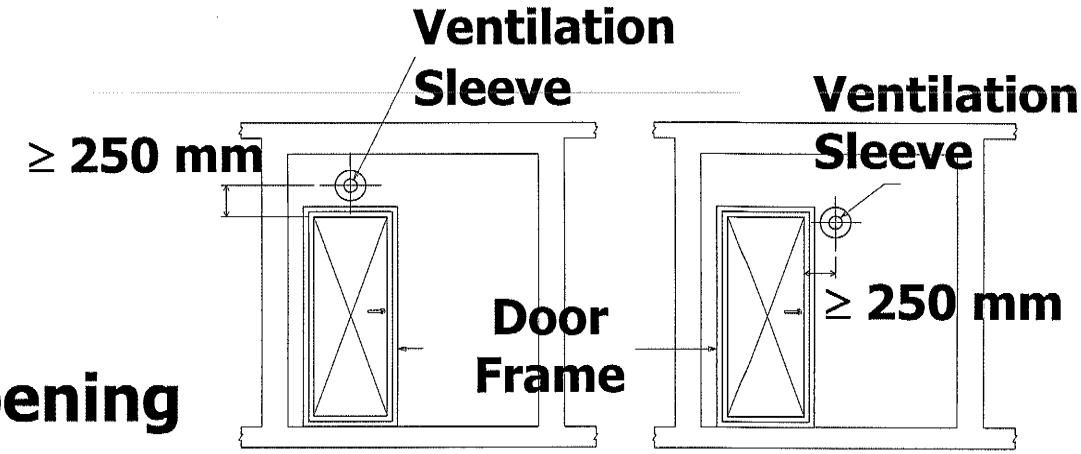
Position

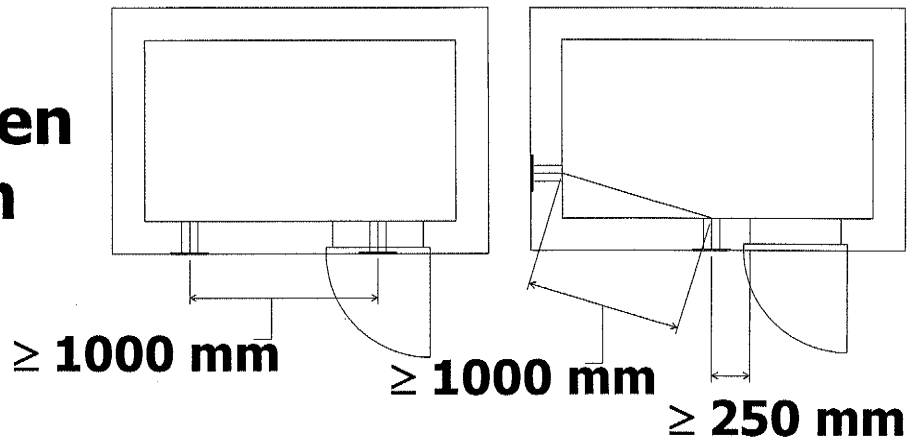
- **Position shall comply with**
  - **1900 mm ≤ Ht of VS ≤ 3600 mm**
  - **Clear space around VS to be area of diameter ≥ 600 mm, measured concentrically from centre of opening**



Position

- **Position shall comply with**
  - **Centre of opening ≥ 250 mm from nearest edge of door frame**
  - **Distance between 2 VS ≥ 1000 mm**





Position outside HS

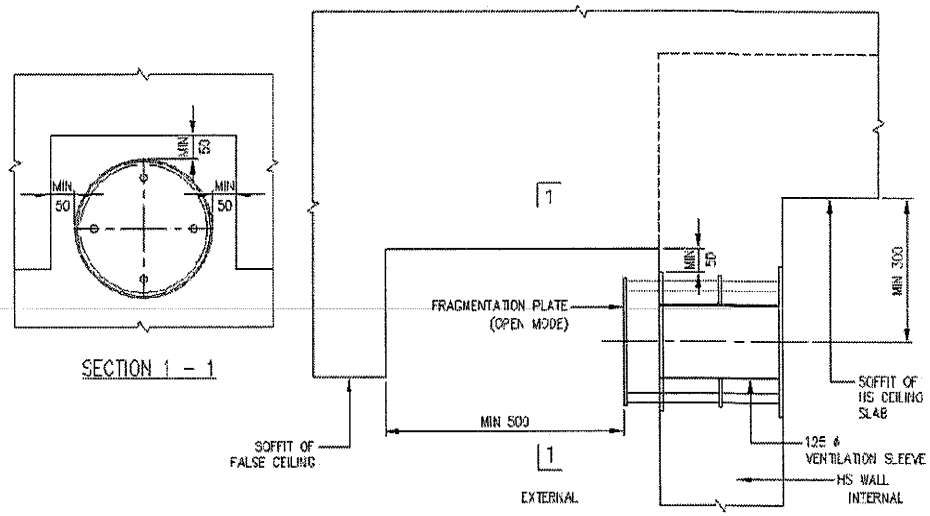


FIGURE 4.3(a) MINIMUM CLEARANCE FOR FRAGMENTATION PLATE

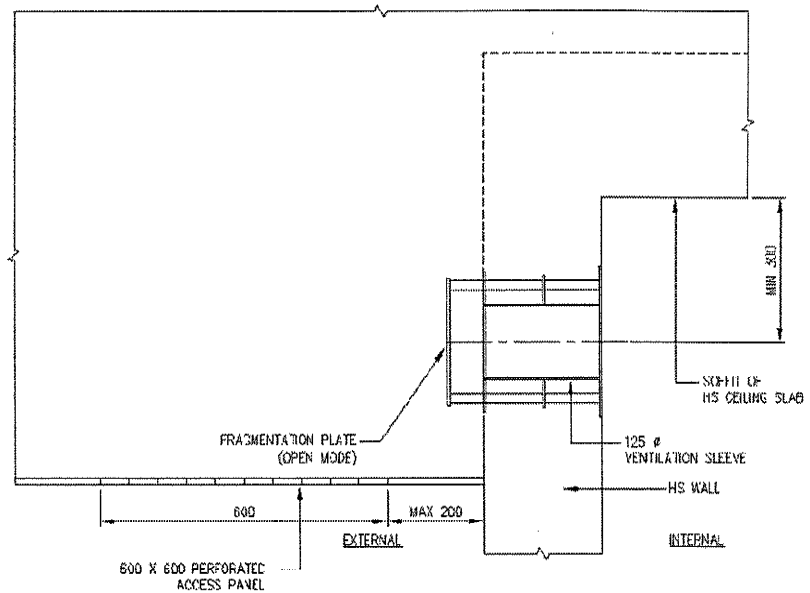
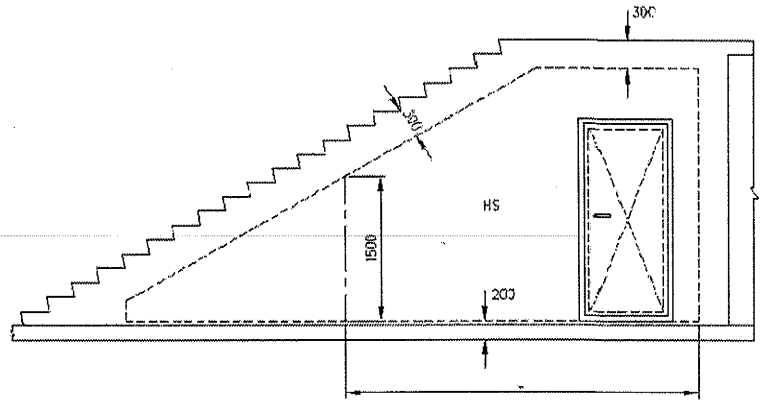


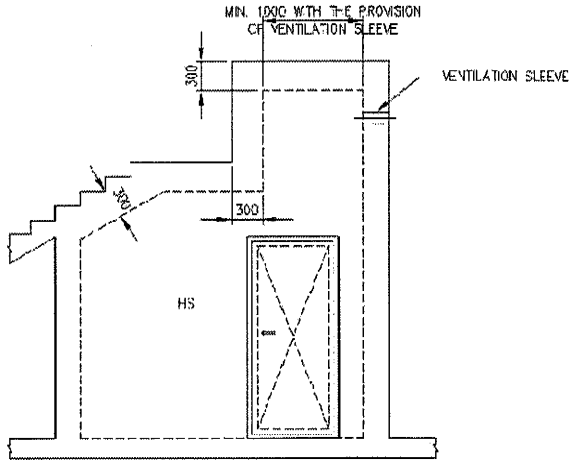
FIGURE 4.3(b) PERFORATED ACCESS PANEL BELOW VENTILATION SLEEVE

Position outside HS beneath internal staircase



SECTIONAL ELEVATION
(TYPE A)

NOTE:
THE DIMENSION, L OF THE FLOOR SHALL BE USED FOR COMPUTING THE INTERNAL HS FLOOR AREA FOR THE PURPOSE OF TABLE 2.2.



SECTIONAL ELEVATION
(TYPE B)

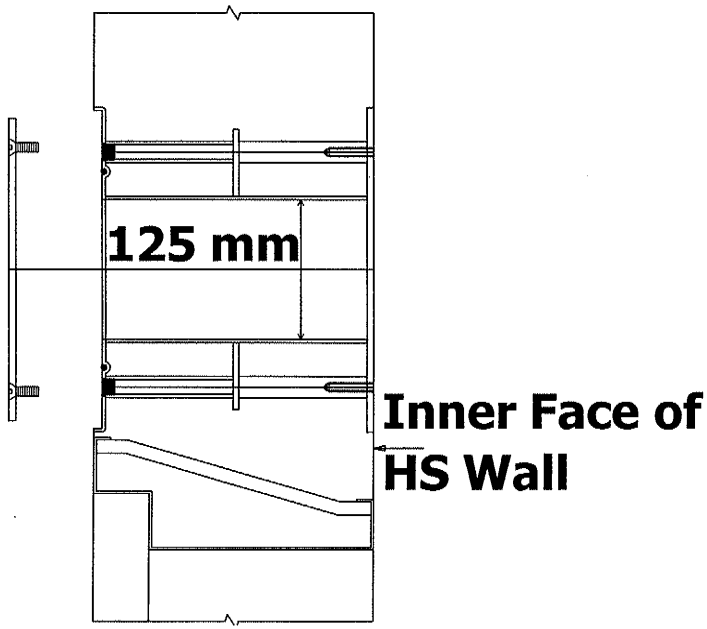
FIGURE 2.9 HS BENEATH AN INTERNAL STAIRCASE

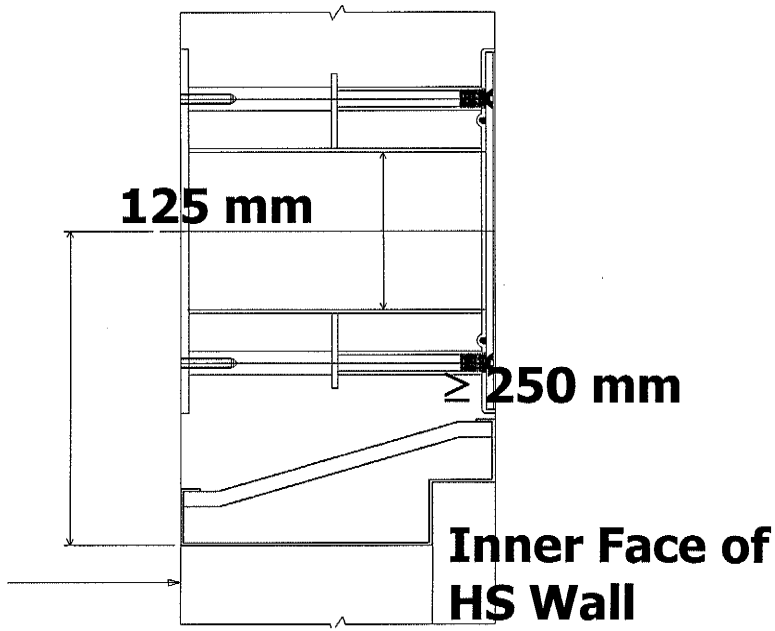
False Ceiling below VS

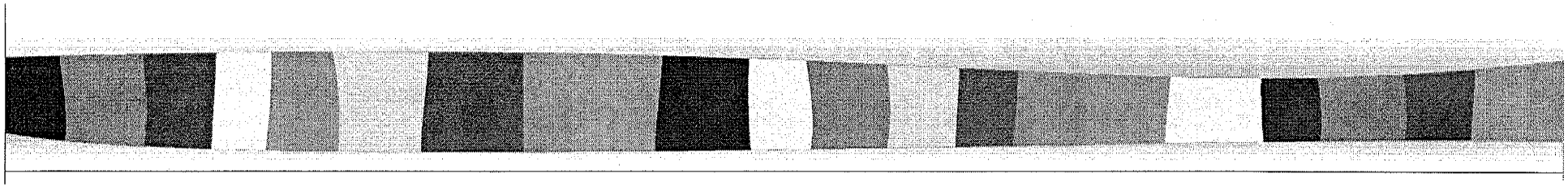
- 1 access panel shall be provided
  - 600 mm × 600 mm
  - Directly below each VS

Fragmentation Plate

- 6 mm Fragmentation Plate – Fig 4.2 (c)
  - Stainless Steel
  - Mounted on External Face
  - 10 mm Stainless Steel Bolts



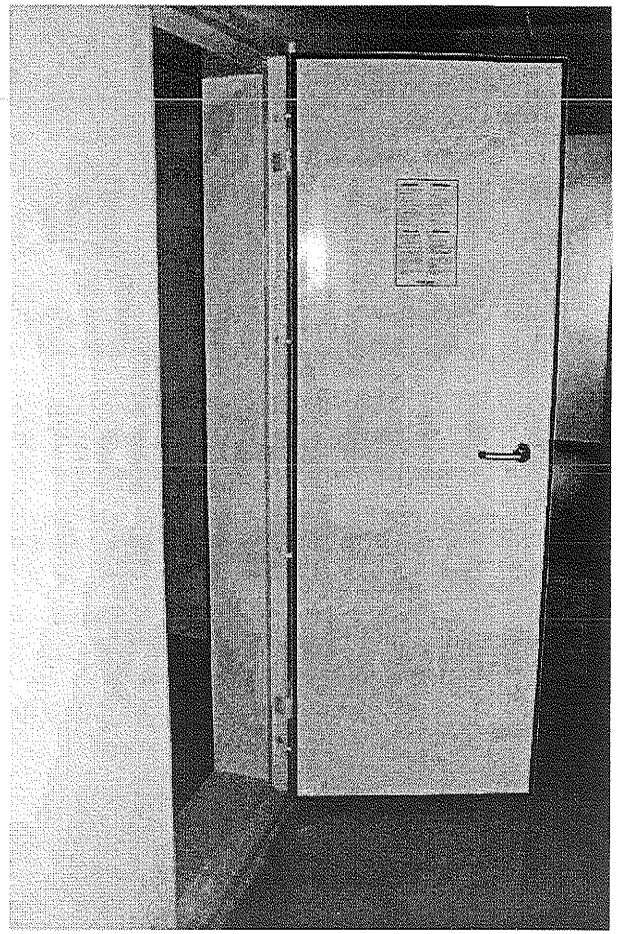




HS DOOR

General

- HS Door shall
  - Provide air-tightness to the HS
  - Designed to open outwards at least 90 degrees from the HS

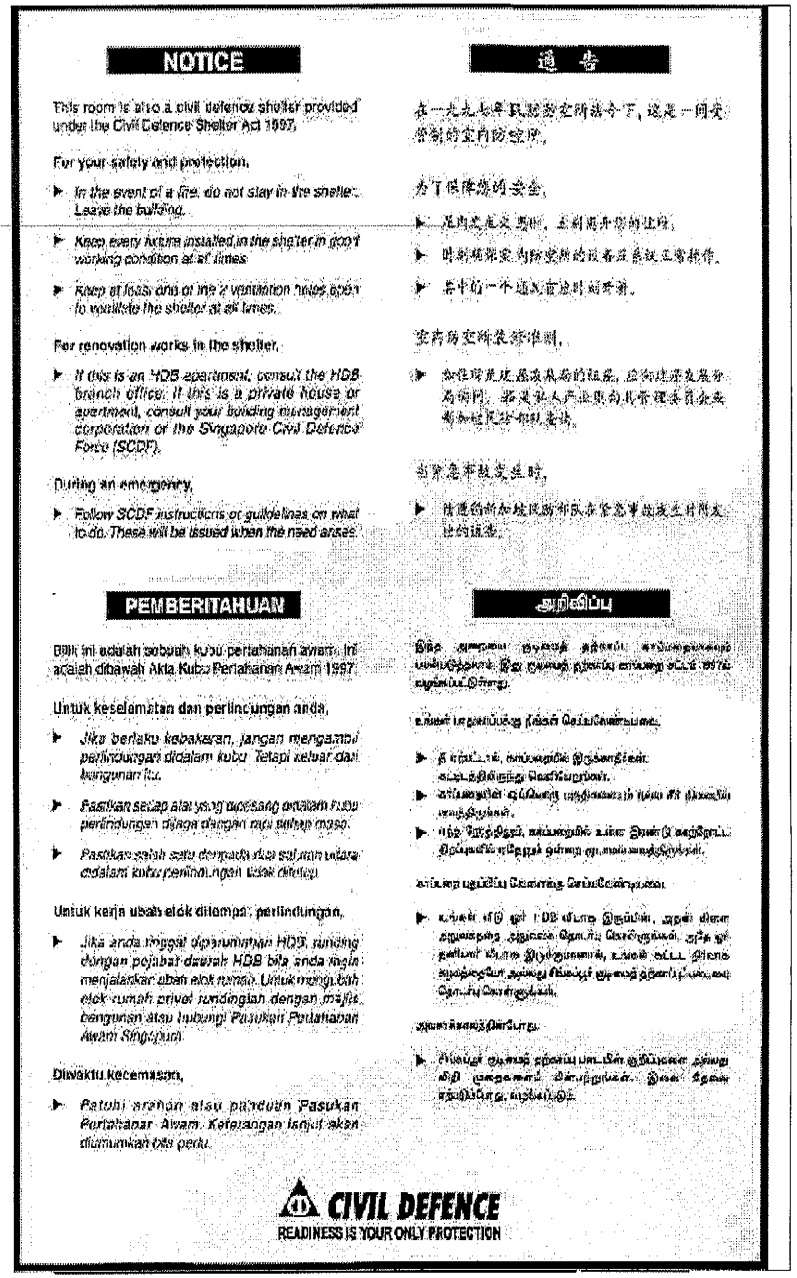


Approved HS Door

- Only HS Doors of approved design shall be used
- List of approved HS door designs is available from the relevant authority

HS Door Notice

- **Every door shall have the notice affixed on its internal face**
  - **Position – Fig 5.3 (a)**
  - **Sample Notice – Fig 5.3 (b)**



NOTICE

This room is also a civil defence shelter provided under the Civil Defence Shelter Act 1997.

For your safety and protection,

- *In the event of a fire, do not stay in the shelter. Leave the building.*
- *Keep every fixture installed in the shelter in good working condition at all times.*
- *Keep at least one of the 2 ventilation holes open to ventilate the shelter at all times.*

For renovation works in the shelter,

- *If this is an HDB apartment, consult the HDB branch office. If this is a private house or apartment, consult your building management corporation or the Singapore Civil Defence Force (SCDF).*

During an emergency,

- *Follow SCDF instructions or guidelines on what to do. These will be issued when the need arises.*

通 告

本一九九七年民防掩蔽所法令下，这是一间受[illegible]的室内防空所。

为了保障您的安全，

- [illegible]
- [illegible]
- [illegible]

室内防空所装修准则，

- [illegible]

当紧急事故发生时，

- [illegible]

PEMBERITAHUAN

Bilik ini adalah sebuah kubu pertahanan awam ini adalah dibawah Akta Kubu Pertahanan Awam 1997.

Untuk keselamatan dan perlindungan anda,

- *Jika berlaku kebakaran, jangan mengambil perlindungan didalam kubu. Tetapi keluar dari bangunan itu.*
- *Pastikan setiap alat yang tersedia dalam kubu perlindungan dijaga dengan rapi setiap masa.*
- *Pastikan salah satu daripada dua saluran udara adalah untuk perlindungan tidak ditutup.*

Untuk kerja ubah elok dilompat perlindungan,

- *Jika anda tinggal dipanumiman HDB, runding dengan pejabat daerah HDB bila anda ingin menjalankan ubah elok rumah. Untuk mengubah elok rumah privat tandingan dengan majlis bangunan atau hubungi Pasukan Pertahanan Awam Singapura.*

Diwaktu kecemasan,

- *Patuhi arahan atau panduan Pasukan Pertahanan Awam. Kelangan lanjut akan dikeluarkan bila perlu.*

அறிவிப்பு

[illegible]

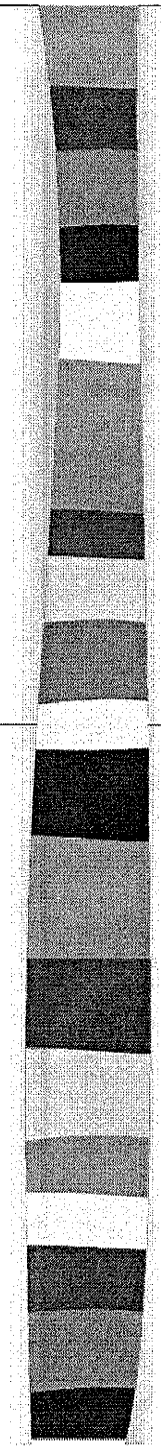
[illegible]

- [illegible]
- [illegible]
- [illegible]

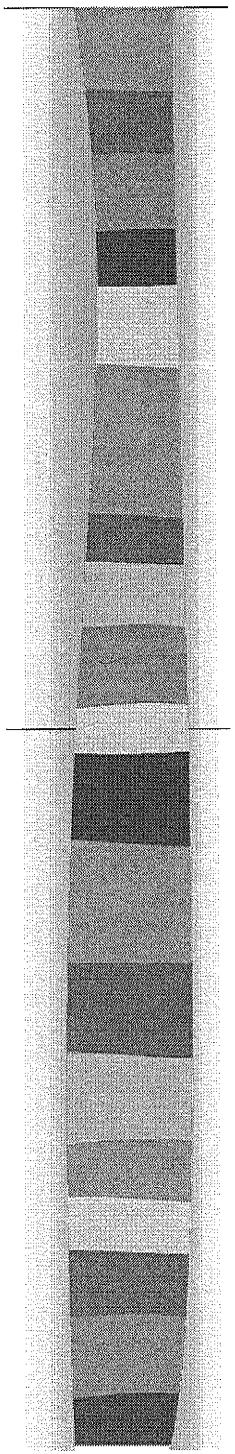
[illegible]

- [illegible]

CIVIL DEFENCE
READINESS IS YOUR ONLY PROTECTION

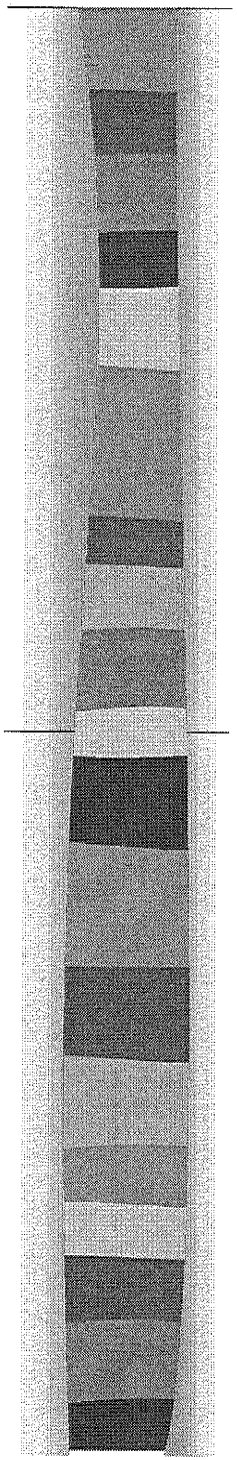


"Method statement of the remedial work on structural elements, including HS door frame, shall be approved by the Commissioner of Building Control"



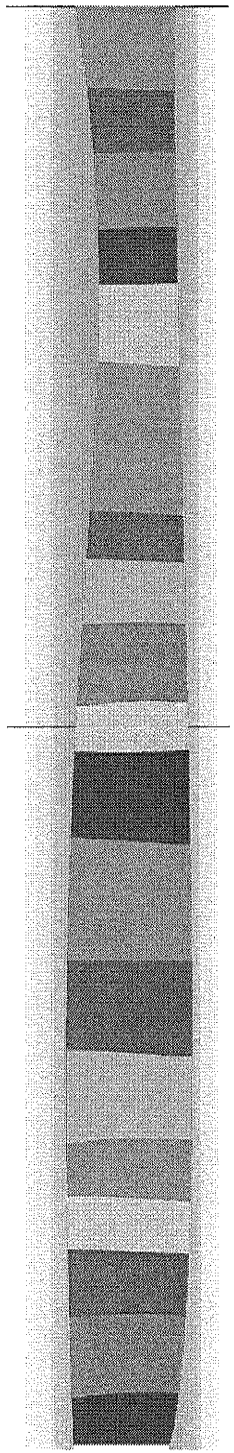
WEAPON EFFECTS

Building and Construction Authority



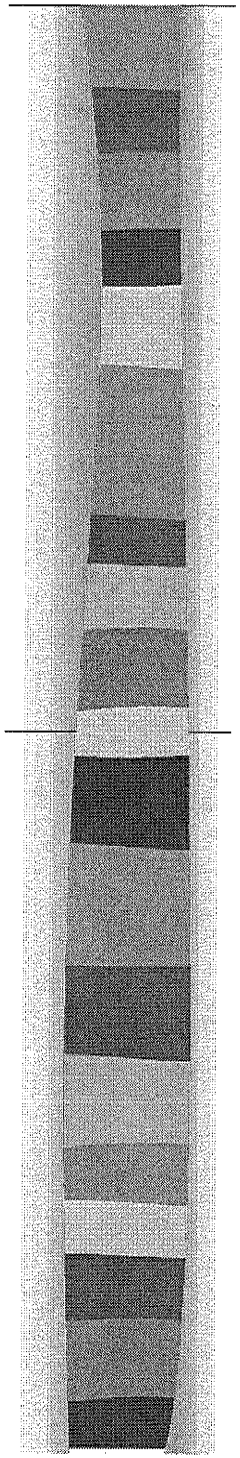
WEAPON EFFECTS

- Penetration
- Air Blast
- Fragmentation



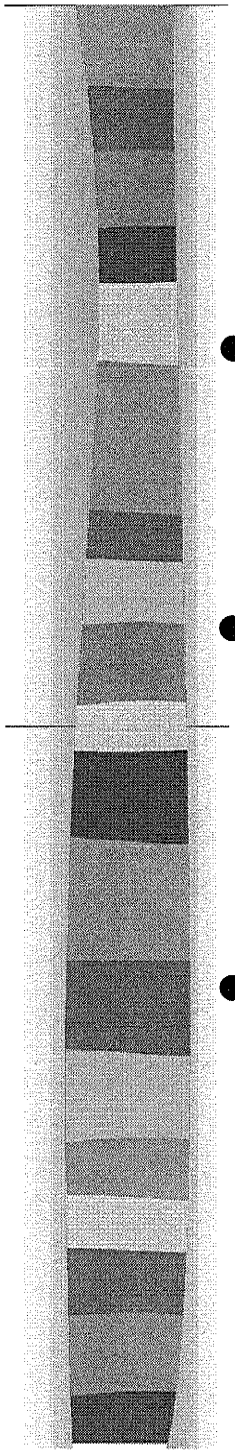
PENETRATION

The ability of the weapon to pierce a hardened protective layer



PENETRATION

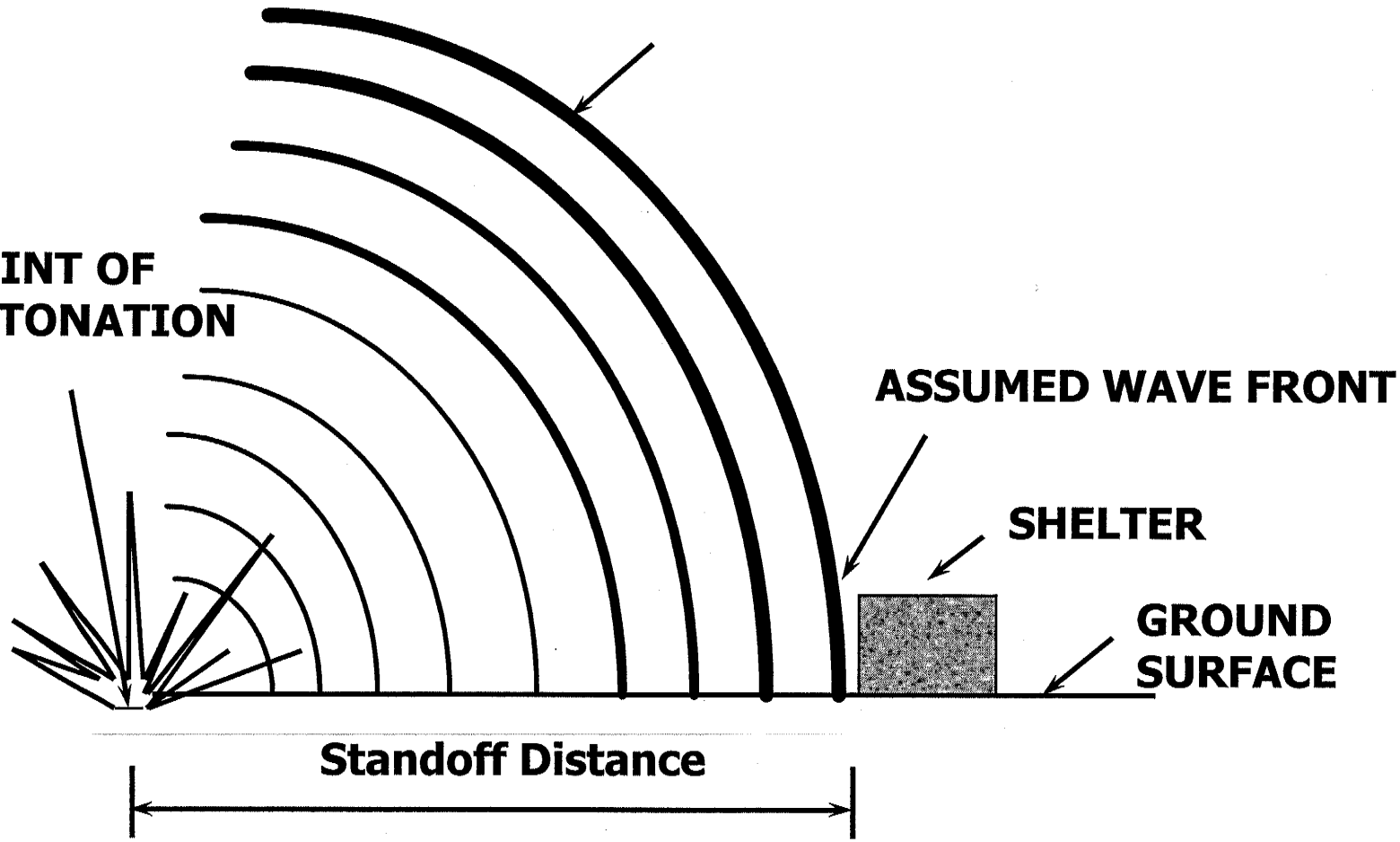
Influenced by the characteristics of the projectile & target, e.g. geometry, line of impact, projectile velocity and type of material (brittle or ductile)



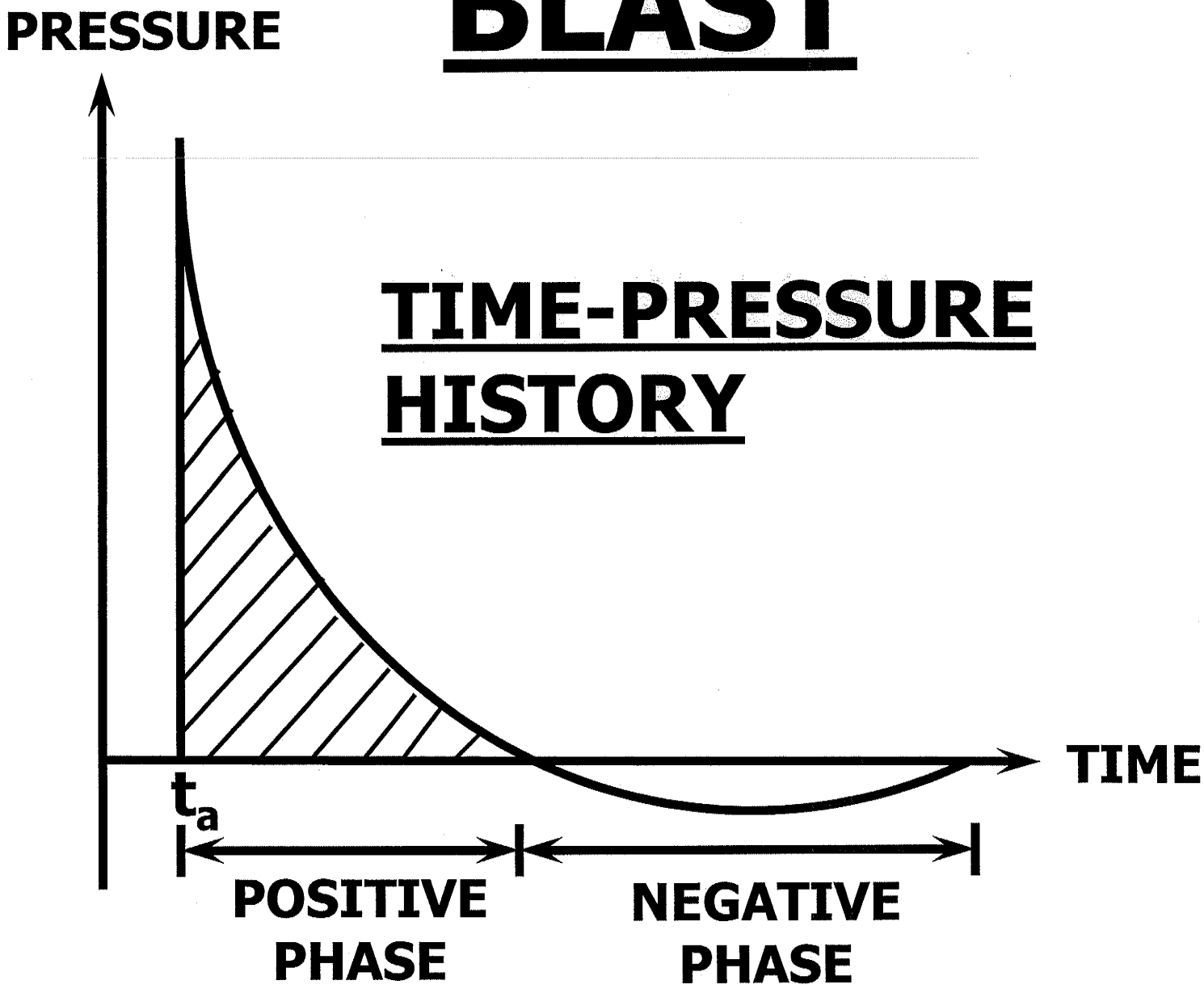
BLAST

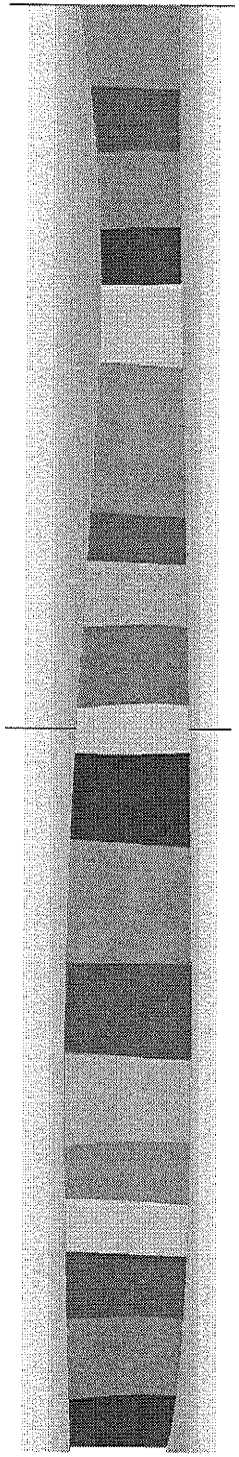
- Caused by a shock wave propagating from the point of detonation
- Defined by transmission velocity, peak overpressure, positive phase duration and the impulse
- Affected by the relative location of the weapon (in free air, surface or shallow buried) and the structure

BLAST


GROUND REFLECTED WAVE
POINT OF DETONATION
ASSUMED WAVE FRONT
SHELTER
GROUND SURFACE
Standoff Distance

BLAST


PRESSURE
TIME-PRESSURE HISTORY
TIME
t_a
POSITIVE PHASE
NEGATIVE PHASE



BLAST

Blast pressure can be reduced by increasing standoff distance

Blast Effects decrease exponentially as standoff distance increases

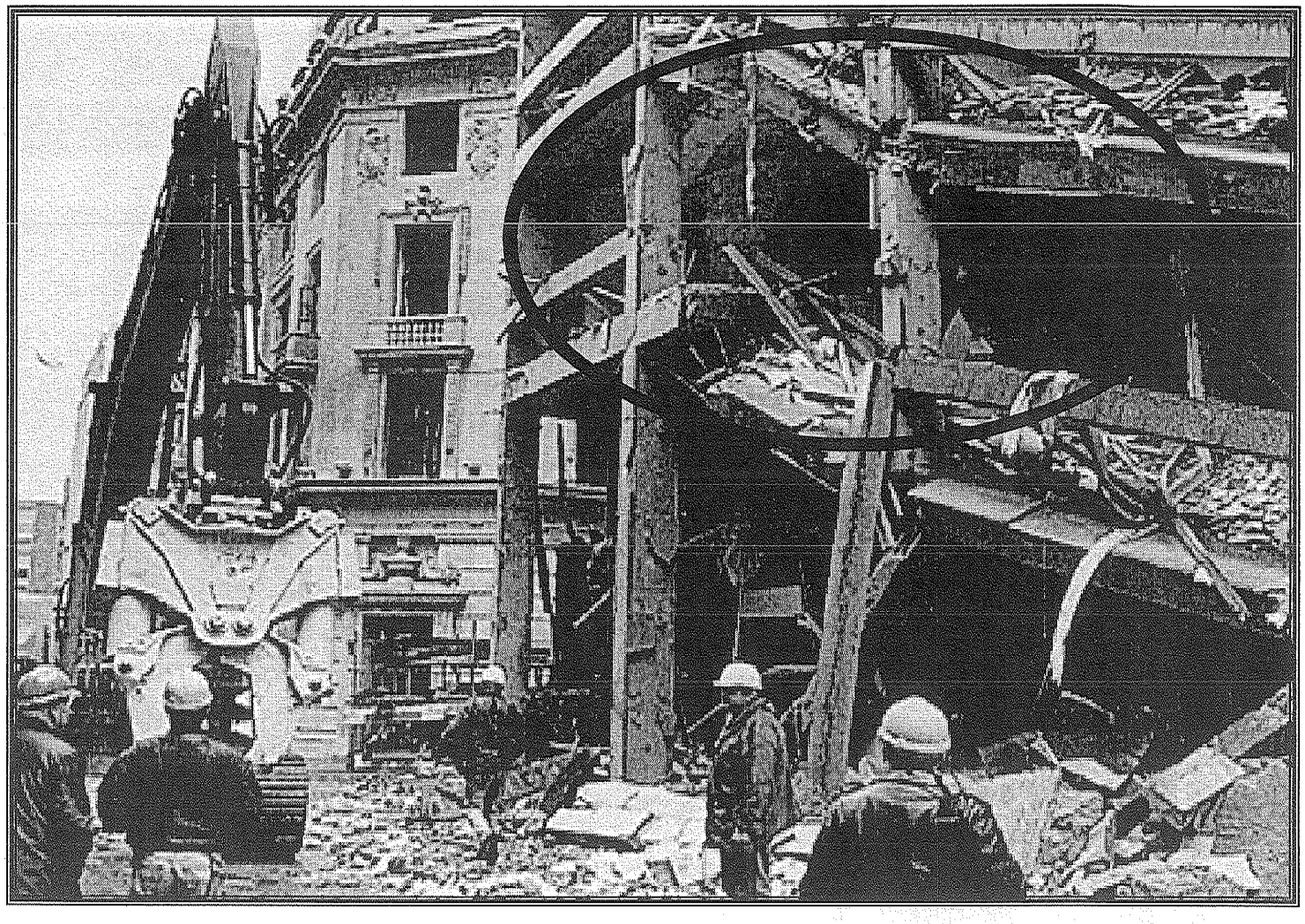
BLAST

Blast effects are largely reduced by:

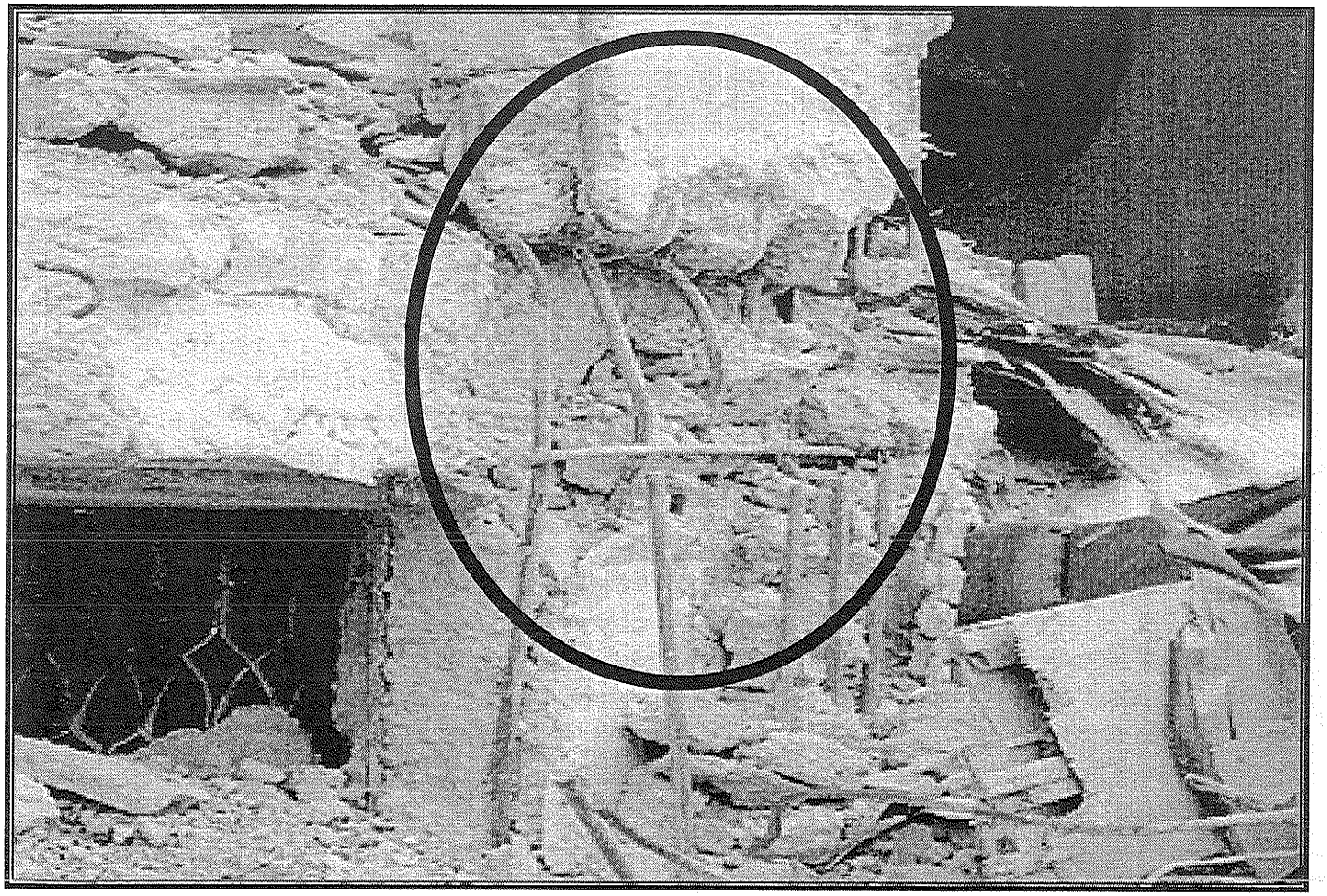
- **Having thicker concrete wall**
- **Installation of a certified blast door**
- **Use of ductile elements in design**
- **Use of fixed supports in design**
- **Proper detailing for joints**



BLAST DAMAGE TO STEEL FRAMED FLAT AND A CHURCH WITH LOAD-BEARING MASONRY WALL



FAILURE OF SIMPLY SUPPORTED JOINT

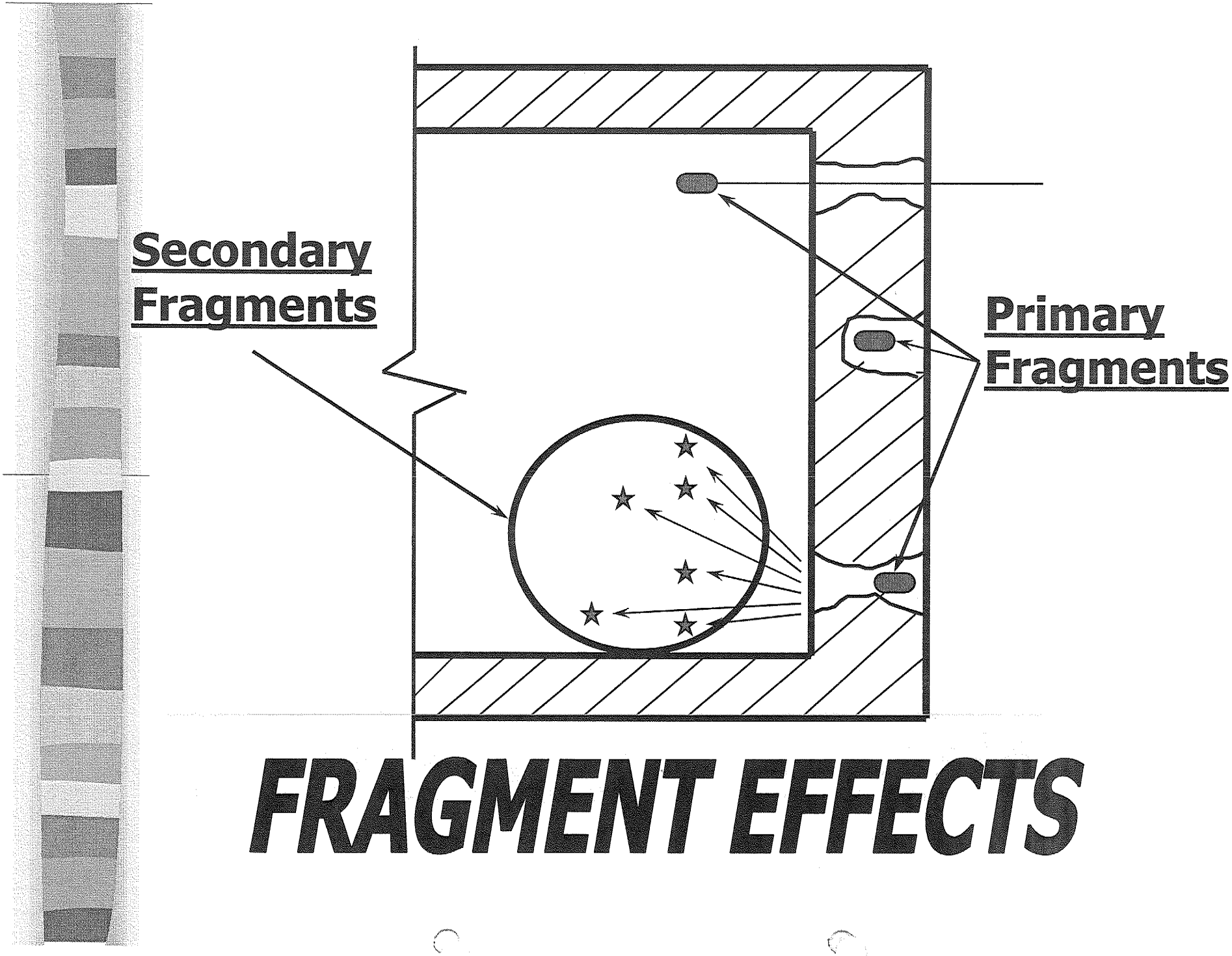


FAILURE DUE TO INSUFFICIENT TIES, POOR CONCRETE QUALITY AND DETAILING OF JOINTS

FRAGMENTAION

Two types of fragments:

- Primary fragments
- Secondary fragments



FRAGMENT EFFECTS

FRAGMENTATION

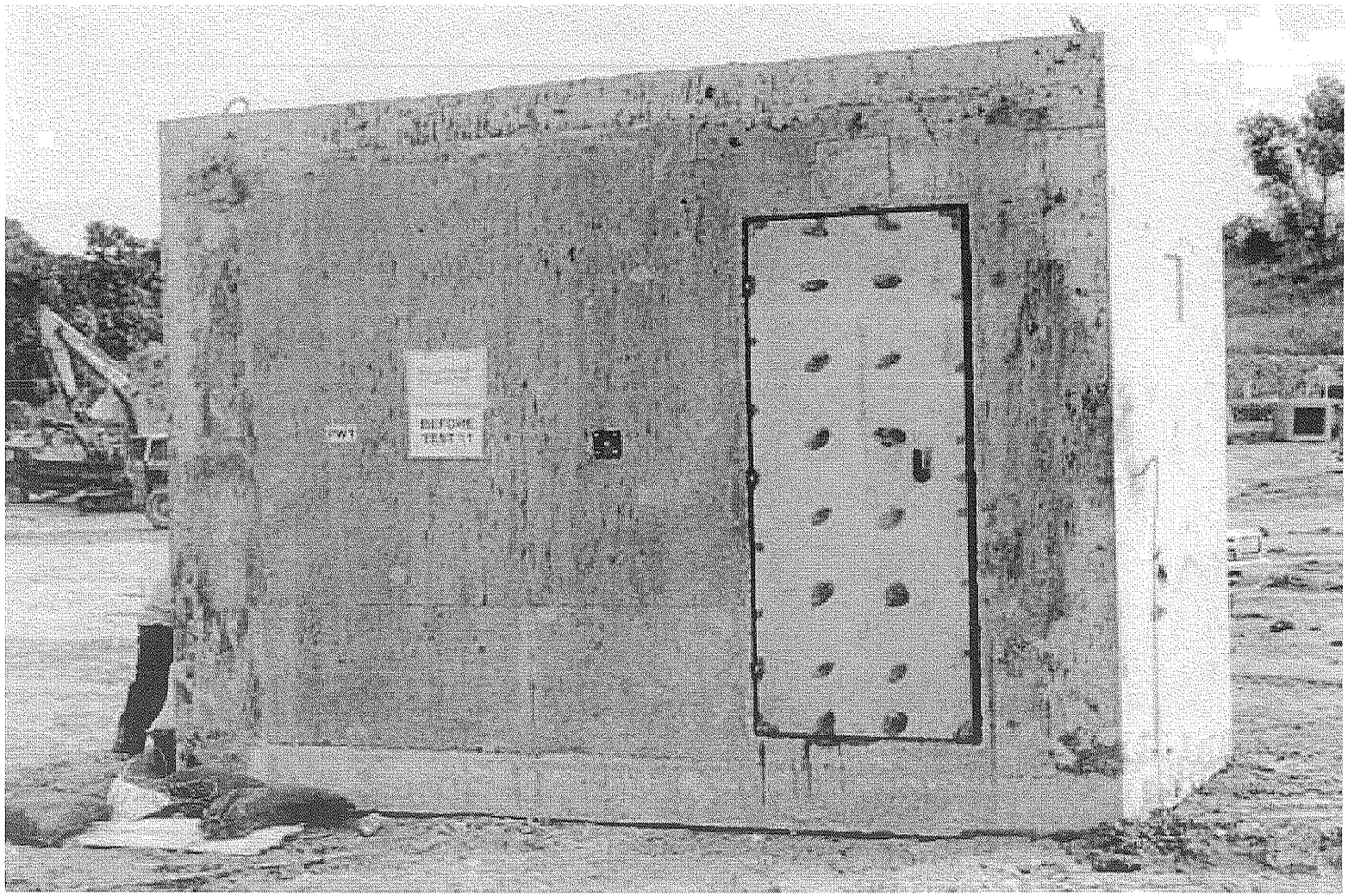
Resistance provided by:

- Thickness of reinforced concrete walls
- Setback distance of element from the external building line
- Thickness of steel plate for the ventilation openings

