Material change for a better environment

WAS 003-003: Offsite Construction Case Study

Waste Minimisation through Offsite Timber Frame Construction

Offsite Timber frame construction utilises efficient manufacturing processes that reduce waste through design, material procurement, manufacturing and onsite installation to levels under 2% of the material used.

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Front cover photograph: Timber frame: floor cassettes ready for delivery on site

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The Old Academy
21 Horse Fair
Banbury, Oxon
OX16 0AH

Tel: 01295 819 900
Fax: 01295 819 911
E-mail: info@wrap.org.uk

Helpline freephone
0808 100 2040

Executive summary

Offsite construction methods are increasingly popular amongst the construction industry. Offsite construction, also referred to as Modern Methods of Construction (MMC), offers many advantages in terms of quality of construction, cost control, construction time and environmental credentials. They are also seen as a means to help reduce the amount of waste generated on site.

Timber frame construction techniques are now well understood by the UK construction industry and frequently adopted for residential and small institutional and commercial buildings. The market for timber frame mainly encompasses low and medium rise buildings (up to 7 storeys).

The simplicity of timber frame construction allows mass production of wall panels and floor cassettes. The process is often automated and carried out within a controlled environment. The factory setting allows better quality control of materials, chain production set ups and easier implementation of processes and manufacturing methods. Recent studies have demonstrated that the use of timber frame construction components can reduce the amount of waste generated on site by up to 40%.

This case study presents Stewart Milne as an exemplar to highlight the positive impacts of modern production lines on the waste generated during the production and erection of modern timber frame structures. The data made available for this study reveals that Stewart Milne's factory waste arising sent to landfill are less than 1.6% of the materials used in the manufacturing process.

Waste is dealt with from the inception of projects until the completion of the erection on site. By careful optimisation of the use of materials for the production of wall panels and floor cassettes, Stewart Milne ensures that the procurement and treatment of the materials produces minimal waste. Furthermore, the involvement of a full time Environmental Manager has helped the company to half wastage levels in the last 5 years by the implementation of various methods and techniques along the line.
Table 1 summarizes the performance of Stewart Milne.

Activities	***Waste generated***		***Waste disposal (%)***			***Saved Material (%)***
	Type	***%***	***Reuse***	***Recycle***	***Landfill***	
DESIGN & PROCUREMENT						
Accurate engineering	None	-/-	-/-	-/-	-/-	Timber (-8%) OSB (-9%) Joists (-8%)
Chipboard cutting patterns	None	-/-	-/-	-/-	-/-	
Optimisation of cutting patterns	None	-/-	-/-	-/-	-/-	
Use of 15m lengths for joists and beams	None	-/-	-/-	-/-	-/-	
Large size floor chipboards	None	-/-	-/-	-/-	-/-	
Top & bottom plate assembly and saw plant	None	-/-	-/-	-/-	-/-	
Protective Polyethylene sheet	Plastics	2%	0%	100%	0%	-/-
Cardboard packaging boxes containing nails	Cardboard	Negligible	0%	100%	0%	-/-
MANUFACTURING						
Wall panels and floor cassettes	Studs and Plates	8%	15%	85%	0%	-/-
	OSB	9%	20%	80%	0%	-/-
	Joists	8%	15%	85%	0%	-/-
Other operations (offices, cantine, steel straps, etc.)	Various	<1%	5%	75%	20%	-/-
SHIPPING & ERECTION						
Use of recycled timber pallets returned to factory	Timber based	0%	100%	0%	0%	-/-
Optimisation and planning	None	-/-	-/-	-/-	-/-	Lorry Movements (-5% to -10%)
Site activities	Timber	Negligible	0%	50%	50%	-/-
	Insulation	Negligible	95%	5%	0%	-/-
	Other	Negligible	20	70	10	-/-

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1.0 Timber Frame : a popular Offsite Construction Method

Amongst the offsite construction methods, timber frame is certainly the method that has evolved the most in terms of market share since the government and its agencies, in the late 1990's, started to implement programmes to encourage the construction industry to consider what was referred to as "Modern Methods of Construction", particularly for housing projects.

