

PAG Associates Limited *Structural Calculations*

Consulting Civil and Structural Engineers

Red Oaks, South Lane, Nomansland, Wiltshire SP5 2BZ

Tel: 07908 126750 or 01794 399952

PROJECT: 34 LOVEDEAN LANE, WATERLOOVILLE **BY:** P GODDARD

PROJECT No: 220317-01

DATE: 9TH May 2017

Loadings

Existing and new Pitched Roof

Plain tiles	0.635 kN/m ²		
Battens and felt	0.065		
Rafters (top boom of truss)	<u>0.100</u>		
43° slope	~~0.800 (estimated slope)~~		
	1.094 kN/m ²		
Ceiling Joists	0.100		
Insulation	0.140		
Loft boarding	0.100		
<u>Plasterboard</u>	<u>0.170</u>		
	1.604 kN/m ²	x 1.4 =	2.246
Ceiling Imposed	0.250	x 1.6 =	0.400
Roof Imposed	0.750 kN/m ²	x 1.6 =	<u>1.200</u>
Totals	<u>2.604 kN/m²</u>		<u>3.846 kN/m²</u>

Existing First Floor

22mm Chipboard	0.143 kN/m ²		
Floor Joists	0.100		
Acoustic Insulation	0.040		
<u>Plasterboard</u>	<u>0.170</u>		
	0.453 kN/m ²	x 1.4 =	0.634
Floor Imposed	1.500 kN/m ²	x 1.6 =	<u>2.400</u>
Totals	<u>1.953 kN/m²</u>		<u>3.034 kN/m²</u>

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Existing External Walls

Render	0.300 kN/m ²		
External brick skin	2.200		
Internal brick skin	2.200		
Cavity insulation	0.040		
Plaster	0.240		
	4.980 kN/m ²	x 1.4 =	6.972 kN/m ²

Proposed Timber framed (t/f) external walls

Render	0.260 kN/m ²		
Backing board	0.161		
25mm battens	0.015		
12mm OSB	0.080		
Breather membrane	0.002		
95 Celotex between studs	0.040		
100x50 studs @ 600	0.045		
VCL	0.002		
Celotex PL4000 plasterboard + 37.5 insulation	0.180		
	0.785 kN/m ²	x 1.4 =	1.099 kN/m ²

New External Walls

For simplicity assume the same as above.

1. New Rafters to side extension

Clear span on angle = 4m, dead load 0.7 kN/m²

From TRADA tables, use 47x150 C24 rafters at 400mm centres, max 3.97m

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2. Ceiling Joists to the above

Clear span = 3.05 m, dead load 0.41 kN/m²

From TRADA tables, use 44x145 C24 joists at 400mm centres, max 3.27m

3. Rafters over Sitting Room

Clear span on angle = 2.32m, dead load 0.7 kN/m²

From TRADA tables, use 44x100 C24 rafters at 400mm centres, max 2.61 m

4. Ceiling Joists to Sitting Room

Clear span = 3.55 m, total load per joist = 0.76 kN/m² x 0.4m = 0.304 kN/m

Bending moment = $0.304 \times 3.65^2 / 8 + 0.9 \times 3.65 / 4 = 1.328$ kNm,

Assuming 44x145 C24 Joists at 400mm ctrs,

Tensile force due to tying action = 2.27 kN, tensile stress = 0.356 N/mm²

Applied Bending stress = 8.61 N/mm²

Allowable bending stress = $7.5 \times 1.1 \times 1.25 = 10.31$ N/mm² OK

Allowable deflection = 10.95mm

I Required = 13.65×10^6 mm⁴

I provided = 11.2×10^6 mm⁴

From TRADA tables, use 50x150 C24 joists at 400mm centres, I provided = 14×10^6 mm⁴

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5. Beam over new side opening into Extension

