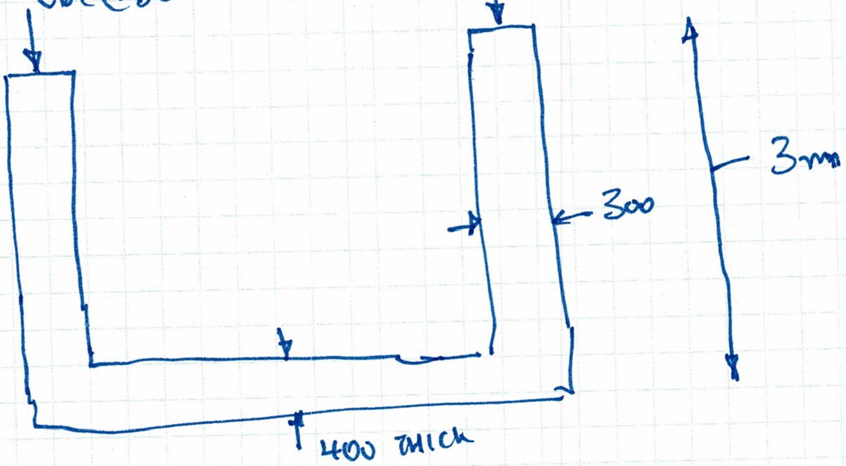
Appendix 4: Ground Movement and Damage Impact Assessment

54 Sumatra Road London NW6 1PR

Bini Struct-e Ltd. Consulting Structural Engineers	Project 54 Sumatra road, London, NW6 1PR		Job Ref 11654	
	Drawing Ref	Calculations by BD	Checked by DB	Sheet of
	Part of Structure UPLIFT FORCE		Date 09.2018	

MOVEMENT DUE TO REMOVAL OF SOIL : i.e. UPLIFT & HEAVE

TOTAL LOAD DUE TO EXISTING BUILDING



∴ DUE TO WALLS & FLOORS ABOVE = 73.6 × (8×2 + 5.2 × 2) = 1928KN

DUE TO WALLS AT BASEMENT = 0.3 × 3×24 × (8×2+5.2×1) = 570KN

DUE TO RAFT SLAB & SCREED = 0.475×24×8×5.2 = ~~[illegible]~~ 474 KN

TOTAL LOAD = 1928 + 570 + ~~[illegible]~~ 474 = 2972 KN

SOIL REMOVAL ∴ TOTAL UPLIFT FORCE

= 18×8×~~3.7~~ × 2.8 + 1.2×8×1.5×18 = 1751 KN

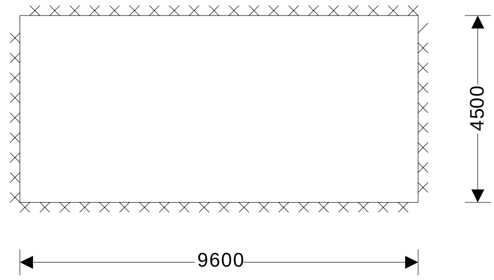
∴ F.O.S = 2972/1751 = 1.7 ∴ NO UPLIFT.

SLAB & HEAVE DESIGN REFER TO FOLLOWING PAGES

RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.10



Slab definition

Type of slab	**Two way spanning with restrained edges**
Overall slab depth	h = **400** mm
Shorter effective span of panel	l_x = **4500** mm
Longer effective span of panel	l_y = **9600** mm
Support conditions	**Four edges continuous (interior panel)**
Top outer layer of reinforcement	**Short span direction**
Bottom outer layer of reinforcement	**Short span direction**

Loading

Characteristic permanent action	G_k = **54.0** kN/m^2
Characteristic variable action	Q_k = **0.0** kN/m^2
Partial factor for permanent action	γ_G = **1.35**
Partial factor for variable action	γ_Q = **1.50**
Quasi-permanent value of variable action	ψ_2 = **0.30**
Design ultimate load	$q = \gamma_G \times G_k + \gamma_Q \times Q_k$ = **72.9** kN/m^2
Quasi-permanent load	$q_{SLS} = 1.0 \times G_k + \psi_2 \times Q_k$ = **54.0** kN/m^2

Concrete properties

Concrete strength class	C35/45
Characteristic cylinder strength	f_{ck} = **35** N/mm^2
Partial factor (Table 2.1N)	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6)	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6)	f_{cd} = **19.8** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30\ \text{N/mm}^2 \times (f_{ck} / 1\ \text{N/mm}^2)^{2/3}$ = **3.2** N/mm^2
Maximum aggregate size	d_g = **20** mm

