Airpacks Ltd

VIKING FOUNDATIONS REPORT

REPORT ON INSULATED FOUNDATIONS

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Introduction

Tanner Structural Designs Ltd were commissioned to prepare a report on the structural capacities of the insulated foundation systems that have been developed by Seamus O'Loughlin of Viking House and are supplied by Airpacks Ltd. This report sets out the basis of design for these foundations and the capacities of the various arrangements. This report makes no comment on the types of superstructures built on top of the foundations.

The insulated foundations examined in this report are basically foundations that are built on structural-grade expanded polystyrene (EPS), thus reducing or eliminating the thermal-bridge between the structure and the ground that exists with traditional foundations. A number of arrangements have been developed to suit various superstructure types and each is examined in turn later in this report.

Basis of Design

The loadbearing elements of the insulated foundations are made from high-strength expanded polystyrene, namely EPS 300. The '300' signifies the short-term load, in kPa (or kN/m^2), that causes a 10% compression of the expanded polystyrene (EPS). However, at this level of loading, the EPS has exceeded its 'yield point', so accepted best practice is to use the 1% compression load, i.e. the load that causes the EPS to compress by 1%. The industry-accepted 1% compression load for EPS 300 is 120 kPa.

The load exerted on the top surface of the EPS 300 spreads through the EPS at an approximate angle of 45 degrees (this only holds true for shallow depths), provided the EPS 300 extends far enough beyond the concrete element on top of it. Thus the load, when transferred to the ground under the EPS, is spread over a larger area, reducing the intensity of the load.

Bearing Capacities of Soils

It is impossible to give accurate bearing capacities of soils without a proper visual and test-based assessment of the soil at any particular site. However, different soil-types generally fall into a range of bearing capacities, depending on their primary constituent. The table shown overleaf gives a range of values for the main soil types, but the soil on site should always be assessed by a qualified Engineer to confirm its likely bearing capacity, as it is unlikely to fall into just one of the main categories. Other factors that have an influence on the bearing capacity of a soil are its native stiffness/compactness and how far the foundation is above the water table level, if at all.

In no case should a building be founded on topsoil, or soil with organic matter in it, as these soils will expand and shrink with changing moisture contents and would cause the building above to move, most likely causing damage to the building. Unless there is a great depth of these types of soil, they should be excavated to non-organic soil level. Where there are great depths of these soils, other options may need to be considered, such as piling. A suitably qualified Engineer will advise on the best solution in these circumstances.

Great care also needs to be taken when building on shrinkable clays that are prevalent in parts of the UK. These clays also expand and shrink with changing moisture contents (not to the same extent as topsoils) and are greatly influenced by the presence of trees in the vicinity of a building. Foundations in these clays generally need to be taken to greater depths than normal to minimise variations in moisture content over time that will cause the clays to shrink and expand, thus causing the foundations and building to move, possibly causing damage. In some circumstances, piled foundations may be required or be the most economical way to avoid excessive movement in the foundations. Piles for lightweight structures such as houses do not need to be large, but they transfer the superimposed loads to a much greater depth, where moisture contents are practically constant and thus shrinkage and expansion of the clays is not an issue. An alternative to piling that is also worth considering is the use of Vibro Stone Columns. These are columns of stone that are vibrated into the ground, consolidating the ground around them and providing columns of highly-compacted stone that transfer the superimposed loads to greater depths, as with piles. Each option outlined here is compatible with the insulated foundation systems (with some minor modifications) discussed in this report. In shrinkable clays, a suitably qualified Engineer should be consulted to advise on the most appropriate foundation solution. Further information on shrinkable clays can be found in Building Research Establishment (BRE) Digest Nos. 240, 241 & 242.

Note: Table taken from 'Soil Mechanics' by R.F. Craig

Soil Type	*Bearing Capacity (kPa)*	*Remarks*
Dense gravel; dense sand & gravel	>600	Water table at least width of foundation (*B*) below base of foundation
Medium dense gravel; medium dense sand & gravel	200 - 600	
Loose gravel; loose sand & gravel	<200	
Compact Sand	>300	
Medium dense sand	100 – 300	
Loose sand	<100	
Very stiff boulder clays; hard clays	<100	Susceptible to long-term consolidation settlement
Stiff clays	150 – 300	
Firm clays	75 – 150	
Soft clays and silts	<75	
Very soft clays and silts	-	

Improving Bearing Capacities of Soils

A proper site investigation should be carried out to determine the soil properties at depth, as the poorest soil is not always nearest the surface, and may in fact underlie a better soil layer nearer the surface. A simple trialhole will probably suffice for many sites, but a more in-depth investigation may be necessary where ground conditions are particularly poor.