Clear span = 3.20 m, Design beam = 3.30m

Loadings

Outer skin

Self weight beam say $0.3 \text{ kN/m} \times 1.4 =$	0.42 kN/m
Outer skin itself $2.5 \text{ kN/m}^2 \times 1.4 \times 2.8 \text{m} =$	9.80 kN/m
New roof to extension $3.846 \text{ kN/m}^2 \times 3.5 \text{m} / 2 =$	6.73 kN/m
Total	16.95 kN/m

Bending moment (inner skin) = $16.95 \times 3.3^2 / 8 =$	23.1 kNm
Effective length = $1.4L + 2D = 4.924 \text{ say}$	4.92m
Allowable deflection = $\text{span} / 360 =$	9.2mm
Moment of Inertia required =	925cm^4

Inner skin

Self weight beam say $0.3 \text{ kN/m} \times 1.4 =$	0.42 kN/m
Inner skin $2.48 \text{ kN/m}^2 \times 1.4 \times 2.8 \text{m} =$	9.72
Existing First floor $3.034 \text{ kN/m}^2 \times 4.3 \text{m} / 2 =$	6.52
Existing roof $3.846 \text{ kN/m}^2 \times 4 \text{m} / 2 =$	7.69 kN/m
Total	24.35 kN/m (critical)

Bending moment (inner skin) = $24.35 \times 3.3^2 / 8 =$	33.15 kNm
Effective length = $1.4L + 2D = 4.924 \text{ say}$	5m
Allowable deflection = $\text{span} / 360 =$	9.2mm
Moment of Inertia required =	1329cm^4

Use 203x133 UB30 to inner skin (S355), $I_{xx} = 2896 \text{ cm}^4$, $M_b = 43.5 \text{ kNm} > 33.15 \text{ kNm}$

Use 203x102 UB23 to outer skin (S355), $I_{xx} = 2105 \text{ cm}^4$, $M_b = 23.3 \text{ kNm} > 23.1 \text{ kNm}$

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Provide 440mm long x 215mm high x 100mm thick dense concrete block padstones (min 10 N/mm²) under the bearings to both beams, in line with the beams and on the inner and outer skin.

$$F_k \text{ required under padstone} = (24.35 \times 3.3/2) \times 10^3 \times 3.5 / (1.5 \times 440 \times 100) = 2.13 \text{ N/mm}^2 \Rightarrow \text{OK}$$

6. New Ground Floor

Because of the likelihood of made ground or topsoil near the surface, provide a suspended beam and block ground floor, spanning between existing side wall and the new side wall

Clear span (Sitting Rm max) = 3.550m, use 150mm Beam and block floor with beams at 525 ctrs

7. Lintel to side and end wall of Sitting Room

Clear span = 1800mm and 2100mm, Design span 1950mm and 2250mm.

Assume 100 medium density blockwork outer and inner skin (Fenlite), 100mm cavity

Loadings (unfactored)

Swt lintel say	0.10 kN/m
Sitting Room roof $2.604 \text{ kN/m}^2 \times 4.5\text{m} / 2 =$	5.86
Masonry above say $4.98 \text{ kN/m}^2 \times 0.3\text{m} =$	1.49
<u>Total</u>	<u>7.45 kN/m</u>

From Catnic brochure, use CG90/100 lintels with 150mm bearing at each end
(use same lintel to other openings in new external walls)

8. Existing roof strut support over Rear bedroom

The intention is to move the wall between the Landing and rear bedroom to line up with the front bedroom wall. However, this wall is thought to provide support to the diagonal strutting in the roof void over, which provides intermediate support to the purlins. It is also likely to support the ceiling joists over. Therefore, provide a beam to replace these lost supports.

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Span = 4.05m

Loadings

Self weight beam say $0.3 \text{ kN/m} \times 1.4 =$ 0.42 kN/m

Point load from purlin struts say $0.75 \times 6.5 \times 4/2 \times ((1.094 \times 1.4) + 1.2) =$ 26.63 kN

Ceiling say $1.114 \text{ kN/m}^2 \times 6.5/2 =$ 3.62 kN/m

Bending moment = 35.25 kNm, Effective length $1.2L + 2D =$ 5.164m

Allowable deflection = 12.15mm

I required = 1365 cm^4

Therefore provide 152 x 152 UC30 (S275), $I_{xx} = 1748 \text{ cm}^4$, $M_b = 41 \text{ kNm}$

Provide 440mm long x 215mm high x 100mm thick dense concrete block padstones (min 10 N/mm^2) under the bearings to both beams.