Reinforcement properties

Characteristic yield strength	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N)	γ_S = **1.15**
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2

Concrete cover to reinforcement

Nominal cover to outer top reinforcement	c_{nom_t} = **30** mm

Nominal cover to outer bottom reinforcement	c_{nom_b} = **30** mm
Fire resistance period to top of slab	R_{top} = **60** min
Fire resistance period to bottom of slab	R_{btm} = **60** min
Axia distance to top reinft (Table 5.8)	a_{fi_t} = **15** mm
Axia distance to bottom reinft (Table 5.8)	a_{fi_b} = **15** mm
Min. top cover requirement with regard to bond	c_{min,b_t} = **16** mm
Min. btm cover requirement with regard to bond	c_{min,b_b} = **10** mm
Reinforcement fabrication	**Not subject to QA system**
Cover allowance for deviation	Δc_{dev} = **10** mm
Min. required nominal cover to top reinft	$c_{nom\_t\_min}$ = **26.0** mm
Min. required nominal cover to bottom reinft	$c_{nom\_b\_min}$ = **20.0** mm

PASS - There is sufficient cover to the top reinforcement

PASS - There is sufficient cover to the bottom reinforcement

Reinforcement design at midspan in short span direction (cl.6.1)

Bending moment coefficient	β_{sx_p} = **0.0480**
Design bending moment	$M_{x\_p} = \beta_{sx\_p} \times q \times l_x^2$ = **70.9** kNm/m
Reinforcement provided	A393 mesh + 10 mm dia. bars at 200 mm centres
Area provided	A_{sx_p} = 786 mm²/m
Effective depth to tension reinforcement	$d_{x\_p} = h - c_{nom\_b} - \phi_{x\_p} / 2$ = **365.0** mm
K factor	$K = M_{x\_p} / (b \times d_{x\_p}^2 \times f_{ck})$ = **0.015**
Redistribution ratio	δ = 1.0
K' factor	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{x\_p}, d_{x\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **346.8** mm
Area of reinforcement required for bending	$A_{sx\_p\_m} = M_{x\_p} / (f_{yd} \times z)$ = **470** mm²/m
Minimum area of reinforcement required	$A_{sx\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_p}, 0.0013 \times b \times d_{x\_p})$ = **609** mm²/m
Area of reinforcement required	$A_{sx\_p\_req} = \max(A_{sx\_p\_m}, A_{sx\_p\_min})$ = **609** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress	$\sigma_{sx\_p} = (f_{yk} / \gamma_S) \times \min((A_{sx\_p\_m}/A_{sx\_p}), 1.0) \times q_{SLS} / q$ = **192.7** N/mm²
Maximum allowable spacing (Table 7.3N)	$s_{max\_x\_p}$ = **259** mm
Actual bar spacing	s_{x_p} = **100** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan in long span direction (cl.6.1)

Bending moment coefficient	β_{sy_p} = **0.0240**
Design bending moment	$M_{y\_p} = \beta_{sy\_p} \times q \times l_x^2$ = **35.4** kNm/m
Reinforcement provided	A393 mesh + 10 mm dia. bars at 200 mm centres
Area provided	A_{sy_p} = 786 mm²/m
Effective depth to tension reinforcement	$d_{y\_p} = h - c_{nom\_b} - \phi_{x\_p} - \phi_{y\_p} / 2$ = **355.0** mm
K factor	$K = M_{y\_p} / (b \times d_{y\_p}^2 \times f_{ck})$ = **0.008**
Redistribution ratio	δ = 1.0
K' factor	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{y\_p}, d_{y\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **337.3** mm
Area of reinforcement required for bending	$A_{sy\_p\_m} = M_{y\_p} / (f_{yd} \times z)$ = **242** mm²/m
Minimum area of reinforcement required	$A_{sy\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_p}, 0.0013 \times b \times d_{y\_p})$ = **593** mm²/m

Area of reinforcement required — $A_{sy\_p\_req} = max(A_{sy\_p\_m}, A_{sy\_p\_min})$ = **593** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sy\_p} = (f_{yk} / \gamma_S) \times min((A_{sy\_p\_m}/A_{sy\_p}), 1.0) \times q_{SLS} / q$ = **99.0** N/mm²

Maximum allowable spacing (Table 7.3N) — $s_{max\_y\_p}$ = **300** mm

Actual bar spacing — s_{y_p} = **100** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in short span direction (cl.6.1)

