Reference Source no.	
Project number	9568
Date of issue	17 May 2010
Security Code	

Investigation of buildability and practical aspects of upgrading of existing roof

ROBUST Project: WP 4.2

Author(s):
Israel Adetunji

Corus Research, Development & Technology
Swinden Technology Centre
ICA
Moorgate
Rotherham
South Yorkshire S60 3AR
United Kingdom

T 01709825537

Initial circulation list

<<Name>> <<Name>> <<Name>>
<<Name>>
<<Name>>
<<Name>>

<<Feel free to add or delete columns in the table above>>

<<Careful, NEVER use textcolumns here! Textcolumns use section breaks, and sections can offset the page numbering!>>

<<Type the initial list. Some people on the circulation list may not require a full copy of the report, in this instance a summary page only, may be provided. Recipients of a summary page will be indicated by an asterisk (*) on the circulation list. Colour copies may also be restricted. Recipients of colour copies will be indicated by a plus (+) on the circulation list.>>

Security Code

Contents **Page**

Reference Source no.

Summary

Investigation of buildability and practical aspects of upgrading of existing roof

ROBUST Project: WP 4.2

Author(s): Israel Adetunji

Reviewer(s):
Date of issue: 17 May 2010
Version no:
Security Code:

This report documented buildability issues and current practices in upgrading of existing roof in the UK. It reviewed the planning permission and building regulations. The report discussed refurbishment options for roofs, with main focus on the conversion of pitched roof to habitable roof. The review covered structural arrangement, thermal performance, ventilation and condensation risk, fire safety requirement of loft conversion.

Customer: RFCS
Programme manager: Simon Vaughan

Approved by: Samir Boudjabeur

Corus Research, Development & Technology
Swinden Technology Centre
ICA
Moorgate
Rotherham
South Yorkshire S60 3AR
United Kingdom

Investigation of buildability and practical aspects of upgrading of existing roof

1. Planning Permission and Building Regulation

1.1 Planning permission

In the UK, a new planning rule was introduced in October 2008. This section provides a brief overview of the relevant parts of the new planning rule to loft conversion works.

Within the new planning rule, the majority of loft conversions fall under "Permitted development". This implies that, most loft conversions can be undertaken without planning permission. Table 1 maps out loft conversion and extension activities against permitted development (i.e. no planning permission required) and planning consent (i.e. where planning consent are required)

Table 1: Loft conversion and extension activities in the context of the new planning rule

Loft Conversion and Extension Activities	Permitted Development	Planning Consent
Dormer windows to the rear of the building	x	
Dormer windows to the side of the building facing the highway		x
Dormer windows to the side of the building not facing the highway	x	
Dormer windows to the front of the building		x
Roof skylights	x	
Loft extension to terraced houses with volume ≤ 40 m^3 maximum	x	
Loft extension to terraced houses with volume ≥ 40 m^3 maximum		x
Loft extension to detached and semi-detached houses with volume ≤ 50 m^3 maximum	x	
Loft extension to detached and semi-detached houses with volume ≥ 50 m^3 maximum		x
Height of extension and/or dormer ≤ existing roof line	x	
Height of extension and/or dormer ≥ existing roof line		x
Dormer position set back at least 200 mm from eaves, as far as practicable	x	
Materials for dormers and roof extension to be similar to the existing house	x	
No balconies, verandas or raised platforms e.g. roof windows with 'fold-out-balconies'	x	
Windows facing sideways to be obscured glazed	x	
Windows openings to be 1.7 m above floor level	x	
Dormers and roof extensions in conservation areas		X[1]
Dormers and roof extensions of listed buildings		X[2]

NOTE:

No extension permitted in a conservation area

No extension permitted but a single application may be submitted for Listed Building Consent

1.1.1 Building regulation

This part of the report presents the list of regulations applicable to loft conversion and building extension works.