This beam could be placed above the existing ceiling joists in order to support the purlin struts, and the existing ceiling joists connected it via hangers.

9. Concrete slab to new Sitting Room

Due to the presence of the Scots pine and its root protection zone, it is not possible to use trench fill foundations around the complete perimeter of the new Sitting Room.

Investigate whether it is feasible to use a reinforced concrete ground floor slab to cantilever out from trench fill foundations to support the part of the building in the RPZ $\Rightarrow$

Assuming a 200mm reinforced concrete slab, floor loadings as follows: -

250 slab	6.000 kN/m ²	
Insulation	0.040	
75 screed	1.800	
	<u>7.840 kN/m²</u> $\times 1.4 =$	10.976 kN/m ²
Imposed	1.500 kN/m ² $\times 1.6 =$	2.400 kN/m ²
	<u>9.340 kN/m²</u>	<u>13.376 kN/m²</u>

Consider spanning in simple bending between foundations, span say 3.50 m

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Bending moment = $13.376 \times 3.50^2 / 8 =$ 20.48 kNm
Effective depth = $250 - 40 - 8 =$ 202mm
K = 0.014 < 0.156 $\Rightarrow$ OK
Z = 0.95d = 192mm
As = 244 mm² / m

Basic allowable span/depth ratio = 20
Actual span/depth ration = 17 Ok

Therefore A393 mesh bottom OK for general span.

Load run downs – unfactored (factored)

Side walls

Roof say $2.604 \text{ kN/m}^2 \times 4.2 / 2 =$ 5.47 kN/m (8.08)
External t/f wall $0.785 \times 2.4 =$ 1.88 kN/m (2.64)
Total 7.35 kN/m (10.72)

End Wall

Roof say spans the other way.
External wall $0.785 \times 3.2 =$ 2.51 kN/m (3.52)

Cantilever Slab design

To avoid the need to excavate within the RPZ, and to avoid piled foundations, look at cantilevering the slab past the trench fill footing to support the end and side walls – ignore the side wall on the east side, as this has a foundation under it, and is therefore beneficial.

For a typical north-south strip of slab, cant' mom = $3.52 \times 2.023 + 13.376 \times 2.323^2 / 2 = 43.21 \text{ kNm}$

Effective depth = $250 - 25 - 8 = 217 \text{ mm}$

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$K = 0.026$, $z = 0.95d = 206$, A_s required = $479 \text{ mm}^2 \Rightarrow$ Use B1131 mesh, with main bars N-S

Edge strip

Assume loading along edge strip resisted by a width of beam of 1m wide,

Additional Load per metre run = 10.72 kN/m (factored)

Additional Bending moment = $10.72 \times 2.023^2 / 2 = 22.13 \text{ kNm}$, $d = 250 - 25 - 6 = 219 \text{ mm}$,

Total bending moment = $22.13 + 43.21 = 65.34 \text{ kNm}$

$K = 0.039$, $Z = 0.95d = 208 \text{ mm}$, $A_s = 719 \text{ mm}^2 \Rightarrow$ Use B1131 mesh top throughout.

Actual span/depth ratio = 9, allowable is 7.

$M/bd^2 = 1.362$

$F_s = 211.9$

$M_{ft} = 1.53$, modified allowable span/depth ratio = $7 \times 1.53 = 10.7 > 9$ OK

Therefore use 250mm thick C28/35 slab.

Overall stability

Taking moments about the pivot point (new foundation across Sitting Room),

Overtopping moment = 82 kNm (one half only)

Restoring moment = 142 kNm, Factor of safety = 1.73 consider Ok – this assumes backspan anchored on one side into 1.5m dp x 0.6m wide trench fill foundation. Also there will be continuity with the continuous foundation, which has been ignored but will be beneficial.

