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MID RISE CLT BUILDINGS – THE UK's EXPERIENCE AND POTENTIAL FOR AUS AND NZ

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ABSTRACT: Over the last 20 years Cross laminated timber (CLT) has become a very successful engineered wood product in Central Europe. 10 years ago it was first used in the UK as roof elements to a conventional building and has grown to become an established building system within the UK's construction Industry. There are now over 100 CLT projects in the UK across all industry sectors. It has developed a special role within the mid rise residential sector, that has stimulated interest across the world. What are the reasons for this, and how has this building material attracted such interest from architects, contractors and their clients?

This paper gives an overview of the history of the CLT in the UK, with a focus on the mid rise buildings from Eurban, one of the leading engineers and contractors of CLT in the UK. It will give also offer a view of the near future as CLT steps into UK's high rise sector and also the potential for its development in new markets in Australia and New Zealand.

KEYWORDS: Timber structures, Building structures, Engineered wood products, Cross laminated timber, Multi-storey buildings, Architecture and structures

1 INTRODUCTION

The first building in the UK to use the CLT material was built in 2000, just few years after the material was developed and available on the market in central Europe. This first project used CLT as simple roof elements as part of a conventional masonry building; the properties of CLT making it an ideal material to deliver the complex roof geometry. This made the UK an early adopter of the material and has turned the UK into a key market for CLT.

Image 1: *Caldicott School* © Henley Halebrown Rorrison

EURBAN was founded in 2002 as a timber engineering and contracting company to facilitate the use of CLT in the UK construction market. EURBAN completed its first project with CLT back in 2003 and it was the first project in the UK where the entire building structure, rather than an element of it, was delivered using CLT. Since then, EURBAN has pioneered the use of CLT so that it now represents an established timber construction system in the UK and also in other countries.

The interest for CLT as a buildings system is increasing especially for the mid rise residential sector where traditional timber framed systems reach their limits. CLT gives the timber industry a valuable option to target this market and compete with steel and concrete.

Image 2: *Bridport House, London UK*

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2 10 YEARS OF CLT IN THE UK

CLT started as a niche product in the UK but it has become over the years a recognised construction system challenging the use of steel and concrete. This in turn has invigorated the timber industry as it has opened up new opportunities in multiple storey residential and large public buildings.
The success can be seen in the various projects which have been built over the last years.

2.1 MID RISE PROJECT FROM 3 TO 8 STOREY

The first mid rise CLT building in the UK was a mixed commercial and residential development at Waterson Street in London. The building was built in 2005 and at five storeys, was the tallest residential CLT project in the world at the time.

Image 3: *Waterson Street, London UK* © Quay2c

There were a number of reasons why Waterson Street was a pioneering project for CLT and the timber industry. Not only the first mid rise residential CLT project completely built in timber above the concrete foundation. It was also the first to use timber for the stair cores and the lift shaft. At this time, delivering the stair and lift cores was a new approach for a timber building and not only in the UK but also in central Europe where still most of the timber mid rise buildings have a concrete cores.
This project demonstrated that timber can compete with bigger buildings made from concrete and steel; which was a key factor as this project was driven by the needs of the developer.
Part of the competitiveness was the faster build programme allowing an earlier income of rents and reduced financing costs. A faster build programme not only reduced the cost during the construction period it also reduced disruption to its neighbours a key factor to consider on a tight urban site.
Access to the building is provided through two cores, one with a lift shaft that runs from ground to 5th floor. CLT gave the architect the flexibility required to accommodate the mix of different users. The ground floor contains four retail or commercial units with direct access to the street. On first floor there are three commercial units of different areas. From second floor up to the top there are 11 one or two bedroom flats.

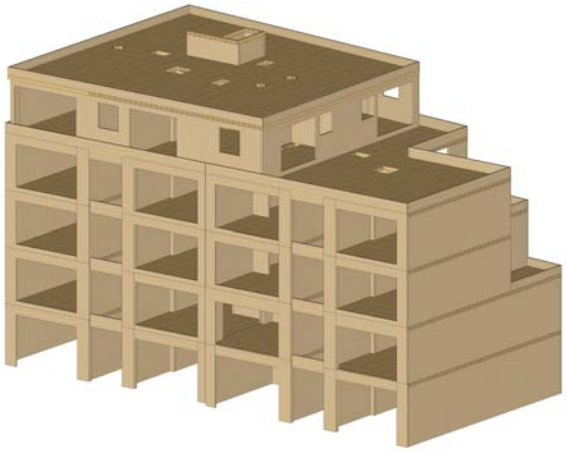

Figure 1: *3D Model Waterson Street* © EURBAN Ltd.