Building regulations provide practical guidance to ensure that all building work is safe and healthy in construction and habitation. In the UK all construction works must comply with a host of building regulations. These regulations are grouped into 'approved documents' (A to P) as follows:

Part A: Structure
Part B: Fire safety
Part C: Site preparation and resistance to moisture
Part D: Toxic substances
Part E: Resistance to the passage of sound
Part F: Ventilation
Part G: Hygiene
Part H: Drainage and waste disposal
Part J: Combustion appliances and fuel storage systems
Part K: Protection from falling, collision and impact
Part L1A: Conservation of fuel and power – new dwellings
Part L1B: Conservation of fuel and power – existing dwellings
Part M: Access to and use of buildings
Part N: Glazing – safety in relation to impact, opening and cleaning
Part P: Electrical safety

2. Current Practices in Roof Refurbishment

2.1 Flat roofs conversion

Two typical refurbishment options are:

- Flat-to-pitched conversion
- Placement of new 'Room-in-the roof'

2.1.1 Flat-to-pitch roof conversion

There are a lot of lightweight cold form steel solutions on the market as well as timber solutions for this application. Previous report (see Review of roof systems all over Europe) has extensively covered this area. The figures below show timber and cold form lightweight steel solutions. However, lightweight cold form steel solution is the most common for this application.

Figure 1: Flat to pitch conversion using timber sections and steel cladding

Figure 2: Flat to pitch conversion using lightweight cold form steel and steel cladding

2.1.2 New structure for room in the roof

The use of timber 'Attic Trussed Rafter' either as 2D panel or 3D module craned on the flat roof structure is very popular. There are a few lightweight systems on the market but not as popular as the timber solutions. Figure 3 shows timber solution while Figure 4 shows light steel solution for this application.

Figure 3: Prefabricated 'Attic Trusses' using timber sections

Figure 4: Prefabricated 'Attic Trusses' using lightweight cold form steel sections

2.2 Pitched roofs conversion to habitable roof

Over the years, more than one million roofs have been converted to creating room in the roof and there are still over a million homes to be converted in the UK. Availability of headroom is a major consideration, when converting roof space. The majority of loft structures provide the minimum of 2.3m headroom height required for conversion. However, there are few cases where roof structure needs to be raised or removed and replaced. Dormer windows are commonly used to increase the width of the room.

The figures below illustrate the three most common existing roof structures within the UK. The main conversion works for these roof types are similar, though the conversion of traditional cut timbers with or without strutted purlin structure is relatively easier than the other two.

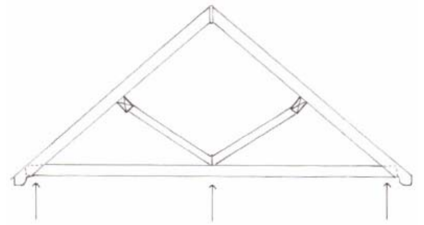	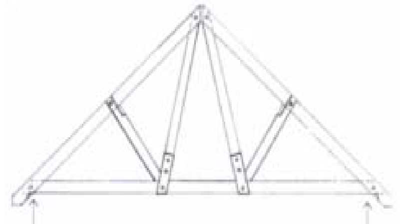	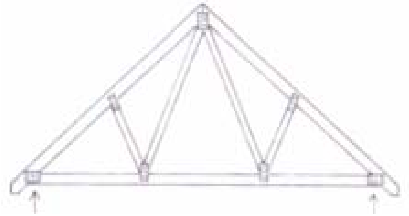
Figure 5: Strutted purlins	Figure 6: Trada trusses	Figure 7: Trussed rafters

The generic structural alteration for these roofs includes:

- Installation of new beam spanning from gable to gable/party wall to carry new floor load
- Installation of new floor joists between the existing joists to save headroom height
- Installation of stud wall on top of the beam to support part of the roof
- Installation of new beam at the ridge level (or near the apex) spanning from gable to gable/party wall for long span rafters or large new dormer window (≥ 1.2m) added
- Installation of collars depending on the span of the rafters
- Removal of existing strutted, purlin or trusses internal members

The most common solution for conversion of existing roof to habitable roof is the use of hot rolled steel beams to carry the floor and roof loads. Very recently, two new solutions have been launched in the market. These are the use of aluminium beams with timber cheek walls; and the use of cold form lightweight steel sections.