Bending moment coefficient — β_{sx_n} = **0.0630**

Design bending moment — $M_{x\_n} = \beta_{sx\_n} \times q \times l_x^2$ = **93.0** kNm/m

Reinforcement provided — A393 mesh + 16 mm dia. bars at 200 mm centres

Area provided — A_{sx_n} = 1398 mm²/m

Effective depth to tension reinforcement — $d_{x\_n} = h - c_{nom\_t} - \phi_{x\_n} / 2$ = **362.0** mm

K factor — $K = M_{x\_n} / (b \times d_{x\_n}^2 \times f_{ck})$ = **0.020**

Redistribution ratio — $\delta = 1.0$

K' factor — $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm — $z = min(0.95 \times d_{x\_n}, d_{x\_n}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **343.9** mm

Area of reinforcement required for bending — $A_{sx\_n\_m} = M_{x\_n} / (f_{yd} \times z)$ = **622** mm²/m

Minimum area of reinforcement required — $A_{sx\_n\_min} = max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_n}, 0.0013 \times b \times d_{x\_n})$ = **604** mm²/m

Area of reinforcement required — $A_{sx\_n\_req} = max(A_{sx\_n\_m}, A_{sx\_n\_min})$ = **622** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sx\_n} = (f_{yk} / \gamma_S) \times min((A_{sx\_n\_m}/A_{sx\_n}), 1.0) \times q_{SLS} / q$ = **143.3** N/mm²

Maximum allowable spacing (Table 7.3N) — $s_{max\_x\_n}$ = **300** mm

Actual bar spacing — s_{x_n} = **100** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in long span direction (cl.6.1)

Bending moment coefficient — β_{sy_n} = **0.0320**

Design bending moment — $M_{y\_n} = \beta_{sy\_n} \times q \times l_x^2$ = **47.2** kNm/m

Reinforcement provided — A393 mesh + 16 mm dia. bars at 200 mm centres

Area provided — A_{sy_n} = 1398 mm²/m

Effective depth to tension reinforcement — $d_{y\_n} = h - c_{nom\_t} - \phi_{x\_n} - \phi_{y\_n} / 2$ = **346.0** mm

K factor — $K = M_{y\_n} / (b \times d_{y\_n}^2 \times f_{ck})$ = **0.011**

Redistribution ratio — $\delta = 1.0$

K' factor — $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm — $z = min(0.95 \times d_{y\_n}, d_{y\_n}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **328.7** mm

Area of reinforcement required for bending — $A_{sy\_n\_m} = M_{y\_n} / (f_{yd} \times z)$ = **331** mm²/m

Minimum area of reinforcement required — $A_{sy\_n\_min} = max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_n}, 0.0013 \times b \times d_{y\_n})$ = **578** mm²/m

Area of reinforcement required — $A_{sy\_n\_req} = max(A_{sy\_n\_m}, A_{sy\_n\_min})$ = **578** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sy\_n} = (f_{yk} / \gamma_S) \times min((A_{sy\_n\_m}/A_{sy\_n}), 1.0) \times q_{SLS} / q$ = **76.1** N/mm²

Maximum allowable spacing (Table 7.3N) — $s_{max\_y\_n}$ = **300** mm

Actual bar spacing s_{y_n} = **100** mm

PASS - The reinforcement spacing is acceptable

Shear capacity check at short span continuous support

Shear force $V_{x\_n} = q \times l_x / 2 =$ **164.0** kN/m

Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200\text{ mm} / d_{x\_n})^{0.5}) =$ **1.743**

Reinforcement ratio $\rho_l = \min(0.02, A_{sx\_n} / (b \times d_{x\_n})) =$ **0.0039**

Minimum shear resistance (Exp. 6.3N) $V_{Rd,c\_min} = 0.035\text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1\text{ N/mm}^2)^{0.5} \times b \times d_{x\_n}$

V_{Rd,c_min} = **172.5** kN/m

Shear resistance (Exp. 6.2a) $V_{Rd,c\_x\_n} = \max(V_{Rd,c\_min}, (0.18\text{ N/mm}^2 / \gamma_C) \times k \times (100 \times \rho_l \times (f_{ck} / 1\text{ N/mm}^2))^{0.333} \times b \times d_{x\_n})$

V_{Rd,c_x_n} = **180.2** kN/m

PASS - Shear capacity is adequate

Shear capacity check at long span continuous support

Shear force $V_{y\_n} = q \times l_x / 2 =$ **164.0** kN/m

Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200\text{ mm} / d_{y\_n})^{0.5}) =$ **1.760**

