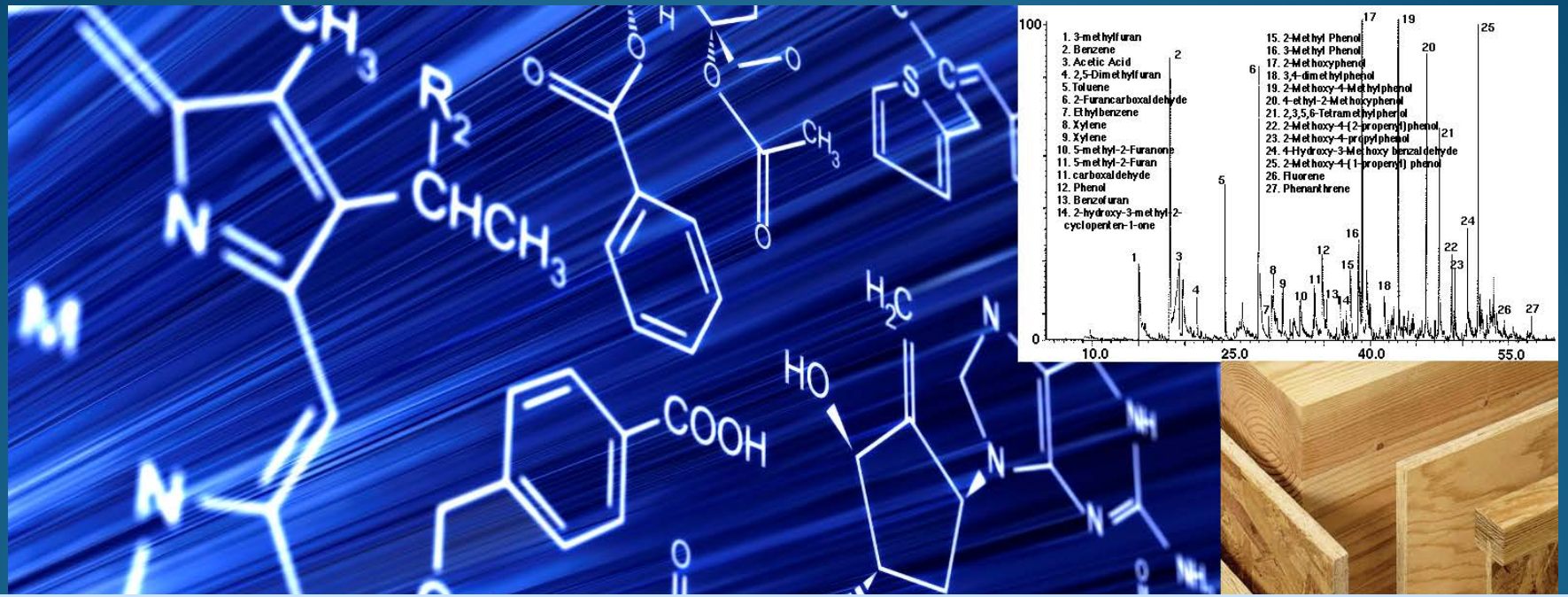


Isocyanate adhesives & high density hardwoods

James Hague

Australian Forest Research Company

The durability of isocyanate-based adhesives under service in Australian conditions. The results from a 3-year exposure study and accelerated testing regime

K. Van Langenberg, P. Warden, C. Adam and H.R. Milner

- Two reports, 216 pages in total
- www.fwpa.com.au

Drivers for using isocyanates

- Clear glue lines
- Reduced resin usage
- Potential for gluing at higher wood moisture contents
- Shorter cure times
- Minimising waste and reducing handling costs
- The possibility of gluing timbers that have been traditionally difficult to glue with PRF resins