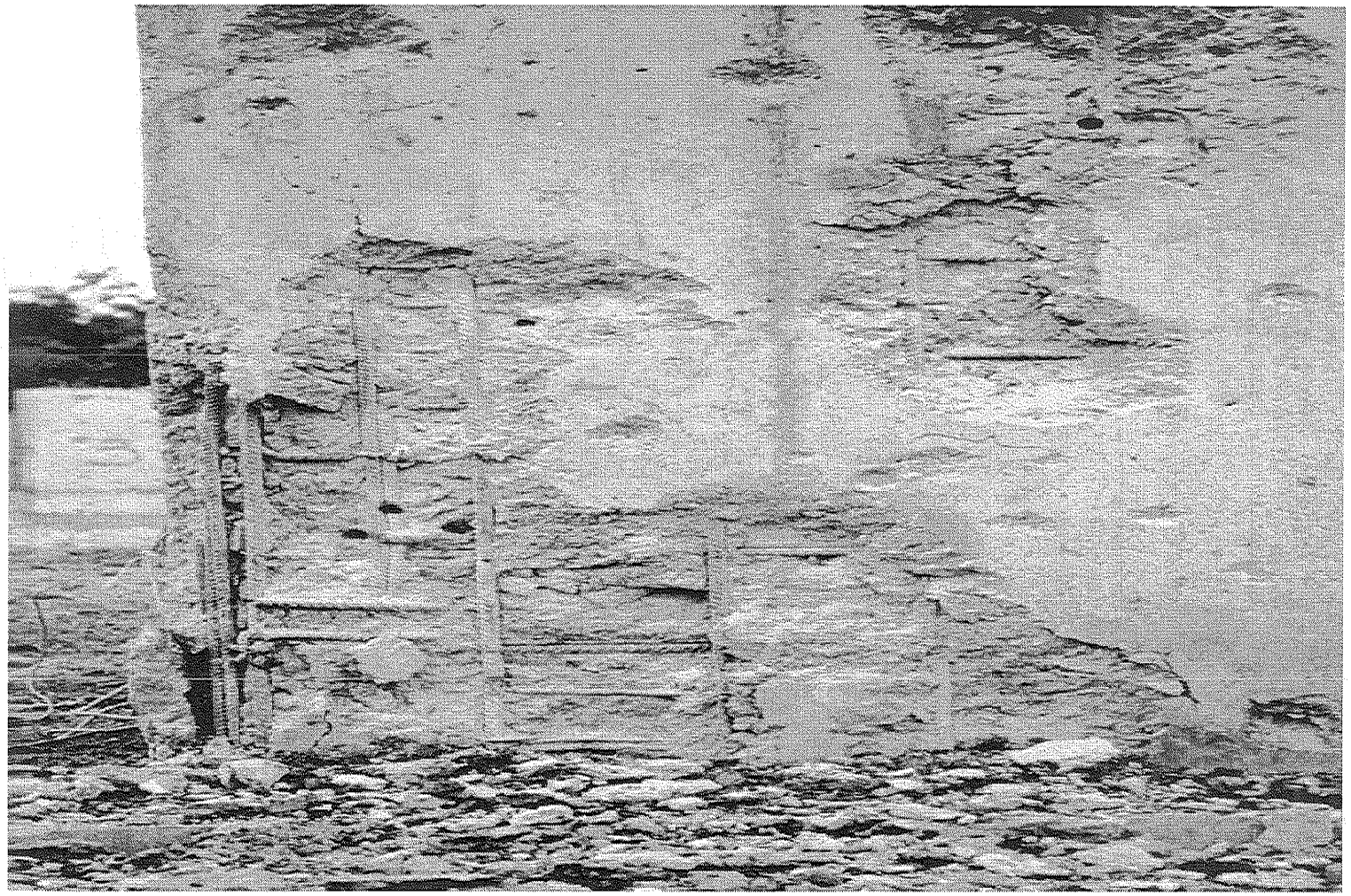


THE DISINTEGRATION OF BUILDINGS DUE TO BLAST LOADING PRODUCES FRAGMENTS THAT COULD INFLICT SERIOUS INJURIES

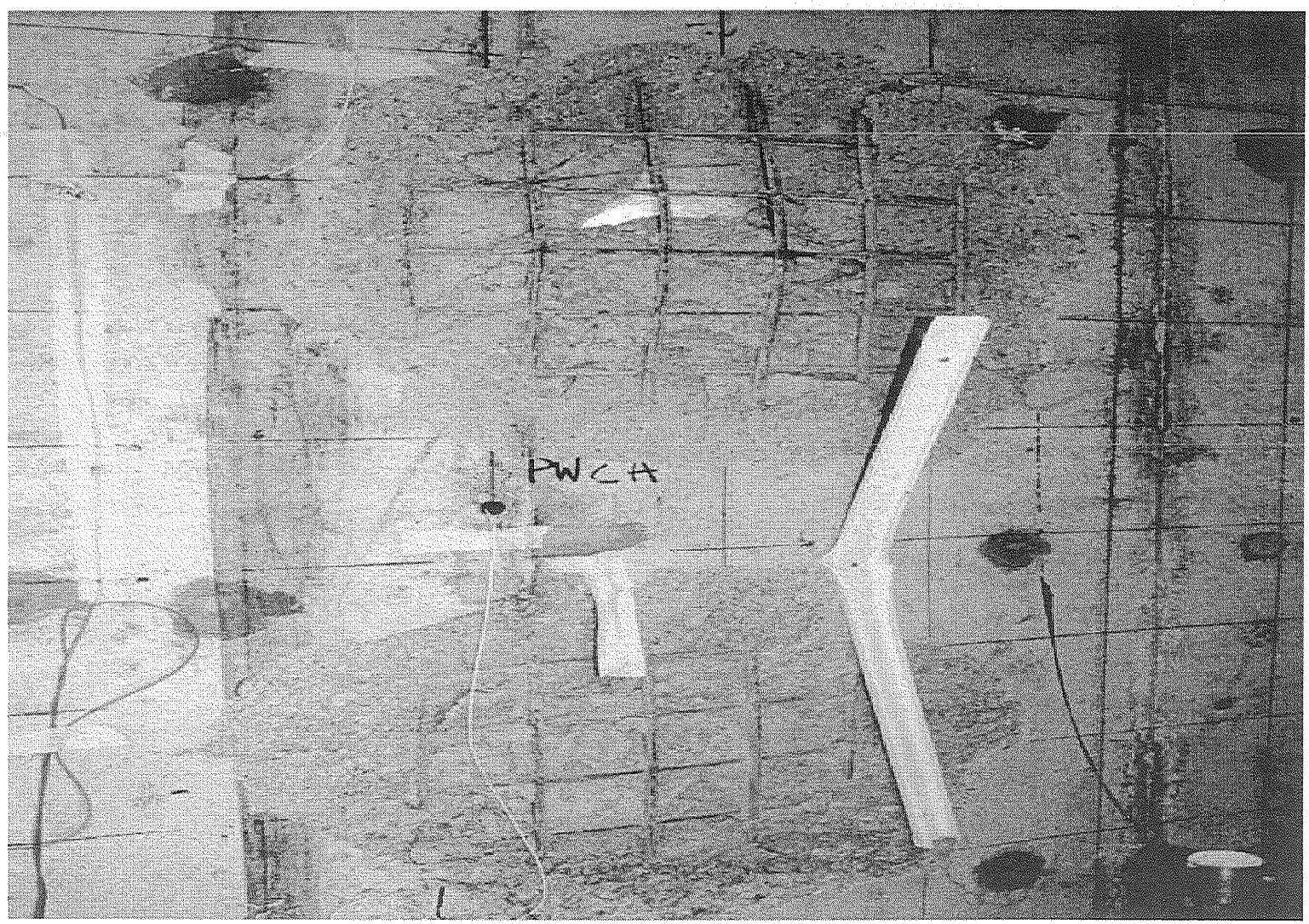
Blast Test on Household Shelter Module



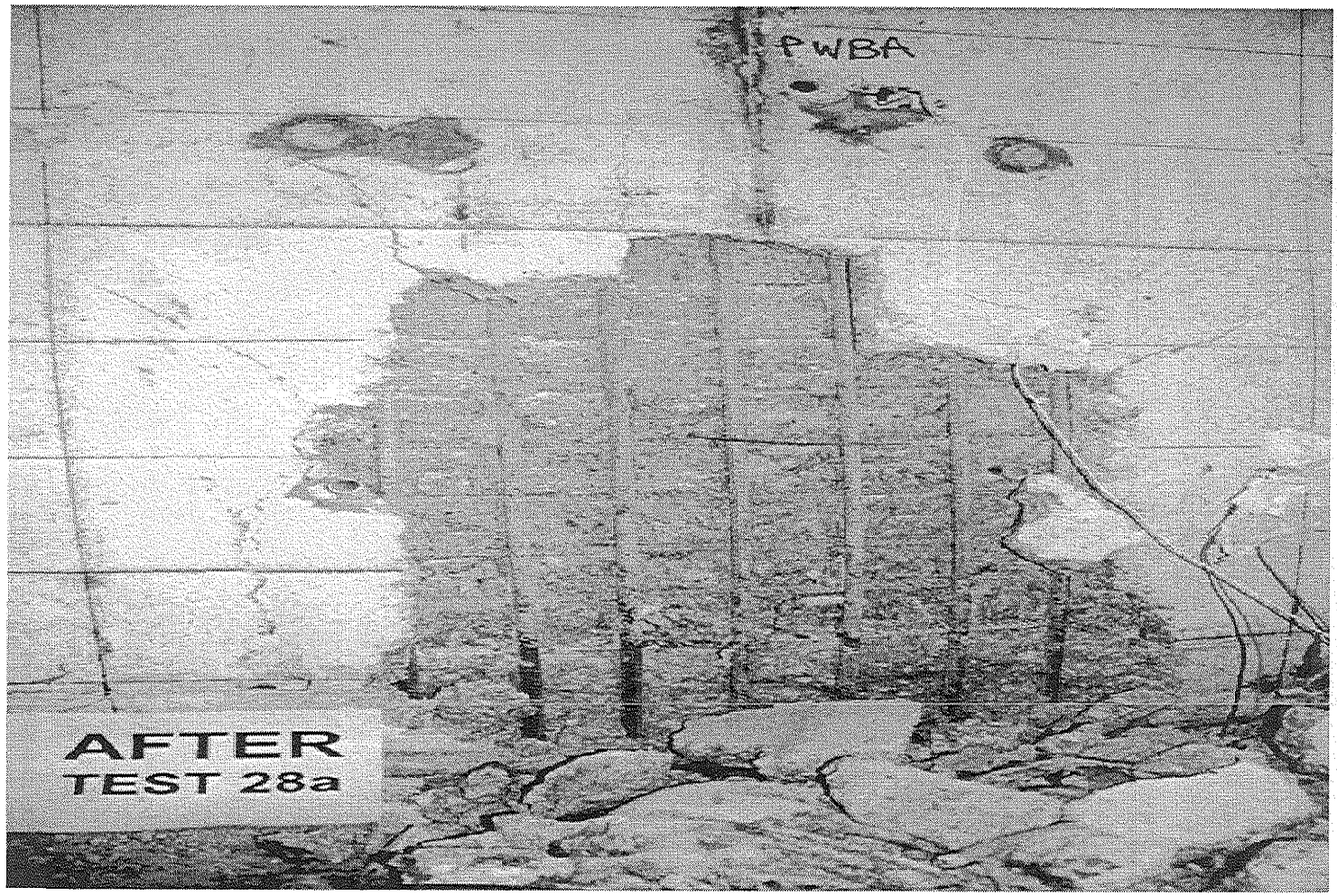
Effects on External Face

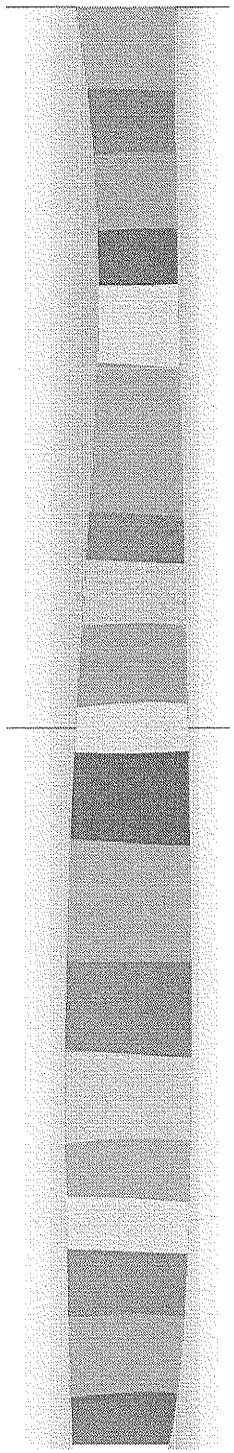


Effects on Internal Face



Secondary Fragments due to Scabbing

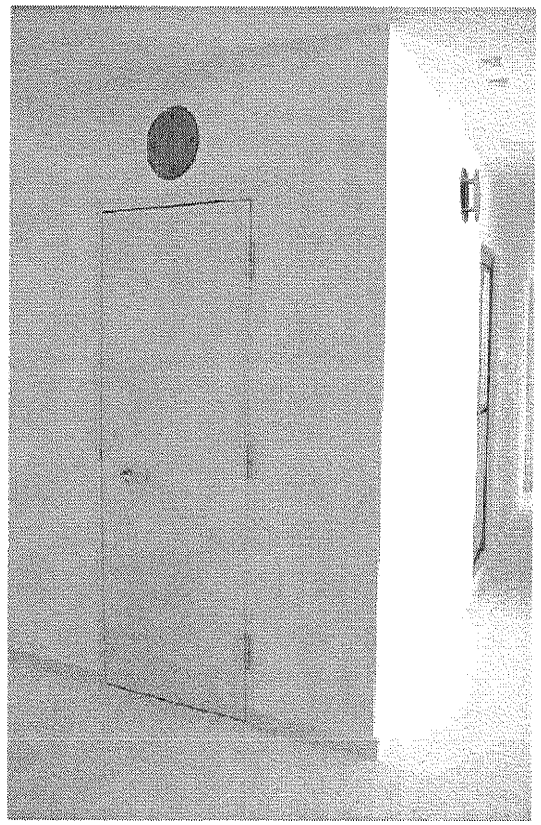




Architectural Requirements of Household Shelters

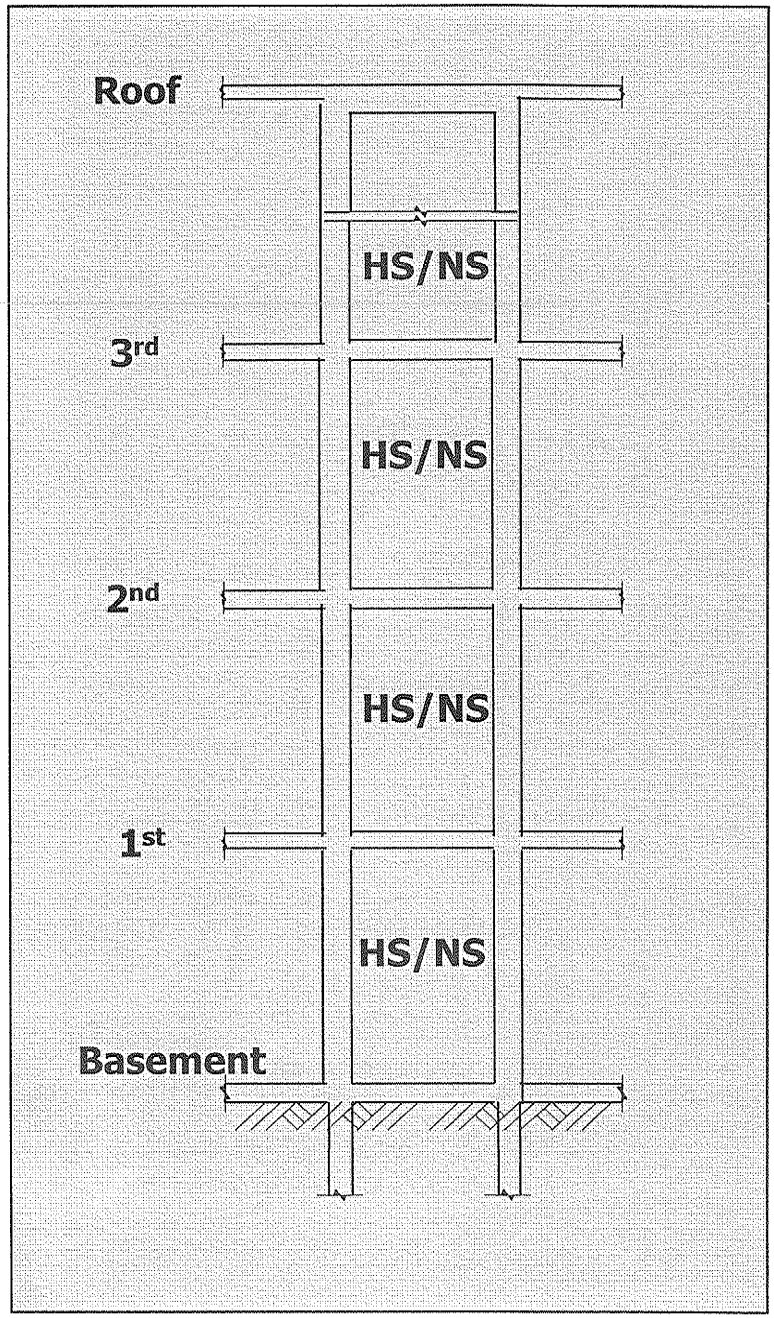
Household Shelter (HS)

- Located inside a house or flat
- For protection of people against weapon effects during a war emergency



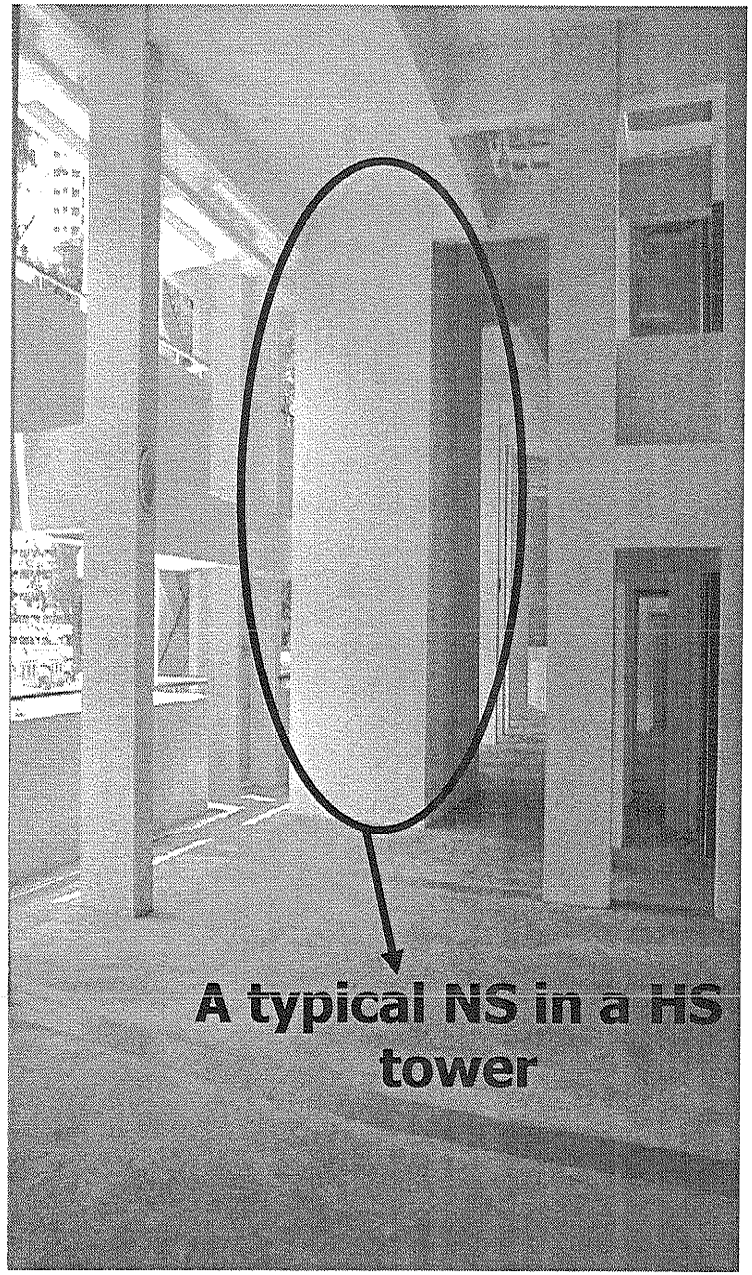
Household Shelter (HS) Tower

- Consists of HS (or NS where applicable) on every storey
- Form a vertical tower and continue to its foundation



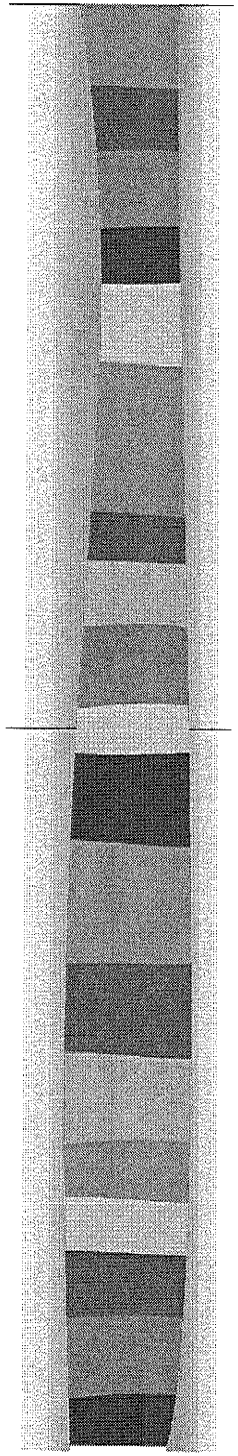
Non-Shelter (NS)

- The space enclosed by walls which continue from shelter above or below
- Not intended for use during a war emergency



ARCHITECTURAL REQUIREMENTS OF HOUSEHOLD SHELTERS

- Size of HS - area and volume
- Position of HS
- Setback distance of HS
- NS in HS tower
- Basement HS in landed dwelling unit
- HS located beneath staircase



HS Dimension

Minimum HS width = 1200 mm

Maximum HS length = 4000 mm

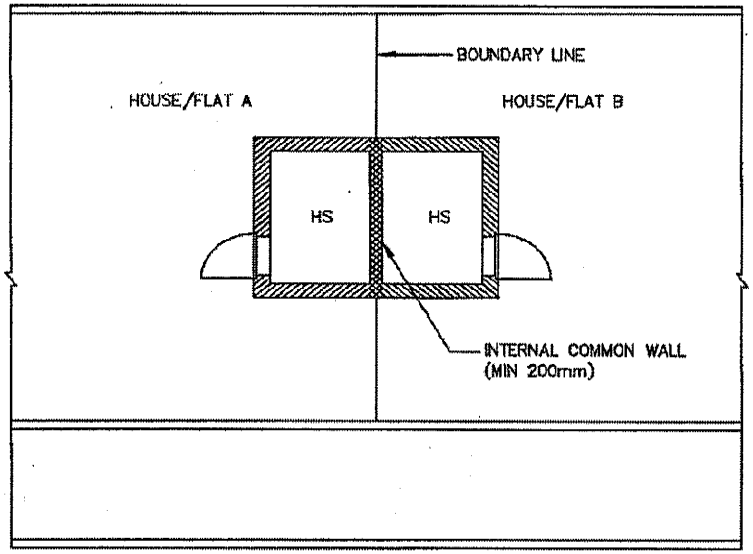
The internal length and width of HS walls shall be designed with an increment of 50mm

HS Area and Volume

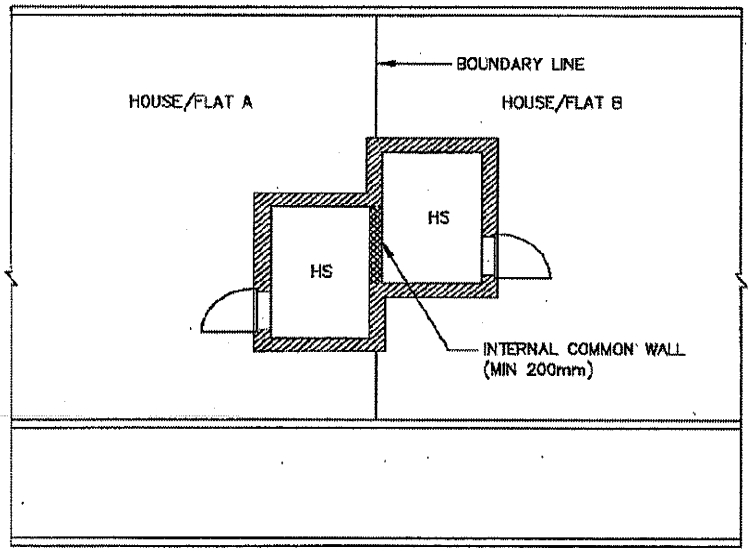
Gross Floor Area of Dwelling Unit (m^2)	Minimum Internal Floor Area of HS (m^2)	Minimum Internal Volume of HS (m^3)
GFA≤45	1.6	3.6
45<GFA≤75	2.2	5.4
75<GFA≤140	2.8	7.2
GFA>140	3.4	9.0

HS Position

INTERNAL COMMON WALL BETWEEN TWO HS IN NON-LANDED AND LANDED CLUSTER HOUSING DEVELOPMENTS



ALTERNATIVE 1

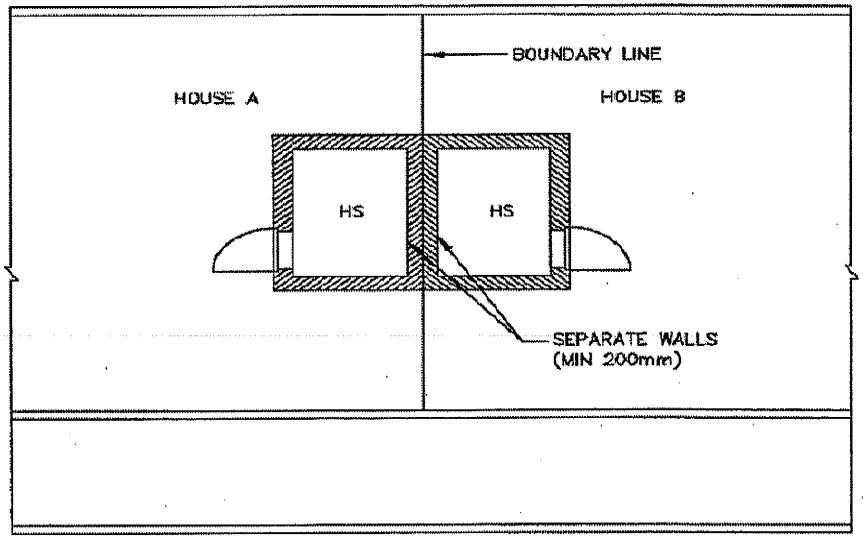


ALTERNATIVE 2

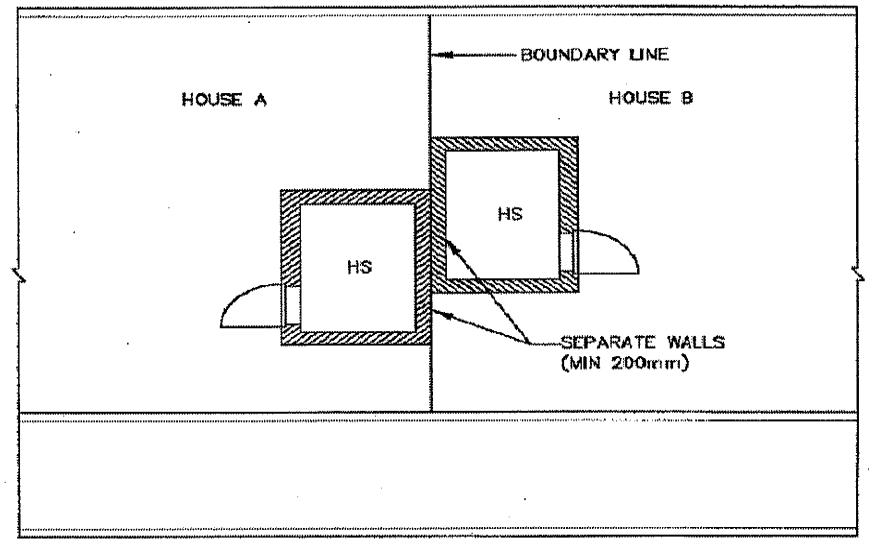
FIGURE 2.3.1(c) INTERNAL COMMON WALL BETWEEN TWO HS IN NON-LANDED AND LANDED CLUSTER HOUSING DEVELOPMENTS

HS Position

SEPARATE WALLS BETWEEN TWO HS IN LANDED DEVELOPMENTS



ALTERNATIVE 1



ALTERNATIVE 2

FIGURE 2.3.1(d) SEPARATE WALLS BETWEEN TWO HS IN INTERMEDIATE LANDED DEVELOPMENTS

Stacking of HS

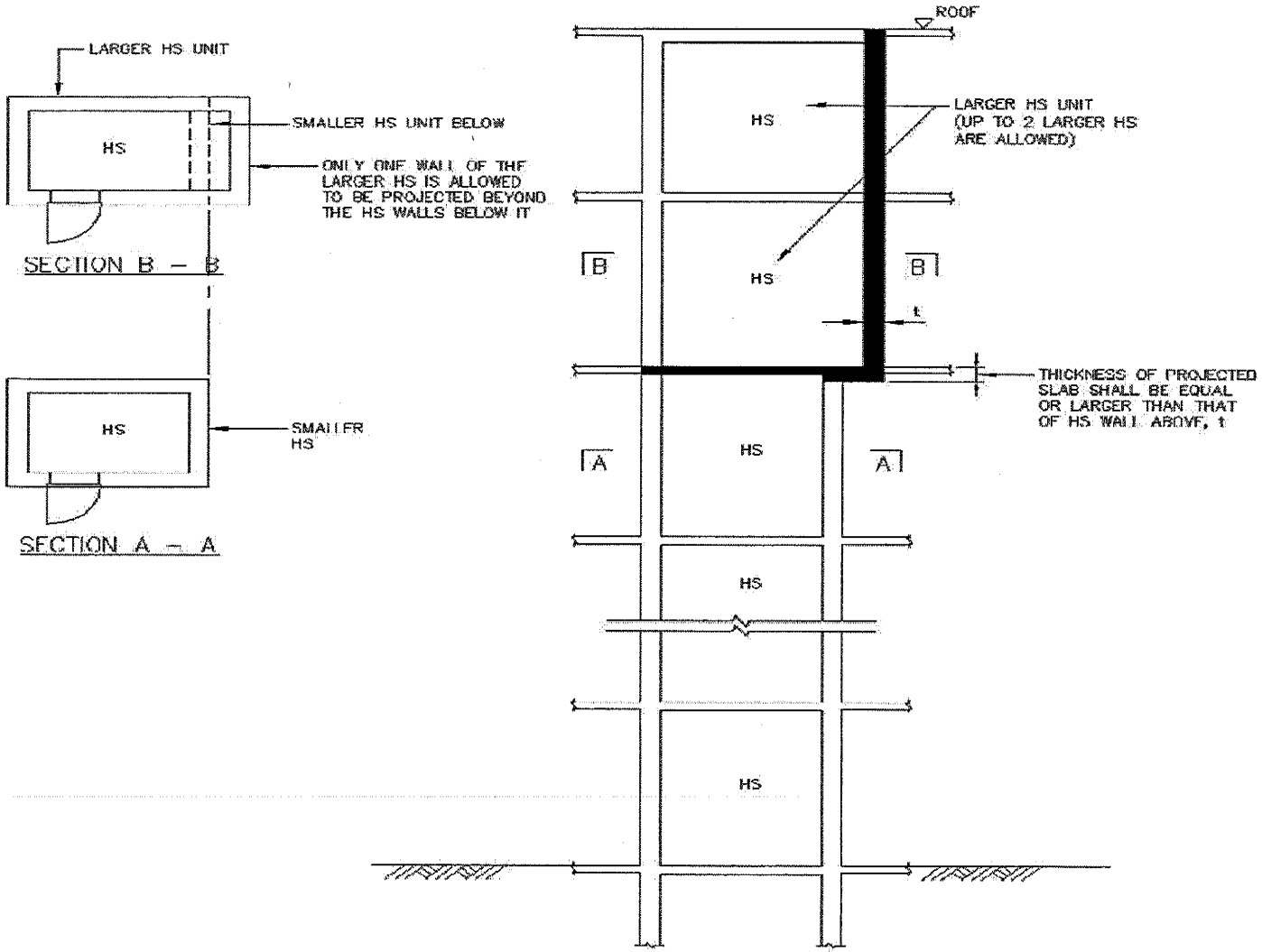
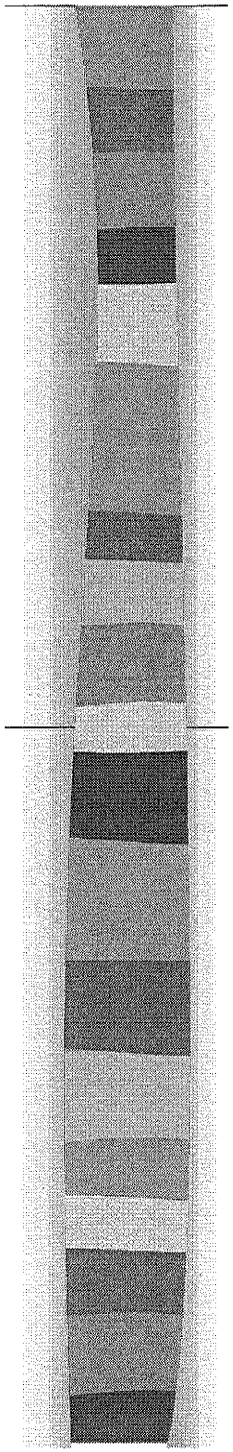


FIGURE 2.4.2(b) HS TOWER WITH TWO LARGER HS AT THE TOP

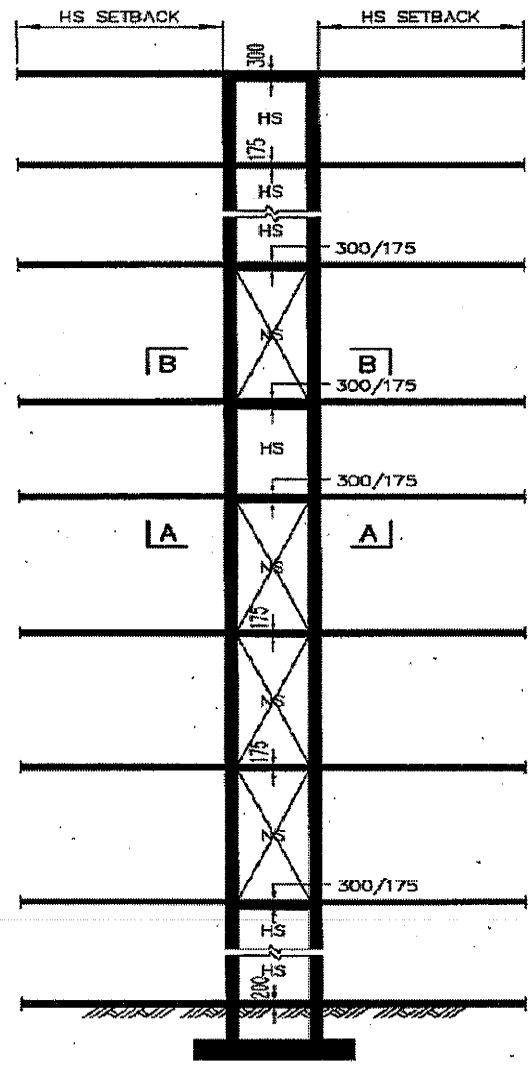


Setback distance of HS on first storey

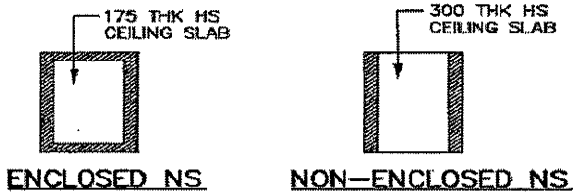
Where the storey height of a HS on the first storey is up to 3.6 m and is greater than the storey heights of the HS directly above it, the minimum setback distances of the HS on the first storey shall be at least the same as the setback distances of the HS above it.

HS and NS in HS Tower

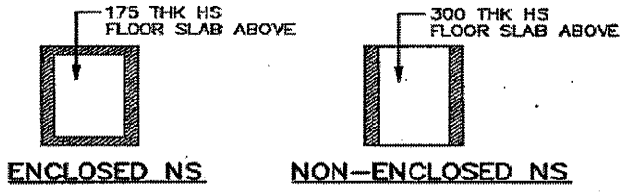
HS TOWER SHOWING HS AND NS (WITH ENCLOSED AND NON-ENCLOSED NS WALL) SLAB THICKNESS



HS TOWER
(HS/NS)



SECTION B — B



SECTION A — A

FIGURE 2.3.2 HS TOWER SHOWING HS AND NS (WITH ENCLOSED AND NON-ENCLOSED NS WALL) SLAB THICKNESS

HS and NS in HS Tower

SECTION OF HS TOWER SHOWING HS AND NS CLEAR HEIGHTS

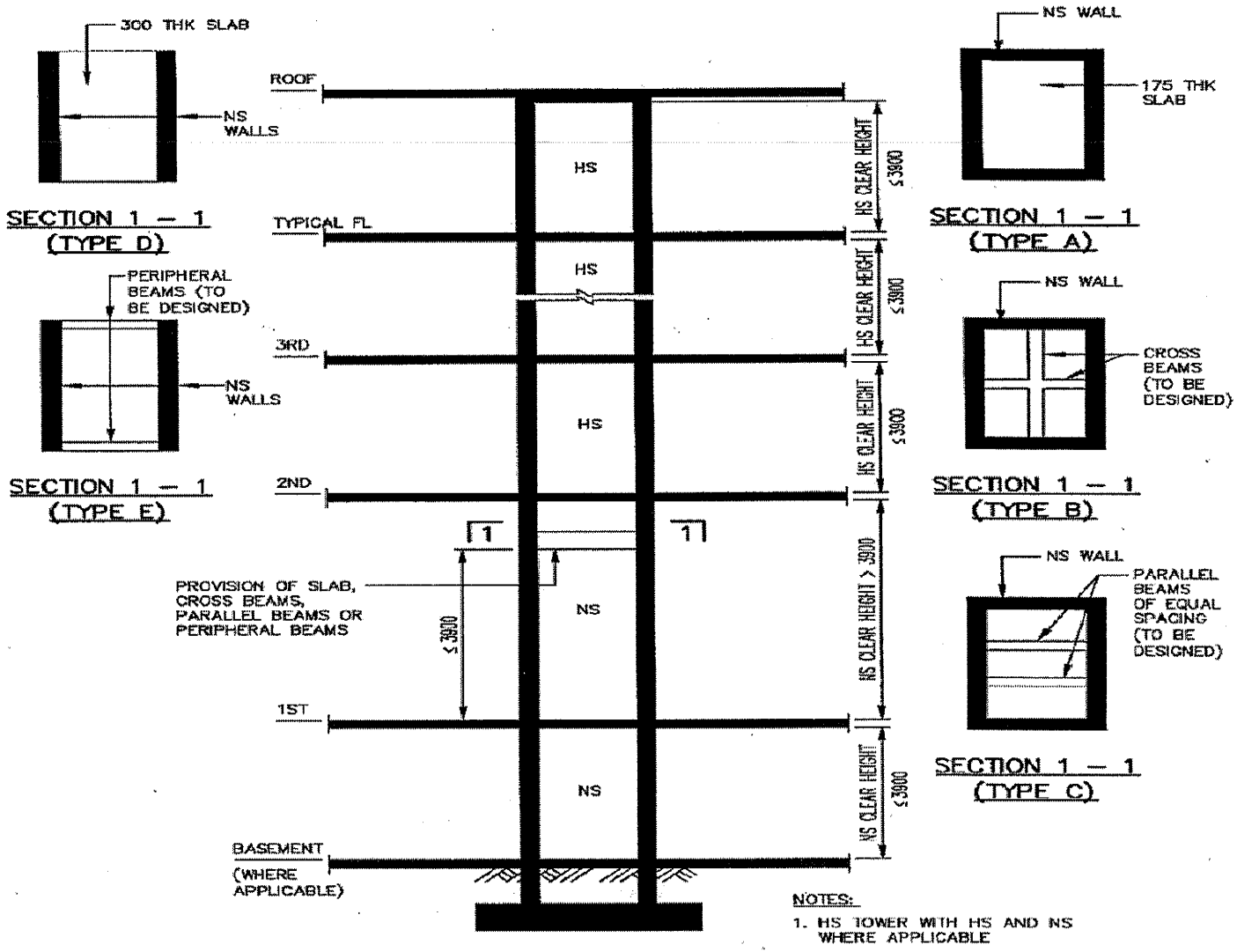
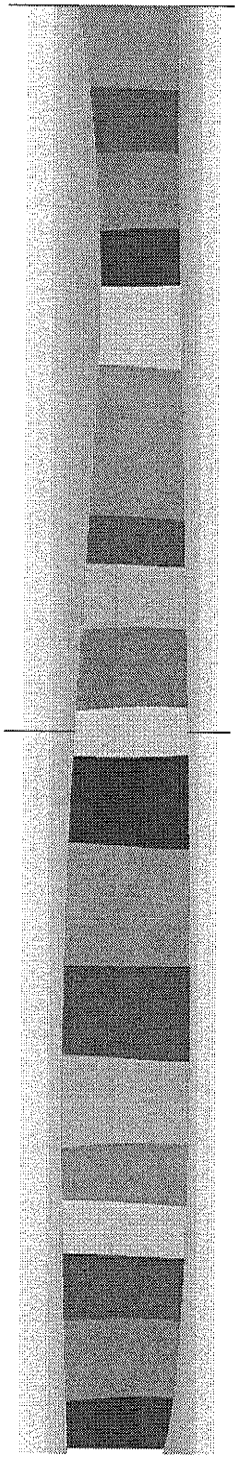
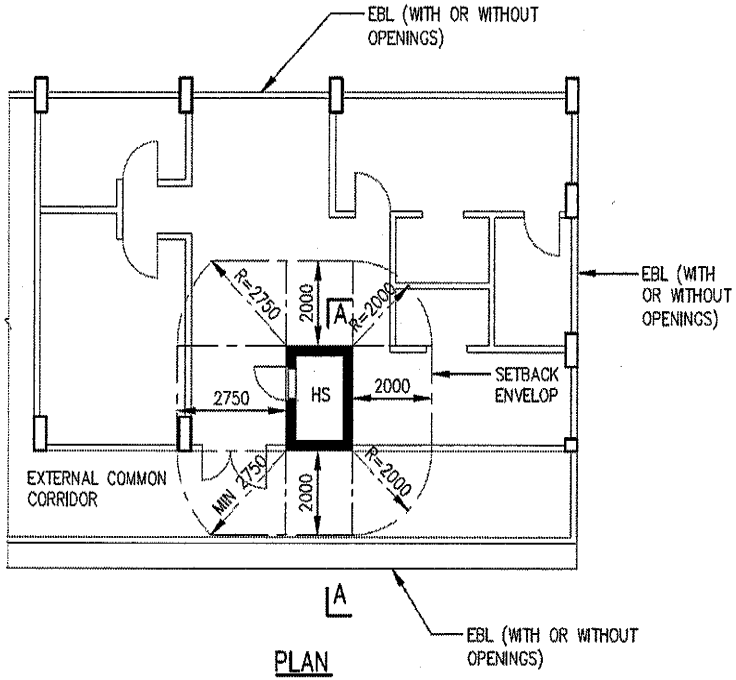


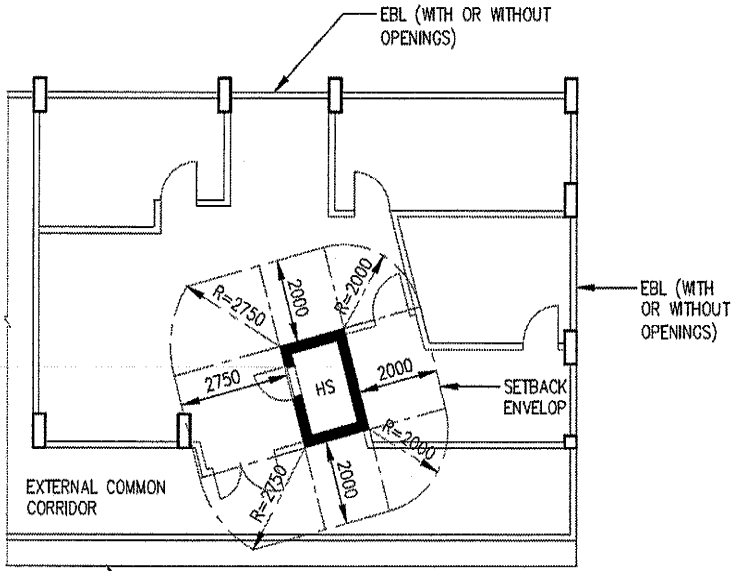
FIGURE 2.2.2(b) SECTION OF HS TOWER SHOWING HS AND NS CLEAR HEIGHTS



Presentation of HS Setback Envelop



PLAN

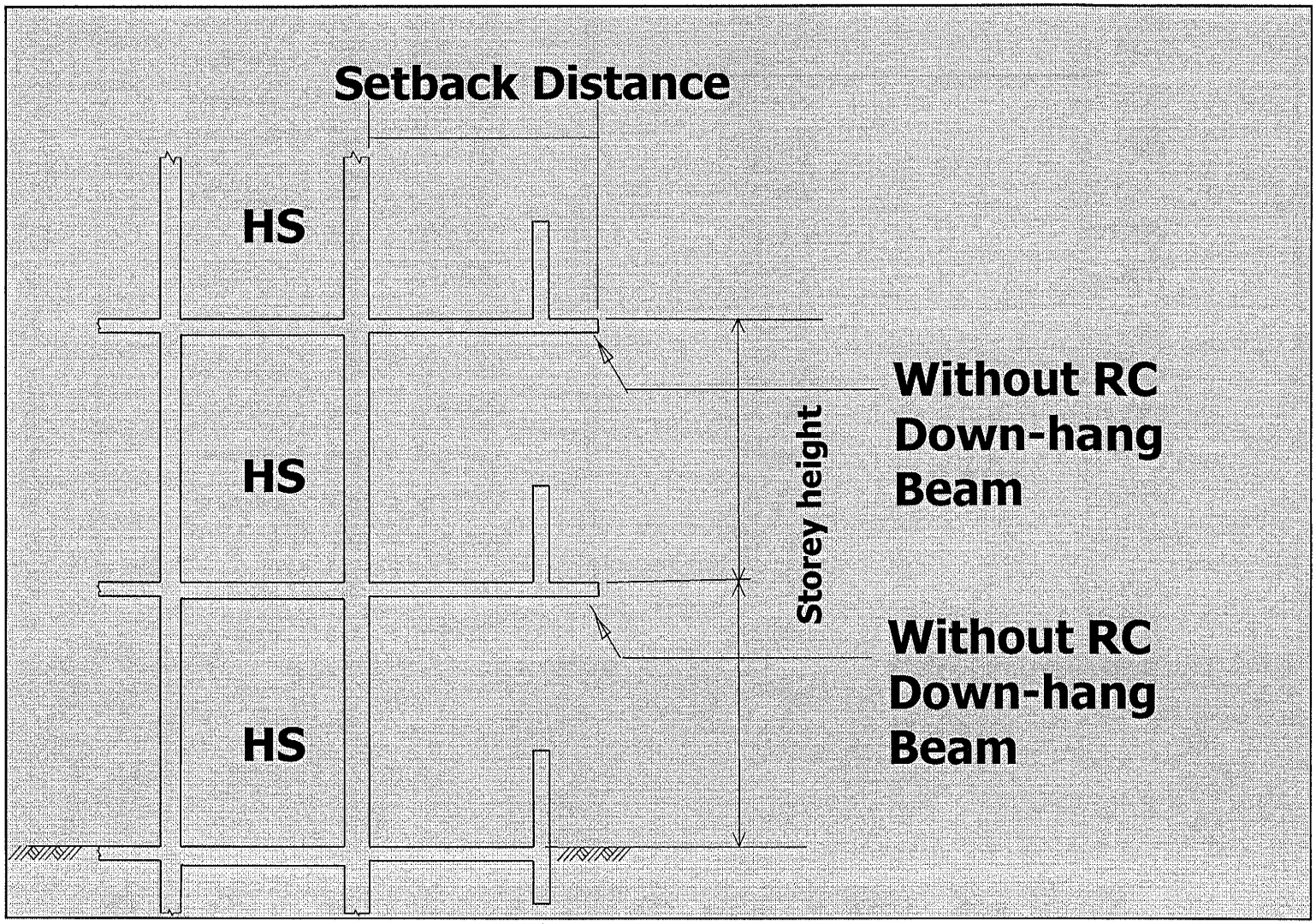


PLAN

NOTES:

1. WHERE TWO ADJACENT SETBACK DISTANCES ARE DIFFERENT, R SHALL BE THE LARGER OF THE TWO.

Setback Distance without RC Down-hang Beam



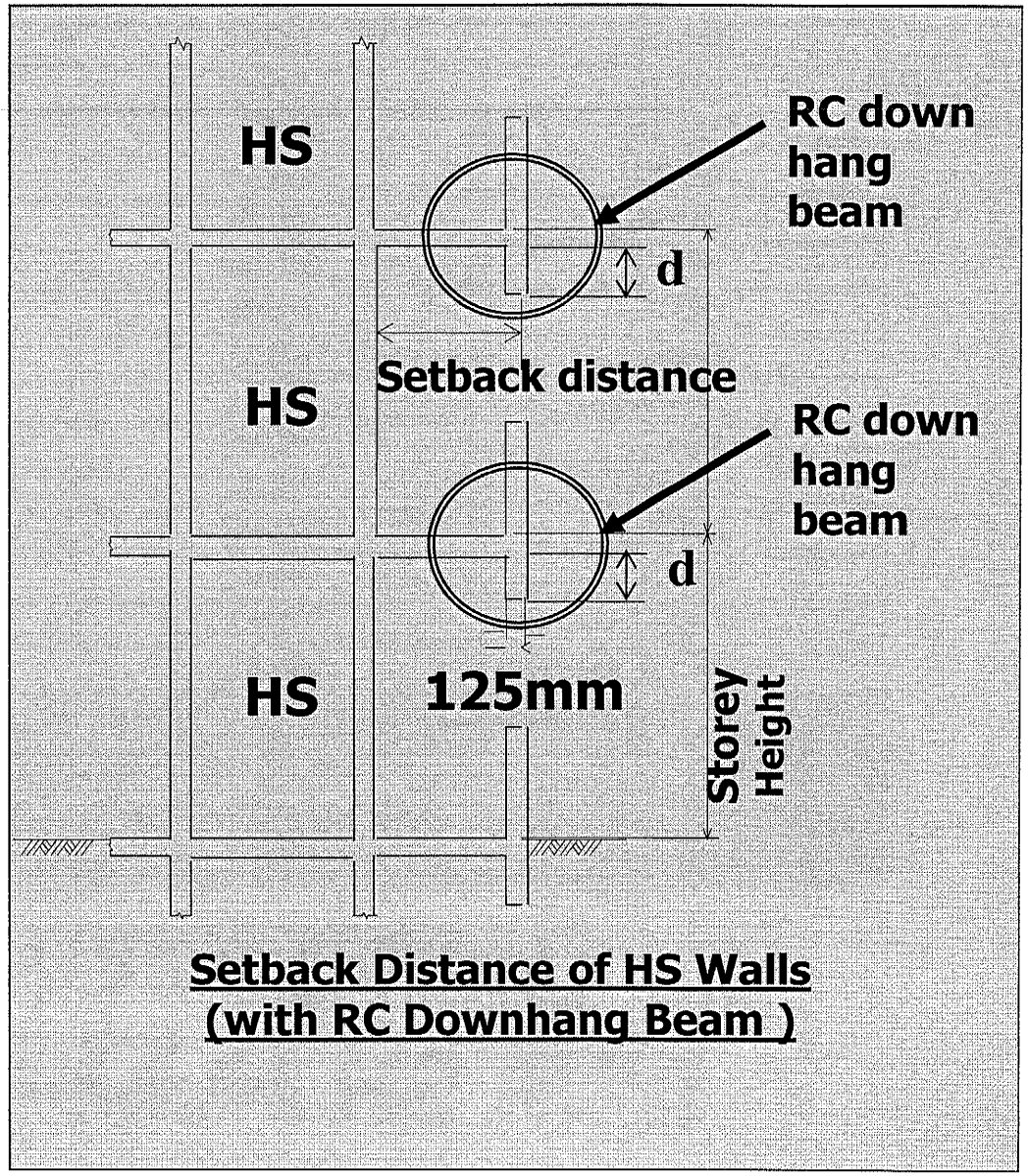
Setback Distance of HS Wall

	Storey Height (mm)	Setback Distance of HS Wall with HS Door (mm)	Setback Distance of HS Walls without HS Door (mm)
1	2500 ≤ Ht ≤ 2800	2750	2000
2	2800 < Ht ≤ 3100	2900	2200
3	3100 < Ht ≤ 3200	2950	2300
4	3200 < Ht ≤ 3400	3050	2400
5	3400 < Ht ≤ 3500	3100	2500
6	3500 < Ht ≤ 4000	3300	2700
7	4000 < Ht ≤ 4500	3600	2900
8	4500 < Ht ≤ 5000	3850	3150
9	5000 < Ht ≤ 5500	4100	3400
10	5500 < Ht ≤ 6000	4300	3600
11	6000 < Ht ≤ 6500	4550	3850
12	6500 < Ht ≤ 7000	4800	4100
13	7000 < Ht ≤ 7500	5000	4300
14	7500 < Ht ≤ 8000	5250	4550
15	8000 < Ht ≤ 8500	5500	4800
16	8500 < Ht ≤ 9000	5750	5000
17	9000 < Ht ≤ 9500	6000	5250
18	9500 < Ht ≤ 10000	6250	5500

Setback Distance with Down-hang Beam

- Down-hang beam along EBL
- Min width of beam - 125mm
- Effective Storey Height

  = Storey height - depth 'd' of down-hang beam



Setback Distance of HS Walls (with RC Downhang Beam)

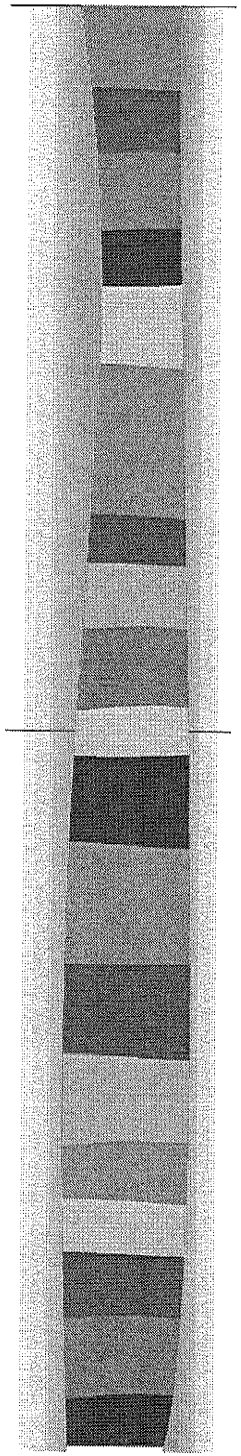
Setback Distance of HS Wall (use of down-hang beam)

	Effective Storey Height* (mm)	Setback Distance of HS Wall With HS Door (mm)	Setback Distance of HS Walls without HS Door (mm)
1	Ht < 2200	2750	1800
2	2200 ≤ Ht ≤ 2800	2750	2000
3	2800 < Ht ≤ 3100	2900	2200
4	3100 < Ht ≤ 3200	2950	2300
5	3200 < Ht ≤ 3400	3050	2400
6	3400 < Ht ≤ 3500	3100	2500
7	3500 < Ht ≤ 4000	3300	2700
8	4000 < Ht ≤ 4500	3600	2900
9	4500 < Ht ≤ 5000	3850	3150
10	5000 < Ht ≤ 5500	4100	3400
11	5500 < Ht ≤ 6000	4300	3600
12	6000 < Ht ≤ 6500	4550	3850
13	6500 < Ht ≤ 7000	4800	4100
14	7000 < Ht ≤ 7500	5000	4300
15	7500 < Ht ≤ 8000	5250	4550
16	8000 < Ht ≤ 8500	5500	4800
17	8500 < Ht ≤ 9000	5750	5000
18	9000 < Ht ≤ 9500	6000	5250
19	9500 < Ht ≤ 10000	6250	5500

HS WALL THICKNESS

TABLE 2. 3(a): MINIMUM HS WALL THICKNESS
(FOR LANDED DEVELOPMENT)

HS Clear Height (mm)	Setback Distance of HS Wall (mm)	HS Wall Thickness (mm)
2400 ≤ Ht ≤ 3900	**≤ 6000**	**250**
	> 6000	**200**



HS/NS WALL THICKNESS

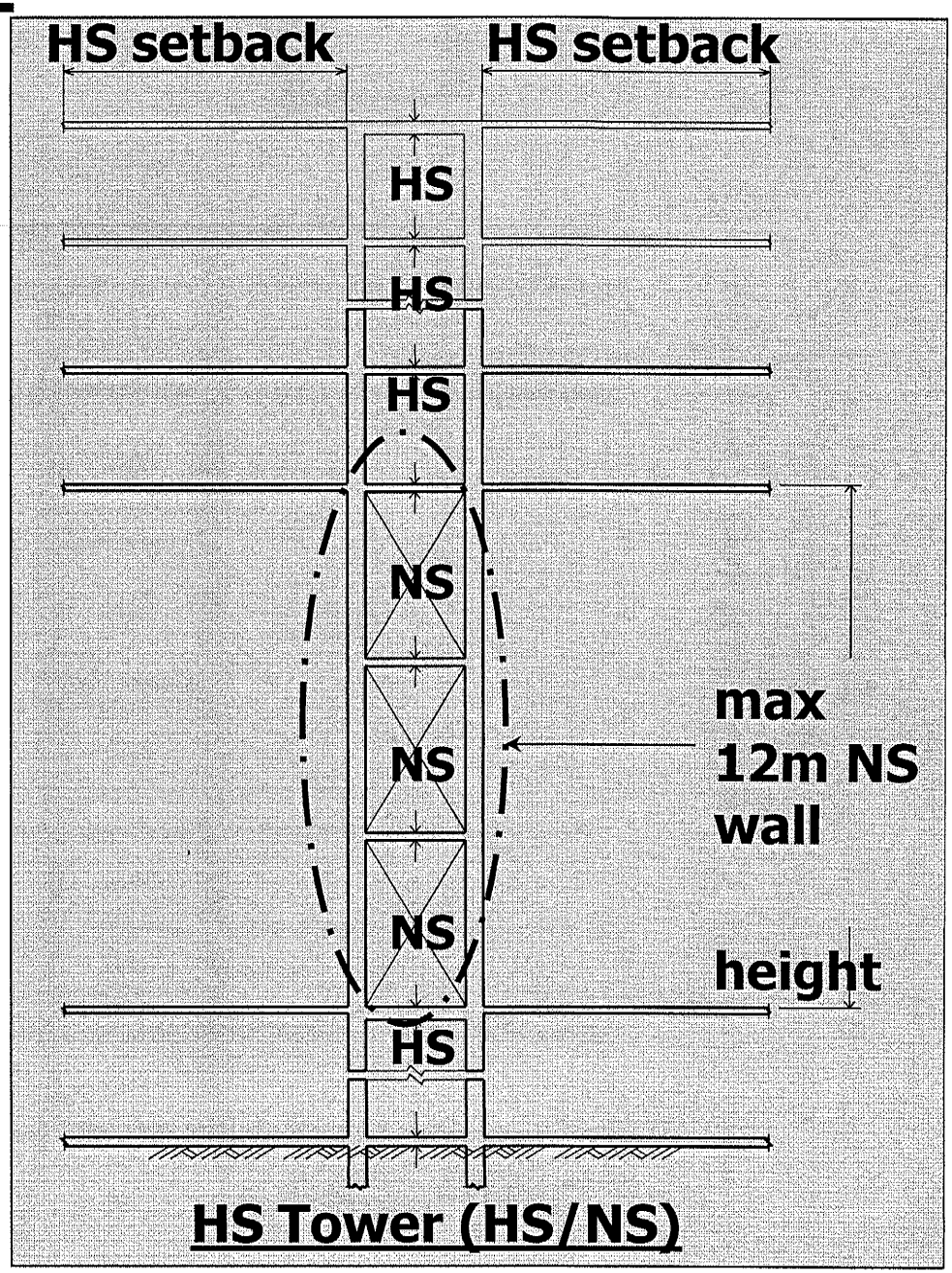
TABLE 2. 3(b): MINIMUM HS AND NS WALL THICKNESS (FOR NON-LANDED DEVELOPMENT)

HS Clear Height (mm)	Setback Distance of HS Wall (mm)	Wall Thickness (mm)
2400 ≤ Ht ≤ 3000	≤ 6000	250
	> 6000	200
3000 < Ht ≤ 3200	≤ 6000	275
	> 6000	225
3200 < Ht ≤ 3900	≤ 6000	300
	> 6000	250

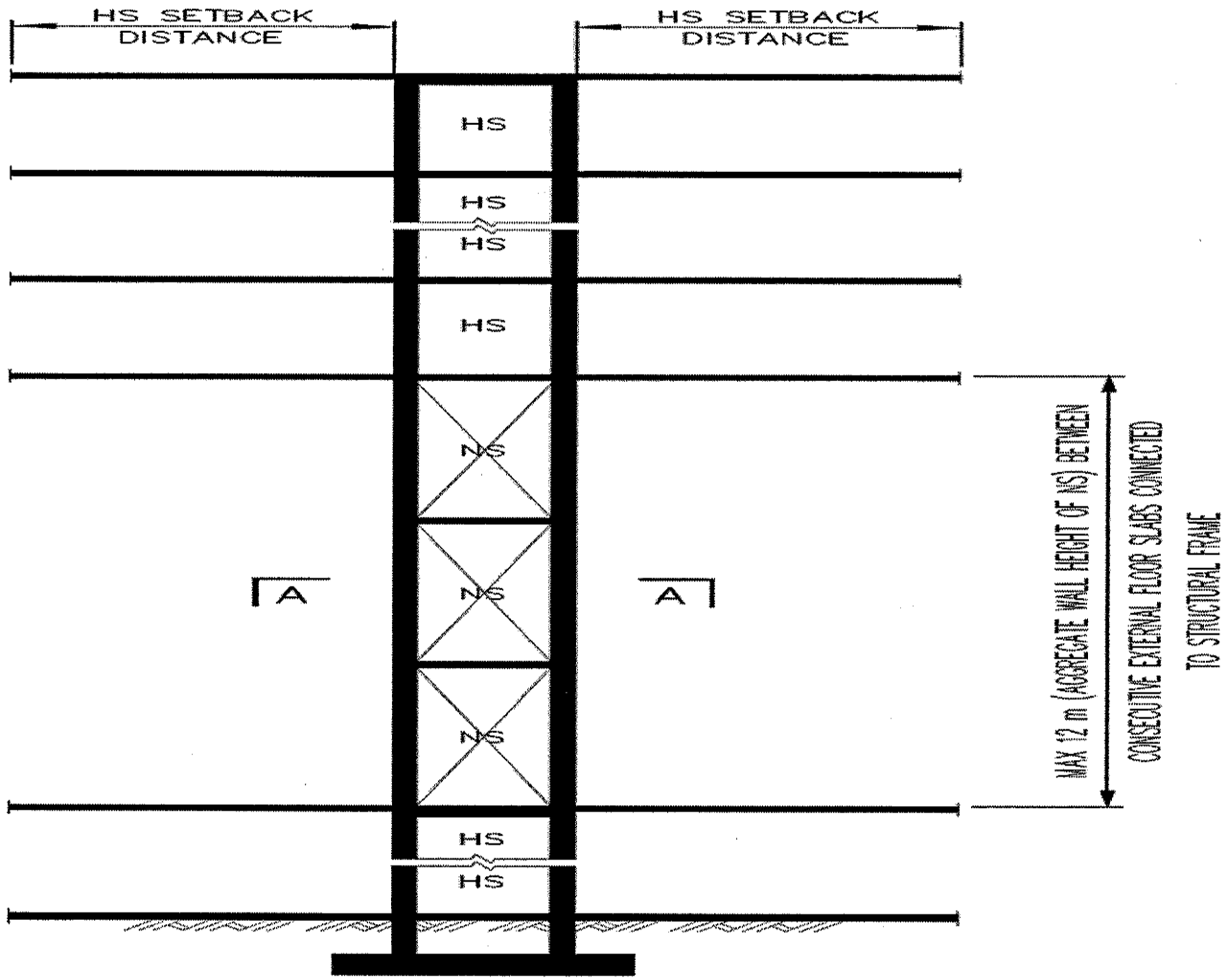
NS in HS Tower

Non Shelter (NS) is a space in a HS tower that is not intended for use as shelter.

External floor slab outside NS is not necessary provided total wall height of NS does not exceed 12m.



