

*Study of feasibility of using*  
**METAKAOLIN-BASED GEOPOLYMERS AS FILLERS  
IN PLASTICS**

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Geopolymer camp, 5<sup>th</sup> July 2016

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# Introduction to Impact



- Independent development and testing company
- Founded in 2002 as a spin-out from BP Chemicals
- Based in Grangemouth, UK
- ISO17025 laboratory with UKAS accreditation & a European notified body

“Working from reactor to recycle”



# Topics:

- Plastic classification
- Role of fillers in plastics
- Sample preparation
- Mechanical and Thermal properties
- Processing methods

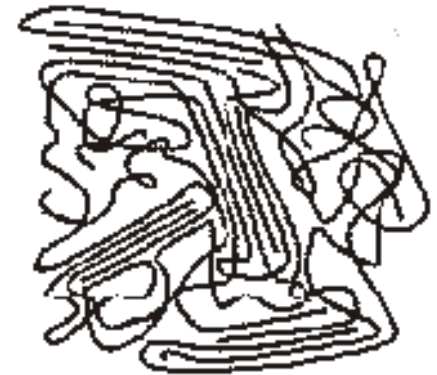
# Plastics: Broad grouping

- Plastics are macromolecules which can be broadly split into two groups
  - **Thermosets** – cannot be reprocessed
  - **Thermoplastics** can be reprocessed
- Thermoplastics are divided into **amorphous**: PS, ABS, PVC, PC
- and **semi-crystalline**: PE, PP, PA

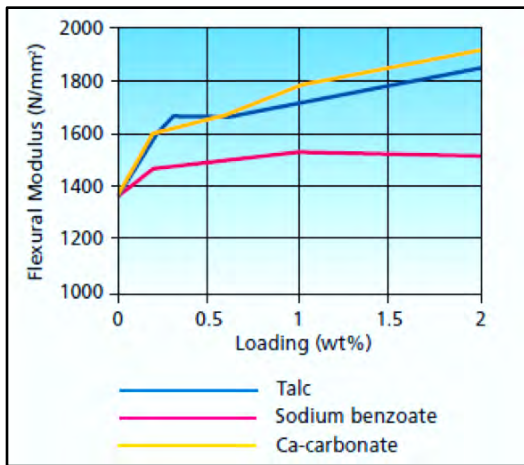
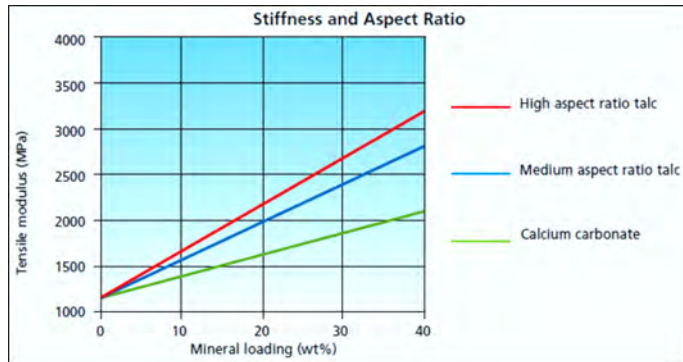
Amorphous



Semi-crystalline



# Why do we need fillers?

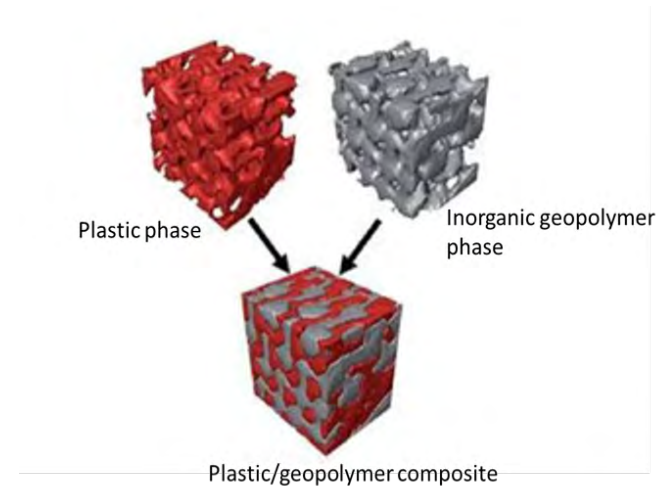


- Replace the costly resin or to improve its mechanical and thermal properties.
- Talc (hydrous magnesium silicate) or calcium carbonate is used to improve the stiffness of the material.
- Reducing cycle times in moulding and increasing productivity.
- Fillers provide dimensional stability and increase density.

*One disadvantage is excess filler reduces the strength of the material.*

# Our goal

- Our aim is to use metakaolin based geopolymers as fillers in plastics.
- Mechanical and thermal properties enhanced due to internal network formed by the geopolymer structure.
- The system formed would be a two phase system as illustrated in the following pic.
- The plastic will provide the required flexibility and strength while the geopolymer phase formed will provide the stiffness and thermal stability.



