RECOVERING PVC: RESPONSIBLE CARE BY DESIGN

Future Designers Program 2014-15: Final Report

Vinyl Council Australia

MADA

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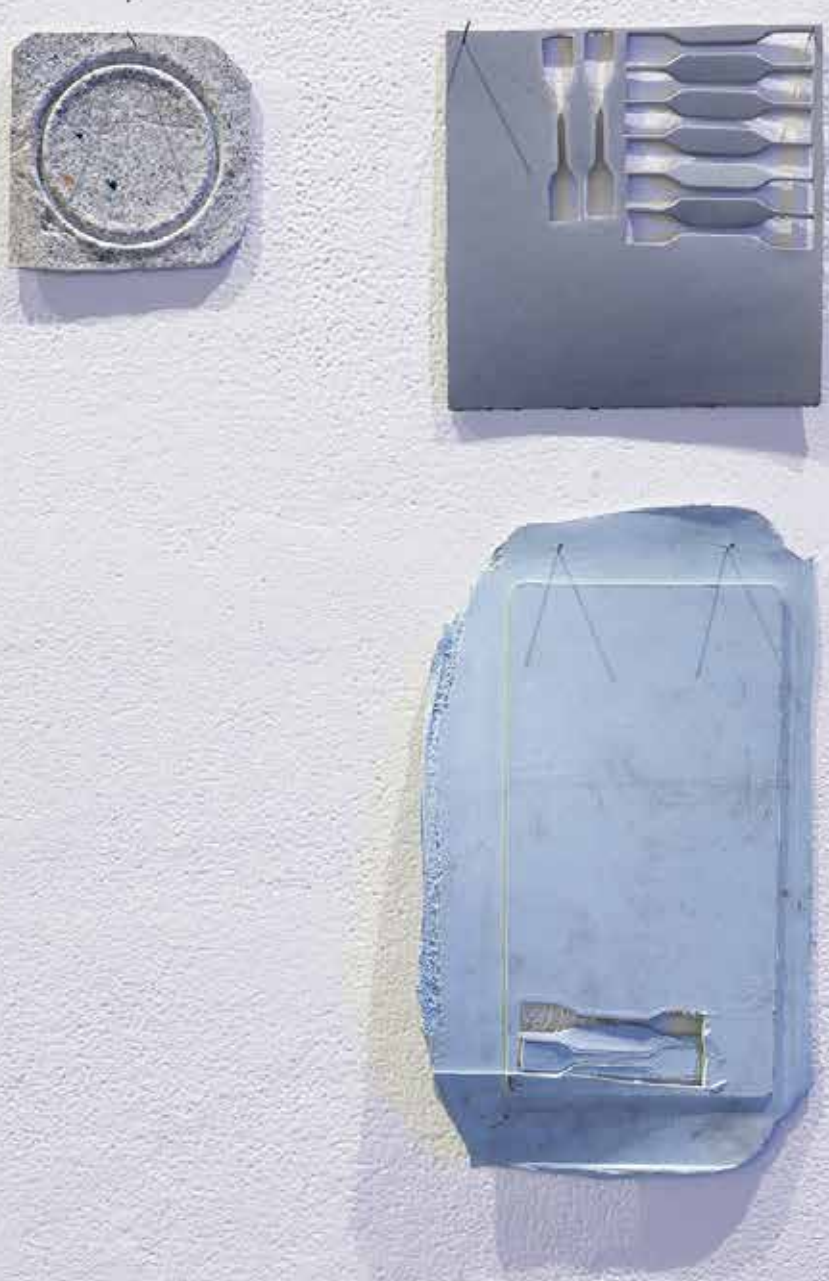

Detail of Process Work

Project Details

Project Title: Recovering PVC: Responsible care by design

Name of Applicant (and Faculty): Mark Richardson, Monash University, Faculty of Art, Design & Architecture

Name of Course of Study: Industrial Design

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Nature of business of Industry partner: Peak body for the vinyl industry

All images unless otherwise stated provided by Mark Richardson

Detail of Process Work

Project Background

In recent times, the reputation of Polyvinyl Chloride (PVC) has been questioned due to a number of commonly held, but disputable views regarding its inherent chlorine chemistry. These include concerns that: its chemical composition makes it difficult to break down in landfill, and when it does, it can leach toxins into the environment; there are potential health risks associated with its manufacture, where carcinogens such as dioxins, ethylene dichloride and vinyl chloride are released into the environment; and a perception that PVC is difficult to recycle. While these claims are not always supported by scientific fact or evidence, they have had a negative impact on the industry.

However, PVC has many positive properties that make it unique in the line up of commercial plastics. It is inherently strong and has excellent longevity, which lends itself to applications in situations where components are difficult to access and replace, require multiple lives or subjected to knocks and abrasions. Its amorphous polymer structure allows it to be mixed with additives and other polymers that can give it great versatility and varying performance properties. It is also inherently fire retarding, and has excellent chemical resistance. These make the material desirable for a range of design applications – from flexible medical products, packaging and flooring to window frames and water pipes.

The vinyl industry's Product Stewardship Program has led to significant progress over the last decade to reduce emissions, use alternative additives that are proven to be safe, and to improve recycling and recyclability of PVC products in Australia. However waste recovery of some PVC applications remains problematic and it would therefore be beneficial for industry to find new ways of dealing with such waste. In both present and future cases, it is important to undertake research to design responsible ways to treat the material, and the collaboration between the Vinyl Council of Australia and Monash University aims to work towards this end.

Project Aims and Scope

The project sought to discover design opportunities for the waste recovery and reuse of certain PVC applications. It aimed to design a range of upcycled or recycled PVC prototypes that could potentially be manufactured locally, using locally sourced materials and processes. It approached PVC upcycling or recycling from a down-stream, post industrial and consumer waste perspective. Specifically, the scope of the study included only PVC coated fabric typically used in advertising banners, truck tarpaulins and grain bunker top covers. The

project explored potential reuses for the material, which were designed and refashioned into newly functional objects that could potentially re-enter the consumer market.

Typically, PVC coated fabric has been reused in consumer goods, such as tote bags and courier satchels (see freitag.com.de), however the volume of waste PVC consumed in these applications is quite low. With design thinking and a collaborative approach with chemical engineering, we aimed to extend the range of possibilities.

The twelve-week studio-based project commenced in November 2014. We undertook a full range of design/engineering tasks at Monash University, including: data collection and analysis, material property analysis, design visualisations, digital modelling, prototyping. We worked with local suppliers and manufacturers to develop valuable research outcomes while at the same time providing students with a greater understanding of industry practices.

Objectives

The project objectives were to:

- identify sources of PVC coated fabric waste that can be reliably reused/ reprocessed as raw materials in manufacturing new products

- develop ways for recovering, reprocessing, recycling and reusing PVC covered fabric

- develop collaborations with surrounding businesses and establish potential 'raw material' supply chains within local markets

- explore processes for designing and making new products from PVC waste using both traditional industrial processes and digital means (such as 2D and 3D printing and CNC cutting)

- design products upfront for continuing reuse

- provide a multidisciplinary experience, where students can engage with commercial clients, manufacturers and engineers in the development of a new range of products

- guide students through the experience of industry practice, with potential for their work to be commercialised during the period of their continuing studies.