Reinforcement ratio $\rho_l = \min(0.02, A_{sy\_n} / (b \times d_{y\_n})) =$ **0.0040**

Minimum shear resistance (Exp. 6.3N) $V_{Rd,c\_min} = 0.035\text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1\text{ N/mm}^2)^{0.5} \times b \times d_{y\_n}$

V_{Rd,c_min} = **167.3** kN/m

Shear resistance (Exp. 6.2a) $V_{Rd,c\_y\_n} = \max(V_{Rd,c\_min}, (0.18\text{ N/mm}^2 / \gamma_C) \times k \times (100 \times \rho_l \times (f_{ck} / 1\text{ N/mm}^2))^{0.333} \times b \times d_{y\_n})$

V_{Rd,c_y_n} = **176.6** kN/m

PASS - Shear capacity is adequate

Basic span-to-depth deflection ratio check (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1\text{ N/mm}^2)^{0.5} / 1000 =$ **0.0059**

Required tension reinforcement ratio $\rho = \max(0.0035, A_{sx\_p\_req} / (b \times d_{x\_p})) =$ **0.0035**

Required compression reinforcement ratio $\rho' = A_{scx\_p\_req} / (b \times d_{x\_p}) =$ **0.0000**

Stuctural system factor (Table 7.4N) K_δ = **1.5**

Basic limit span-to-depth ratio $ratio_{lim\_x\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1\text{ N/mm}^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1\text{ N/mm}^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$

(Exp. 7.16) $ratio_{lim\_x\_bas}$ = **55.29**

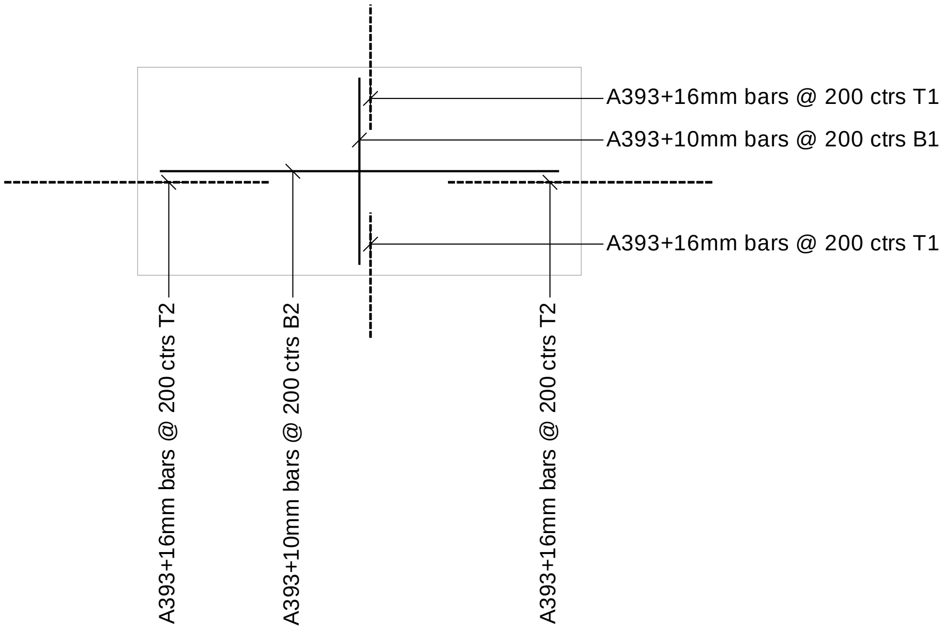
Mod span-to-depth ratio limit $ratio_{lim\_x} = \min(40 \times K_\delta, \min(1.5, (500\text{ N/mm}^2/f_{yk}) \times (A_{sx\_p}/A_{sx\_p\_m})) \times ratio_{lim\_x\_bas}) =$ **60.00**

Actual span-to-eff. depth ratio $ratio_{act\_x} = l_x / d_{x\_p} =$ **12.33**

PASS - Actual span-to-effective depth ratio is acceptable

Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.



