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Roof Typology, Structural Arrangement and Opportunities for the use of Steel for habitable Roof

ROBUST Project: WP 4.2

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ROBUST Project: WP 4.2

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This study is part of the Robust project WP 4 which focuses on investigation of buildability and practical aspects of the upgrading of existing roofs and development of innovative steel technologies for roof applications. The available headroom remains one of the most important factors to consider when converting existing roof into habitable roof without the need to raise the roof height or remove and replace the roof structure. The available headroom is dictated by the type of roof structure. In order to provide a viable and innovative steel intensive solution to creating habitable room in the roof for both existing and new roofs, it is imperative to understand the past and present roof types, shapes and structural arrangements.

This study reviewed roof typologies and structural arrangements of roofs in the UK. It also highlights areas for opportunity for steel intensive solutions for creating habitable room-in-the roof.

The review indicated that the majority of the roofscapes is pitched roof with varying degrees of shape and style as shown in Table 1. There are a few flat roof structures but only common with system buildings and post war prefabricated buildings. Flat roofs became popular during the 1920s but not very common nowadays because of the problem such as water penetration, lack of tolerance to thermal and moisture movement resulting into short design life. Table 2 collates roof typology, structural arrangements, characteristics, span capacity, roof era and opportunities for the use of steel for habitable roof.

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Roof Typology, Structural Arrangement and Opportunities for the use of Steel for habitable Roof

1. Introduction

The most important key issues to consider when creating habitable room in the existing roofs are the available head room and the type of roof structure. In order to provide a viable and innovative steel intensive solution to creating habitable room in the roof for both existing and new roofs, it is imperative to understand the past and present roof types, shapes and structural arrangements within Europe.

Against this background, this study provides a brief history of roof typology and structural arrangements in the UK. It also highlights areas for opportunity for steel intensive solutions for creating habitable room-in-the roof.

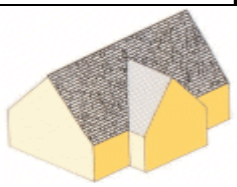
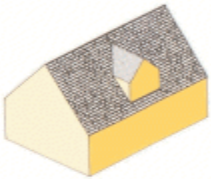
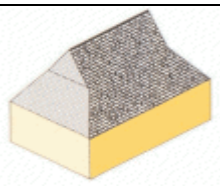
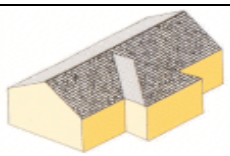
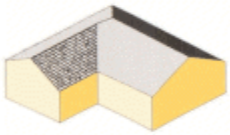
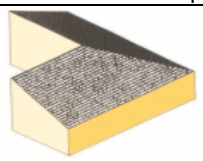
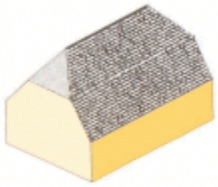
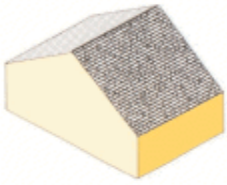
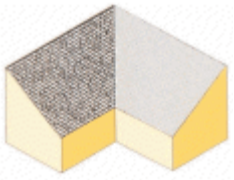
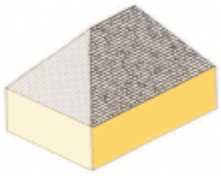
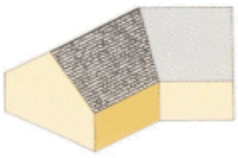
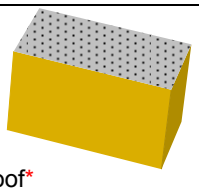
2. Roofs Typology in the UK

There are varieties of roof shapes and styles in the UK. The overwhelming majority of the UK's building stocks have pitched roofs of one kind or another as shown in Table 1. Also, the sides of the roof are either designed as gable end or hipped. Generally, the majority of properties have gable end, that is, the side walls are built up in the form of triangle.