Contributors and Contributions

The project team comprised of four student researchers and three supervisors. Students were selected by interview; two from Monash University's Industrial Design program and two from Chemical Engineering. Mentors consisted of two Monash academics – Mark Richardson from the Department of Design and Esther Ventura-Medina from the Department of Chemical Engineering – and Helen Millicer represented the Vinyl Council of Australia. Additional support was provided by Rojo Pacific, Welvic, Australian Vinyls, PMG Engineering, Outdoor Media Association and Armstrong World Industries.

Project Milestones and Design Approach

Project Milestones:

1. Student Selection – November 10 – 21, 2014
2. Project commencement: scoping studies, material acquisition initial material testing – November 24 – December 12, 2014
3. Design ideation, concept development and material experimentation – December 15 -19 and January 5 – 16, 2014
4. Prototyping and visualisation – January 19 - February 6, 2015
5. Exhibition Preparation and Communication of results –
6. Exhibition – March 12

Design Approach:

3 Week Duration - Market, Data, Materials and Processes Collection and Analysis

- Scope design intervention possibilities
- Map sources of waste
- Acquire materials
- Research applicable material combinations, recycling methods and rapid production processes
- Compile and map design/reuse possibilities – select strategic directions

3 Week Duration - Material Studies/Design Intervention

- Materials experimentation
- Design ideation and visualisation
- Product development and refinement

- Digital modelling and 3D mockups

3 Week Duration - Prototype/Document
- Design refinement and preparation for prototyping
- Fabrication and assembly of preferred designs
- Document successful recycling processes
- Document final outcomes and generate visualisation material for exhibition and publication

3 Week Duration - Communication of Results
- Prepare online promotion material
- Media consultation
- Exhibition preparation and management

Results and Communication

The studio-based collaboration between the industry partners and Monash University's departments of Design and Chemical Engineering saw the development of two 100% recycled materials from regrind particulate: one, a pelt-like roll-formed skin, the other a press-formed tile. Documentation of the research is compiled into a compendium (appendix 3) and access to the work-in-progress blog can be found at <pvcrecovery.tumblr.com> password: pvcrecovery.

Design works stemming from the research were exhibited at the MADA Gallery 2 on March 12 2015. Titled 'ReFORM' (see appendices 1 & 2), the show comprised of six installations that represent prototypical process alongside design outcomes. They captured the essence of the PVC reformation process (shredding, bonding, reforming), while taking on a biological taxonomy texture, in some ways mimicking the form and material language of the natural sciences. The work represented a moment in time in what we hope will be a continuing area of exploration.

The works included:

1. Polymer Hides, 2015, 2500 x 70 x 160cm, recycled PVC coated fabric, found objects and off-the-shelf components, Jeremy Foo, Kim Sho, Tom Millward, Patrick Sohn, Mark Richardson, Esther Ventura-Medina, Melbourne.

2. ReFORM Tiles, 2015, 2500 x 150 x50cm, timber, wire rope and Recycled PVC coated fabric, Kim Sho, Jeremy Foo, Tom Millward, Patrick Sohn, Mark Richardson, Esther Ventura-Medina, Melbourne.

3. Process Work, 2015, 2500 x 150cm, recycled PVC coated fabric, Tom

Millward, Jeremy Foo, Kim Sho, Patrick Sohn, Mark Richardson, Esther Ventura-Medina, Melbourne.
4. Furniture for Fieldwork, 2015, 2000 x 70 x 160cm, Timber and PVC, Tom Millward, Patrick Sohn, Jeremy Foo, Kim Sho, Mark Richardson, Esther Ventura-Medina, Melbourne.

5. ReForm Pockets, 2015, 2000 x 70 x 160cm, PVC coated fabric regrind, Patrick Sohn, Tom Millward, Jeremy Foo, Kim Sho, Mark Richardson, Esther Ventura-Medina, Melbourne.

6. Regrind, 2015, 2000 x 70 x 160cm, PVC banners and PVC coated fabric regrind, Patrick Sohn, Tom Millward, Jeremy Foo, Kim Sho, Mark Richardson, Esther Ventura-Medina, Melbourne.

Communications outlining the project and exhibition were published by the Vinyl Council Australia[1], Outdoor Media association[2] and Monash University[3]. A number of other media releases have been sent to various industry, design and technology newsletters, including Recyling World, Designboom and Gizmag – these are currently awaiting publication.

1. www.vinyl.org.au/news-articles/sandwich-toaster-inspires-recycling-solutions-for-pvc-coated-fabric
2. http://www.oma.org.au/media2/latest-news/archive-items/sandwich-toaster-inspires-recycling-solutions-for-pvc-coated-fabric
3. http://www.artdes.monash.edu.au/design/archive.php#!/artoncampus/events/reform.html

ReFORM Pockets

Student Design Statements and Project Reflections

Tom Millward
Monash University
Industrial Design – 4th Year

Project Reflections

The recovering pvc project gave us an opportunity to see how many of the material processes we had studied were put into practice. It was great to talk frankly with the people who were involved in different stages of the production of PVC and plastics in general.

Working with an interdisciplinary group gave a very different perspective to the project and was useful in achieving grounded results. It was good to ask one of the chemical engineers if something could be done as soon as you came up with the idea, instead of taking time to find other people or sources to clarify it. I really learned a lot from the DIY manufacturing processes we were able to come up with then put them into practice.

There were a number of things we would do differently given another opportunity, our issues mainly stemmed from a struggle to align expectations with reality. The project was expected to have an evenly weighted process of research, ideation and execution, however we found ourselves stuck at the research and ideation phases as there were simply too many ways of processing and testing the material and validating the results.

Also, at times we found it difficult to challenge existing paradigms, given we were working in an industry with a long history and well established processes. However, we were grateful to be given the opportunity to work on bottom-up solutions, even if we couldn't address big-picture issues from the top down.

Overall, it was a good team and I enjoyed working in it. It was beneficial to get to observe the realities of plastic production and to meet some of the people looking to bring about change.

Image opposite: Furniture for Fieldwork

Patrick Sohn
Monash University
Industrial Design – 3rd Year

Project Reflections

The Recovering PVC project was an extremely valuable and unique experience that pushed my practice as a designer into areas that I would otherwise never have an opportunity to discover as a student. Working alongside a graduate Industrial Designer and two Chemical Engineer students, we were able to bring our various areas of expertise into a creative and experimental process during every step of the design. It was great to see the inquisitive nature of each student and the effect this had on our outcomes was significant, as we were able to effectively explore processes that would otherwise have not been thought of or passed off as being non-viable.