A393+16mm bars @ 200 ctrs T1
A393+10mm bars @ 200 ctrs B1
A393+16mm bars @ 200 ctrs T1
A393+16mm bars @ 200 ctrs T2
A393+10mm bars @ 200 ctrs B2
A393+16mm bars @ 200 ctrs T2

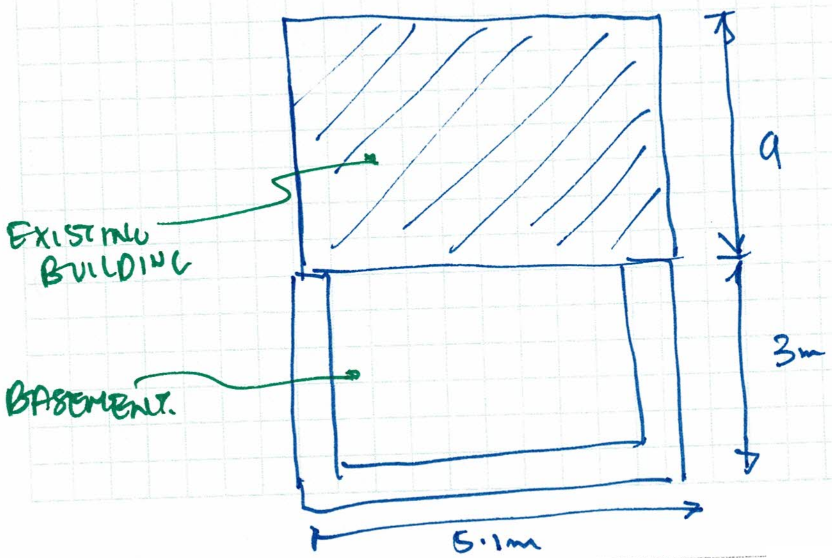
Bini Struct-e Ltd. Consulting Structural Engineers	Project: 54 Sumatra road, London, NW6 1PR		Job Ref: 11654	
	Drawing Ref	Calculations by: BD	Checked by: DB	Sheet of
	Part of Structure: HORIZONTAL MOVEMENT DUE TO EXCAVATION & INSTALLATION OF WALL.		Date: 09.2018	

HORIZONTAL & VERTICAL MOVEMENT ASSESSMENT TO CIRIA C580 FOR EMBEDDED RETAINING WALLS.

TABLE 2.4 CIRIA C580

CATEGORY OF DAMAGE	NORMAL DEGREE	LIMITING TENSILE STRAIN %
0	NEGLIGIBLE	0.00% - 0.05%
1	VERY SLIGHT	0.05% - 0.075%
2	SLIGHT	0.075% - 0.15%
3	MODERATE	0.15% - 0.3%
4 to 5	SEVERE TO VERY SEVERE	> 0.3%
5		

THE HORIZONTAL MOVEMENT WILL BE DETERMINED BASED ON ACCOMMULATION OF POTENTIAL MOVEMENT DUE TO WALL EXCAVATION & INSTALLATION.



Bini Struct-e Ltd. Consulting Structural Engineers	Project 54 Sumatra road, London, NW6 1PR		Job Ref 11654	
	Drawing Ref	Calculations by BD	Checked by DB	Sheet of
	Part of Structure HORIZONTAL MOVEMENT CONT..		Date 09.2018	

POTENTIAL MOVEMENT DUE TO WALL INSTALLATION

- HORIZONTAL SURFACE MOVEMENT = 0.05%

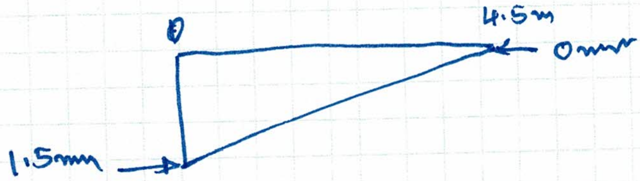
$\delta H = 0.05\% \times 3000 = 1.5mm$

- VERTICAL SURFACE MOVEMENT = 0.05%

$\delta V = 0.05\% \times 3000 = 1.5mm$

DISTANCE BEHIND WALL TO NEGLIGIBLE MOVEMENT

$lh = 3000 \times 1.5 = 4500mm$



POTENTIAL MOVEMENT DUE TO WALL EXCAVATION

HORIZONTAL SURFACE MOVEMENT = 0.15%

$\delta H = 0.15 \times 3000 = 4.5mm$

~~DISTANCE~~ VERTICAL SURFACE MOVEMENT ≃ 0.1%

$\delta V = 0.1 \times 3000 = 3mm$

DISTANCE BEHIND WALL TO NEGLIGIBLE MOVEMENT

$lh = 3000 \times 3.75 = 11250$

∴ TOTAL HORIZONTAL MOVEMENT OVER 11250mm = 6mm.

$\therefore \delta i = 6/11250 = 0.053\%$

- ∴ THE ANTICIPATED DAMAGE TO BUILDING/S IS CATEGORISED AS NEGLIGIBLE TO VERY SLIGHT CATEGORY