Although modern timber frame construction has been known in the UK since the last World War and extensively used during the 1960's, this method of construction has become more popular in the late 1990's with the pressure made by the government on the industry to use Modern Methods of Construction (MMC) particularly for the housing sector.

With the collaboration of the likes of TRADA and the BRE, manufacturers and government have sponsored studies and researches including TF2000, that helped the whole timber frame industry to improve the quality of systems and to propose construction methods and details that have become today's standards in the industry.

This has led to the key timber frame manufacturers working together to form the UK Timber Frame Association (UK TFA) and the recently introduced Q-Mark quality system covering a wide range of industry subjects from best practice in design and installation through staff training.

Lately, timber frame construction has been praised for its durability and its positive environmental impacts. Various research has documented that the embodied energy of timber frame construction and its thermal properties altogether reduce the dwellings carbon footprint.

Timber frame offsite construction methods can have a significant impact on the reduction of waste generated on construction sites as well as the positive effects on energy consumption and resources. Furthermore, the manufacturing process allows better and more rigorous quality controls and monitoring of the assembly activities whilst providing a better management of waste. This case study will review these important factors and their effects on the overall waste associated with timber frame buildings.

2.0 Timber Frame

Timber is a material easy to harvest, work with and one of the most common construction materials used. All over Europe, examples of medieval and Tudor timber beam and post type dwellings and barns are still inhabited or in use, proof of the resilience and durability of timber frame structures.

In countries where climate conditions are extreme, like Canada, Scandinavia, the US, or Germany, timber frame construction has remained strong primarily because of the availability, renewability and thermal properties of the resource. The construction methods, however, have evolved from the more traditional beam and post approach to a lighter build based on studs and sheathing construction.

With over 90% of the residential markets dominated by modern timber frame construction methods in North America and Scandinavia, timber frame construction provides a flexible, cost effective, quickly erected and thermally efficient method of construction. The timber frame racking systems and methods are well known and established in these countries and has become one of the construction industry's standard methods of construction, particularly in housing and small commercial buildings.

In England and Wales, where traditional brick and block construction is most common, the timber frame industry has been investing in the training of the labour to improve the quality of the construction on site, and to increase the knowledge and the skills of the workforce in timber frame construction. Here, in the UK, Timber frame systems are used mainly for the following applications:

- Single occupancy dwellings (detached and semi-detached properties up to 3 storeys)
- Medium rise buildings (mostly flats - up to 7 storeys)
- Small commercial or institutional buildings (mainly 1 or 2 storeys)

The timber frame market is characterised by the following forms of assembly:

1. **Stick build**: The assembly of the structure is performed on site. Usually, the timber is delivered on site in bundles of pre-cut studs, and random lengths of timber for the sole, bottom and top plates. Joists are usually pre-cut to length as kits to be assembled on site.

2. **Panelised walls**: Counting for most of the UK timber frame construction, manufactured timber frame panels are brought to site where they are assembled to form structural load bearing walls, and non-load bearing interior partitions. Panelised wall elements can be manufactured to include, insulation, doors, windows, services, exterior finishes, and interior lining.

3. **Floor / roof cassettes**: Larger elements can also be manufactured for floors or roofs. Similarly to the wall panels, these elements would at least include the joists and beams, and the floor boards. In some more advanced systems, insulation, lining and services can be added at the factory prior to shipping and delivery to site.

The market also differentiates between the following two methods:

1. **Beam and Post;** Construction relies on the assembly of larger structural elements (columns and joining beams) that form a skeleton and that provide the racking resistance necessary to suit a particular site. The walls and floor are completed by in-fill panels and self supporting timber planks. In the UK, beam and post construction is mainly sold to the high-end, self-build market and remains marginal.

