

## **Lean Startup Approach Identifies a New Value Proposition in Portal Frame Building Design**

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*New Zealand Steel, through its subsidiary Steltech<sup>®</sup> and in collaboration with manufacturer Donovan Group Ltd, utilised the “Lean Startup” development and innovation process to develop a novel light-weight and efficient nested tapered box beam (NTBB) solution for portal frame buildings. In New Zealand, medium-span portal frames are dominated by imported hot rolled steel sections. The NTBB solution, produced from coil plate folded into two tapered C’s nested inside one another, is able to compete against cold formed sections, hot rolled section and welded beams, as well as finding application in large clear spans.*

*The rapid prototyping and early market trialling, which typifies the “Lean Startup” approach, is easy to apply in the digital world. Contemporary examples of Lean Startup are most often found in high tech and fast paced industries, with key proponents of Lean Start-Up including Intuit, Dropbox, and General Electric. The NTBB project is a “bricks and mortar” example where the minimum viable product had to meet a range of engineering design requirements and building codes. The initial value proposition of the NTBB was considered to be an overall reduction in fabrication costs due to weight savings and the NTBB’s simple external geometry. However, based on early customer feedback, an additional (and unexpected) attribute was identified as having strong value to the market. This paper describes how the Lean Startup methodology was applied to develop a novel nested tapered box beam and the associated attributes of value to the building market.*

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### **Introduction**

Steltech Ltd produces custom welded beams and columns to a wide range of sizes, shapes and lengths based on an elegant and efficient design process. Donovan Group Ltd (DGL) designs, fabricates and erects portal frame buildings across New Zealand. Together, the partners identified a means to fill a gap in the Steltech offer that was previously being filled by imported hot rolled steel sections or light galvanised cold formed sections. The initial target market for the product was to fill the product offer gap in the twenty to thirty-five metre clear span for portal frame buildings with domestically manufactured product.

Cold formed steel framed buildings are effective to approximately twenty-five metres but DGL customers had reservations regarding building robustness as the span increased. The market was therefore largely serviced by hot rolled sections or, less commonly, trusses. The NTBB design methodology has now been proven in both medium span projects, as well as larger projects (fifty metre clear spans with spans up to seventy metres possible).

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## Custom Welded Beams

Custom welded beam (CWB) designs are the standard design solution for large clear span buildings. Steltech has demonstrated, over its large portfolio of CWB projects, typical weight savings of 20-30% over hot rolled beams. This weight saving is achieved by ensuring that the steel is placed where required by the point loads or moments, whereas hot rolled section sizing depends on the overall critical design loads. A typical example of a CWB is shown in Figure 1. The cost of fabricating CWBs is offset, and in many cases improved, by the weight savings and improved yield through reduced waste. The NTBB project aimed to capture similar weight savings as CWBs combined with additional customer benefits.



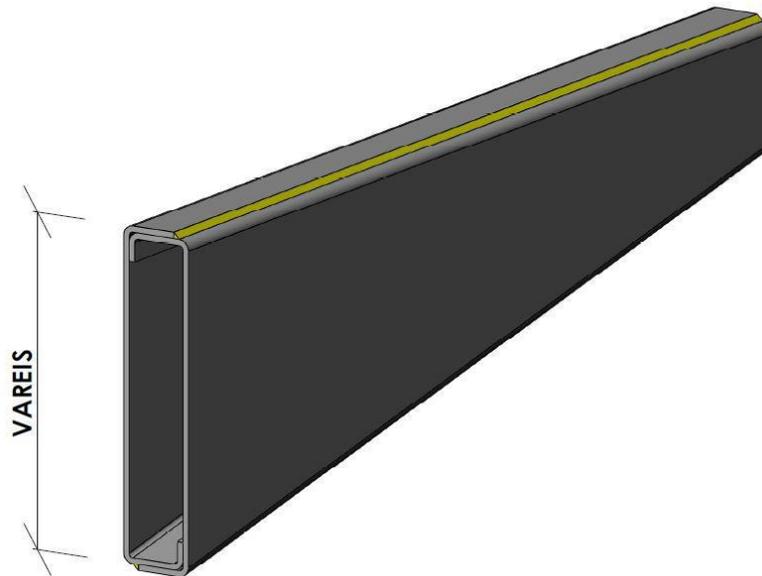
**Figure 1.** Custom welded beams produced by Steltech. NZ Post sorting room Highbrook Business Park, 60m clear span

