

Earthship Fife
– Building Control and Monitoring Issues

Final Report



Gaia Research

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1.0 Introduction

1.1 Overview of SCI Scotland and the Earthship Fife

(This document is intended for use by SCI Scotland and as such no explanation is given regarding the Earthship concept and wider environmental aspects)

- 1.1.1 Earthship Fife is the first Earthship to be built in the UK (a second project has recently begun in Brighton, England) and as such has an important role to play in testing the compatibility of the current Technical Standards with an innovative construction method driven by sustainability.
- 1.1.2 The stated purpose of building the demonstration building is threefold:
to demonstrate the Earthship Concept in the UK and Scotland
to pave the way for future applications for Earthship Dwellings in other areas of Scotland
to provide data from monitoring the performance of the Earthship in the Scottish Climate over 3 years.
- 1.1.3 The Earthship has been built – largely with volunteer labour and a high proportion of donated or sponsored materials - over the preceding two years or so having gained Planning Permission and a Temporary Building Warrant Approval from Fife Council.

1.2 Earthship Fife and Building Warrant – the Current Situation

- 1.2.1 Earthship Fife has been classified by Building Control Fife as an experimental office building and granted a limited life warrant of 5 years. This temporary warrant was given because Building Control Fife were not able to be convinced about a number of issues pertaining to the Earthship design, both specifically, and generically.
- 1.2.2 These issues are:

Daylighting	Flat Roof Construction
Tyre Walls	Can / Concrete Walls
- 1.2.3 Additional Issues which require to be addressed, if the Design Concept is to be promoted on a wider basis are:

Ventilation	Heating
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- 1.2.4 For the purposes of this study, these issues may be divided into two types; those where it was felt by Building Control Fife that the submitted details were specifically *not acceptable* in relation to the Technical Standards, and those where there was *concern* as to the suitability / durability of certain details, and no evidence to support the use of these details.
- 1.2.5 Subsequently, two routes emerged to deal with the issues raised. The first is to deal with the specific detail concerns such as daylighting, flat roof details and others. The other is to undertake either monitoring, or further study to include an assessment of other monitoring worldwide, so as to be able to offer evidence that would support the use of cans and tyres underground and hopefully quell the legitimate concerns of Building Control.
- 1.2.6 It may be hoped that all issues and concerns can be resolved to the satisfaction of Building Control Fife such that the Earthship may be granted a permanent warrant. Gaia Research did not undertake to attempt to resolve any of these concerns specifically, but have made brief comments based on initial discussions and consideration of the details concerned.
- 1.2.7 Beyond this however, SCI Scotland wish to demonstrate the generic suitability of the Earthship concept so that it could be used without prejudice throughout Scotland and the UK as one example of a sustainable construction type for dwellings in particular. To this end, they wish to pursue the idea of attaining 'Type Approval' for the Earthship design. SCI Scotland have asked Gaia to investigate this route with recommendations as how best to proceed. This is covered in section 3.8.

2.0 Brief

2.1 Brief

- 2.1.1 A series of discussions took place between Paula Cowie of SCI Scotland and Sandy Halliday and Chris Morgan of Gaia Research. Whilst there was a general consensus on what appeared to be needed, it took some time to establish what could realistically be achieved in one day, and the best way to use the specific expertise of Gaia to best effect given the range of issues needing attention.
- 2.1.2 It was agreed that Gaia would concentrate on two particular aspects.
- 2.1.3 The first was the issue of pursuing 'Type Approval' from Building Control for the Earthship concept and establishing exactly what was required in order to achieve this.
- 2.1.4 The second was to further investigate the issue of monitoring and advise on the most effective issues upon which to concentrate and how these could be quantitatively established.
- 2.1.5 In addition Gaia would comment on the specific Building Control queries if there was time but that this was not a priority for this study.
- 2.1.6 The above relate to SCI Scotland's stated requirements of:
 - a) "advice on how to achieve our aims of establishing a system for future Earthship applications as permanent buildings, both residential and non-residential, and
 - b) design advice on how to monitor the performance of the Earthship in the Scottish climate over 3 years."

3.0 Considerations

3.1 Daylighting

- 3.1.1 Concern about daylighting centres around the internal glass screen not being recognised as allowing the necessary amount of light through to the 'living' space. This is simply an anomaly and should be able to ironed out with Building Control as a limitation of definition on their part.
- 3.1.2 By mounting light sensors at the rear of the building, it would be possible to use the monitoring to show that adequate daylight reaches the rear of the building throughout the year. However, this seems a waste of money and effort when it really is a case of persuading Building Control to see sense in this case.