# Material and sample preparation

- Plastic used: PVC

*PVC is easy to blend, can be made stiff / flexible by changing the amount of plasticizer.*

- Geopolymer mix made of metakaolin and potassium silicate liquid solution a hardener.
- Sample preparation

The metakaolin powder + potassium silicate activating liquid were mixed together and added in PVC plastic.

- Test sample prepared using compression pressing.
- Testing: 3 point bend test and Heat deflection temperature

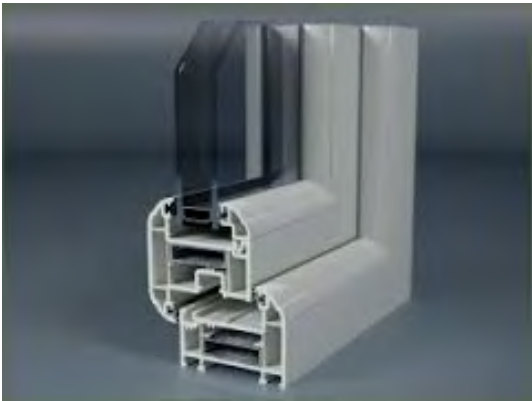
# Use of flexural and heat deflection properties



Automotive



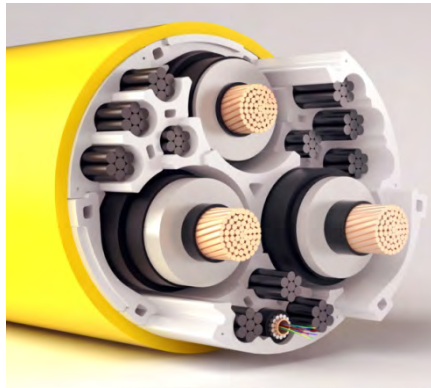
Utilities



Construction



Packaging

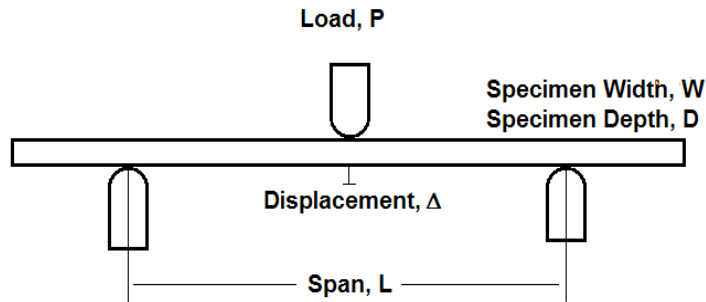


Oil & Gas



# Flexural Tests on Plastic

In many applications (containers, tanks, etc.), plastics are subject to bending or flexural forces and it can be more appropriate to measure their response in this mode of deformation