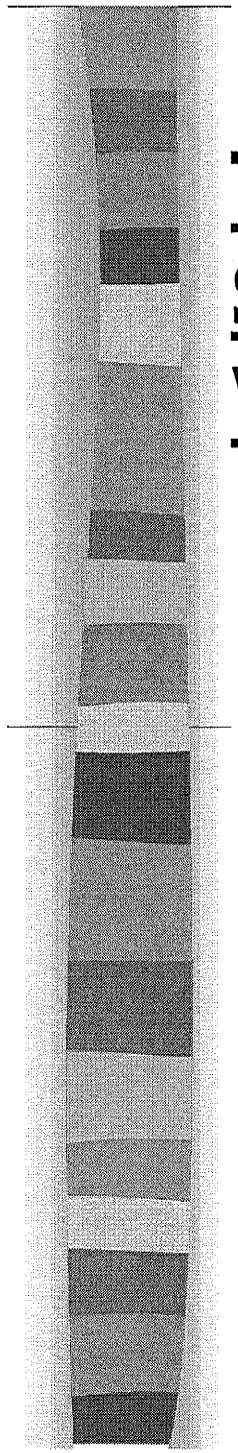
HS Tower



HS TOWER
(HS/NS)



SECTION A — A
PLAN FACADE OF NS WALL

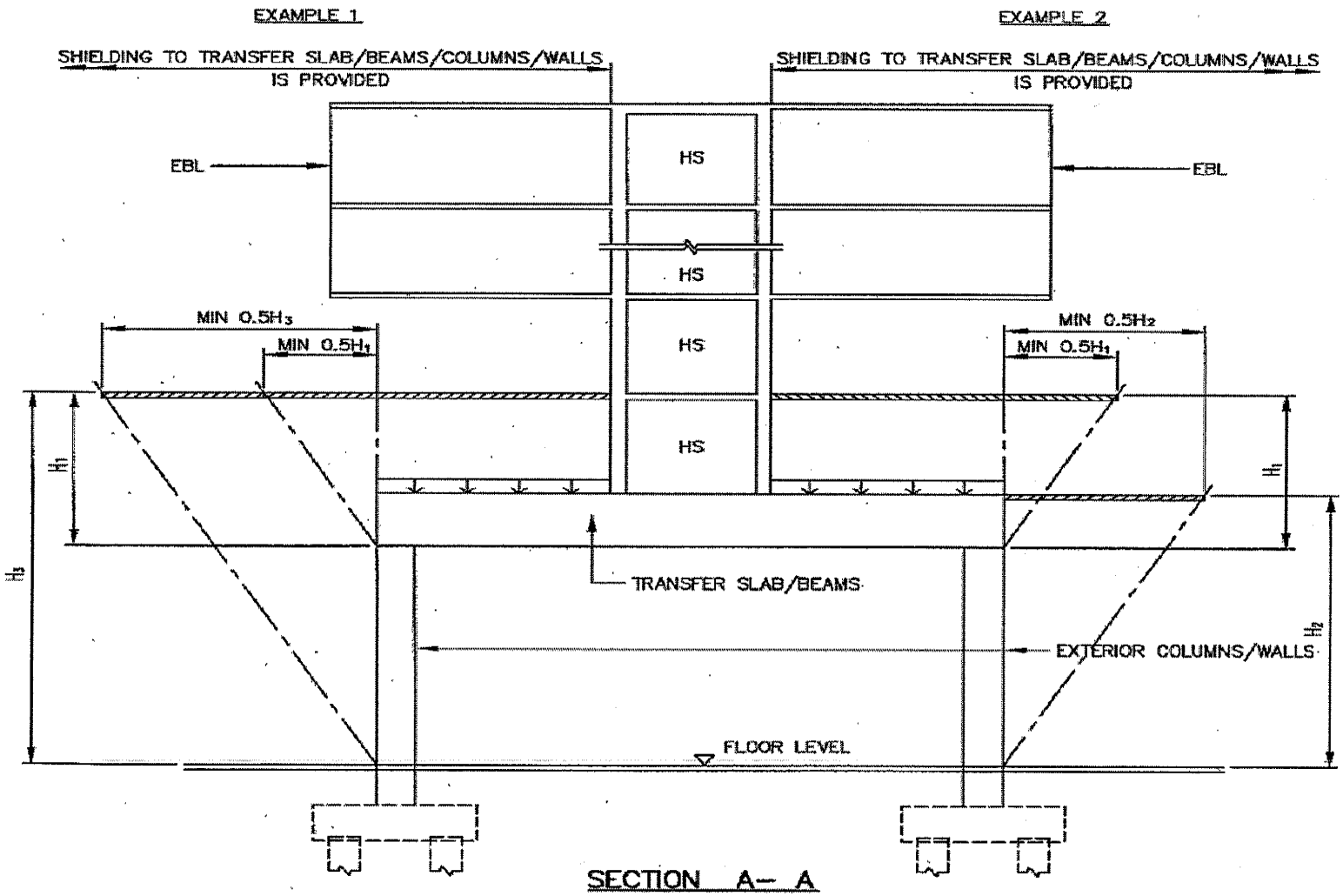


Technical Requirements of Transfer Structure And Non Shelter (NS) Walls Supporting HS Tower

a) Transfer structure for household shelter tower (HS Tower)

b) Non-shelter walls supporting HS tower

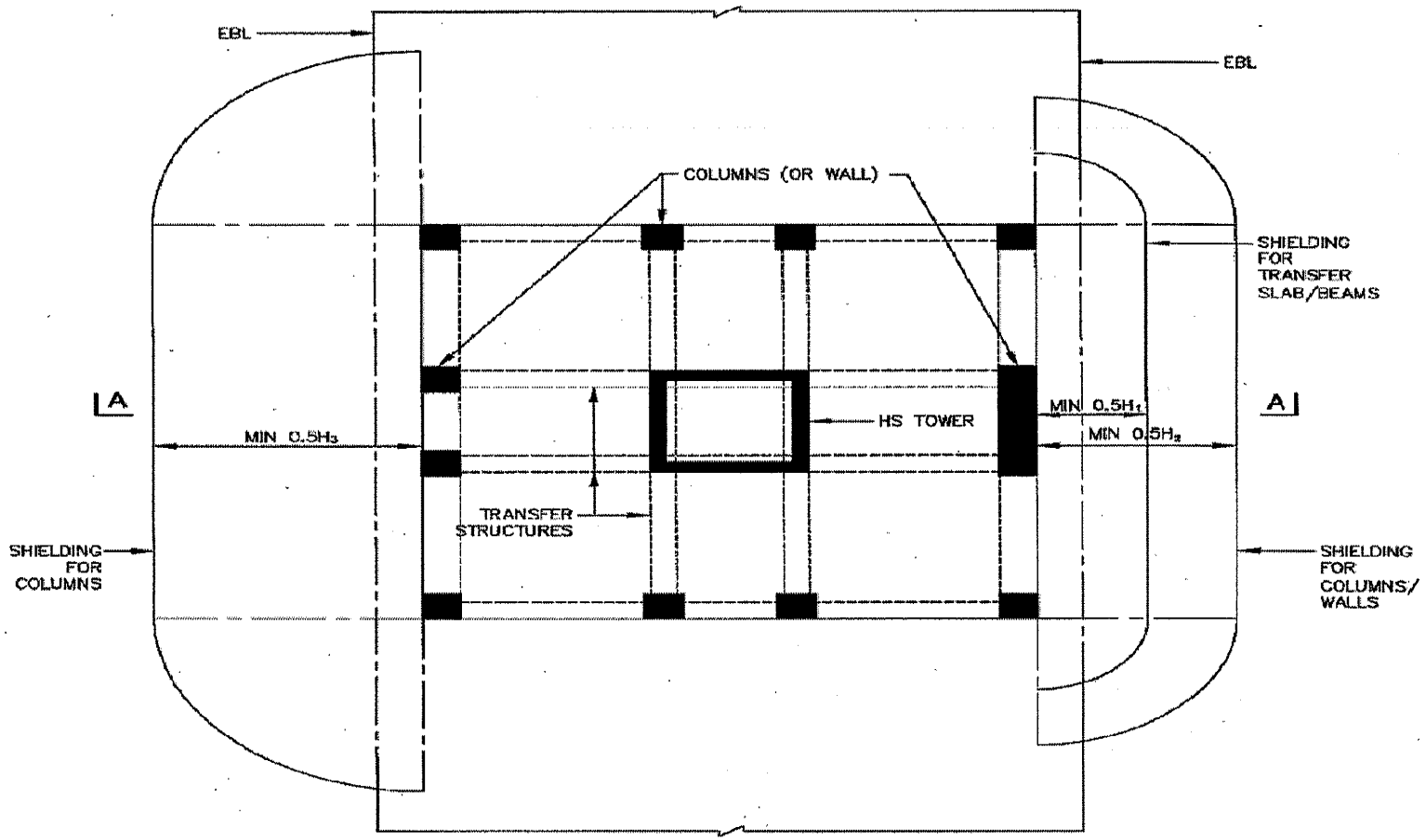
Technical Requirements of Transfer Structure



SECTION A– A

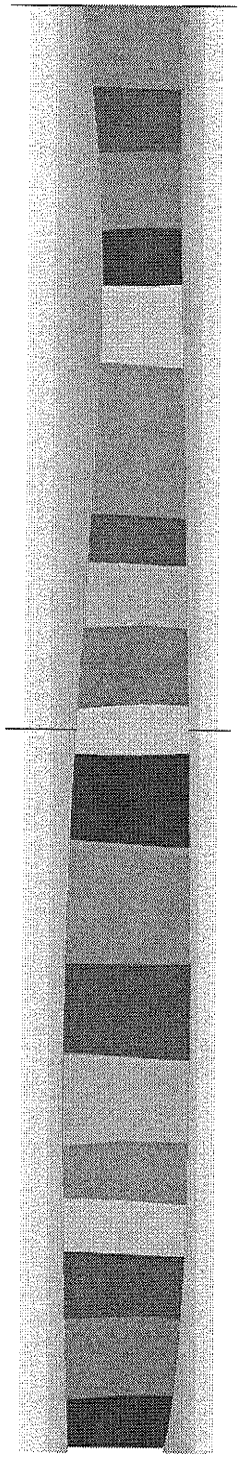
FIGURE 2.8.1(b) SHIELDING OF TRANSFER SLAB/BEAMS/EXTERIOR COLUMNS/WALLS

Technical Requirements of Transfer Structure



PLAN

FIGURE 2.8.1(a) SHIELDING OF TRANSFER STRUCTURES SUPPORTING HS TOWER



Transfer Structure Design

For Unshielded Columns/Walls

- Partial Safety Factor γ_f for all loads, including collapse load to be 1.05
- Partial Safety Factor γ_m for material strength
  - Concrete: 1.3
  - Steel Reinforcement: 1.0

Design against Collapse Load

Table 1 : Load Combination and values of partial safety factors (γ_f) for Ultimate Limit State

Load Combination	Load Types						
	Dead		Imposed		Earth and Water Pressure (if applicable)	Wind (if applicable)	Collapse
	Adverse	Beneficial	Adverse	Beneficial			
Dead and imposed and wind and collapse load (and earth and water pressure)	1.2	1.2	1.2	1.2	1.2	1.2	1.05

Unshielded Columns/Walls
Removal of Columns/Walls

Table 2 : Load Combination and values of partial safety factors (γ_f) for Ultimate Limit State

Load Combination	Load Types						
	Dead		Imposed		Earth and Water Pressure (if applicable)	Wind (if applicable)	Collapse
	Adverse	Beneficial	Adverse	Beneficial			
Dead and imposed and wind and collapse load (and earth and water pressure)	1.05	1.05	1.05	1.05	1.05	1.05	1.05

Double-rebate Doorframe and Door Handle Recess

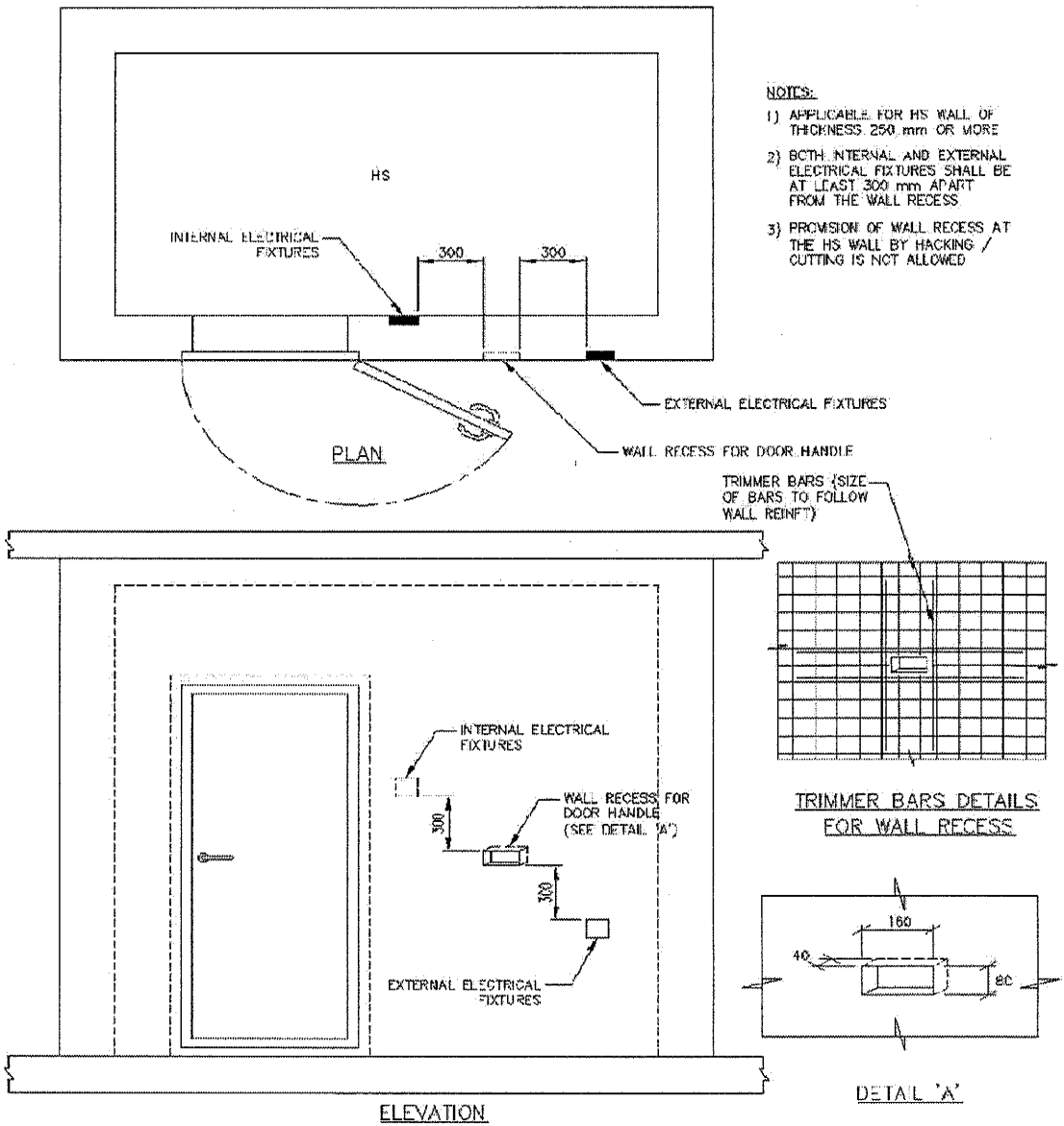
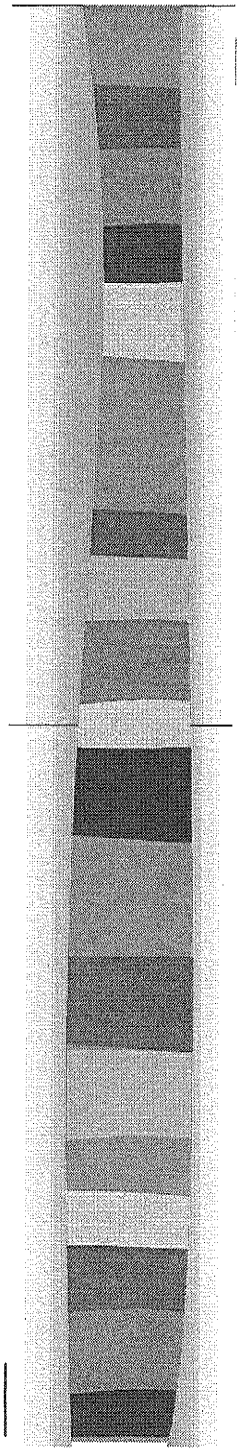


FIGURE 2.11 DETAILS OF WALL RECESS FOR HS DOOR HANDLE

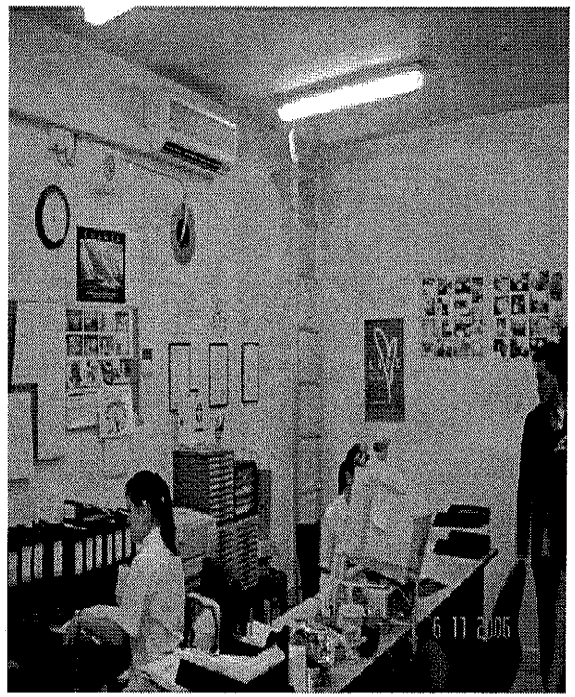


Building and Construction Authority

ARCHITECTURAL REQUIREMENTS OF STOREY SHELTERS

Storey Shelter (SS)

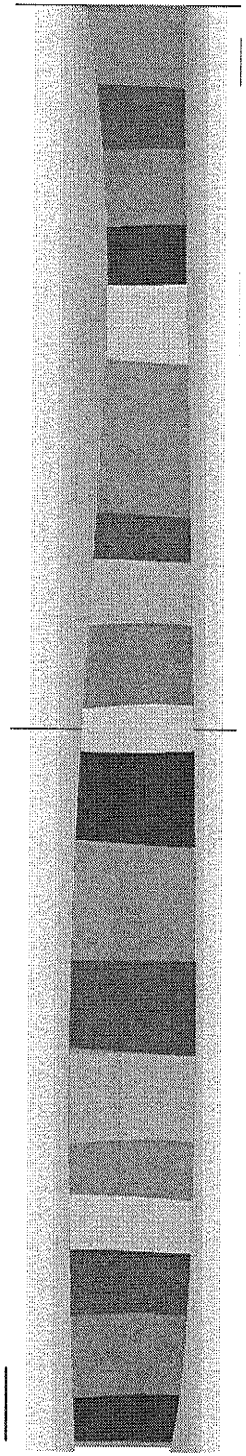
- Located at a common property area of a storey
- For protection of people against weapon effects during a war emergency



Staircase Storey Shelter (SSS)

- Located at a fire exit staircase



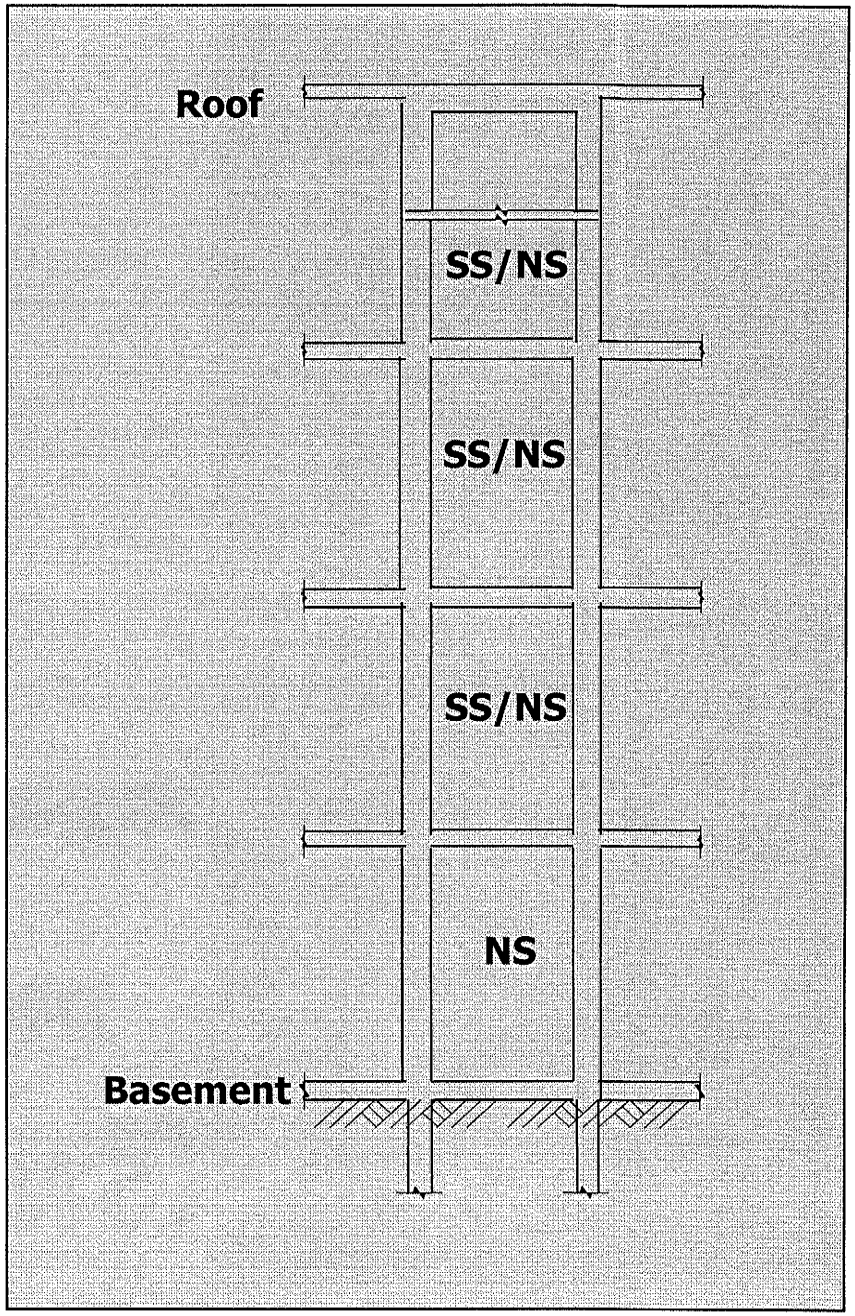


Shelter Protection Concept

- **Air-tight Mode - short stay**
- **Filtration Mode - long stay**

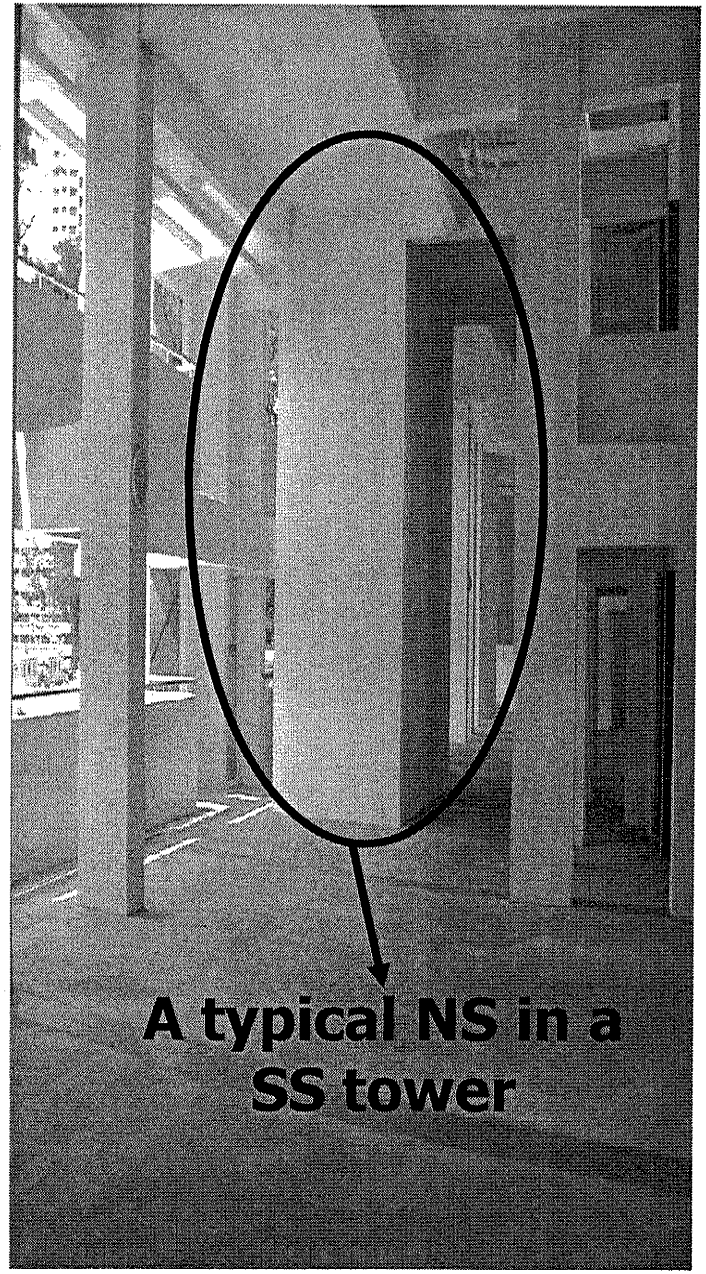
Storey Shelter (SS) Tower

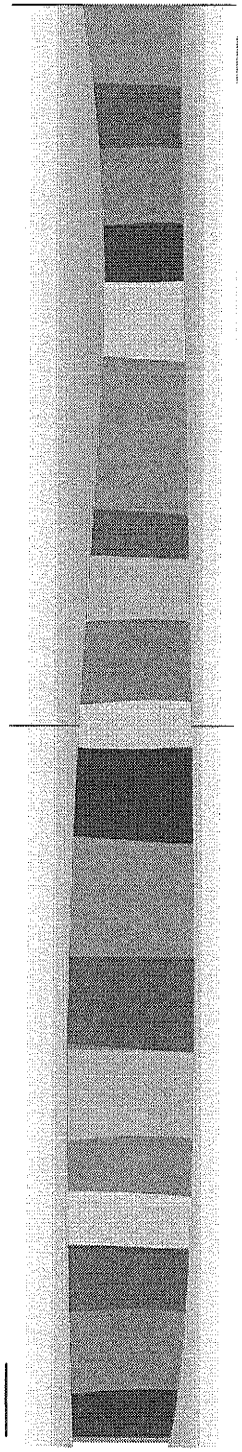
- Consists of SS (or NS where applicable) on every storey.
- Form a vertical tower and continue to its foundation.



Non-Shelter (NS)

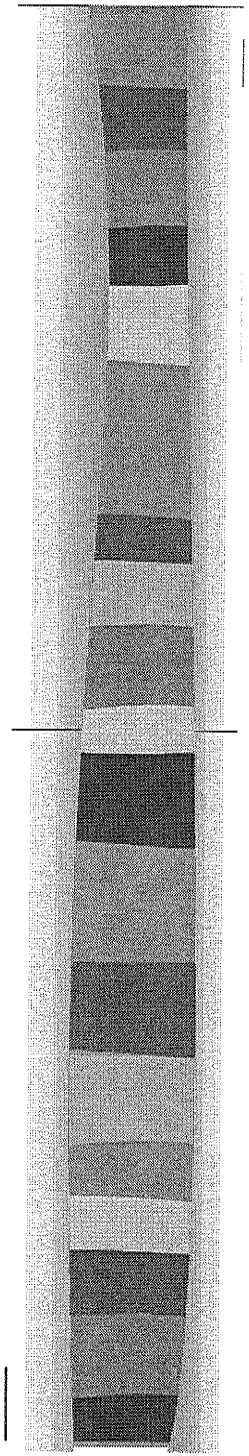
- The space enclosed by walls which continue from shelter above or below.
- Not intended for use during a war emergency.





ARCHITECTURAL REQUIREMENTS OF STOREY SHELTER

- Size of SS - area and volume
- Setback distance of SS
- NS in SS tower

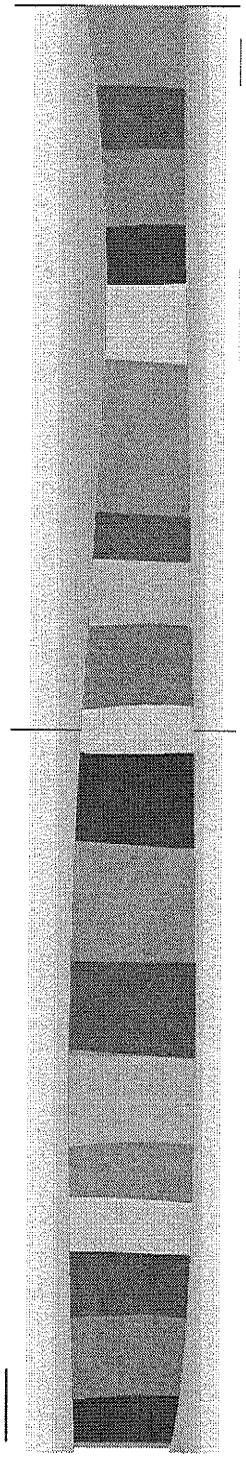


ARCHITECTURAL REQUIREMENTS OF STOREY SHELTER

- Minimum internal length: 1.2 m
- Maximum internal length: 8.0 m
- Minimum clear height: 2.4 m
- Maximum clear height: 3.9 m
- Maximum NS clear height: 3.9 m
- Maximum SS area: 32 m^2

SS Area and Volume

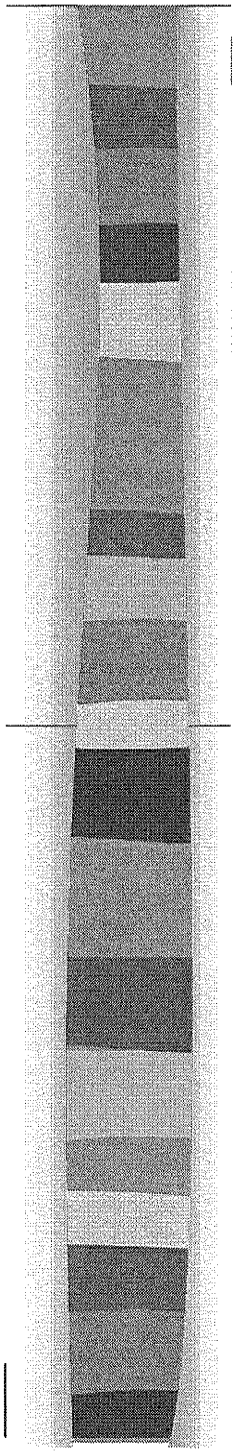
Gross Floor Area of Dwelling Unit	Nominal Occupancy of Dwelling Unit (No. of persons)
GFA≤45	2
45<GFA≤75	3
75<GFA≤140	4
GFA>140	5



Area of SS = TNO x 0.6 m^2

Volume of SS = TNO x 1.8 m^3

TNO: Total Nominal Occupancy

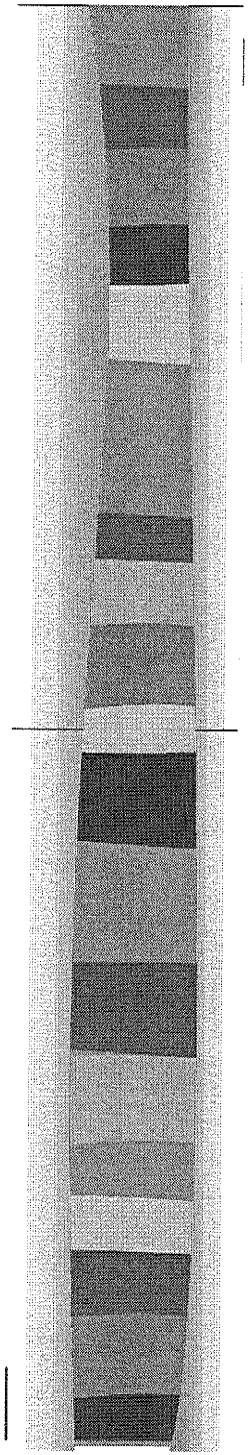


Setback Distance of SS Wall

- without the need of introducing RC down-hang beam concept if there is sufficient setback distance

- with RC down-hang beam - at the external building line

- use of trellis to compensate against shortfall in setback distance

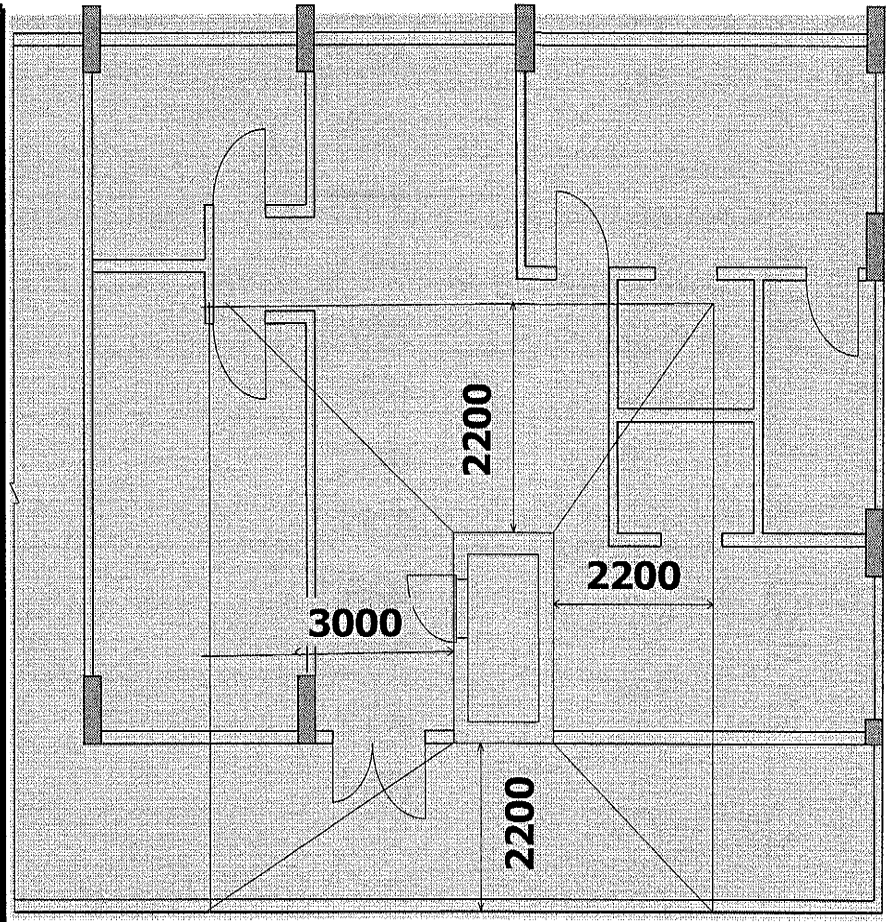


Setback Distance of SS Wall

Storey Height (SH) (mm)	Setback Distance of SS Wall with SS Door (mm)	Setback Distance of SS Walls without SS door (mm)
$2500 \leq SH \leq 2800$	3000	2200
$2800 < SH \leq 3100$	3200	2400
$3100 < SH \leq 3500$	3400	2600
$3500 < SH \leq 4000$	3600	2800
$4000 < SH \leq 4500$	3850	3050
$4500 < SH \leq 5000$	4100	3300
$5000 < SH \leq 5500$	4300	3500
$5500 < SH \leq 6000$	4550	3750
$6000 < SH \leq 6500$	4800	4000
$6500 < SH \leq 7000$	5000	4200
$7000 < SH \leq 7500$	5250	4450
$7500 < SH \leq 8000$	5500	4700

Setback Distance

Storey Height (mm)	Minimum Setback Distance of SS Wall with SS door (mm)	Minimum Setback Distance of SS Walls w/o SS door (mm)
2500≤Ht≤2800	3000	2200
2800<Ht≤3100	3200	2400
3100<Ht≤3500	3400	2600
3500<Ht≤4000	3600	2800



Setback Distance of SS Walls

Setback Distance of SS Wall (with down-hang beam and w/o door)

Effective Storey Height (Ht) (mm)	Setback Distance of SS Walls (mm)
Ht ≤ 2200	2100
2200 < Ht ≤ 2800	2200
2800 < Ht ≤ 3100	2400
3100 < Ht ≤ 3500	2600
3500 < Ht ≤ 4000	2800
4000 < Ht ≤ 4500	3050
4500 < Ht ≤ 5000	3300
5000 < Ht ≤ 5500	3500
5500 < Ht ≤ 6000	3750
6000 < Ht ≤ 6500	4000
6500 < Ht ≤ 7000	4200
7000 < Ht ≤ 7500	4450
7500 < Ht ≤ 8000	4700

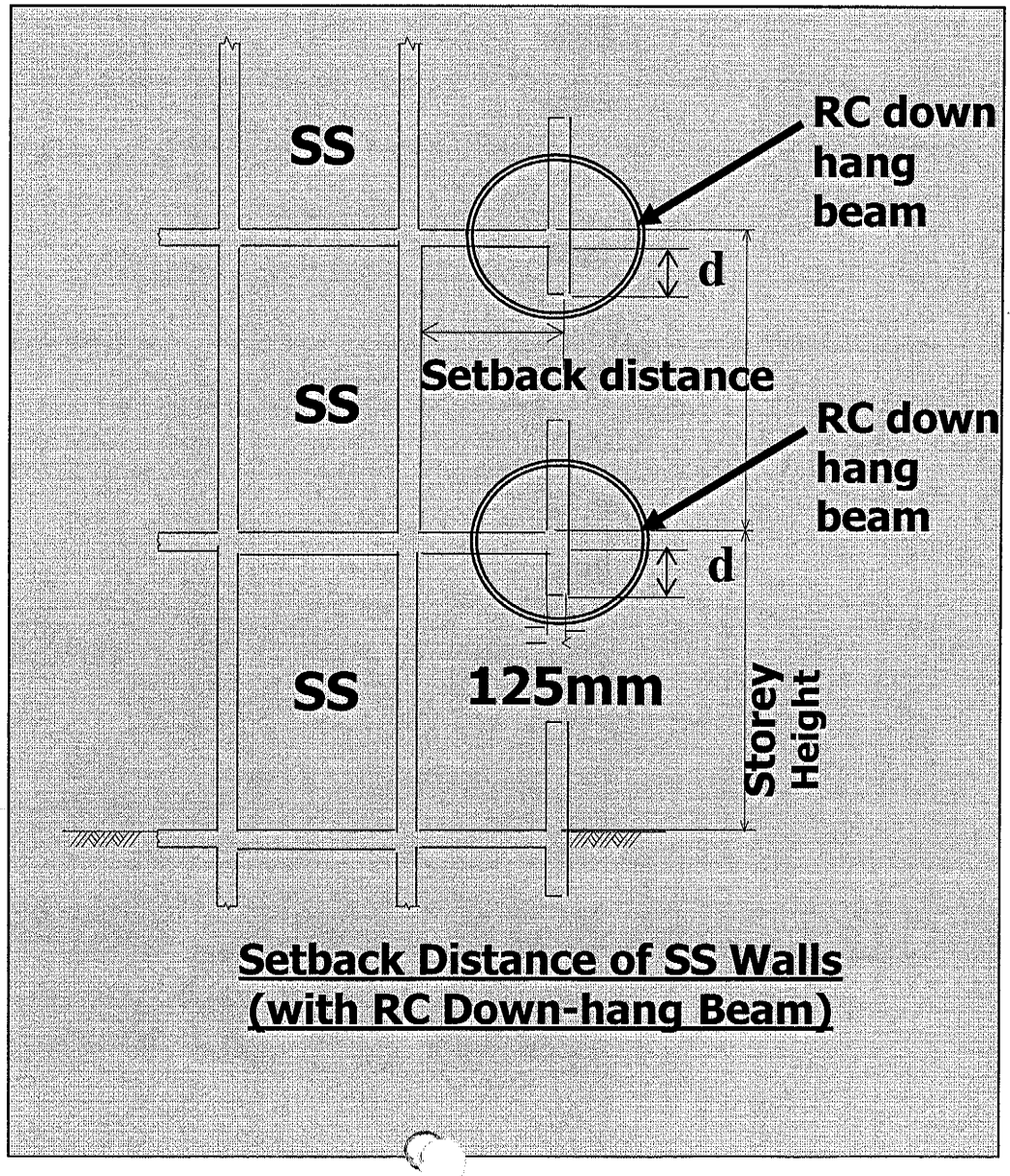
Setback Distance of SS Wall (with down-hang beam and with door)

Effective Storey Height (Ht) (mm)	Setback Distance of SS Wall With SS Door (mm)
Ht ≤ 2800	3000
2800 < Ht ≤ 3100	3200
3100 < Ht ≤ 3500	3400
3500 < Ht ≤ 4000	3600
4000 < Ht ≤ 4500	3850
4500 < Ht ≤ 5000	4100
5000 < Ht ≤ 5500	4300
5500 < Ht ≤ 6000	4550
6000 < Ht ≤ 6500	4800
6500 < Ht ≤ 7000	5000
7000 < Ht ≤ 7500	5250
7500 < Ht ≤ 8000	5500

Setback Distance with Down-hang Beam

- Down-hang beam along EBL
- Min width of beam - 125mm
- Effective Storey Height

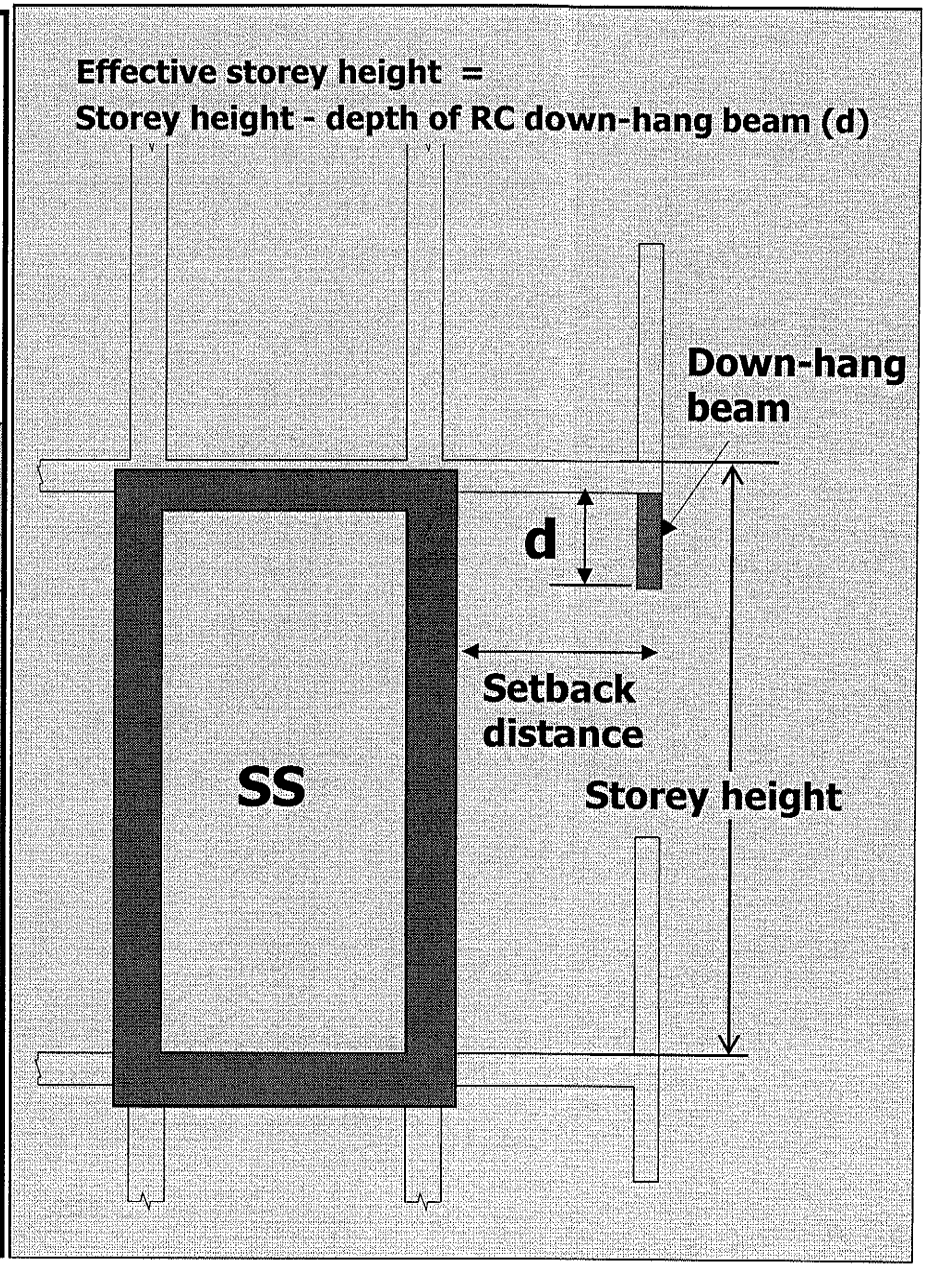
  = Storey height - depth 'd' of down-hang beam

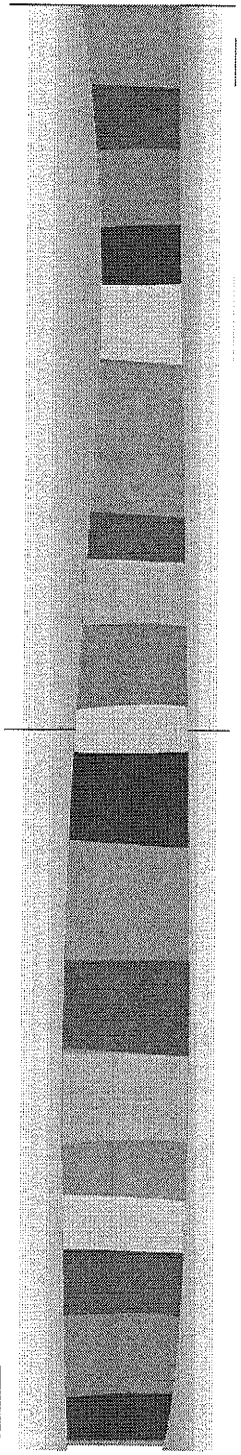


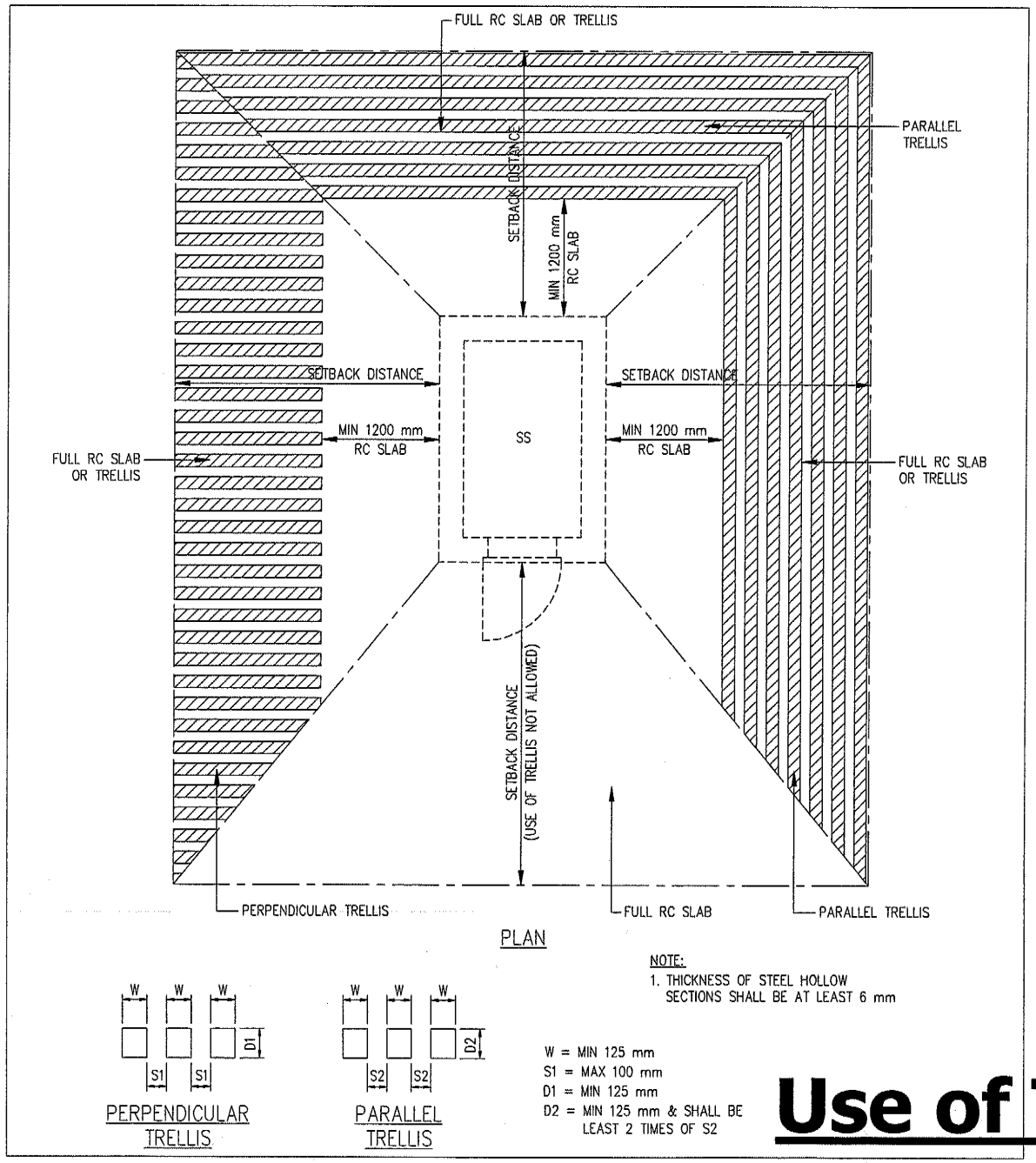
Setback Distance of SS Walls (with RC Down-hang Beam)

Setback Distances With RC Down-hang Beam

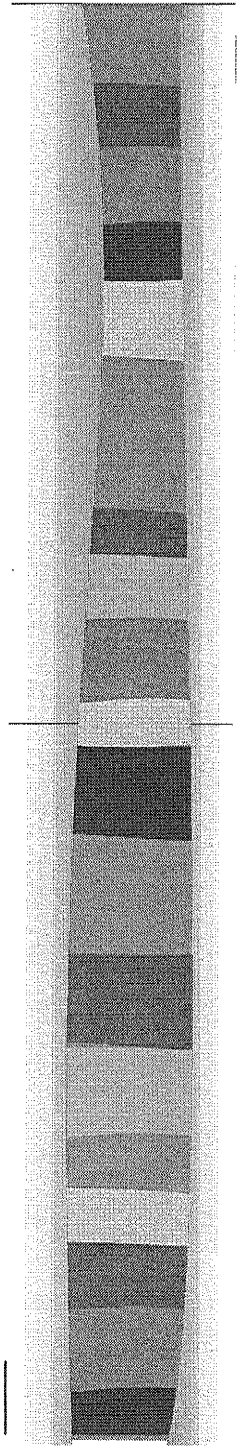
Effective Storey Height (mm)	Setback Distance of SS Wall with SS door (mm)	Setback Distance of SS Walls w/o SS door (mm)
Ht ≤ 2200	2100	3000
2200<Ht≤ 2800	2200	3000
2800<Ht ≤3100	2400	3200
3100<Ht≤ 3500	2600	3400
3500<Ht≤ 4000	2800	3600





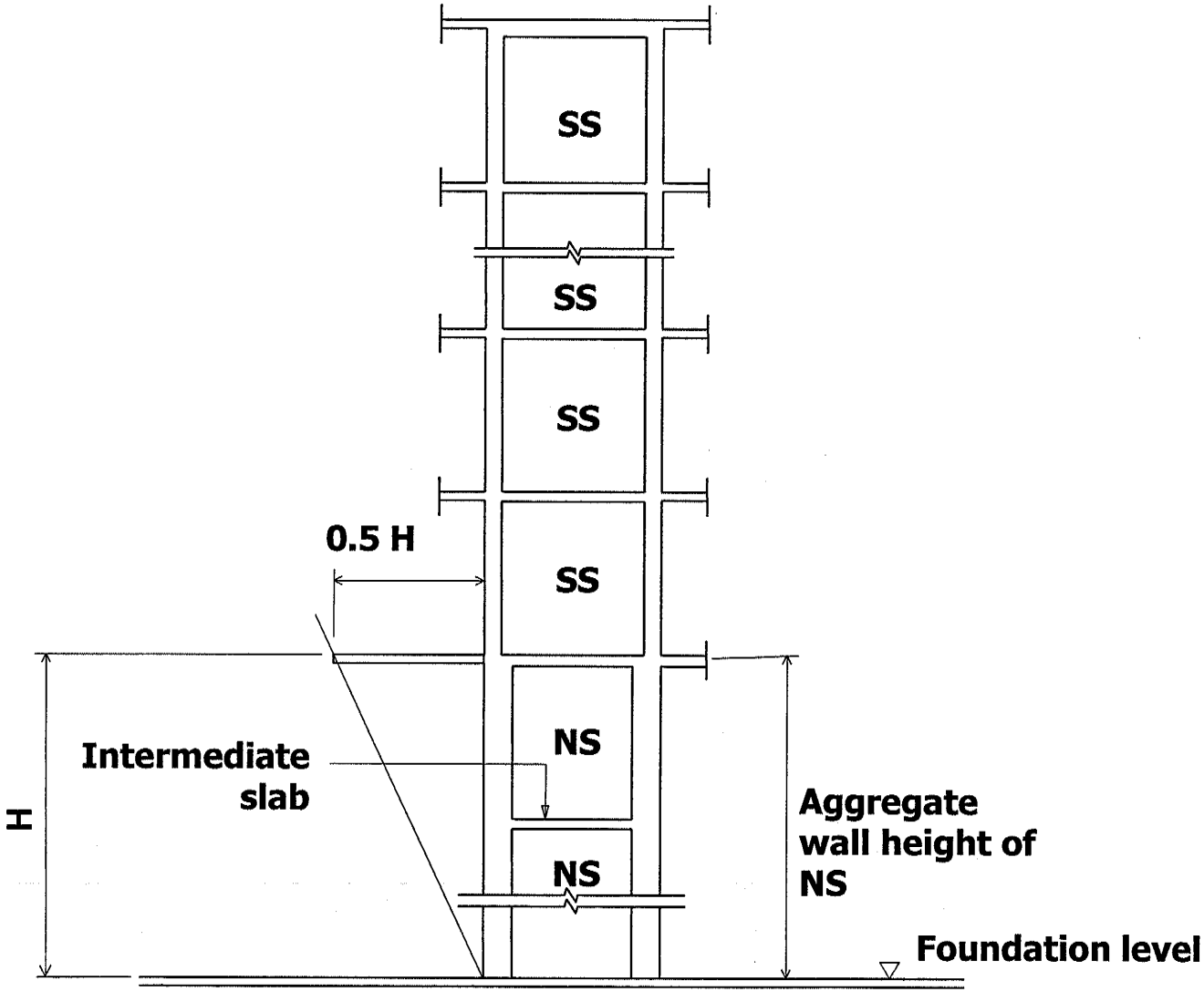


Use of Trellis

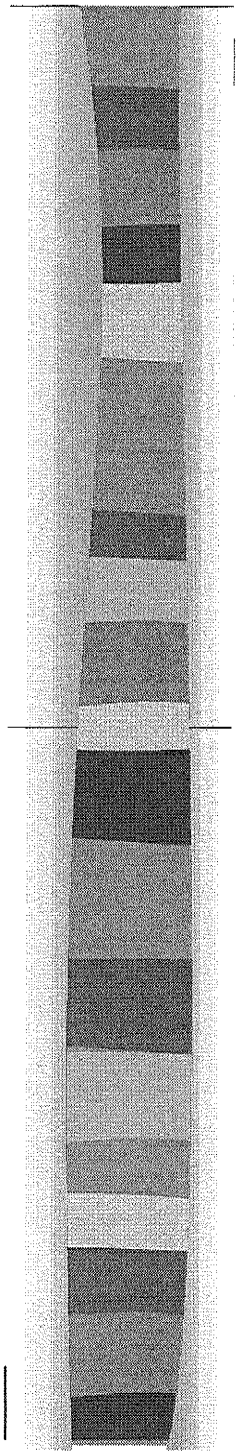


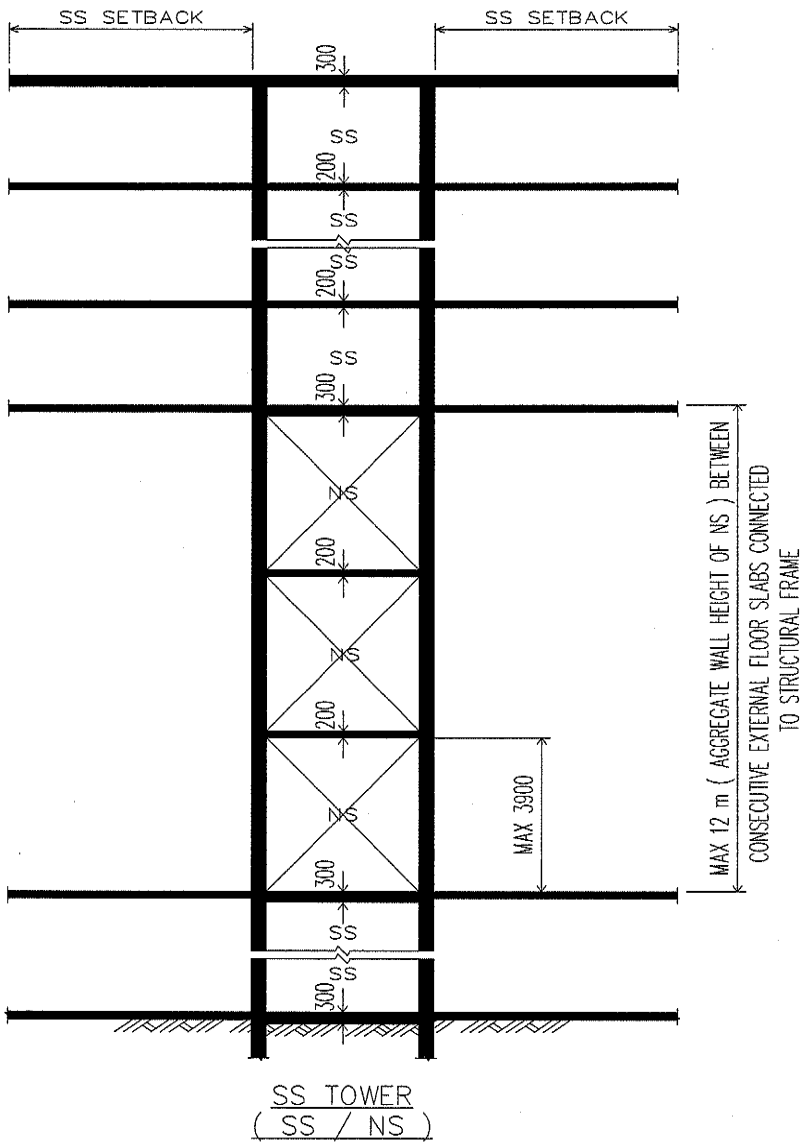
SS WALL THICKNESS

SS Clear Height (Ht) (mm)	Setback Distance of SS Wall (mm)	SS Wall Thickness (mm)
2400 ≤ Ht ≤ 3400	**< 6000**	**300**
	≥ 6000	**250**
3400 < Ht ≤ 3900	**< 6000**	**325**
	≥ 6000	**275**