I believe that the key factor to the success of this project was the constant and invaluable discourse we were able to enjoy with industry partners. For this, the efforts of the Vinyl Council of Australia cannot go unnoticed. We were able to gain a clearer understanding of the current practice within the domestic manufacturing industry and their efforts to cater for our enquiries and the use of industrial machines for experimental purposes were crucial milestones in delivering both a well researched and a tangible design outcome. As a student, it was exciting to see some of the unexpected results of material experiments and the surprised reactions that the industry figures had when we presented these to them. As an industrial designer, I found the experience of working with these partners from all stages of a product manufacturing cycle particularly interesting.

It has, no doubt, had a great influence on the way I see the whole design process in terms of the sheer amount of resources that goes into producing a product, and exposed me to the impact that design can have in reducing the impact of this in the future.

Image opposite: ReFORM Pockets

Jeremy Foo
Monash University
Chemical Engineering - 4th year

Project Reflections

I had an amazing time working on the project. As briefed by the Vinyl Council of Australia in the first meeting, the material we were given to work with is certainly not one of the most forgiving materials around. At present, using ideas that make use of the properties of the materials, but concentrate mainly on the aesthetics is no longer a viable option for the recycling and upcycling industry at this scale. Therefore, in order to make an impact it is necessary to look at re-engineering materials and products considering factors such as market demand and the feasibility of the processes. The challenge this project posed was assessed from both the chemical engineering and industrial design perspectives, with the aim of establishing a potential new material created by using the PVC fabrics. By placing these as our upmost considerations, from close collaboration with local business and industries partners, we successfully developed two novel materials. These two materials, originating from the same piece of PVC-coated fabric waste, were produced using two different process paths. I personally think the two novel materials have the potential to be integrated into vinyl flooring applications (sheets and tiles), due the their phenomenal resemblance to the currently existing vinyl floorings available. Personally, I enjoyed the challenge present throughout the project as it not only inspired me to think creatively within the realm of what is possible, but also encouraged my passion for problem solving further. I believe what we achieved is just the start to another great project, with many possibilities and potentials still remain unexplored.

Image opposite: Polymer Hides

Kim Sho
Monash University
Chemical Engineering - 3rd year

Project Reflections

Sustainability is a common term to keep in mind when performing in a chemical engineering project, to minimise waste of resources as well as creating an environment friendly process. Being a part of the ReFORM project in discovering effective recycling method for PVC coated polyester fabrics provided me with an insightful experience of looking at the sustainable concept from a broader perspective. Engagement with industrial design was a success for me, to witness the progress of conceptual idea to prototype of product. Collaboration of theory to industry application where I applied engineering knowledge to design skills is the most invaluable experience and will be useful in my future career.

The project aimed to recycle the material using a cost and process effective method alongside creating a new local supply chain for the new recycled product, the greatest challenge imposed to both industrial designers and chemical engineers in the team. Inspired by the 'sandwich maker', leading to trialling the material with heat treatment process, we found exciting outcomes where it was a new 'raw material' for further treatment process. This first rigid product formed had its potential use in industrial flooring and protective surface, and more to come as we ventured into the actual manufacturing process from pilot scale experimentation.

'Less is more' is the backbone concept applied when designing the treatment process to make recycling worthwhile, also the philosophy I learnt from the project too. Minimal treatment process fully utilised the authentic profile of the material for a strong and durable product. There must be alternative pathways to recycle the 'valuable' resources from our daily lives, apart from sending them to landfill. Appreciation of material is essential for everyone in order to create a sustainable living, not limited for ourselves but for our future generations too.

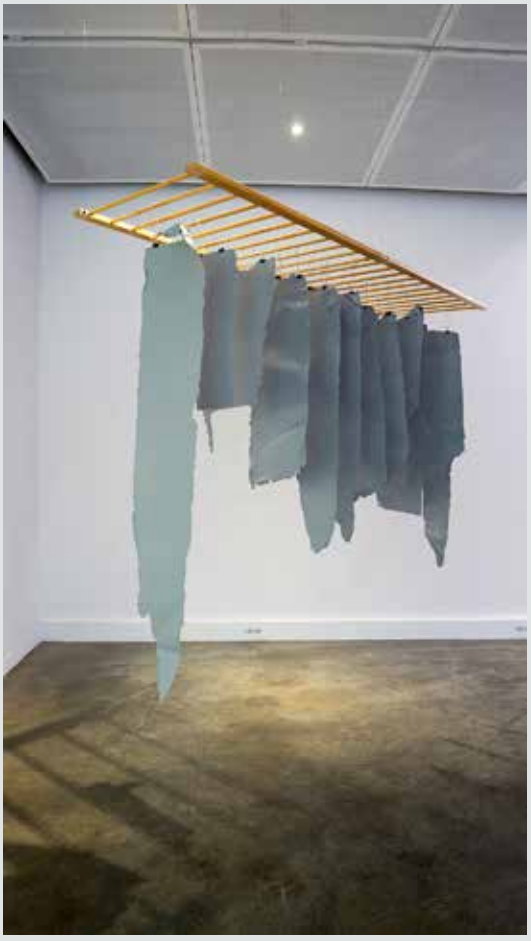
Image opposite: Detail of ReFORM Tiles

Appendix 1.

Exhibition Documentation

ReFORM exhibition overview

Process Work



Detail of ReFORM Tiles

Detail of Furniture for Fieldwork

ReFORM Tiles

Image opposite: Regrind
This page: Detail of Regrind

Detail of Process Work

Appendix 2.

Exhibition Catalogue

Images: Mark Richardson

A Future Designers Program project
Recovering PVC:
Responsible Care by Design

6-8pm, March 12, 2015
MADA Gallery 2
Ground Floor, Building G
900 Dandenong Rd
Caulfield East, 3145

Exhibition curated by Mark Richardson
Catalogue by Mark Richardson

ISBN 978-1-921994-39-5

Exhibitors:
Tom Millward
Patrick Sohn
Jeremy Foo
Kim Sho

Vinyl Council Australia

State Government Victoria
DEPARTMENT OF STATE DEVELOPMENT BUSINESS AND INNOVATION

MADA

ReFORM

Recovering PVC: Responsible Care by Design

In recent years, the reputation of Polyvinyl Chloride (PVC) has come into question due to a number of commonly held, but disputable views regarding its inherent chlorine chemistry. While the vinyl industry's Product Stewardship Program has made significant progress in mitigating these – for example, by reducing emissions, using safe alternative additives and improving recycling and recyclability – each year we are still faced with thousands of tonnes of PVC waste disposed to landfill in Australia. Of this, there is over 1,200,000 m2 of PVC coated polyester advertising banners, which represents over 400 tonnes of quality manufactured and printed product. The challenge for this project was to add value to this particular waste and discover ways to redirect it back to market.

Funded by the Department of State Development, Business & Innovation's Future Designers Program, this twelve-week interdisciplinary research project approached PVC upcycling from a down-stream, post-industrial and consumer waste perspective. The studio-based collaboration between the Vinyl Council of Australia and Monash University's departments of Design and Chemical Engineering saw the development of two 100% recycled materials from regrind particulate: one, a pelt-like roll-formed skin, the other a press-formed tile. From these, a number of design propositions were derived.