2. **Racking wall;** This system is made up of equally spaced slender timber elements, called studs, which are held in position by Orientated Stranded Boards (OSB) or plywood sheathing for racking resistance. This method of construction is now the most commonly used in the UK. Because of its level of standardisation and its repetitive structural patterns, timber frame is ideally suited for simple manufacturing process.

2.1 The system

Timber frame wall structures are made of vertically aligned slender treated and structurally graded timber studs which provide the vertical resistance to the dwelling loadings. The studs are framed by a top and a bottom plate that ensure the adequate positioning of the studs, spaced up to 600mm centres. The racking resistance of the panels is provided by means of OSB or plywood boards affixed to the exterior face of each of the studs. These panels are assembled in factories using different nail types and finishes (galvanised or polished) depending on their application (e.g. galvanised nails on exterior walls, polished nails for interior walls).

Floors can also be assembled at the factories into cassettes. Floor cassettes comprise a series of timber joists (solid or engineered timber). The platform is completed with weather protected chipboard fixed to the top of the joists.

Roofs generally consist of timber roof trusses or pre-assembled roof cassettes where there is a need for habitable space under the roof (room-in-roof).

In recent years, the UK Timber Frame Association (UK TFA), in cooperation with TRADA and the BRE, has encouraged the industry to review the design of the timber frame to standardise it. Studies by the BRE, TRADA, the Palmer Partnership and the UK TFA on structural, fire, thermal and acoustic performances have been done in a controlled environment. The results were compiled in a handbook published under the title “TF2000”. Further to this publication, TRADA also released “Timber Frame Construction” which provides guidelines and standard details for the design and construction of timber frame buildings. A wealth of publications on timber frame is available through TRADA, BRE, CIRIA and UKTFA, covering design, erection methods, health and safety and repair works.

The wall panels and floor cassettes are delivered on site on flat bed lorries, either on stillage (mainly for closed panels systems) or in bundles. The erection is relatively easy but requires important preparatory activities;

- checks of foundation levels and dimensions;
- checks of squareness of foundations; and
- installation of a Damp Proof Course DPC and sole plate.

The levels and squareness of the sole plates have to meet very strict tolerances. The wall panels are then nailed to these sole plates and fixed together by studs. The floor cassettes are then craned into place and fixed to the supporting wall panels.

The thermal performance is provided, in most cases, by mineral fibre insulation fitted between the studs. Other methods of insulation are available, such as cellulose based blown insulation, but remain marginal. To prevent moisture travelling through the panel wall thickness, a vapour control layer is fixed on the interior face of the studs. The exterior walls are also covered by a breather membrane that allows the moisture to migrate to the outside of the building whilst protecting the racking boards (OSB or plywood) from excessive moisture..

2.2 Market

The UK timber frame industry has experienced significant highs and lows in terms of popularity over the course of the last 40 years. In the UK, the UK Timber Frame Association (UKTFA) has around 85 members that are manufacturers of timber frame housing kits. Of this number, 50 companies have completed the Q-mark assessment run by TRADA and obtained independent Third Party accreditation. Amongst these companies, the largest UK-based manufacturers include:[1]

- Century Homes
- Pace
- Prestoplan Purpose Built
- Robertson Timber Frame
- Scotframe
- Space4
- Stewart Milne
- Taylor Lane

The overall turnover of the timber frame industry for 2005 has been estimated to be in the region of £390 million. This generally includes factory and site installation/erection activities.

The largest client base for timber frame construction elements remains the residential and housing market. With nearly 20% of the market share of new build in this sector in 2005, the timber frame industry is now confident that it could reach 30% of the market share for the single and multiple occupancy construction due to the requirements now imposed by the latest release of Part L of the building regulations, and of the new Code for Sustainable Homes. These new requirements in terms of sustainability of the materials, air tightness and energy consumption, can potentially be dealt with through timber frame construction methods.