2.2.1 Hot rolled steel beams with timber floor and cheek wall

Hot rolled steel beams are installed gable to gable/party wall to support new timber floor joists. Joist hangers attached to the steel beams to carry new timber floors. Timber cheek walls are built off the steel beams to support the timber rafters. Third steel beam sometimes required to support the rafters at the ridge. Timber sections are used as cross beams to tie the rafters at the top and as ceiling joists to carry plasterboard.

Generally, hot rolled steel beam remains the most preferred options despite the fact that getting the steel beam into the loft is a major logistic operation. Sometimes the beam needs to be cut into 2 or 3 small beams, which are then bolted together once they are transported into the loft. Considering that up to three steel beams are generally required for a typical loft conversion as shown in Figure 8 and 9, this means that each of these beams may have to be cut into 2 or 3 pieces for ease of installation. This makes the logistic of loft conversion extremely tedious. Hence, this reinforces the massive opportunity for the use of cold form lightweight steel for this application.

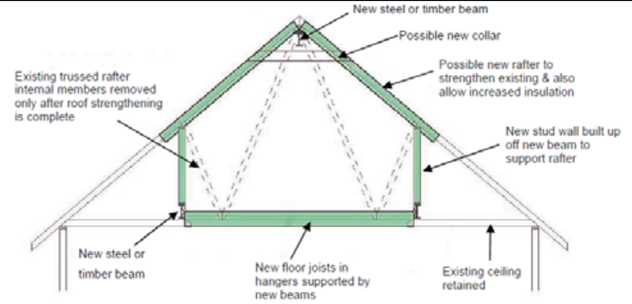

Figure 8: Typical structural modifications of Trussed rafters for habitable roof

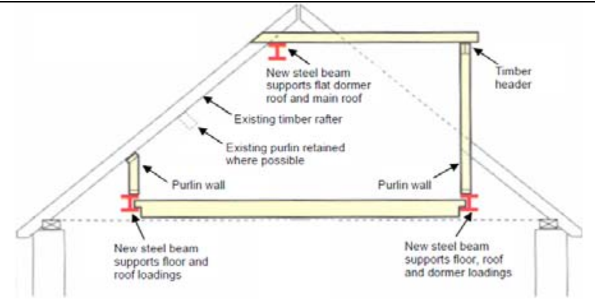

Figure 9: Typical structural modifications of purlin roof with large dormer window

2.2.2 Aluminium beams with timber cheek walls

Aluminium hollow beams with I-section out-trigger are installed, eaves – to – eaves, parallel to existing trusses to form the new floor joists as shown in Figure 10 and 11. For each existing truss, two of this aluminium beams are installed on each side of the truss. Timber cheek walls are built off the aluminium beams to support the existing timber rafters. Timber sections are used as cross beams to tie the rafters at the top and as ceiling joists to carry plasterboard. The main advantage of this system over the traditional solution is the relative speed and ease of installation. However, the disadvantage lies in the exorbitant cost of the system.

Figure 10: Aluminium I-section and box section installed from the eaves

Figure 11: Aluminium floor beams supporting timber cheek wall

2.2.3 Lightweight cold form sections for floor and cheek wall

Lightweight cold form C-sections are installed, eaves – to – eaves, parallel to existing ceiling joists to form the new floor joists. The cheek walls are made of lightweight cold form panels. This consists of U-sections at the top and bottom and C-sections internal members. The light steel cheek walls panels are built off the cold form steel floor to support the existing timber rafters. Similarly, lightweight cold form panels are used as cross beams to tie the rafters at the top and as ceiling joists to carry plasterboard.