ReFORM comprises of six installations that represent prototypical process alongside design outcomes. They capture the essence of the reformation process (shredding, bonding, reforming), while taking on a biological taxonomy texture, in some ways mimicking the form and material language of the natural sciences. The work represents a moment in time in what we hope will be a continuing area of exploration. *Mark Richardson*

This project has been made possible through the vision and contribution of the Vinyl Council of Australia, Monash University (Industrial Design and Chemical Engineering), Victorian Department of State Development, Business and Innovation, Rojo Pacific, Welvic, Australian Vinyls, PMG Engineering, Outdoor Media Association and Armstrong World Industries.

List of Works

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Appendix 3.

Design Process Compendium

(For full details go to <pvcrecovery.tumblr.com>
password: pvcrecovery)

Recovering PVC

Responsible Care by Design

Contributors

Tom Millward

Patrick Sohn

Jeremy Foo

Kim Sho

Supervisors

Mark Richardson

Esther Ventura-Medina

Recovering PVC

Responsible Care by Design

The project seeks to uncover design opportunities for the waste recovery and reuse of certain PVC applications.

It aims to design a range of upcycled or recycled PVC prototypes that could potentially be manufactured locally, using locally sourced materials and processes.

Students will undertake a full range of design/engineering tasks at Monash University, including: data collection and analysis, material property analysis, end-user profiling and materials analysis/exploration, design visualisations, digital modelling, prototyping, and engagement with local suppliers and manufacturers.

This experience will provide students with a greater understanding of industry practices while concurrently developing precedents for new, more sustainable products and production processes.

Objectives

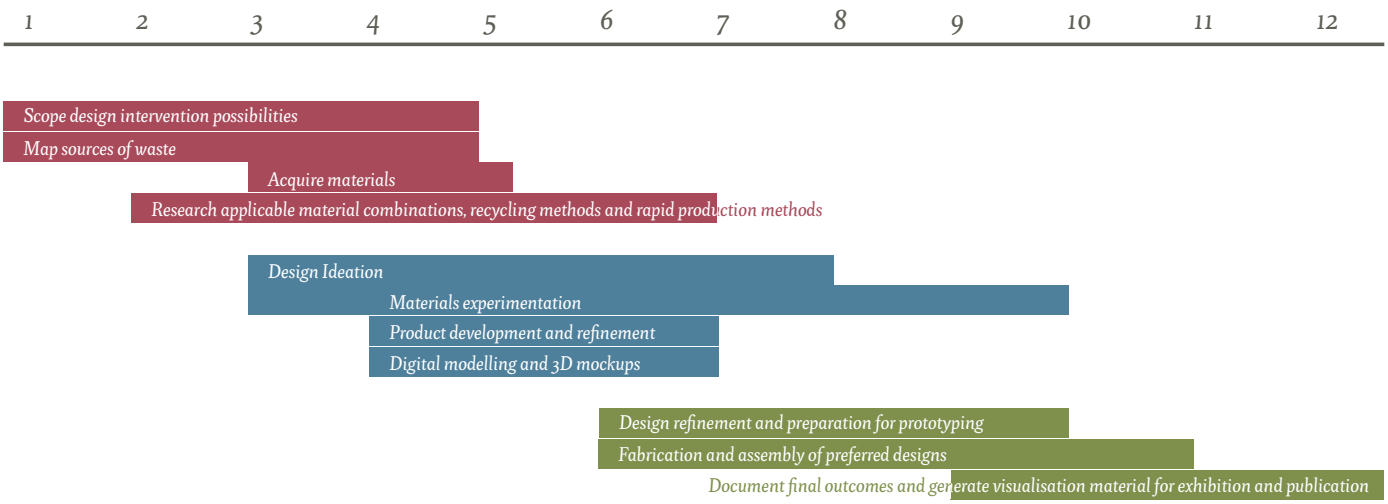
Identify sources of PVC coated fabric waste that can be reliably re-used/reprocessed as raw materials in manufacturing new products.

Develop ways for recovering, reprocessing, recycling and reusing PVC covered fabric.

Develop collaborations with surrounding businesses and establish potential 'raw material' supply chains within local markets.

Explore processes for designing and making new products from PVC waste using both traditional industrial processes and digital means (such as 2D and 3D printing and CNC cutting).

Design products upfront for continuing reuse.



Stage 1
Preliminary Research

Nov 24 - Dec 12

Milestones

- Create project plan
- Meet with factory representatives

Stage 2
Materials Studies / Design Interventions

Dec 12 - Feb 2

Milestones

- Propose concepts which address the issue of effectively recycling PVC banner material
- Document theoretical and practical research

Stage 3
Prototyping and Documentation

Feb 2 - Feb 29

Milestones

- Document concept refinement
- Produce range of prototypes for potential design solutions

Research Questions

What has been done before?

Of the existing ideas, what could be done better?

What mechanical and chemical processes lend themselves to this project?

What existing products and systems lend themselves to the production of recycled vinyl on a large scale?

What are the opportunities in this product category? What hasn't been done before?

Our team initially reseached methods by which vinyl was currently being recycled. This Included:

Garden Hoses
-Single Layer
-Double Layer

Membranes and Foils

Coated Textiles

Mats, Plates and Profiles

Boots and Shoe Soles

Tote Bags, Messenger Bags

Temporary Shelters

http://www.vinyloop.com/en/products-en/applications.html

http://learninglegacy.independent.gov.uk/documents/pdfs/design-and-engineering-innovation/221-implementation-of-pvc-policy.pdf

Opportunities in the environment

I walked around my local area to assess areas objects which could potentially be supplanted by recycled PVC.

Probably because we have been meeting with in-industry experts specialising in these kind of materials, but thoughts gravitated towards road-indicators.

Could PVC banners be vacuum formed?

Because there was no access to a vac former, one was constructed to test the theory. This was done out of scrap parts.

Holes which would suck the heated material down were drilled by hand. The holes were evenly spaced for a consistent molding action across the machine.

—

The vacuum forming was a success in that the banner material held itself in the shape of the mold.

The material did not pull enough to hold without creasing in places. This could be due to the material not being hot enough.

The edges at the top of the cast held a surprising amount of detail.

This method would work well with molds made of generous draft angles and curves. However, a better result could be expected on an industrial machine.

Freitag System

Vinyl Messenger bags are the most well practised method of banner re-use. Due to this we deemed investigating other methods of recycling to be more productive. The system by which they were recycled was worth investigating however.

Freitag sources their materials from used truck tarpaulins. 440 tons are sourced each year.

—

Eyelets, straps and belts are removed

Washed

Patterns cut

Sewn

http://www.freitag.ch/kowalski






Material and process testing

Applicable manufacturing processes were evaluated through physical testing.

The properties of the results of this testing were then evaluated.

T he production methods were divided and broken down into steps to qualify the number and types of processes to make each material.