From a structural engineers point the strength of CLT was a big benefit to deal with these changes in layout and for the overall stability of the whole structure. It was also the first CLT building which fell into category 2B after the classification for buildings under BS EN 1991-1-7. This means it is in a higher risk category for disproportionate collapse. Part of UK building legislation (under part A) which was introduced to reduce the risk for progressive collapse. CLT is not mentioned in the current guidance but through the strength of the system it performs very well in an accidental load situation which is important to the market for buildings over 5 storeys. This storey height has previously been a barrier for timber frame buildings and is one of the reasons why timber was never widely used in the mid rise residential sector. However with CLT we now have now the right product to enter the market.
After Waterson Street a few other mid rise buildings in CLT followed, a four storey residential building in East London and in 2009 the first complete mid rise social housing project was built in Bristol. Whilst only three storeys the Bristol project demonstrated that the CLT system could compete with traditional building methods in a very price sensitive sector.

Image 4: *Pennywell Road, Bristol UK*

In addition, other companies entered the UK market with their own CLT projects: for example KLH with Murray Grove (also known as the Stadthaus project) in London, which is still the tallest CLT building in the world. The Stadthaus was completed 2009, taking three years after Waterson Street, for the next big milestone in the CLT mid rise market. Another two years later the next significant residential project was delivered with the completion of Bridport House.
Bridport House is the biggest residential CLT project in the UK and with eight storeys nearly as tall as the nine storey Stadthaus. Unlike the Stadthaus, which sits on a concrete podium first floor, Bridport House is entirely CLT above the concrete foundations.

2.2 Bridport House

Bridport House contains 41 social housing apartments, which meant the mix and the size of the apartments were dictated by the regulations for social housing and less by the design. It was the architects challenge to combine all these requirements into a design which settles into the surrounding neighbourhood but also with a modern touch to it. CLT was the preferred choice of material by the architects Karakusevic and Carson from the start, following the successful delivery of other projects together with EURBAN.

Image 5: *Bridport House, Architects Model* © KCA

There were many reasons for this choice. In addition to the environmental credentials of CLT, one reason is the flexibility which CLT gives to Architects on projects where space constraints are critical and also the green aspect. However, in this instant, the most important aspect was the much lower dead weight of a timber structure compared to concrete. A large Victorian sewer runs through the site and this limited the weight of the new building above the sewer. The part of the building directly over the sewer was only allowed to be 10% heavier than the existing 5 storey building, but the new building needed to accommodate the twice the number of apartments.
Part of the brief was also to have a variety of sizes of the apartments from two to four bedroom units. This is achieved with a layout consisting of four bedroom maisonette houses on the ground and first floor and a more typical apartment block layout for the floors above.

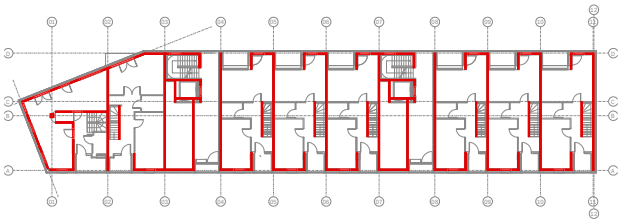

Figure 2: *Ground and First Floor Layouts* © EURBAN Ltd.

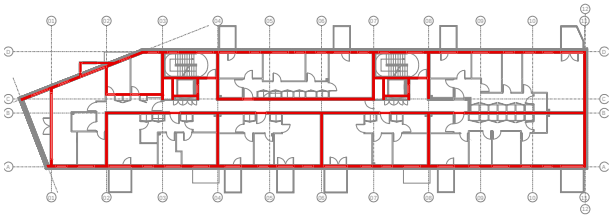

Figure 3: *Upper Floor Layouts* © EURBAN Ltd.

