



Analytical Evaluation of Fire Resistance of FRP Reinforced Concrete Beams

*Fire Safety Engineering Research
and Technology Centre (FireSERT)*

University of Ulster

Muhammad Masood Rafi, Ali Nadjai and Faris Ali



TOPICS COVERED

- ❖ Introduction
- ❖ Effects of fire on FRP
- ❖ Transient heat transfer analysis
- ❖ Structural analysis
- ❖ Finite element model
- ❖ Discussion on analytical results
- ❖ Conclusions

INTRODUCTION

- ❖ FEM used routinely in RC design and analysis
- ❖ Powerful tool to quantify responses, e.g.
 - Strain development
 - deflection
 - Load capacity
 - Stress distribution
 - Temperature propagation

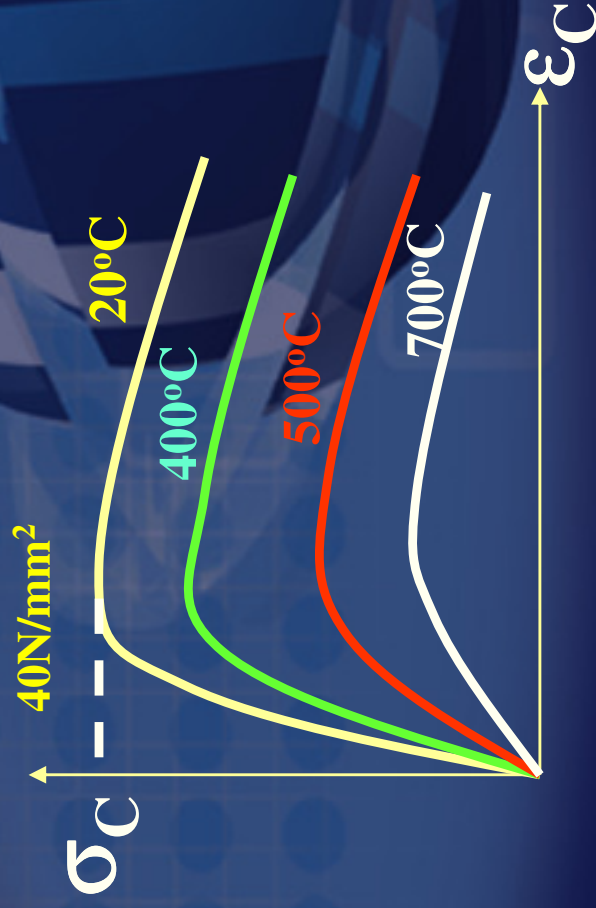
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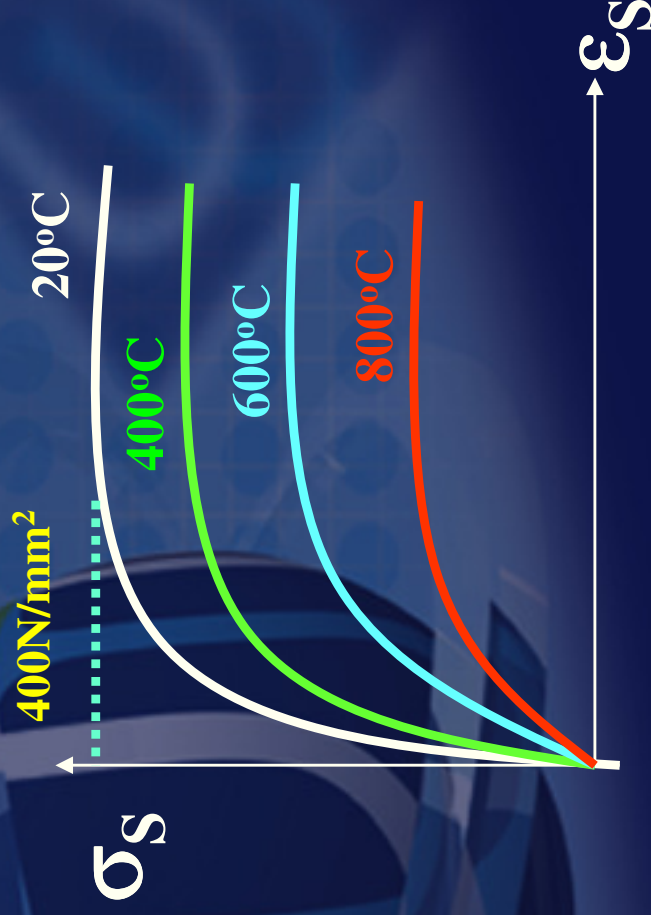
INTRODUCTION