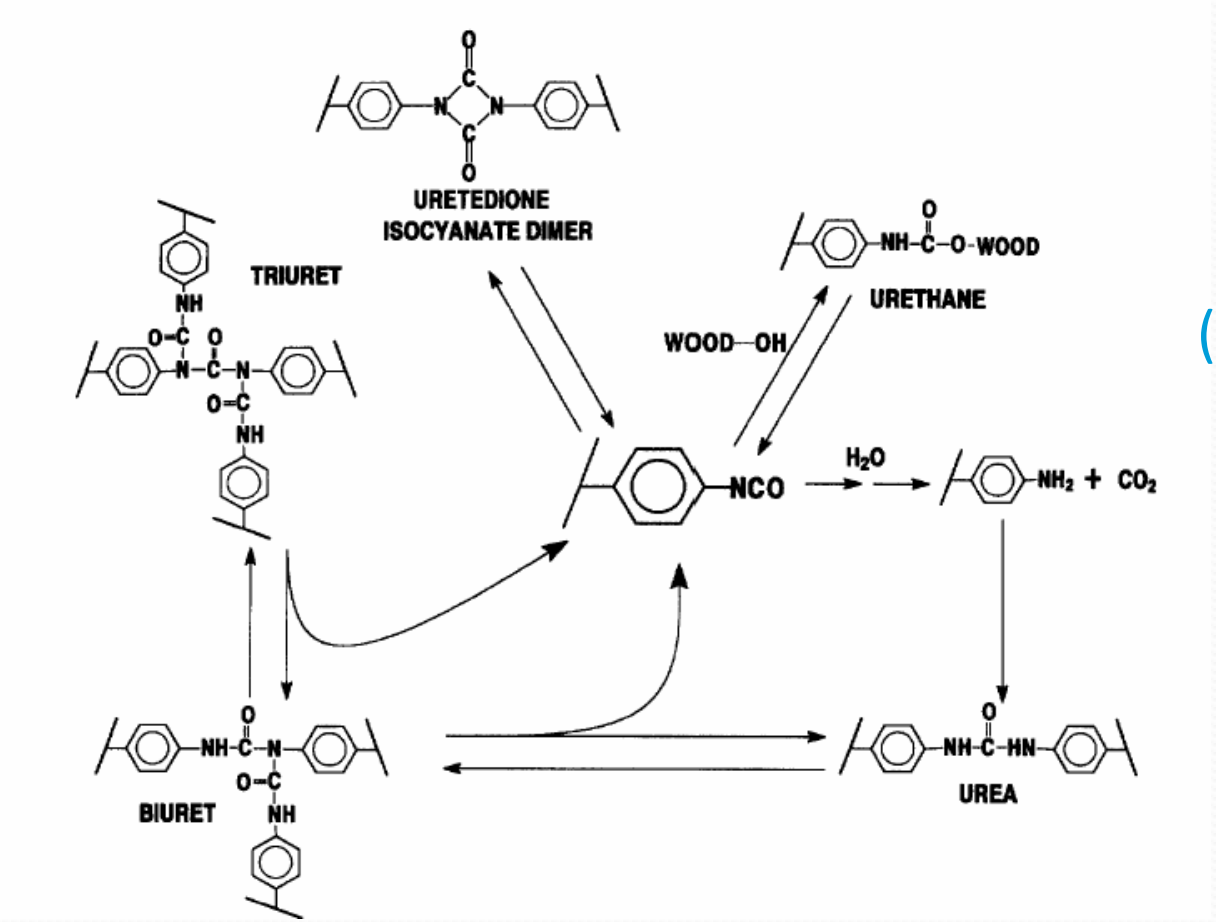
Issues, questions, problems

- OHS – sensitisation?
- How durable are isocyanates?
  - Covalent bonding with wood?
  - Lack of wood failure in (wet) destructive tests
- Creep behaviour at elevated temperatures?
- How to test & predict long term performance?