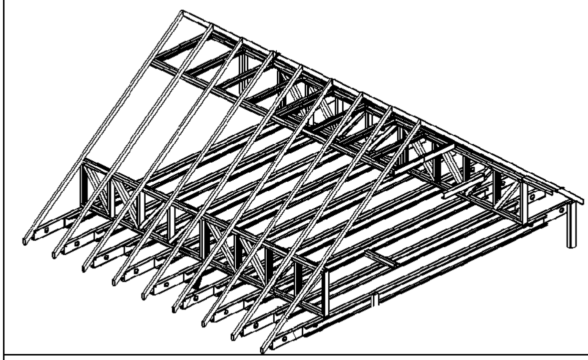	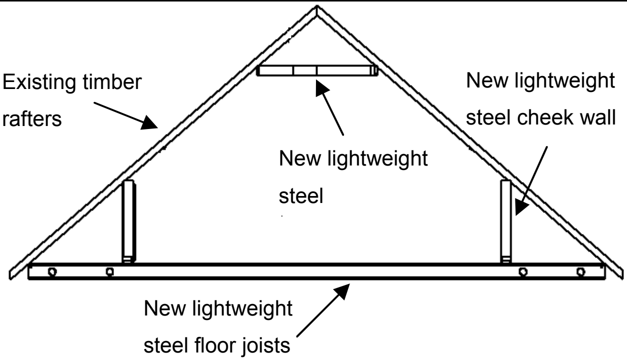
Figure 12: 3D View of lightweight steel solution	Figure 13: Cross section view of lightweight solution

2.3 Structural consideration

The challenge of roof conversion is finding the safest means of transferring the new heavier loads down to the existing foundations without the building cracking, subsiding or collapsing.

2.3.1 Load transfer

The general idea is transferring the additional loads from the new loft rooms into the existing external walls. This is achieved by supporting new beam (or joists) on the external walls. In the majority of loft conversions the new beams are supported by the external and/or party walls. However, in some cases where the existing internal walls are load bearing, the new beams or joists can be supported on these walls. This is rarely the case.

2.3.2 Foundation

In most cases, with the exception of bungalows (single story building), the existing foundations are adequate to cope with the additional loading. Therefore, underpinning of existing foundation is normally not required.

2.3.3 Internal load bearing wall

In majority of buildings, the internal load bearing walls stop at the first floor and the existing roof structure spans from outer walls to walls.

2.3.4 Beams

New beams to support the roof rafters and new floor joists are the essential part of loft conversion. Hot rolled steel beams are commonly used because of the small size relative to strength and also, it is readily available and relatively cheap to procure. The four common types are shown in Figure 14 below.

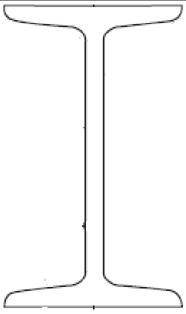	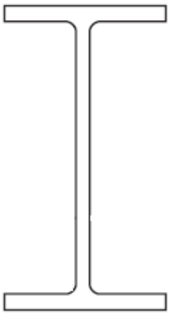	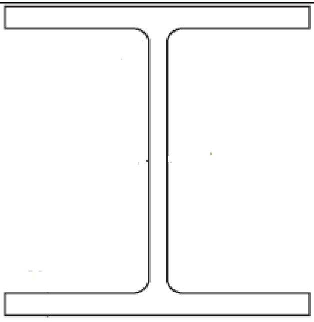	
RSJ – rolled steel joist: 152 x 127mm x 37kg up to 203 x 152mm x 52kg	UB – Universal beam: 127 x 76mm x 13kg up to 457 x 191mm x 74kg	UC – Universal Column: 152 x 152mm x 23kg up to 254 x 254mm x 89kg	PFC – Parallel Flange Channel: 100 x 50mm x 10kg up to 430 x 100mm x 64kg

Figure 14: Common Steel Sections used for loft conversion

The main disadvantage of hot rolled section is the difficulty in manoeuvring the beam in a very tight space available in the loft. Steel beams are normally sized 200mm longer than the actual span to provided 100mm bearing each side of the support wall. This means that small opening are either cut into the side gable wall or roof hip so that the steel beam can be threaded into the loft. Alternatively, where this is not possible e.g. mid-terraced house, the only option is to splice this beam into 2 or 3 pieces and bolted together once in position. Typical types of splice joints are shown in Figure 15 and 16. Spliced are designed to transmit all the member forces and provide sufficient stiffness. High strength bolts (HSFG) bolts are used to avoid deformation associated with slip before bearing in bolts.