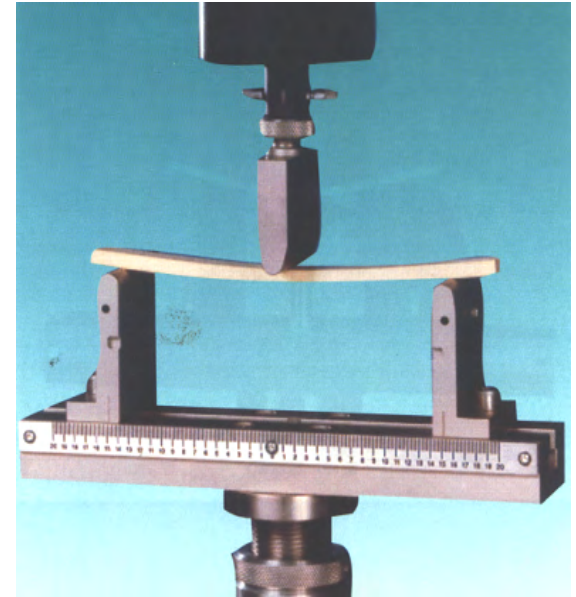


Modulus, E  
Strength,  $S_f$   
Maximum Load,  $P_f$

$$\text{Flexural Modulus } E = (P/\Delta) * L^3 / 4BD^3$$

$$\text{Flexural Strength } S_f = 3P_f L^3 / 2BD^2$$

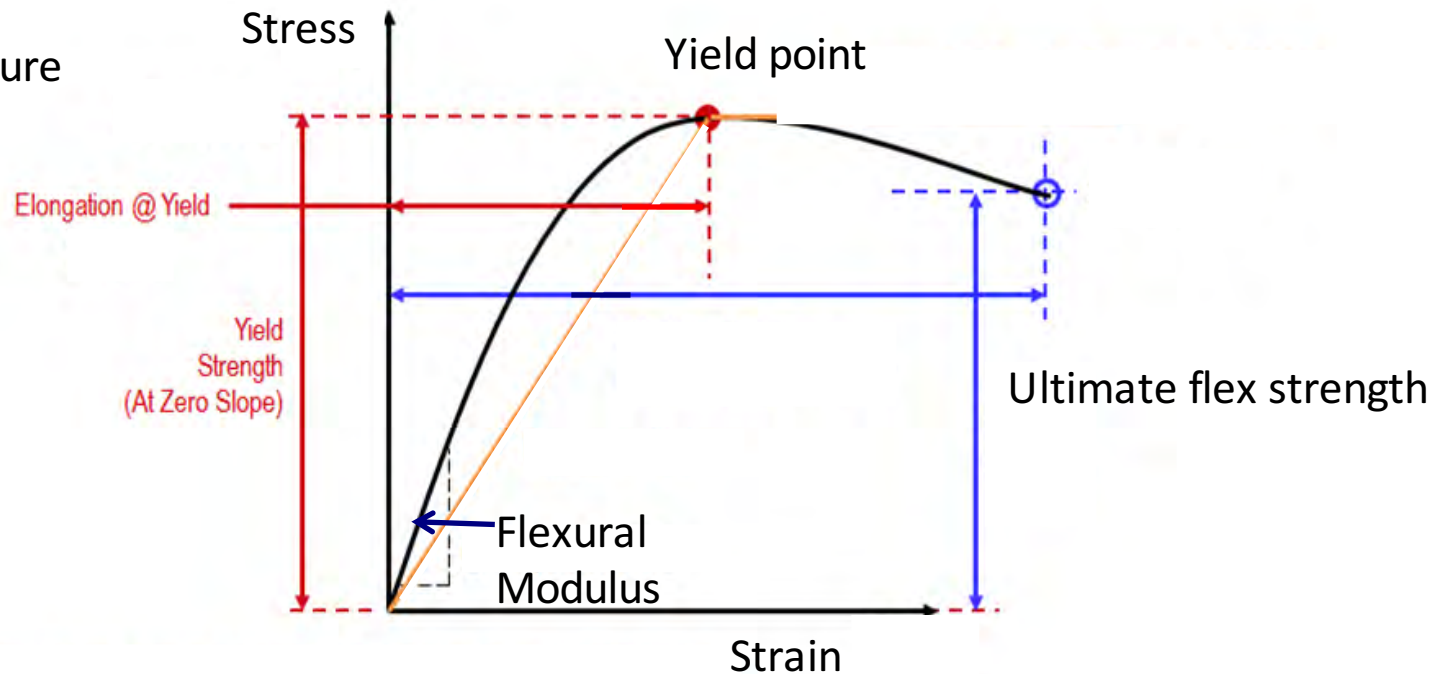
$P_f$  = Failure Load



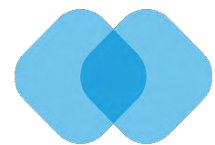
ISO 178

# Typical flexural curve

Like tensile properties  
the flexural parameters  
are effected by test  
speed and temperature



ISO 178

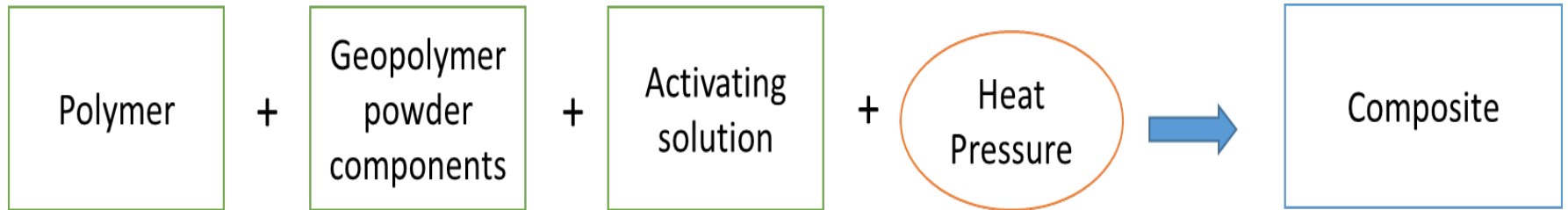


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**Mechanical  
Properties**

# Compression moulding

- Compression moulding is a common method of moulding thermoset plastics products or thermoplastic test specimens.
- Compression moulding:  
Produces a very dense plaque.  
Samples with 0 – 100 % geopolymer loading can be pressed.



# Compression moulded samples

- Samples with varying% of geopolymer filler were prepared and tested for flex and heat deflection tests.
- The ratio of the metakaolin and potassium silicate liquid was crucial in compression moulding.