2.3 Timber Frame and waste

Recent studies[2] have shown that the use of timber frame could reduce waste on construction sites by between 20% and 40% depending on the level of offsite fabrication of the walls and floors.

In general, Timber frame structures delivered to site do not require further modifications during the erection period. To complete the exterior walls and some of the interior partitions, some additional loose materials are needed. These materials include:

[1] *Unpublished research works – Offsite construction survey*

[2] *WRAP. "***Current Practices and Future Potential in Modern Methods of Construction – Final report***". published.*

- Nails or other fixing
- Timber and plastic shims
- Sole and connecting plates
- Breather membrane
- Vapour control layer (usually polyethylene)
- Insulation (usually mineral fibre)

Timber frame design allows the engineer to have a very precise knowledge of the materials required for the assembly of the structure, both at the factory and on site. By issuing bills of materials for each of the projects, it becomes easier to control the additional materials sent to site which, in turn, helps avoid further wastage of materials. Furthermore, the operations on site are limited to the unloading and erection of the walls and floor panels into a complete structure. This is normally done by nailing adjacent panels together and does not require any modifications. Therefore, most of the waste is generated at the factory during the manufacturing process.

3.0 Exemplar Offsite Manufacturer

This case study uses information from Stewart Milne Timber Systems to highlight the potential for waste minimisation through the use of timber frame construction.

The Stewart Milne Group is one of the UK's leading privately owned house builders. It has been a period of successful progression since its initial origins in the North East of Scotland in 1975. The group now includes 4 divisions:

- Homes
- Timber systems
- Construction
- Development

The group has a strong commitment to quality in construction, timber frame and to the environment. The sister companies all work closely together and, this continuous interaction between the divisions of the Group increases the awareness to the importance of waste management and sustainable solutions. The sharing of knowledge and best practice between the divisions ensures the continual improvement of waste minimisation and recycling throughout the business.

3.1 Stewart Milne's attitude toward waste: an example in the industry

The data made available for this study reveals that Stewart Milne's factory waste arising sent to landfill are less than 1.6% of the materials used in the manufacturing process.

The timber frame industry has been very pro-active in its approach to environmentally sound management of the whole timber frame operation, from inception to delivery of the complete structure. Through the UK Timber Frame Association and TRADA, the majority of the industry has endorsed the quality programme proposed by TRADA and referred to as the Q-mark. The Q-mark is a bespoke timber frame quality assurance scheme, suitable

for all members of UK TFA and including elements of design, manufactured product conformity and site erection, as well as the compliance to ISO 9000 and 14000, and FSC wood chain-of-custody certification.

Stewart Milne is no exception to this environmentally responsible approach and has endorsed, like many of its competitors, the commitments laid out by the programme. Furthermore, Stewart Milne has undertaken a series of actions to improve its environmental standards, waste minimisation and management through;

- **Appointment of full time Quality and Environmental manager**. This person has the responsibility to develop and implement sustainable procedures (including waste minimisation) through the manufacturing facilities, including the offices.
- **Implementation of Cradle to Grave certification (PEFC-FSC).** Stewart Milne is currently implementing the necessary controls with its supply chain in order to ensure that the timber products used in the fabrication of the wall panels and floor cassette are harvested from approved FSC or PEFC sustainable managed forest. The Cradle to grave certification also allows Stewart Milne's clients to trace the origin of the timber back to the forest sections where the trees were harvested.
- **Implementation of recycling through all the activities of the factory and on construction sites**. All employees in the office, on the factory floors and on construction sites are encourage to segregate their waste in order to facilitate the management and recycling of waste materials, through the use of marked containers.
- **Optimisation of material use and human resources**. From inception to construction on site, the design, manufacturing and erection process are constantly reviewed in order to ensure that the use of resources, human and materials, are optimised.
- **Ensuring that the basic materials used are the most sustainable.** The supply chain is also involved in reaching the environmental programme set by the company by being encouraged to supply and deliver products to the required environmental specifications.
- **Ensuring continuity of the factory approach to the construction sites.** The factory environment permits rigorous quality controls at each stage of design and production. In such an environment, waste segregation at the point of production is relatively easy and encouraged. This factory led mentality is strongly encouraged on site. Erection procedures and training programmes have been developed to improve the erection process in order to obtain factory like erection processes and to minimise the generation of waste on site.