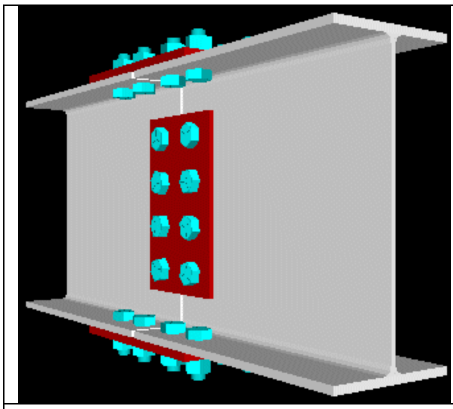	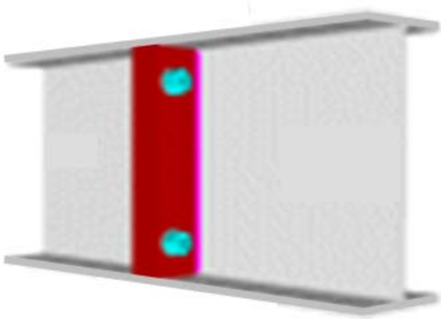
Figure 15: Flange and web plate splice	Figure 16: End plate splice

2.3.5 Padstones and plates:

Steel plates or concrete padstones are generally required under the support beams to spread the load because the existing brick walls are quite weak. As the existing brick walls are built with lime mortar and have a low comprehensive strength of about $0.21 N/mm^2$. The beams bearing are typically a minimum of 100mm on the steel plates or concrete padstones.

2.3.6 Beams in party walls:

Party walls are normally built with a solid or block cavity wall. This is the same thickness with the traditional main solid walls (229mm thick). Typical practice is to ensure that:

- End of the support beams at 100mm do not extend beyond the mid line of the party walls.
- Support beams do not bear into chimneys or the party wall between chimneys. Sometimes, to avoid penetrating into chimney breast, new steel ridge beam is supported on a steel column.
- Combustible materials e.g. timber are separated from a brick or block chimney breast by at least 40mm from the outer surface of the chimney (and 200mm from the flue itself).
- Metal fixings such as joist hangers that contain combustible materials (e.g. timber joist) are positioned at least 50mm from a flue.

2.3.7 Loft floor

Existing timber loft joists are relatively small section of 50 x 75 - 100mm thick at 400 – 600mm centres. These are too weak to carry the new imposed floor loads arising from loft conversion. As a result, these are normally left in place to carry the ceiling load. New thicker timber sections of 50 x 200 – 250 mm thick are installed between the existing joists to maximise headroom. The new floor is suspended to ascertain that new imposed floor load is not transferred to the existing loft joists. For example a 50 x 220mm thick grade C24 timber spaced at 400mm centres span up to 4.85m with maximum dead load of 1.25kN/m^2 and imposed load of 1.50kN/m^2.