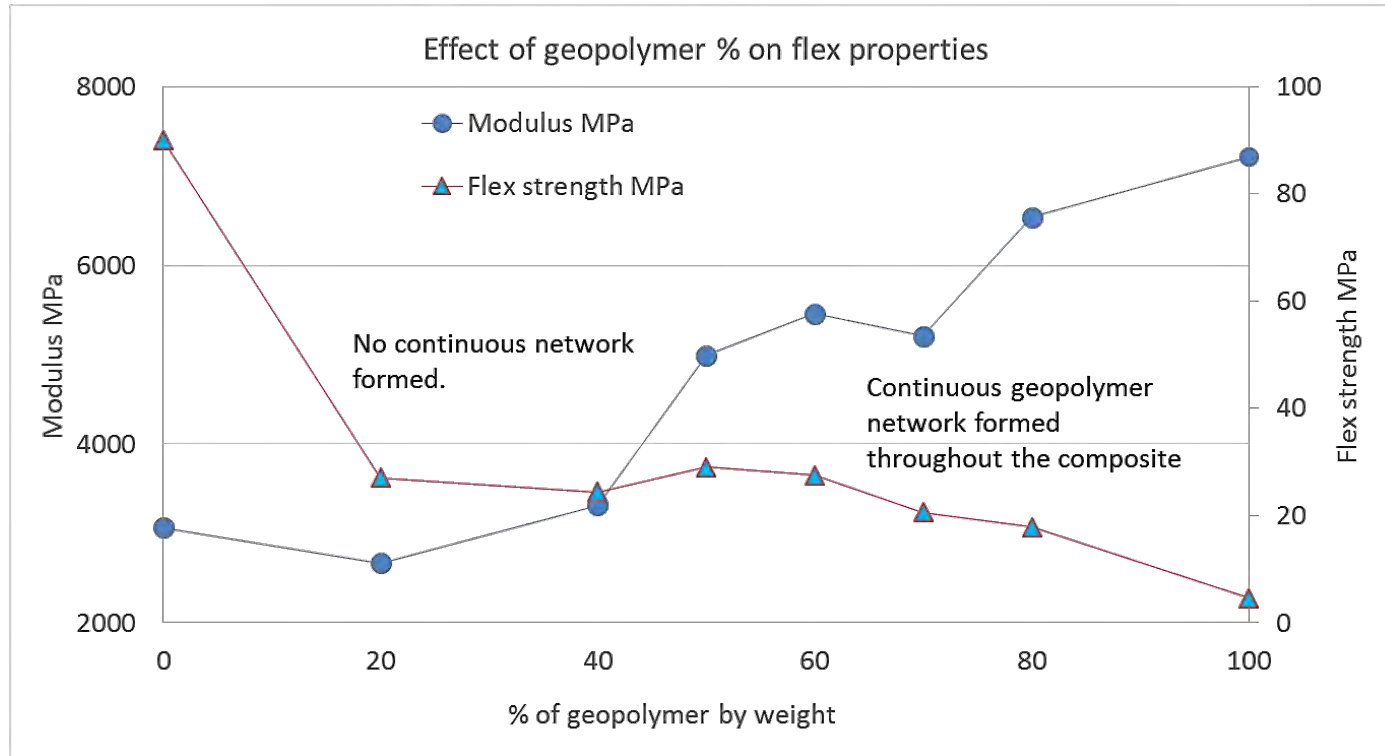


# Problems with compression moulding

- Batch process.
- Limited to plaque dimensions.
- Inhomogeneous mixing as geopolymer powder forms agglomerates when it comes in contact with hardener solution.
- Problems in sample ejection from the mould frame.