❖ Temperature dependant mechanical properties:

- Concrete
- Steel



Concrete stress-strain curves



Steel stress-strain curves

Cont.



INTRODUCTION

- ❖ Lack of similar relation for FRP bars
- ❖ Need of a constitutive model
- ❖ No study to include thermal and mechanical loading
- ❖ Commercial FE programme DIANA
- ❖ Analytical and experimental behaviour compared



EFFECTS OF FIRE ON FRP

- ❖ Polymer softens at glass transition temperature T_g
- ❖ Change in molecular structure
- ❖ Force transfer reduces
- ❖ Decrease in elastic modulus
- ❖ Reduction in tensile strength



TRANSIENT HEAT TRANSFER ANALYSIS

- ❖ To calculate temperature distribution
- ❖ Methods of heat transfer
 - Conduction
 - Convection
 - Radiation
- ❖ Galerkin weighted residual method
- ❖ Direct integration scheme (generalised trapezoidal rule)



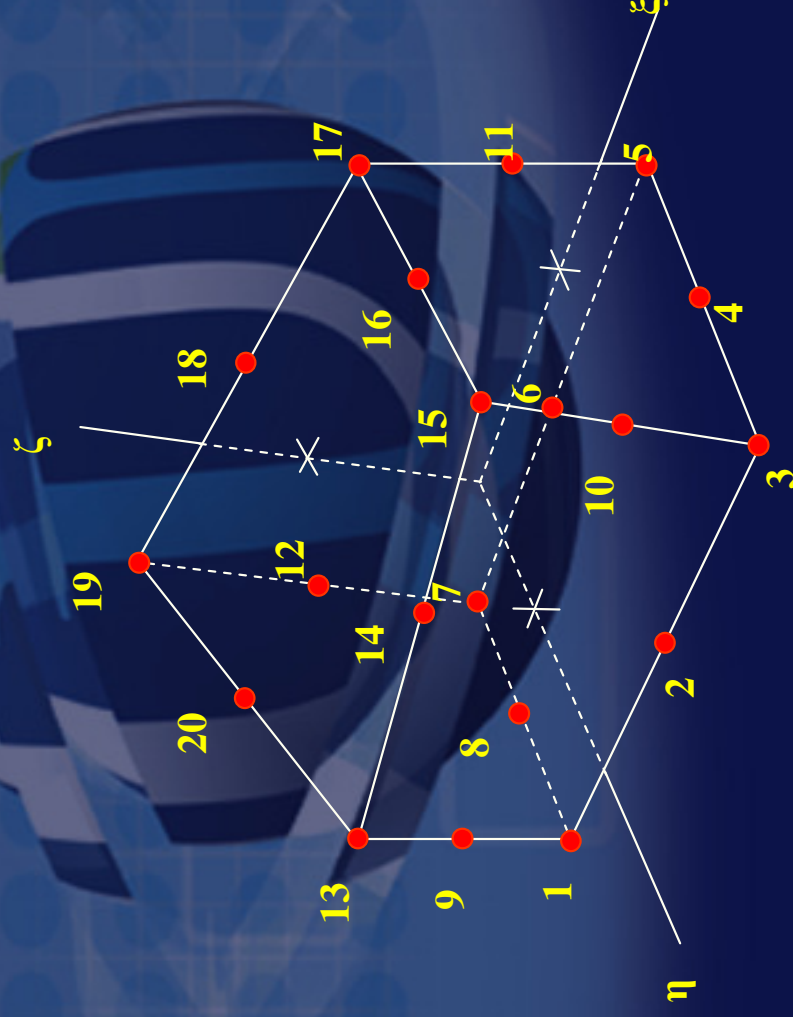
STRUCTURAL ANALYSIS

- ❖ Smearing crack concept
- ❖ Non-linear softening of concrete
- ❖ Perfect bar-concrete bond
- ❖ Only tension bar included
- ❖ Material and geometric non-linearities
- ❖ Temperature dependent properties