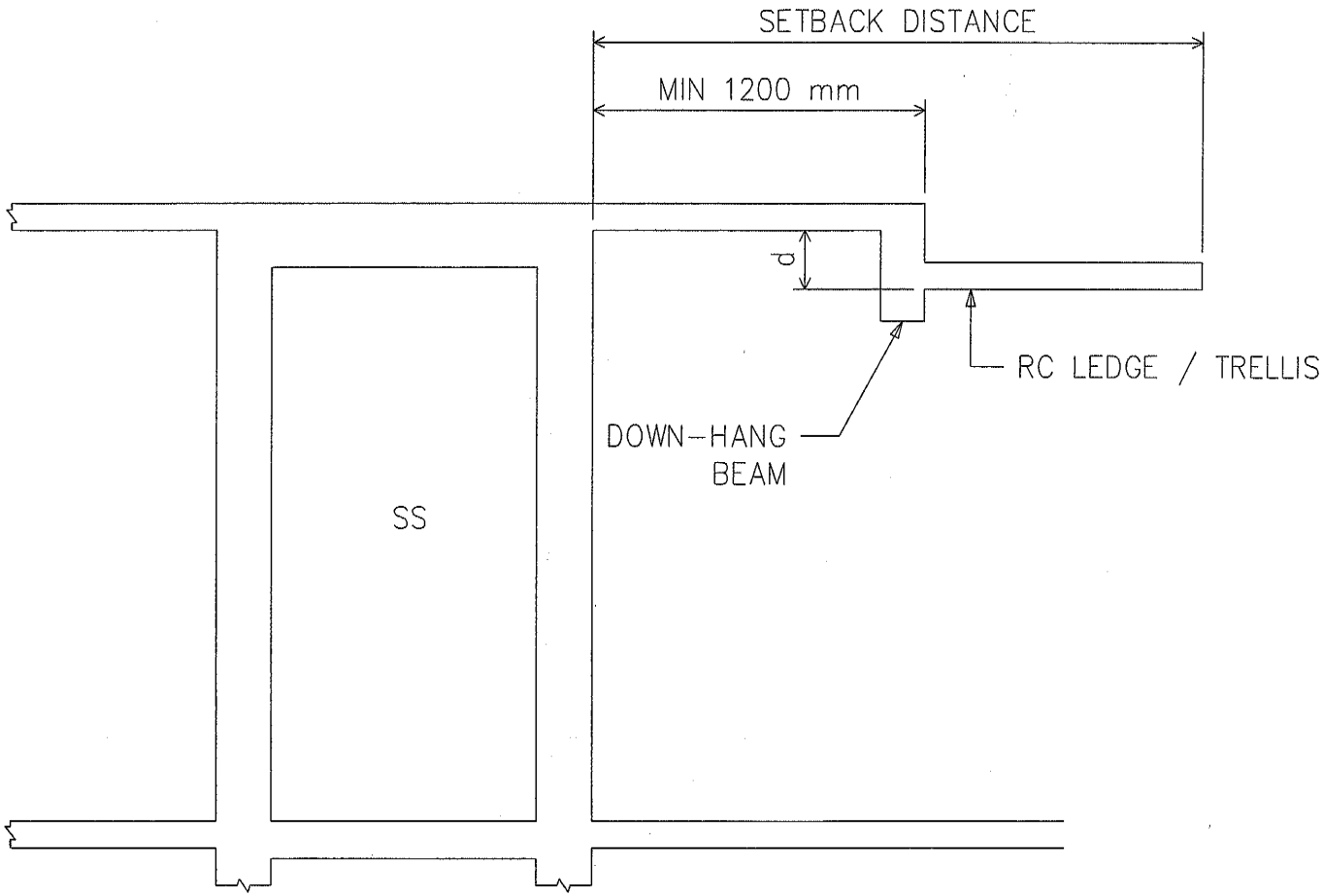
Cross Section of SS Tower



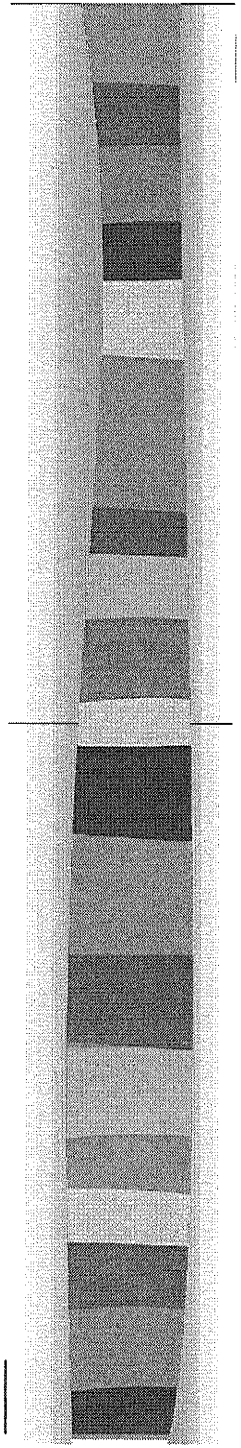


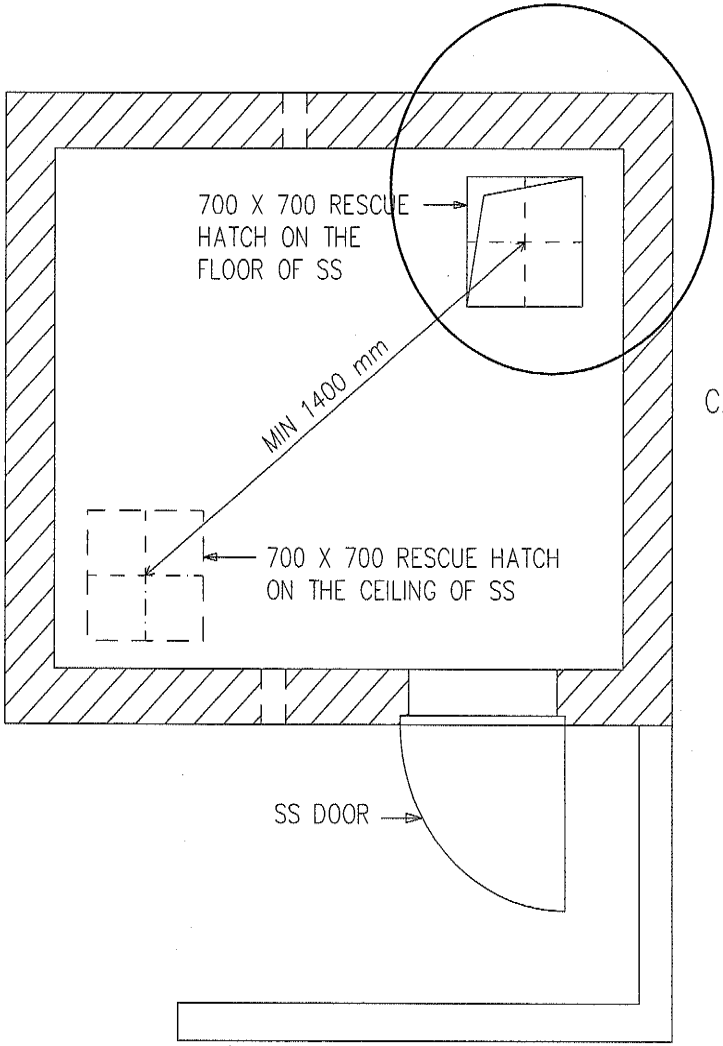
Thickness of SS Slab

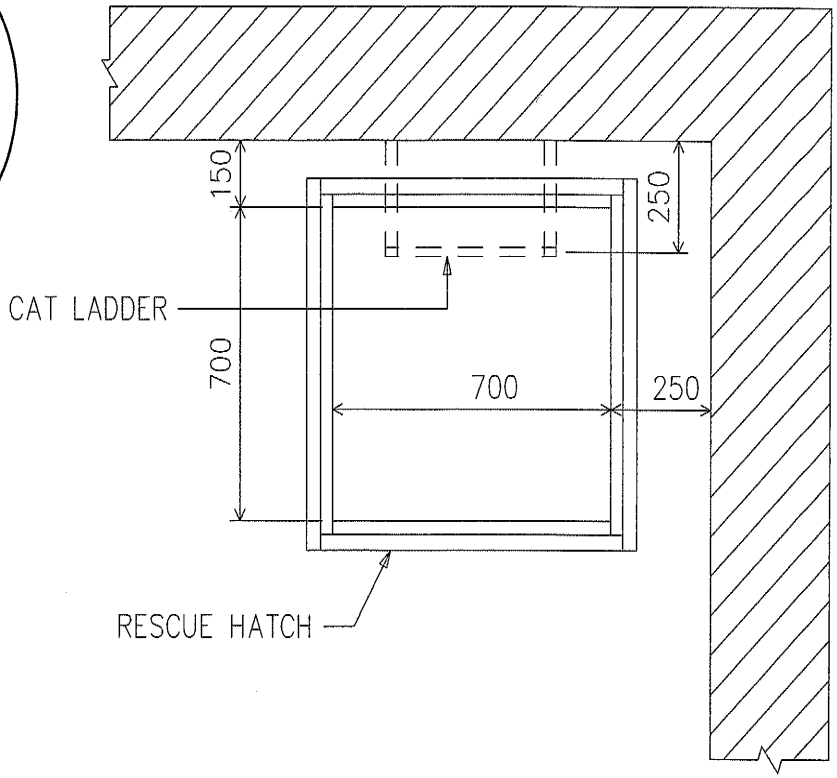
Location of down-hang beam or trellis



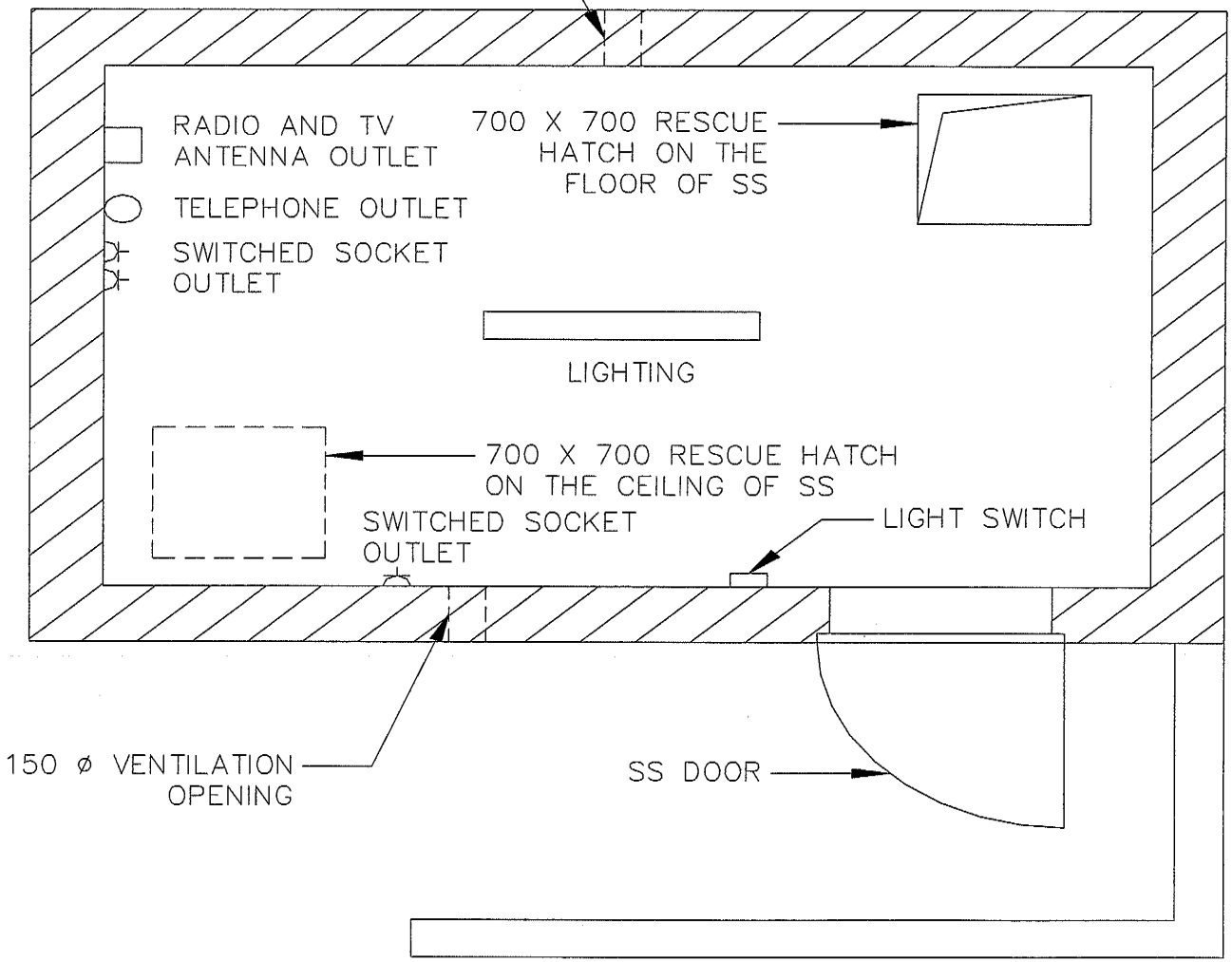
Rescue Hatch in SS

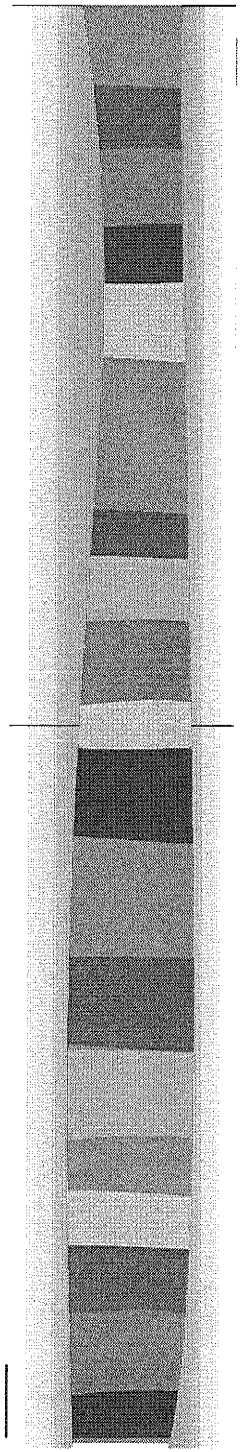




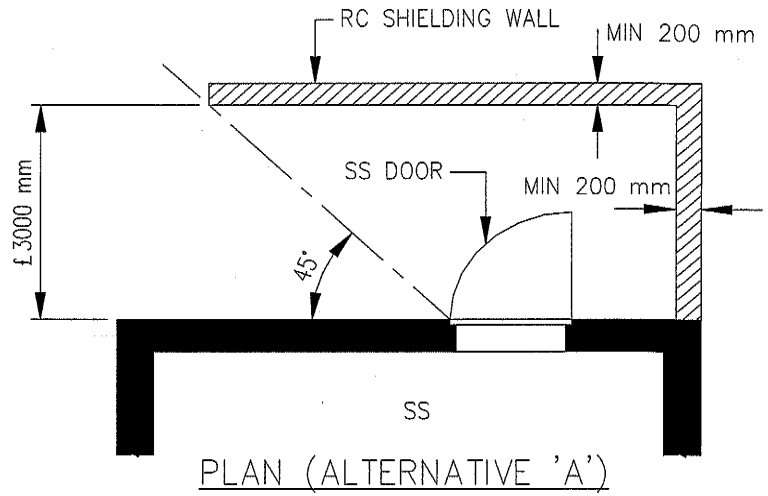


Fixture in SS

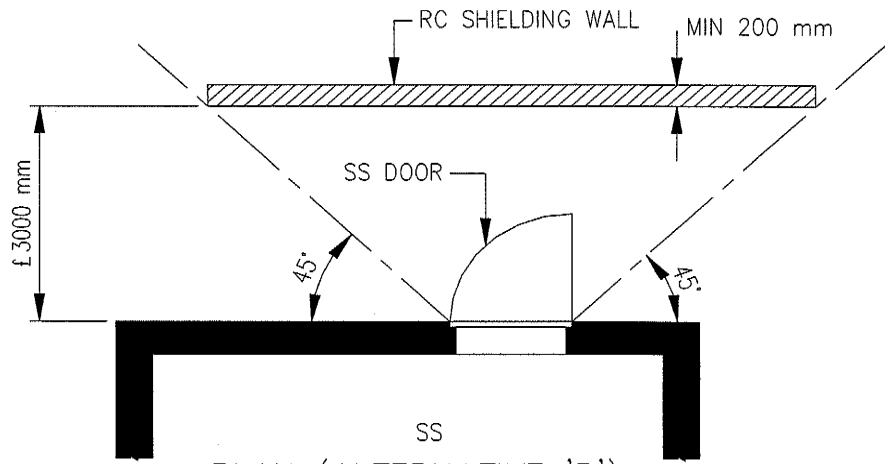




Shielding Wall

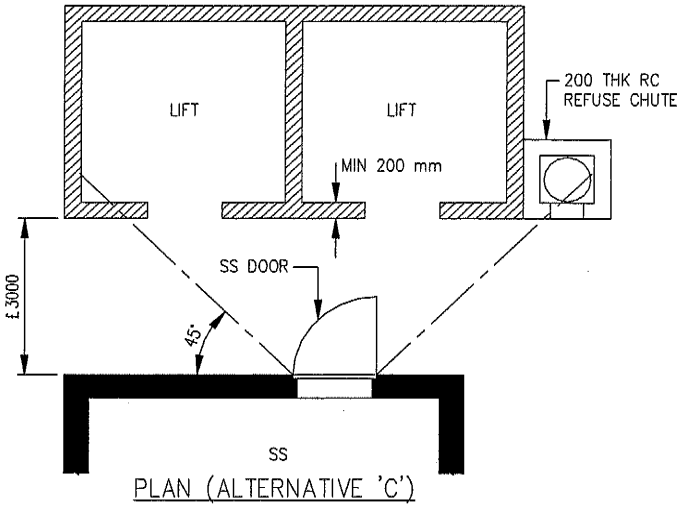


PLAN (ALTERNATIVE 'A')



PLAN (ALTERNATIVE 'B')

Shielding Wall



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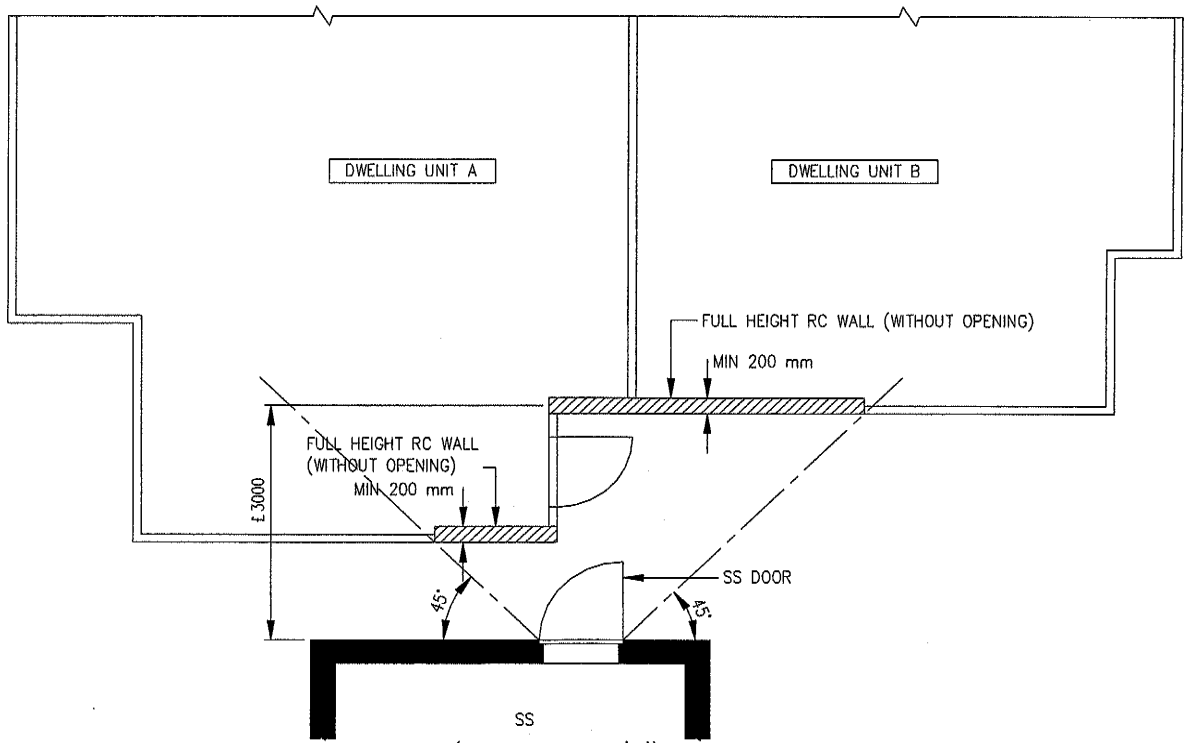
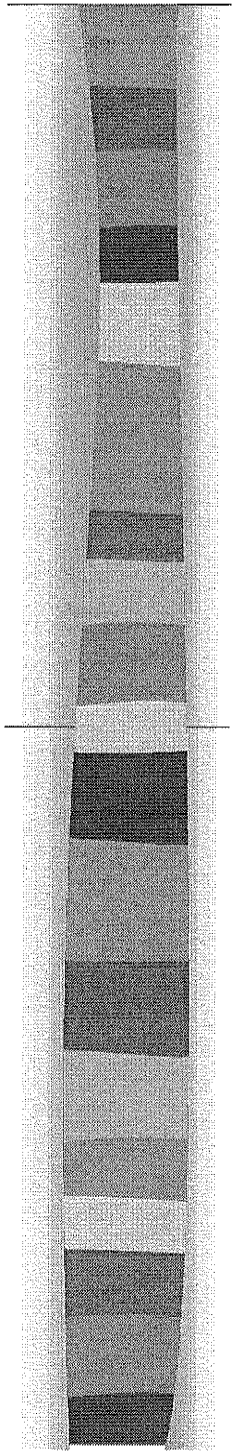
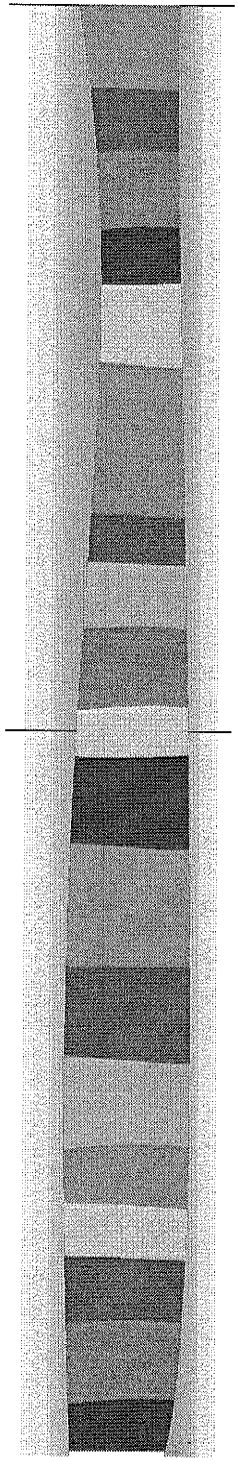


PLAN (ALTERNATIVE 'D')

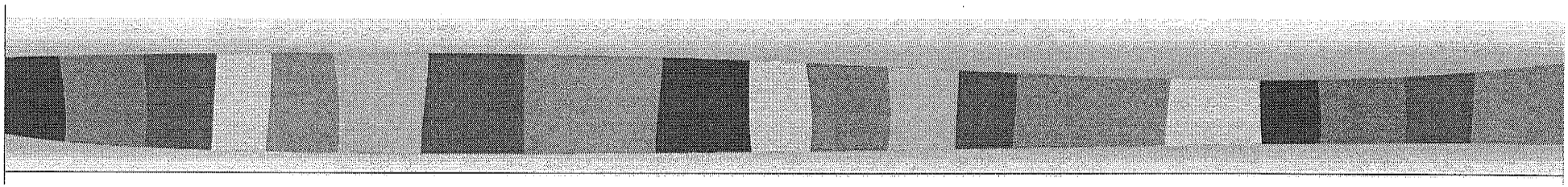


Building and Construction Authority

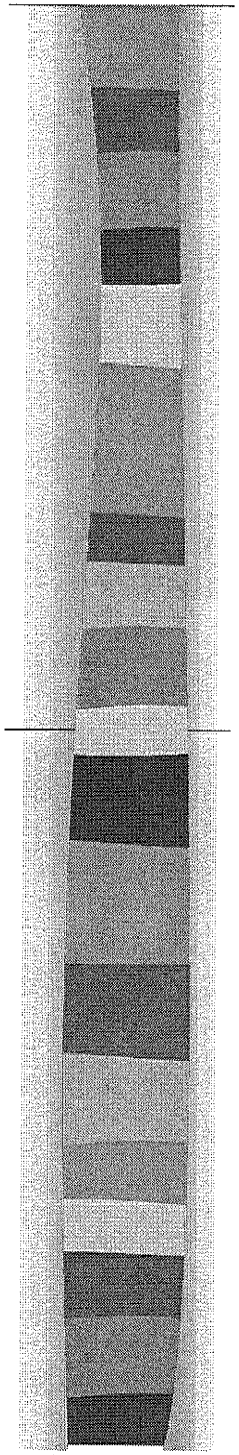
STRUCTURAL AND OTHER REQUIREMENTS OF STOREY SHELTERS



- **STRUCTURAL REQUIREMENTS**
- **VENTILATION SLEEVES**
- **SS DOOR**

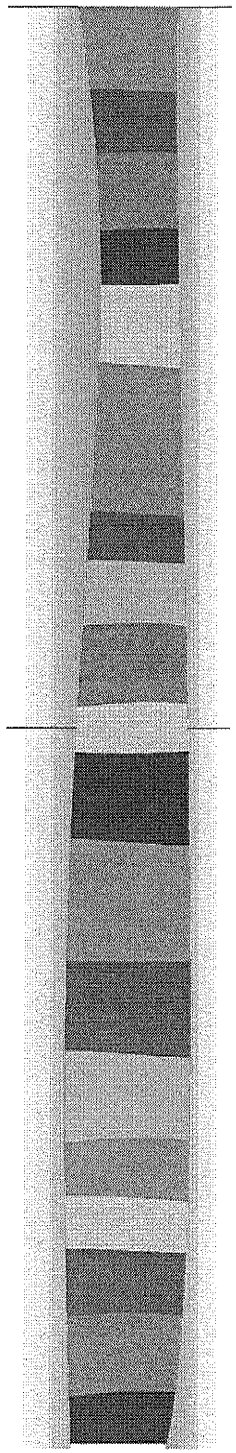


STRUCTURAL REQUIREMENTS



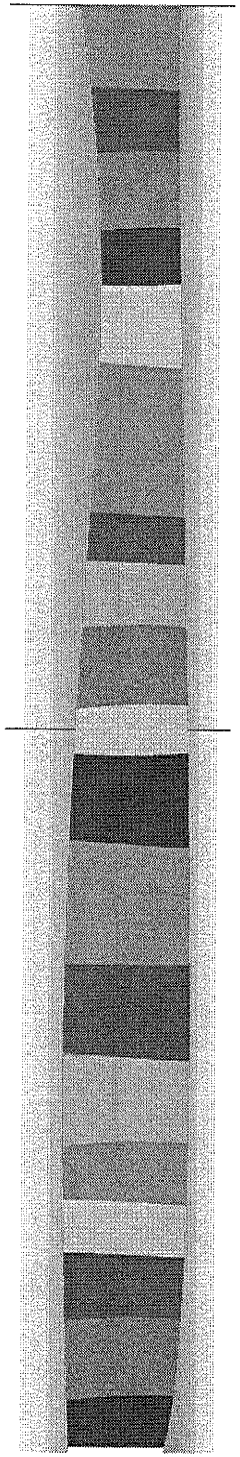
Material

- **Concrete**
  - Minimum Grade 30
  - Pre-stressed Concrete NOT permitted
- **Steel Reinforcement**
  - Main Reinforcements: 460 N/mm^2
  - Shear Links: 250 N/mm^2



Analysis

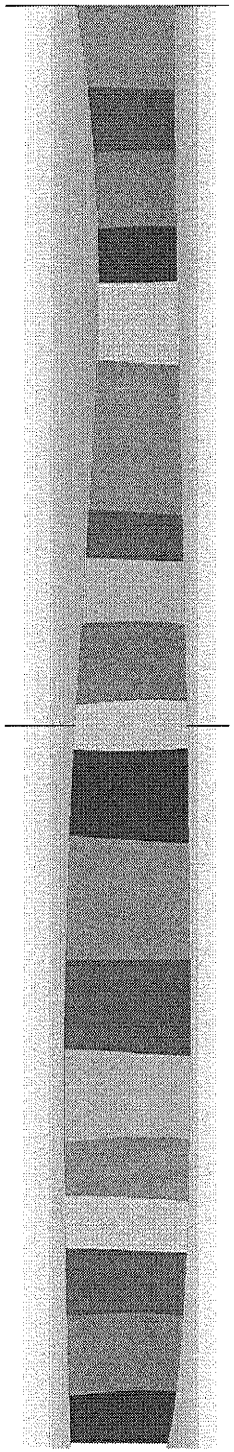
- **General**
  - Walls of SS Tower shall carry their loads directly to the foundation
- **Structural System**
  - SS/NS shall form a continuous structural HS Tower



Member Dimensions

■ Member Dimensions

- SS Walls: Clause 2.4 of Arch Requirements
- Intermediate (double slab): 200 mm
- Ceiling Slab of Top-most SS: 300 mm
- Floor Slab of Bottom-most SS: 300 mm
- Floor Slab of NS above SS: 300 mm
- Shielding Wall in front of SS door: 200 mm

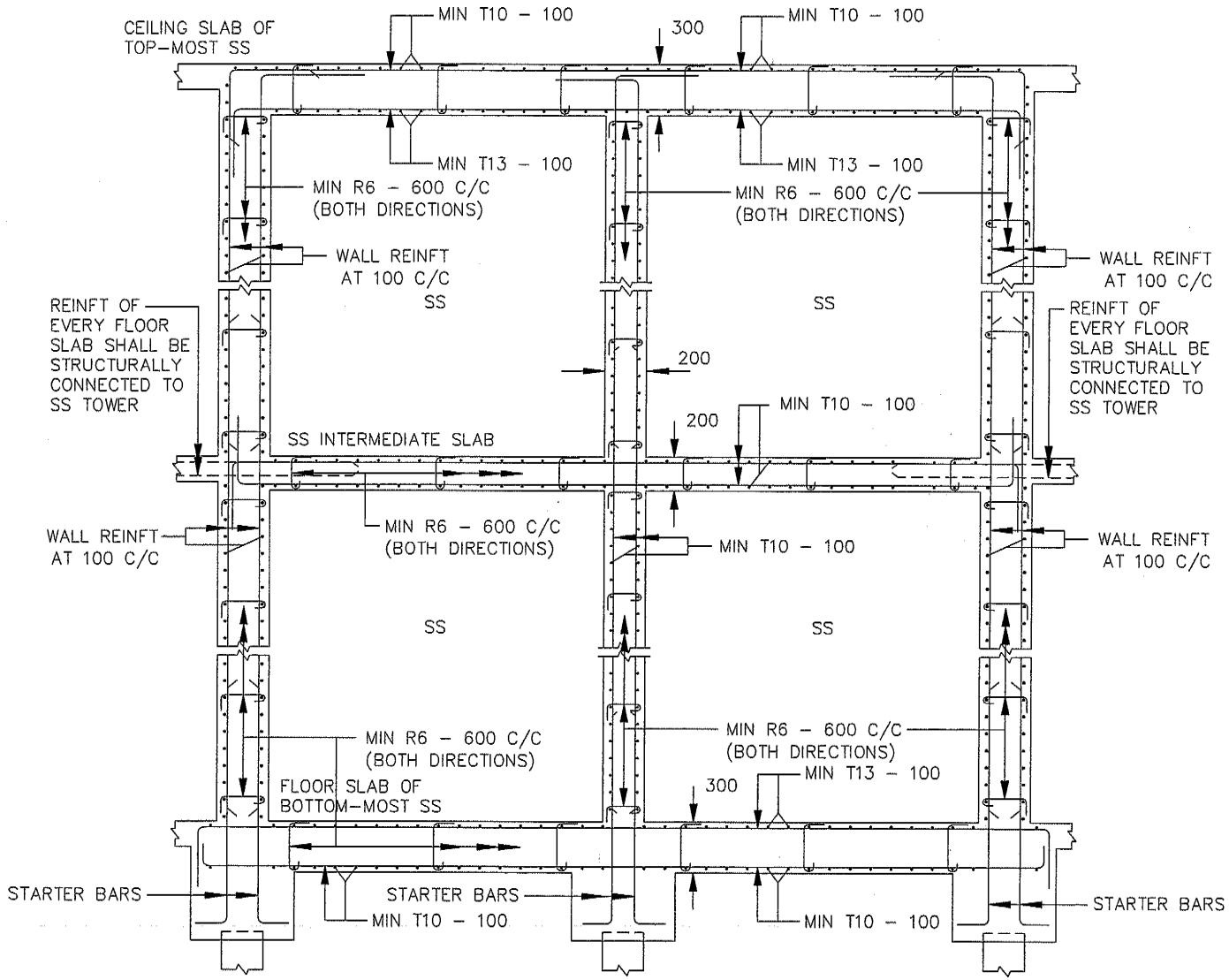


Reinforcement Amounts

■ Amount of Reinforcement

– SS/NS Wall Reinforcements: Table 3.4.2

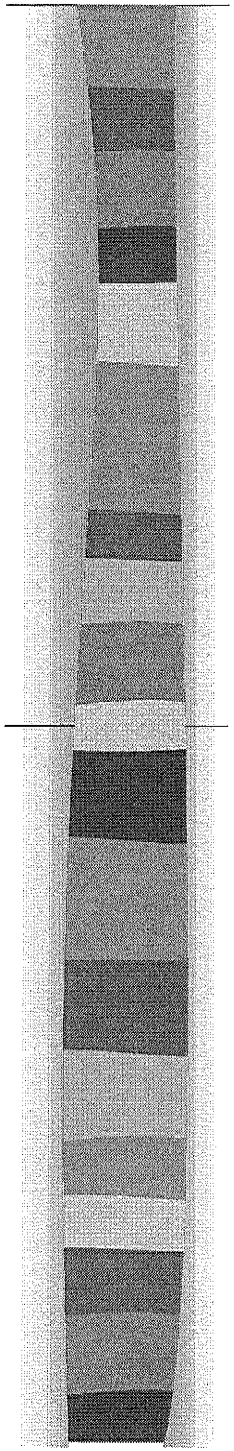
SS/NS Clear Height (mm)	Reinforcement at internal face of wall (both directions)	Reinforcement at external face of wall (both directions)	Shear Links (both directions)
2400 ≤ Ht ≤ 3400	**T13 - 100 c/c**	**T10 - 100 c/c**	**R6 - 600 c/c**
3400 < Ht ≤ 3900	**T16 -100 c/c**	**T13 -100 c/c**	**R6 - 600 c/c**



SECTION B - B

NOTE:

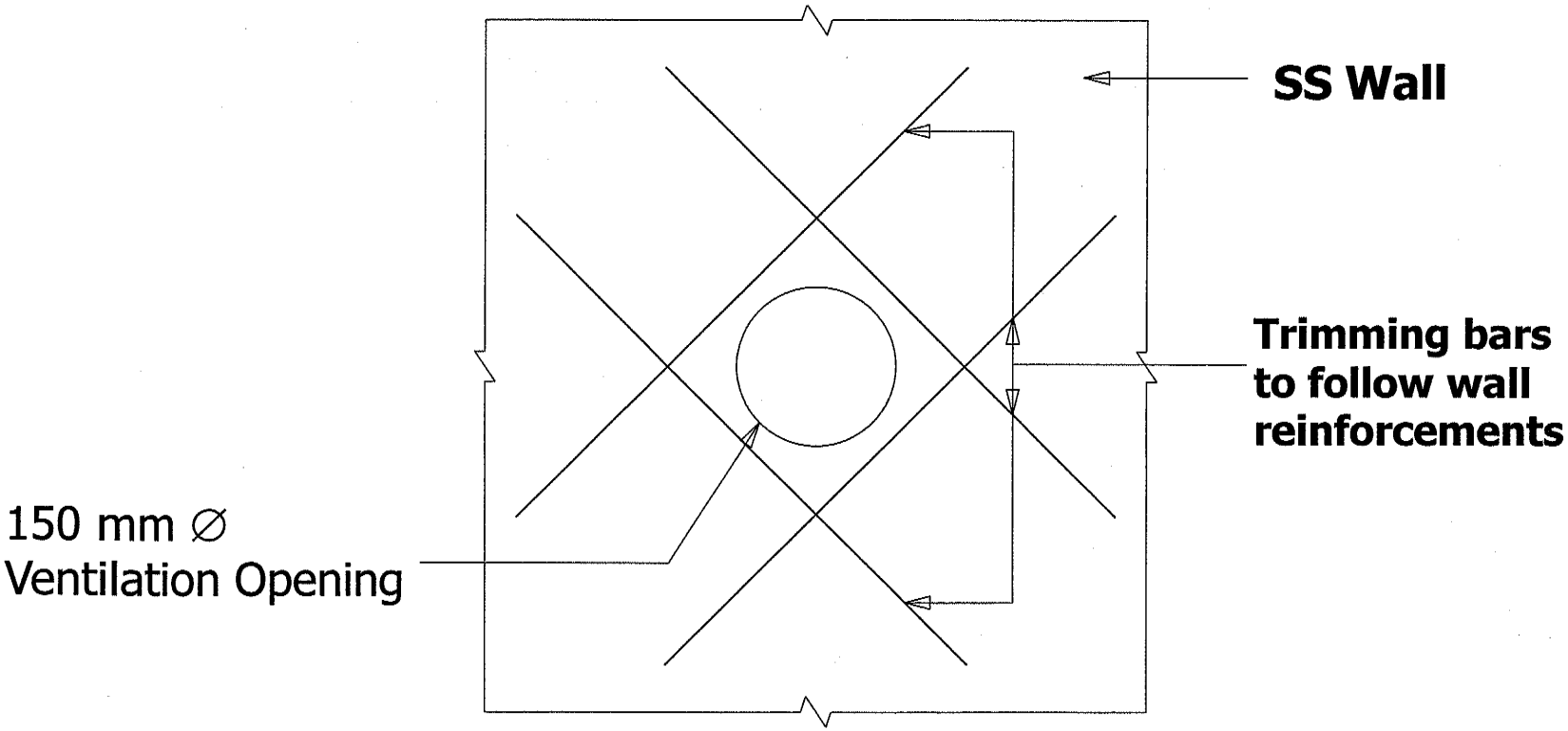
1. WALL REINFT REFER TO TABLE 3.4.2
2. TENSION LAP LENGTH AND TENSION ANCHORAGE LENGTH TO BE 37 TIMES THE DIAMETER OF THE REINFORCEMENT FOR CONCRETE GRADE = 30 N/mm² (CP65 1999)

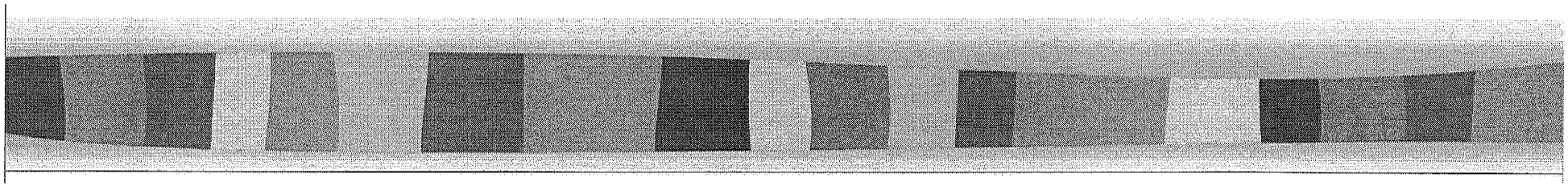


Detailing of SS

- **Cast-in-Situ and Pre-cast Elements**
  - **Cast-in-Situ : Fig 3.5.4 (a) – (h)**
  - **Pre-cast SS Elements : Fig 3.5.4 (j) to Fig 3.5.4 (p)**

■ Typical Details of Trimmer Bars for Ventilation Sleeve - Fig 3.5.4(h)

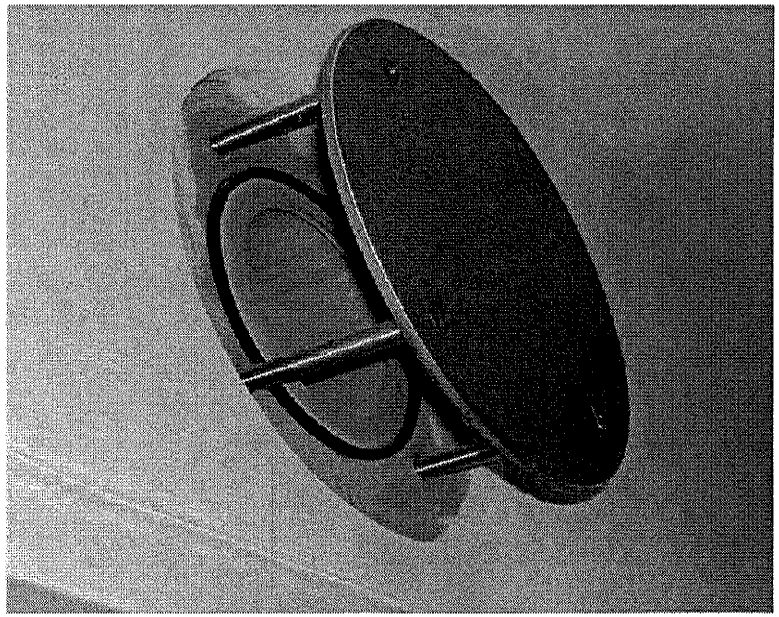




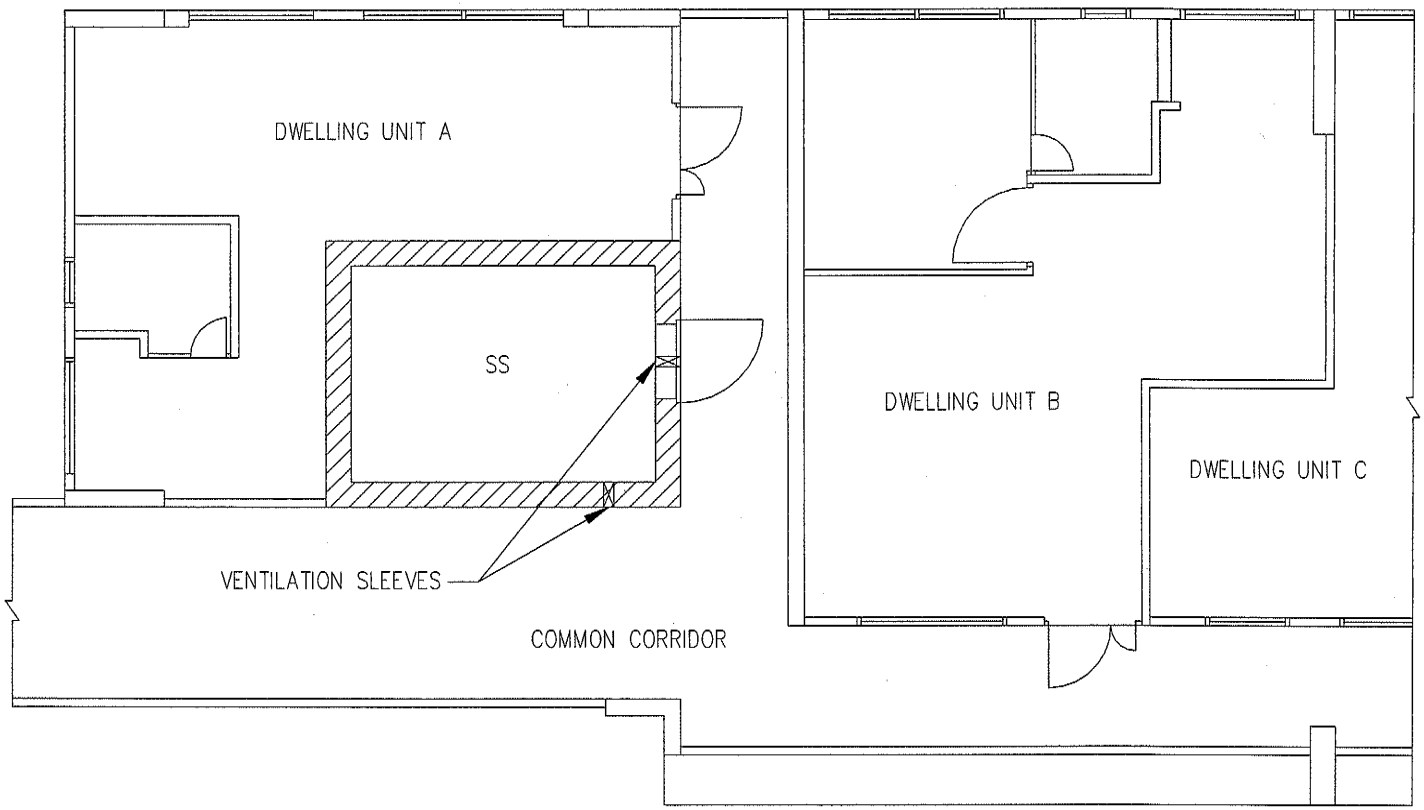
VENTILATION SLEEVES

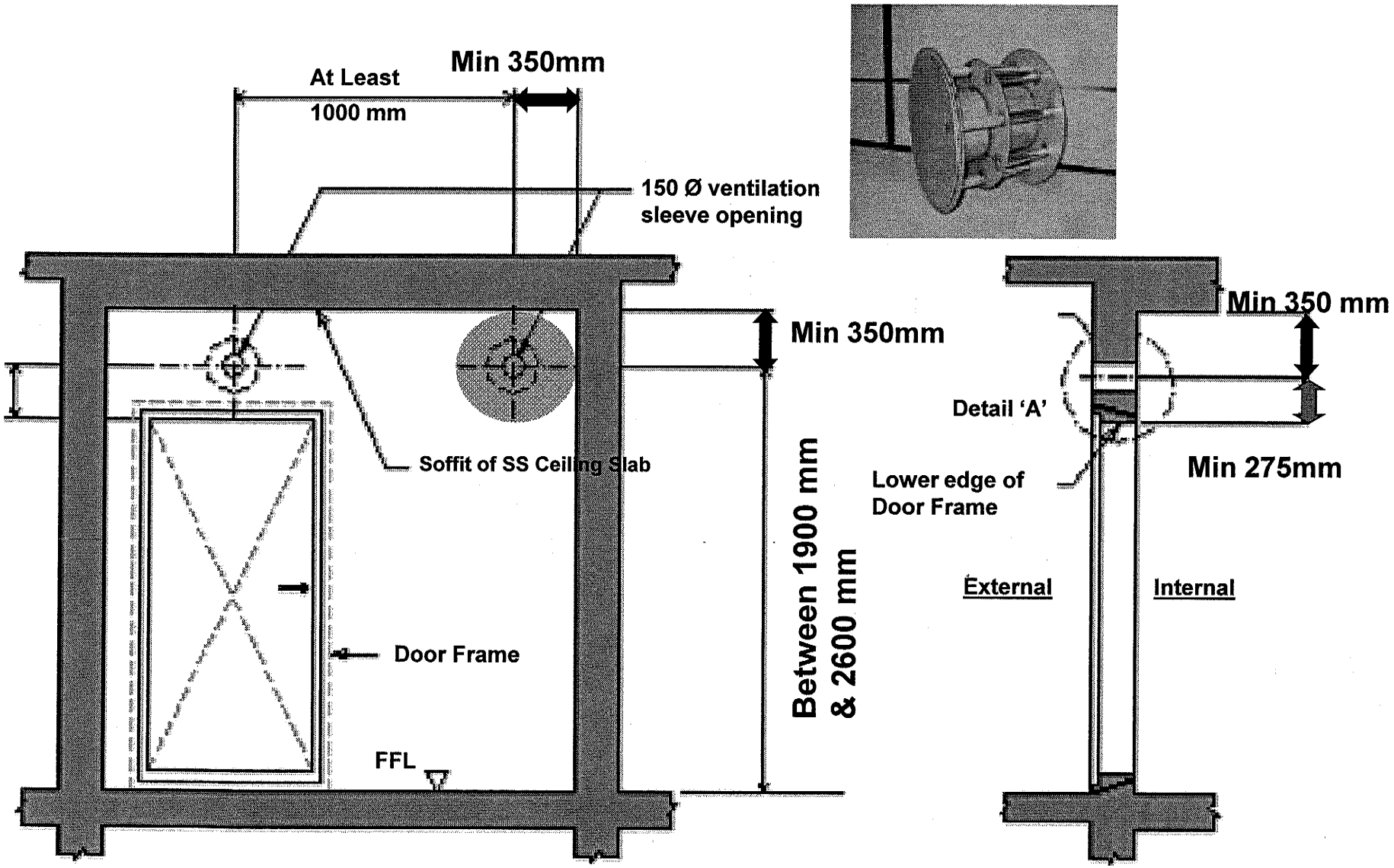
General

- **Two 150 mm diameter Ventilation Sleeves shall be cast into the wall/s of the each SS**



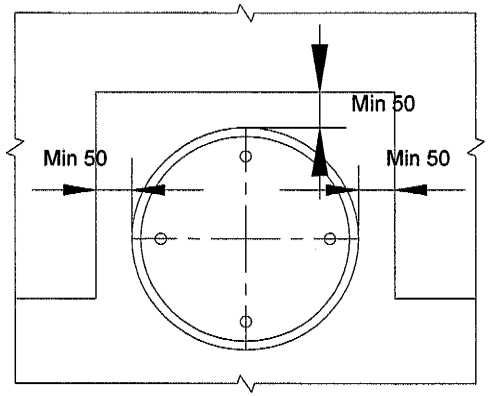
Position of 2 Sleeve Openings



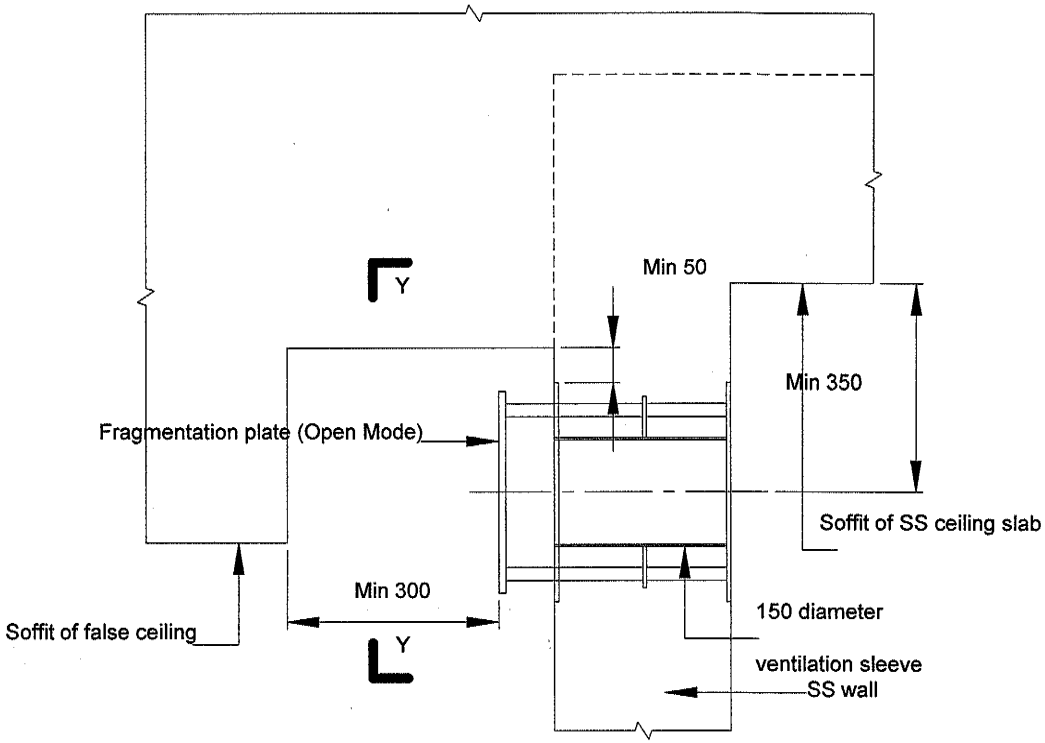


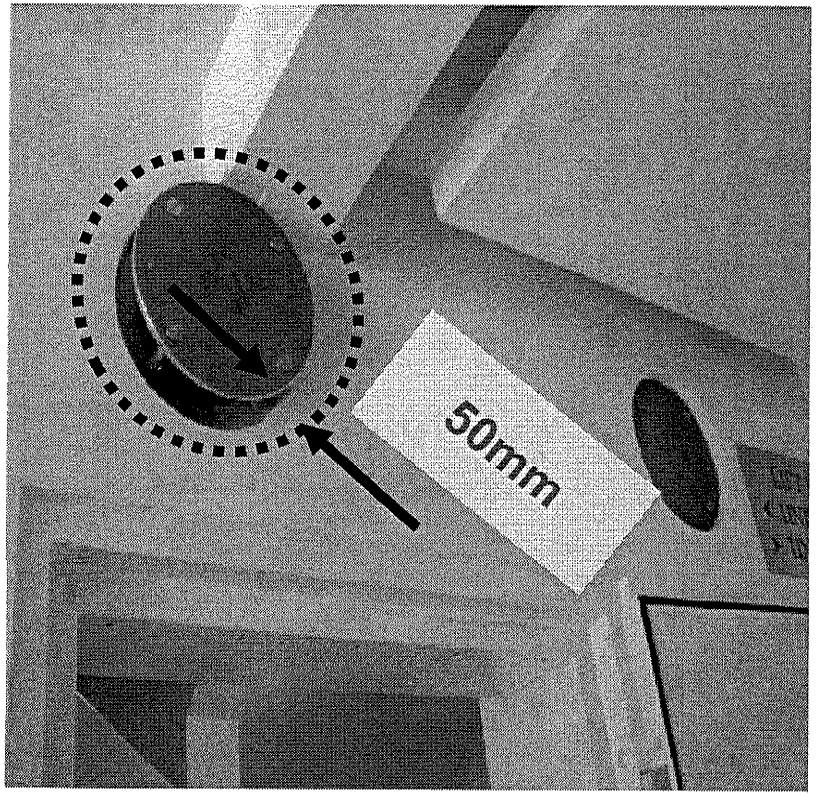
Ventilation Sleeve Clearance Distance from Internal SS Slab or Wall

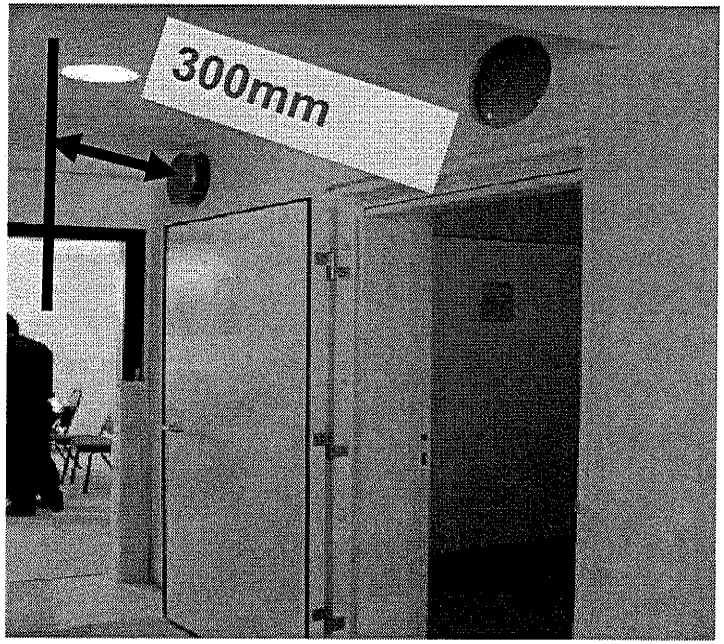
Clearance distance of fragmentation plate

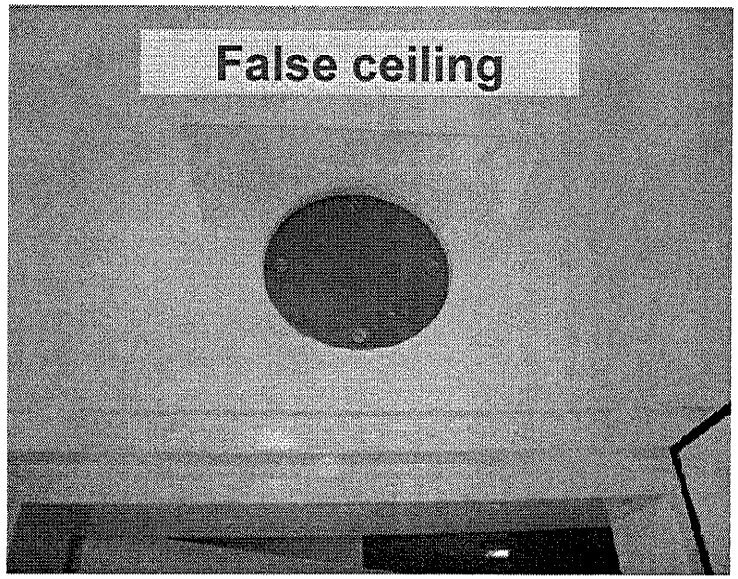


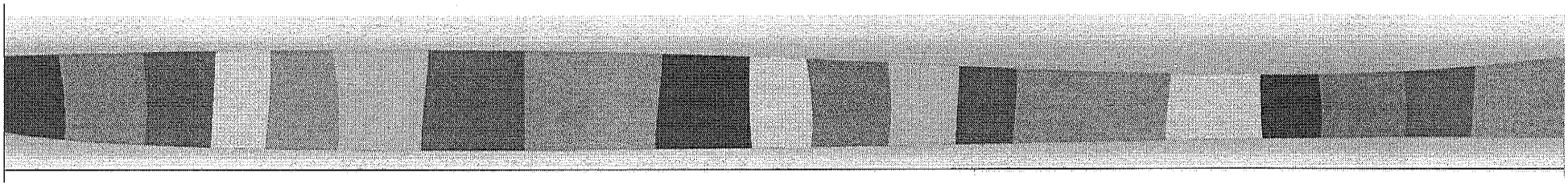
Section Y-Y




50mm


300mm

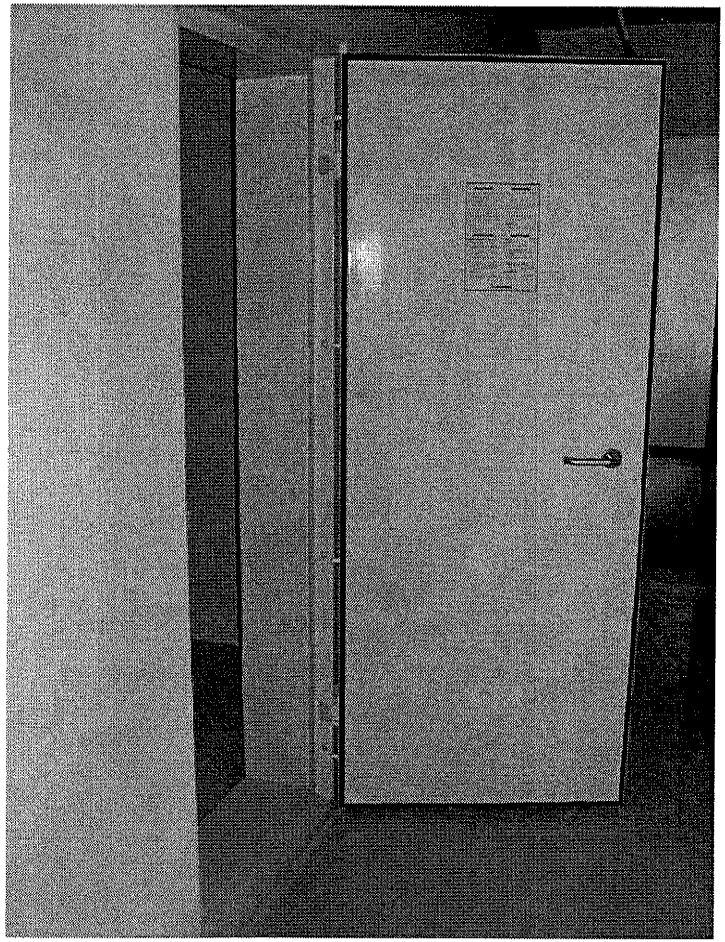

False ceiling

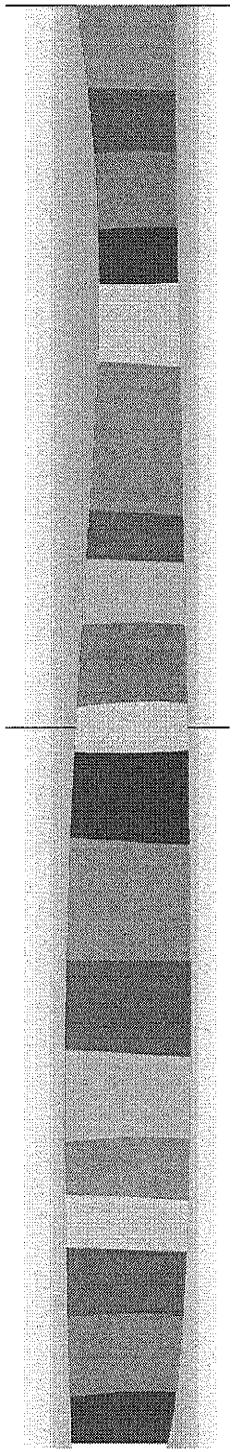


SS DOOR

General

- SS Door shall
  - Provide airtight closure to the SS
  - Designed to open outwards from the SS

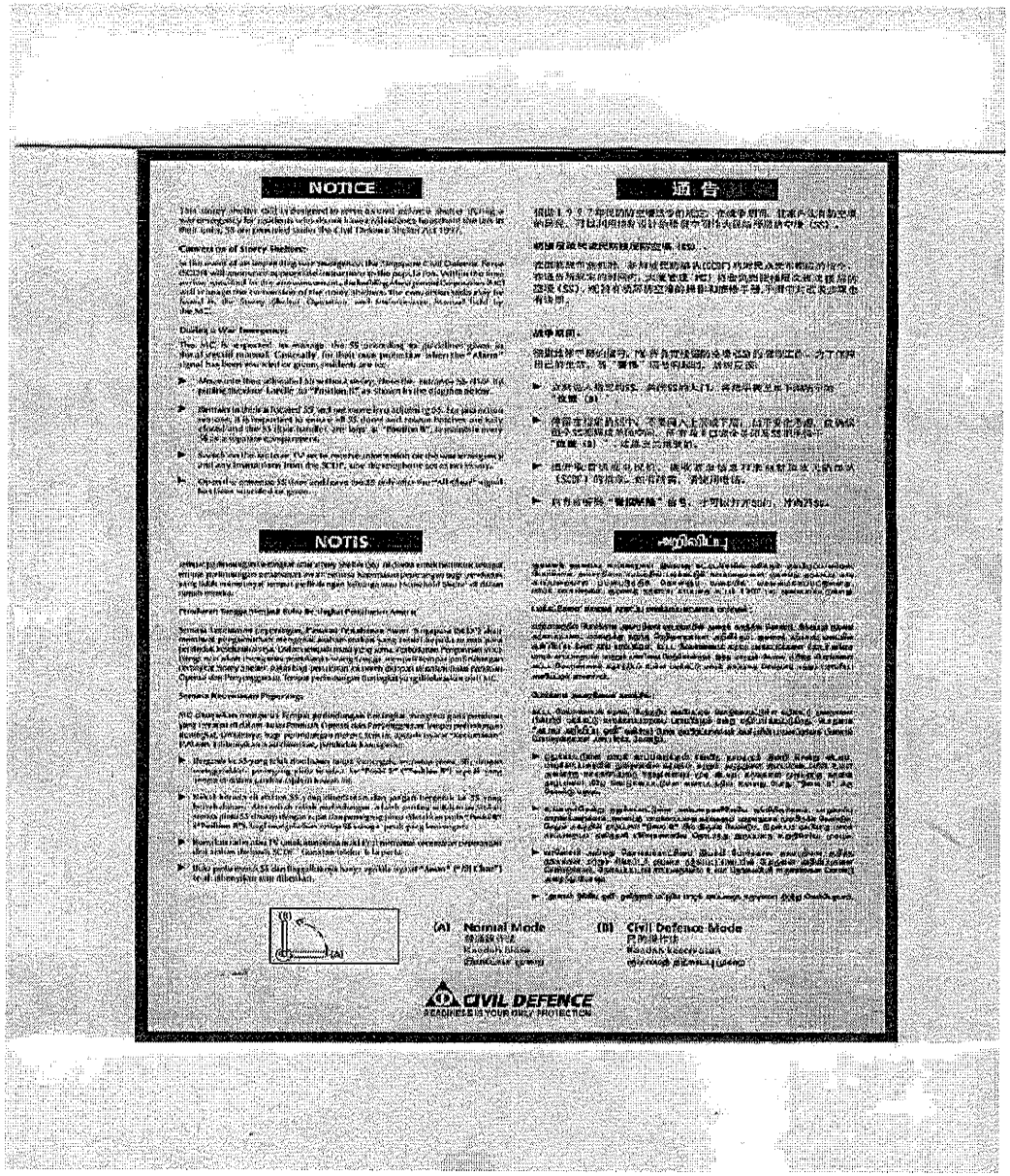




Approved SS Door

- Only SS Doors of approved design shall be used
- List of approved SS door design is available from the relevant authority