The result of the different apartment configurations are two different load bearing layouts for the structural system. The main load bearing walls on ground and first floor are the cross walls and the floor panels are running parallel to long elevation. This system changes at second floor with the main load bearing walls turning 90 degrees and running longitudinal to the building with floor panels spanning the width of the building.
The load bearing internal wall panels span as deep beams from cross wall to cross wall at the lower level. These internal walls are always supported at the crossing points and not between, which allows the wall panels to act as single or double span deep beams. The nature of CLT, with the possibility to span in both directions, allows this structural solution.

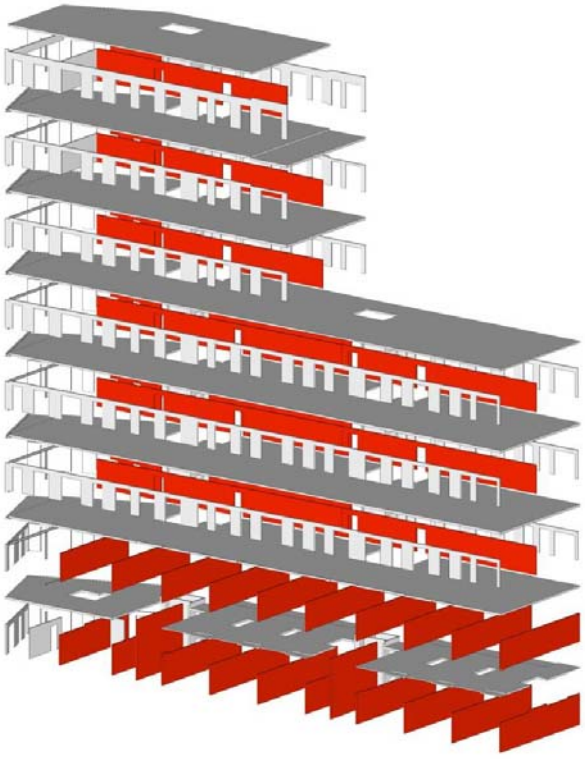

Figure 4: *Structural Layout, Bridport House* © EURBAN Ltd.

The overall stability of the building is achieved through the two access cores and some full height cross walls. The key elements for the stability are the access cores which are located at the rear of the building, one in the eight storey and the other in the lower five storey part. Each of these cores contains a lift shaft and staircase. The cores are completely constructed from CLT panels. The wall elements are running over two floors to reduce the amount of connections and also to reduce deflection and movement.
The CLT structure, as a whole, was reduced to a minimum and only the structural walls are in CLT. The non structural internal partitions walls in the apartments are constructed in lightweight stud walls. This reduced the building cost and increased flexibility, allowing for future changes to the layout of the flats. The principle is that only the outside walls and the compartment walls between flats are structural and therefore in CLT.
The compartment walls also act as acoustic and fire separating walls. To achieve the required performance every compartment walls has on each side an independent layer for separation. This layer contains two layers of plasterboard on lightweight steel stud with an acoustic insulation between. There is an air gap between this layer and the CLT wall to avoid any noise transfer. This system work very well and the first reactions from tenants and the onsite test results are positive and better than expected.
The Bridport House project demonstrates the technical possibilities of CLT for mid rise buildings with a challenging structural layout and it also shows the potential of CLT as a building material. There is no reason, from a structural engineer's view, why CLT shouldn't be used more often as a replacement for concrete or steel.
An important factor for selecting CLT on Bridport House was also the speed of construction. The whole CLT superstructure was build in only 10 weeks, which gave a 2 months saving in the overall construction programme. It is not only the speed of the superstructure erection the whole construction process can be optimized due to the precision of offsite manufacturing. Other building elements like doors and windows can be produced from the drawings and installed straight after the erection of the structure without the need of taking onsite measurements. The benefit of a dry construction method reduces the construction programme even more with the following trades. Feedback from the installation of services and other works can speed up as fixing components to a timber structure is simple and flexible when compared to concrete or masonry and so increases the overall building quality.
The logistics for a building of this size are very important not only for the manufacturing process but also for delivery of the installation which needs to be well organized such that all materials arrive on site only when required. The just-in time system works in favour for projects in cities where site space is limited and site constrains are high.