3.2 Dealing with waste: The environment manager

In order to help the group to monitor, develop and implement recycling and waste minimisation procedures, Stewart Milne created, a specific role for a dedicated environmental manager in 2006 who reports directly to the Production Director and has the following responsibilities:

- assessment of Stewart Milne's activities and identification of material and resource waste;

- development and implementation of waste management policies;
- development and implementation of environmental policies;
- establishment of contacts with organisations and companies with regards to re-cycling, reuse and disposal of waste;
- management of ISO 14001 environmental accreditation; and
- management and monitoring of PEFC-FSC certification and audits.

Whilst, in the course of the last 5 years, the production of timber frame structure has doubled, the quantity of waste generated by the production line has remained constant (at around 20tons a week). In relative terms, the introduction of the waste minimisation and environment policies has cut the proportion of waste by half. It is noteworthy to stress that only approximately 20% of this waste is currently sent to landfill. Stewart Milne plans are now to ensure that by the end of 2007 all waste generated at the factory are recycled or reused.

3.3 Estimation and Design Stage

The main market for timber frame is residential and housing construction, including detached and semi-detached single occupancy dwellings, and multi-occupancy buildings up to 7 storeys. Although the timber frame technique is now relatively well known, some of the projects submitted for price estimates and manufacturing may not always make the most of the advantages that timber frame offers. Therefore, Stewart Milne, as most of its competitors, will carefully assess all projects submitted to them, and will propose, where deemed necessary, modifications that will make the design of the project easier to produce. In some instances, the building design and specifications could be such that the manufacturer may decline the opportunity to pursue the project beyond the estimation stage on the grounds of technical incompatibility. Although disappointing in commercial terms, these dismissals save time and resources, and certainly reduce the waste generated by errors.

Once the client approves a scheme and proceeds with the order, the design team will prepare the manufacturing and erection drawings for approval by the clients and for internal review. At Stewart Milne, the design team optimises the building using state of the art computer CAD-CAM systems in order to limit the unnecessary use of materials in the manufacturing of the wall panels and floor cassettes. To achieve this, the design engineer will consider the following aspects:

- **Dimensions of exterior walls:** Dimensions should be within multiples of 600mm, which is half the width of the racking boards. This decreases the amount of materials required per square meter of construction and optimises the management and utilisation of OSB board, the material most difficult to reuse or to recycle.
- **Locations of framed openings.** The positioning of doors and windows to optimise the use of materials. This would have a direct effect on the number of studs used in wall panels, as well as the cutting patterns of OSB panels.
- **Amount of materials**. Through the design process engineers will quantify the exact number of nails, plates, connections, ties, etc. required for each building. Producing an exact bill of materials for all of the required materials for the manufacture and erection.
- **Number of different parts**. The design engineer will also ensure that, for each of the panels, the number of different parts is limited in order to avoid errors during the manufacturing process. This standardisation also decreases the amount of materials required in stock and facilitates the management of components and materials in the

factory. By working with a limited number of details, the personnel at the factory and the erectors on site save time and limit errors that could cause the complete loss of materials and panels.

- **Use of generic details**. The design engineer will create the building using a limited number of standard details as developed by TRADA. The use of the TRADA details also allows other timber frame workers not only to properly erect the structure, but to modify or repair buildings years after their completion.
- **Cutting patterns**. The design team will also produce cutting patterns for chipboard for floor cassettes and for OSB racking panels. These are especially important to reduce the amount of wasted materials and to ensure a better utilisation of the chipboard and OSB boards.
- **Optimisation of length used**. Joists and beams are delivered at the factory in 15m lengths. The design team will produce a cutting list to optimise the use of the joists and beams and to reduce the waste. This computer aided process looks into daily production to ensure minimum waste of materials.