SS Door Notice

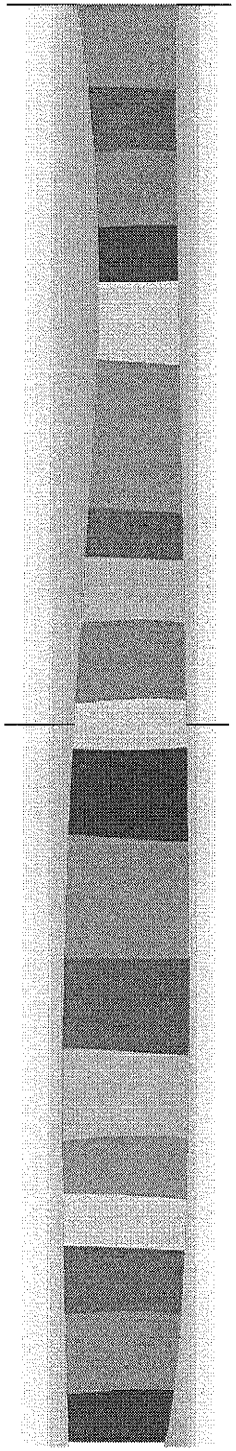


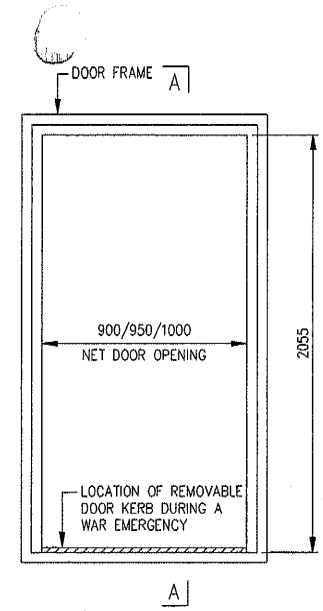
NOTICE

(A) Normal Mode

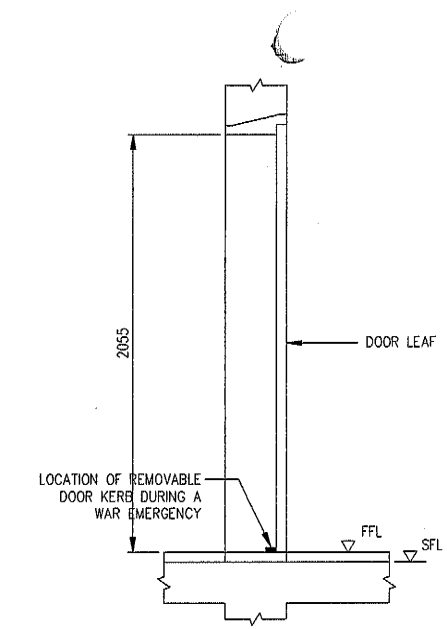
(B) Civil Defence Mode

CIVIL DEFENCE
READINESS IS YOUR ONLY PROTECTION

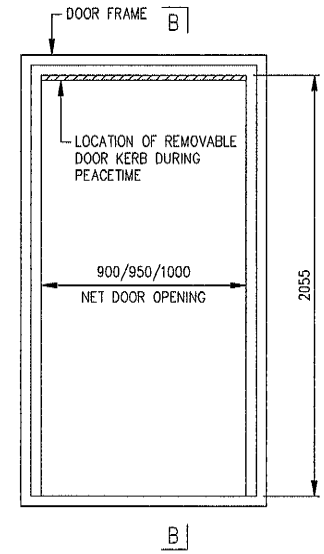




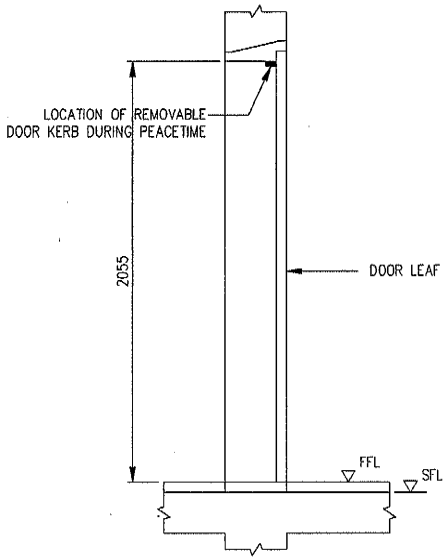
ELEVATION OF SHELTER DOOR



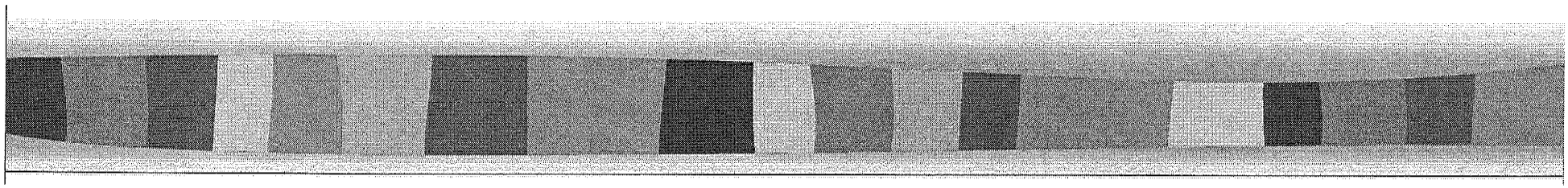
SECTION A – A



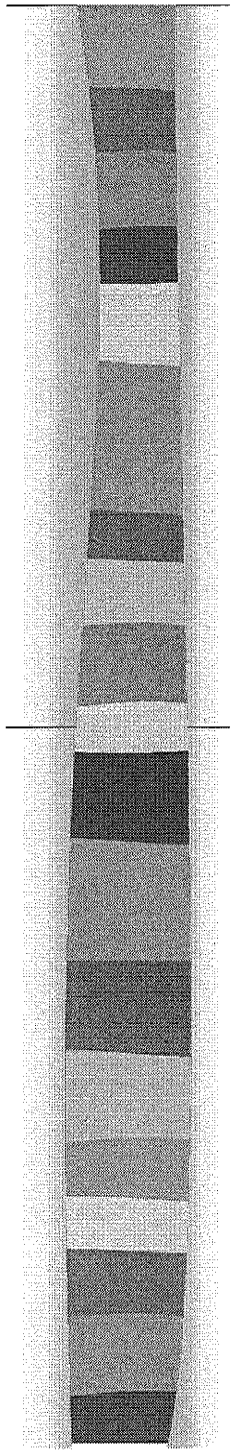
ELEVATION OF SHELTER DOOR

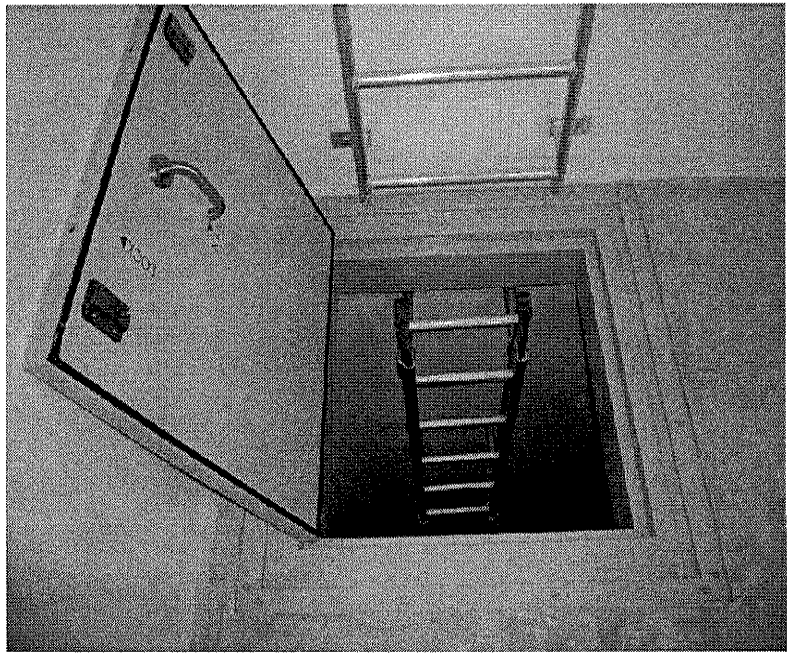


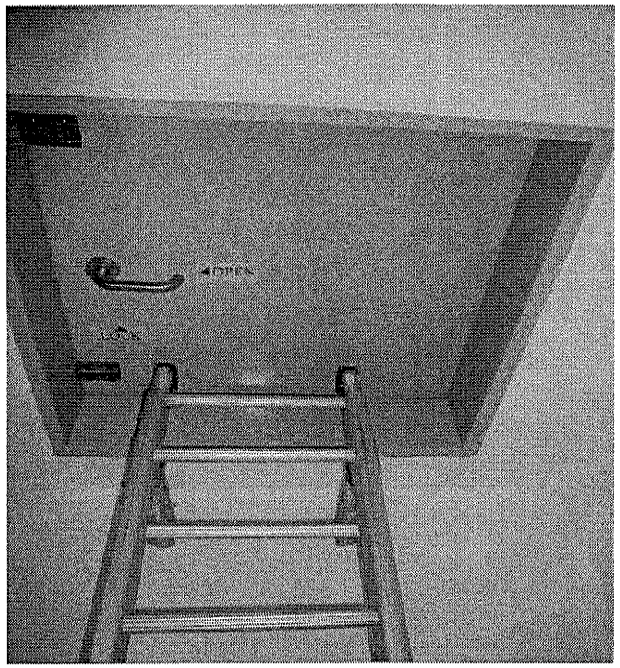
SECTION B – B

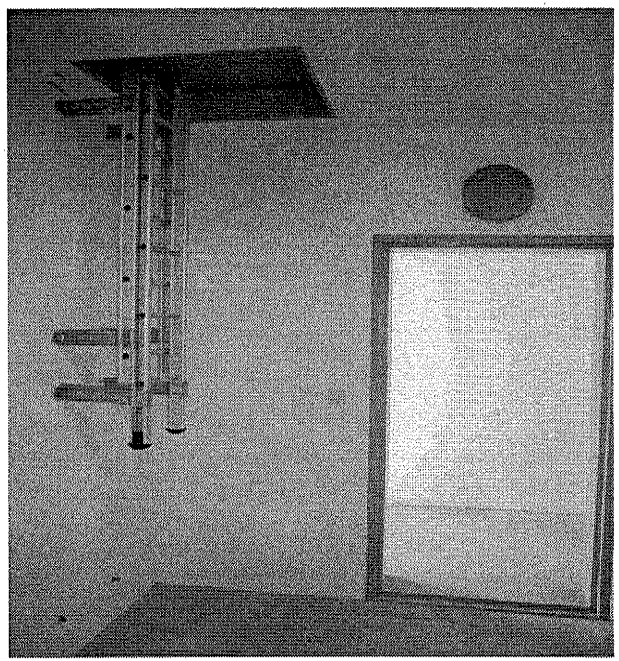


RESCUE HATCH AND CAT-LADDER

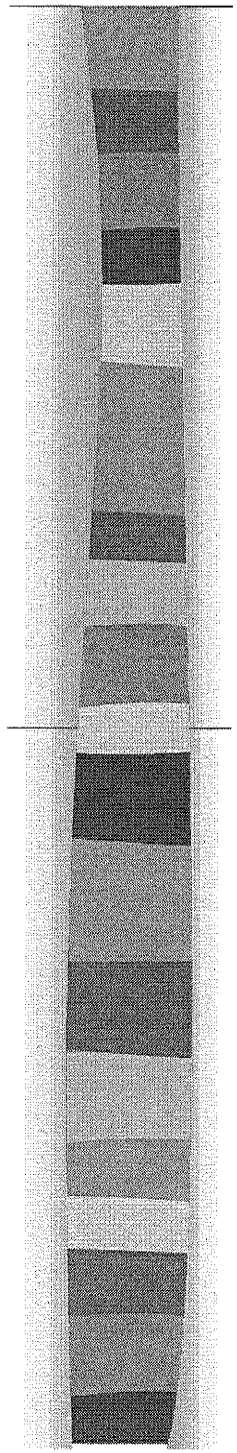






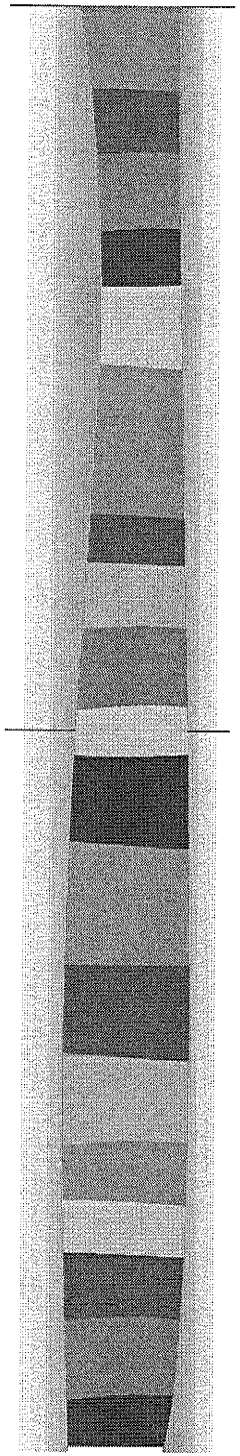


Rescue Hatch and Cat-ladder in Storey Shelter

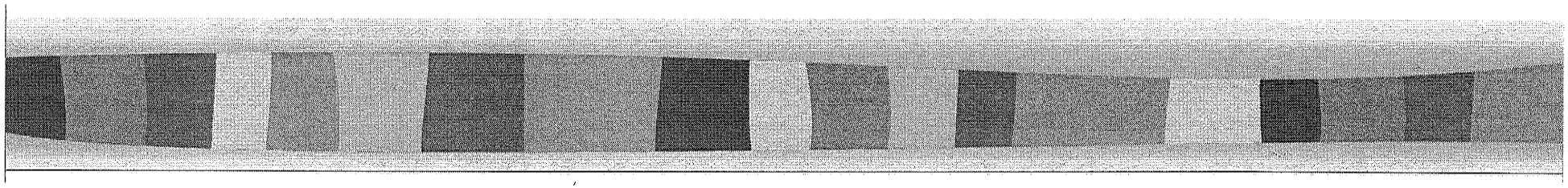


Building and Construction Authority

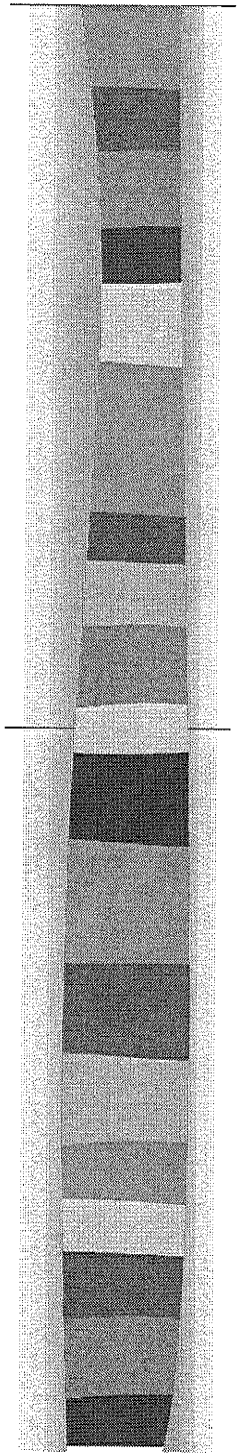
STRUCTURAL AND OTHER REQUIREMENTS OF STOREY SHELTERS



- **STRUCTURAL REQUIREMENTS**
- **VENTILATION SLEEVES**
- **SS DOOR**

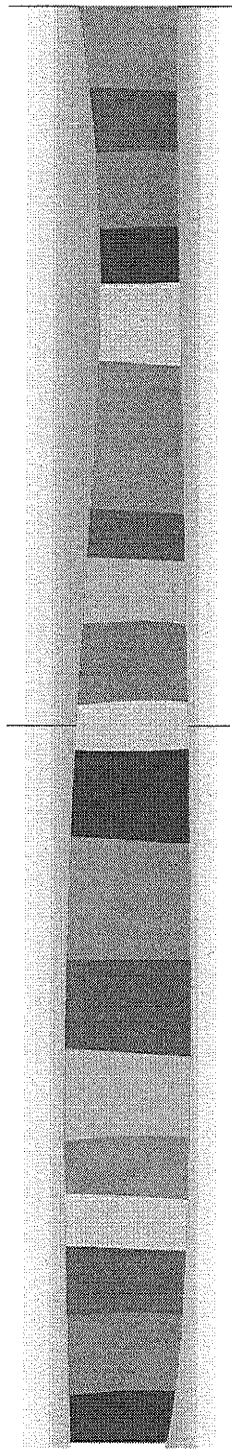


STRUCTURAL REQUIREMENTS



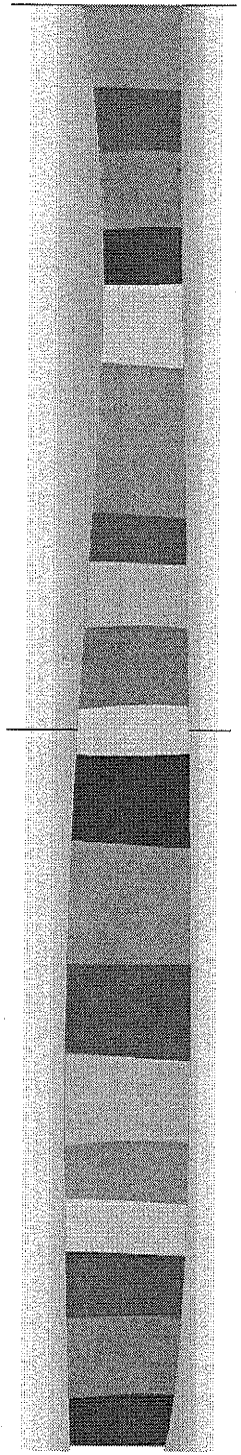
Material

- **Concrete**
  - Minimum Grade 30
  - Pre-stressed Concrete NOT permitted
- **Steel Reinforcement**
  - Main Reinforcements: 460 N/mm^2
  - Shear Links: 250 N/mm^2



Analysis

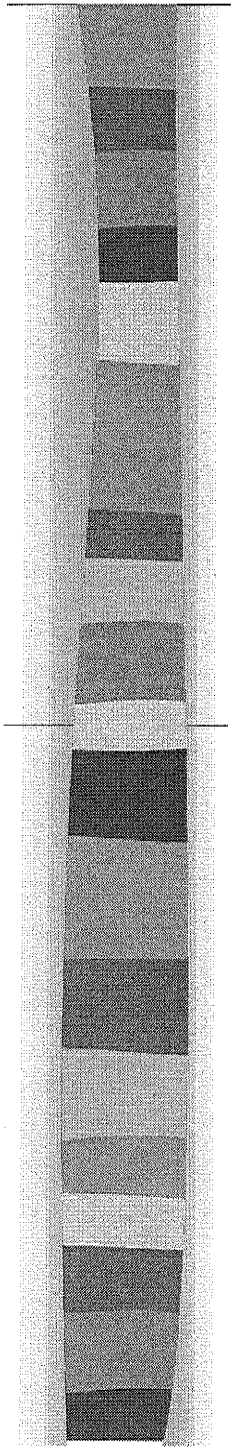
- **General**
  - Walls of SS Tower shall carry their loads directly to the foundation
- **Structural System**
  - SS/NS shall form a continuous structural HS Tower



Member Dimensions

■ Member Dimensions

- SS Walls: Clause 2.4 of Arch Requirements
- Intermediate (double slab): 200 mm
- Ceiling Slab of Top-most SS: 300 mm
- Floor Slab of Bottom-most SS: 300 mm
- Floor Slab of NS above SS: 300 mm
- Shielding Wall in front of SS door: 200 mm



Reinforcement Amounts

■ Amount of Reinforcement

– SS/NS Wall Reinforcements: Table 3.4.2

SS/NS Clear Height (mm)	Reinforcement at internal face of wall (both directions)	Reinforcement at external face of wall (both directions)	Shear Links (both directions)
2400 ≤ Ht ≤ 3400	**T13 - 100 c/c**	**T10 - 100 c/c**	**R6 - 600 c/c**
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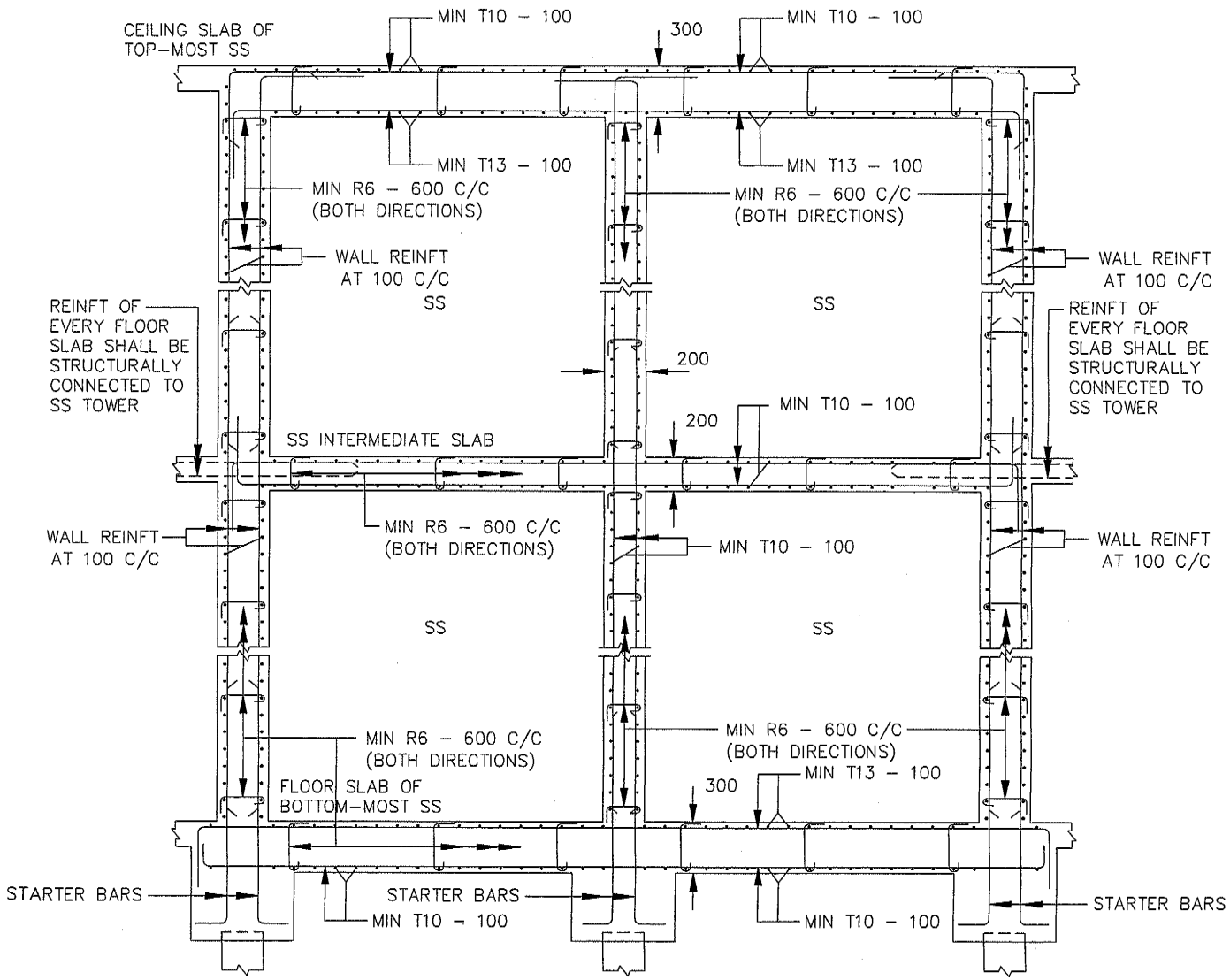

SECTION B - B

NOTE:

1. WALL REINFT REFER TO TABLE 3.4.2
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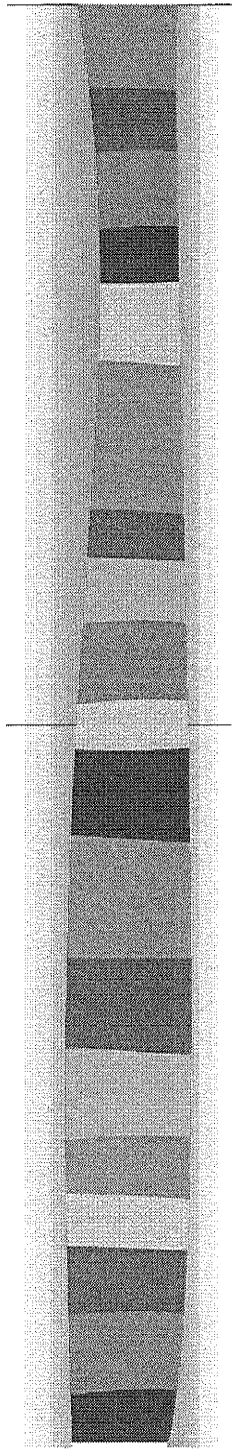
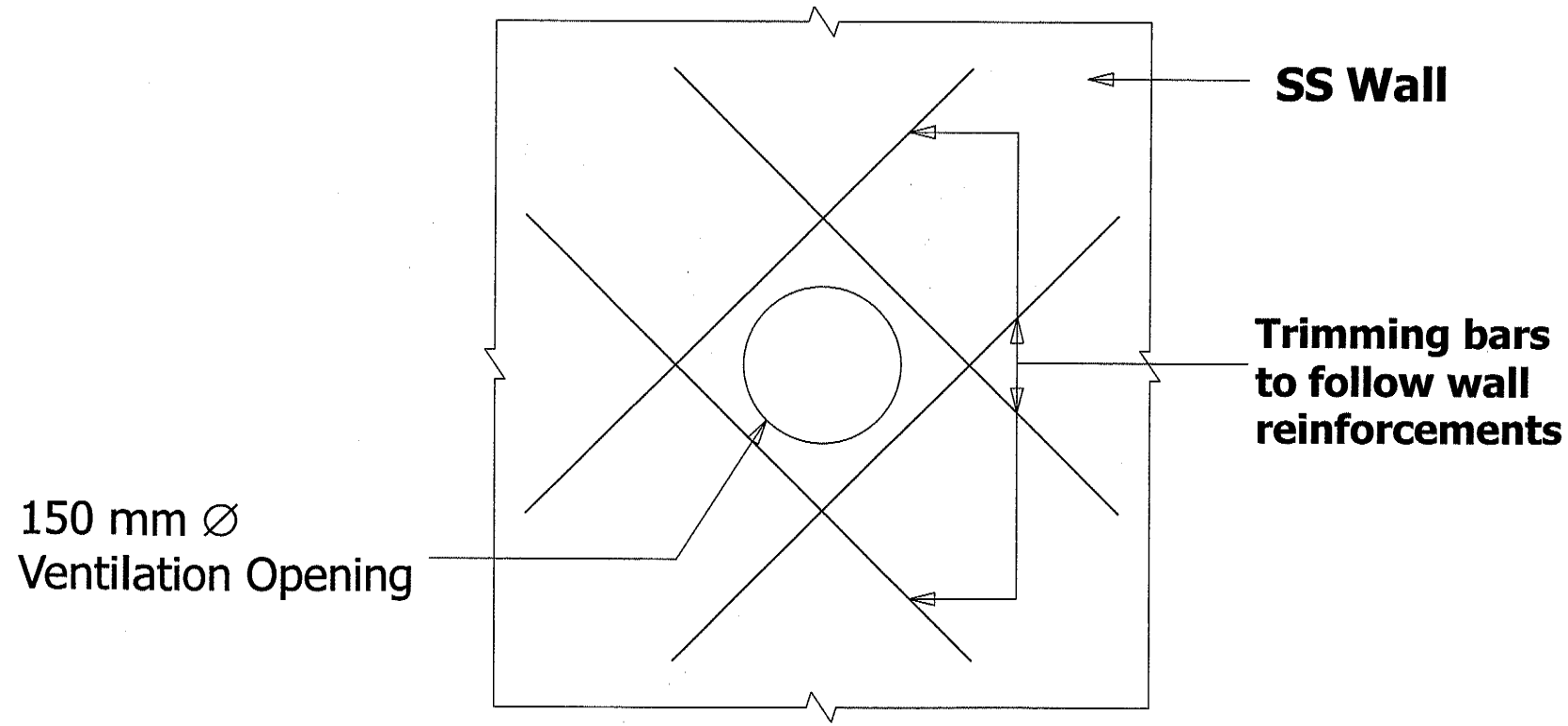
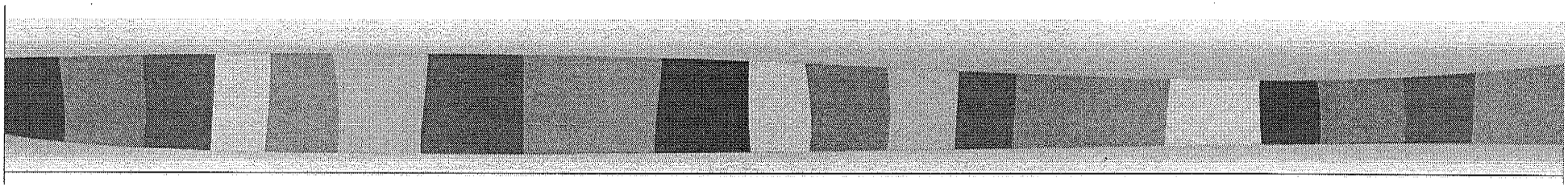


Detailing of SS

- **Cast-in-Situ and Pre-cast Elements**
  - **Cast-in-Situ : Fig 3.5.4 (a) – (h)**
  - **Pre-cast SS Elements : Fig 3.5.4 (j) to Fig 3.5.4 (p)**

■ Typical Details of Trimmer Bars for Ventilation Sleeve - Fig 3.5.4(h)

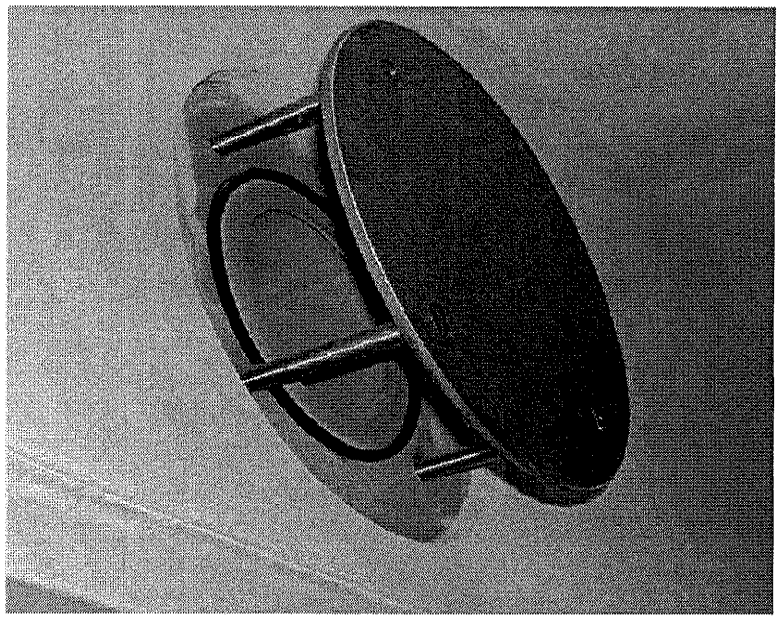




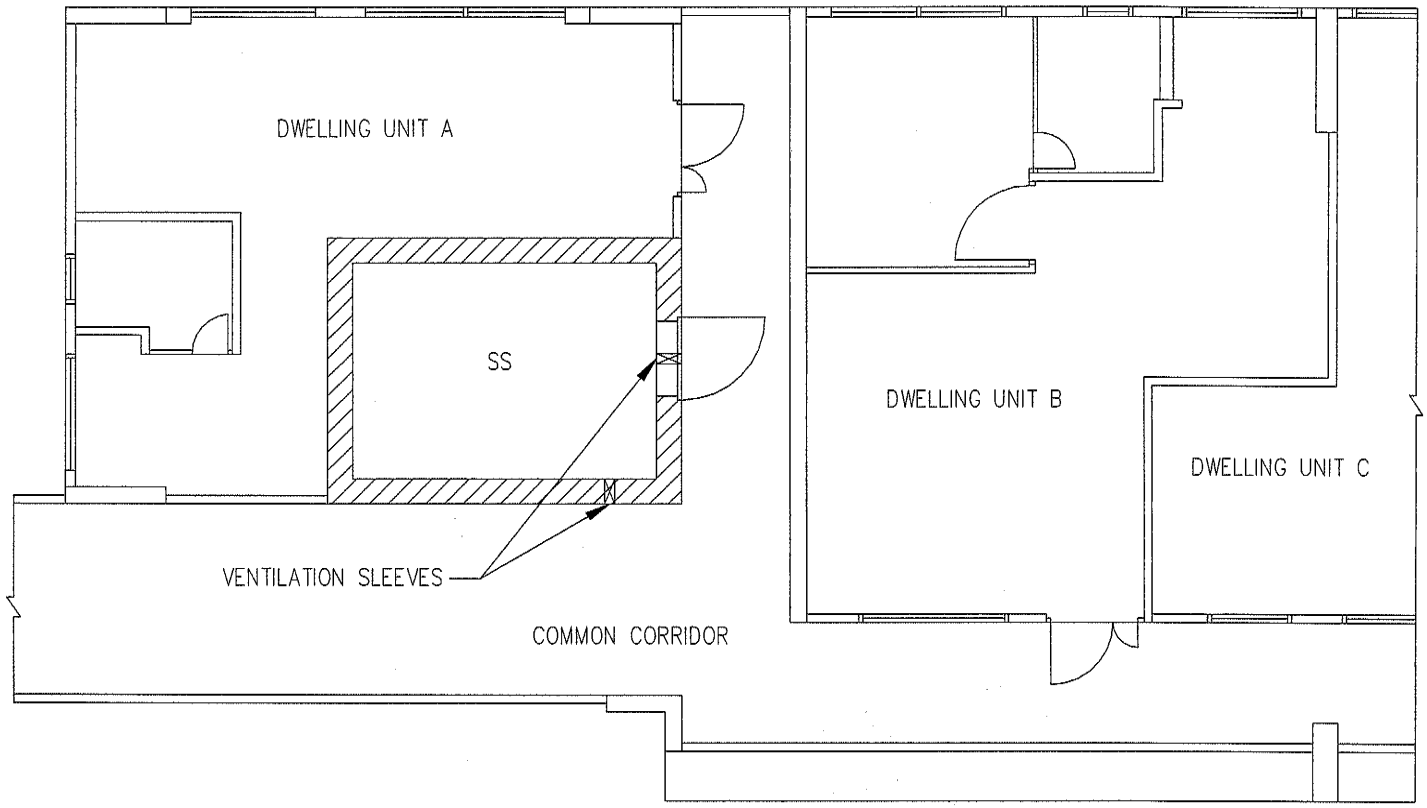
VENTILATION SLEEVES

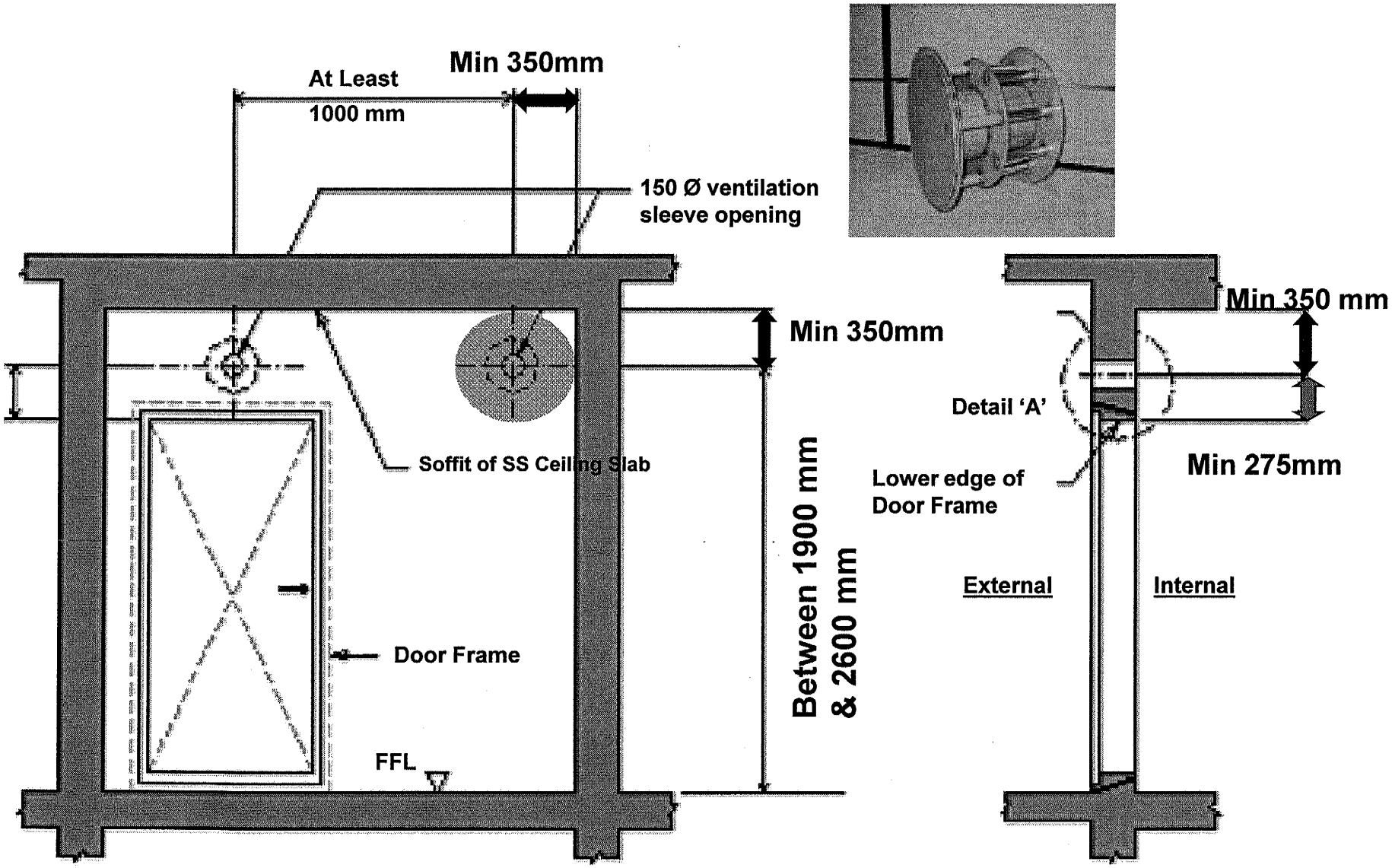
General

- **Two 150 mm diameter Ventilation Sleeves shall be cast into the wall/s of the each SS**



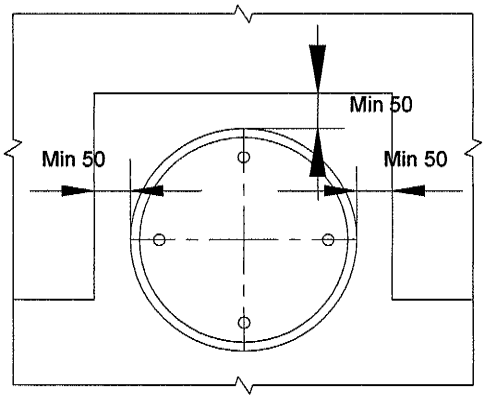
Position of 2 Sleeve Openings



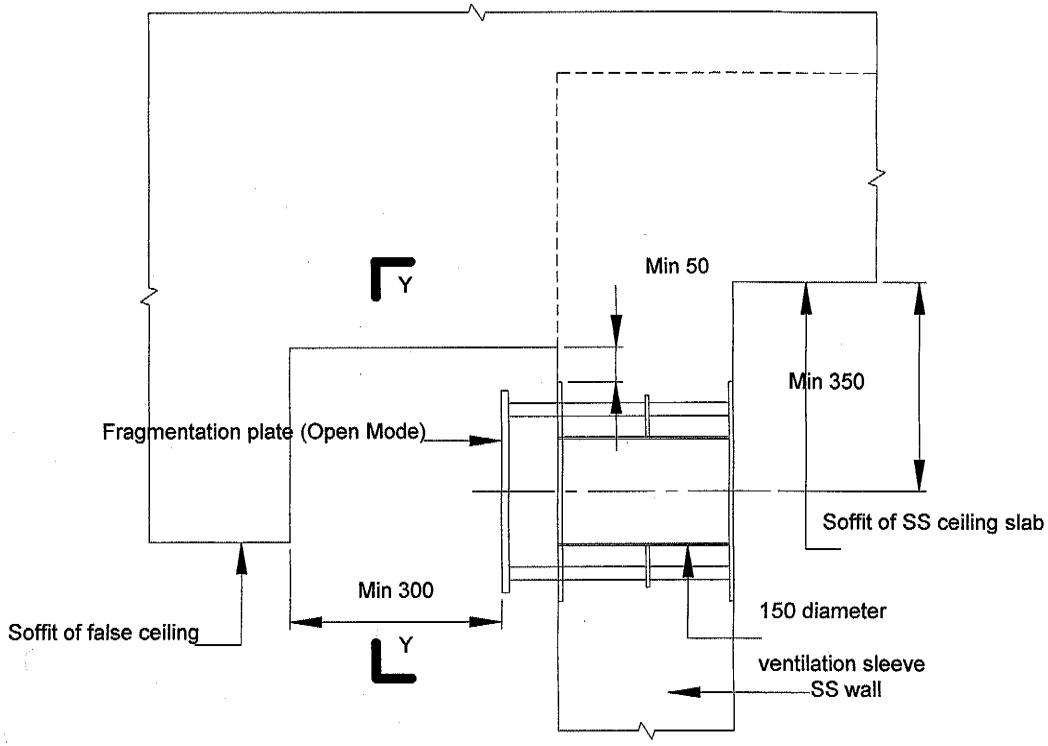


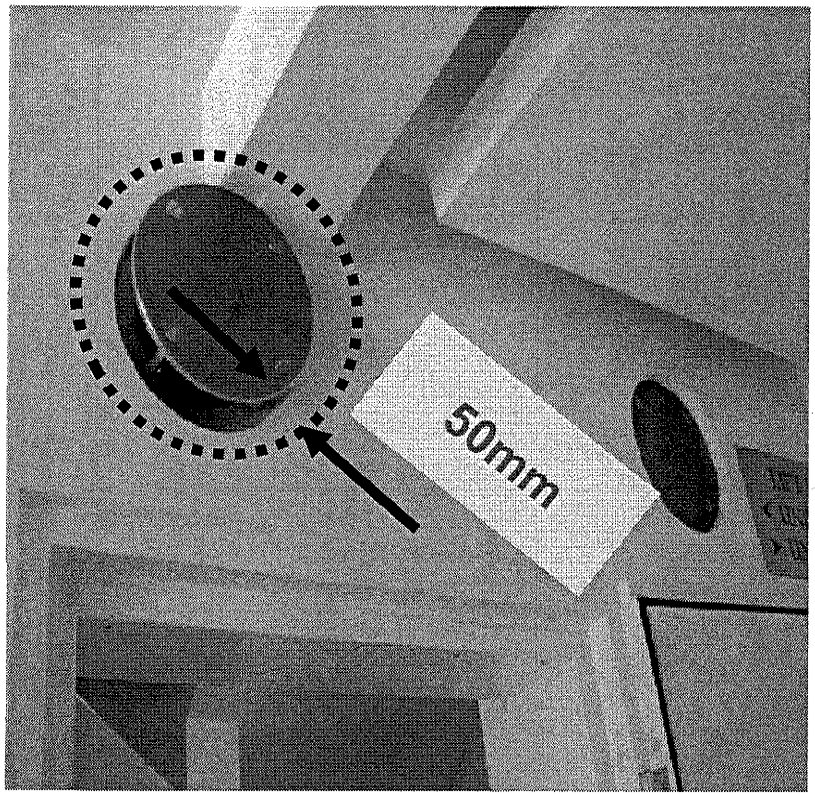
Ventilation Sleeve Clearance Distance from Internal SS Slab or Wall

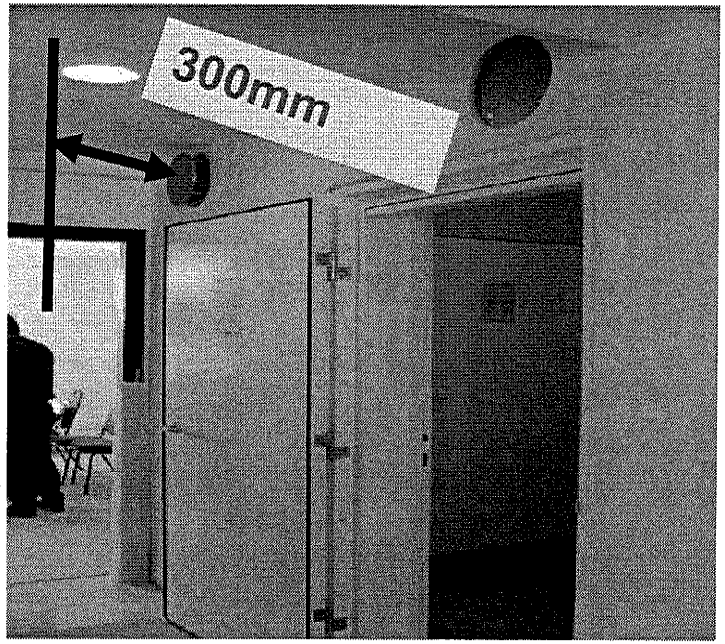
Clearance distance of fragmentation plate

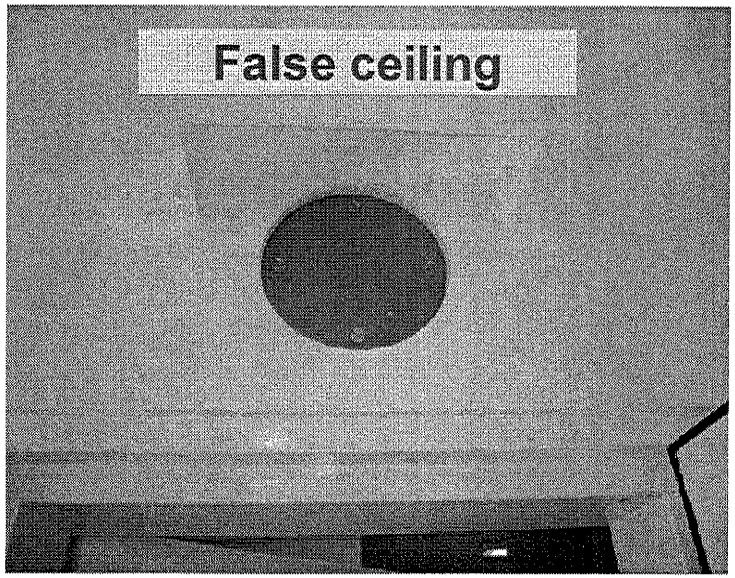


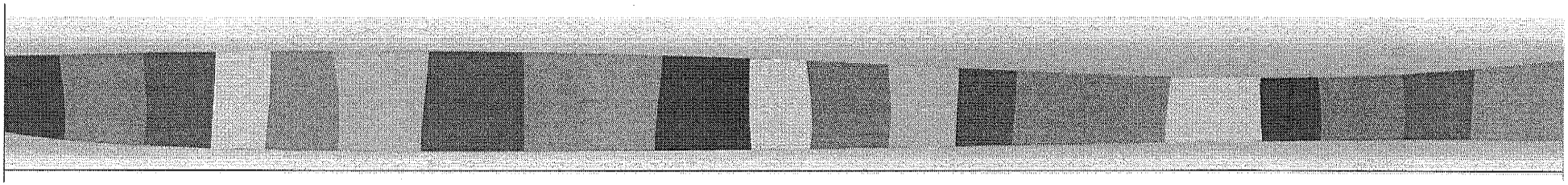
Section Y-Y




50mm


300mm

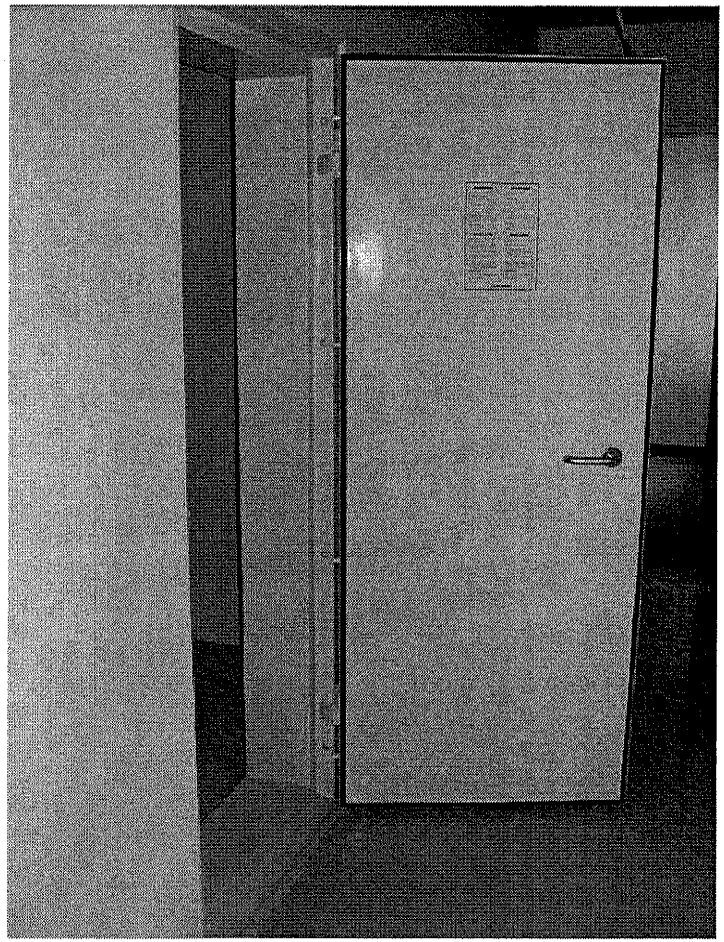

False ceiling

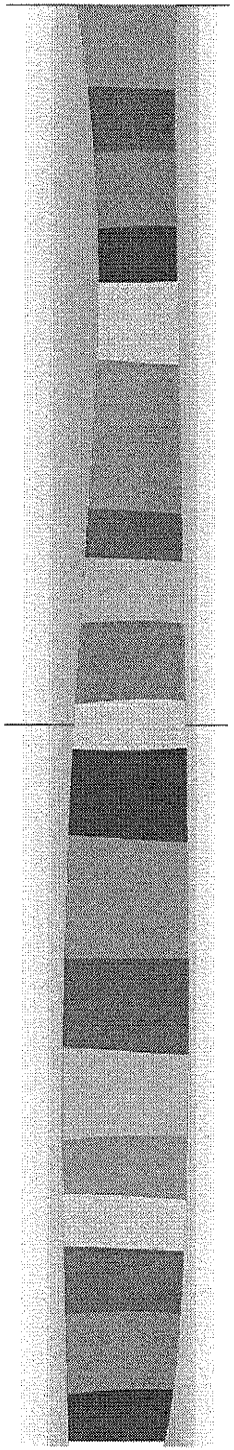


SS DOOR

General

- SS Door shall
  - Provide airtight closure to the SS
  - Designed to open outwards from the SS

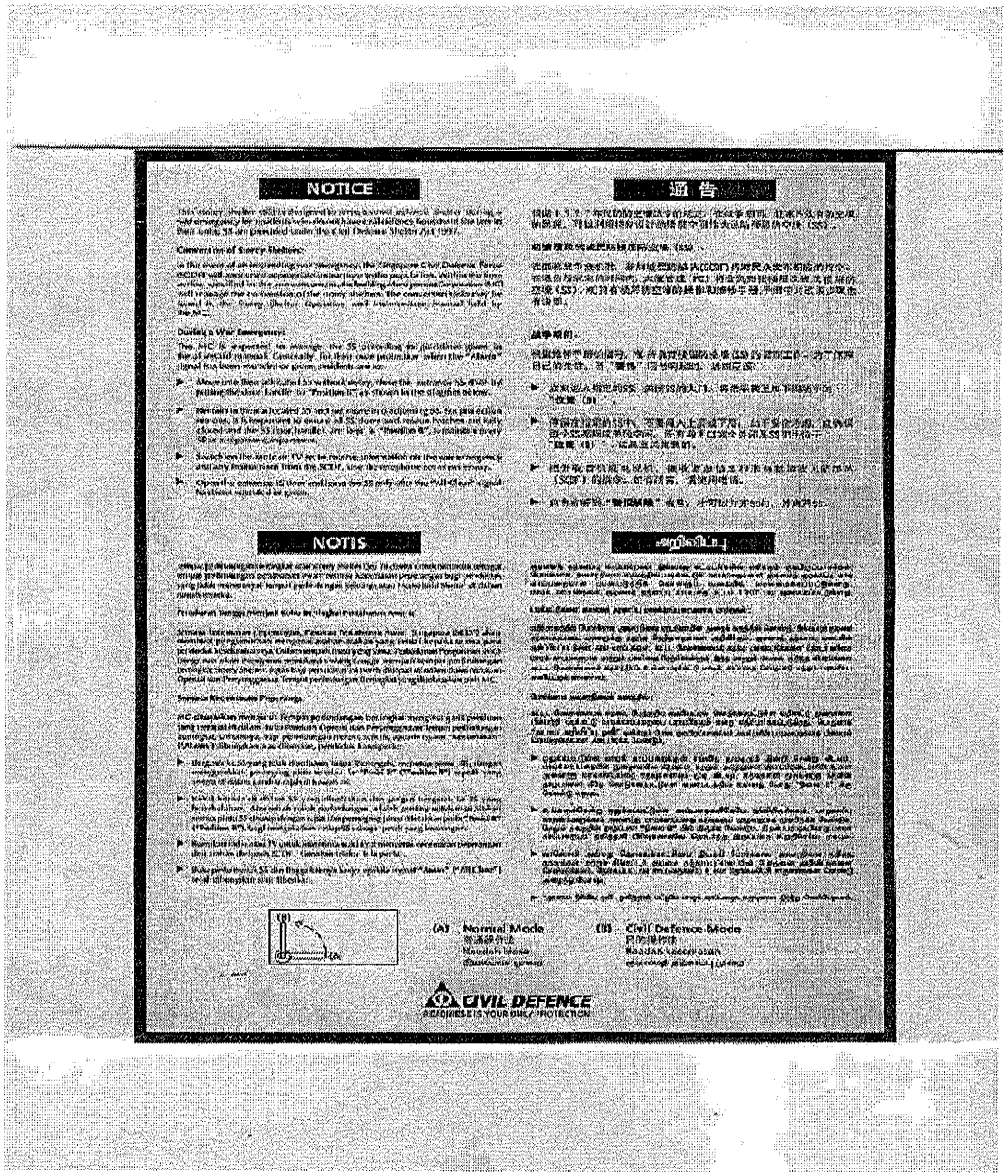




Approved SS Door

- Only SS Doors of approved design shall be used
- List of approved SS door design is available from the relevant authority

SS Door Notice



NOTICE

通告

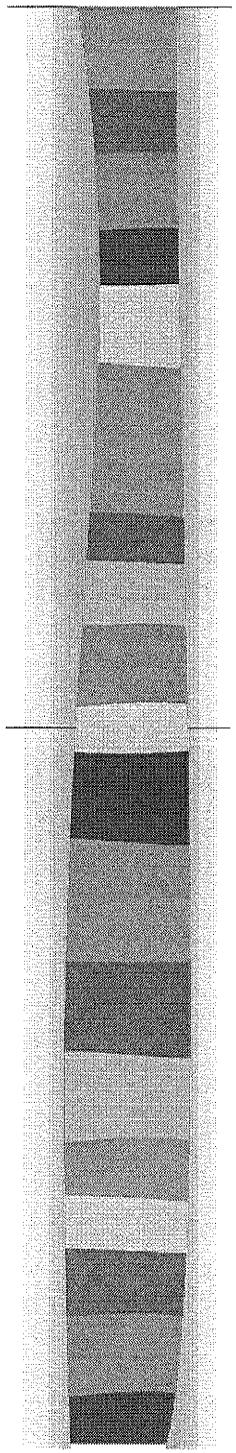
NOTIS

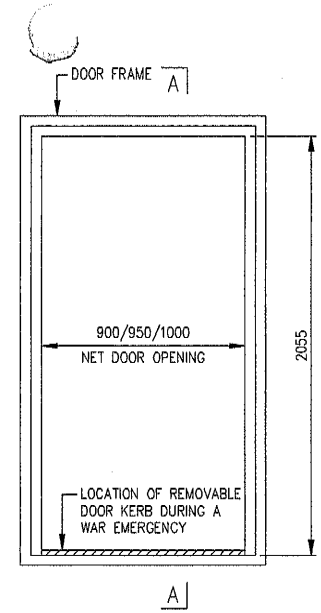
அறிவிப்பு

(A) Normal Mode

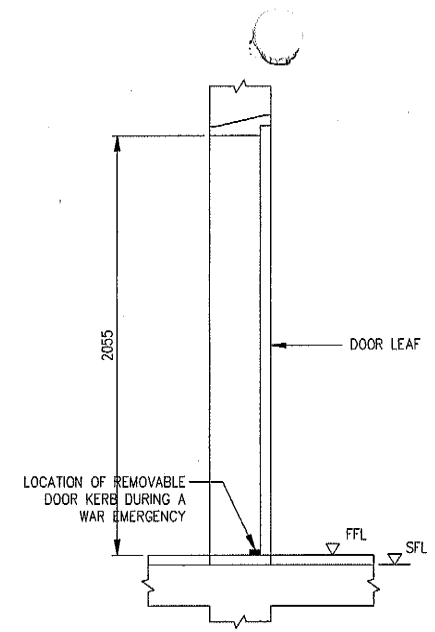
(B) Civil Defence Mode

CIVIL DEFENCE
READINESS IS YOUR ONLY PROTECTION

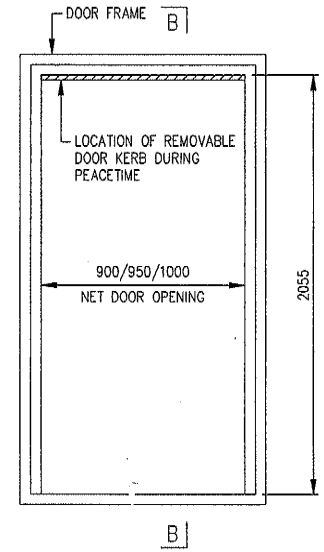




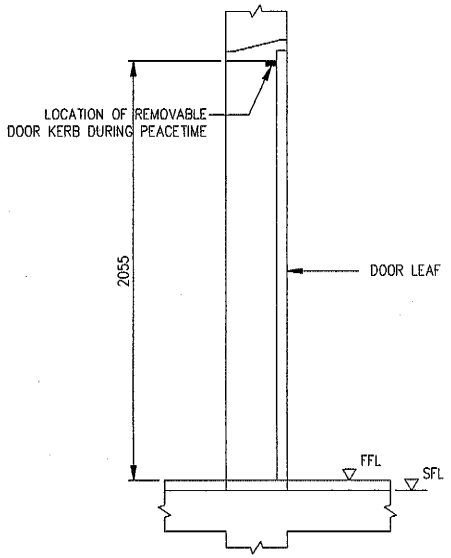
ELEVATION OF SHELTER DOOR



SECTION A – A



ELEVATION OF SHELTER DOOR



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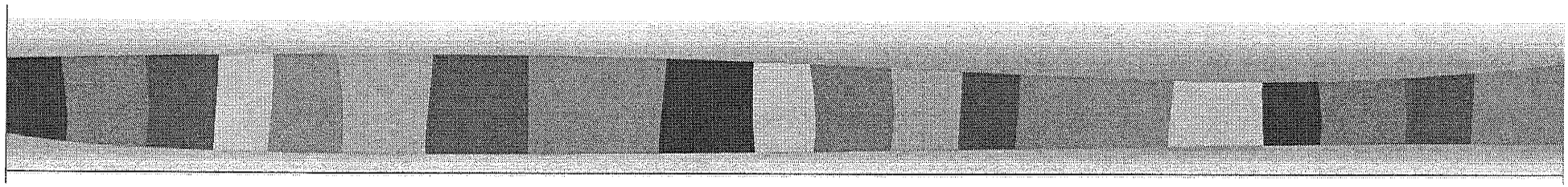
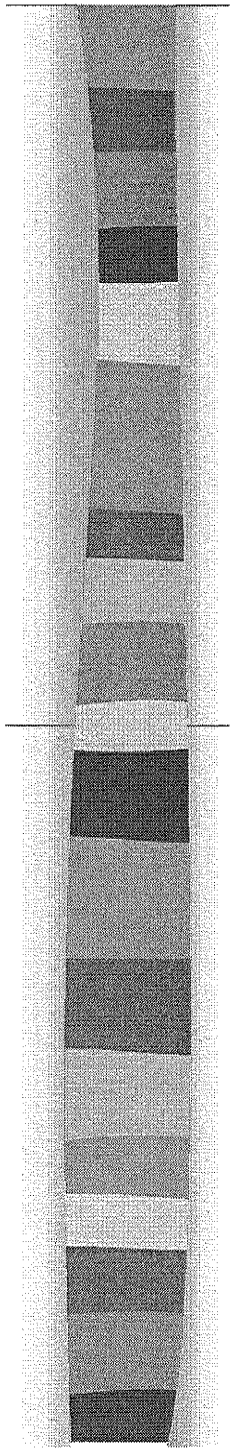
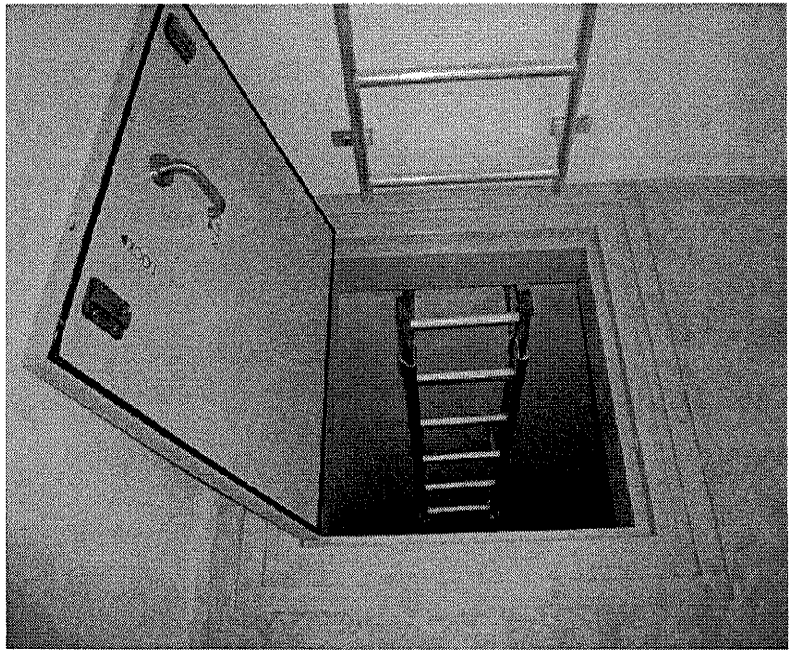
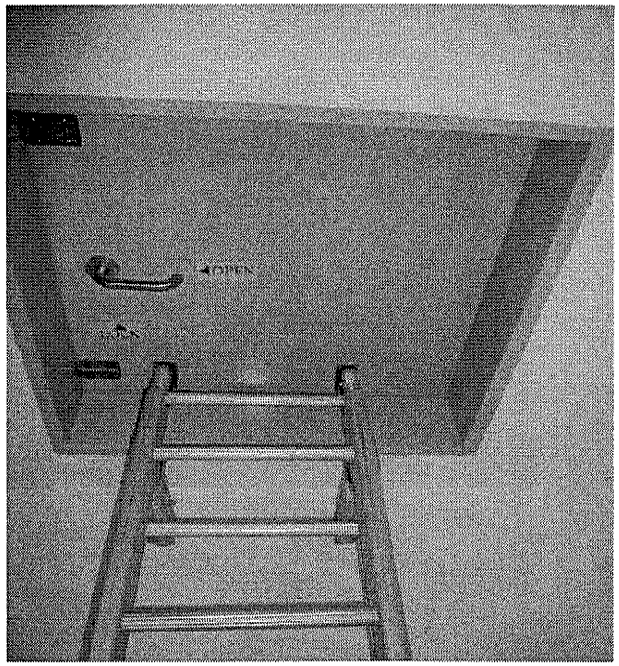


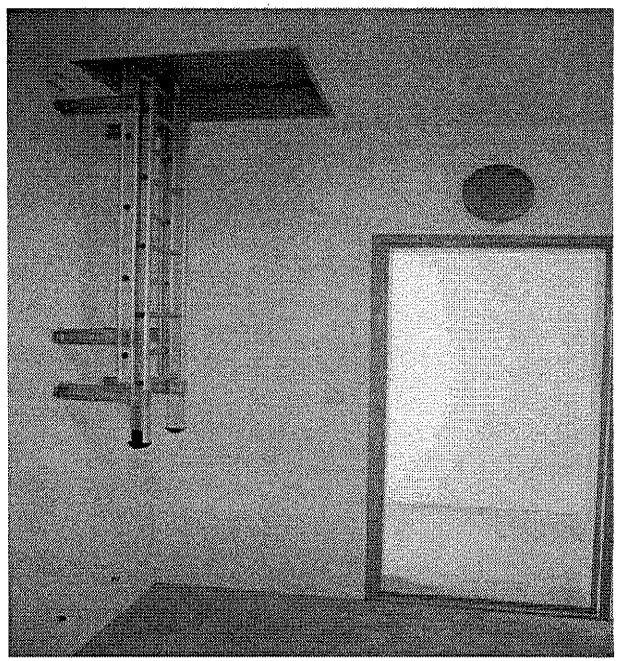
RESCUE HATCH AND CAT-LADDER







Rescue Hatch and Cat-ladder in Storey Shelter



Building and Construction Authority

CONSTRUCTION AND COMMISSIONING OF HOUSEHOLD/STOREY SHELTERS

Part I: HS/SS CONSTRUCTION

Part II: HS/SS COMMISSIONING

SHELTER INSPECTION

CD Shelter Inspection

Ensure Notice of approval (NOA) for HS/SS Structural Plan is obtained before commencing construction of CD shelters

CD Shelter Inspection

Shelter Inspection conducted at random.