Where soils are deemed to be too weak to support the loads imposed on them, a number of options can be considered to allow them be built upon. Most options do not improve the bearing capacity of the native soil, per se, but they reduce the bearing pressure on the native soil such that loading exerted from the new building will not have an adverse effect on the native soil.

For insulated foundations, the standard depth of hardcore under the EPS is 150 – 225mm of 18 – 35mm hardcore, compacted in layers appropriate to the compaction method. The most common approach adopted where underlying soils are weak is to increase the depth of this hardcore layer. Since the load spreads as it travels downward, the deeper the hardcore, the smaller the load exerted on the underlying soil. This works because the hardcore has a predictably suitable bearing capacity to take the higher intensity bearing pressures nearer the surface. It is also strongly advised, especially in poorer ground, to lay a geotextile on the excavated surface before placing the hardcore under the insulated foundation. This layer helps to spread the loads further and also prevents fines in the underlying soil migrating into the hardcore, which would reduce the bearing capacity of the hardcore.

For very poor soils, other options may need to be considered, such as piling or other specialist ground improvement methods like Vibro Stone Columns, as discussed briefly in the previous section. It is outside the scope of this report to discuss these options further.

Another option for building a lightweight building on very soft ground has been employed previously in Scandinavia. The weight of the building is carefully calculated and then a similar weight of soil is excavated under the footprint of the building. The void is filled with EPS and the building is built on top of the EPS. In this way, there is the same net load on the underlying soil as was present prior to construction. The soil was in a state of equilibrium before construction began and should remain in such a state after construction is completed. This option requires careful consideration of loads and stability of the excavated soil, etc. and would only be used in carefully considered circumstances.

Traditional Strip Foundations

The standard foundations used for walls in this country heretofore have been concrete strip footings dug into the native soil and cast directly on the soil or on a thin blinding layer. Typical dimensions of a strip footing are 900mm wide x 300mm deep for the external walls of a two-storey house.

Typical loads from a two-storey house built with standard concrete blockwork are 45 – 55 kN/m. The resulting bearing pressure on the soil under the strip footing is 58 – 68 kPa.

Typical loads from a three-storey house built with standard concrete blockwork are 60 – 85 kN/m. The resulting bearing pressure on the soil under the strip footing is 76 – 98 kPa.

Insulated Foundations

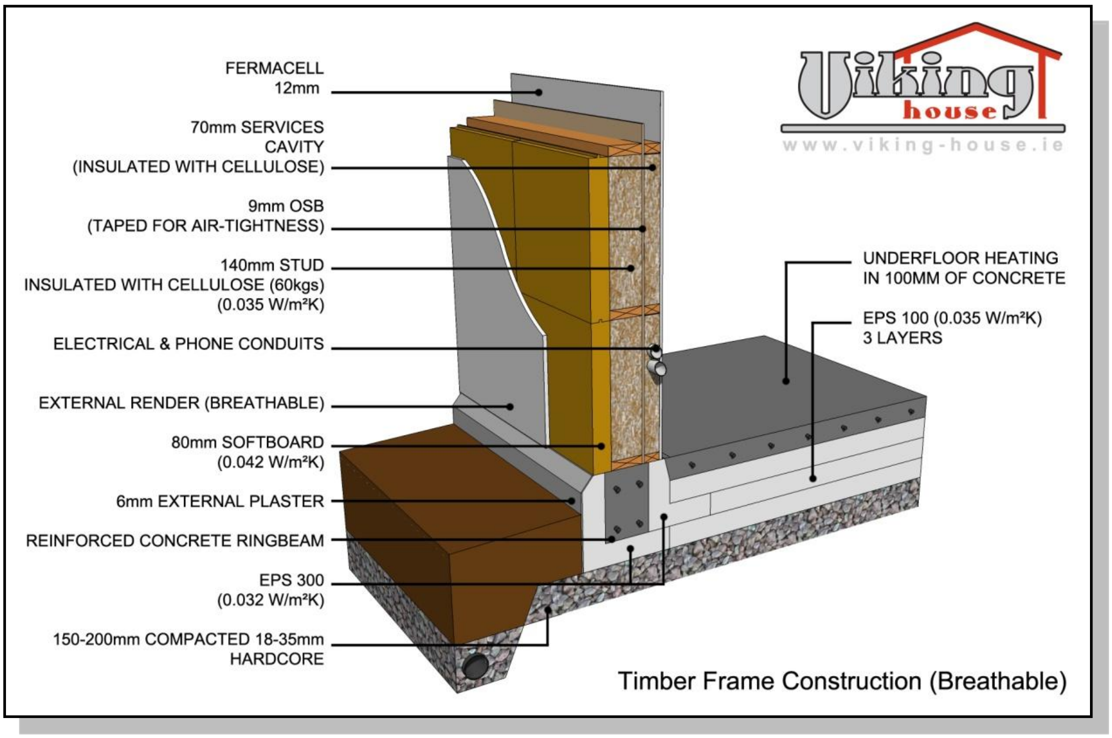
As mentioned in the Introduction, insulated foundations are built on high-strength expanded polystyrene (EPS). Various arrangements have been developed by Seamus O'Loughlin of Viking House to suit various types of superstructure. Each arrangement is examined in turn over the following pages. The foundations are generally designed to support line loads from walls. However, some points of note are discussed first below.