1 Step	2 Steps	3 Steps	
Shredding	*Heat Pressing*		*Boards*
The recylcled banner material is torn apart in a a shredder.	The shredded material is fused to gether with the aid of pressure and heat into a strong and flexible board.		
	Pelletising	*Injection Molding*	*Complex Parts*
	This process allows for the shredded material to be reconstituted into a size and shape which is appropriate for injection moulding.	The PVC pellets are formed into the shape of the desired mould	
Cutting	*Heat Welding / Sewing*		*Tents*
The banner material is cut into smaller shapes to fit a specific purpose.	These processes provide a means of joining fabric into more complex forms. Welding specifically allows for the possibility of waterproofing.		
	Weaving	*Edging*	*Bags*
	This process allows for the joining of pieces without chemical or heat treatment. Adds breathability.	This finishes the edge to prevent separation of the strips.	

1 Step	2 Steps	3 Steps	
Laminating			*Boards / Sheets*
Pieces of the banner material are laminated together with the use of heat.			
Chemical Adhesion			*Boards / Sheets*
The PVC is bonded together with the use of adhesives. these could be layered together to create boards.			
Mould Making	*Vacuum Forming*	*Cutting*	*Shells*
A mould is formed in the desired shape. There can be no under-cuts and the mould should be designed so that the part can be easily ejected after use.	The banner material is heated and formed over a mold with the aid of a vacuum chamber.	The usable part of the mold is cut away.	

A sandwich toaster was used to heat press shredded PVC banner material. This produced a flexible board with an extensive list of potential uses

This home-style manufacturing process was a a major brakthrough in our material research. Credit for the technique goes to Ben Paul.

Testing PVC Cement

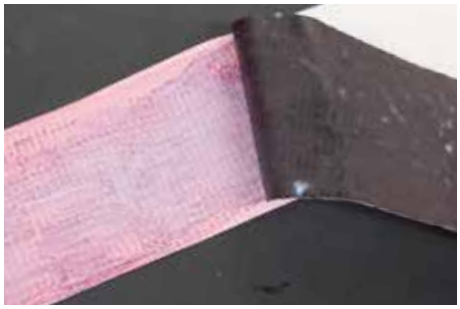
Method

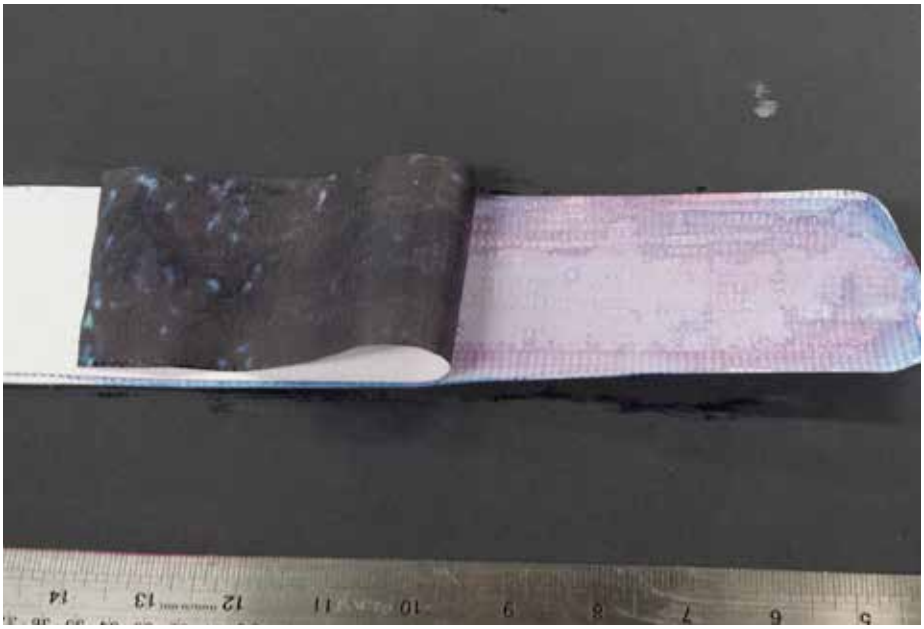
1. Apply PVC primer, immediately followed by PVC pipe cement.
2. Join the treated sides together.
3. Apply an evenly distributed amount of pressure on the test piece for 30 seconds.
4. Allow piece to dry and test strength of bond.

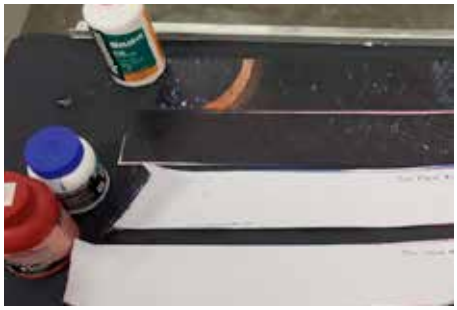
Test one

Treatment: Side 1 treated with primer only, side 2 treated with both primer and cement.

Observation: Unsatisfactory bond - resulted in a weak join that peeled away with little force. Fabric felt noticeably softer in texture and stiffness.







Test two

Treatment: Both sides treated with both primer and cement.

Observation: Similar result as test 1 - longer drying time required? Would the bond be stronger if both sides were unprinted surfaces?

Test three

Treatment: Two unprinted sides treated with both primer and cement.

Observation: Bonding strength of a small portion was tested yielding similar results.

Re-test after 24 hours

Observation: Strong bonding of surfaces acheived - was unable to cleanly peel the two sides apart without de-laminating one side of the fabric. Bonded fabric was slightly stiffer than prior to bonding - possibly due to added thickness.