Submit the construction schedule 2 weeks after NOA of Shelter Structural Plans has been issued.

BCA will conduct checks according to the construction schedule submitted.

Rectify non-compliances noted during BCA shelter inspections within 1 month after issuance of WD.

Keep a set of approved CD & CS plans at site office as required under BC Act.

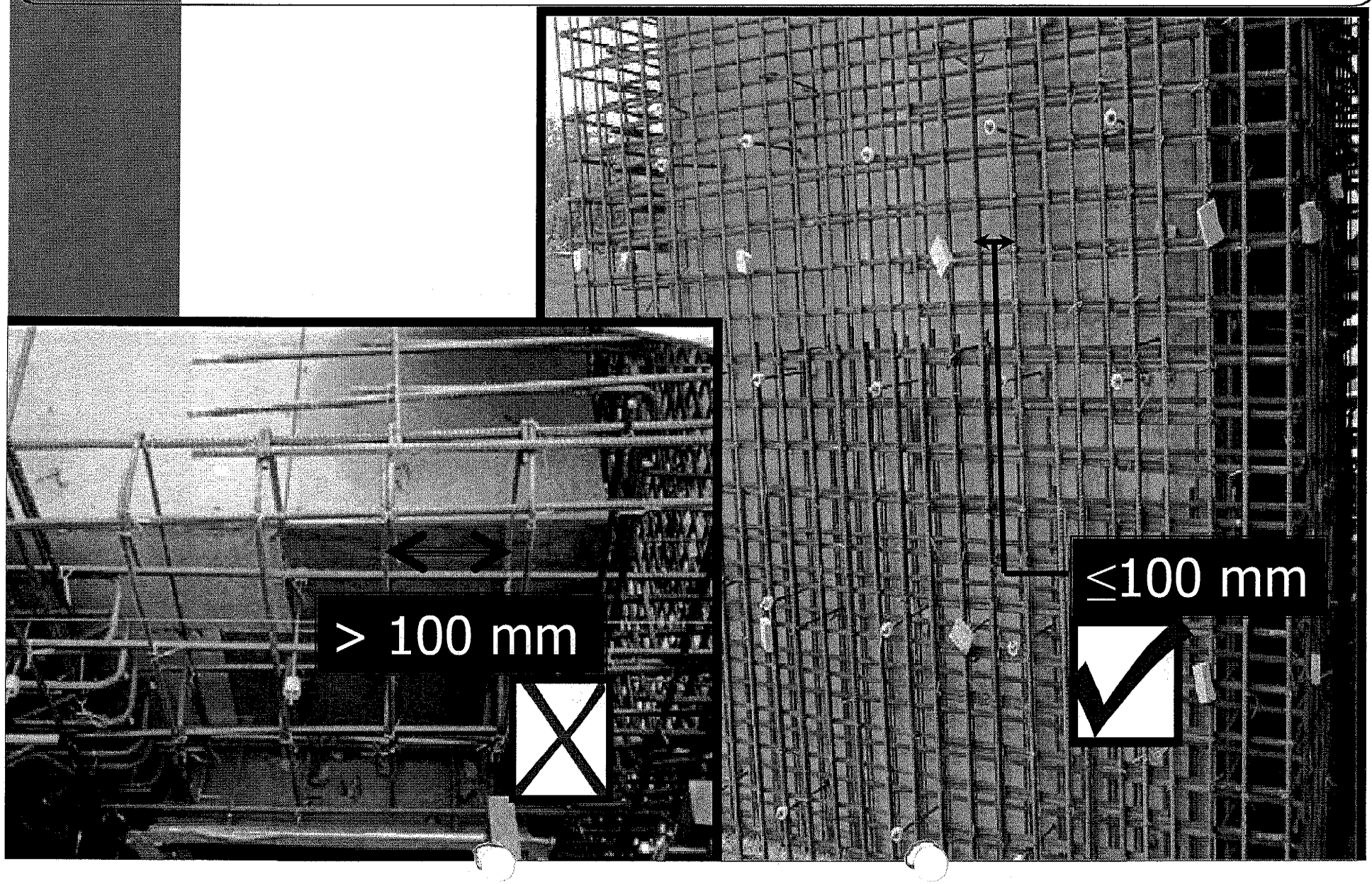
Part I:

CONSTRUCTION OF HOUSEHOLD/STOREY SHELTERS

HS/SS Walls and Slabs

- Bar Size & Spacing 100 mm
- Shear links
- Tension Anchorage / Lap Length
- Excessive concrete cover
- Form Ties
- Reinforcement near Door Frame and Kerb
- Precast HS Door Frame

Reinforcement Bar Spacing



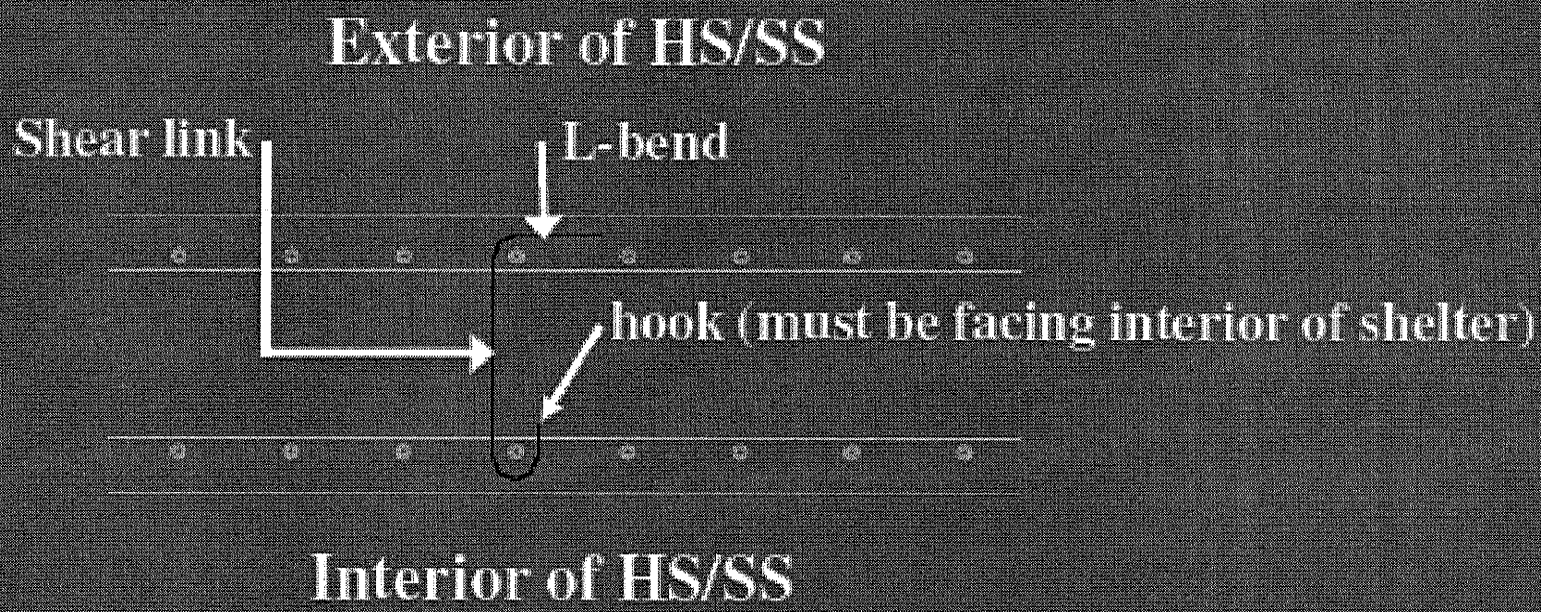
Reinforcement Bar Spacing

beams/columns in shelter walls



Reinforcement bars to be at 100mm c/c

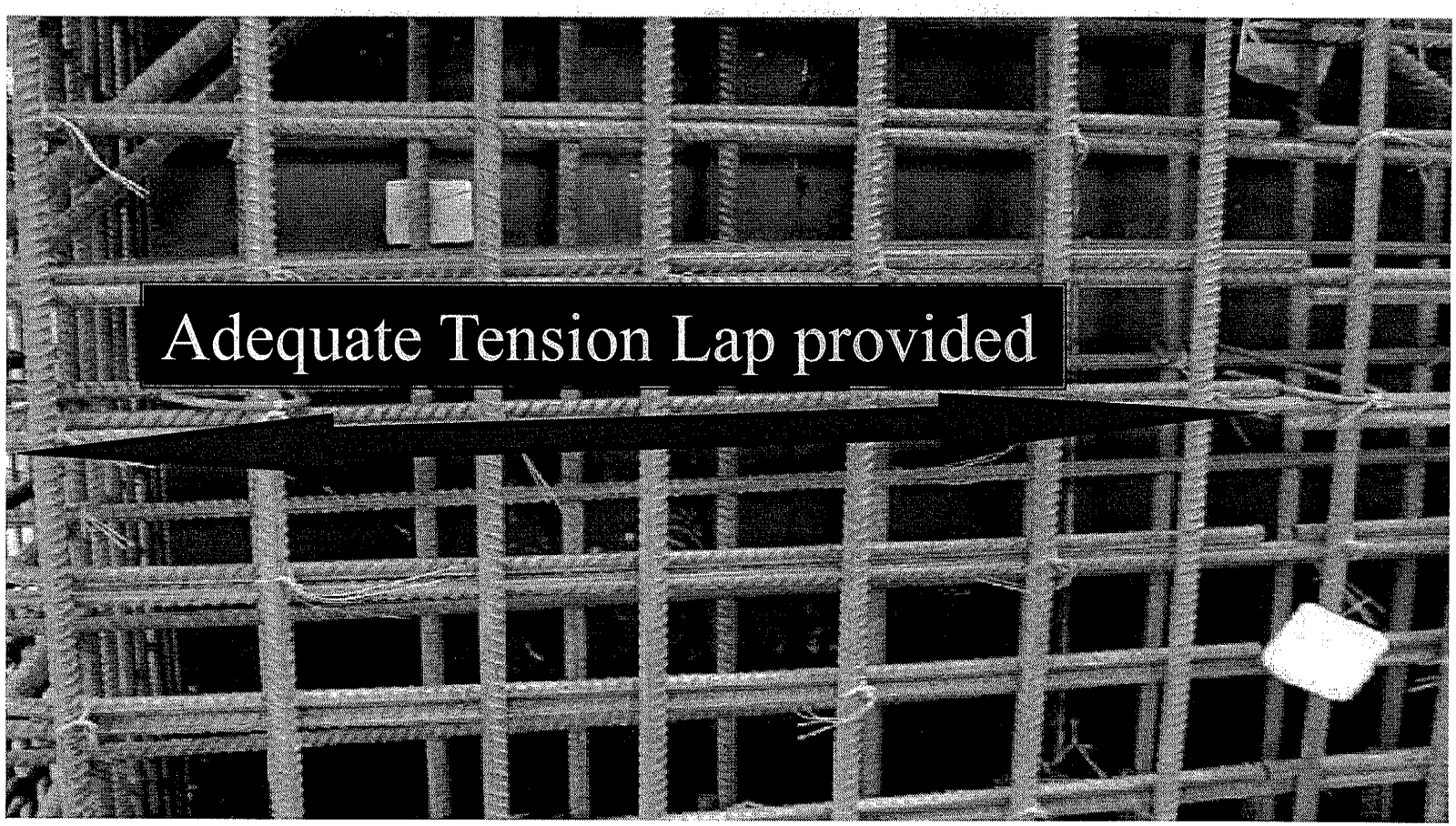
Shear Link @ Shelter Wall



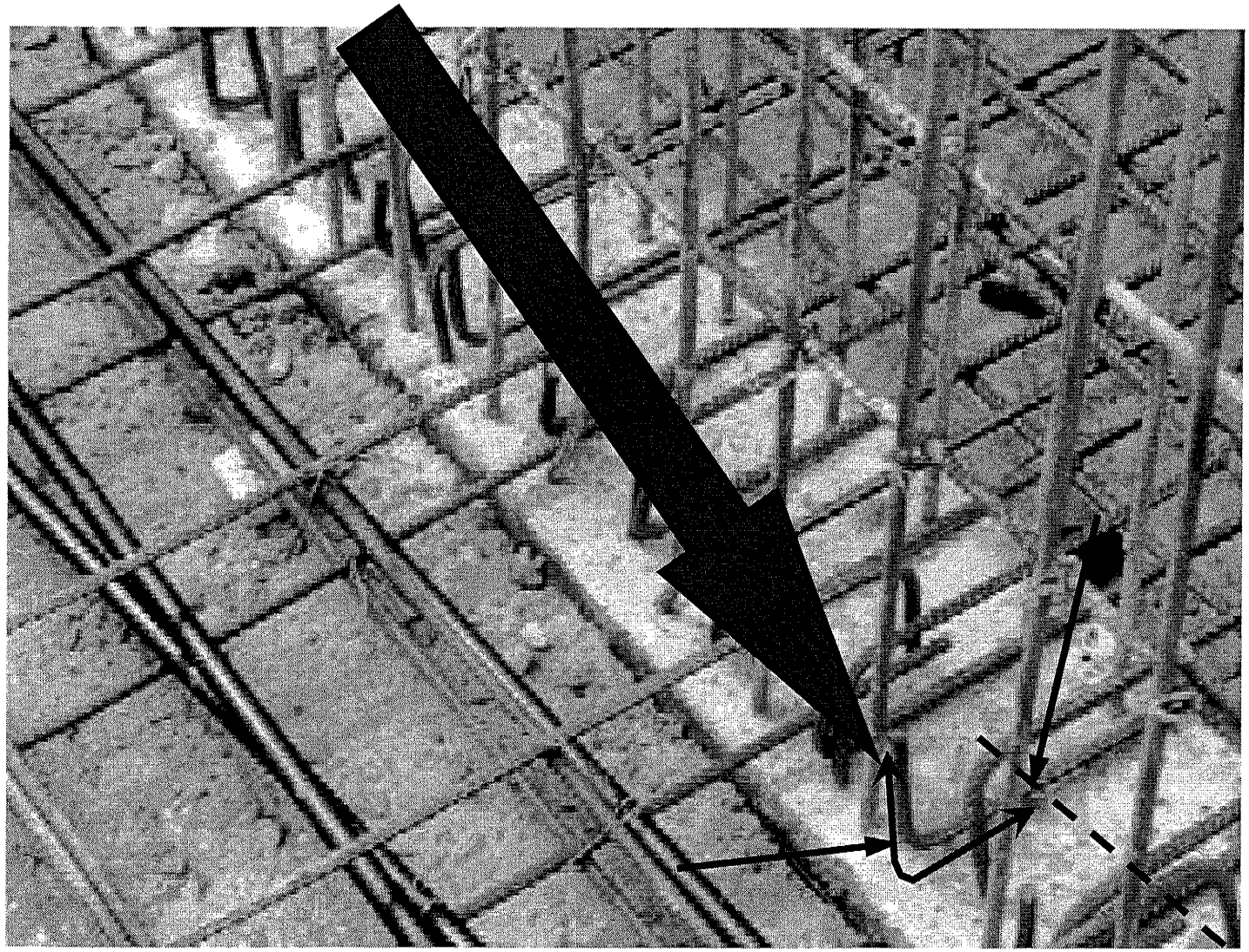
Plan showing shear link orientation

Tension Lap/Anchorage Length

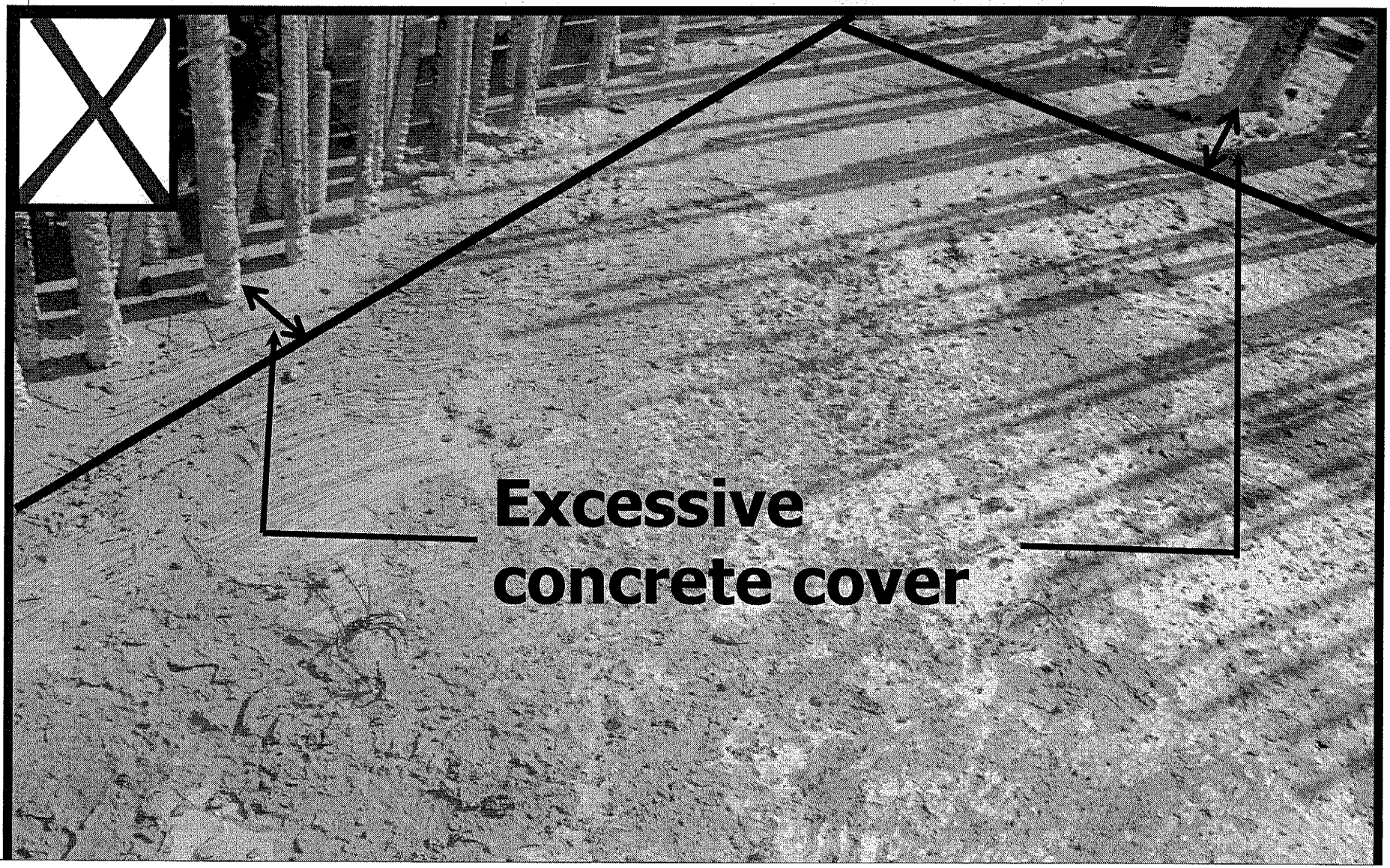
- Ensure tension lap/anchorage length provided



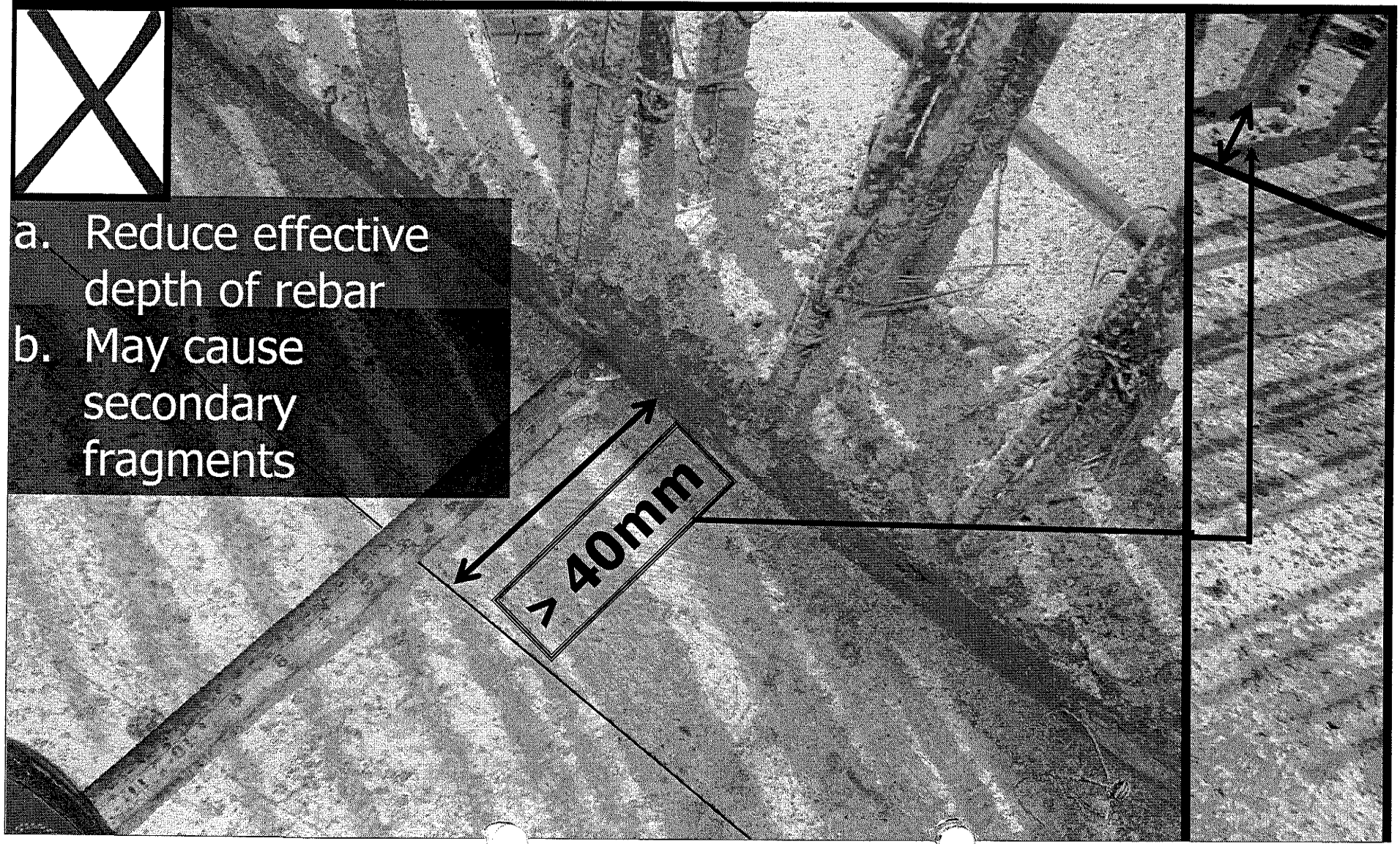
Floor Slab
Insufficient Anchorage Length



Excessive Concrete Cover - 40mm max

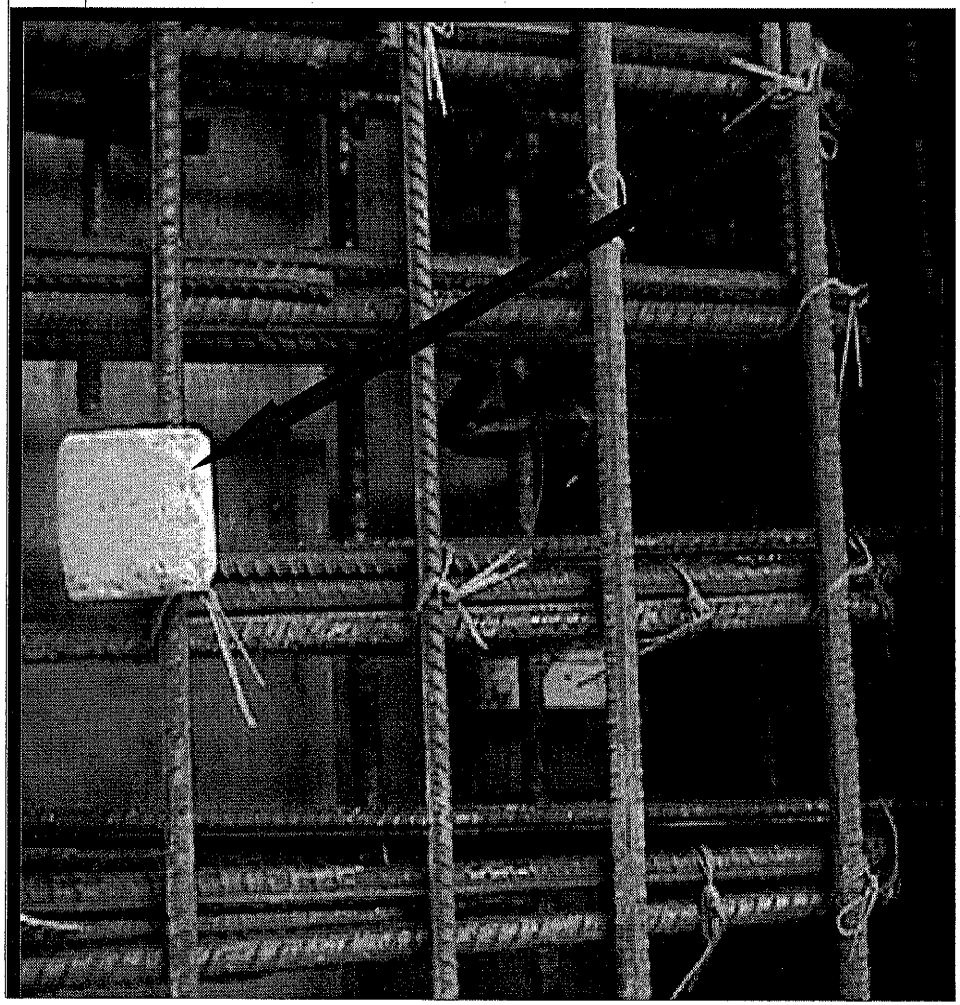


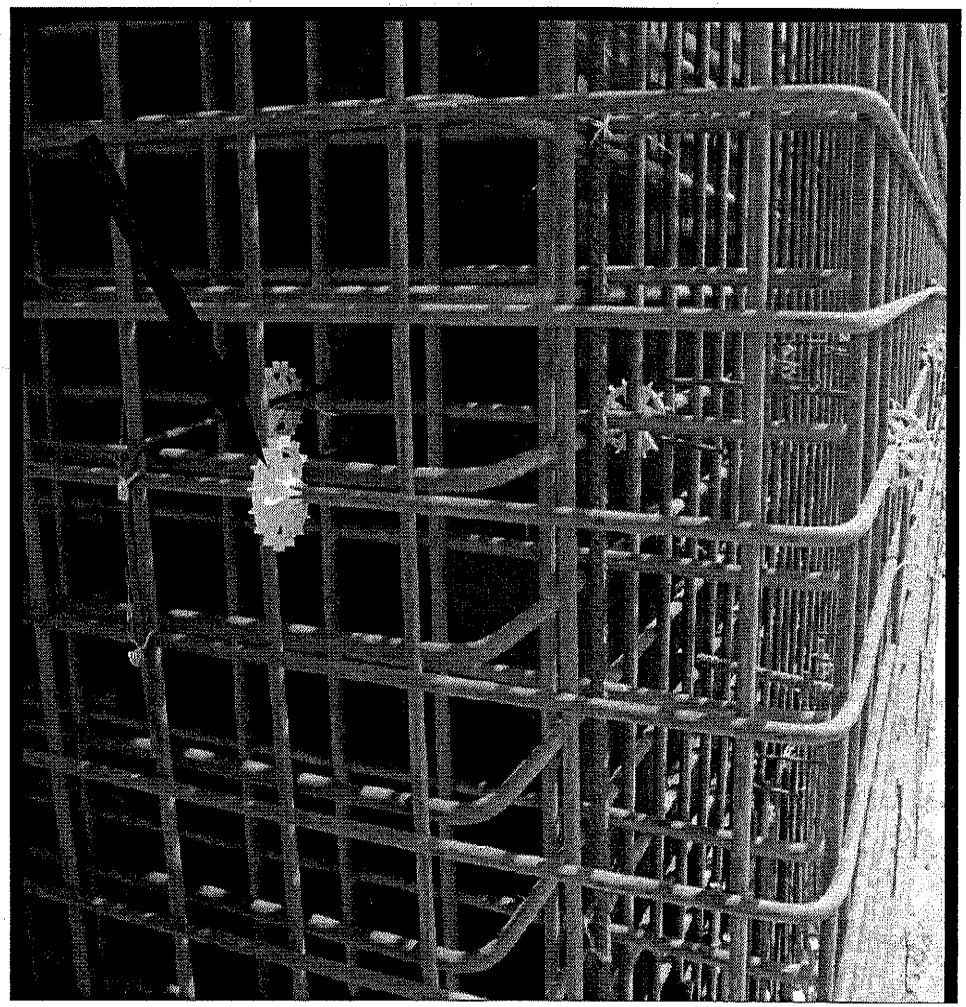
Excessive Concrete Cover
> 40mm max



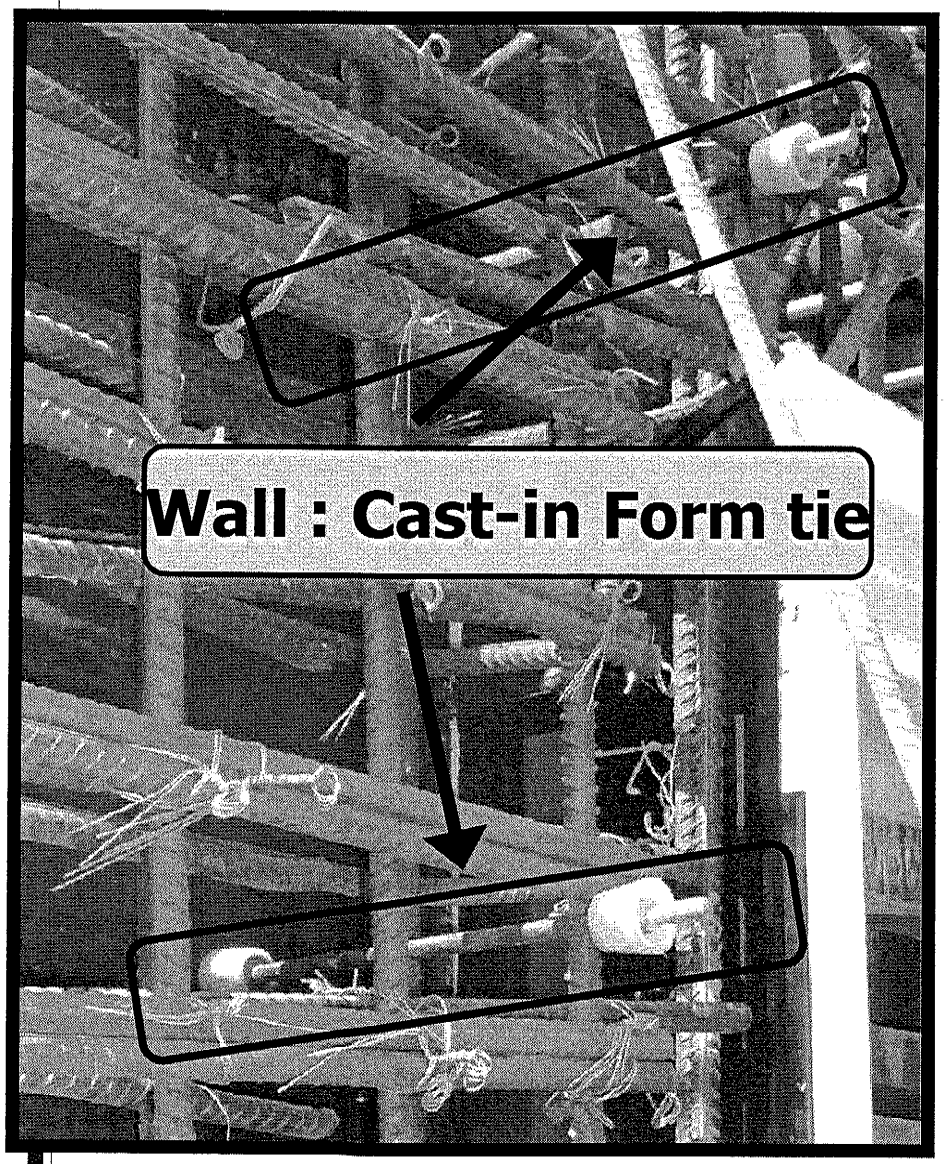
Excessive Concrete Cover

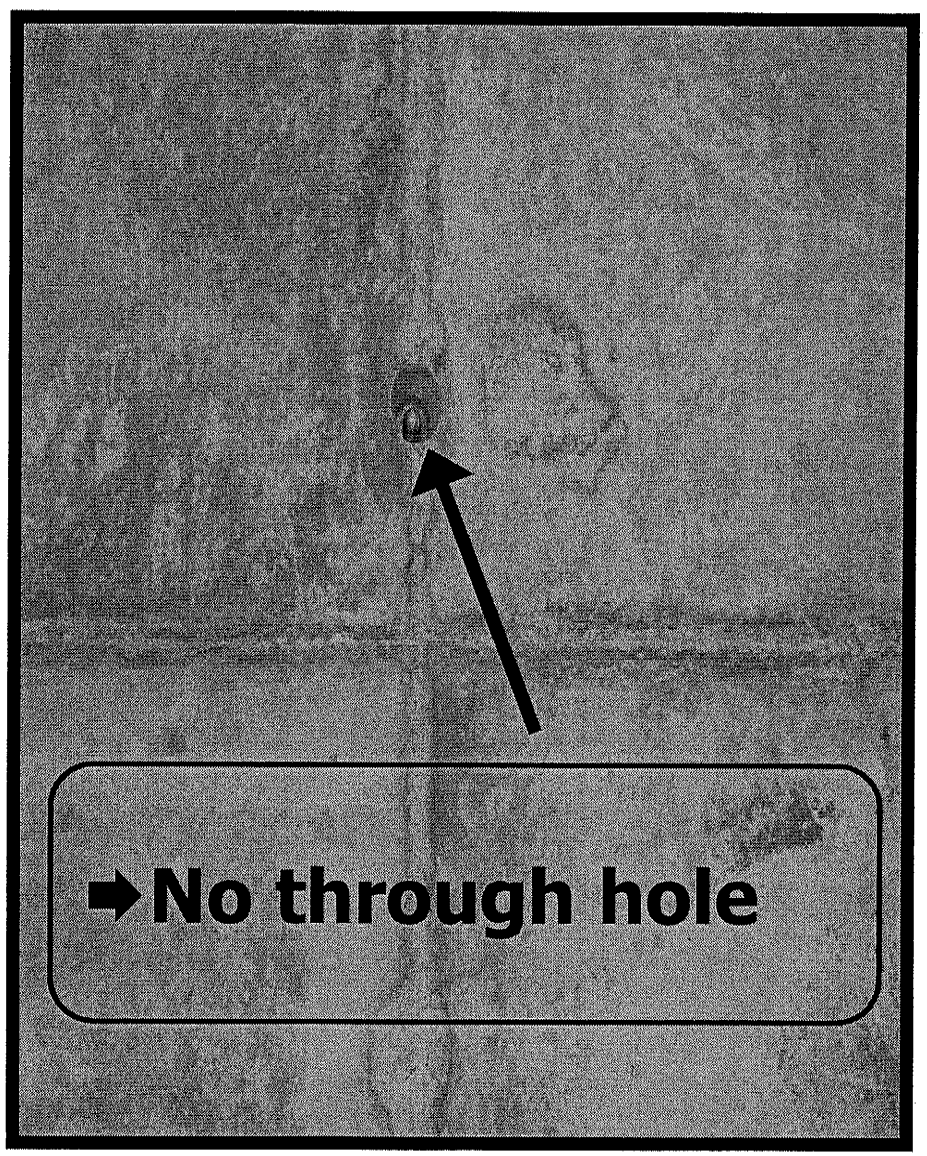
Good practice - insert spacer to maintain concrete cover
- Insert spacer bar to maintain proper spacing between the 2 layers of reinforcement





Permitted Form Ties

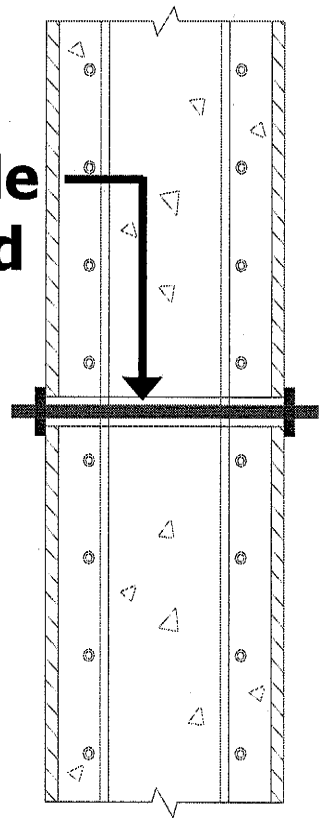


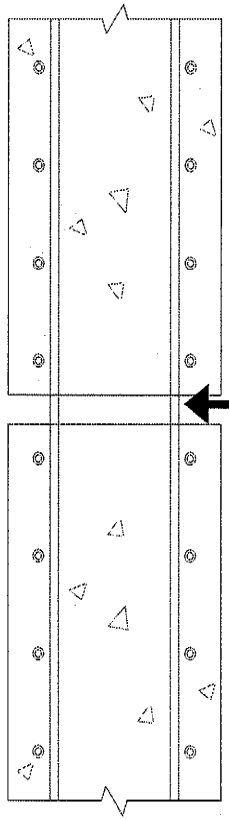


Not Permitted Form Ties

Wall : Removable form tie is not permitted

Removable rebar used in UPVC pipe to secure formwork





➡ **hole after removing form work & form tie not acceptable**

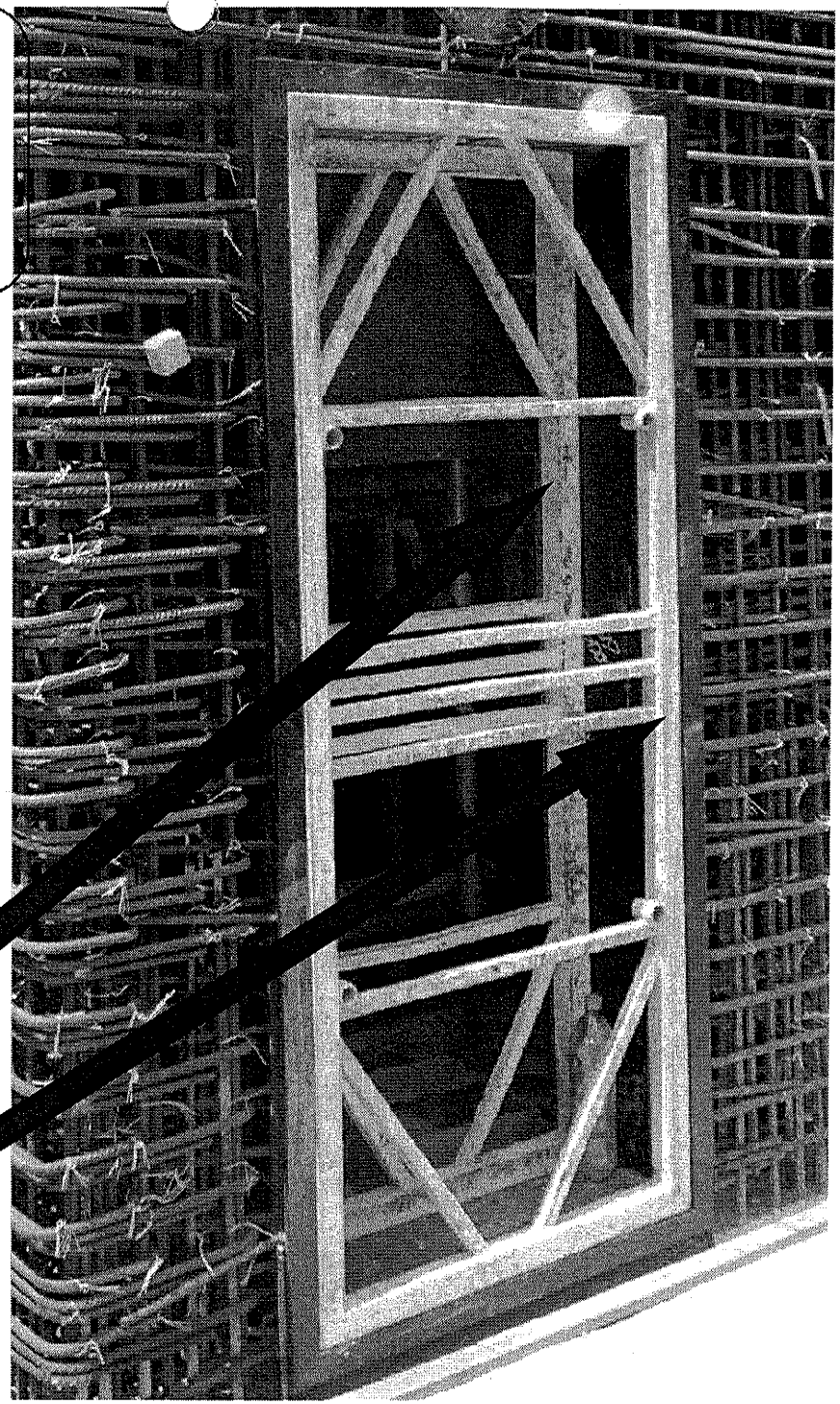
Installation of Shelter Door Frame

- Check Verticality of Door Frame
- Brace with Dummy Door Frame

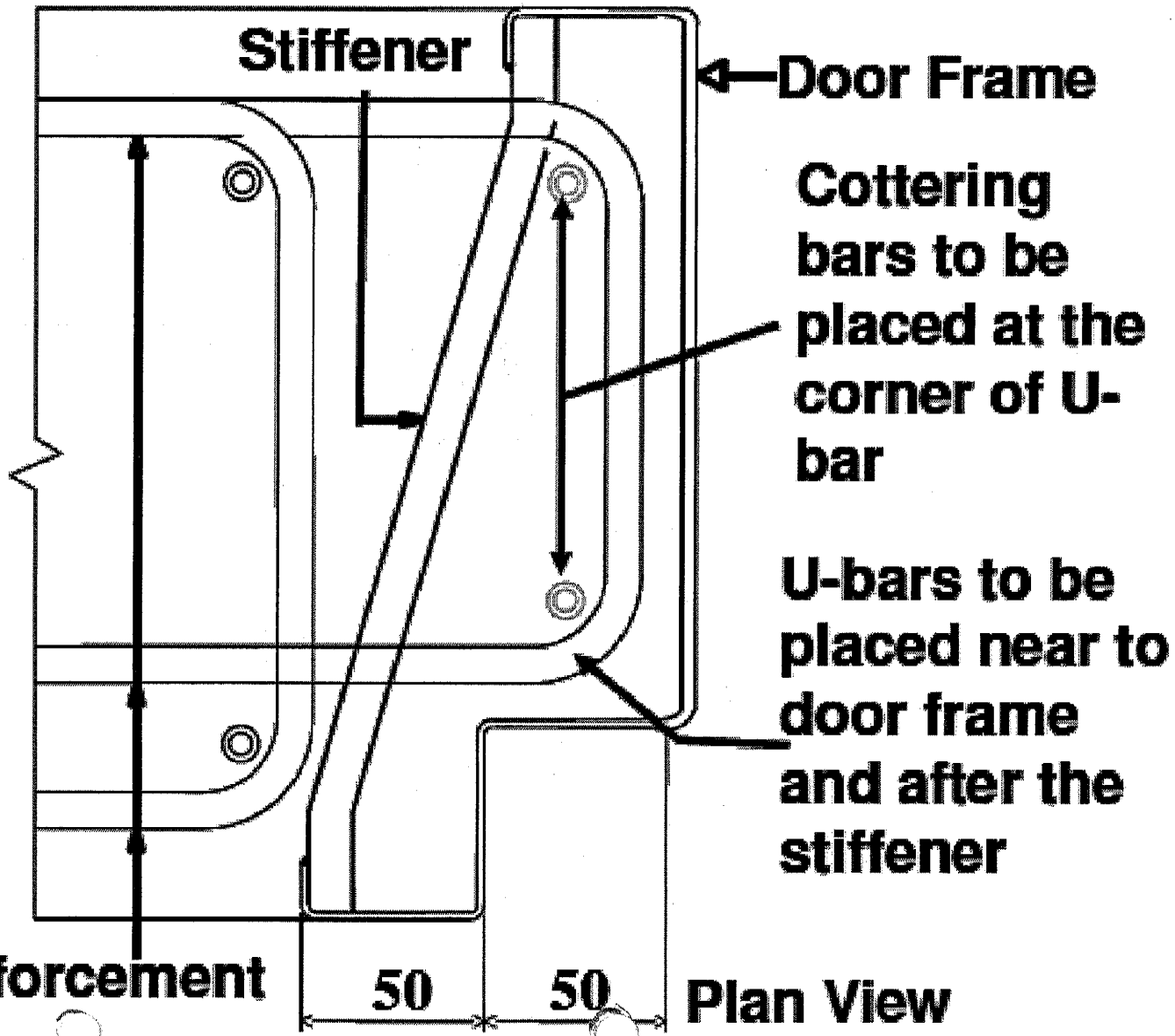
Installation of Shelter Door Frame

- **Before casting, ensure HS/SS door frame is properly braced by dummy door frame to prevent distortion during casting**

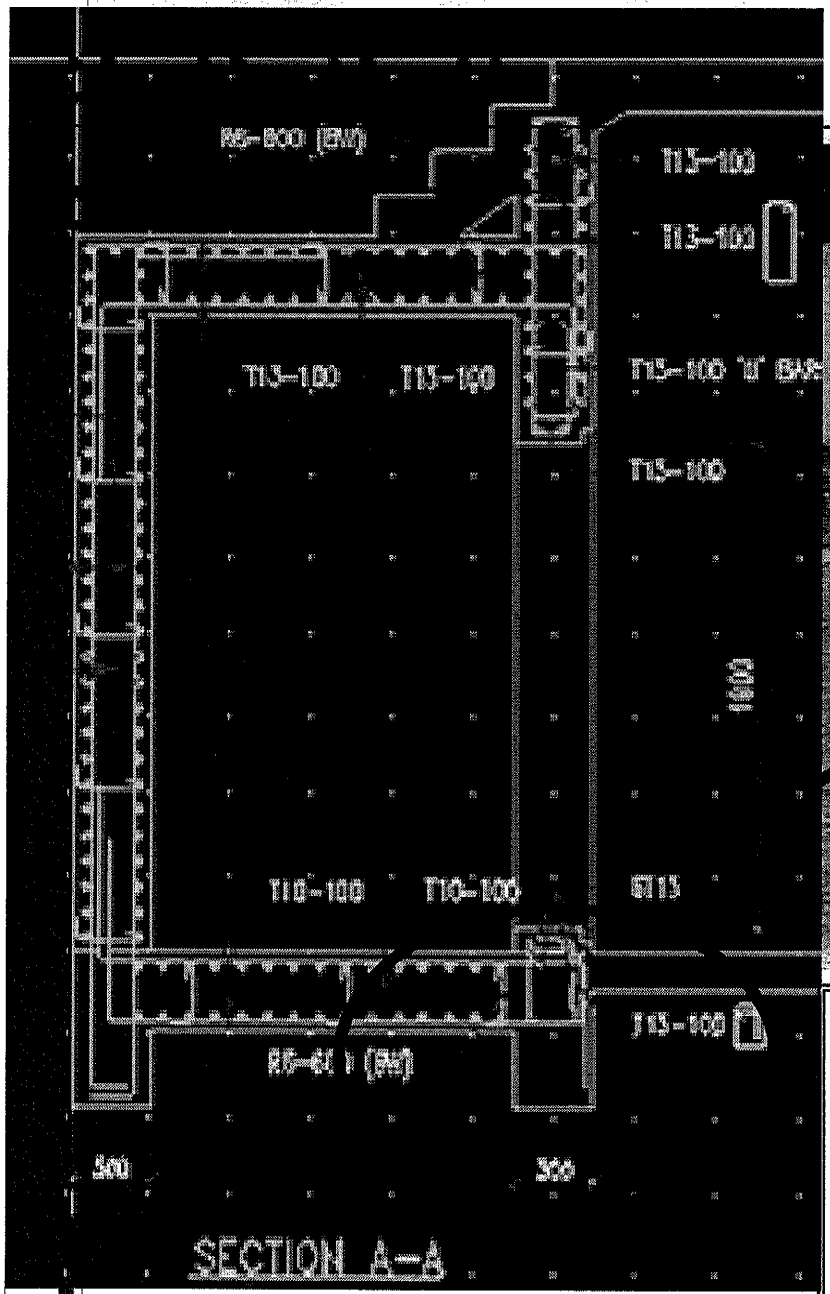
Dummy Door Frame



Reinforcement Details at Shelter Door Frame



Shelter Door kerb area

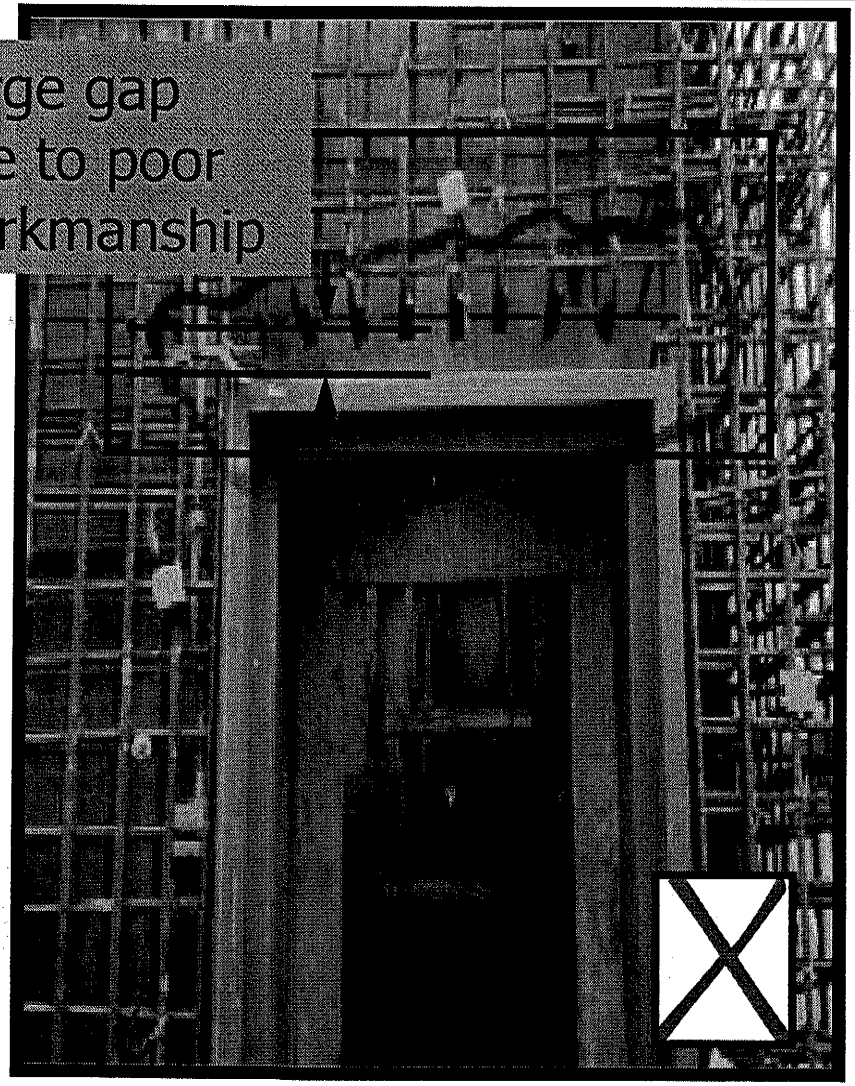


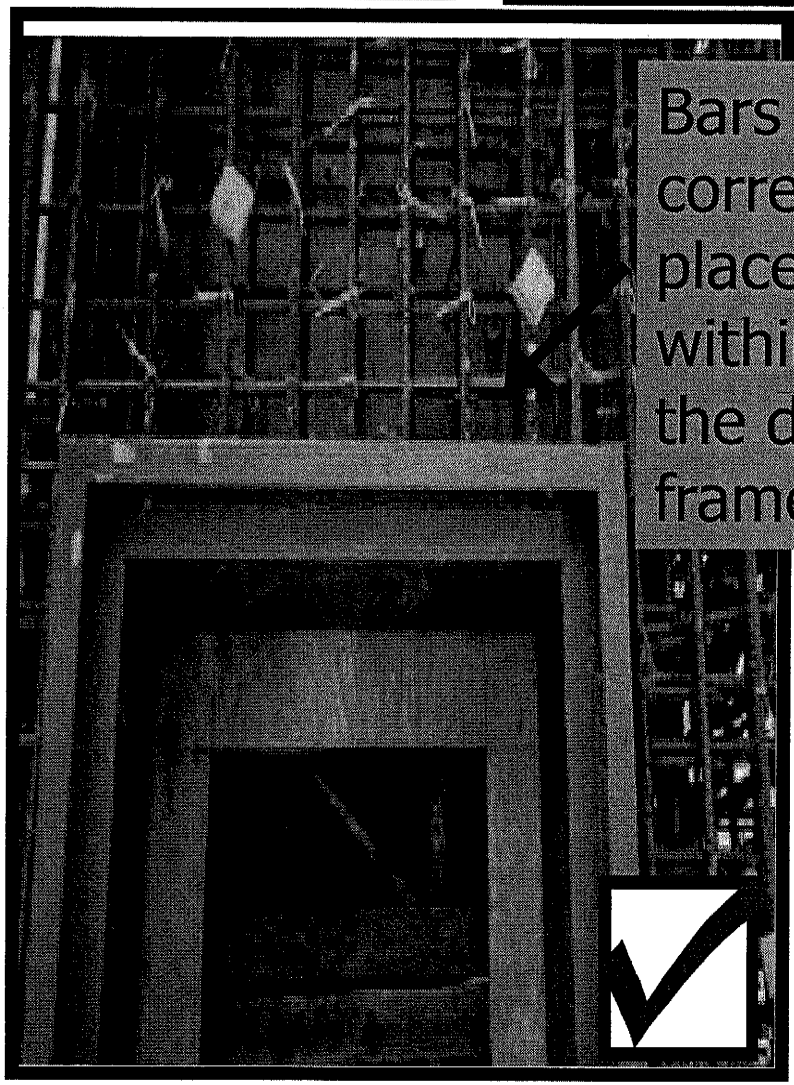


Missing cottering bars to be placed at corner of U-bars for shelter door kerb

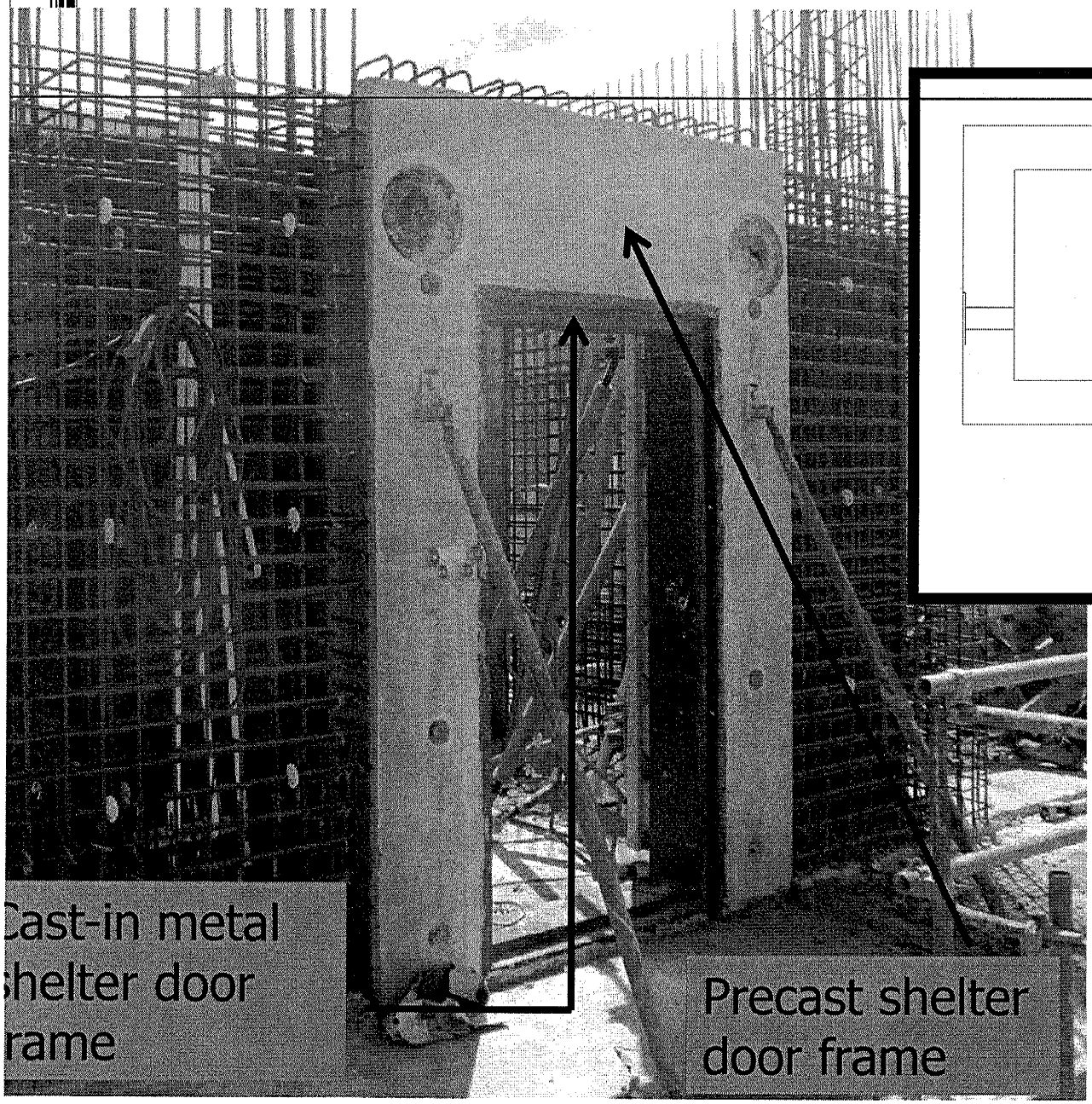
Missing Rebars Above Shelter Door Frame

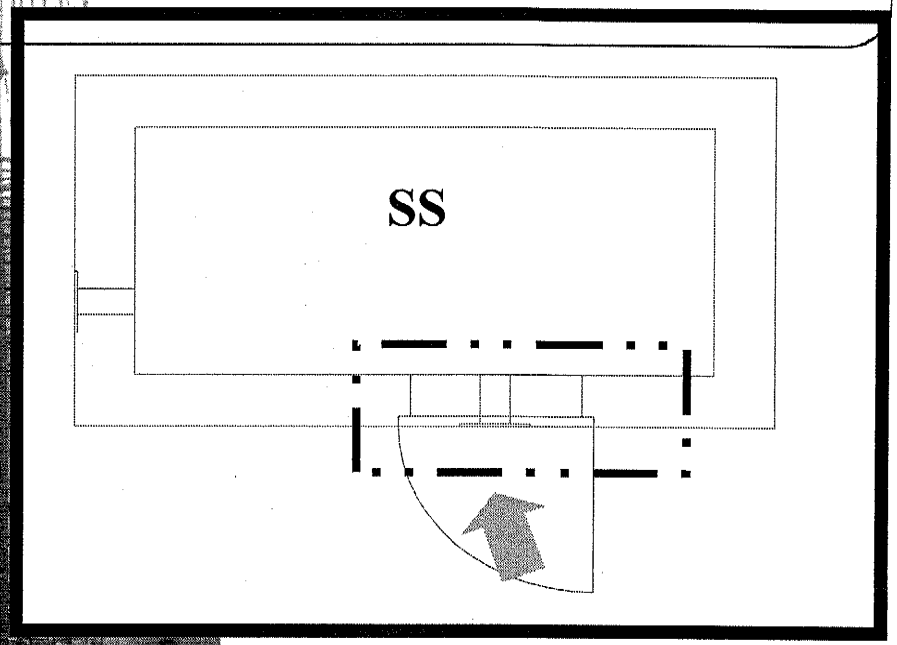
[redacted]