OHS

- Irritants and respiratory-tract sensitisers
- MDI key component of interest
  - But, low vapour pressure, so reduced risk
- Volatilisation or association with airborne particles significantly increases risks of sensitisation
  - MDF, OSB, Particleboard
- Unlikely to be an issue with EWPs such as glulam, assuming good OHS practices

Proposed chemical reactions in the wood/isocyanate bond-line



(Frazier *et al*, 1998)

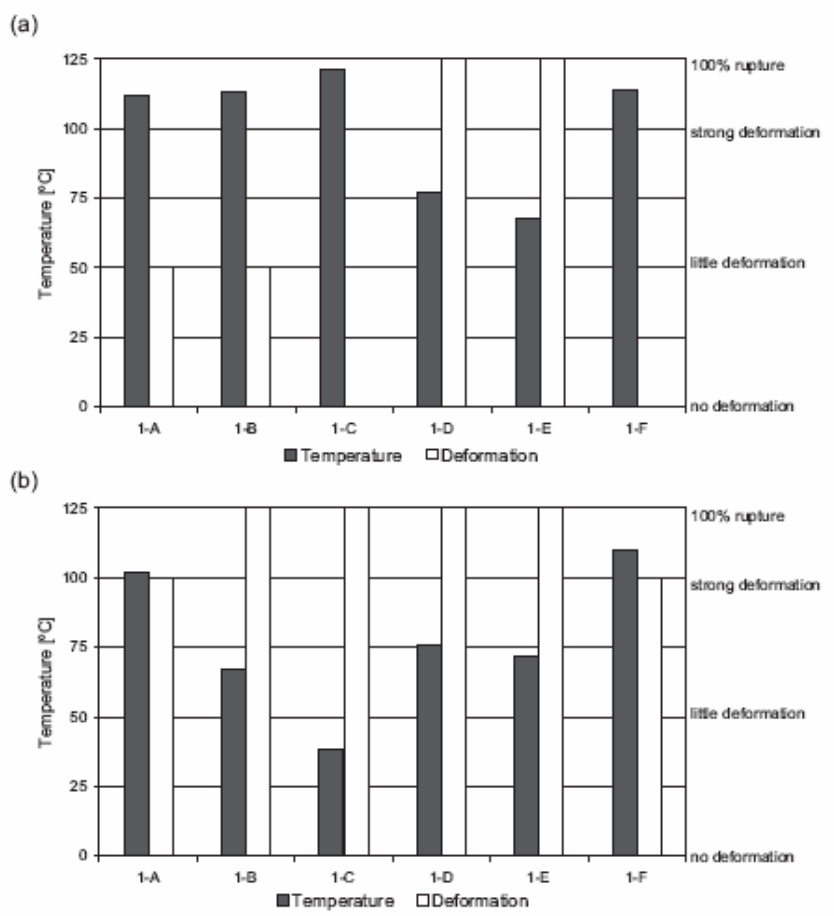
Evidence for covalent bonding

- The most recent studies suggest that there is little or no covalent bonding
- Adhesive penetrates wood surfaces and reacts primarily with water present in wood
- Key bonding mechanism is mechanical ‘lock & key’
- Lack of wood failure may be related to similarity in physical properties of wood and isocyanates cf. PRFs

Creep behaviour

- Evidence that isocyanates exhibit significantly increased creep at elevated temperatures (that could potentially be experienced in service)
- Complicated by very variable behaviour between product types/brands
- Glueline thickness can also be a factor

Creep behaviour vs glueline thickness



Thin glueline

Thick glueline

(Richter *et al*, 2005)

Creep monitoring

- Germany, 13 years
- Protected external
- Isocyanates vs PRFs
- -11 – 32 C
- Comparable performance

Testing & prediction of long-term performance

- The ‘Holy Grail’ for researchers – how to accurately predict long-term performance from short term tests?
- ASTM, EN, Canadian, ISO, AS/NZ
- Various combinations of shear, boil, delamination, creep tests etc.
- Standards typically moving towards performance-based criteria

ASTM 3434 – boil test

- Multiple boil/dry cycles (up to 800)
- Good correlation with 13-yr long term performance data
- All new adhesives required to be tested
- Only one machine in existence

Current international status

- Sensitisation issues can be minimised with good OHS practice
- Increasing confidence that isocyanates will provide long-term performance
  - Up to 14 years' 'in service' data in buildings in Europe
- ISO standard likely to be based on the Canadian standard, with some elements of ASTM. Performance-based.
- Work needed to understand performance with Australian species under Australian conditions