Drainage: All the insulated foundation arrangements shown in this report need to incorporate a land-drain around the perimeter of the building at a depth of at least 600mm below ground level to prevent frost heave in very cold weather. Frost heave can happen if water is present near the underside of the foundation; it could freeze due to the shallow depth, and because water expands when it turns to ice, it could cause the foundation above it to rise and move, possibly causing damage to the building.

Point Loads: The capacities calculated for each arrangement are for linear loads, i.e. the maximum line load that a particular arrangement can support. If there are point loads on the foundation, proper account needs to be taken of these to ensure the capacity of the EPS is not exceeded, even locally. Often there is some spare capacity in the foundation, i.e. the line load applied is not as large as the capacity of the foundation, so by using appropriate reinforcement the point load can be spread over a length of the foundation such that the capacity of the foundation is not exceeded. Where point loads are large and there is insufficient spare capacity in the foundation, other measures need to be taken, such as constructing a pad footing under the insulated foundation and connecting this to the insulated foundation such that the excess load is transferred to the pad footing and is supported directly on the ground. For internal point loads, it is usually sufficient to create a pad footing within the insulation, with EPS 300 underneath, thus avoiding the slight thermal-bridge introduced by the arrangement described above.

Reinforcement: Steel reinforcement is used in the ringbeam and floor slab to distribute loads and control cracking in the concrete. The ringbeam reinforcement usually consists of 4 no. reinforcing bars; 2 no. near the bottom of the beam and 2 no. near the top. Sometimes shear links are also used in the ringbeam, depending on the load intensities and arrangements. The floor slab incorporates a layer of steel mesh reinforcement, principally to control cracking in the slab, as the floor slab is not divided up by rising walls in the way traditional floor slabs were, and thus there is a greater risk of shrinkage across the full slab that will lead to cracking unless controlled. Where the slab is thickened to support an internal loadbearing wall or column, reinforcement bars or mesh is used near the bottom of the thickening to spread the loads over the full area of the thickening.

Arrangement No. 1:



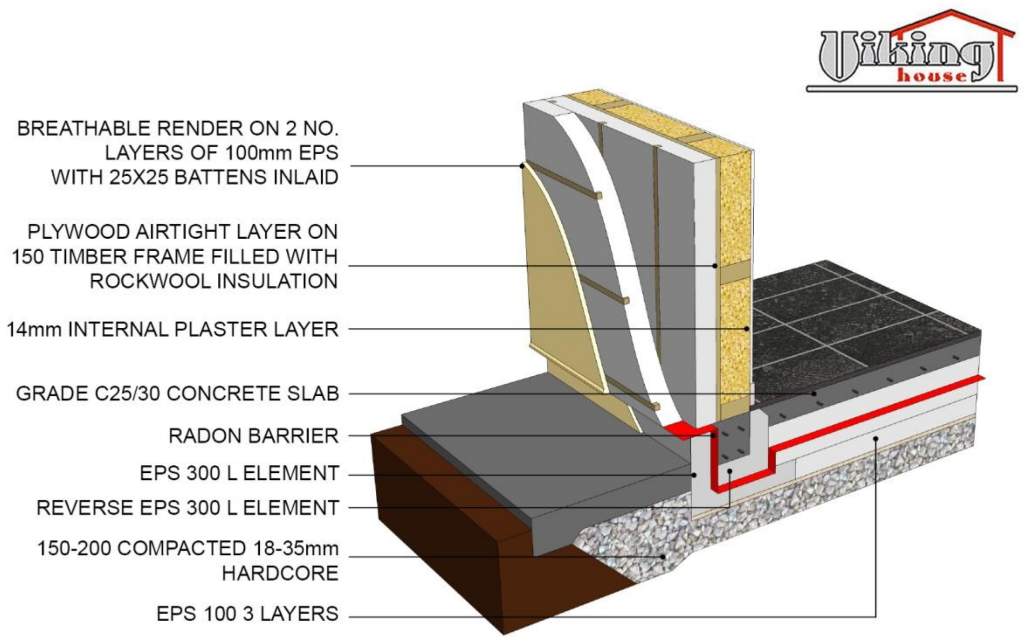
This is the most common arrangement of the Viking Insulated Foundations. The width of the ringbeam under the external wall can be varied to suit the dimensions and/or loads of the wall on top of it. The concrete ringbeam is tied to the floor slab through the EPS upstand to prevent torsion of the ringbeam, which could lead to uneven loading of the EPS 300 under the ringbeam with the associated uneven compression of the EPS.