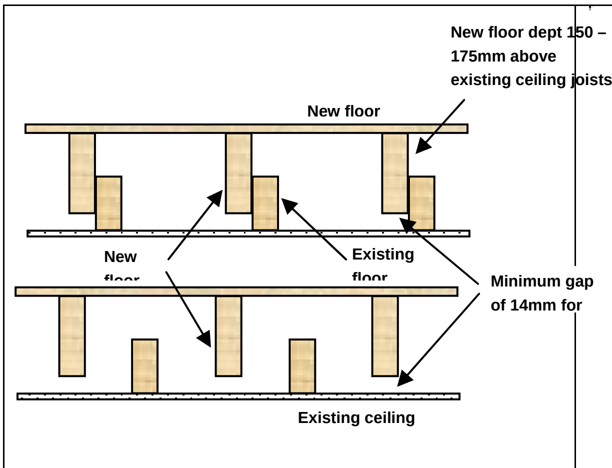

Figure 17: New floor joists alongside existing joists

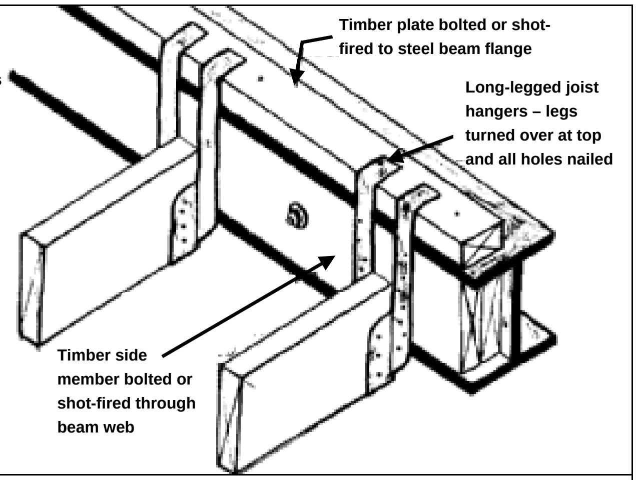

Figure 18: Connection of new joists to the steel beam

2.3.8 Rafters:

Existing timber rafter sizes are typically 50 x 75 – 125mm thick. These rafters are sometimes strengthened by either doubling up the joists or installation of steel beam to reduce the rafters span. Also, rafters are doubled up on either side of rooflights or steel beams are used where two rooflights are to be provided side by side.

2.4 Thermal performance

The Building regulation Part L1B requires that the material used in loft conversion or extension regulation meets certain thermal performance. Typical practice involves the use of insulation between and/or under the roof rafters/ceiling joists to achieve the required minimum thermal performance. The minimum thermal performance (U-values) requirements for loft building elements are collated in Table 2 below.

Table 2: Loft element and thermal requirement

Loft Element	**Minimum thermal performance (U-values) W/m^{2}K**
New attic walls, new dormer walls	0.30
Existing gable/party wall	0.35
Pitched roof warm construction	0.20
Pitched roof with cold deck	0.16
New flat roof e.g. over dormer	0.20
Roof lights	1.85

2.5 Ventilation and Condensation

In most buildings, the internal air is more humid than the outside air. The humidity differential drives the moisture from inside through the insulation to the outside of the building. However, the presence of a relatively cold surface and impermeable surface immediately after the insulation may cause condensation, which needs to be vented off. Generally, no ventilation gap is required for a warm roof. A warm roof is where insulation boards e.g. polyurethane are lay over the top of the rafters. This is the most effective method but only applicable to new roof or where the existing roof tiles are striped and re-roofed.

In loft conversion, stripping and re-roofing of existing roof to create a warm roof construction is not a common practice as this requires planning permission because the existing roof line will be higher. Most loft conversions involve upgrading the original roofs from the inside. Typical practice involves adding insulation between and/or under the roof rafters. This demands the need to avoid condensation risk because the existing felt layer is a traditional non-breathable membrane. Condensation risk is avoided by either provision of cross ventilation above the insulation layer on the cold side of the roof (see Figure 19). The provision for cross ventilation involves a continuous 5mm gap (ridge vents) at the ridge and 25mm gap (eaves vents) at the eaves both front and rear of the roof. Also, a minimum clear gap of 50mm over insulation in sloping and horizontal ceiling areas is maintained. Alternatively, the roof tiles could be striped and the existing traditional non-breathable felt layer replaced with a vapour permeable layer (breather felt) as shown in Figure 20. In this case, the ventilation gap above the vapour permeable layer can be reduced to 25mm.

Table 3 illustrates typical construction specifications to achieve U-value of 0.20 W/m2K and avoid condensation risk.