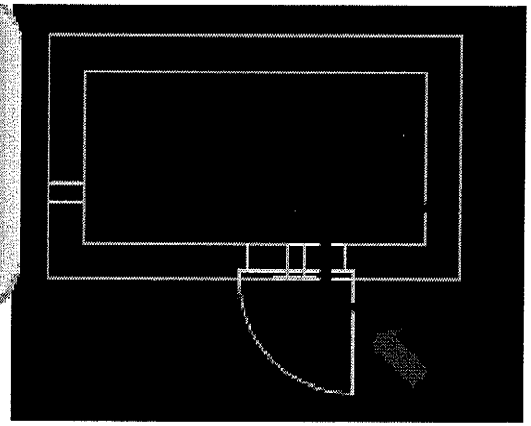


Use Precast Shelter Door Frame Panel



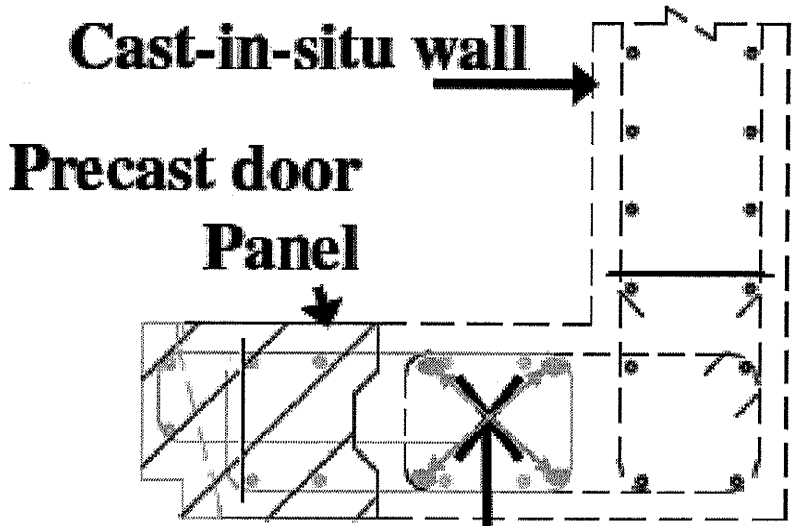


Precast Shelter Door Frame Panel

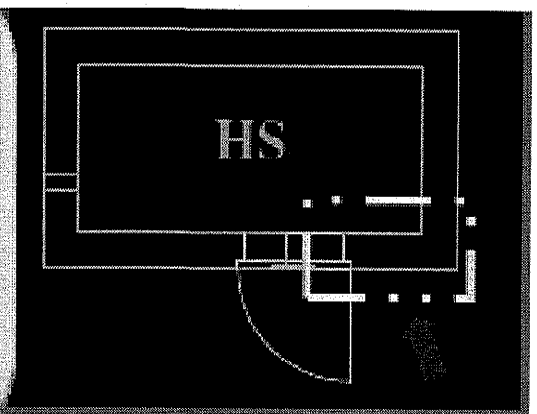


View

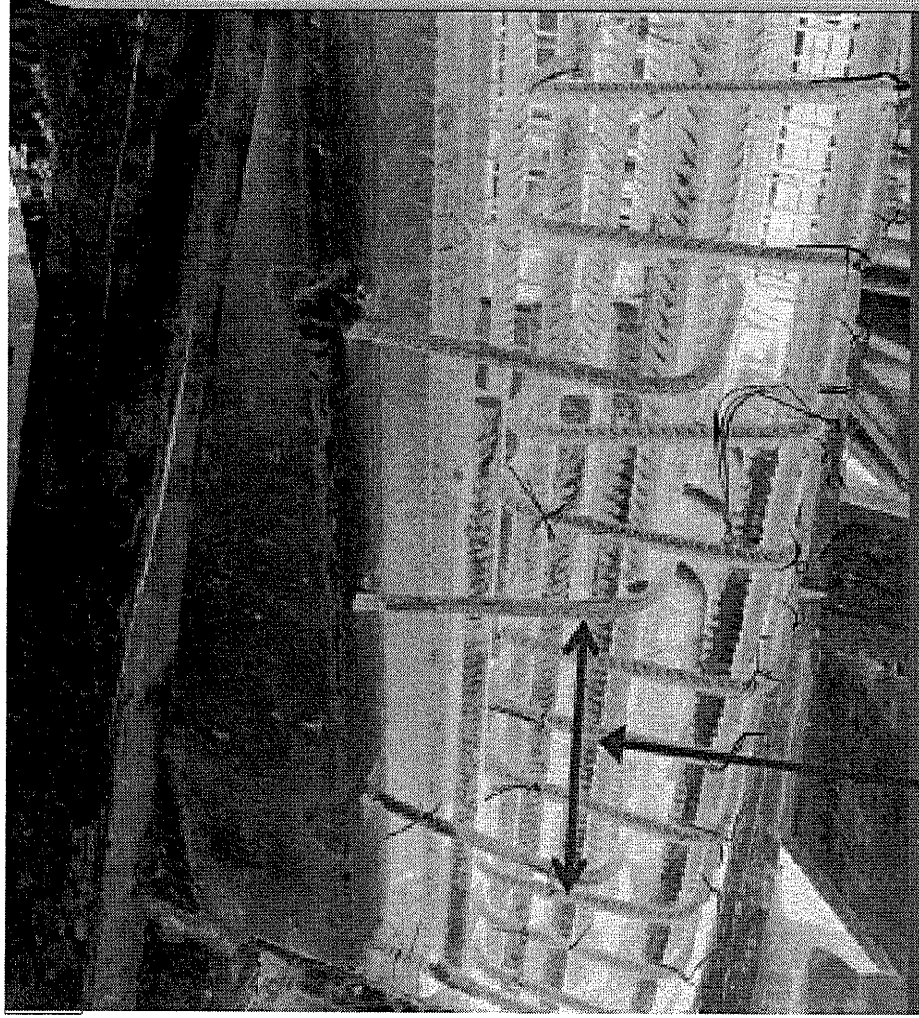


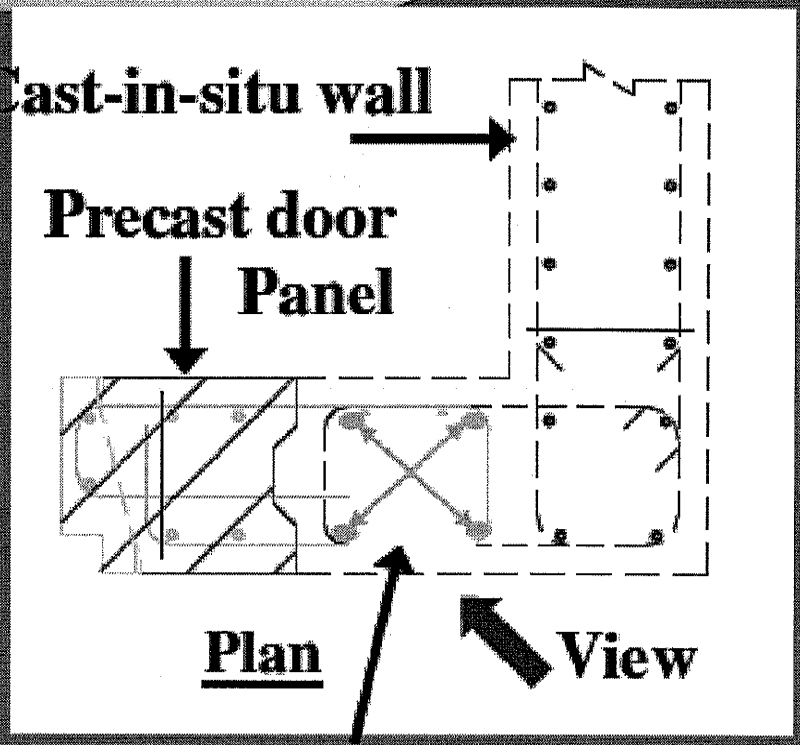


Precast Shelter Door Frame Panel – starter bars spacing incorrect



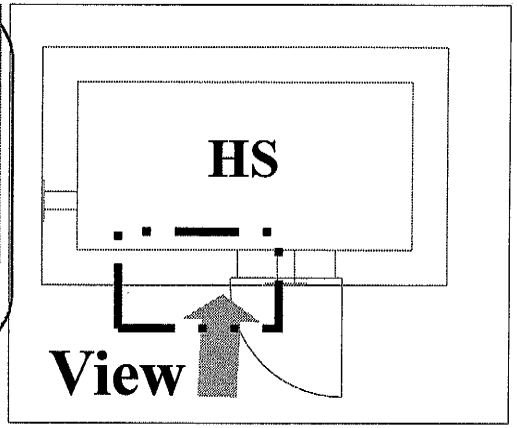
View

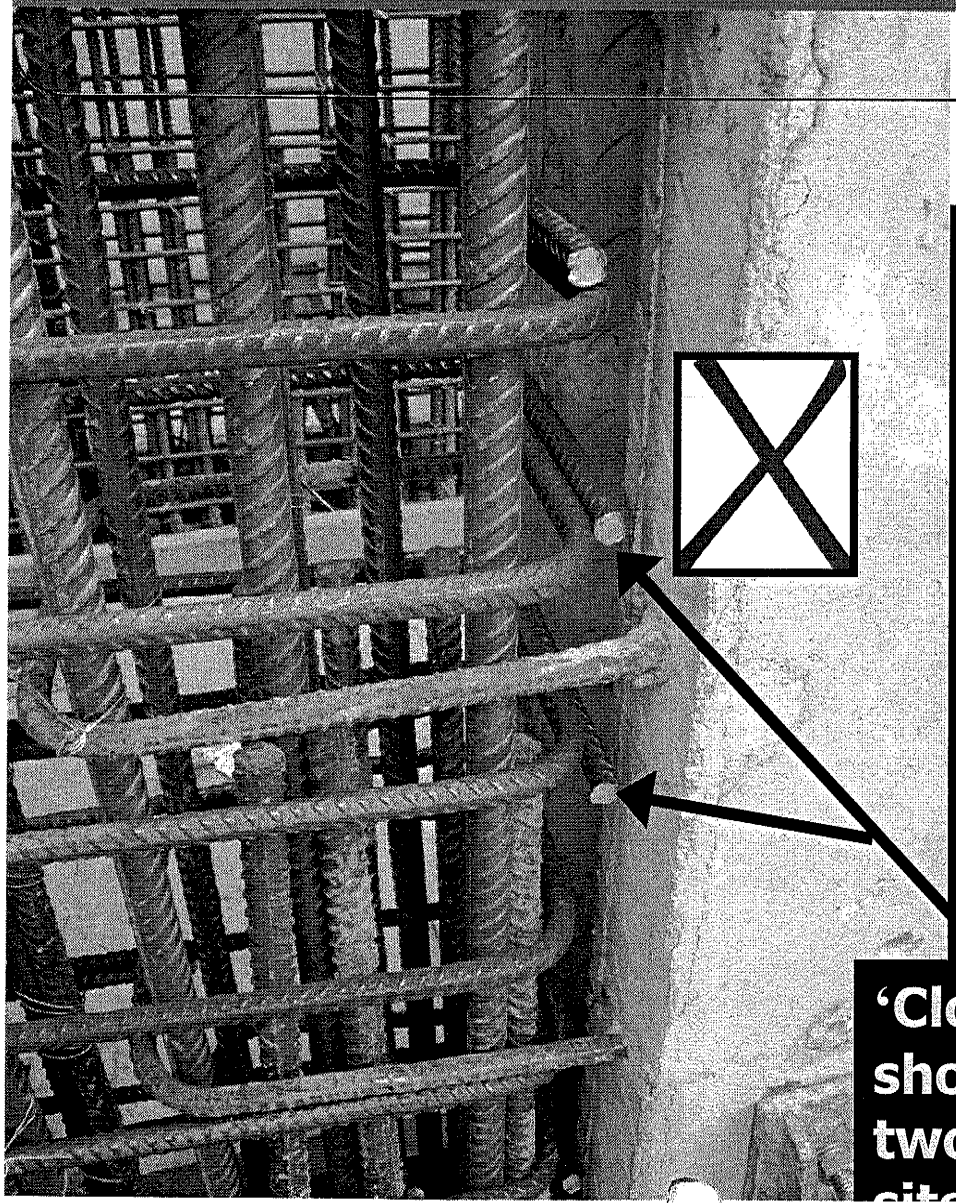


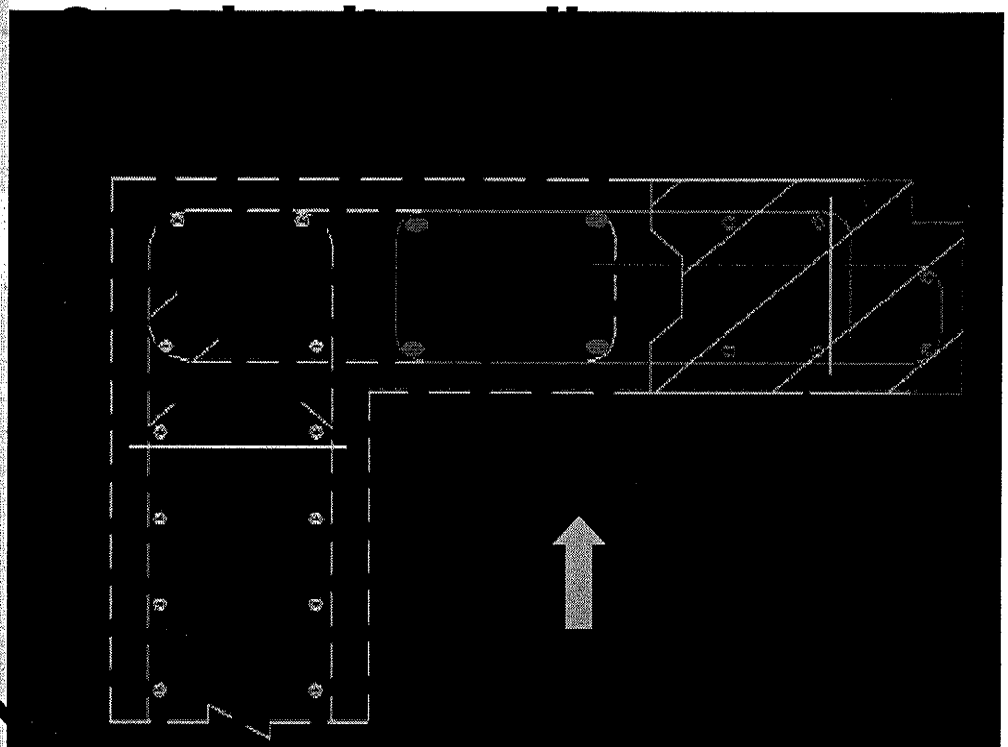


'U' loop rebars were not placed at 100mm c/c as required in approved plans

Precast Shelter Door Frame Panel







'Closed ' shape connection rebars as shown on plan should be used <u>and not</u> two 'C'- shape bars as fabricated at site

Part II:

HS/SS COMMISSIONING

Administrative requirement implemented in Aug 2011

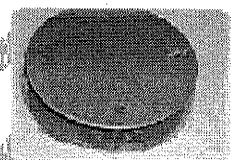
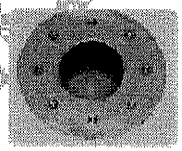
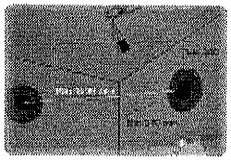
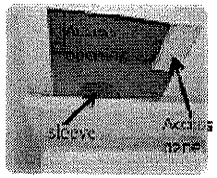
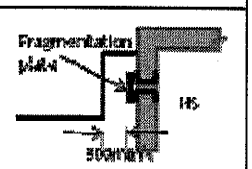
- **New practice**

  QPs are advised to fill up commissioning checklist and send in photos of HS/SS when submitting application for project HS/SS commissioning

Checklist

- Serve as a guide for site inspection by builder, site supervisor and/or QPs
- Assist developer and QP in getting shelter commissioning approval at first inspection

Sample checklist for Commissioning of Household Shelter

S/No	Items	Sample photos
A 1	**Readiness condition of HS** Fully comply with approved plan and technical requirements of HS (e.g. setback distance, services, door, ventilation sleeves, no plastering on the internal wall, etc).	
B 1	**Ventilation Sleeves** Both external and internal face of ventilation sleeve shall be cleared and free of cement grout and painting.	
2	Screw threaded holes on the internal flange of ventilation sleeve shall be cleared and free of cement grout.	
3	Ventilation sleeve shall be positioned such that the centre of the sleeves shall be: a) at least 300 mm from any wall and ceiling slab. b) at least 1900 mm above finished floor level. c) at least 1000 mm apart.	
4	Fragmentation plate of the ventilation sleeve on outside HS wall must be able to close and open without obstruction.	
5	For ventilation above false ceiling, access opening and panel of 600 mm X 600 mm shall be provided.	
6	False ceiling fronting the ventilation sleeves shall be at clear distance of at least 300 mm away from the fragmentation plate in open position.	

Version: 1.1 –Aug 2011

COPY

Checklist

- ❑ QP to fill up and endorse the checklist
- ❑ Submit checklist with attached photos at least 3 days before appointment date

Checklist for submission with application for commissioning of Household Shelter (HS)

Project Reference: _____

Project Address: _____

S/No	✓		Items
A		**General view of HS**	Overall view of HS unit
1	☐	Fully comply with approved plan and technical requirements of HS (eg setback distance, services, door, ventilation sleeves, no plastering on the internal wall, etc).	
B		**Ventilation Sleeves**	External view of Ventilation sleeve
1	☐	Both external and internal face of ventilation sleeve shall be cleared and free of cement grout and painting.	
2	☐	Screw threaded holes on the internal flange of ventilation sleeve shall be cleared and free of cement grout.	
3	☐	Ventilation sleeve shall be positioned such that the centre of the sleeves shall be: a) at least 300 mm from any wall and ceiling slab. b) at least 1900 mm above finished floor level. c) at least 1000 mm apart.	Internal view of Ventilation sleeve
4	☐	Fragmentation plate of the ventilation sleeve on outside HS wall must be able to close and open without obstruction.	
5	☐	For ventilation above false ceiling, access opening and panel of 600 mm X 600 mm shall be provided.	
C		**Door / Door frame**	View of HS door in open mode
1	☐	PSB label and HS door notice shall be pasted on the door.	
2	☐	HS door and door frame shall be completed with final painting.	
	☐	HS door shall be able to close and lock in CD mode as shown in the door notice.	
	☐	External floor finish shall be clear from the bottom edge of the HS door.	
3	☐	Alignment of door pins and pin holes on the HS door frame shall not exceed 3mm.	
4	☐	The 5mm gap between the HS door and door frame shall not be less than 2mm or more than 8mm.	
5	☐	Rubber gasket shall be fully secured into the recess along the side of the door panel.	
D		**Services**	View of socket showing cable sealed with sealant
1	☐	Socket outlet/fixtures for Telephone, SCV and Power point (2nos or twin) shall be installed.	
2	☐	Both open end of each conduit shall be sealed with sealant to a depth of 100mm.	
E		**Commissioning testing (Trial)**	
1	☐	Trial testing is carried out by a competent site representative to all HS units.	

I, _____ (QP) certify that the above have been checked by _____ (a competent technical representative) that the HS shelters are built of good quality and are ready for commissioning.

_____

(Signature of QP)

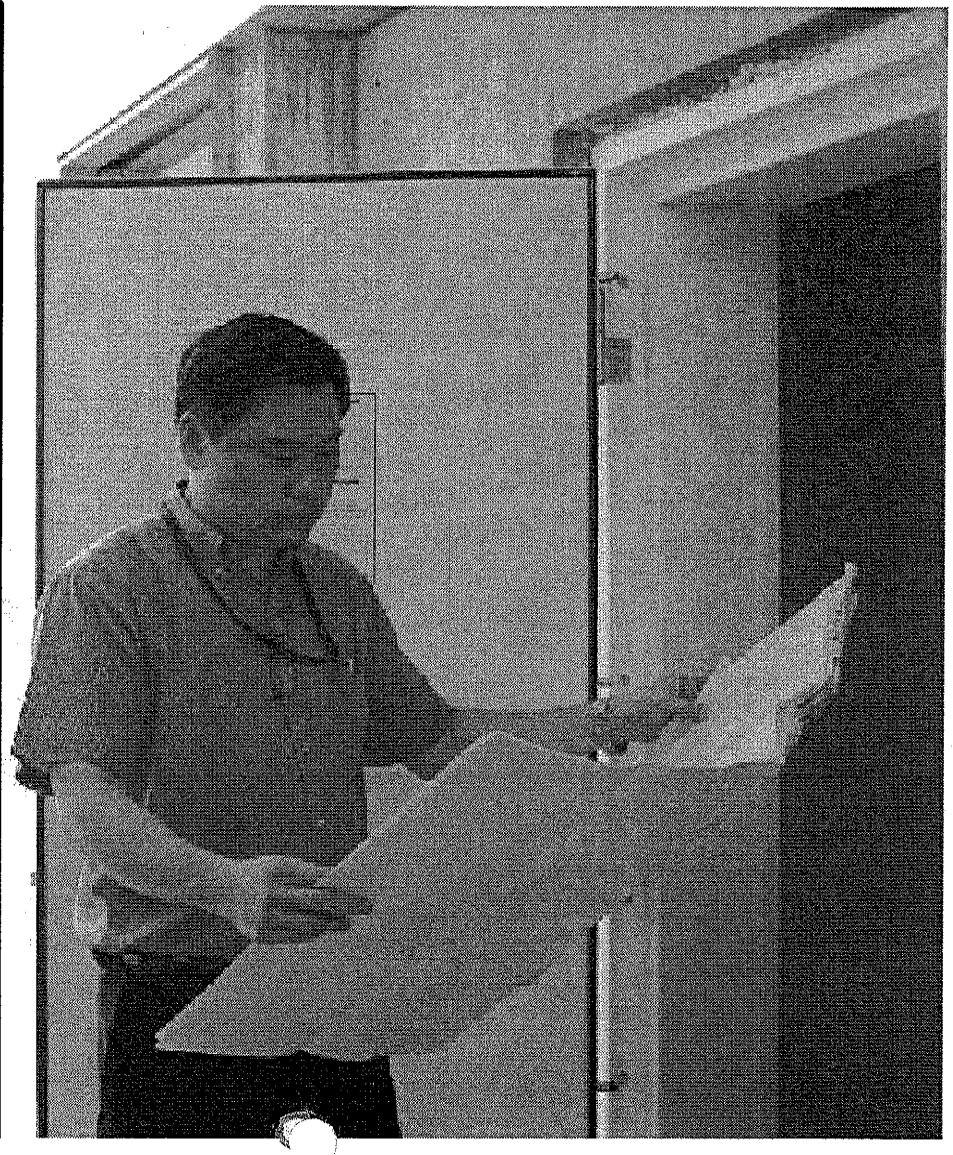
Ver:1.1-Aug2011

A) GENERAL INSPECTION OF HS/SS

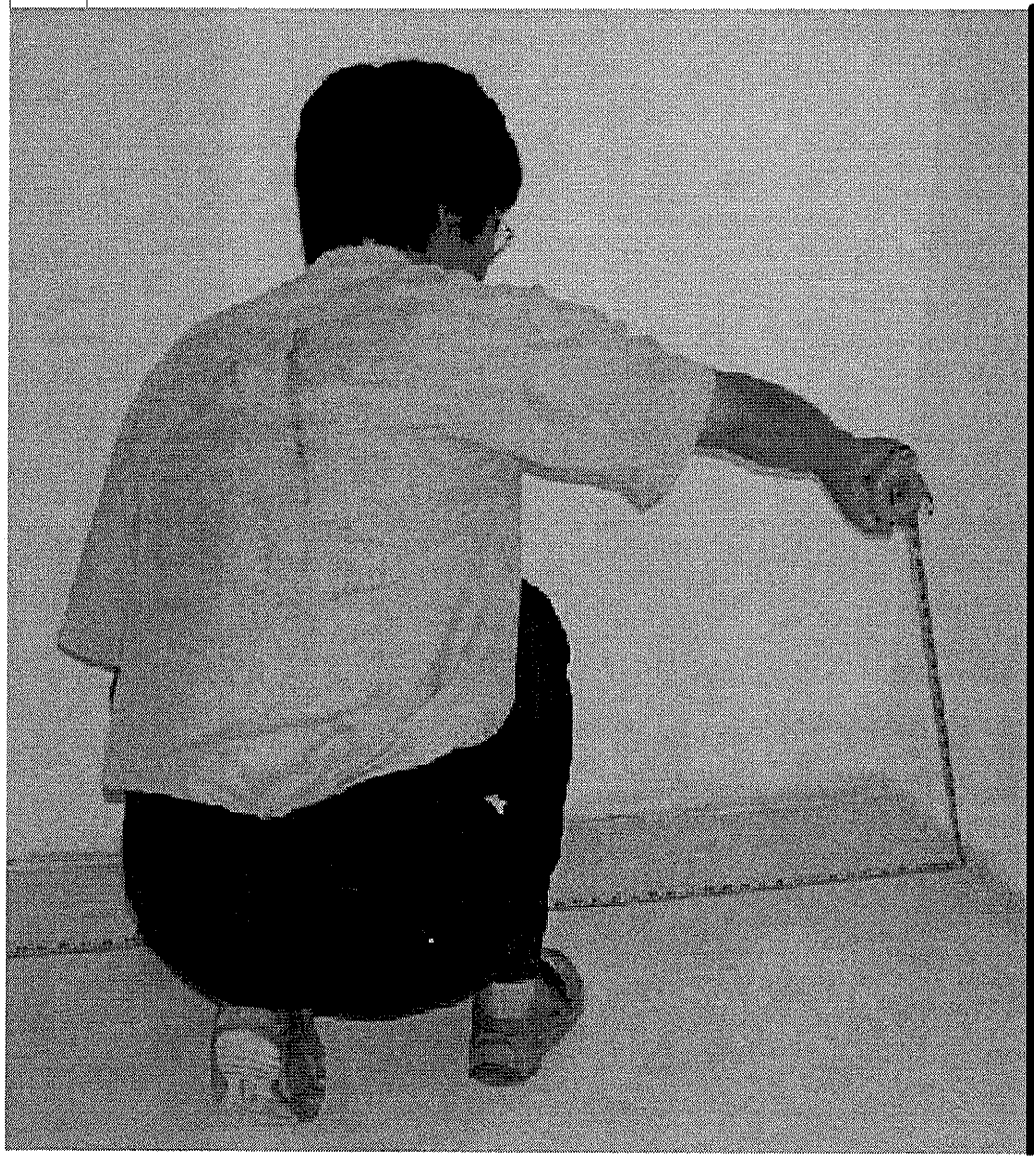
General Inspection of HS

Architectural Plans (Building works)

- Setback distance
- Provision of down-hang beam/trellis
- Plastering on internal HS/SS Wall (if any)



General Inspection of HS



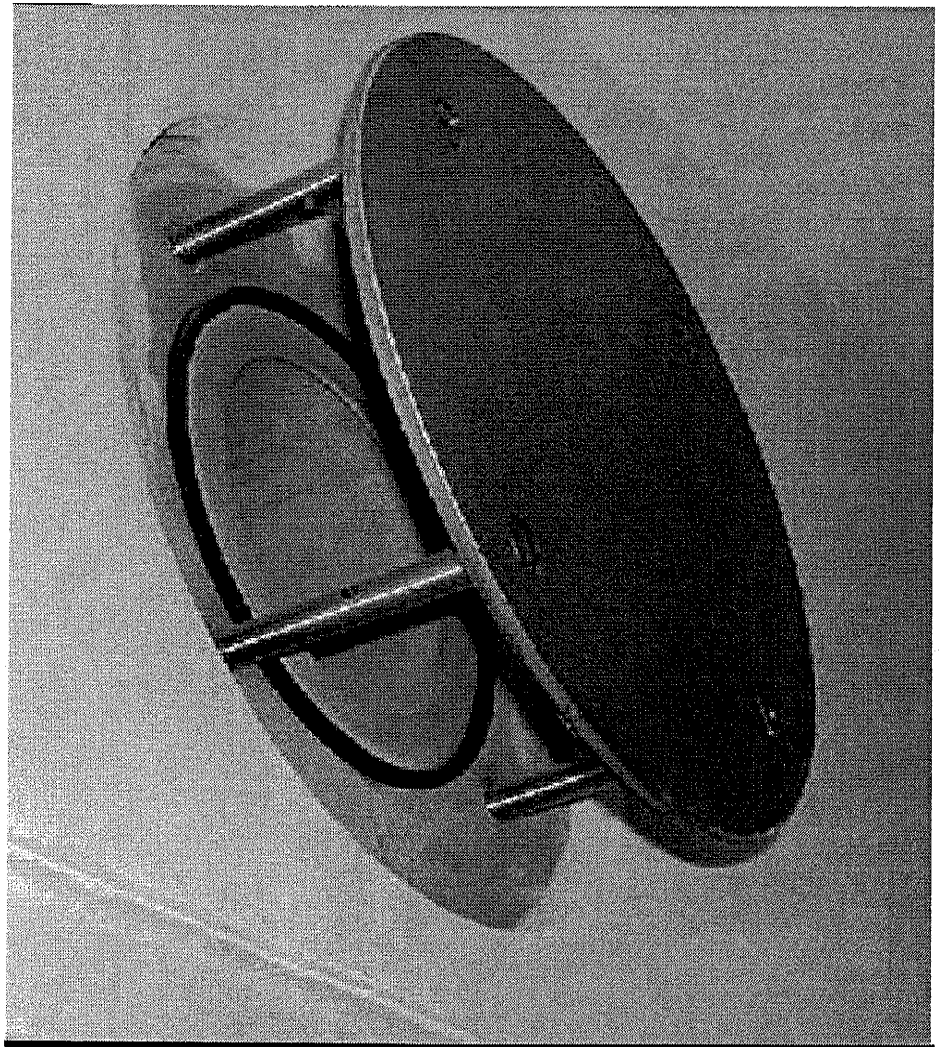
Architectural Plans (Building works)

- HS/SS internal Dimension
- HS/SS Clear Height

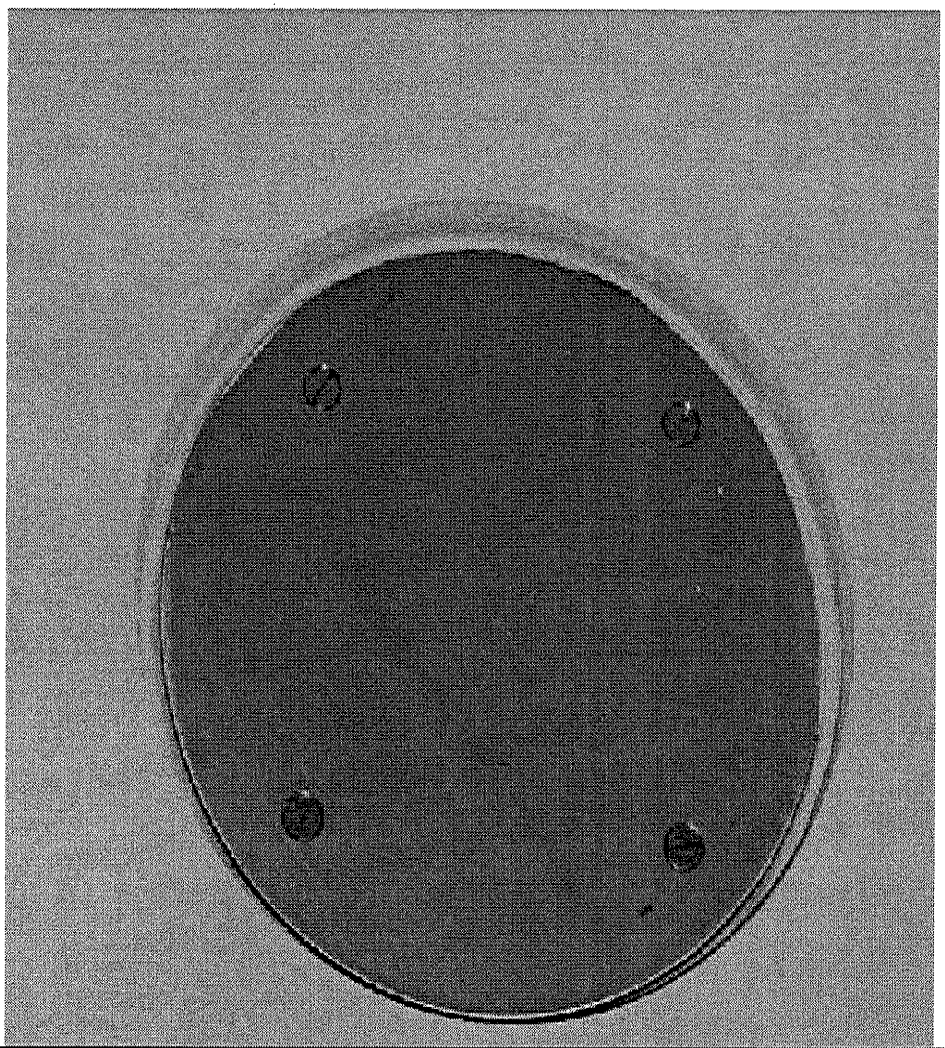
B) VENTILATION SLEEVES

Ventilation Sleeves (VS)

- Able to set-up in closed and open mode without obstruction
- General Inspection of VS - satisfy the various clearances
- Must be accessible

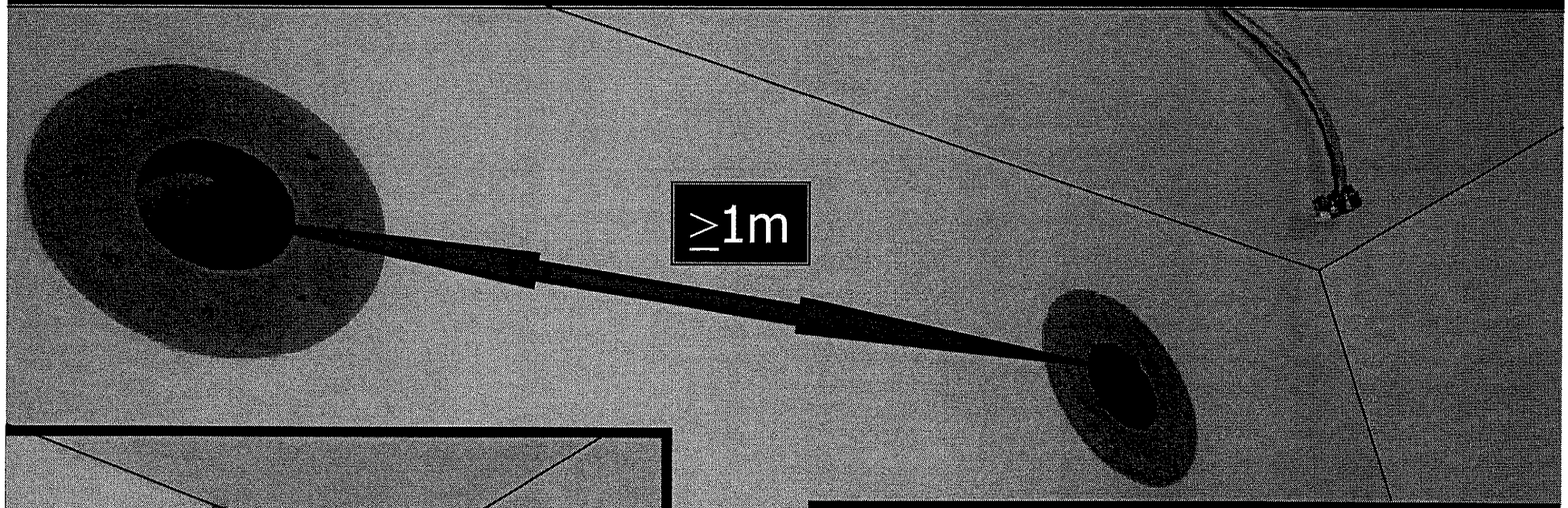


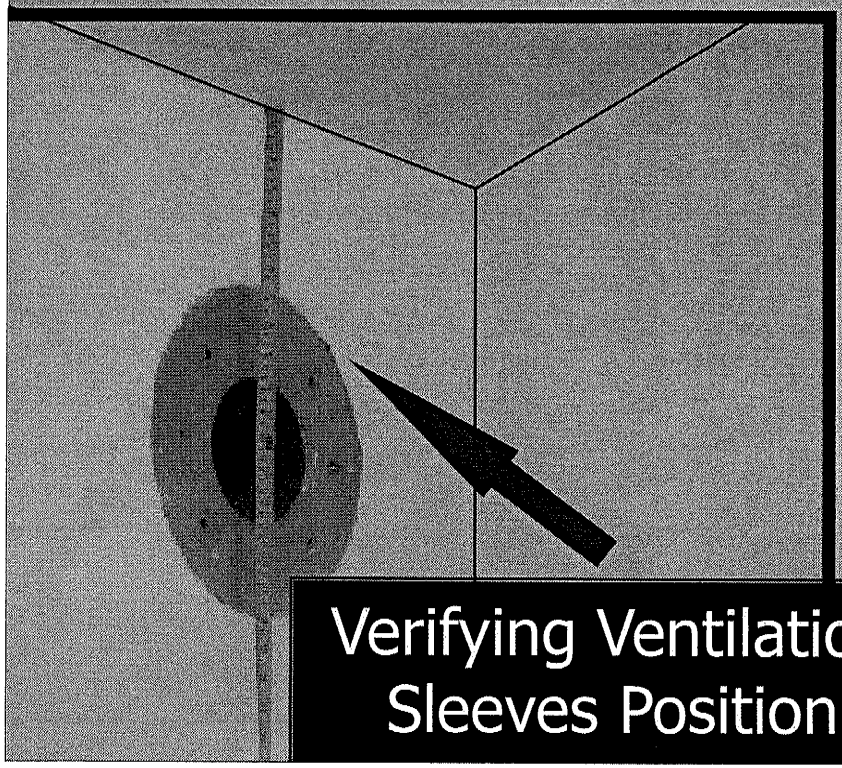
Ventilation Sleeve in Open Mode



Ventilation Sleeve in Closed Mode

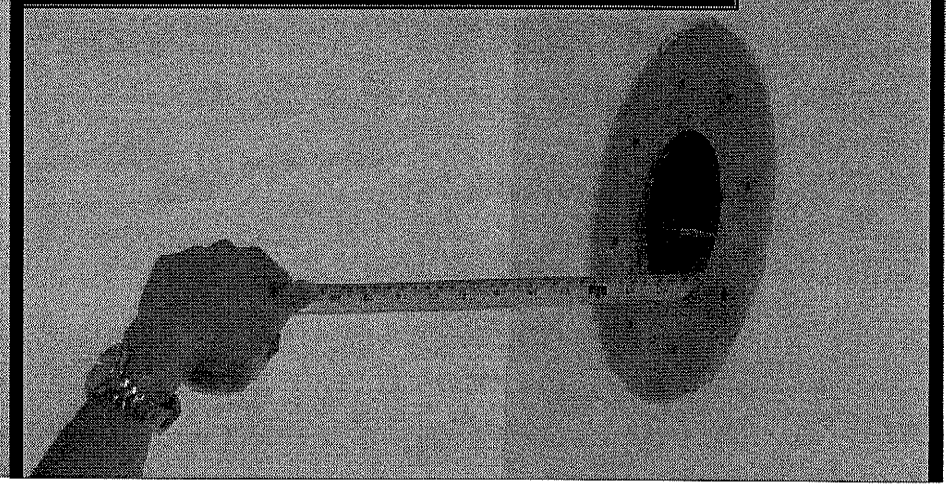
Ventilation Sleeves



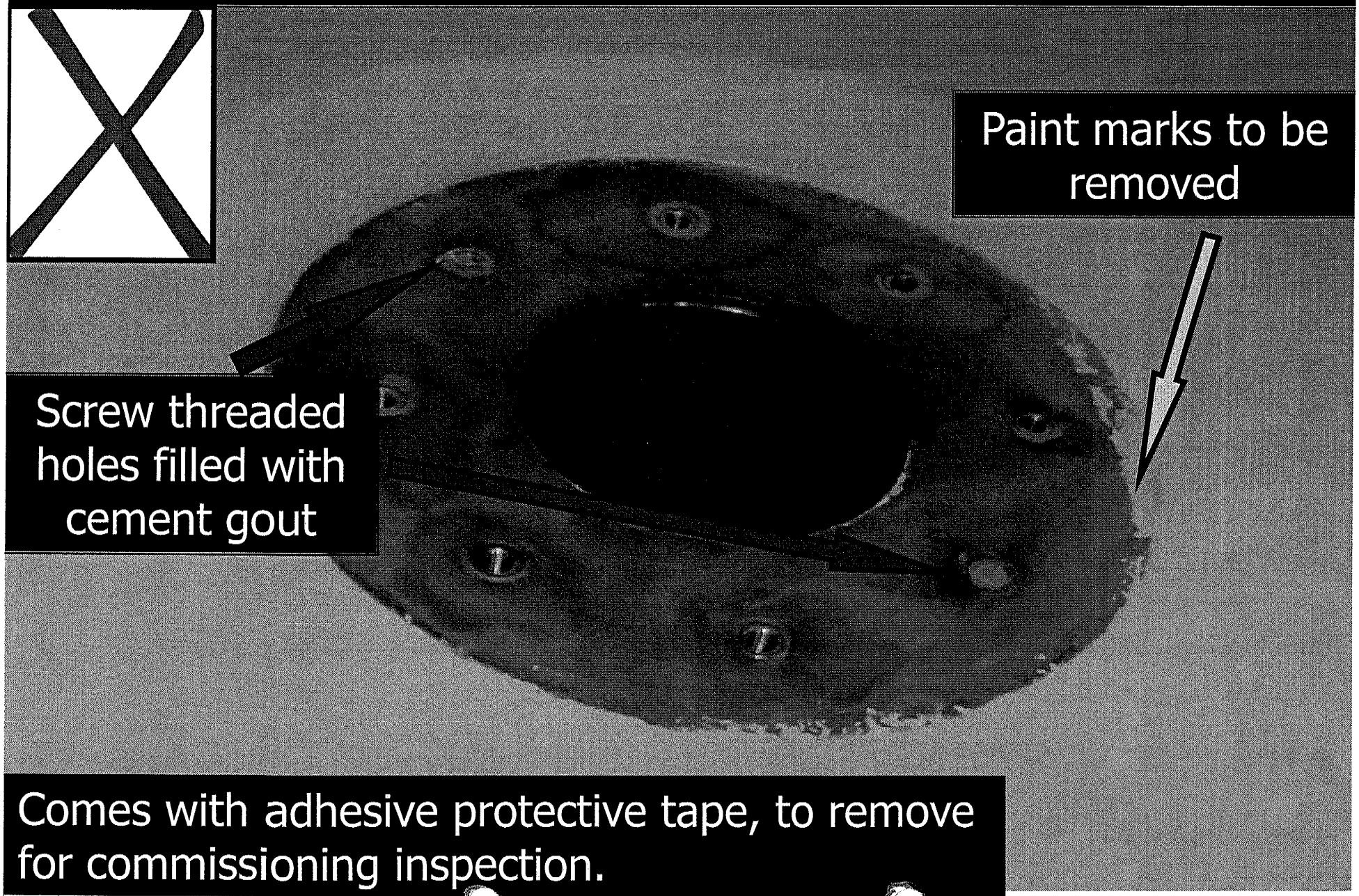


Verifying Ventilation Sleeves Position

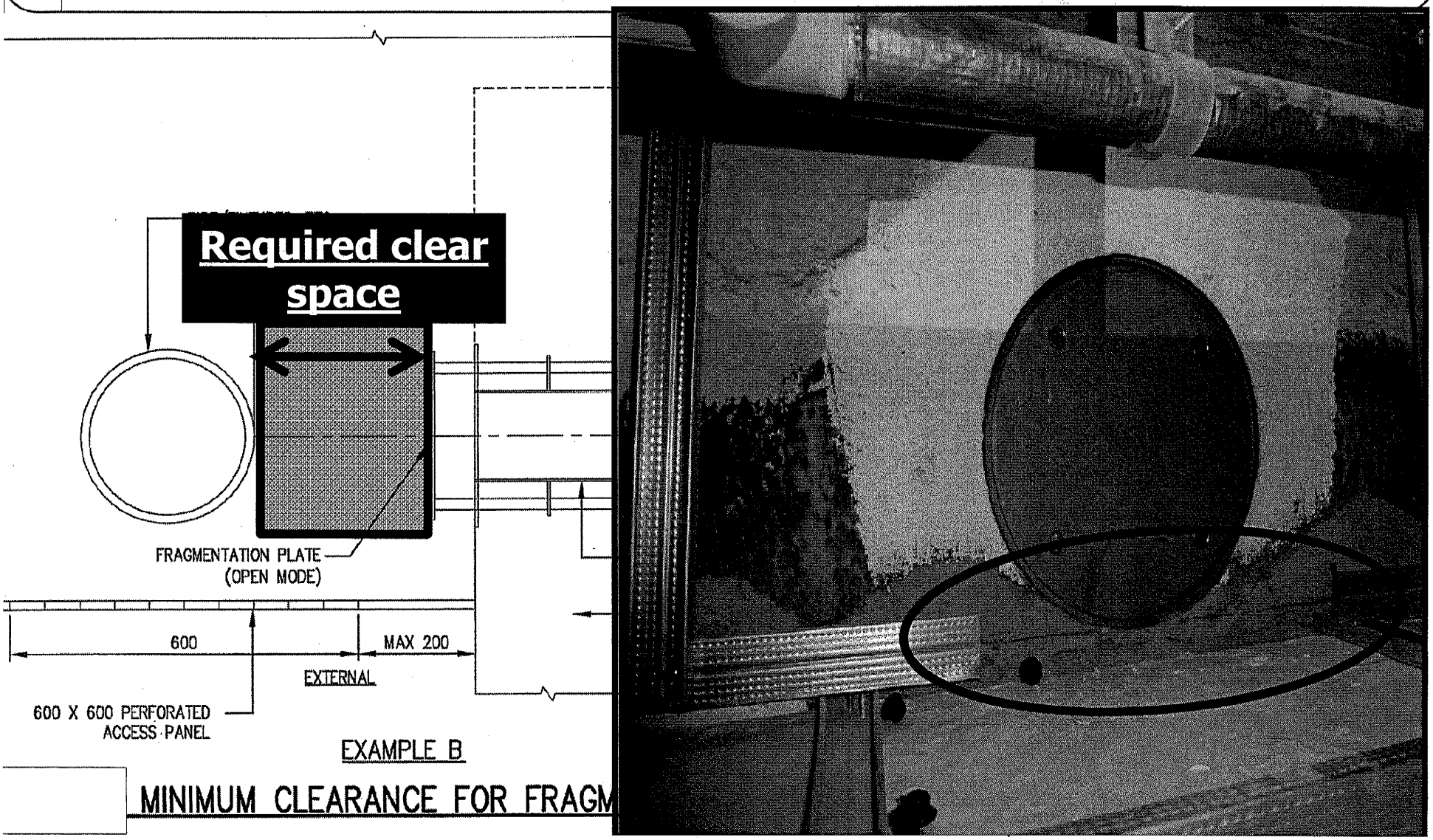
Check wall thickness



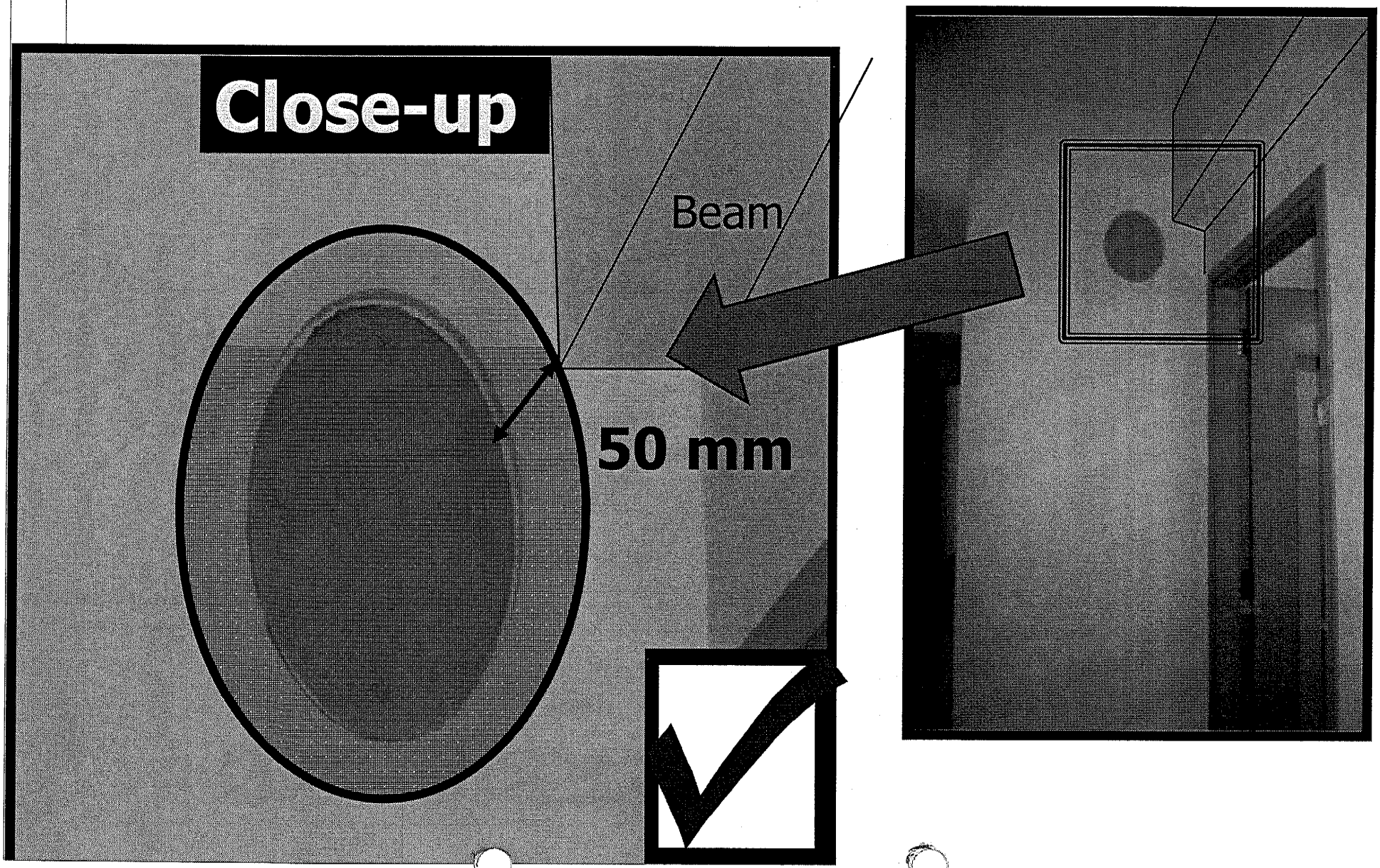
Ventilation Sleeves



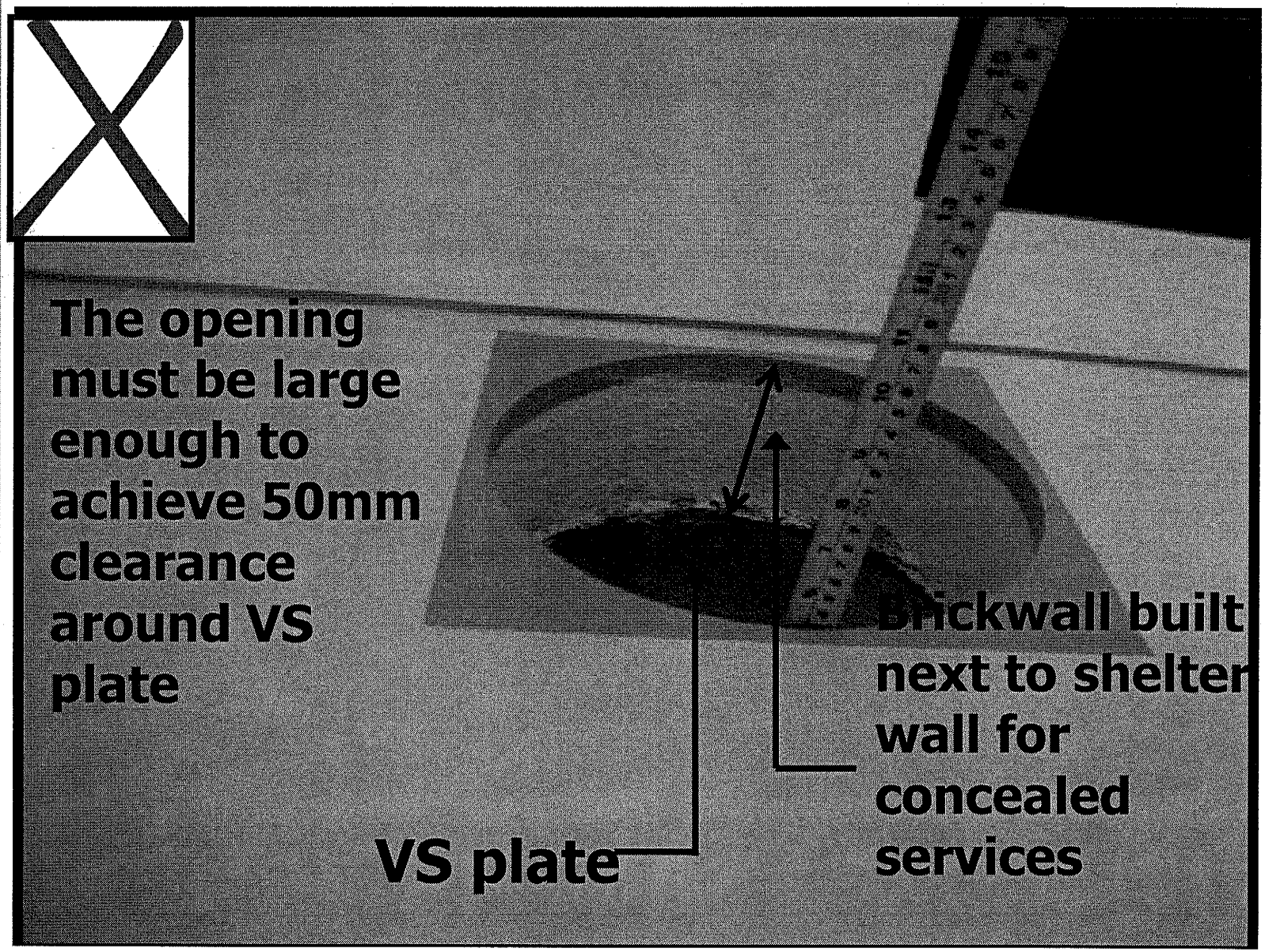
OBSTRUCTIONS IN FRONT OF VENTILATION SLEEVE/PLATE



