Disruptive ideas for self build using simple techniques

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Aims of presentation

To present for discussion some recent work on simple building systems that we consider Disruptive. They are comparatively straightforward and easy to learn.

Two different processes:

A light-weight structural systems steel/plywood composite system that is recyclable and can use waste plywood off-cuts

Formwork for concrete using flexible textile fabrics, can produce better quality concrete, with easier fabrications in more complex and structurally efficient shapes
Move from lab into workshop, design-based research through process considers Architecture, construction and engineering
The Steel Days conference 2011 some observations

Steel not ‘malleable’, prefabrication restricts local adjustment, unlike timber
Needs adequately trained and skilled workers

Gap between technical quality and liability

Large portion of people are left to build back on their own

Cost of steel
Steel plywood composite structures

A disruptive technology

Uses mass produced steel components in conjunction with standard plywood
Saves transportation

Uses simple tools to assemble, does not need skilled craftsmen but proper guidance and control

Steel section can be re-used
Circular economy: steel it a ‘technical nutrient’ and plywood is a ‘biological nutrient’

Combination of plywood and steel facilitates hybrid constructions with timber- easily Adapted to differing contexts
Steel-plywood composite construction
Fabricated using simple tools

8 metre clear span
Attic roof with 4.5 metre room space

Low capital construction

Can use waste plywood and is recyclable
Prototype roof construction designed to create functional roof space

The floor beam is 300 mm deep, comprising 12mm plywood webs with flanges Formed from two C sections 63 by 24 mm, 1.5 mm in thickness. The prototype Consisted of two identical trusses spaced at 600 mm centres. The large plywood Fins connecting the floor beam to the rafter were cut from 1500 by 3000 sheets
Load was applied using dense concrete Blocks, (19kg)
Graph shows total load of 1833 kg, approx 1.5 times the design load for a house. Image shows final load test total load of 3439kg, nearly three times design Load without failure.
full scale beam tests – using specially developed flange component
Flange component with Pre-punched holes and Swages to improve shear
Self-drilling and tapping screws
Clamp steel to plywood

Detail of plywood to steel connection
A series of tests were carried out on full-scale prototype beams. The beams were 6 metres long and 300mm in depth. The flanges were produced by a local steel fabricator. The beams were assembled by a graduate engineering student. Initially, three beams were produced and tested. A fourth beam was then produced by re-using the flanges from one of the tested beams and scrap plywood found around the workshop.
Beam under test

The beams were tested under two applied point loads in a series of cycles of increasing load to failure.
<table>
<thead>
<tr>
<th>Beam no.</th>
<th>comments</th>
<th>Failure load kN</th>
<th>Load at deflection of 20 mm, final cycle kN</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Low grade plywood, Screws at 100mm</td>
<td>17.5 kN</td>
<td>12.0</td>
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<tr>
<td>2</td>
<td>As beam 1 but with two 300 mm voids in mid-section</td>
<td>17.5 kN</td>
<td>11.2</td>
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<tr>
<td>3</td>
<td>As beam 1 but screws at 200 mm spacing</td>
<td>10.5 kN</td>
<td>8.0</td>
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<td>4</td>
<td>Web used ten separate piece of plywood, flanges recovered from previous test beam, Screws at 100 mm</td>
<td>32.5 kN</td>
<td>15 kN</td>
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</table>

Summary of test results on beams
Note performance of beam 4 made with completely re-cycled material
Comparing two beams. Beam 4 is manufactured using re-cycled Steel flanges and scrap plywood. Ply wood higher grade that beam 1 Demonstrates recyclability of system and use of waste plywood.
The Tropical House designed by Jean Prouvé
An interesting idea that could be developed in steel/ply composite
Plywood steel system
Flange component mass produced by roll-forming
Long lengths possible – easily transportable
Plywood sourced locally as needed or recovered waste ply used
Assembled locally by semi skilled workforce easily trained
Simple disassembly and re-use of flange
Large range of possible designs
Beams, trusses, frames
Fits local context
Circular Economy
Fabric formwork for concrete

The use of flexible textile fabrics as formwork for concrete – Paradigm shift
Question of control, restraint and relaxation
Seen as counter-intuitive
It also is a Disruptive Technology
Simplifies fabrication of formwork
Allows complexity of form
Reduces labour
Improves appearance of concrete and durability

Apparently less control
Changes conventional procurement
Apparent lack of robustness
Conventional formwork – restraint and control

It may be noted that although reinforced concrete has been used for over a hundred years and with increasing interest during the last few decades, few of its properties and potentialities have been fully exploited thus far....,

...the main cause of this delay is a trivial technicality: the need to prepare wooden forms, PL Nervi 1956.
A large variety of forms possible with accuracy and precision. These projects produced by Architecture students with little prior experience of concrete after five or six weeks.
Non Prismatic columns using fabric formwork much simpler to construct yet geometry more complex - Simplified construction and improved appearance
Proprietary flexible tube
Simplify process
‘Jazz’ concrete is simple kit of parts with no stitching needed that produce a range of designs.
Non prismatic columns with constant volume of concrete
Convex and concave profiles
<table>
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<tr>
<th>Column No.</th>
<th>Shape</th>
<th>Difference between Max - min. diameter mm</th>
<th>Compressive strength N/mm²</th>
<th>Failure load kN</th>
<th>Failure load/Compressive strength</th>
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</thead>
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<td>1.</td>
<td>Concave</td>
<td>25</td>
<td>-</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>2.</td>
<td>Concave</td>
<td>42.6</td>
<td>214.5</td>
<td>5.04</td>
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<td>Concave</td>
<td>34.3</td>
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<td>144</td>
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<td>102</td>
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</table>

Structural tests of columns of different shapes
The ratio of transverse strain to axial strain reduces with concavity
Non –prismatic shape can improve load capacity without increasing cost of fabrication
Further studies in complexity: single formwork

Increasing complexity: single piece of formwork
Form active beams- complex geometry, simple fabrication
Development of beam geometry through successive tests

Evolution of optimised geometry for beam: the simplification of fabrication allowed iteration of form in successive prototypes. Final form resulted in fully effective structural performance, with no shear reinforcement.
Final geometry of beam

Final beam has approximately 30% less carbon footprint than an equivalent rectangular concrete beam
Fabric formed concrete

12 years of experimentation
Simple techniques, can be easily learned
Uses ’soft logics’, fabric deforms to best
To carry wet concrete
Permeability of the fabric a bonus-
Less surface defects better finish
Accuracy is comparable to rigid form
Greater understanding of precision, be
Precise where it is critical