Appendix A15.2: Shierglas Farmhouse Structural Overview

1 Executive Summary

1.1.1 The Shierglas Farmhouse dates from 1728 and is a Category B Listed building (Historic Environment Scotland LB6039). It is located adjacent to the existing A9 trunk road near Blair Atholl, north of Pitlochry. Adjacent to the farmhouse is one of the largest limestone quarries in Scotland. The proposed scheme shall require construction works to be carried out in relatively close proximity, approximately 25m from the farmhouse.

1.1.2 Following an inspection by Jacobs UK Ltd in June 2016, the farmhouse was considered unsafe, structurally unsound and at risk of further collapse. Therefore, the building structure of the farmhouse shall be potentially susceptible to vibration generated by construction plant whilst constructing the proposed scheme.

1.1.3 As the structural robustness of the farmhouse is in question, temporary or long-term propping has been ruled out on the grounds of safety, resulting in a minimisation of vibrations with frequent monitoring being assessed as the most practical approach.

1.1.4 From a safety perspective demolition and if necessary re-building the structure should be considered. The building is in a significant state of disrepair and even minimal vibration may cause further deterioration of the structure.

2 Introduction

2.1.1 Jacobs UK Ltd acting under the instruction of Transport Scotland was requested to visit Shierglas Farmhouse, off the existing A9 near Blair Atholl. The purpose of the visit was to review and assess the existing structural condition of the two storey Category B Listed farmhouse building with the associated single storey portion to the rear. Ron Gilchrist of Jacobs attended site 4 June 2016, accompanied by an archaeologist who was carrying out his own assessment of the site.

2.1.2 The Shierglas Farmhouse was constructed circa 1728 as dated from the “wedding lintol” over the main front door entrance. The property is in a poor state of repair and has been vacant for a number of years. The west gable of the two storey farmhouse has collapsed and the single storey part to the rear is simply a shell with no roof. Buildings of this age and traditional construction methods are not usually more susceptible to vibration than their modern equivalents. With the larger mass of their walls and floors they can be better able to dampen resonance from vibration. In the case of the Shierglas Farmhouse this can no longer be applied due to its poor condition, degradation and historical collapses.

2.1.3 This report aims to assess the likely impact of construction operations, predominantly those that propagate vibration on the farmhouse structure. There are a number of variables and unknowns that have the potential to introduce errors to any attempt at theoretical assessment of the vibration forces transfer to the structure and the ability of the structure to resist these. Therefore, a conservative assessment has been made based upon previous published guidance and common practice which has largely been developed out of piling operations.

3 Observations and Review

3.1.1 The Category B Listed building forming the subject of this report is a vacant domestic dwelling which has been neglected for decades and is now in a derelict and ruinous state of repair.

3.1.2 The building dates from 1728 and is of traditional construction with random rubble external walls. The main part of the property is two storeys with a single storey return to the rear. The single storey section of the building is a roofless shell. The west gable to the two storey part has collapsed some time ago. The ground falls away steeply from this gable down to the access track and there is an assumed culverted water course or drainage ditch between the building and access track.

3.1.3 The internal first floor structure of the building, formed with timber joists, has partially collapsed as has the ceiling over the first floor with joists slipping out of their bearing pockets to the walls. All the timber elements within the farmhouse appear rotten and in various stages of decay depending on their exposure to the elements.

3.1.4 There are numerous holes through the roof permitting water ingress, large settlement cracking to various points of the external masonry walls and the remaining two chimneys are in a poor condition and leaning. A remedial steel corner tie appears to have been installed at some point to address movement to the walls in what would have been the kitchen. It is unclear when this was installed but it is thought to have been some time ago.

3.1.5 It is noted on historic regional council inspection records that the structure has deteriorated rapidly over the last decade and that blasting from the limestone quarry adjacent to the building was a contributing factor. One such inspection report from 2014 states that the pace of the decay has appeared to slow following the loss of the west gable wall.