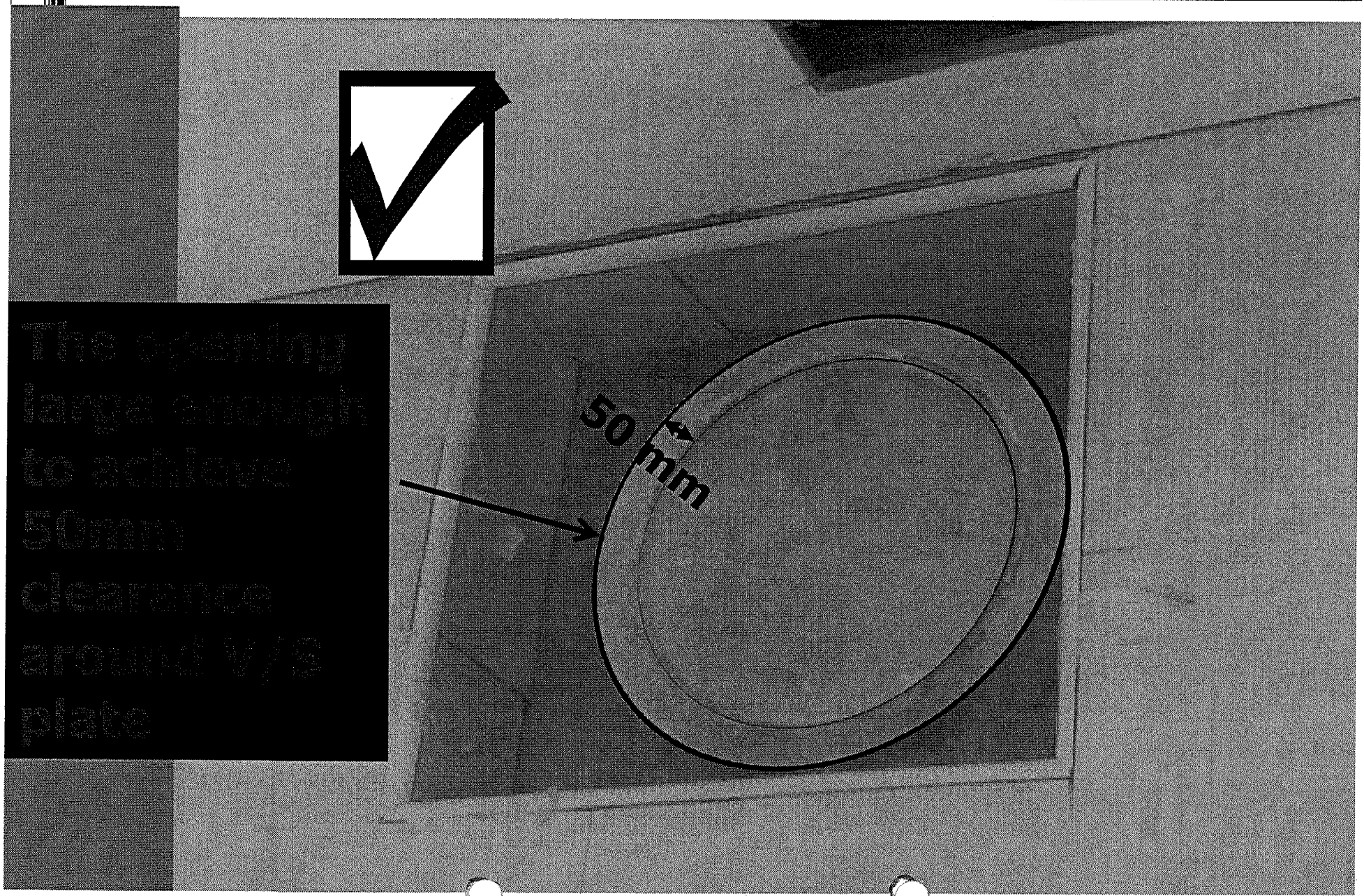
Ventilation Sleeves (external)



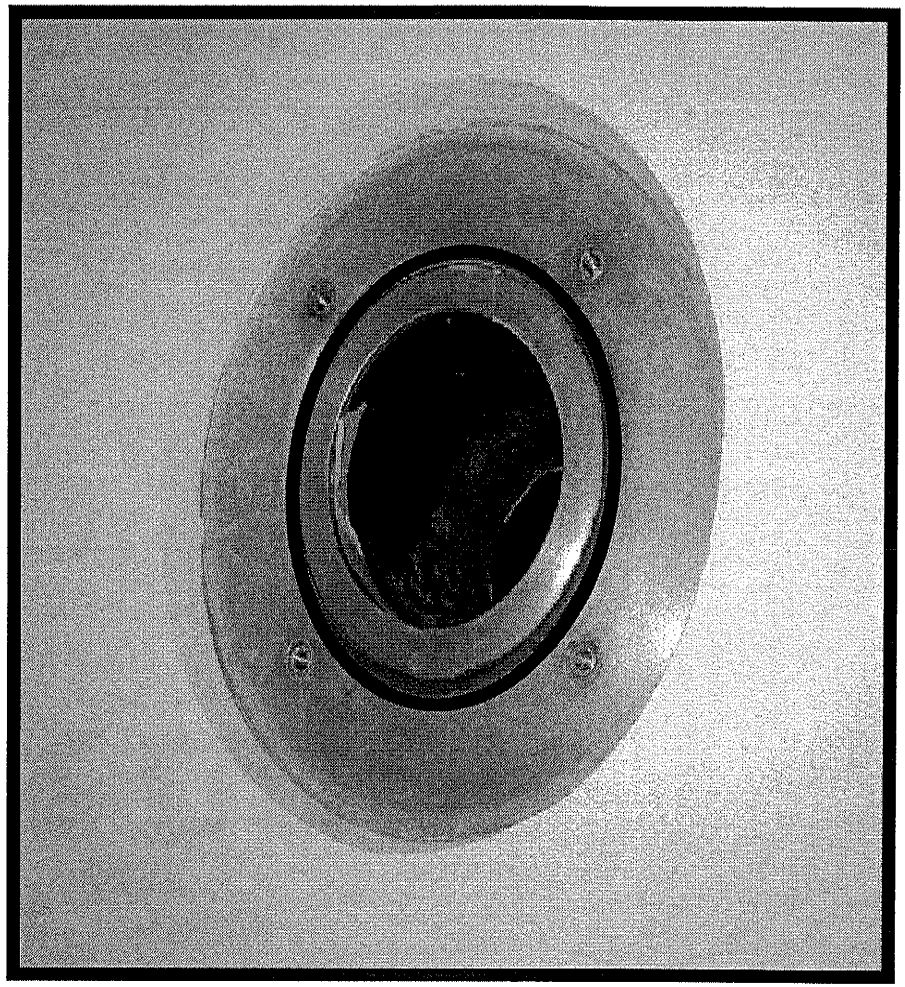
Ventilation Sleeves (external)



Ventilation Sleeves (external)



- **Rubber O-ring placed in the grooves of ventilation sleeves is loose**
- **Inadequate bonding**



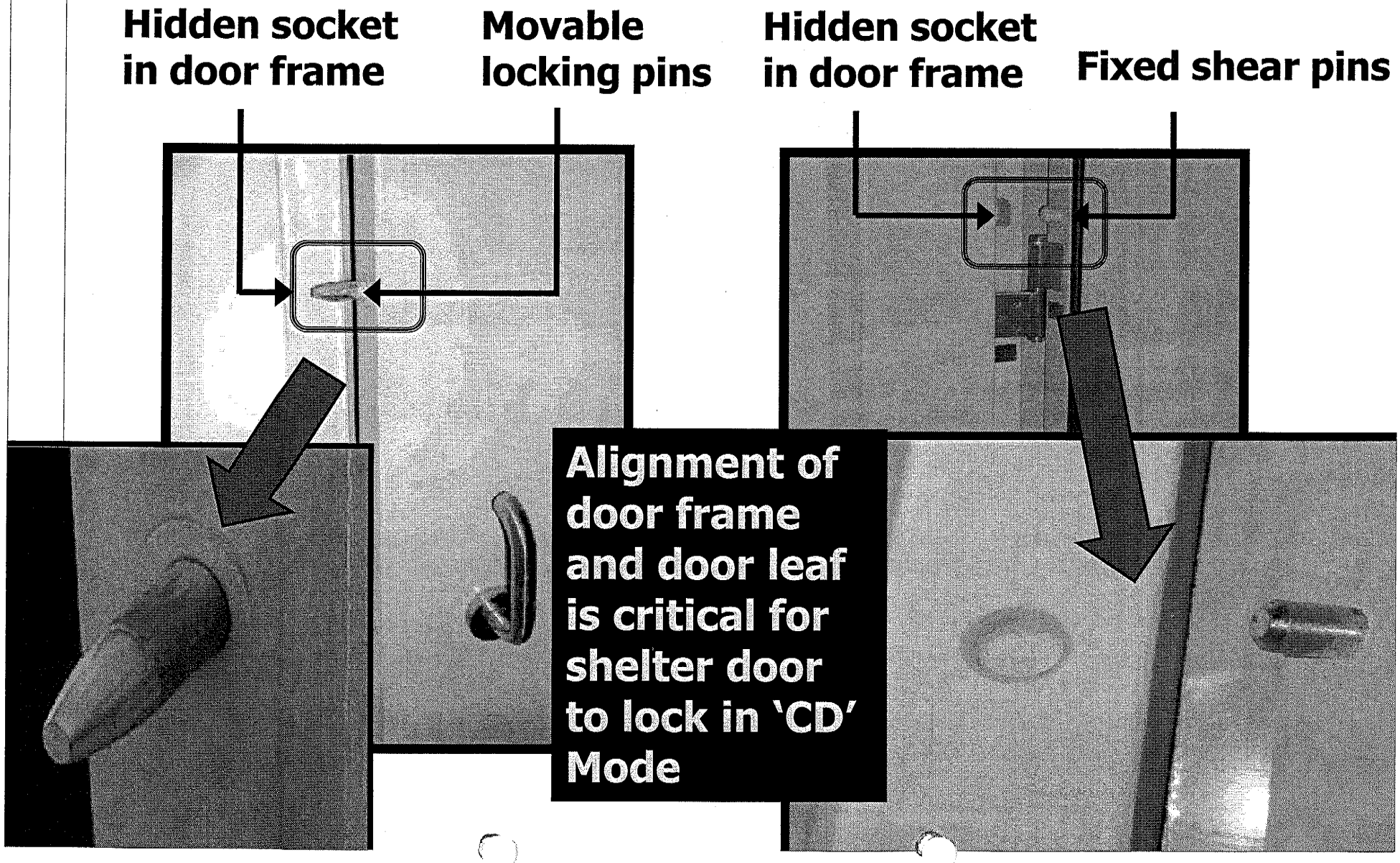
C) SHELTER DOOR

Commissioning Requirements

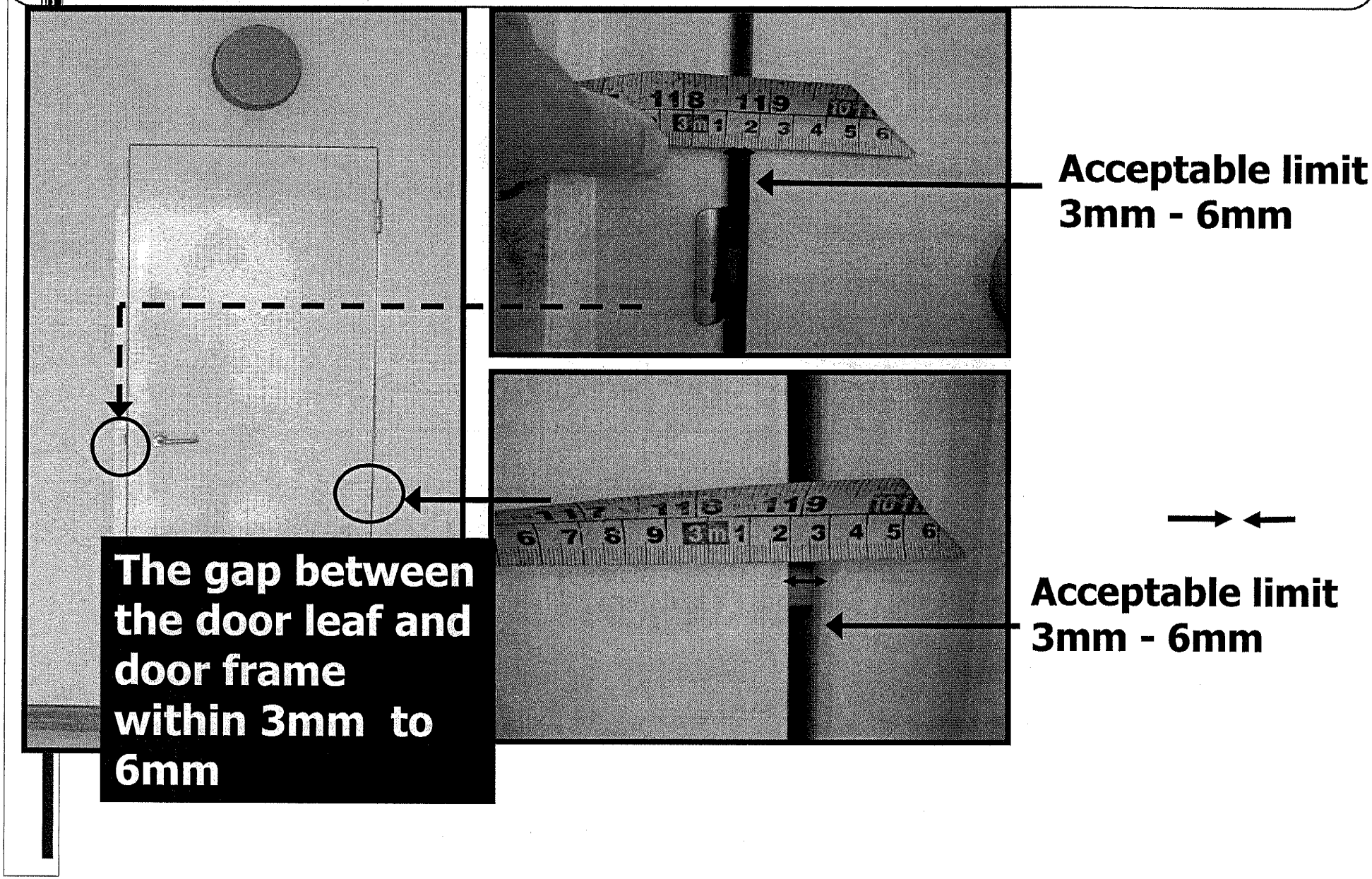
Door Frame / Door Leaf

- Alignment and Functionality
- Compression of Door Leaf to Door Frame
- Rubber Seal
- Door Hinges

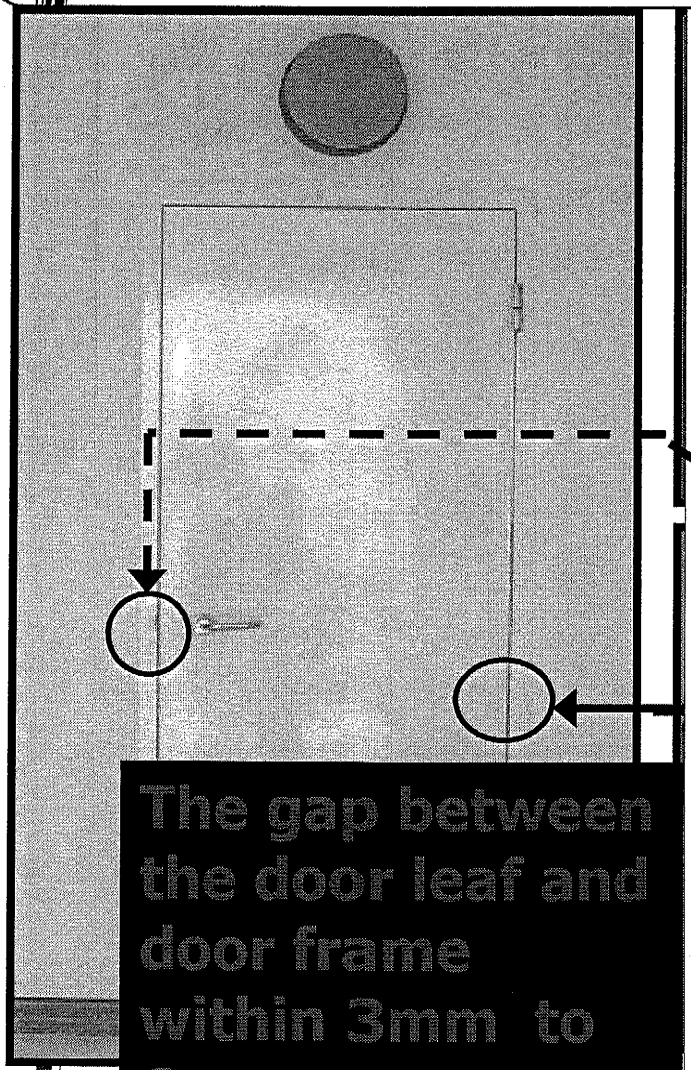
Engage Shelter Door in 'CD' Mode



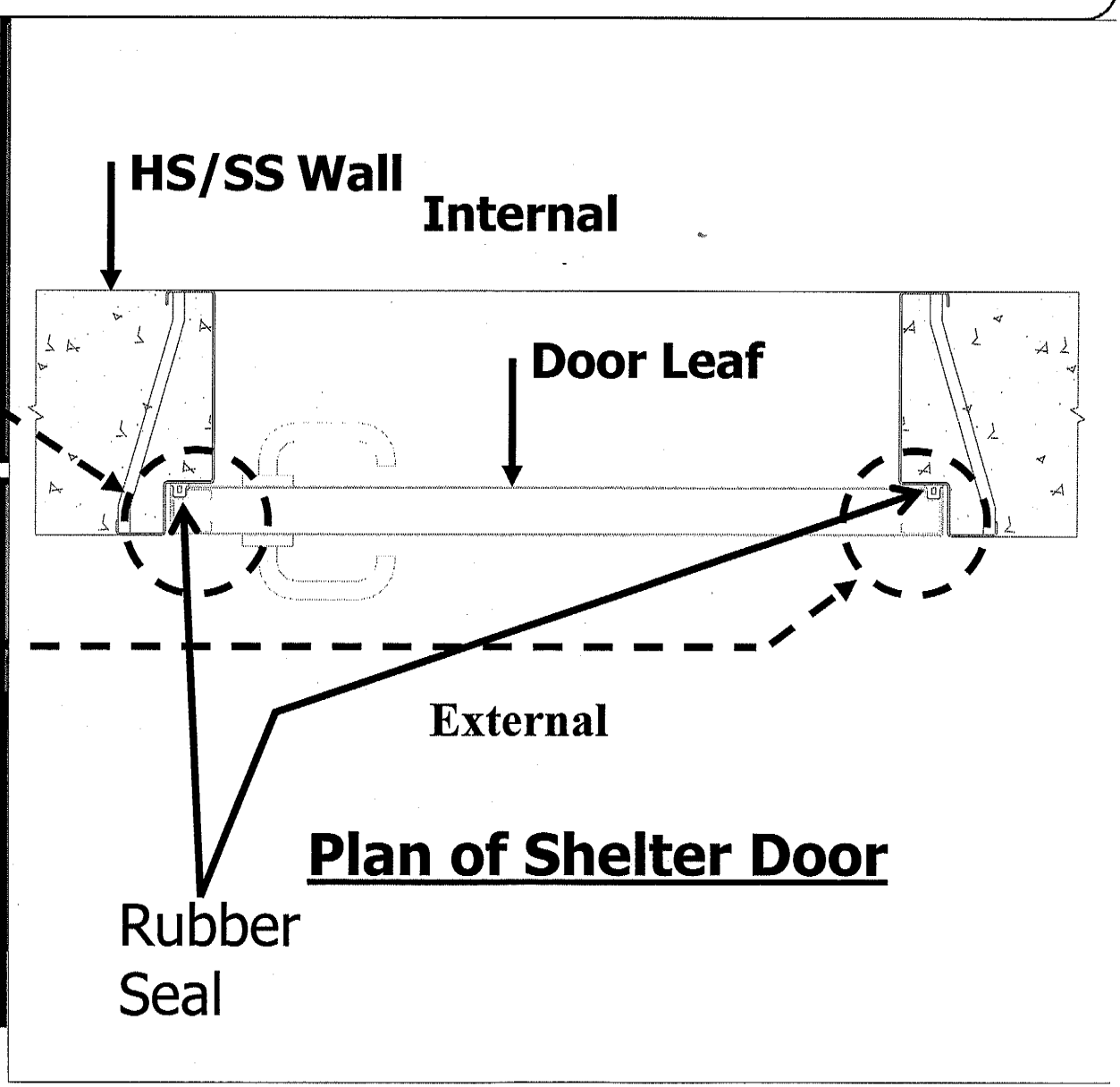
Gap between door and door frame



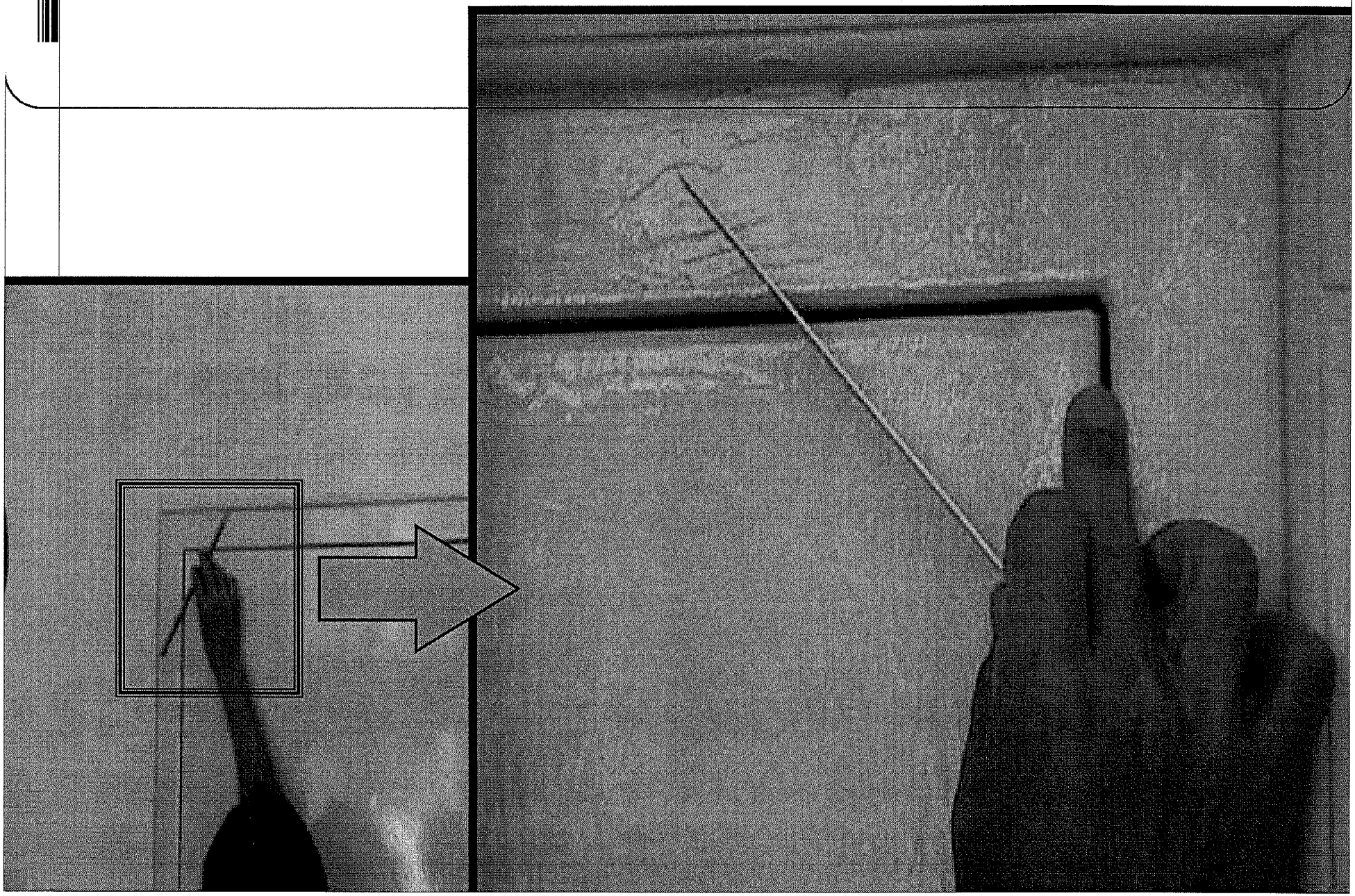
Gap between door and door frame



The gap between the door leaf and door frame within 3mm to 6mm

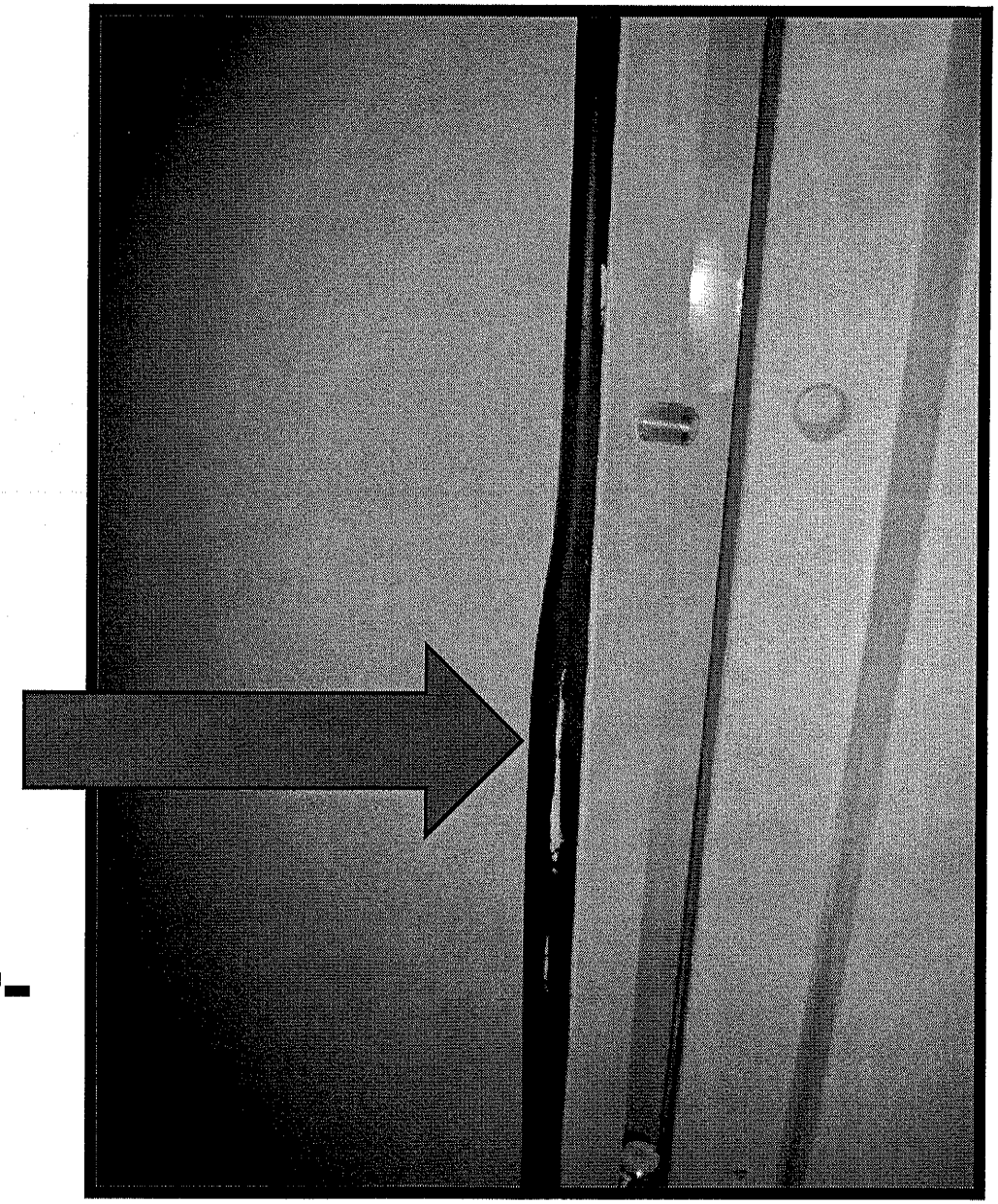


Planarity of Shelter Door and Frame

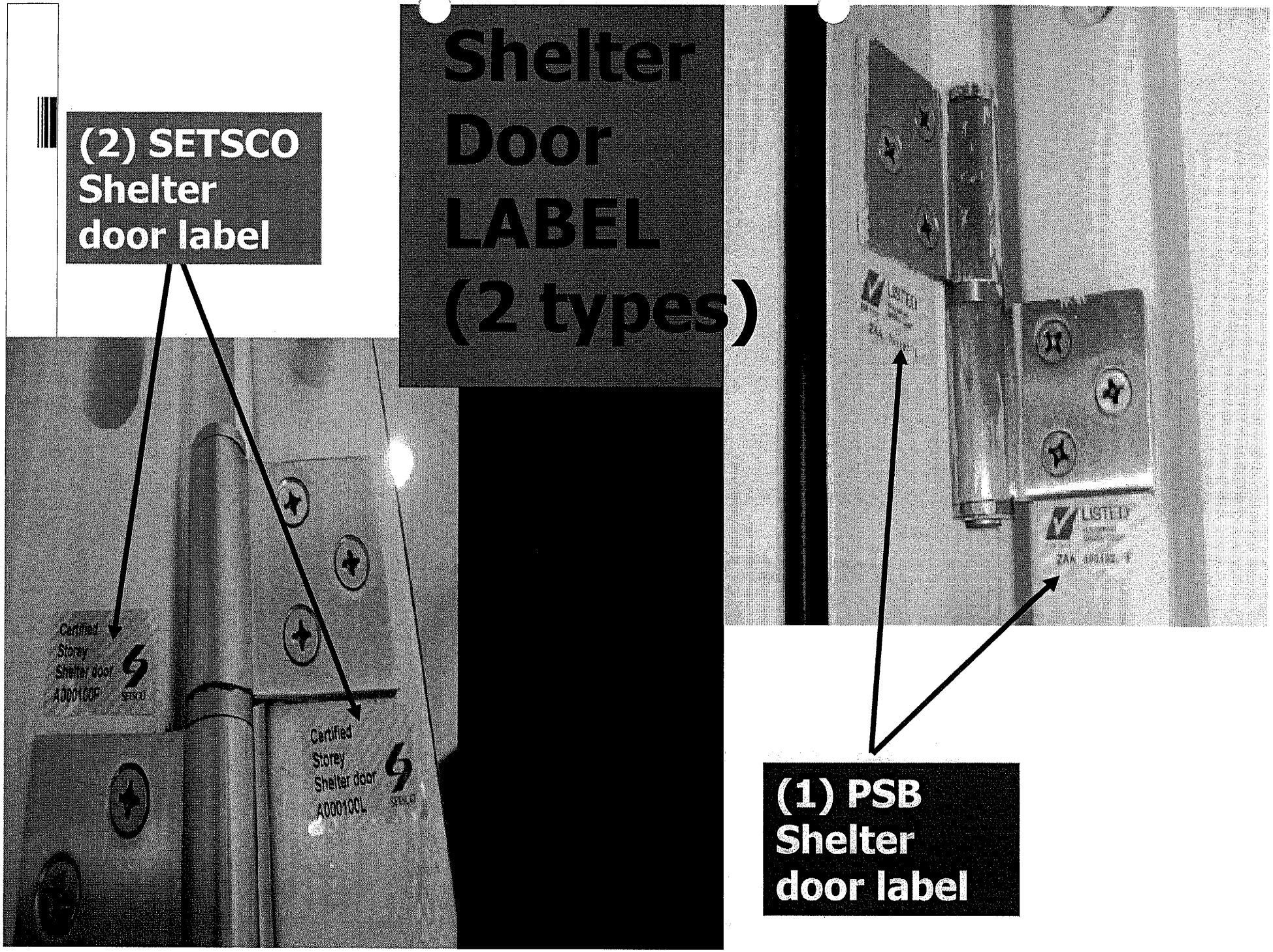


Shelter Door Rubber Seal

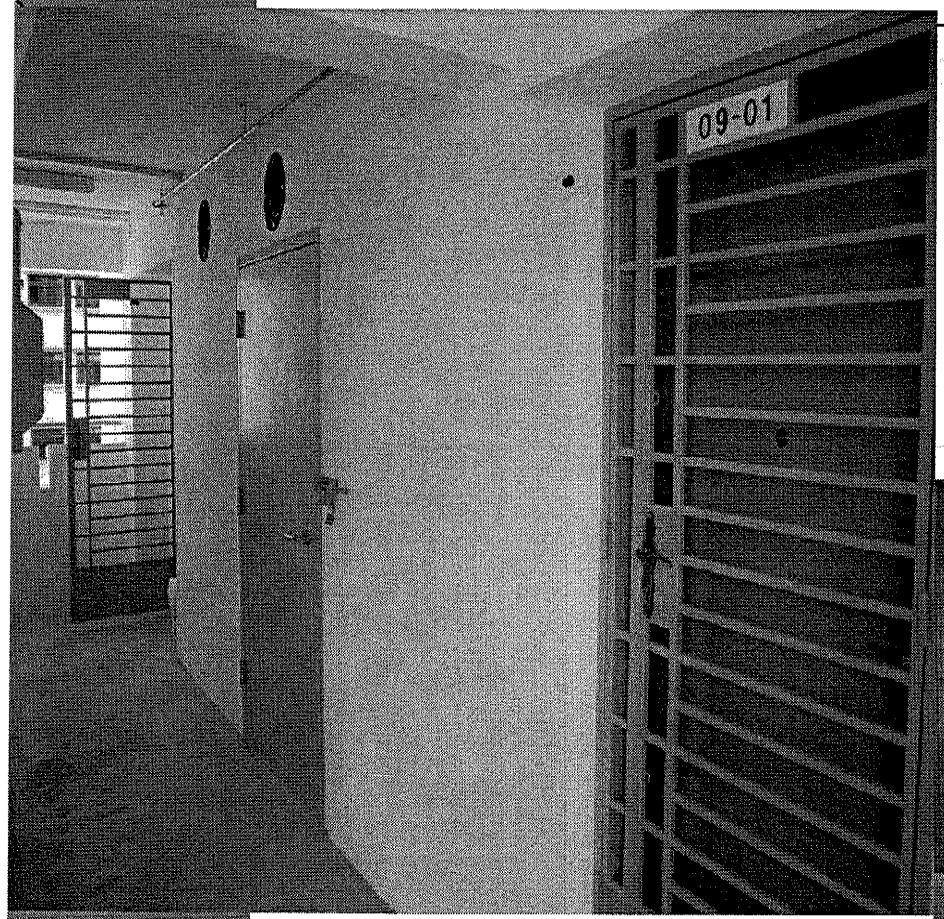
- **Rubber seal to door leaf is loose**
- **Inadequate bonding**
- **Cannot pass air-tightness test**



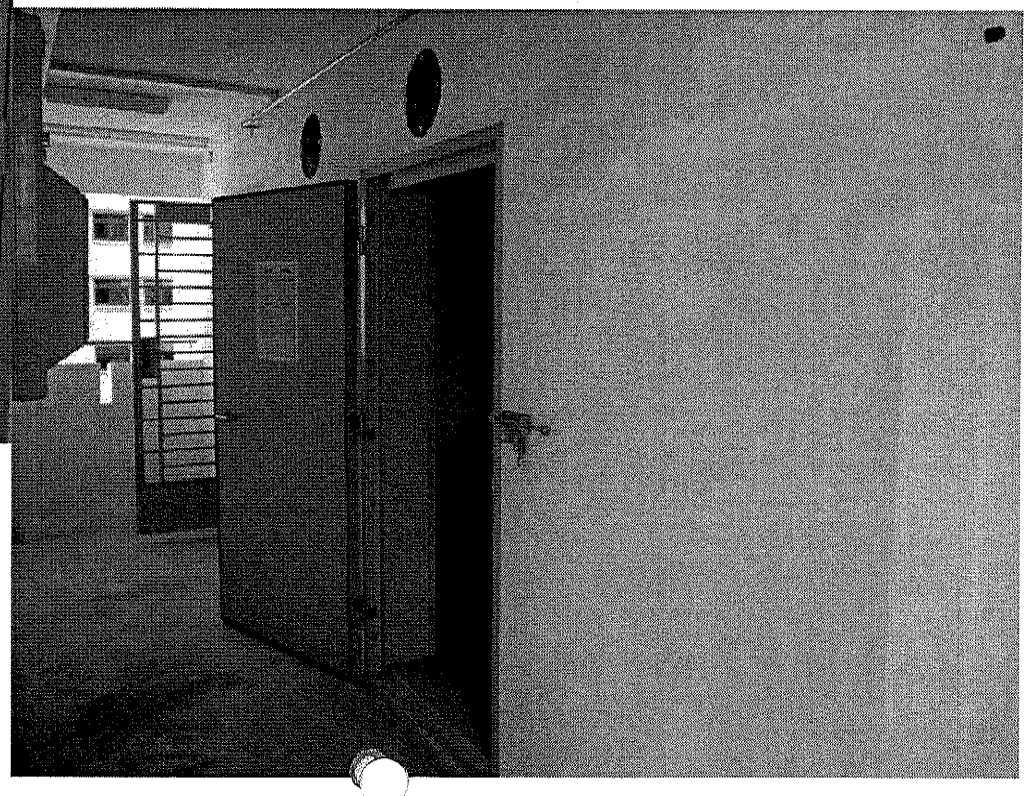
Shelter Door LABEL (2 types)



HDB Storey Shelter

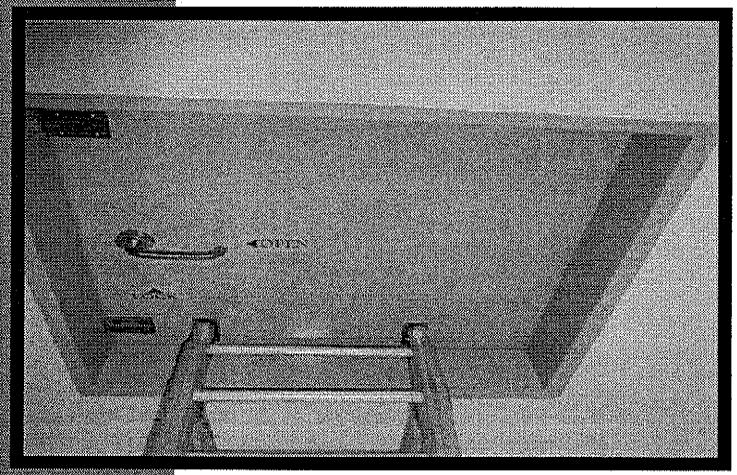


Storey Shelter in common area of HDB flats at every storey

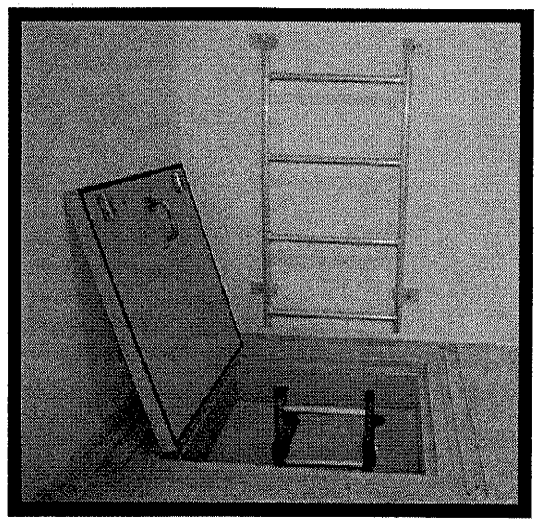


Rescue Hatch @ HDB SS

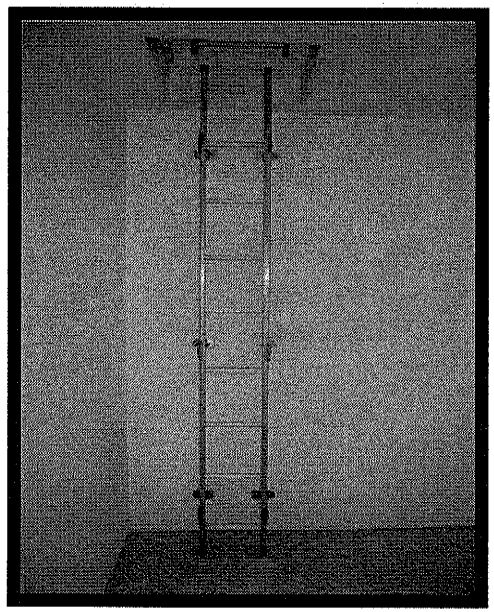
View of rescue hatch on ceiling



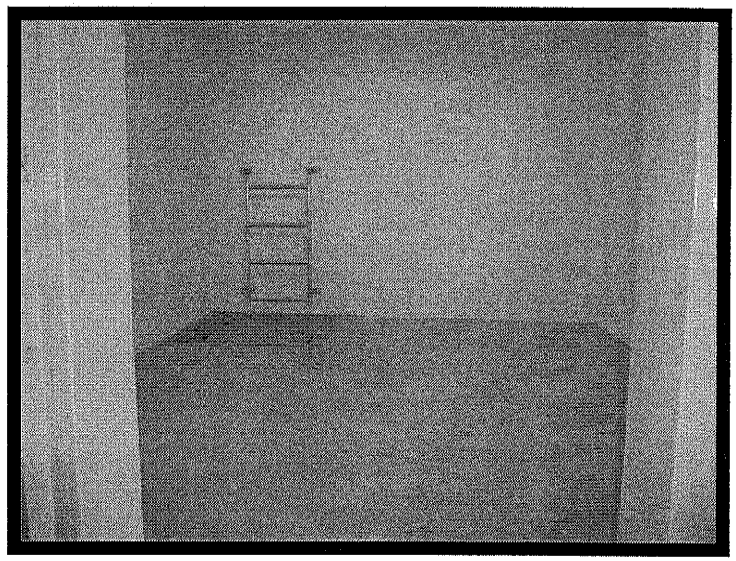
Rescue hatch swings upwards into SS above



View of cat ladder

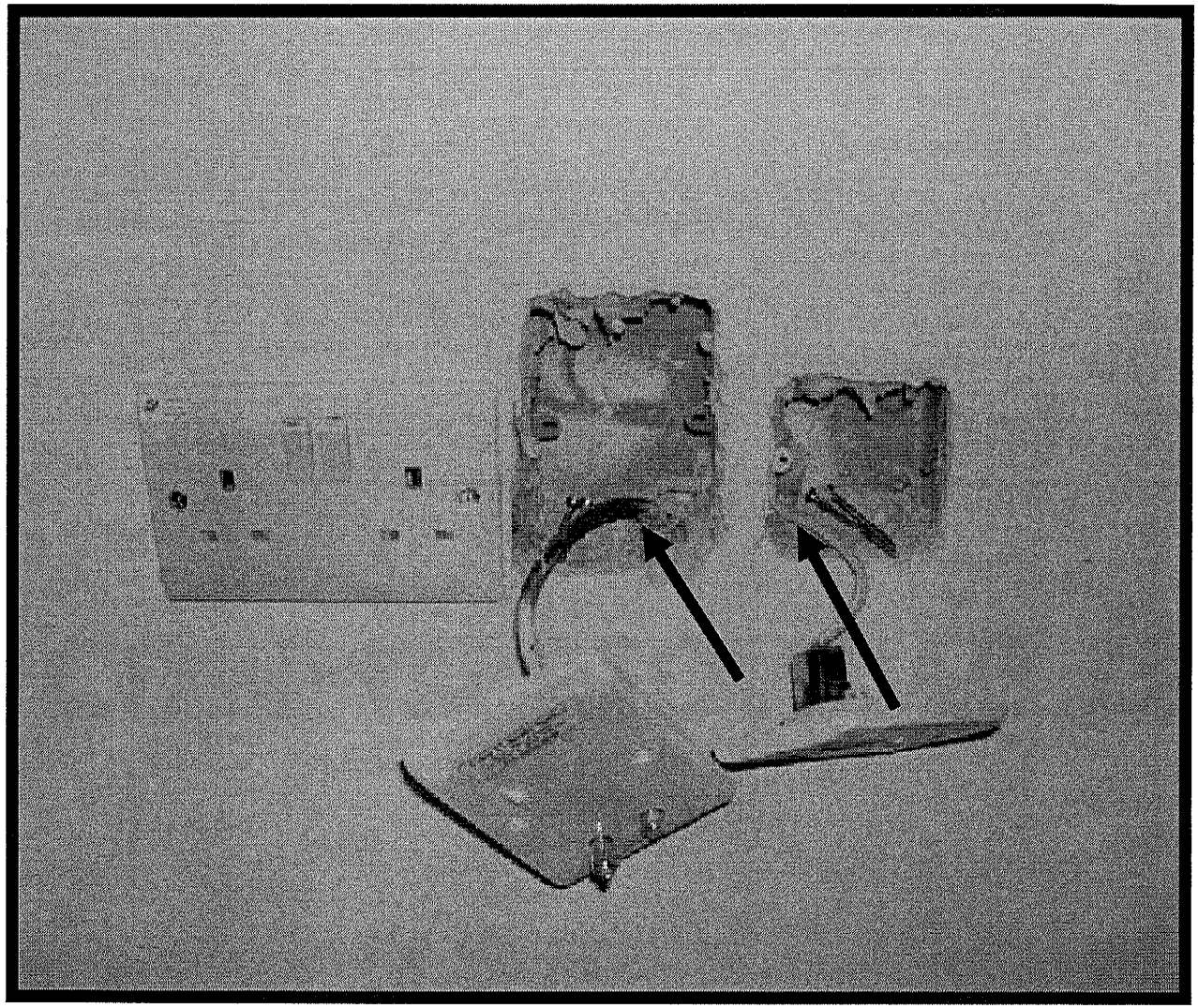


View of rescue hatch from SS above



D) SERVICES

Both Ends of Conduits to be Sealed

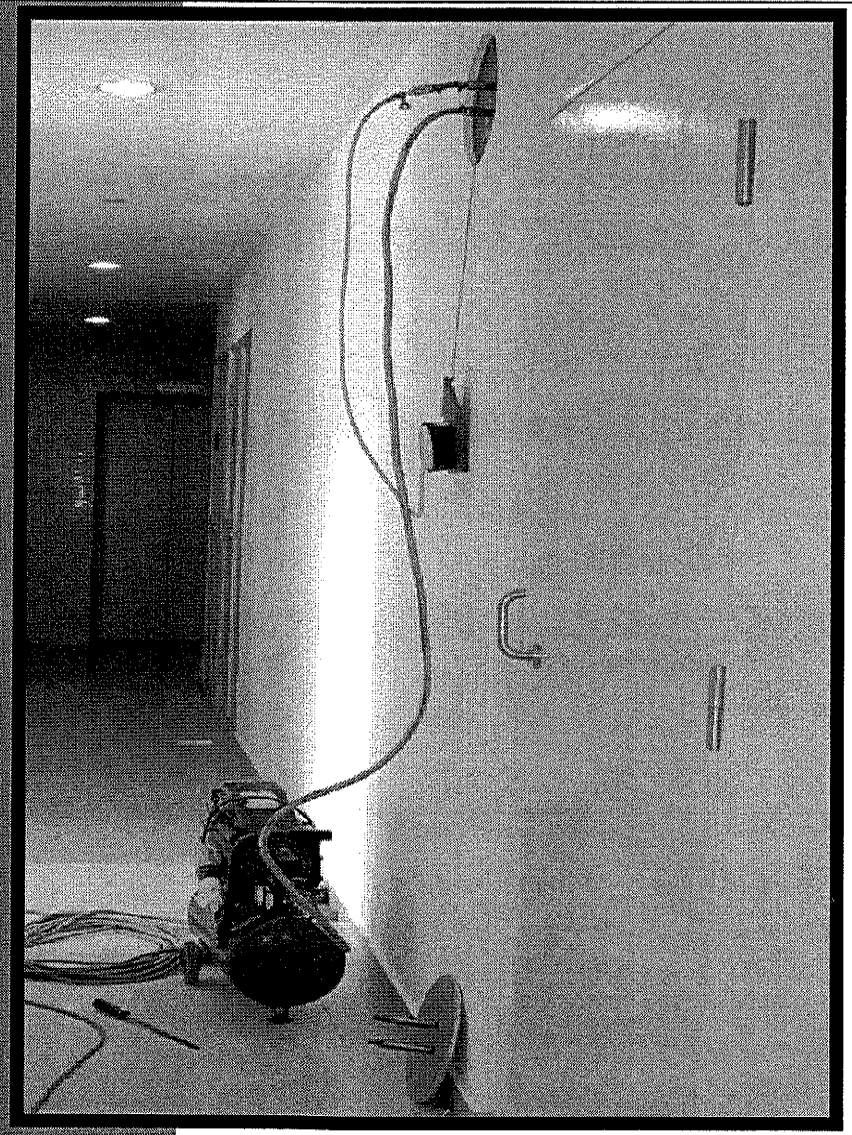


E) COMMISSIONING TEST

Overpressure Air-tightness Test

- Shelter is Engaged in CD Mode
- Initial Air Pressure Difference of 25 mm Water
- Air Pressure Difference Monitored for 45 sec
- Air Pressure Difference $\geq$ 5 mm Water

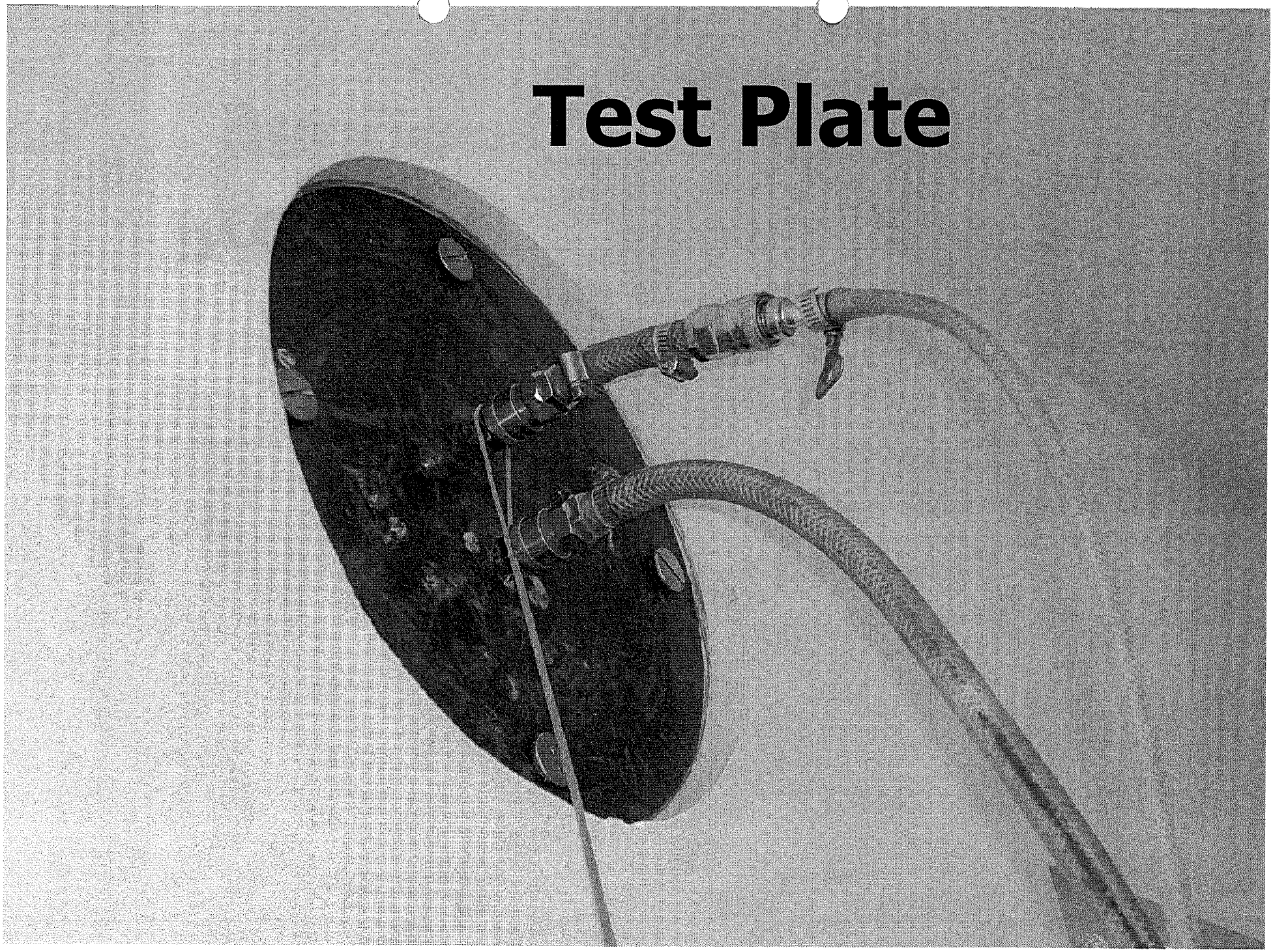
Final Stage :
Commissioning Test for air tightness of Shelter

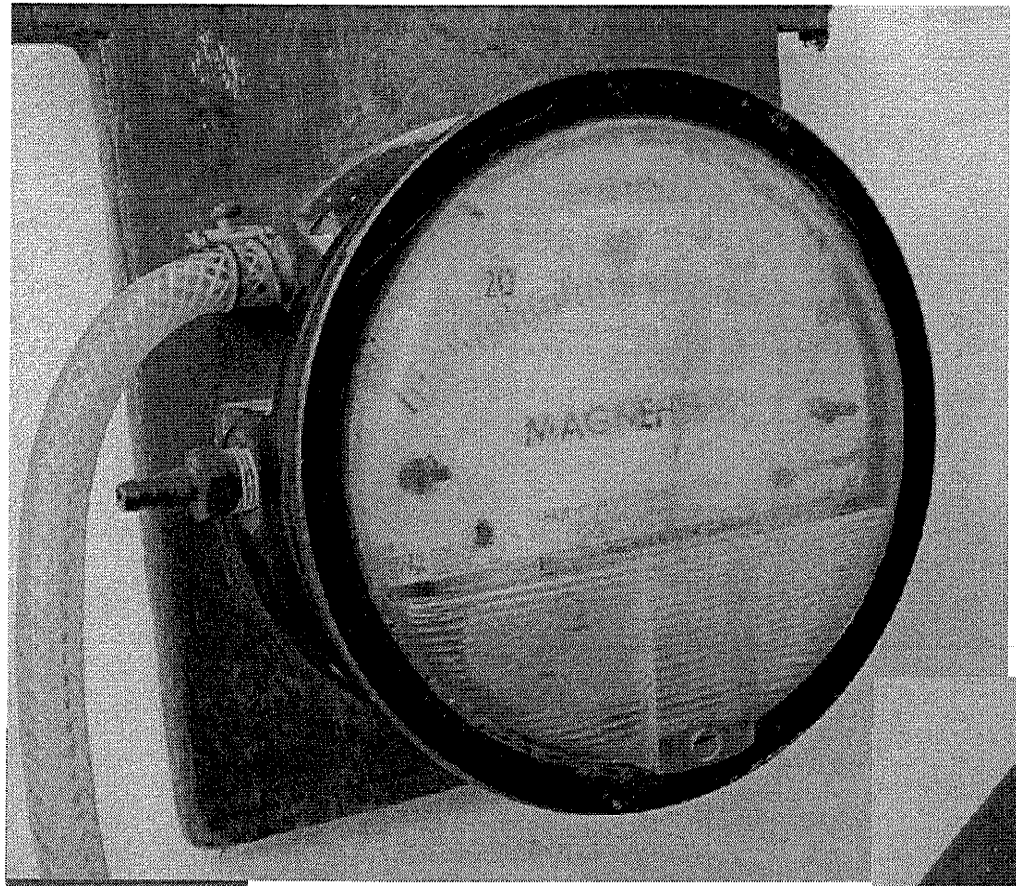




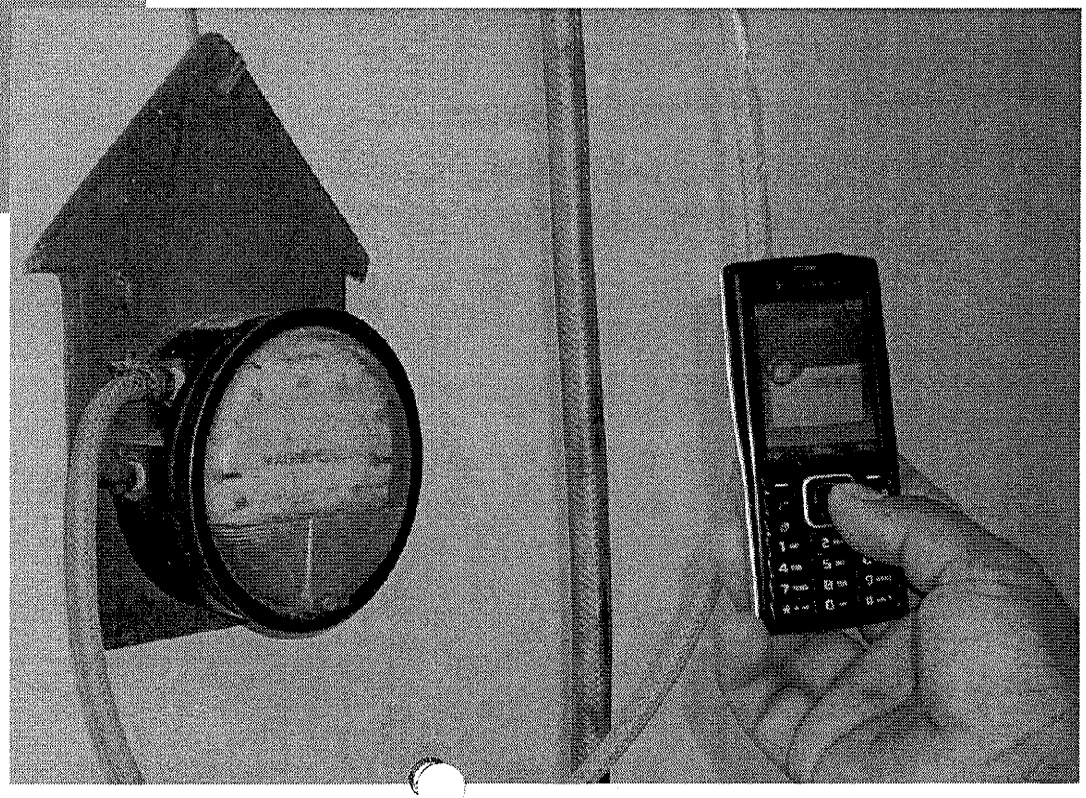
Mechanical pump & pressure gauge set-up

Test Plate





Pressure gauge



Prevention is CHEAPER than cure

- Be committed to build it first time right
- Check against approved plans before casting
- Ensure proper protection of shelter door/ventilation sleeves
- Exercise good construction quality control to avoid costly rectifications and obtain NOA at first commissioning inspection