The capacities of various widths of ringbeam and the corresponding bearing pressure exerted on the hardcore directly under the EPS are shown in the table below.

Ringbeam Width (mm)	Capacity* (kN/m)	Bearing Pressure (kPa)
150	18	52
175	21	56
200	24	60
250	30	67
300	36	72
350	42	76

* The capacities quoted are all working-load capacities.

Arrangement No. 2:

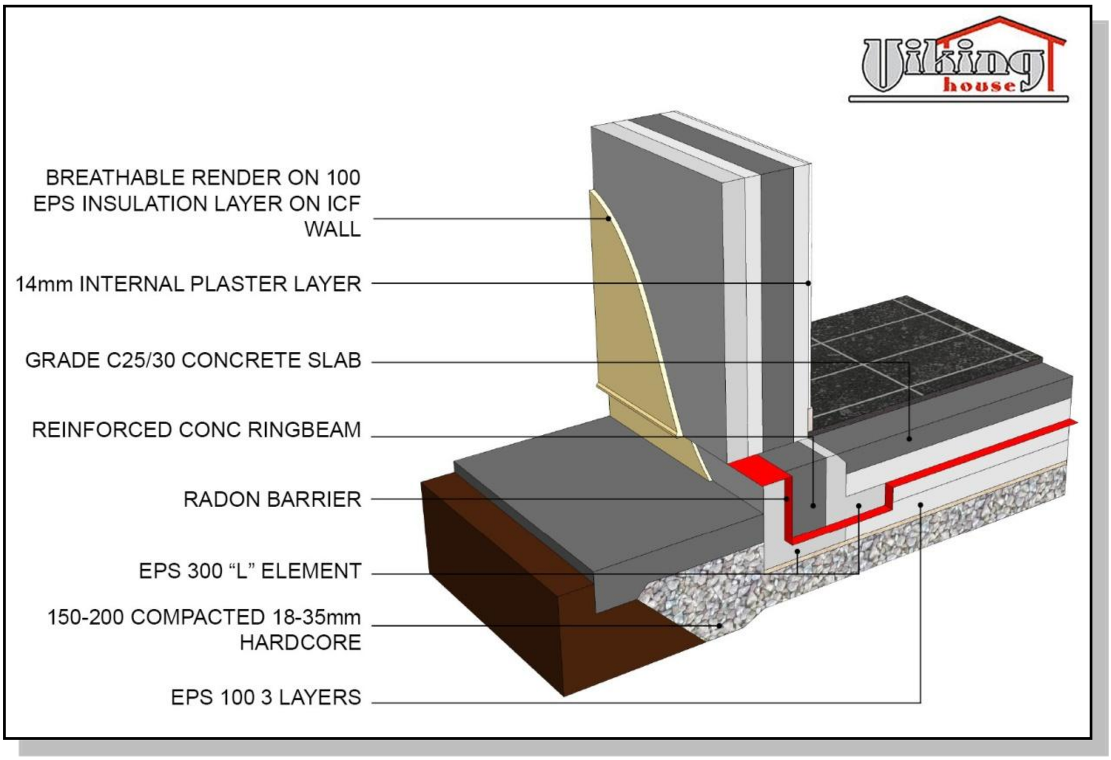


This arrangement is a variation of the previous one, with a shallower ringbeam. This is ideal for lighter superstructures such as light timber frames where the greater strength given by a deeper ringbeam is not required. This arrangement has the advantage of extra insulation under the ringbeam, which obviously means less heat loss, but it also spreads the load further before it is transferred to the hardcore under the EPS. Again the ringbeam is tied to the floor slab to prevent torsion of the ringbeam.