3.2 Unconventional Flat Roof Construction

- 3.2.1 The flat roof construction, as understood from the drawings and specification sent to Gaia, is strange. It does not use the depth of the cavity created by the deep TJI beams to create a highly insulated roof, as might be expected, nor is it a 'breathing' construction, which might also be expected given that no other external surface is able to offer this valuable function for moisture control. Presumably the lack of more insulation within the beams is a cost issue, and the presence of the polyurethane above is to overcome 'cold bridging' by the beams themselves. All in all it appears ill-conceived and could have been simpler, much cheaper, better environmentally, health-wise and technically superior.
- 3.2.2 Having said this, the presence of the vapour barrier means that, in theory, interstitial condensation cannot occur within the roof construction and for this reason we are unclear as to why this appears to be a concern of Building Control Fife.
- 3.2.3 Has the vapour barrier been conscientiously applied across the whole roof? Equally, it is not clear from the drawings how vapour is prevented from entering the roof from around its perimeter and junctions with walls, internal glazing etc. and this again may give rise to legitimate concern. Lack of clarity and certainty on these two points may explain the concern. For the sake of the building, any problems here should be immediately rectified before the colder months.

3.3 Tyre Walls

- 3.3.1 As noted by SCI Scotland the concerns expressed by Building Control Fife in regard to the use of tyres were: durability of tyres, fire resistance, moisture and the use of tyres in contaminated land. Concerns have also been raised about the potential for tyres to leach hazardous chemicals to the ground and groundwater.
- 3.3.2 While tyres are combustible, they are coated in thick layers of non-combustible earth plaster in Earthship design and so this should not cause any problems. The only limitation to their use would be in fire escapes or other areas requiring completely non-combustible materials. Such areas are limited, especially in domestic designs and so this should not offer any obstacles to the authorities.
- 3.3.3 Since the tyres used in Earthships are contained within the overall waterproof membrane which encases the main structure, the potential for tyres used in Earthships to leach contaminants to the surrounding ground is essentially zero. This equally reduces the risk of potential contaminated land affecting the overall durability of tyres, since they are not exposed to contaminated soil, except any that is enclosed within the waterproof membrane, which can be checked if there is cause for concern.
- 3.3.4 Further information regarding the hazards associated with tyres in the soil are reproduced in the box below, but such considerations are largely redundant given the relative isolation of tyres from surrounding soil and groundwater flows. In addition, according to the Used Tyre Working Group (UTWG) Website (www.tyredisposal.co.uk), tyres are not classified as hazardous waste, so we have not investigated the issue further and presume the issue can be relatively simply resolved with Building Control or Type Approval Officials in due course.

The following words in italic have been sourced from the Earthship website: www.earthship.org regarding information on the potential leachate associated with tyre disposal.

*"From: New Mexico Environmental Department - Solid Waste Bureau
re: University of Wisconsin Study*

"Rather than trying to pull out specific parts of the study that could be used to let people know that scrap tires are not a problem with respect to out-gassing, I decided to have a copy made of the whole report and send it to you. You can use whatever information in the report you choose." The title of the report is "Use of Scrap Tires in Civil and Environmental Construction" May 10, 1995. Environmental Geo-technics Report No. 95-2. Geo-technical Engineering Program Department of Civil & Environmental Engineering.

Did you know? Tires are being recommended to absorb off-gassing produced by waste water from communities, industries, and agriculture activities. Here are some highlights from the report:

"If tires are reused as a construction material, the unique properties of tires can once again be exploited in a beneficial manner (Ahmed 1993). The benefits of using scrap tires are particularly enhanced if they can be used to replace virgin construction materials made from nonrenewable resources. Additionally, scrap tires are shown to have significant sorption capacity for organic liquids and vapors (Park, Kim, and Edil 1993). Recent research indicated that shredded tires do not show any likelihood of being a hazardous waste material or of having adverse effects on groundwater quality (Edil and Bosscher 1992)."

"There may be some concern about leachate quality since scrap tires are considered a waste material. Laboratory and field evidence available does not show any likelihood of scrap tires being a hazardous waste or having potential for significant adverse effects on water quality (Edil and Bosscher 1992)."

"In order to obtain an early evaluation of potential environmental problems, duplicate EP toxicity and AFS leaching tests were performed on tire chip samples by the State Laboratory of Hygiene (Edil, Bosscher, and Eldin, 1990). The duplicate results showed excellent correlation for all substances (see Appendix C [in report]). These test results indicate that the shredded automobile tire samples show no likelihood of being a hazardous waste."