Before the information is sent to the manufacturing floor, the bills of materials are rigorously checked by the production manager to ensure that there are no abnormalities in the design, and that the design uses generic and easily available materials. Additional materials, precisely determined by the design engineer, are also reviewed and sent to site.

The estimation and design stage represent very important steps in the optimisation of the use of resources and reduction of waste throughout the manufacturing and erection process. During the past few years, Stewart Milne set improvement targets for waste from the primary production process on each project. These basic targets for 2007 are established as follows:

- Studs and plates: 8% (from 16% in 2000)
- Boards: 9% (from 18% in 2000)
- Joists 8% (from 16% in 2000)

The Company also has a policy in place to reduce the waste generated by 20% a year over the next 3 years, to levels under 5%.

It is important to stress that most of the materials are reused in the process. Some of the techniques are explained later.

The design team, therefore, must design the buildings with these targets in mind, and must also ensure a dialogue with the production managers in order to optimise the manufacturing process. This is done using state-of-the art computer software able to process two days worth of production and to establish cutting patterns that enhance the performance of the production facility in terms of waste minimisation. The environmental and waste management performances are regularly compared to the target figures, which are formally reviewed once a year to reflect the improvements implemented during the year. In the last 5 years, the levels have been lowered annually, reflecting the constant improvement of the design and production of timber frame, cutting the waste generated by the manufacturing facilities by half.

3.4 Manufacturing of Timber Frame panels

Due to the high level of standardisation of the open-cell panel assembly methods, timber frame manufacturing is relatively easy to set up. Small companies use a labour intensive approach for the production of timber frame panels, whilst other large organisations, like Stewart Milne, have automated production lines able to manufacture the equivalent of one dwelling every 45 minutes. Most of these large manufacturing facilities benefit from the use of CAD-CAM software that is coupled to individual cutting machinery optimisation software. Based on the daily production schedule, this optimisation software determines the most efficient cutting patterns of timber, beams, joists, etc. so to decrease, if not to eliminate, the generation of waste that would normally occur through the preparation of timber elements cut on a panel by panel basis.

3.4.1 Wall Elements

The production of timber frame exterior and interior wall panels requires the following materials:

- CLS rated treated timber (various dimensions) – structural skeleton
- Oriented Strand Board (OSB) or plywood– racking resistance
- Breather membrane
- Nails (various dimensions)

The production of top and base plates is based on a mixture of long lengths of CLS timber that are connected together by nail plates with smaller off cut pieces (longer than 900mm) recovered from other activities in the factory. The machinery that produces the top and bottom plates does not produce waste other than the sawdust resulting from the cutting of the plates to the required lengths.

Up to now, at Stewart Milne, the studs are cut to the standard lengths at the factory. The machinery used is able to cut through standard timber bundles to an accuracy of 1mm. The procured length of the bundles is such that two or three standard stud lengths can be cut from the same bundle without producing additional waste other than the sawdust which is collected by vacuum. In other factories, the manufacturers would order pre-cut studs ready for use.

The racking resistance is provided by the OSB or plywood sheathing affixed to the exterior side of the studs. Because of the standard dimensions of the OSB being multiples of 600mm, the design engineering will ensure that all panels lengths are also a multiple of 600mm. Doing so, it provides the manufacturing floor a chance to reuse the off cuts of boards onto other wall panels. However, due to most of the building architectural designs being based on brick dimensions (exterior skin), the design engineer will also include one panel per exterior wall that has dimensions which are not multiple of 600mm. The subsequent OSB off cuts are sent to a charity that uses these off cuts to produced small artefacts sold for funding.