Experiment 1: Heating time

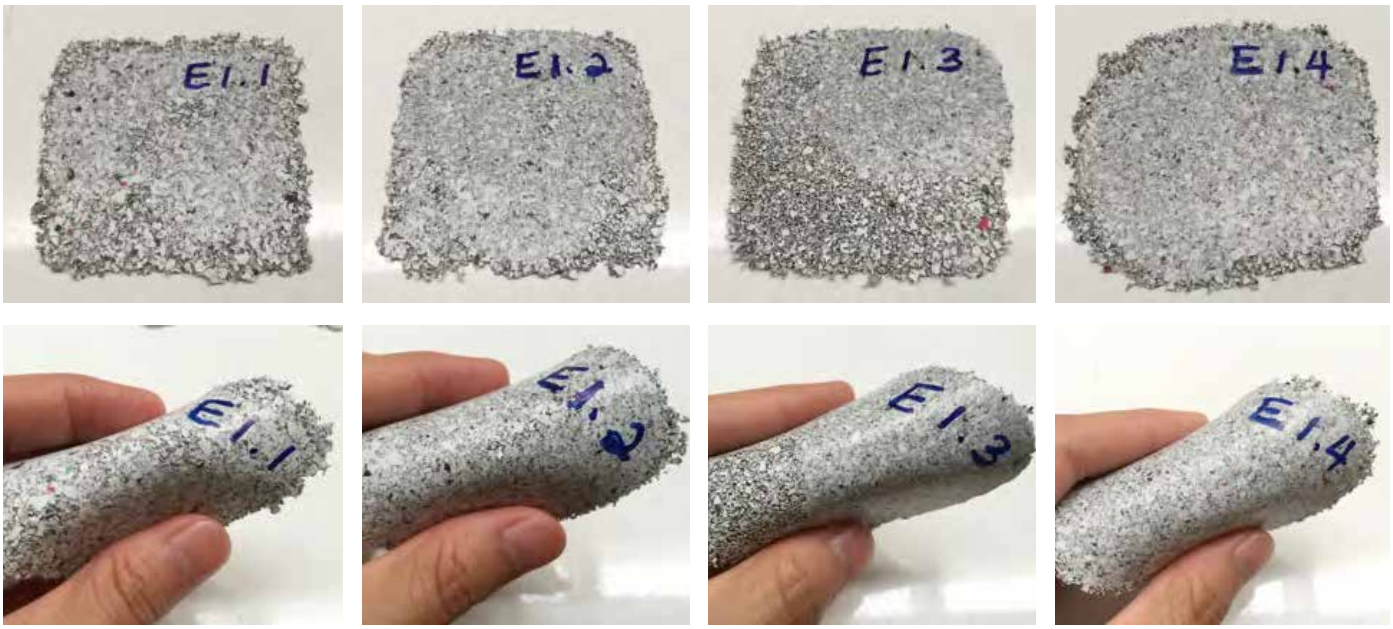
Preheat time: 4 minutes

Cooling time: 6 minutes

Area: 5×5 cm2 (approx.)

Quantity of shredded pieces: 14.79 cm3 (3 teaspoons)

2 minutes	4 minutes	6 minutes	6 minutes
-Thickness: 2 mm -Shredded pieces fused together partially, with significantly individual pieces observable -Small pits in centre	-Thickness: 1 mm -Shredded pieces fused together partially -Smooth surface -Small pits in centre	-Thickness: >1 mm -Shredded pieces fused together partially, with significant pits observable -Thin thickness and partial fusion may be due to uneven heat distribution during heating	-Thickness: 1mm -Shredded pieces fused together partially -Smooth surface



Experiment 2: Quantity of shredded material

Preheat time: 4 minutes

Heating time: 8 minutes

Cooling time: 6 minutes

Area: 5×5 cm2 (approx.)

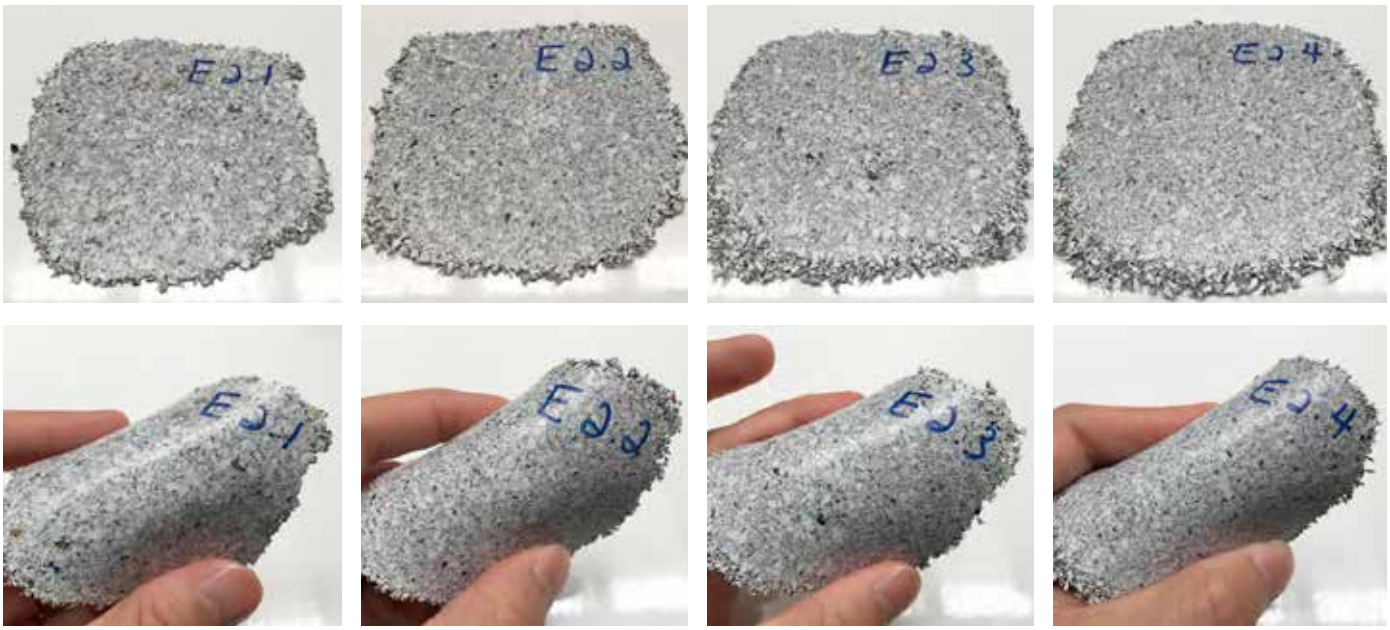
Results

Thickness of 1 - 3 mm achieved

Shredded pieces fused together to form smooth surface, despite the increased quantity for a fixed area

Varying degree of flexibility from different thickness

14.79 cm3	19.72 cm3	24.65 cm3	29.57 cm3
3 teaspoons	*4 teaspoons*	*5 teaspoons*	*6 teaspoons*



Concepts

These are some of the ideas from the materail research phase that have been expanded into initial concepts

Speaker

A speaker was used as an example of how the reconstituted PVC material could be applicable to consumer electronics.