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Existing retaining wall

At the western boundary of the property, there is a 225mm thick brickwork retaining wall, which retains an approximate height of soil on this property's side of 700mm.

This wall runs the full length of the side of this house, and the whole wall has rotated along part of its length towards the neighbouring property. The gap between the top of the wall and the adjacent property varies from 110mm (where the wall is still vertical) to 40mm (where it has rotated).

This rotation is caused by the lateral soil pressure behind the wall, which is exerting a horizontal force on the wall. This has caused the wall to rotate, not by overturning, but by rotation of the foundations. If the foundations were originally not wide enough to transfer this lateral earth pressure into the underlying ground, then the ground below becomes overstressed and the foundation settles. This results in rotation of the wall, as the soil below becomes compressed.

If the wall was to be repaired, the ground behind it would need to be removed temporarily and the wall would need to be demolished down to foundation level. Also, the existing foundation would need to be replaced with a wider foundation, and the wall then rebuilt. The new wall could then be backfilled to the original ground level. This option would be time consuming and expensive.

The other more cost-effective option would be to retain the wall in its current state, but remove the cause of the rotation, which is the retained soil behind it. Once this retained soil is reduced in level, then the forces causing the wall's rotation have been removed. If the wish was to retain the level behind the wall at the current level, then this could be achieved with timber decking spanning between the top of the existing retaining wall and the new side wall of the extension. This way the void below could be bridged over.

At the front and rear of the property, this change in ground levels could be accommodated by extending the foundations to the front and rear wall of the extension out to the retaining wall, and the section in between reduced in level (see drawings for both options).

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Check existing retaining wall under current loading

Retained height approx 700mm

Assume wall backfilled with free draining granular fill, angle of shearing resistance 30°.

Coefficient of Active Pressure, $K_a = 0.333$

$$\begin{aligned}\text{Lateral earth pressure on wall} &= 0.333 \times 18 \times 0.7 = 4.196 \text{ kN/m}^2 \\ \text{Active pressure} &= 4.196 \times 0.7/2 = 1.469 \text{ kN/m run}\end{aligned}$$

$$\text{Applied Moment on stem} = 1.469 \text{ kN/m} \times 0.7/3 = \underline{0.343 \text{ kNm/m run}}$$

$$\text{Resistance Moment of stem} = (f_k x / \gamma_m + g_d) Z, f_k x = 0.4 \text{ N/mm}^2, \gamma_m = 3, g_d = 0.02 \text{ N/mm}^2$$

$$\text{Wall is 215thk, Section modulus } Z = b d^2 / 6 = 1000 \times 215^2 / 6 = 7.7 \times 10^6 \text{ mm}^3$$

$$\text{Moment of Resistance of stem} = ((0.4/3) + 0.02) \times 7.7 \times 10^6 \times 10^{-6} = \underline{1.18 \text{ kNm/m run}}$$

Therefore, applied moment is less than resistance, therefore masonry itself is not overstressed, but the foundation has failed. The foundation cannot be assessed as there is no information available to confirm its actual size and depth.

Ground conditions encountered in adjacent boreholes tend to indicate a deep level of topsoil (over 1 m) over firm to stiff clay. Assuming firm clay underlies the wall, then this would have an allowable bearing capacity of approximately 75 kN/m² – use this value to size an appropriate footing.

Assuming a 450mm wide x 300mm deep concrete foundation, eccentricity = 82mm, slightly outside middle third, max bearing pressure = 17.33 + 19 = 36.33 kN/m² < 75 ⇒ OK

$$\begin{aligned}\text{Force causing sliding} &= 2.43 \text{ kN/m run} \\ \text{Frictional force resisting} &= W \tan \phi = 7.801 \times \tan 30 = 4.5 \text{ kN/m}\end{aligned}$$

This provides a factor of safety of 1.85, which is not enough ⇒ increase base to 600x300mm thick.