Image 6: *Installation Bridport House*

At Bridport House the building footprint comes very close to the overall site boundary. The delivery schedule needed to be planned to suit the site conditions which meant, in this case, the CLT elements could be installed direct from the lorry. Site conditions can be also important for the design of the structure and may dictate the size of panels that can be delivered to site because of access, craneage or other site constrains.
The CLT system is an ideal way to build in urban areas due to this inherent speed of construction and the low noise level of the site works. Keeping disruption to the neighbours at a minimum is a necessity for the efficient delivery of new buildings in urban centres.
Bridport House shows the many benefits of CLT in mid to high rise buildings, but the most important fact is that CLT can compete with the traditional building systems in cost and programme. The social housing market is very competitive and cost driven, therefore it is essential to able to compete at the same level as other structural systems.

Image 7: *Bridport House* *© Ioanna Marinescu*

Bridport house is great example for the benefits of timber as building material and it will be important for the further success of CLT in the market.

2.3 KEY FACTORES FOR THE SUCCESS

There are a number of different factors which have made CLT so successful in recent years: speed of construction, system performance, durability and the simplicity of solid timber construction has made it a viable contender to more traditional structural systems.
CLT is not only a structural material it delivers as a system more benefits then a traditional structural system. A CLT structures are not only structural they also provide a high quality building envelope with a high level of airtightness and reduced risk of thermal bridging.
Due to the mass of the structure it prevents overheating in the summer. It controls the humidity level much better than concrete and provides a better indoor air quality.
The prefabrication and simplicity of the system are important factors for the quality control. The prefabrication which is driven by the latest CAD-CAM technology allows a controlled and integrated process from the design into production to avoid fabrication errors. This system allows also the production of complex projects with many different elements. Every panel is an individual and bespoke element for a certain position in the building. This process doesn't stop at the factory gate it is also used for the organisation on site and makes sure every panel arrives at the right time on the right delivery. The special numbering system allows the installation team to identify the element and place it on their right position in the building. With the individual number every panel can be followed through from the production to the finished structure. This process of Quality Management and Control is vital to delivering large projects on significantly reduced construction programmes. The precision of the prefabrication also makes the installation process more efficient as no on site adaptation of elements should be required. The high level of fabrication and construction tolerance is also a benefit for the following trades and it speeds up their time on site. The simplicity and the repetitiveness of the connection details make it a reliable system for the works on site. The quality of the installation can be easy checked as most of the connections are visible in the structure allowing for continuous quality checks without interrupting the construction programme or sequence.
Whilst CLT can present a sound case as an alternative construction system, perhaps the more interesting factor for the mid rise residential market developer is its unique ability to create low carbon or carbon neutral developments. CLT is uniquely placed to reduce the carbon footprint of the construction industry. CLT building structures are a carbon store and can contribute significantly to the construction industries challenge of delivering on its carbon reduction strategies.
Storing carbon in your building structure can also be a cost effective alternative to on site renewables. At Bridport House the 2044 tons of sequestered Carbon has the equivalent saving to providing 20% of the buildings energy requirement in use for 139 years.
Timber is not only a carbon sink it is the only widely used renewable building material and at the moment the only renewable alternative for mid rise building. CLT offers an additional opportunity to reduce the carbon footprint for the industry by recycling the structural material. A CLT building can be dismantled in the same way as it was installed and every layer of the building envelope can be removed separately and reused. That means for the CLT panels they can be reused as structural panels or they can be converted into another wood product like OSB or chip board. This method puts the timber and the stored carbon back into a building where it will stay for another 60 year cycle. Ultimately, if the timber cannot be reused or recycled the timber can be used as biomass fuel. A CLT building never needs to go to landfill.

2.4 NOT ONLY IN THE UK

The UK is not the place in Europe where CLT is on the front foot in the mid rise market. There are projects all over Europe and not only in the traditional strong timber market like the alpine region and Scandinavia. CLT is entering more and more urban regions as shown in a seven storey building in Berlin, Germany or in Vienna, Austria. Another good example is the four multi story residential buildings in Växjö Sweden.

Image 8: *8 Storey residential buildings in Växjö Sweden*

There are many other examples already built or coming in the near future that show the potential of CLT under different climatic conditions and in cultural regions.

3 THE NEXT STEPS

All of the mid rise residential buildings discussed today demonstrate the future possibilities for CLT and timber structures.
These projects are important milestones and references showing designers and their clients that it is possible to build large scale and multiple storey structures using timber.

3.1 NEW MID RISE PROJECT

Bridport House is the latest mid rise CLT building in the UK. Being one the first projects of a wider program of regeneration there are a number of neighbouring developments inspired by the success of this building. So much so, that a number of other projects previously planned as concrete may now change to timber.