A range of capacities and bearing pressures are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150	18	40
175	21	44
200	24	48
250	30	55

Arrangement No. 3:

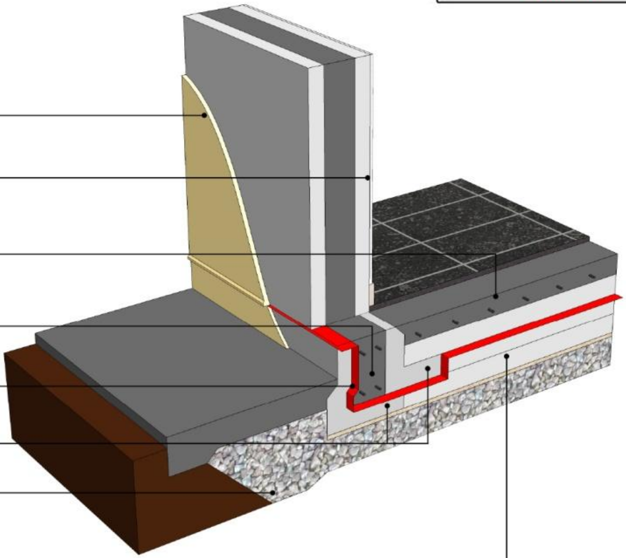


This is an almost identical detail to Arrangement No. 1. This detail is designed for an Insulated Concrete Formwork (ICF) superstructure.

A range of capacities and bearing pressures are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150	18	52
175	21	56
200	24	60
250	30	67

Arrangement No. 4:

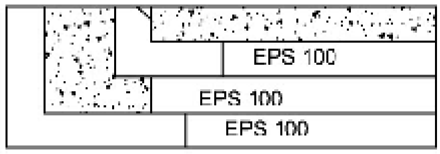


The shape of the ringbeam produced by this arrangement is designed to increase the capacity of the ringbeam. Sometimes it is necessary to keep the top of the ringbeam narrow to give a proper plinth detail, but if the ringbeam is restricted to this width, the loadbearing capacity may not be sufficient to support the superstructure. By widening the base of the ringbeam, the loadbearing capacity is increased. As per the previous arrangements, the ringbeam is tied to the floor slab to prevent torsion of the ringbeam.

This arrangement is intended for use with an ICF superstructure and is manufactured in one width only. The capacity and bearing pressure for this arrangement are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150 @ Top 200 @ Bottom	24	60

Arrangement No. 4A:

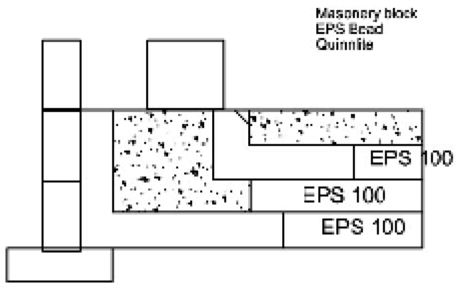


This arrangement is a variation of the above arrangement that increases the width of the base of the ringbeam to effectively increase the capacity of the ringbeam by spreading the load in the ringbeam over a larger width. The concrete needs to be carefully vibrated into the ringbeam form to ensure the concrete extends fully into the 'toe' and can thus spread the load effectively.

A range of capacities and bearing pressures are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150 @ Top, 250 @ Bottom	30	67
175 @ Top, 275 @ Bottom	33	70
200 @ Top, 300 @ Bottom	36	72

Arrangement No. 4B:



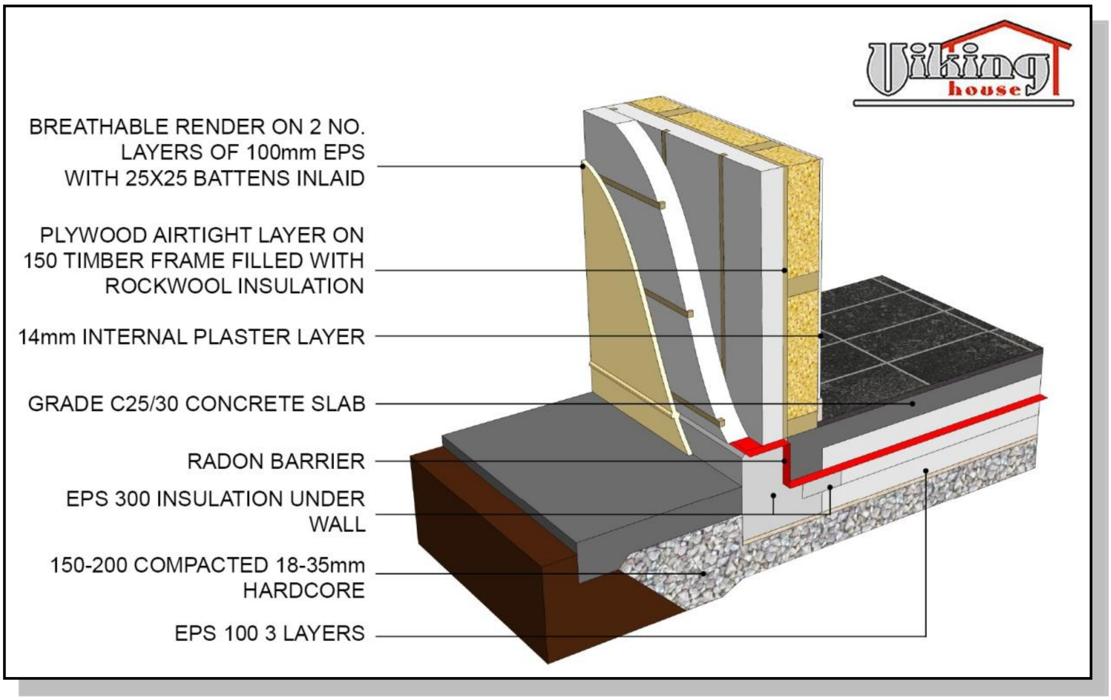
This arrangement is a further variation of the ringbeam with a widened base. This arrangement incorporates a separate strip footing to support an external leaf of blockwork/brickwork. The strip footing should support the blockwork/brickwork only and all other loads, such as roof and floor loads, should be supported by the inner leaf. Again, careful vibration of the concrete in the ringbeam is required to ensure the concrete extends fully into the 'toe'.

For reasonable ground conditions, a 600mm wide strip footing is suitable support up to two storeys of blockwork/brickwork and a gable. There is some potential for differential movement between the outer and inner leaves of blockwork in this arrangement, but this movement should be small and can accommodated by the wall-ties.

A range of capacities and bearing pressures for the ringbeam are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
200 @ Top, 300 @ Bottom	36	72
250 @ Top, 350 @ Bottom	42	76
300 @ Top, 400 @ Bottom	48	80

Arrangement No. 5:



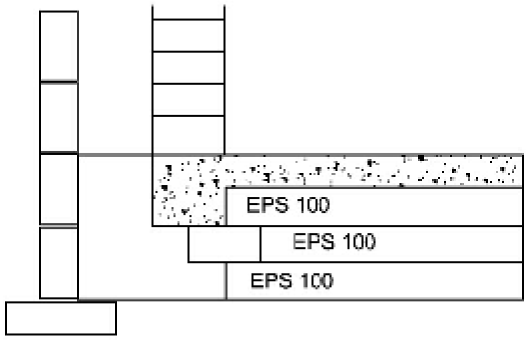
This arrangement is more like a raft slab and can be designed as such if required. The ringbeam and the floor slab are monolithic, with a thick EPS upstand at the outer edge of the ringbeam. This arrangement is suitable for superstructures with a large thickness of external insulation and also for ground conditions that dictate the need for a raft slab.

Where a raft slab is required, a gridwork of extra reinforced ribs can be introduced into the slab by leaving gaps between the top-layer sheets of EPS. These ribs will make the slab more rigid and spread the full building load more effectively over the whole slab area. As with all the arrangements discussed here, this should be designed by a suitably qualified Engineer.