Plastic Roadways

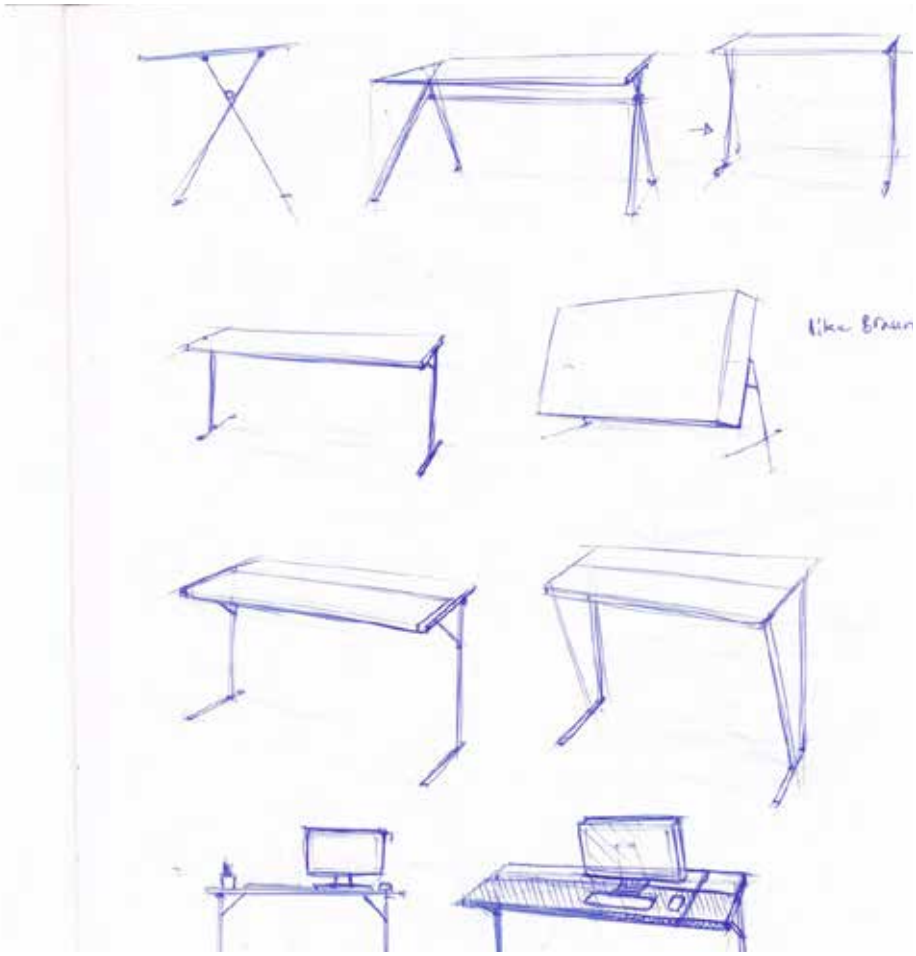
Initial trials of plastic roadways in India have been a success. The project aims to find a use for discarded plastic as it is becoming an increasing issue in the developing world.

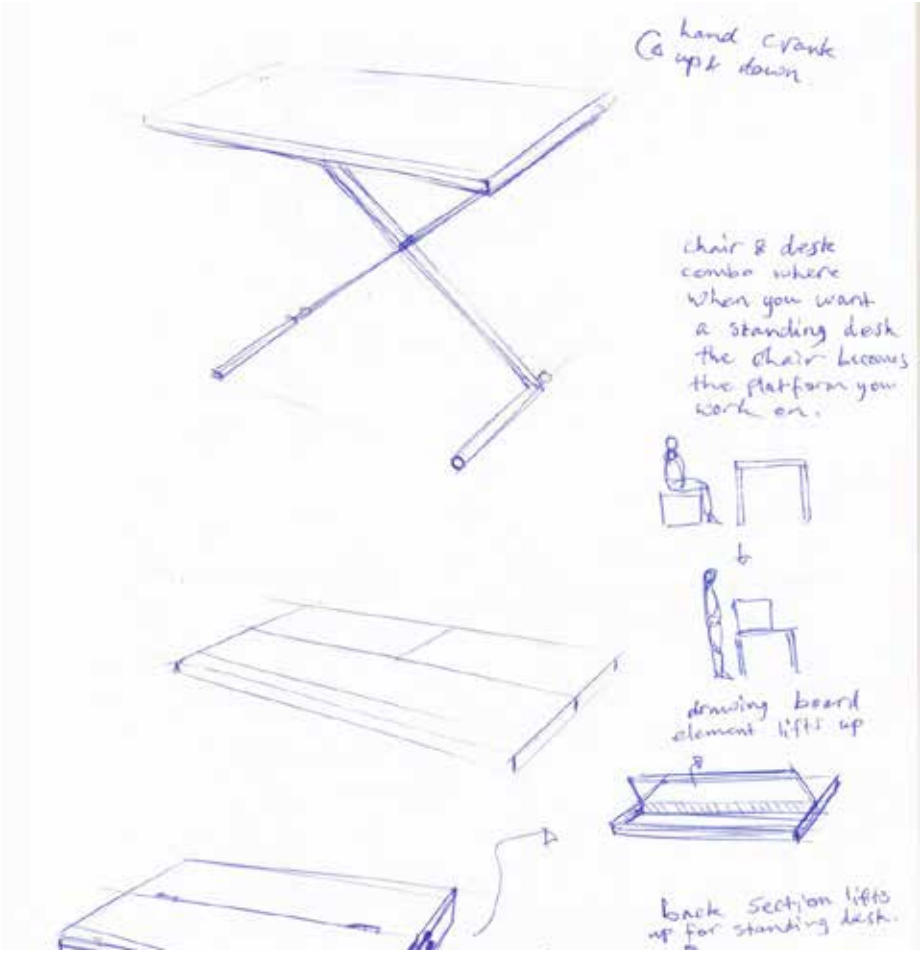
The study found that plastic, when mixed with tar, was not only appropriate as a substitute in bitumen but in many cases outperformed traditional materials. The plastic "increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life". Additionally, the cost would be comparable to regular method.

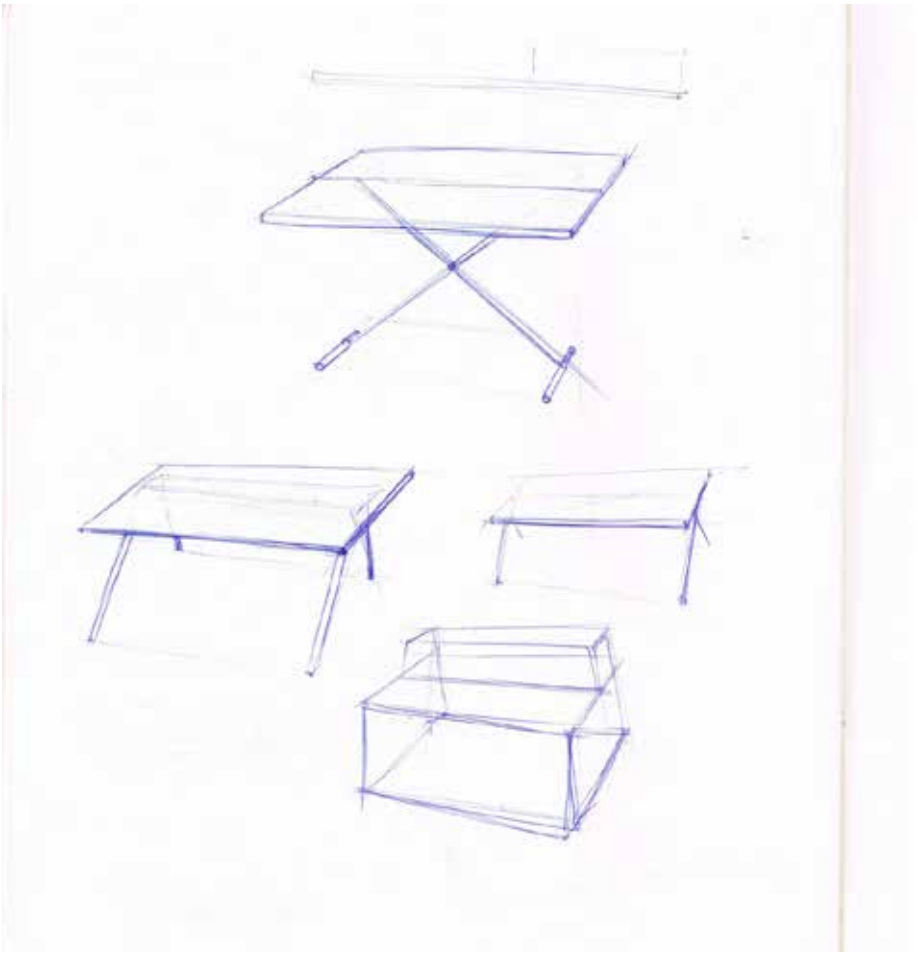
With the similar properties of the PVC banner particulate it could be appropriate for this process. While the melting point of the PVC is much lower than other plastics, combined it with polyester it was shown to have surprising durability and heat resistance in practical testing.