The two most common roof shapes are gable end and hip roofs. Table 1 collates the wide varieties of roof and highlights their level of popularity in the UK. The breadth of these roofscapes can be broadly grouped into four typologies as follows:

- Duopitch gable roof
- Duopitch hipped roof
- Monopicth gable roof
- Flat roof

Table 1: Roofscapes[1] and level of popularity in the UK

 'T' Intersection roof with gable side*	 Dormer roof gable side*	 Gablet roof with hipped side
 Overlaid hip roof with gable side*	 'L' Return roof with gable side*	 Mono 'L' Return roof with gable side
 Dutch/Barn Hip roof with gable and pitched side	 Duopitch roof with gable side*	 Monopitch roof with gable side
 Hipped roof*	 Dogleg roof with gable side*	 Flat roof*

*The red highlighted are the most common in the UK

3. Roof structures

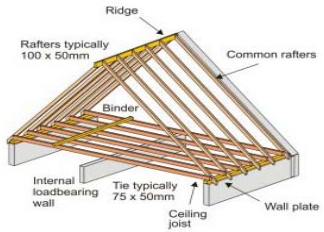
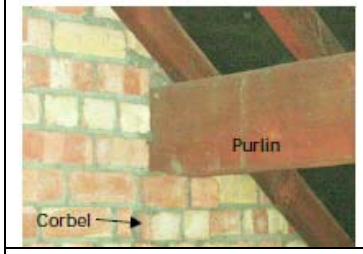
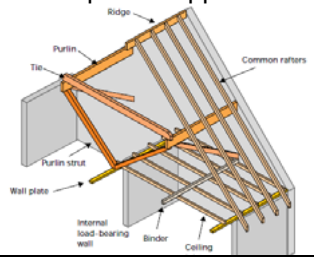
Traditionally, domestic roofs in the UK have always been constructed in timber and the methods of fixing are nails, screws and bolts. The type of roof structure generally depends on the era when the building was built. The UK existing building stock roof structures can be broadly grouped into the following:

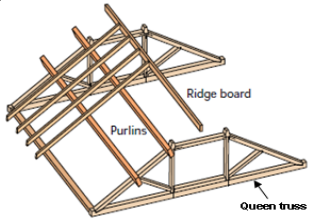
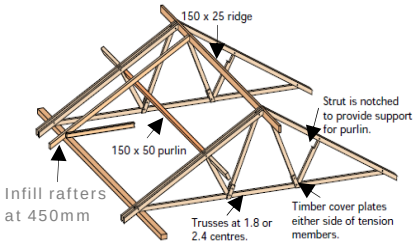
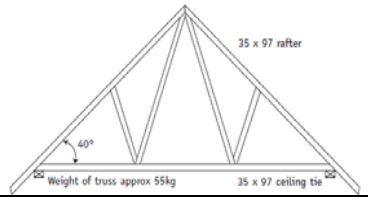
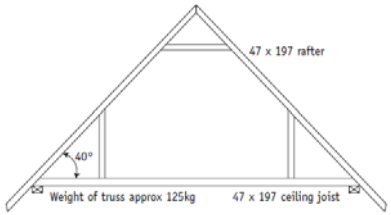
1. Flat roof
2. Cut timber roof structure
   - Closed couple
   - Purlin with or without strutted purlin
3. Pre-war truss structure
   - Combined purlin/rafters with transfer trusses
4. Post war truss structure
   - Trada truss rafters
   - Trussed rafters
5. Modern truss structure
   - Room-in-roof trusses

4. Opportunities for the use of steel

The table below collates roof typology, structural arrangements, characteristics, span capacity, roof era and opportunities for the use of steel for habitable roof.