Where this arrangement is not utilized as a raft slab, the capacities and bearing pressures for the ringbeam are given below.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150	18	45
200	24	60

Arrangement No. 5A:



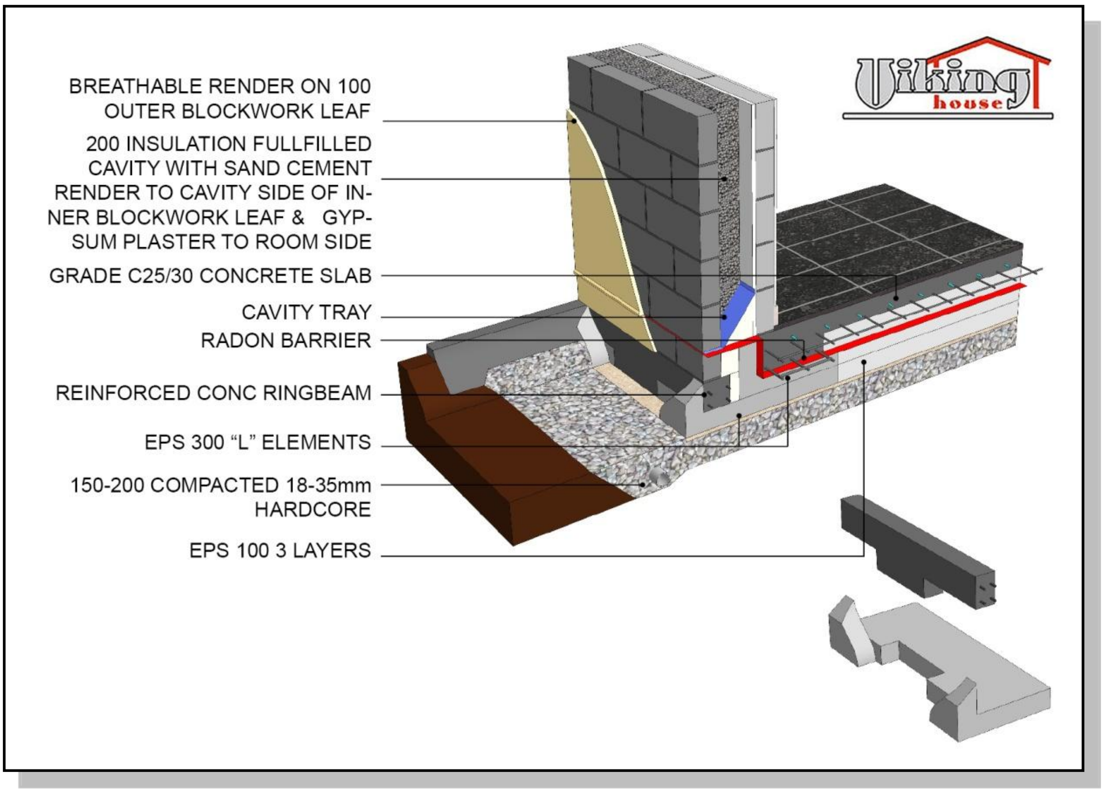
This is a variation of the above arrangement, with the addition of a small strip footing to support an external leaf of blockwork/brickwork. This strip footing should only carry the self-weight of the wall. Therefore all other loads such as roof and floor loads should be supported on the inner leaf, which sits on the ringbeam.

For reasonable ground conditions, the strip footing should be min. 600mm wide to support a two-storey high single-leaf blockwork/brickwork wall. The potential for differential movement between the outer and inner leaves of blockwork is as per Arrangement No. 4B.

The capacity and bearing pressure for the ringbeam are exactly as they were for the above arrangement.

Ringbeam Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
150	18	45
200	24	60

Arrangement No. 6:



This arrangement is primarily designed to support a traditional blockwork cavity wall, but is also used for timber-frame structures with a masonry external leaf. The internal leaf, with floor and roof loads, is supported on a ringbeam at the edge of the slab. Appropriate reinforcement needs to be incorporated into the slab at this location.