3.1.6 The foundations to a building of this age are likely to be simple and comprise of large stones laid directly onto virgin soil. The foundations to the farmhouse are suspected to be very shallow at only around 300mm below ground level. The shallow depth of the foundations not only leaves them susceptible to environmental factors such as frost heave, but also external factors such as accidental undermining though excavations. It was noted that an access track has been cut along the rear of the farmhouse to access an open fronted barn. This access track has resulted in a short but steep batter from the farmhouse down to the access track.

3.1.7 Record photographs of the farmhouse and environs can be found in Section 9.

4 Proposed A9 Development

4.1.1 The current design for the proposed scheme adjacent to the Shierglas Farmhouse is to construct the new carriageway online, largely over the existing pavement. In order to limit the encroachment of earthworks towards Shierglas Farmhouse a 0.5m high retaining wall is proposed to skirt a short section of the proposed road curtilage, around 25m from the farmhouse.

4.1.2 The proposed formation of the new dual carriageway shall largely consist of earthworks and pavement installation. Vibrating compaction of formation and engineered fill below parts of new carriageway is assumed to be the most significant source of construction vibration.

5 Existing Factor Classification

5.1.1 With reference to BS ISO 4866:2010(E) the following assessment was carried out to estimate the Shierglas Farmhouse resistance to vibration and its building class as indicated in Diagram 1 below. The following parameters were considered in accordance with the guidance:

- Category of Structure (ascertained form Table B.1) = 8.
- Ruins and near ruins and other buildings all in a delicate state. All class 7 constructions of historical importance.
- Foundation Class (as per clause B.5) = Class C: Class includes large stone footings & no foundations – walls directly built on soil.
- Type of Soil (as per clause B.6) = Type e: Loose non-cohesive solid (sands, gravels, boulders), soft cohesive soils (clays) organic soil (peat).

Diagram 1: BS ISO 4866:2010(E) Table B.2 Classification of buildings according to their resistance to vibrations and the tolerance that can be accepted for vibrational effects

Class of building[a]		Category of structure (see Table B.1)							
		1	2	3	4	5	6	7	8
		Categories of foundations (upper case letter) and types of soil (lower case letter) (see B.5 and B.6)							
← Level of acceptable vibration decreasing	1	A a							
	2	A b	A a	A a	A a				
	3		A b B a	A b B a	A b	A a A b			
	4		A c B b	B b	A c	A c B a B b			
	5		B c	A c		B c	B a		
	6		A f		A d	B d	B b C a	B a	
	7			A f	A e	B e	B c C b	B b C a	
	8						B e C c	B c C b	
	9		B f				C d	B d C c	A a
	10			B f			C e	B e C d	A b
	11				C f	C f		C e	B a
	12						C f		B c C a
	13							C f	B d C b C c
	14								C d C e C f

[a] High class number = high degree of protection required

5.1.2 The documented guidance confirms the expectation that Shierglas Farmhouse has a low tolerance of groundborne vibration due to its current condition, foundation construction and soil conditions. As the table states, a high class number signifies that the building shall require a high level of protection.

6 Construction Vibration

6.1.1 There are a number of variable factors which shall affect the level of vibration that shall be experienced by the farmhouse during the planned construction works; type of plant and construction methods to be used, existing ground conditions and the foundation construction of the farmhouse.

6.1.2 From borehole investigation carried out in the area of the farmhouse, it appears that the ground conditions are formed of gravelly clays with silty fines and occasional cobbles, so the use of a rock breaker/pecker is not envisaged. Therefore, the most significant source of vibration is likely to be vibrating compaction rollers and tracked plant.

6.1.3 There is usually a tendency to specify an upper limit of manmade vibration to be experienced by an existing building in an attempt to prevent cosmetic & structural damage to a building. BS 7385-2:1993 provides vibration guide values which are stated in the case of transient vibrations, to limit cosmetic damage. The values are shown in Diagram 2 below.