In the vicinity of Bridport House there are number of new mid rise buildings in the planning and CLT is one of the favoured materials for the structure. This is not only down to the very positive reaction from the residents of Bridport House CLT is also very popular with the Local Authority as a result of the success with Bridport House. There is real potential that the whole area could turn into very good showcase for CLT with all the projects due over the next few years. It would also reflect the versatility of CLT as there is a mix of different size buildings require: from three storeys up to as high as twelve or even more storeys. A variety of end users will also be represented as high quality private developments, as well as social housing, are planned.
The next CLT mid rise project will be a seven storey residential block in Southwest London, where works on site should start in autumn 2012. This building will be located in an expensive part of London and shows CLT buildings are representative of high quality and high performance as well as being competitive on cost and programme. Again a key requirement here will be the speed of erection on site and a very low level of disruption to neighbours.
There are also a handful of other project across London in the pipeline as well as projects in very popular locations within the City.

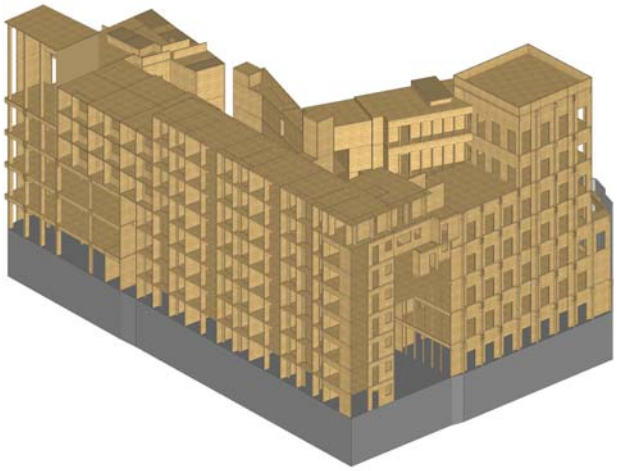

Figure 5: *Feasibility Study Central London* © EURBAN Ltd

EURBAN is currently working on a larger scheme in central London which would be even higher than Bridport House. A project in one of the most important areas of central London, it could raise mid and high rise timber buildings to a new level. It is possible that in the future London will become the capital of mid rise CLT buildings.
Also in other UK's cities the interest is growing to build mid rise residential using the CLT system. But it will be really depend on the economy and some potential government driven housing projects to boost the market.
CLT is still at a relatively early stage of development, however its potential shows that there is much more to come.

3.2 MOVE TO THE NEXT LEVEL

To move CLT to next level in the mid rise residential market it is important to get the awareness from more stakeholders in the market. CLT needs to become a natural choice by designers like steel and concrete. Architects should think from the start of project that it could be CLT and engineers need to get confident using CLT as structural material.
Developers need to understand the marketing potential of timber as carbon neutral material and the improved quality of living which timber buildings can offer. Most of potential clients like the feel and the benefits of timber and its use shouldn't be restricted to the fit out. One of the main drivers for developers is the cost against performance, but several projects have now showed that there isn't any premium to the traditional building methods if all the benefits of timber are taken in account.
To convince contractors to use CLT it is crucially important that they understand the benefits of the whole building process when compared to traditional methods. It is often the contractor and their ability to compete on cost that drives the building process. As a result of the successful delivery of projects like Bridport House some contractors are beginning to appreciate that CLT is a real alternative to traditional forms of construction.
The best way to get all these stakeholders to understand the benefits of CLT is to simply deliver more projects, but it takes time and it means that learning process will start each time at zero if projects are procured in a way where timber is the second option to conventional structural; materials.
It is therefore important to get a timber specialist engineer involved from the start of the project to get the best solution to the structure & delivery to site. This doesn't mean an engineer who knows about timber. It is crucial to the success of a project that the engineer understands CLT and its importance to the building envelope.
Another important point is to get a European design standard for CLT which reflects the possibilities and the behaviour of this product. This would boost the process of standardising the various CLT products in to one standard timber product as has happened with glulam. This would help everybody see CLT as a standard building system and not as a specific product from one supplier; in doing so CLT can be specified by design without an early commitment to any one particular supplier. In turn this will open up the market and make it more competitive as some clients can feel nervous if they are required to commit to one manufacturer early in the process.
The fact is that until recently, every CLT producer has been marketing his product as unique making it hard for some to see CLT as a standard timber product and a universal construction system. For many people this is confusing and it makes it simply easier for them to specify a generic product like steel or concrete.
The standardising of CLT materials would make it also easier to adopt into Building Standards separating it clearly from timber frame. That would means the behaviour of CLT could be reflected better in the regulations. This very important for the behaviour in the