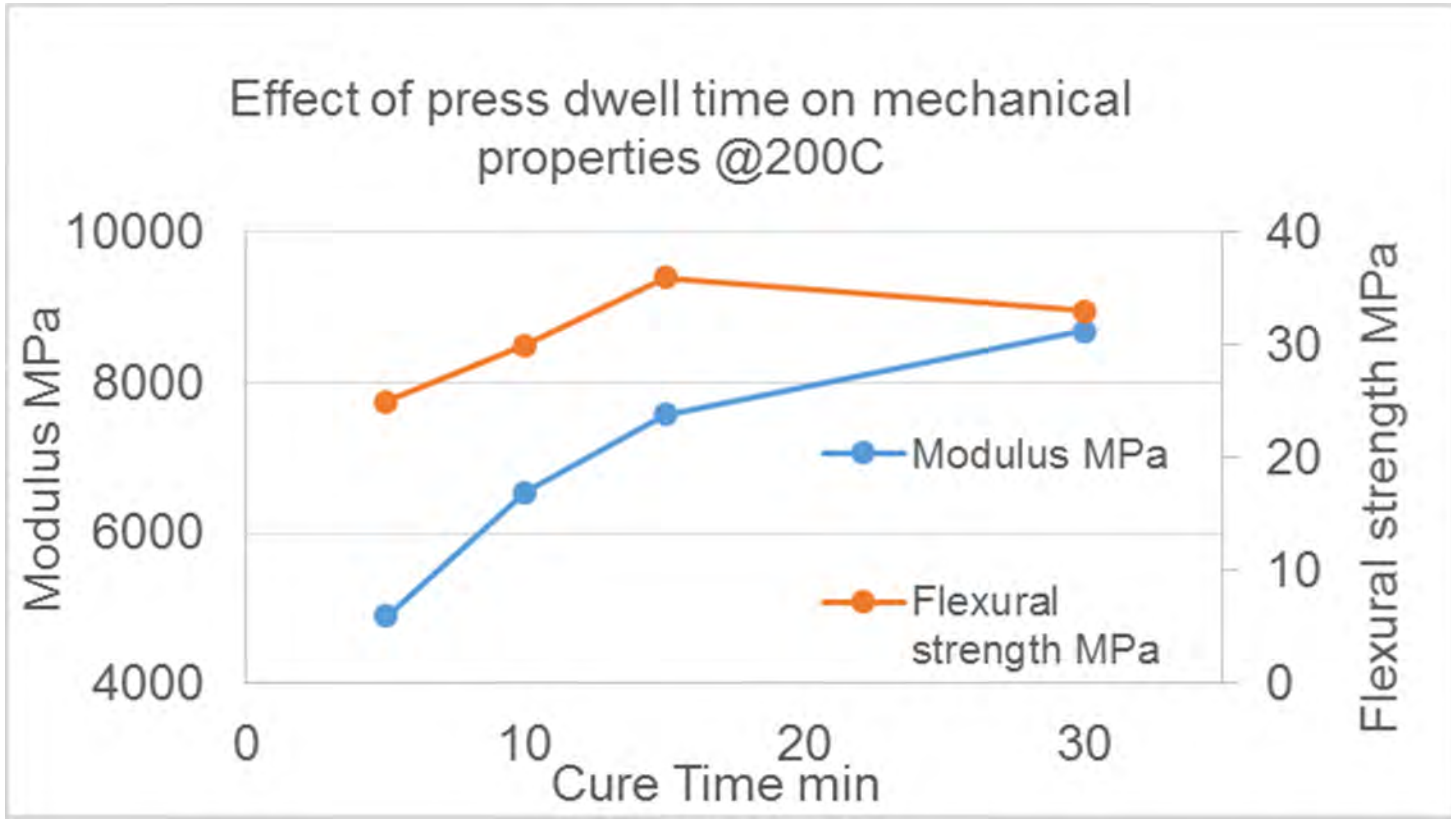


# Effect of geopolymer % on flex properties



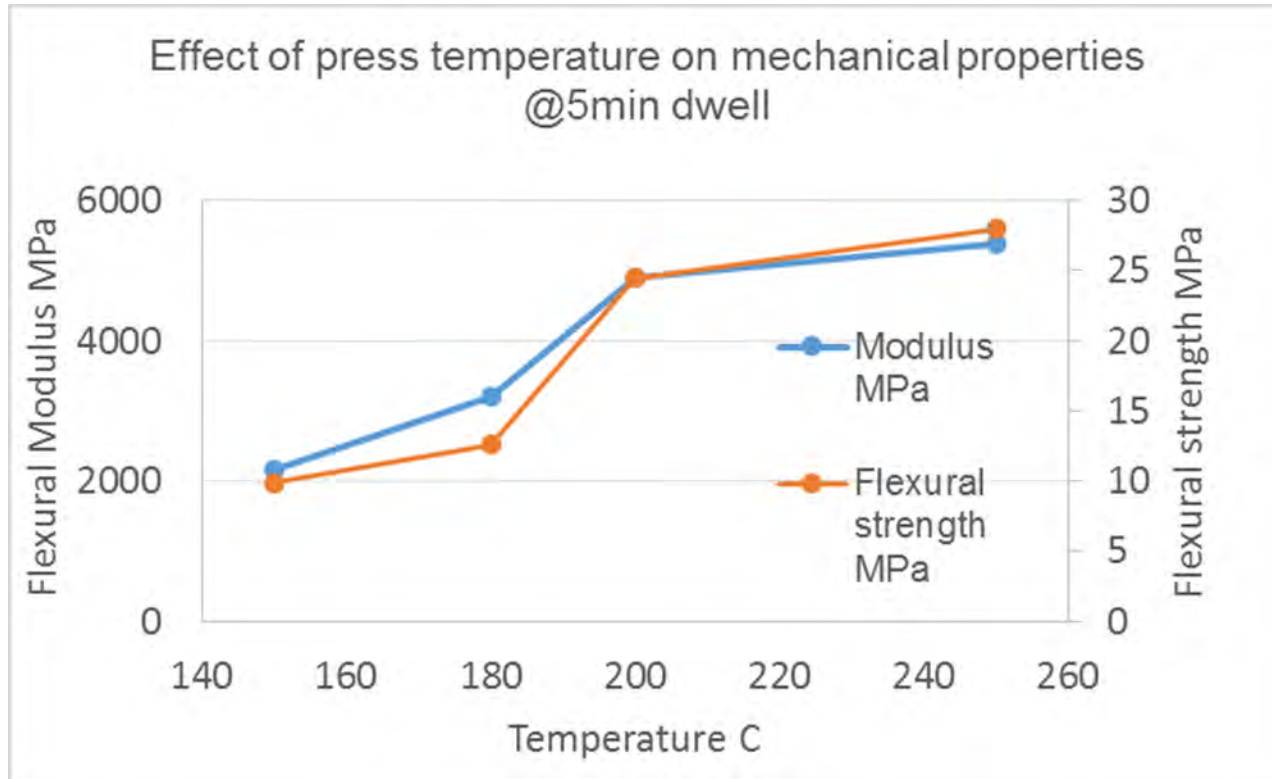
The gradual increase in the stiffness is due to formation of continuous geopolymer network throughout the composite.