Diagram 2: BS 7385-2:1993 Table 1, Transient vibration guide values for cosmetic damage

Line (see Figure 1)	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commerical type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTE 1 Values referred to are at the base of the building (see **6.3**).

NOTE 2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

6.1.4 In the case of Shierglas Farmhouse, partial structural collapse and the damage from long term dilapidation has already occurred. The poor condition and unstable nature of the building structure represents a significant issue in as far as quantifying the level of vibration it could potentially withstand. In addition, vibrations from a vibrating roller should be treated as a continuous vibration source and not as transient due to the duration of excitation the farmhouse shall experience from their operation.

6.1.5 A continuous vibration source does not permit sufficient intervals between vibration events to permit the amplitude to diminish to an insignificant level, potentially allowing resonance to occur. It is also recognised that the vibrations emitted by plant are greater during start up and shut down then when the plant is running effectively in its normal cyclical operation.

6.1.6 Guidance on a conservative piling operation threshold for minor and cosmetic damage is given by *BRE Digest 403 – Damage to Structures from ground-borne vibrations*, where it derives threshold values for a 10-50 Hz frequency range from BS 5228: Part 4, which is now withdrawn. The threshold values also take cognisance of a continuous vibration event on structures with apparent significant structural defects. These threshold values are shown in Diagram 3 below.

Diagram 3: BRE Digest 403 Table 1, Peak particle velocities which provide conservative thresholds for minor damaged from piling operations. (Derived from BS 5228: Part 4 and applicable to a frequency range 10 - 50 Hz)

Status	Intermittent mm/s	Continuous mm/s
Soundly constructed residential property and similar property in good repair	10	5
Structures where preliminary surveys reveal existing significant defects of a structural nature	Reduction of the above values by up to 50%	
Light and flexible structures for commercial and industrial use	20	10
Heavy and stiff structures for commercial and industrial use	30	15

At low frequencies (below 10 Hz), large displacements and associated large strains necessitate lower ppv values (50% lower).

At high frequencies (above 50 Hz), much smaller strains allow the ppv limits to be increased (100% higher).

6.1.7 Assuming that the proposed plant on the site adjacent to Shierglas Farmhouse shall operate within the frequency range of 10 - 50 Hz, it can be read that a conservative threshold value of 2.5mm/s at foundation level should be unlikely to result in further significant damage to the existing dilapidated farmhouse. However, given the current condition of the farmhouse structure this cannot be guaranteed.

6.1.8 Propping of the structure with raking shores and internal struts could have been an option to arrest the structural dilapidation of the farmhouse but this opportunity has been missed and the current condition of the building is unsafe and unpredictable. Shoring works would require operatives to be working within close quarters to the building and internally, excavating rubble to form level/firm bearing points for the shoring and applying loads to the largely unrestrained walls via the props and struts. Therefore, shoring works have been discounted as being feasible at this time.

6.1.9 The most suitable approach is to be limiting the level of mechanical vibration and shock experienced by the farmhouse structure from construction works. The exact level of vibration generated by the construction plant is unknown at this time. Various types of vibrating plant may be used over the site and the ground conditions shall vary. Citing the example values of structural responses given in ISO 4866:2010, petrol vibrating plant operating at a frequency of 26Hz produced an amplitude of 6.1mm/s at a distance of 6.5m. No details of the amplitude at source or ground conditions/damping are supplied to review the vibration dissipation rate. It is assumed at distances similar to that between the proposed scheme and the farmhouse (25m) that the excitation level shall be below the conservative threshold of 2.5mm/s. Assessment of the plant to be used, along with on-site testing and monitoring shall be required to confirm this.

7 External Factors

7.1.1 Whilst the project can look to reduce the mechanical vibrations and shock it generates at the Shierglas Farmhouse section of the proposed scheme by carefully selecting construction methods and plant, there shall remain factors out with the control of the project.