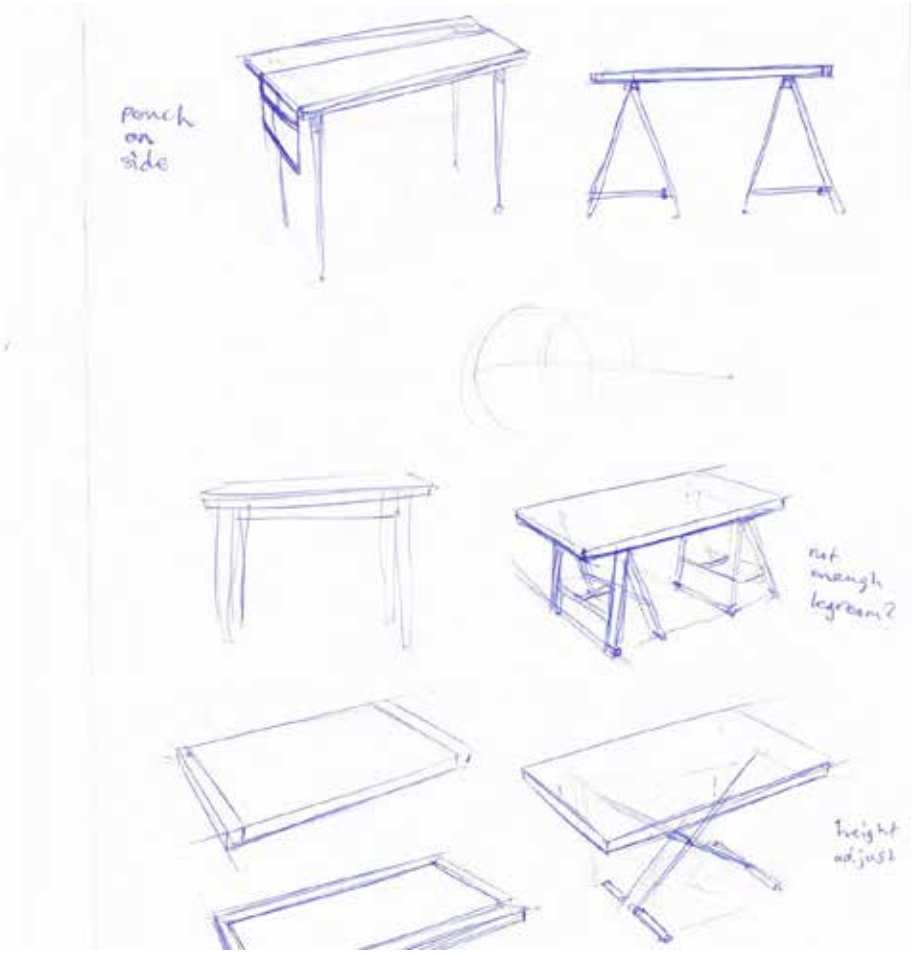
https://www.youtube.com/watch?v=uZDrk29TnZA

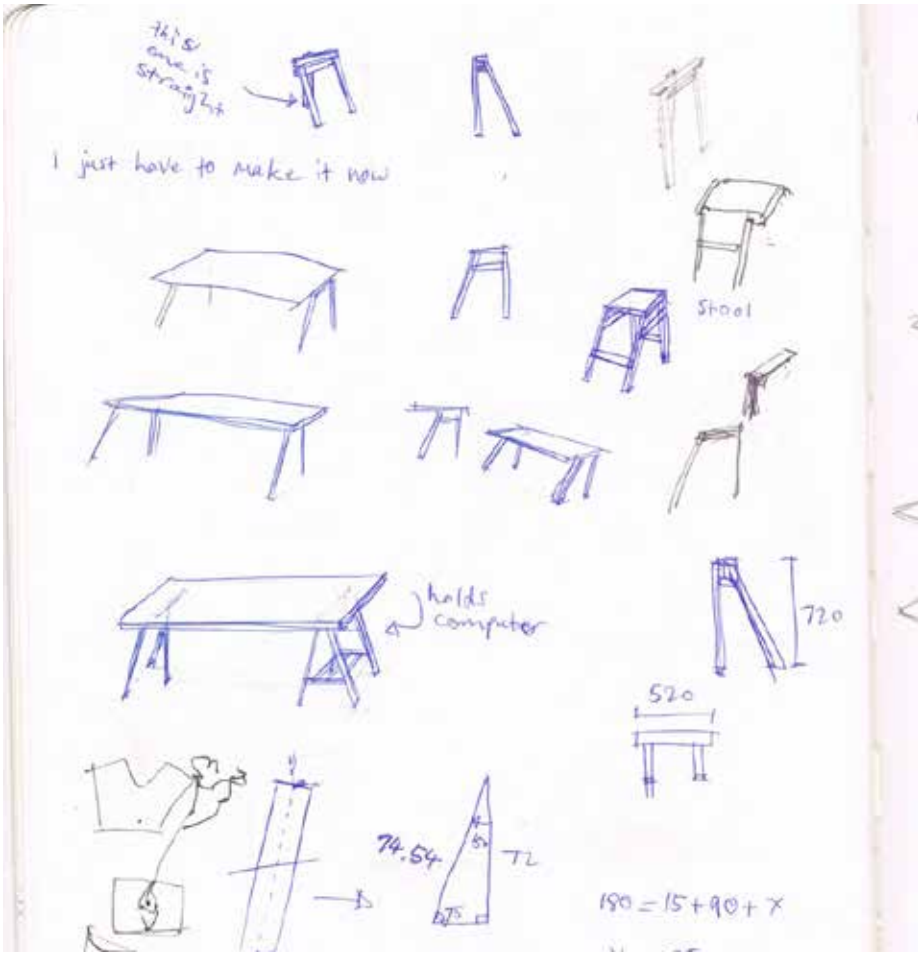
Verma, S. S. "Roads from plastic waste." The Indian Concrete Journal (2008): 43-44.




hand crank
up & down
chair & desk
combo where
when you want
a standing desk
the chair becomes
the platform you
work on.
drawing board
element lifts up
back section lifts
up for standing desk.




pouch on side
not enough legroom?
weight adjust


I just have to make it now
Stool
holds computer
720
520
74.54
180 = 15+90+x