# Effect of dwell time in press



A steep decrease in properties after 15min is due to decomposition of plastic due prolonged exposure to high heat.

# Effect of press temperature on mechanical properties

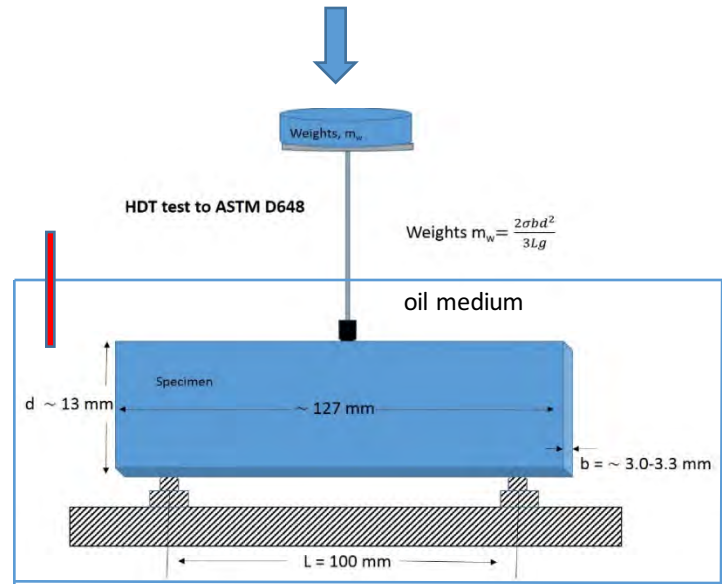


A steep decrease in properties after 15min is due to decomposition of plastic due prolonged exposure to high heat.



# Heat Deflection Temperature

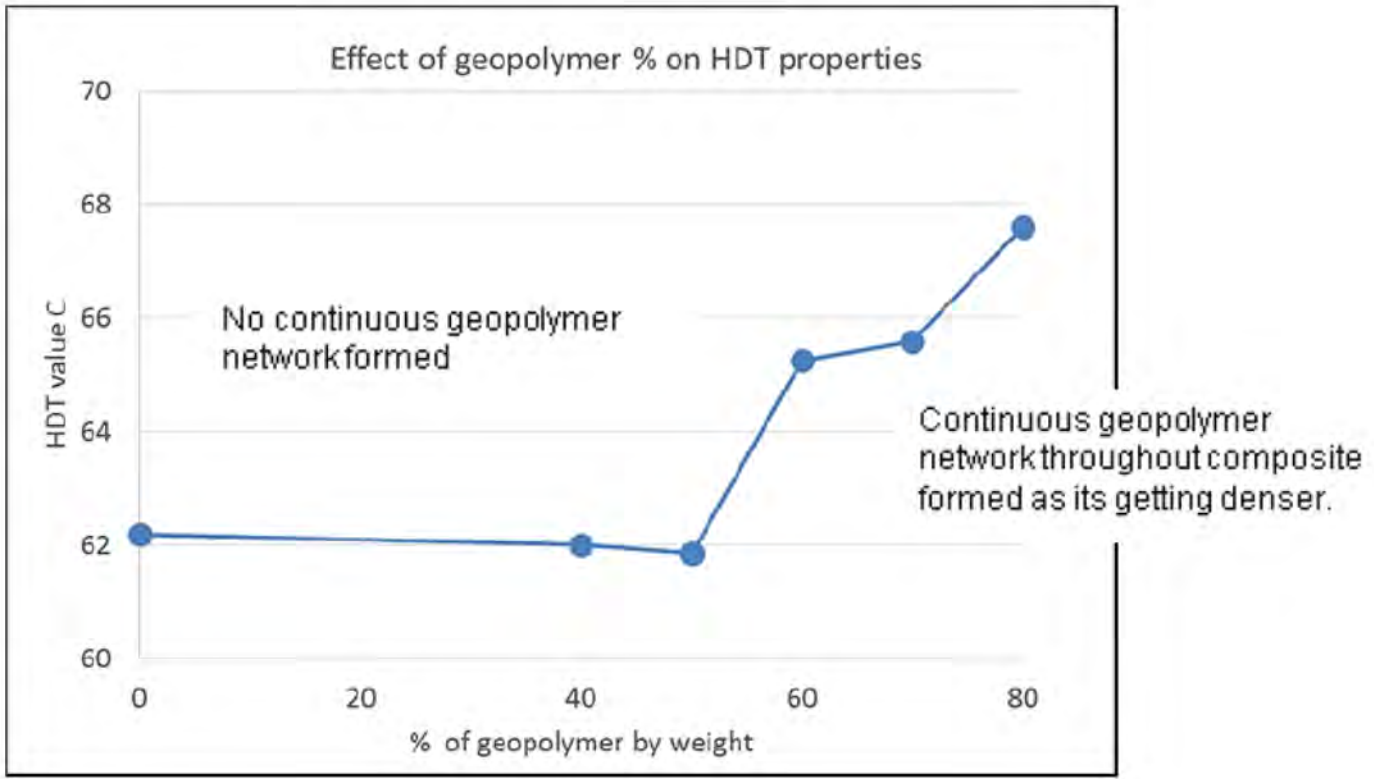
- HDT is the temperature at which a plastic sample deforms under a specified load.
- A point load is applied to a supported sample bar to give a stress of 0.45MPa or 1.8MPa
- The sample is held under oil and the temperature is raised at a specific rate.
- This property gives a guide to a plastics maximum operating temperature
- Injection moulded parts are safe to remove from the mould only when parts are below the HDT