Analysis of the waste generated by its activities showed Stewart Milne had a significant number of off cuts that could be used for the in-house production of pallets. The production of these pallets is sufficient to provide the Company its shipping requirements. Furthermore, the pallets are brought back from site and reused constantly. At the end of the pallets' life, they are dismantled and timber sent for composting.

Finally, the small quantity of timber OSB off cuts that can not be reused as top and bottom plates, re-cut for packing purposes, or integrated into pallets is sent to a sub-contractor that transforms this timber into compost/litter for garden and stables. The sub-contractor collects the timber from large containers on the factory site, and processes the timber into semi-composted materials sold to the public.

Furthermore, the plastic sheets used to wrap the bundles of timber product delivered at the factory are collected, compacted and sold to a sub-contractor that recycles plastics. Other packaging materials such as cardboard boxes are segregated and sent to recycling.

From the whole design and manufacturing processes, very little waste is currently sent to landfill (less than 20% of the total waste produced). However, Stewart Milne has created task groups to identify methods to further minimise waste generated by its activities and to ensure that, by the end of 2007, all waste is either reused or recycled.

3.4.2 Floor Cassettes

Floor cassettes are made from the following components:

- Joists (solid timber or engineered timber)
- Beams
- Floor chipboards

The joists supplied by joist manufacturers can be delivered at the factory as pre-cut kits to be assembled. This is the preferred method for those factories not having the necessary equipment in house to prepare and assemble floor cassettes. In large factories, the joists would be delivered in 15m lengths and cut to the required lengths on a computer controlled saw bench. The computer would run and optimisation programme that would take into account the daily production required and optimise the cutting patterns for joists and blockings based on the 15m lengths, hence reducing the waste produced.

The joists are then fed to a semi-automated line that ensures the exact positioning of the joists and the squareness of the floor cassettes.

The floor chipboards are pre-cut to size from larger boards (1.2m x 2.4m)

The waste generated by the floor cassette production is limited because of the large scale of the element assembled. All wasted materials are normally not re-usable, thus sent to composting.

3.5 Delivery to site

Parallel to the manufacturing process, the logistic / delivery team provides the additional materials that are needed for the erection of the timber frame structures on site. The quantity required for each of these additional parts and materials are precisely estimated by the design team.

Utilising Stewart Milne's own fleet of trucks ensures that the delivery programme, based on a just-in-time delivery schedule, is planned in accordance with the needs of the erection crews on site. By better controlling the transport to site and synchronising the transport with production and the needs on site, it has been possible to reduce the ratio of traffic to site per dwelling by between 5% and 10% since 2000.

The operations on site are carried out by trained personnel that are fully aware of the objectives of the Company in terms of environmental performance and waste reduction. Training programmes for the construction staff (approved sub-contractors) include methods to reuse insulation off-cuts and to properly install vapour control layers. Traditionally, these two materials represent a substantial amount of waste disposed to landfill. With simple methods, Stewart Milne has been able to reduce the amount of insulation wasted to levels less than 1%.

4.0 Conclusion

The production of timber frame elements takes place in a protected environment where quality controls are rigorously applied at every stage of the manufacturing process. The nature of the factory environment also permits manufacturers like Stewart Milne to optimise the design of the elements, and to maintain total control on the use of every component that is assembled to form either wall panels or floor cassettes.

The use of timber frame methods on a construction site has the potential to reduce the amount of waste generated on site by between 20 - 40%, depending on the degree of offsite fabrication of the delivered elements. Offering a neat and precise methodology of erection, the use of timber frame structures reduces the amount of unnecessary materials on site, hence reducing the quantity of waste generated.

Timber frame techniques will also allow the erection crews to rationalise the use of materials, including insulation and vapour membrane, to nearly eliminate waste, by, for example, re-using the off cuts of insulation within the wall depths. Training and supervision on site are paramount to the implementation of such methodologies that are an extension of the factory led mentality to the construction site.