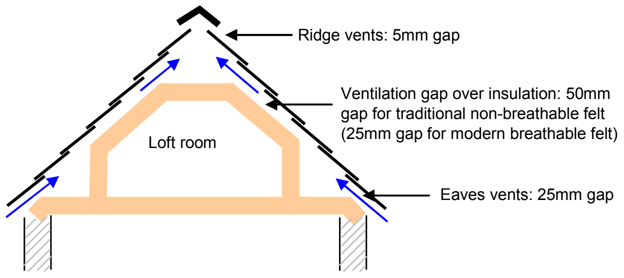	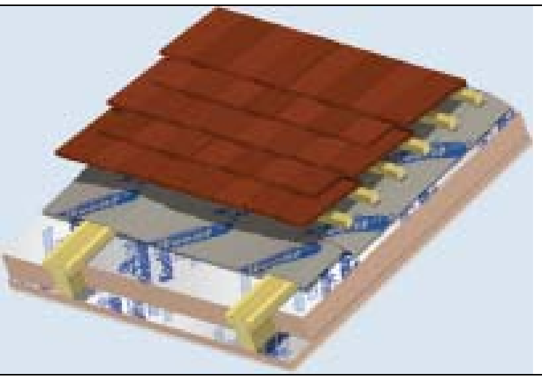
Figure 19: Cross ventilation of room-in-roof to avoid condensation risk	**Figure 20: Between and under rafter insulation with modern breathable membrane**

Table 3: Typical construction specifications for habitable roof rafter

Option 1: based on 100mm thick rafter, existing roof tiles striped and re-roofed.	**Option 2: based on 100mm thick rafter and existing roof tiles kept in place**
Modern breathable felt 25mm air gap 75mm insulation between rafters 50mm insulation under rafters 12.5mm plasterboard	**Traditional non-breathable felt** 50mm air gap 50mm insulation between rafters 75mm insulation under rafters 12.5mm plasterboard
Option 3: based on 100mm thick rafter, existing rafter extended with 20mm internal batten and existing roof tiles kept in place	**Option 4: based on 100mm thick rafter, existing rafter extended with 20mm internal batten and existing roof tiles kept in place**
Traditional non-breathable felt 50mm air gap 70mm insulation between rafters 50mm insulation under rafters 12.5mm plasterboard	**Traditional non-breathable felt** 50mm air gap 50mm insulation between rafters 30mm multifoil insulation under rafters 25mm cross batten Vapour control layer 12.5mm plasterboard

2.6 Fire safety

Provision of means of escape and fire protection is required for a loft conversion. However, there is a lack of clarity for loft conversion of a bungalow due to shorter travel distances. Nonetheless, the following represent the common practices in compliance with the fire safety regulation:

- Staircase must discharge close to a door leading to an external safe place and not in a room.
- All doors openings and walls enclosing staircases must be at least 30 minutes fire resistance, with the exception of toilets and bathrooms doors.
- Mains powered interlinked smoke detectors are to be provided, with a minimum of one detector per level.
- If the building has a basement its ceiling must be at least 30 minutes fire resistance and the basement is to be separated from the ground floor by fire resisting construction.
- First floor ceiling is to achieve at least 30 minutes fire resistance.
- If the conversion involves forming a dormer, dormer cheeks within 1 metre of a boundary are to be at least 30 minutes fire resistance in both directions. The dormer roof is to be at least 30 minutes fire resistance to avoid external fire spread

3. Conclusion

This study has provided an overview of the building regulations and planning issues relevant to upgrading of existing roofs. It highlighted current refurbishment practices for flat roof and pitched roofs. The study heavily focused on the conversion of pitched roofs to create habitable roofs. It presented the three typical roof structures common within the UK existing building stock and existing solutions to creating habitable roofs. The review covered key issues such as structural considerations, thermal performance, ventilation and condensation, and fire safety practices.

Reference

1. Hymers, P., (2008): Home Conversions: The Complete Handbook, New Holland Publishers, UK
2. Kingspan: Breathable membrane for unventilated pitched roofs: http://www.insulation.kingspan.com/uk/pdf/nilvent.pdf
3. Planning Portal UK: http://www.planningportal.gov.uk/england/public/planning/applications/
4. Rock, I.A., (2008): The Loft Conversion Manual, Haynes Publishing, Sparkford, UK
5. Steel Splice: http://www.steel-connections.com/lmc_types.htm
6. Telebeam Ltd: http://www.telebeam.co.uk/
7. TRA, (2007): Creating Roofspaces with Trusted Rafters, Trust Rafter Association, Product Data Sheet No. 6
8. TRA, (2007): Loft Conversions with Trusted Rafter Roofs,Trust Rafter Association, Product Data Sheet No. 8
9. U-roof Ltd: http://www.uroof.co.uk/index.htm