ASTM D648 – edgewise/ISO 75 - flatwise

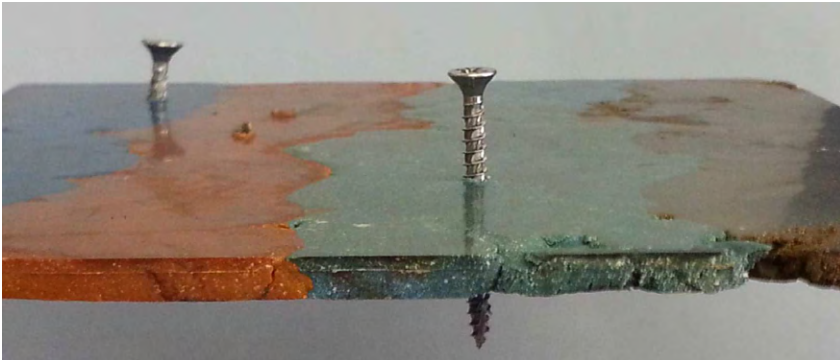
Material	100-mm (3.937-in.) Span
ABS, 1.8 MPa	81.9
PP natural, 0.45 MPa	85.2
PP filled, 0.45 MPa	116.6
Nylon, 1.8 MPa	156.1

# Heat deflection temperature



# Aesthetic properties

- Our samples can be coloured using master batch.
- The surface has smooth finish which could easily be painted.
- Sample produced at 50-60% loading were strong enough to be drilled and screwed.



# Use of two roll mill for sample preparation

- PVC melted and geopolymer mix added to make blends.
- 2-3 mm thick sheets obtained which were compression pressed.

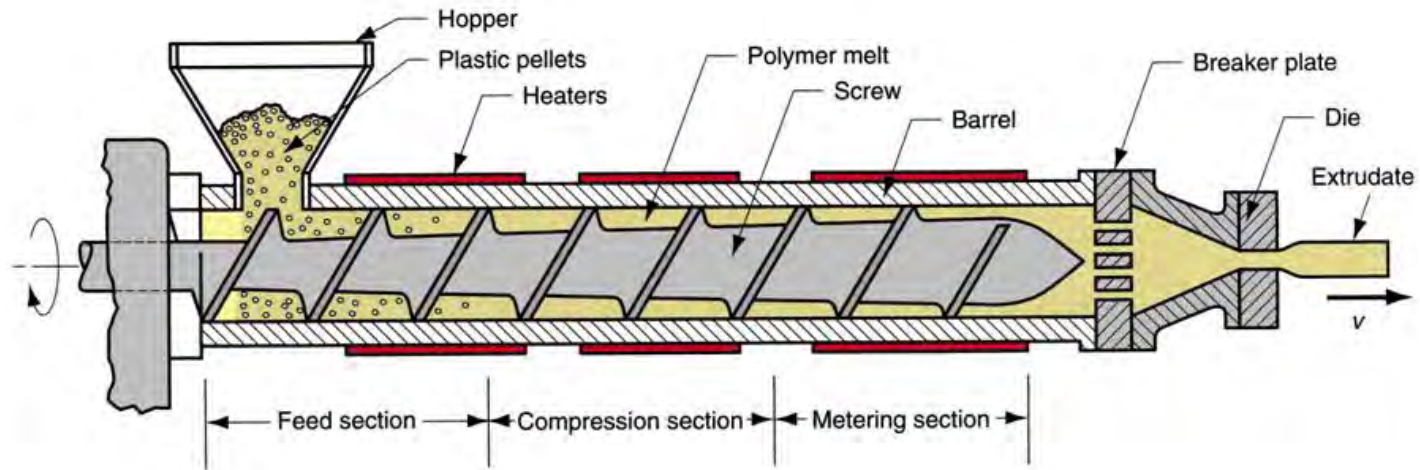


# Problems with two roll mill



The geopolymer mix started to stick and cure on the surface of the two roll mill.