"Styrene-butadiene rubber is the most important synthetic rubber used by the tire industry. This material is known to absorb large amounts of hazardous organic chemicals from the surrounding environment (Park, Kim, and Edil, 1992). This can actually impart certain beneficial environmental attributes to shredded tires. In summary, shredded tires leach very small amounts of substances compared to other wastes. By comparison to other wastes for which leach test and environmental monitoring data are available, the tire leach data indicate little or no likelihood of shredded tires to have effects on ground water."

Publications by Professors Edil and Bosscher, as noted above, may be sourced via the University of Wisconsin-Madison website:
<http://www.wisc.edu/pubs/home/archives/ug97/07engineering/civileng.html>

- 3.3.5 This only leaves the issue of durability, which is related to moisture.
- 3.3.6 According to SCI Scotland (pers. comm.. 21.07.03) the main reason for the banning of tyres in landfill is because of their durability, that is, they represent a long term waste problem in the ground. The majority of our efforts on this study have been to seek official confirmation of this which should allay the concerns of Building Control about durability of tyres in the ground. This would then mean no research or monitoring of this is necessary.
- 3.3.7 In the limited amount of time available to us however, we have not been able to acquire what might be considered 'cast iron' proof of the durability of tyres in the ground. Despite this, and following around twenty conversations with tyre specialists of one sort or another, we are certain that tyres ARE durable in the ground and that they pose no risk of degradation which would imply either

excessive toxic leachate to the ground, or structural failure with regard to their role as loadbearing walls in the Earthship design. Three of the various projects which have used tyres in the ground or in water are noted below to support our assertion.

- 3.3.8 Since 1998, there has been an experimental tyre artificial reef structure in Poole Bay, to which the Engineering and Physical Sciences Research Council (EPSRC) provided funding. The tyre modules are still in their original position and have colonised successfully with marine life. The University of Southampton's School of Ocean and Earth Sciences is responsible for this reef, which has been put in place to study the biological and chemical effects of tyres in the sea. We note that the tyres have lasted well in the conditions, which must be assumed to be more testing than those in an Earthship. Dr. Ken Collins (02380 596 010) who has been involved in the project notes that tyres are degraded by a) uv light, b) excessively high temperatures, c) abrasion and d) certain oxidising agents. None of these agents are present in the conditions normally associated with Earthships. A number of similar experiments using tyres have been undertaken, particularly in the South-East of England.
- 3.3.9 A company called Northern Tyre Recycling Ltd. (contact Dennis Scott 01463 790 033) has pioneered (in the UK) the use of crushed (but not broken) tyre 'bales' which have been used for road bed sub bases, particularly in wet and boggy conditions where heavier, solid sub-base material tends to lead to compression and sinking of the road surface. Examples of this use of tyre bales are in the Spey Bay Landfill Road Project (Contact Moray Council; S. Williamson, Waste Management Officer 01343 557 041) and the B871 Kinbrace to Syre Road (Contact Highland Council Roads Dept / Biffa Waste Services – 01382 350 408) This latter project is presently undergoing extensive monitoring, one secondary result of which is likely to be an understanding of the durability or degradation of tyres in boggy ground.
- 3.3.10 To conclude, we suspect that, with a little more time and effort to elucidate the necessary information, it would be possible to show conclusively that tyres will be durable in their anticipated role in Earthships. In this case, there is no need to monitor this aspect and we advise that efforts by SCI Scotland are geared in the short term in acquiring the necessary documentary evidence of durability.

3.4 Can/Concrete Walls

- 3.4.1 The (steel) cans are used to form a cement mortar matrix in secondary walls such as internal partitions and other non-loadbearing inner and outer walls. It may be that because all such uses are secondary, i.e. non-critical, that any residual Building Control concerns may be avoided by simply not using them.
- 3.4.2 Structurally, the walls would be covered by the Structural Engineer's Certificate, and it would be easy to establish that, in structural terms alone, the walls remain useful even if the cans rust, since it is the cement mortar matrix which is providing all structural resistances.
- 3.4.3 Beyond this, the concerns may be that where the cans form a barrier to weather, rodents, moisture, light, the passage of heat or any other 'environmental' element, the possibility of degradation could lead to a failure of the wall overall. We would advise that:
- a) in any wall performing an thermal or acoustically insulative function, or needing to remain intact throughout the life of the building, that cans are not used, or that specific measures are taken to avoid the cans getting damp, such as damp proof membranes as necessary.
 - b) lime or clay / earth is used in preference to cement since they donot "keep" moisture locked into their cell structure in the same way – increasing the risk of rust – and infact tend to help reduce moisture build-up by "wicking" it away through the natural vapour pressure differentials which develop either side of any wall construction and are able to move the vapour through the material.
- 3.4.4 It is unlikely that there need be any residual concern by Building Control if these measures are acted upon, and we do not advise that monitoring of durability is necessary.