Australian research aims

- Durability of four isocyanate adhesives (cf. PRF)
  - 3 x 1-part (Purbond & Bostik), 1 x 2-part (Ashland)
- 3 timbers – radiata, Vic ash, spotted gum
- Residual bond strengths after 1 and 3 years' exposure in the field and in controlled environments
- 5 accelerated test methods
  - 2 x delamination, cleave, shear, moisture resistance
- Other short term testing approaches
  - PALS, Hygro-mechanical testing of thin adhesive films

Test beam preparation

Test beam preparation

- Warrnambool Timber

Test beams

Exposure of loaded beams

Exposure of unloaded beams

Environmental conditions

- Darwin
  - 12 – 38 C, 30 – 100% RH
  - Max daily rainfall 240mm
- Controlled environment (Monash)
  - Ambient to 50 C / 80% RH, fortnightly cycles
- Tested for shear strength after 1 & 3 years

Radiata – Darwin, 3 years

Radiata - Summary

- Higher adhesive strength losses in outdoor specimens
- Higher adhesive strength losses in loaded specimens
- Any strength losses occurred mainly after 1 year
- No significant differences between adhesive types

Vic ash - Summary

- Higher adhesive strength losses in outdoor specimens
- Generally higher adhesive strength losses in loaded specimens
  - 1 isocyanate adhesive exhibited opposite behaviour
- 25-35% strength losses after 3 years
- No significant differences between adhesive types

Spotted gum - Summary

- Higher adhesive strength losses in outdoor specimens
- All loaded specimens failed after 3 years (inc PRF)
  - Exception 1 isocyanate adhesive, with a small residual retained strength
- All unloaded specimens failed after 3 years (inc PRF)
  - Exception 1 different isocyanate adhesive, with a small residual retained strength
- No significant differences between adhesive types

Spotted gum - unloaded

Spotted gum – key issues

- Unfavourable surface chemistry?
- Density
  - Relationship between swelling pressure of timber and density is exponential
  - Higher density species ‘self destruct’ under changing RH conditions
- Glued material should not be considered for structural applications unless very stable service conditions can be guaranteed.

Short term tests

Delamination tests

- AS/NZS 4364:1996 and CSA O112.9-04
- Vacuum pressure soak and drying cycles
- Different specimen sizes, pressures, drying temperatures, cycle times, test durations.
- Measures extent of glueline delamination

Delamination tests

Delamination tests

- Different results between the two methods
- All adhesives performed badly with Spotted gum
- Species dependence for isocyanates – some performed better with radiata, others with Vic ash
- Some isocyanates had equivalent performance with PRF, others poorer performance

Cleave test

- AS/NZS 1328.1:1998
- Tested dry and after vacuum pressure soak cycle
  - Tested for extent of wood fibre failure
- Isocyanates gave reduced wood fibre failure rates with radiata & Vic ash when tested wet
  - PRF unaffected by moisture
- In Spotted gum, all adhesives gave low wood fibre failure rates in both dry and wet conditions

Longitudinal tensile lap shear test

- AS/NZS 4364:1996
- Cold & boil soak
- Tested wet & dry
- No significant degradation of adhesives
- Some minor between adhesive/wood species differences

Hydrolytic stability test

- ASTM D4502
- Wet & dry heat & moisture aging
  - Broad testing guidelines
  - Over 3000 test specimens investigated
  - Tests conducted over increasing time intervals
- Block shear tests
- No significant differences between adhesives…..

Conclusions

- Other parts of the world ahead of Australia
- For Australian data, poor correlation between long and short term tests
- Variable performance of different isocyanate types/brands
- Isocyanates equivalent or poorer than PRF
- Two types of delamination test give different results
  - Both are currently being suggested as equivalent alternatives in draft AS/NZS and ISO standards
- More work required……

Conclusions

- Spotted gum should be avoided for structural applications where it is required to be glued

Forest&Wood Products Australia

CSIRO

Thank you