event of fire as there is a significant difference between a stick frame and a CLT structure which isn't recognised in the building regulations yet. The fire behaviour is only one example for the difference between stick frame and CLT. Others are thermal mass, robustness and behaviour for preventing disproportionate collapse.
There is still a lot to do to move CLT to a similar level as steel and concrete and it would need the whole industry to work together to achieve this.

3.3 THE POTENTIAL FOR HIGH RISE

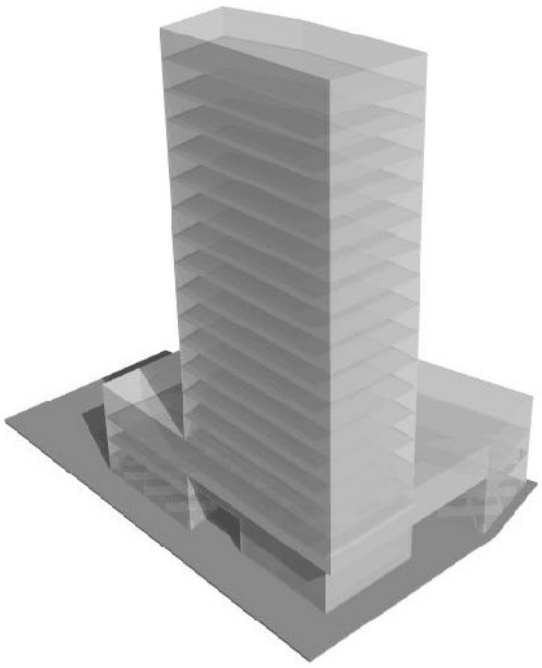

Image 9: *Feasibility Study 19 Storey Tower © EURBAN Ltd*

Four years ago EURBAN undertook a feasibility study for a 19 storey tower in East London. The five low level floors contained open space retail and office areas and it was therefore designed as a concrete structure with 14 storey residential CLT tower. To achieve the necessary fire performance of four hours for the access core and to achieve the horizontal stability, the core was also designed in concrete. The concrete core is situated in the middle of the towers with the apartment arranged in rings around the core. The CLT structure is fixed back to the concrete core to transfer the horizontal loads into the core. The vertical load goes through the CLT structure into the concrete podium.
Unfortunately the building never progressed due to a lack of funding at this time.
But the feasibility study demonstrated the possibility to build a building that tall in CLT and this not only from a technical point, it was also competitive on cost.
This feasibility study and all the others show it is only matter of time until the 12 storey mark is broken. The studies and current experience demonstrates it is possible and with a proven track record only needs the right client for them to go ahead.

4 THE POTENTIAL FOR AUS AND NZ

In Australia, construction costs for apartments are significantly higher than construction costs for housing. Timber and masonry, the main materials used for buildings under 3 storeys, are less expensive than steel and concrete and competition amongst sub contractors would appear to of held costs down. In other construction sectors, commercial builders utilising concrete and steel, means costs have remained high. It is in these markets that CLT will create new opportunities for the timber industry.
The fact that New Zealand is in an earthquake zone gives timber and especially CLT a good chance for a share of the market. The market looks similar to Australia with the bigger market potential in the mid rise sector where the main competitors are steel and concrete.

4.1 POTENTIAL PROJECTS IN AUS

There are few projects in different stages in Australia and the first mid rise projects using CLT will be on the ground by middle of 2012. The first project will be a landmark project for the whole timber industry in Australasia and would raise the profile of CLT in the whole region.
The interest for CLT in Australia started two to three years ago as more and more CLT projects from Europe and in particular from the UK got attention from architects and developers.
A feasibility study for a development in the suburbs of Sydney in early 2011 demonstrated the competitiveness in this market. The development contains three mid rise building from six to eight storeys. The six and seven storey CLT structures are sitting on top of underground parking deck and a basement floor in concrete. One of them is on a two storey concrete podium for commercial use.