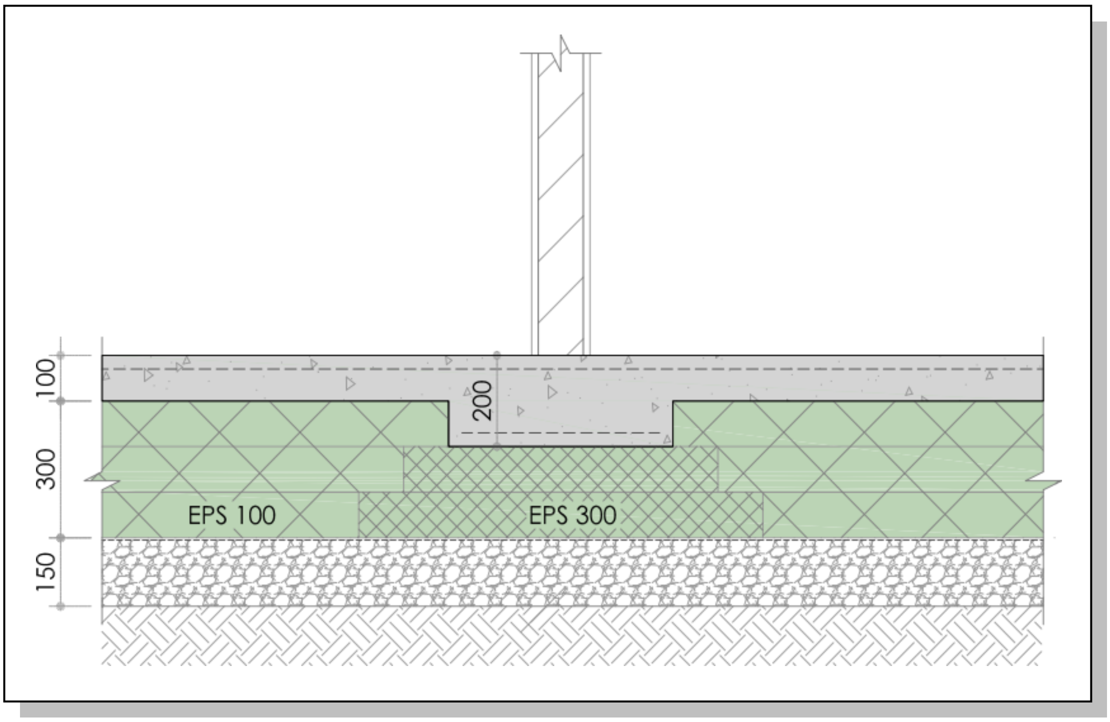
The outer ringbeam is designed to span between cut-outs in the EPS formwork that allow the ringbeam bear directly on the compacted hardcore underneath. In this instance the EPS is acting more as a formwork that minimises the use of concrete, and allows the full foundation and slab to be poured in a single pour. The outer ringbeam is not tied into the floor slab, but this is not a big issue because the ringbeam is supported by the hardcore, which is not as susceptible to creep deflection/compression like the EPS is. The potential for differential movement between the blockwork leaves is the same as for Arrangement No. 4B.

The load capacities for the ringbeam given for Arrangement No. 5 apply to the inner leaf.

The table below gives the height of standard 100mm blockwork/brickwork that can be supported on various widths of the outer ringbeam. The range allows for variation in the hardcore bearing capacity. The blockwork should be centred on the ringbeam to minimise any torsion on the ringbeam.

Ringbeam Width (mm)	Height of Blockwork (m)
100	5.5 – 6.9
150	8.3 – 10.4
175	9.7 – 12.1

Arrangement No. 7:



This is the typical arrangement for internal loadbearing walls. The width of the thickened portion of the floor slab can be adjusted to support larger line loads. The concrete needs to be suitably reinforced to adequately spread the load. The 2 no. layers of EPS 300 under the internal wall are made progressively wider than the thickening to allow the load to spread properly.

Capacities and bearing pressures for a few common widths of thickening are given below, but the width can be made as wide as necessary provided it is adequately reinforced and the bearing capacity of the EPS 300 (and ground under the foundation) is not exceeded.

Thickening Width (mm)	Capacity (kN/m)	Bearing Pressure (kPa)
300	36	60
400	48	70
600	72	80

Insulated Foundations vs. Traditional Strip Foundations

From a heat-loss point-of-view, an insulated foundation is obviously better than a traditional strip footing, and the thermal performance of each is not discussed in this report.

In general, for housing in Ireland, strip footing design has been done using rules-of-thumb that often fail to take into account special load cases or ground conditions. In contrast, an insulated foundation makes much more efficient use of concrete and so each foundation needs to be engineered, taking into account the complete loading pattern from the superstructure and sizing the elements accordingly. This is probably the principle reason why there are, relatively speaking, many more failures of strip footing foundations than insulated foundations. If strip footings were fully engineered there would probably be fewer failures.

Insulated foundations sometimes need to incorporate strip footings under them in special circumstances, such as very high loads or where the surrounding ground is a lot lower that the floor level and a depth of 'deadwork' is visible. In these circumstances the strip footing and deadwork are constructed and the fill is placed up to the top of the deadwork. The insulated foundation EPS formwork is then placed on top of the deadwork and sections of the base of the formwork are removed at intervals to allow the ringbeam bear on the deadwork and thus transfer the loads down through the deadwork and strip footing to the soil. These strip footings should be engineered as part of the insulated foundation calculations.