Table 1 summarises the areas where timber frame, as a manufactured product and a construction process, tackles waste. When comparing the level of waste of timber frame to the waste generated on traditional construction sites, it becomes apparent that the use of offsite construction methods such as timber frame makes a substantial difference in terms of waste minimisation and management.

The data made available for this study reveals that Stewart Milne's factory waste arising sent to landfill are less than 1.6% of the materials used in the manufacturing process.

When timber frame structures are delivered to construction sites, the waste directly generated by the erection of the structure is negligible. More traditional construction sites would normally generate, for the equivalent structural components, a significant amount of inert waste (dismissed blocs, surplus of mortar), insulation surplus and off cuts, packaging, timber pallets, etc.

The use of floor cassettes also impacts on the amount of timber wasted on more traditional construction sites where joists and floor boards are delivered in standard lengths and cut to suit the specific dimensions on site. In these cases, the off-cuts and extra materials from the on-site construction of floor are often thrown away or burnt on site.

Stewart Milne is an example of a pro-active and responsible manufacturer that reflects the wide spread mentality of the timber frame industry. Working with natural and sustainable materials, its is important for the timber frame industry to demonstrate that their product significantly impacts the construction both in terms of sustainability of the resource as well as of the carbon and waste footprint of buildings. Stewart Milne has demonstrated that by reviewing its manufacturing process and investing on software and machinery that optimise the cutting patterns, for example, and by identifying the environmental responsible suppliers and waste sub-contractor, it is possible to drastically cut materials and resources wastage. Also, by involving all its personnel into the implementation of simple segregation of waste at the point of generation, it is possible waste management coupled with re-cycling and reuse of materials can lead a manufacture to zero waste to landfill.

Table 1: Summary of saved materials and waste generated (Stewart Milne as an example)

Activities	*Waste generated*		*Waste disposal (%)*			*Saved Material (%)*
	Type	*%*	*Reuse*	*Recycle*	*Landfill*	
DESIGN & PROCUREMENT						
Accurate engineering	None	-/-	-/-	-/-	-/-	Timber (-8%) OSB (-9%) Joists (-8%)
Chipboard cutting patterns	None	-/-	-/-	-/-	-/-	
Optimisation of cutting patterns	None	-/-	-/-	-/-	-/-	
Use of 15m lengths for joists and beams	None	-/-	-/-	-/-	-/-	
Large size floor chipboards	None	-/-	-/-	-/-	-/-	
Top & bottom plate assembly and saw plant	None	-/-	-/-	-/-	-/-	
Protective Polyethylene sheet	Plastics	2%	0%	100%	0%	-/-
Cardboard packaging boxes containing nails	Cardboard	Negligeable	0%	100%	0%	-/-
MANUFACTURING						
Wall panels and floor cassettes	Studs and Plates	8%	15%	85%	0%	-/-
	OSB	9%	20%	80%	0%	-/-
	Joists	8%	15%	85%	0%	-/-
Other operations (offices, cantine, steel straps, etc.)	Various	<1%	5%	75%	20%	-/-
SHIPPING & ERECTION						
Use of recycled timber pallets returned to factory	Timber based	0%	100%	0%	0%	-/-
Optimisation and planning	None	-/-	-/-	-/-	-/-	Lorry Movements (-5% to -10%)
Site activities	Timber	Negligible	0%	50%	50%	-/-
	Insulation	Negligible	95%	5%	0%	-/-
	Other	Negligible	20	70	10	-/-

Written by:

Mtech Consult Limited
Maple House
The Professional Quarter
Shrewsbury Business Park
Shrewsbury
SY2 6LG

With the participation of:

Stewart Milne Timber Systems
Falcon House
Curbridge Business Park
Downs Road
Witney
Oxon
OX29 7WJ

Published by
Waste & Resources Action Programme

The Old Academy
21 Horse Fair
Banbury, Oxon
OX16 0AH

Tel: 01295 819 900
Fax: 01295 819 911
E-mail: info@wrap.org.uk

Helpline freephone
0808 100 2040

www.wrap.org.uk