Image 10: *Feasibility Study, Sydney AUS © architectus*

To achieve as much flexibility as possible only the outside and internal party walls are in CLT. The internal partitions walls are non structural formed out of lightweight stud walls. The floor and roof panels are running over at least two bays to get the advantage of a multiple span system.

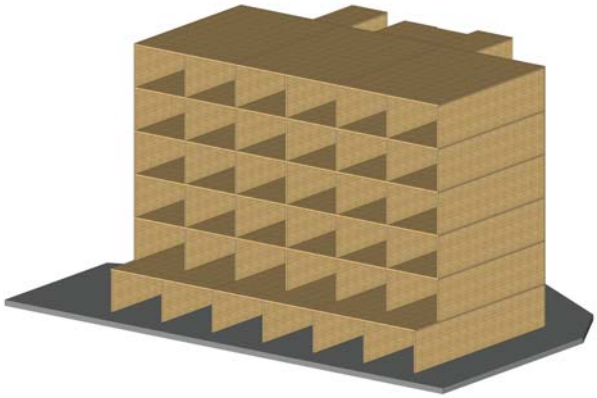

Figure 6: *3D Model Block A © EURBAN Ltd.*

The required fire performance is achieved through a combined calculation of the plasterboard lining and the charring of the CLT elements. The access cores which are sitting to the rear of the blocks can be either in CLT or in more conventional precast concrete elements. The whole structure is very similar to a traditional concrete scheme. This makes it much easier to adopt the CLT structure in the building process which is important to get a real breakthrough for CLT in the Australian market.
The structural solution which was chosen for this project can be easily adopted for other potential project and clearly demonstrates the great potential in the Australian mid rise residential market.
The first mid rise CLT project due on site in the southern hemisphere is a 10 storey residential project in Melbourne. This project will be very important for the boosting the profile of the CLT market in Australia.

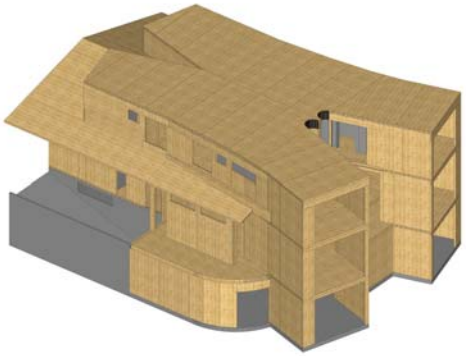

Figure 7: *3D Model House Melbourne, AUS © EURBAN Ltd.*

Another potential market for CLT in Australia is the non standard architectural housing market. This is demonstrated by another ongoing project in Melbourne. This project consists of a pair of semi-detached family homes with non standard shape with some underground parking space and basement in a mixed structure of CLT and concrete. The two upper floors are completely designed in CLT. It shows the possibility to create complicated shapes with CLT and achieve a great and controlled building quality.
The building is in the design process at the moment and it should be erected on site in autumn 2012.

All this ongoing work will help to form the Australian market for CLT but sooner or later it will be important to get some locally produced material, rather than rely on imported panels. Latest research projects confirm the suitability of native Australian softwood species the production of CLT.

4.2 POTENTIAL PROJECTS IN NZ

A big opportunity for CLT mid rise buildings in New Zealand will be as part of the rebuilding process of Christchurch. The behaviour of CLT in an earthquake is outstanding and has been demonstrated with the rebuilding of L'Aquila in Italy. The seismic performance of CLT has been rigorously tested in different research projects and brings unique opportunities for building in earthquake zones all over the world.
The inherent properties of the material and the benefits that come with the building system will naturally be of interest to designers and contractors in New Zealand and it will only be a matter of time before the first project will be delivered.
There is now a CLT manufacturing facility near Nelson NZ, which will play an important role in the success of CLT in New Zealand. This local production makes the country more independent from European or North American suppliers and there should be a real cost and time advantage. It will give the timber industry in New Zealand the chance to start smaller and expand the capacities with the growing demand from the market.

5 CONCLUSIONS

The success of CLT in the UK is not only the success for one product. It has been very important for the timber industry as a whole, particularly the presence of engineered timber structures in the UK. It is, once again, a real alternative to concrete or steel.
This regeneration can also work in other world regions as CLT gives designers and the industry an ability to move into new markets and challenge the traditional systems on cost, building performance and sustainability.
It is important to see CLT as an addition to the timber industry and not as rival for the traditional timber industry.