7.1.2 As noted previously, the farmhouse is located adjacent to one of the largest functioning limestone quarries in Scotland. It is understood that blasting operations are still frequently undertaken on the site. Again citing the example structural response values given within ISO 4866:2010, quarry blasting can generate an amplitude in the region of 3.7mm/s at a distance of 200m from the blasting face. Consideration of the quarry operations shall be required.

7.1.3 The effects of vibration generated by road traffic using the existing A9 during the works will need to be considered also. The frequency and amplitude propagated by the traffic shall vary but the influence from the road traffic may affect the overall resonance at the farmhouse structure during construction works. Again site testing and monitoring shall be required to confirm the level of vibration from the road traffic.

8 Conclusion

8.1.1 The condition of the existing Category B Listed Shierglas Farmhouse is extremely poor, dilapidated and it has suffered the collapse of its west gable, areas of internal floors and part of its roof. This structure in its current condition is unsafe and has lost much of its robustness and stability. The building should be fenced off to prevent unauthorised access and to provide a safe exclusion distance around the building in the order of 1.5 times the height of the building. Exposing the farmhouse structure to any significant degree of mechanical vibration and resonance would be undesirable and the structure requires a high degree of protection.

8.1.2 Temporary propping of the building was ruled out due to the unstable nature of the building structure and desire to avoid placing operatives in a high risk environment. It would be more likely the propping would have to be long term as its removal without remedial works on the farmhouse structure could result in areas collapsing once the support is removed.

8.1.3 There are multiple variables to be considered such as the plant to be used, ground conditions, external factors, unknown foundation construction and their current condition. Considering the

variables and their potential impact on the propagation of vibration on the site, the most practical approach would be to minimise vibrations generated on site and apply a conservative threshold based on previous guidance and common practice. The threshold believed to be most appropriate is 2.5mm/s at the Shierglas Farmhouse foundations in the frequency range of 10 to 50Hz.

8.1.4 Reducing mechanical vibrations on site to their lowest feasible levels should be the preferred approach, omitting vibrating compaction plant in favour of alternatives where possible.

8.1.5 Prior to the works beginning in earnest, a dilapidation survey with record photographs of Shierglas Farmhouse and surrounding buildings should be undertaken. Vibration monitoring transducers should be installed around the farmhouse in locations advised by a specialist and a base log of vibration information gathered. These transducers should also be used to monitor vibration and ensure works remain below the threshold.

8.1.6 It would be advisable to install survey retro reflective targets on areas of the building if it is safe to do so, to record the current verticality at the corners and areas thought to be at significant risk, such as the chimneys. These locations should also be monitored frequently throughout the works for indications of potential movement.

8.1.7 Limiting the potential influence of external factors such as the quarry works and the road traffic should be addressed by obtaining blasting schedules from the quarry operator and ceasing works prior to the blasting. If the vibration from road traffic is found to be an issue, it could possibly be addressed by lowering the speed limit and preventing sources of increased vibration propagation from ramps, potholes, changes in the road surface level and avoiding the use of road plates to temporarily cover excavations.

8.1.8 Should reducing the vibration experienced by the farmhouse become incongruous with the works it may be necessary to consider other methods of isolating the farmhouse from the construction works such as a cut-off trench. The formation and eventual back-filling of a deep cut off trench has its own issues in as far as vibration is concerned. Cut off trenches usually require filling with bentonite slurry as they are not self-supporting and they are not effective in all conditions. The topography of the site does not appear favourable to this solution. Further guidance from a specialist geotechnical engineer would be required.

9 Record Photographs

Photograph 1: Access track to farmhouse

Photograph 2: Collapsed gable end

Photograph 3: Ground levels reduced to form track

Photograph 4: Open sided barn

Photograph 5: Batter from farmhouse to access track

Photograph 6: General view on farmhouse from west