3.5 Ventilation

- 3.5.1 It has been agreed with Building Control Fife that the trickle vents on the rooflights are adequate for the space at Kinghorn, but that for the building to be deemed suitable for a dwelling, that these would need to be complemented by trickle vents on the windows.
- 3.5.2 Ultimately, this solution is not ideal from an energy saving point of view since, in practice, trickle vents tend not to be used efficiently nor in close concert with the prevailing weather conditions. A greater degree of control would be advisable though this is not an issue for Building Control and therefore perhaps worth ignoring, and is in any event beyond the scope of this study.

3.6 Heating

- 3.6.1 Building Control concern over heating centres on the fact that a living area should have a recognised heat source. We have not investigated the “Zero-energy” house in Aberdeenshire as part of this study, but there appear to be two options, which are not mutually exclusive.
- 3.6.2 The first is to accept the need for a heat source and install – as has been done at Kinghorn – a simple wood burning stove or similar. Whilst this goes against the philosophy of the autonomous Earthship concept, it removes an obstacle to acceptance and, assuming timber only is used as a fuel, the building remains arguably solar energy heated.
- 3.6.3 Notwithstanding the next paragraph, it is the opinion of Gaia Research that installing a wood burning stove is helpful in that whilst it may not be needed on purely technical grounds, it however provides additional (and from experience – welcome) heat, an element of drying of the internal climate which is valuable in the wet Scottish Climate (and huge moisture mass provided by the earth at the rear of the building), and an element of psychological control over the surroundings which is extremely valuable to potential occupants.
- 3.6.4 The second option is to prove the case for (passive) solar heating by monitoring the internal and external temperatures. This could show that a) the sun may be considered a heat source in the terms of the Technical Standards (this would have a number of complex implications) and / or b) that this heat source is adequate to maintain a dwelling at a comfortable temperature throughout the year.
- 3.6.5 Monitoring of this sort would be relatively simple and cheap to do. For further discussion of this please refer to the section on monitoring.

3.7 Monitoring

- 3.7.1 As part of this project, Gaia Research agreed to comment upon the potential monitoring proposed at the Earthship by way of suggestions as to what may best be investigated.
- 3.7.2 Initial discussions about monitoring centred around the measurement of temperature and moisture issues. Subsequently it was felt that monitoring of tyres and cans in the ground may be necessary with regard to the concerns of Building Control Fife about their durability. Finally, it may be prudent to consider other of the Building Control Fife concerns such as daylighting, ventilation and heating so that any monitoring may directly complement other efforts to achieve approval from the Building Control Authorities.
- 3.7.3 As mentioned above, it may be helpful to monitor the **daylighting** levels at the rear of the building, but this would seem a waste of time compared to persuading the Officials that in this case the regulations do not apply.
- 3.7.4 Comments regarding **Tyre Walls** and **Can Walls** have been made in the relevant sections above and are not discussed here. We would advise against the use of monitoring monies to investigate tyre and can durability. We would advise that such problems as are indicated by Building Control be either avoided through alternative detailing, or are able to be resolved through further investigation into existing literature / data. The time constraints of this one-day project have not allowed us to be able to confirm, for example, the durability characteristics of cans, however, this information is likely to be available to those able to investigate a little further.

- 3.7.5 It appears that ventilation issues will be resolved without the need for monitoring.
- 3.7.6 Monitoring of the **thermal** patterns of the building, using both internal and external thermostats and data loggers would be useful and relatively simple and cheap. We may further assume that it would be fairly straightforward to gain Building Control approval (or Type Approval) based on the results of this monitoring, though a period of at least three years recorded temperatures would probably be needed to persuade officials that the information was reliable.
- 3.7.7 To conclude, we suggest that it is possible that no monitoring is strictly necessary to achieve Building Control acceptance since all outstanding concerns may be plausibly resolved through other measures. However, we would regard monitoring of the thermal climate as valuable as it might allow subsequent Earthships to do without additional heat sources, so saving money and time for those involved. In addition it would prove the sense and value of the Earthship concept in Scotland and the UK.
- 3.7.8 It would in addition be interesting and potentially valuable to monitor the relative humidity in the internal climate and in the walls. This would offer supplementary information about the thermal climate – the two being intimately interdependent – and also information about the capacity of the construction to regulate moisture and hence its value as a health-supporting design. This information would not be currently required by Building Control, nor any Type Approval submission, however, it might support the concept of Earthships in the future, particularly as moisture issues are widely perceived as only now growing in recognition.