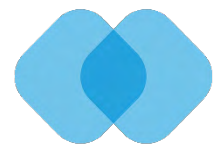
# Extrusion of profiles



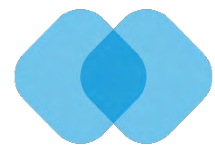
**Major components:** Barrel, Screw

Die - not an extruder component (*Special tool that must be fabricated for particular profile to be produced*)

Widely used in plastics industry. Common applications include pipes, tubes, sheets and profiles.



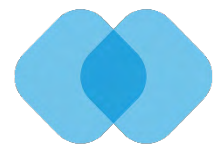
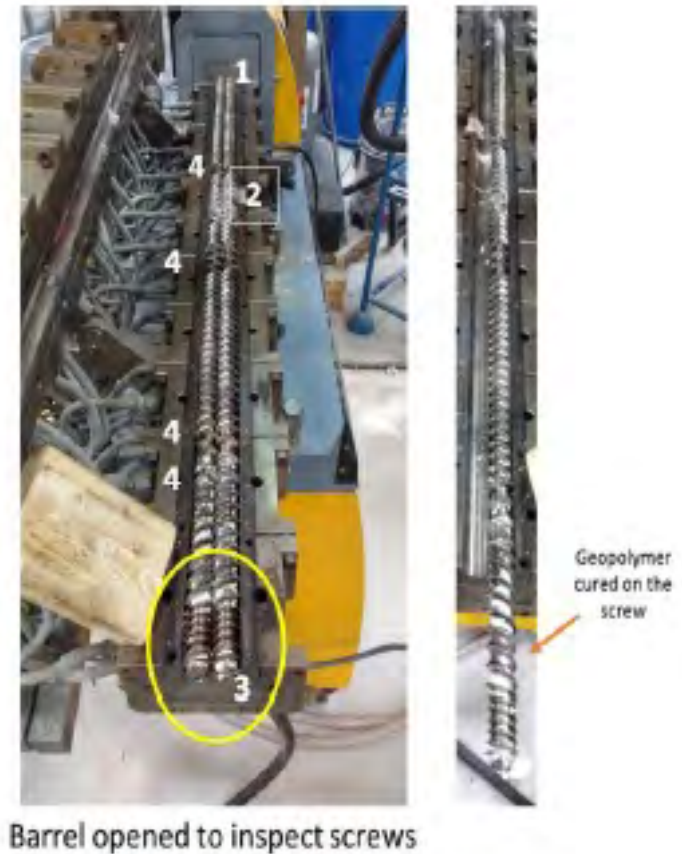
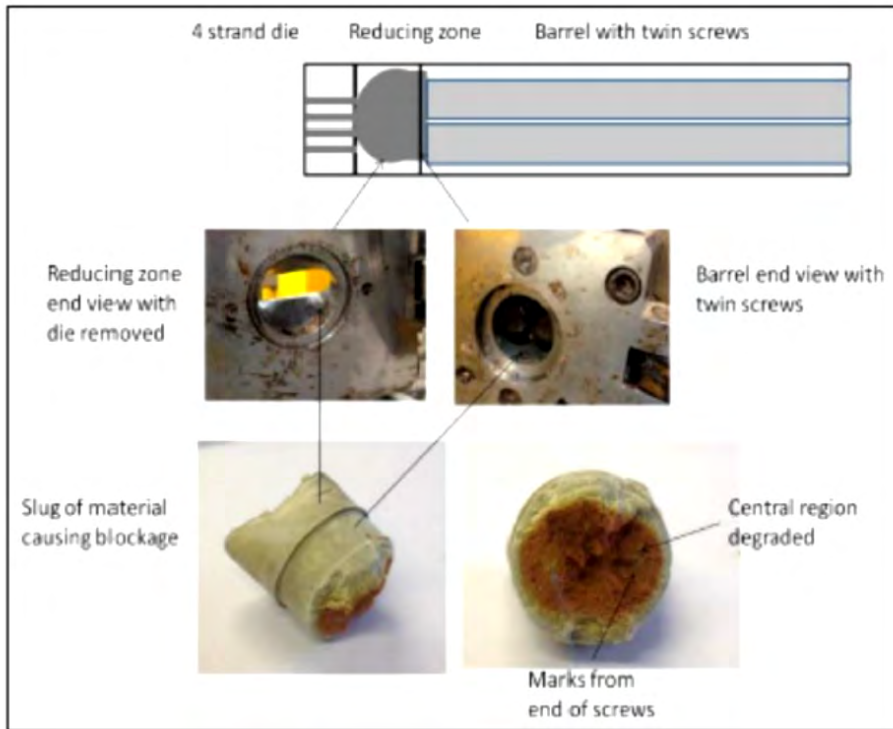
# Extrusion of profiles



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Aesthetic  
properties

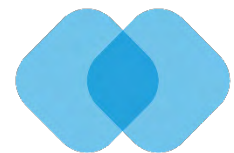
# Problems with extrusion





*THANK YOU*  
QUESTIONS?

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