## Nested Tapered Box Beams

For the trials, DGL manufactured the NTBB using New Zealand Steel 6mm-10mm thick AS1594 HA300 coil plate. Eight metre tapered beam sections were cut, folded and welded with the final frame bolting being completed on site using a similar erection process as to CWBs. The finished building included the typical bolted hip and rafter connections shown in Figure 2.



**Figure 2.** A new DGL build North of Christchurch for PlaceMakers using the NTBB, 30m clear span.



**Figure 3.** The depth of the NTBB varies along the longitudinal length and a includes return leg on the inside of the nested sections.

### **Lean Startup Approach**

NZ Steel uses a Lean Startup methodology for its product developments. Customer validated learning are at the heart of the Lean Startup methodology, which is based on a “build, measure and learn<sup>i</sup>” feedback cycle to deliver rapid results. Lean Startup builds on Lean Manufacturing principals<sup>ii</sup> common in manufacturing sectors, which aim to eliminate or minimise all types of wastes from production processes<sup>iii</sup>. Lean Startup thinking is specifically aimed at the wastes that arise during innovation and step change development and is summarised by Eric Ries:

*“if startups invest their time into iteratively building products or services to meet the needs of early customers, they can reduce the market risks and sidestep the need for large amounts of initial project funding and expensive product launches and failures”<sup>iv</sup>.*

What Lean Startup aims to prevent is businesses developing technically perfect products that customers neither need nor value. The tools in Lean Start-up help to test product or service iterations to evaluate propositions against customer value. These validated learnings are key to identifying whether the correct business decision is to persevere with development or change direction and focus on a refined value proposition or business model based on real customer feedback.

#### **Lean Startup: Evaluating the Minimum Viable Products**

Prior to erecting the first NTBB frames, the engineering design methodology based on AS/NZS 4600:2005, was verified by the New Zealand Heavy Engineering Research Association<sup>v</sup> (HERA). The typical section of a NTBB beam, Figure 3, validated in the HERA methodology considered:

- tapered members subject to bending – Direct Strength Method;
- tapered members subject to axial compression (closed section) and for combined axial compression and bending; and
- shear capacity of webs and combined bending and shear.

The Lean Startup methodology promotes the early testing of minimum viable products (MVPs) with customers. This ensures that no time is wasted on developing technically superior products, while missing important customer insights. In the NTBB product development, once the HERA validated design was obtained, the system was trialled with customers through a number of iterations.

The initial NTBB design concept included only a parallel beam solution. Tapering of the beam was added after DGL confirmed that nesting folded tapered fabrication was practical. Adding tapering to the NTBB allowed for similar weight savings compared to a CWB. Additional fabrication cost reductions were achieved through optimising the size of the two longitudinal weld details.

The first NTBB buildings included a large return on the inside of the nested beam (Figure 3). Engineering development identified this as an area that could be reduced without impacting on the NTBB's torsional or buckling performance.

These improvements were made based on experiential learnings. Modified versions of the MVP were re-trialled in a 'build, measure and learn" loop, leading to significant improvements in the design and validation of the product's key value propositions.

### **Validating Our NTBB Value Propositions Assumptions**

The most valuable innovations make something hard to do into something easy to do. When developing new products, product development teams often assume that they understand what the market values. A key aspect of the Lean Start-Up methodology is in market evaluation of these assumptions.