Table 2: Roof structure and opportunities for the use of steel

Structure	Types	Characteristic	Span	Period	Opportunities for steel
Flat Roof	Flat roof structure 	Started as part of the so call modern movement led by Bauhaus. A few system-built houses and schools of late interwar and post war period still exists. But less common nowadays. Typical timber joists ranges from 50 x 125mm to 200mm deep spaced @ 400 – 600mm centres	2.5 - 4.5m depending on section sizes	Around 1920s – 70s	**Big opportunities are:** • Flat to pitch roof conversion - there are already several truss systems on the market using lightweight steel. • Roof top extension to create habitable pitched roof – lots of opportunities exist for the use of lightweight steel.
Cut timber Roof Structure	Closed coupled roof 	High head rooms. Lot of space for storage. Roof structure not supported on the internal load bearing wall. Typical timber rafter sizes 50 x 100mm to 150mm deep and ceiling joists 50 x 75mm spaced @ 400 – 600mm	2.5 – 3.5m depending on section sizes	Before 1950s	The head room is generally ≥ 2.3m. Dormer may not be required where the headroom is up to 2.8m. Easier to convert to habitable roof. **Big opportunities:** There is opportunity for the use of lightweight cold form steel trusses. Another opportunity is the use of innovative light weight steel floor to replace timber section to save headroom. Available headroom is a major consideration for loft conversion. A typical new timber joists floor and floorboard adds about 175mm to the existing ceiling joists. Therefore, there is an opportunity for a long span (up to 8m) floor with shallow depth using lightweight cold form steel.
	Purlin roof without Internal support 	High head rooms. Lot of space for storage. Purlins supported at gable/party walls. Typical timber rafter and ceiling joists sizes 50 x 125mm spaced @ 400 – 600mm. Purlins are 75mm x 175 mm deep	Up to 7.5m	Before 1950s	
	Strutted purlin supports Rafters 	High head rooms. Some space for storage. Roof structure supported on internal load bearing wall. Typical timber sizes for strut are 75 x 75mm, for purlin 150 x 50mm, for collar 50 x 125mm. Rafter 50 x 150 and for floor joists 50 x 125mm spaced @ 400 – 600mm	Up to 10m	Before 1950s	

Structure	Types	Characteristic	Span	Period	Opportunities for steel
Pre-war Truss Structure	Combined purlin/rafters with transfer trusses 	High headroom. Some space for storage. Roof structure not supported on internal load bearing wall. Trusses are made of large timber sections and provided alternative means of supporting the purlins, which in turn supports the infill rafters.	Up to 12m	Up to 1950s	The conversion of this roof structure is less complicated than above mentioned systems. This sometimes required less or no steel members because the existing timber purlins may be left in place depending of their sizes and position. Nonetheless, the same **opportunities as above.**
Post-war Truss Structure	Trada trusses 	Shallow headrooms. Trusses spanning from front outer wall to back outer wall. Truss uses less timber compared to the pre-war trusses and are spaced at 1.8-2.4 apart with rafter infill. All truss members are the same timber sizes and bolted together. Typical member size is 38 x 97mm thick.	Up to 8m	Late 1940s–1960s	More complicated to convert because of the shallow headrooms but the principle of conversion is the same. Headroom is up to 2.4m in some cases. Dormer windows are generally required to increase headroom height and room space. **Opportunities:** In addition to above, prefabricated dormer windows using cold form steel is another opportunity.
	Trussed rafters 	Extremely shallow. Trusses normally span from wall plate to wall plate without internal support. All members are the same with typical timber sizes 35 to 47 x 72, 84 or 97mm thick spaced @ 600mm.	Up to 8m	Late 1960s till now	Trussed rafter members are invariably smaller in size than traditional roof timbers. More support beams may be needed and the opportunities are the same as described above.
Modern Truss structure	Room-in-roof 	Purposely designed for habitable roof and timber members are more than double the size and weight of the trussed rafters. Typical timber section for 8m span is 47 x 197mm thick.	Up to 8m	From 2000 till now	Timber room-in-roof trusses are extremely popular for modern homes and also for rebuilding old existing shallow roofs. **Opportunities:** Prefabricated lightweight cold form steel roof with integrated renewable energy system for replacing existing roof and also for new build roofs.

Reference:

1. TRA, (2007): Creating Roofspaces with Trusted, Rafters Trust Rafter Association, Product Data Sheet No. 6
2. A Brief History of Roof: http://environment.uwe.ac.uk/video/cd_new_demo/conweb/house_ages/evolution_roofs.pdf
3. Rock, I.A., (2008): The Loft Conversion Manual, Haynes Publishing, Sparkford, UK