3.8 Building Control Type Approval

- 3.8.1 As previously mentioned, 'Type Approval' offers a sort of generic approval for the given construction type so that all subsequent applications made are simplified and easier to get through the system. With its emphasis on promoting the Earthship concept along with wider sustainability proposals, and supporting those who wish to pursue such avenues, such an approach is clearly desirable to SCI Scotland.
- 3.8.2 The 'Type Approval' system was previously administered by COSLA, but since April of 2002 has been run by the Scottish Building Control Divisions on a joint basis. Only a few submissions have thus far been made so there is little by way of precedent against which to judge the likely outcome of this approach.
- 3.8.3 Gaia have discussed the issue with Bob Renton of Scottish Borders Council Building Control Division on two occasions. He initially requested further information on the Earthship proposals which were forwarded after checking with SCI Scotland that this was acceptable. Mr. Renton agreed to look over the proposals and forward his response and the relevant documentation. The relevant forms are appended to this document.
- 3.8.4 The procedure, broadly, is that the specifications, drawings and other supporting documentation are submitted, with the relevant forms, to three Building Control Divisions. In this case, Fife would be approached and two other Building Control Divisions. These three assess the proposals and report back on what they see as the issues pertaining to the proposals.
- 3.8.5 There are three types of approval: Domestic, Commercial and 'System' (as distinct from building). It is assumed that SCI Scotland would choose the 'Domestic' section, for which the fee is £250.00 plus £50 for each additional dwelling submitted at the time.
- 3.8.6 Subsequent submissions for Building Warrant approval, quoting the Type Approval already gained, should be simpler, since the bulk of technical issues have been agreed, but are still charged by Local Authorities at the standard rate and are still subject to scrutiny because of the various site specific issues which must be established in each case.
- 3.8.7 Having studied the drawings and specifications sent to him, Mr. Renton was of the opinion that in the case of Earthships, these 'Site Specific Issues' would be numerous in each case and that the process would not be straightforward given the difference between the Earthship concept and conventional construction.

- 3.8.8 On the other hand, the fact that Earthships develop in a wholly modular fashion, with adjacent “U”s’ across the gradient, means that a type approval is quite effectively geared to the sort of generic development of the Earthship concept that is anticipated. In other words, type approval for one “U” at SCI Scotland would be easily applicable to a 4x module “U” such as would be necessary for a ‘proper’ house design.
- 3.8.9 It is likely, but not certain, that applying for Type Approval would involve SCI Scotland in more work than in simply applying for permanent Building Warrant Approval from Fife Council because, in practice, the approving organisations would have to be doubly certain that all official checks had been undertaken. We would anticipate that this work would be undertaken by the Project Manager as part of her existing remit and as such this additional work – while unhelpful – would not constitute an obstacle to application.
- 3.8.10 Finally, it is clear that the advantages associated with attaining Type Approval far outweigh those associated with a simple Building Warrant Approval from Fife Council for the Earthship at Kinghorn whilst the risks or disadvantages associated with making the submission are largely the same.
- 3.8.11 To conclude, whilst we recognise that submission for Type Approval may involve more effort on the part of SCI Scotland, or its agent, we would suggest that the potential to promote the Earthship concept and support those who subsequently wish to pursue such an approach is far greater than a simple Warrant Approval for the individual building in Fife.

4.0 Recommendations

4.1 Monitoring

- 4.1.1 We recommend that monitoring be undertaken on thermal issues as discussed herein, along with moisture and humidity issues if the funding can be identified for it. This is based on the assertion that all other Building Control concerns can be alleviated by other measures – this may not turn out to be the case – and our conviction that Building Control concerns over heating may best be dealt with in this way.

4.2 Type Approval

- 4.2.1 We recommend that Type Approval is sought in preference to a single Building Warrant submission to Building Control Fife. However, this should be preceded by thorough discussion with Mr. Bob Renton of Scottish Borders Council, the Secretary of the Type Approval Scheme in order to establish both the practical aspects of the process and a mutual clarity as to the risks and benefits of so doing.