Development of the NTBB initially focused on offering customers: 1) a more robust engineering solution for medium span buildings, compared to cold formed section; and 2) a lighter-weight solution than hot rolled section design. When the product was tested in market with real customers an additional three value propositions were identified:

1. cost savings – initial design calculations predicted that the bulk of cost savings for the NTBB would be provided by weight savings (being 10% lower weight than hot rolled sections). When a NTBB design was compared to a CWB solution, commonly used by a leading pre-fabricated building design company in North America (See Appendix 1 for details), it showed a small weight increase but identified a new cost saving. Due to its simplified external geometry, compared to a CWB, the NTBB offered much lower painting costs;
2. shorter erection times—in the Placemakers project, Figure 2, DGL identified a 10% reduction in time to occupancy compared to what would be expected for a cold formed portal frame; and
3. building health– the flush layout of the beams to purlins and cladding, as well as specific detailing in the girts, meant that birds and rodents could not move along the beams or roost (Figure 4). This was a completely unexpected design feature that is particularly attractive to the food, storage and manufacturing industries that require clean work areas. Prior to the NTBB solution vermin proofing of traditional portal frame designs relied on a range of products and services such as poisoning, pest control and installing netting to exclude birds (Figure 5), all of which come at additional costs to building owners. Site inspections of buildings using the NTBB building system found no evidence of beam or ground fouling.



**Figure 4.** A typical example of the vermin proof NTBB design, combined with the inclusion of nested purlins.



**Figure 5.** An example of the installation methods for bird proofing. Access is being added to roof space in a building using bird netting and hot rolled section frame.

### **Learnings from the Lean Startup Approach**

The NTBB is an excellent example of how the application of Lean Startup to the building design, fabrication and construction process (even within the constraints of engineering and building codes) can lead to fast-tracked product development and unexpected customer insights. The key learnings included:

1. early trials can avoid time being wasted on refining product design features that are not of value;
2. early trials can identify new attributes to focus product development resource allocation;
3. product development teams can make assumptions about market needs but unexpected design features with real value to customers are only uncovered during in market trials.

### **Conclusions**

Development of the NTBB is an example of how Lean Startup thinking has redirected a product development to focus on solutions valued by a large customer segment. Creation of the NTBB healthy building systems has solved a difficult problem for customers, which the product development team was initially not focused

on solving. This has led to radical innovation in an established field where innovation is traditionally focused on incremental step changes rather than offering a whole new value proposition to the market.

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**Appendix 1**

**Cost Comparison between a NTBB and a CWB portal frame**

The design comparison<sup>vi</sup> frame considered was a 30m clear span portal with a 6.1m hip height and a roof slope of 2.3°. Table 1 outlines the comparison methodology for the two beam systems. For an accurate structural comparison, AS/NZS 4600 was used as the plate slenderness limits are more relaxed and provide answers similar to a standard three plate beam. The structural Steel Standards AS4100 and NZS3404 would have over-penalized the slender North American three plate design members and not provided a fair comparison. A summary of the costs comparing the production and painting of the nested box beam verses the three plate options is provided in Table 2.

**Table 1.** NTBB compared to a three plate welded beam

Step 1 - Frame Analysis:	A frame analysis model was created using loads provided from a typical North American warehouse design.
Step 2 - Box Beam Design:	The NTBB was designed using AS/NZS 4600: Cold Formed Structures Standard -using forces obtained from the frame analysis.
Step 3 –Frame Check:	The frame was checked against AS/NZS 4600: Cold Formed Structures Standard - using forces obtained directly from the Frame Report.

**Table 2.** Comparison of a three plate welded beam design and NTBB

<b>Three plate welded beam</b>			
Steel, heavy plate	2.3t	\$1,435	\$3,300
Processing	2.3t	\$938	\$2,157
Paint	80L	\$28	\$2,240
<b>Total</b>			<b>\$7,697</b>
<b>Nested tapered box beam</b>			
Steel, coil plate	2.8t	\$1,320	\$3,696
Processing	2.8t	\$609	\$1,705
Paint	34L	\$28	\$952
<b>Total</b>			<b>\$6,353*</b>
<b>Difference</b>			<b>-17.5%</b>

\*Note: Additional savings in weight and labour are not included due to the NTBB being stiffer in torsion and therefore requiring fewer fly braces.

**References:**

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