FINITE ELEMENT MODEL

- ❖ 20 nodes 3D brick element for concrete
- ❖ Three degrees of freedom

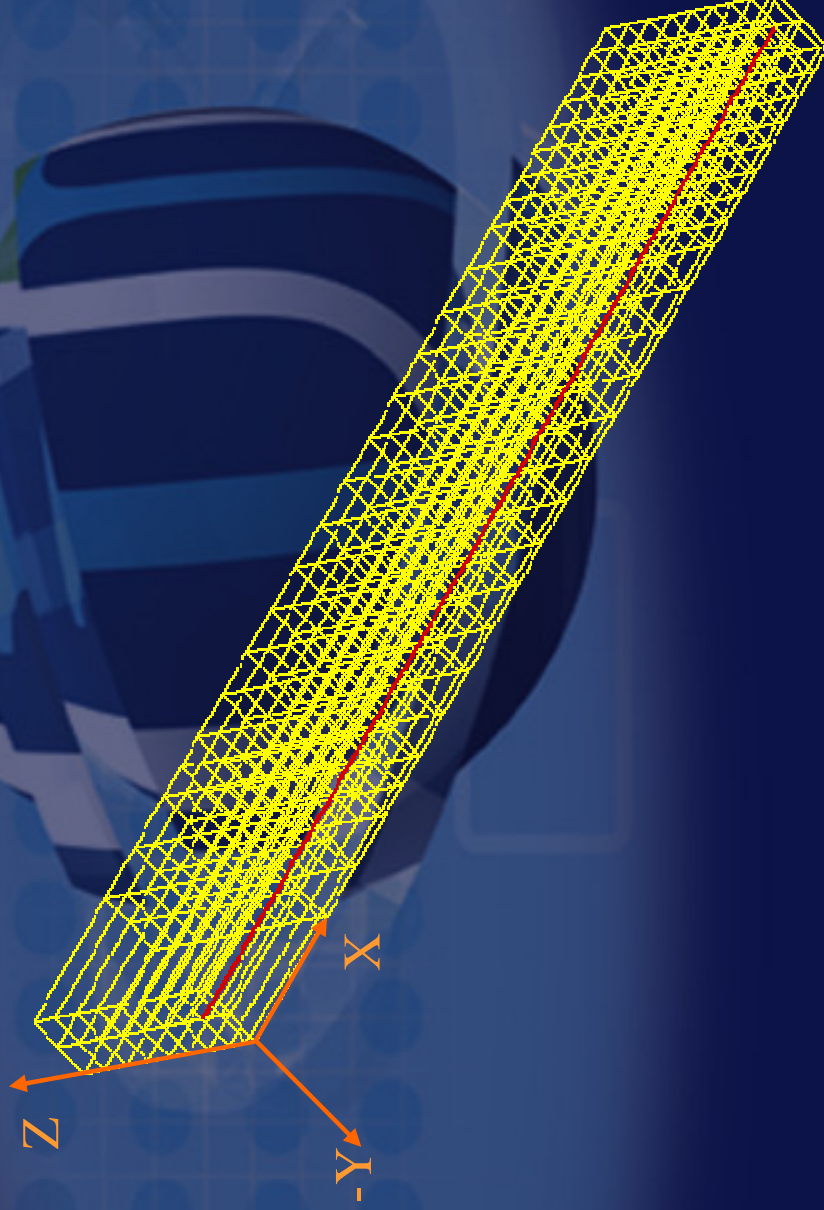


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FINITE ELEMENT MODEL

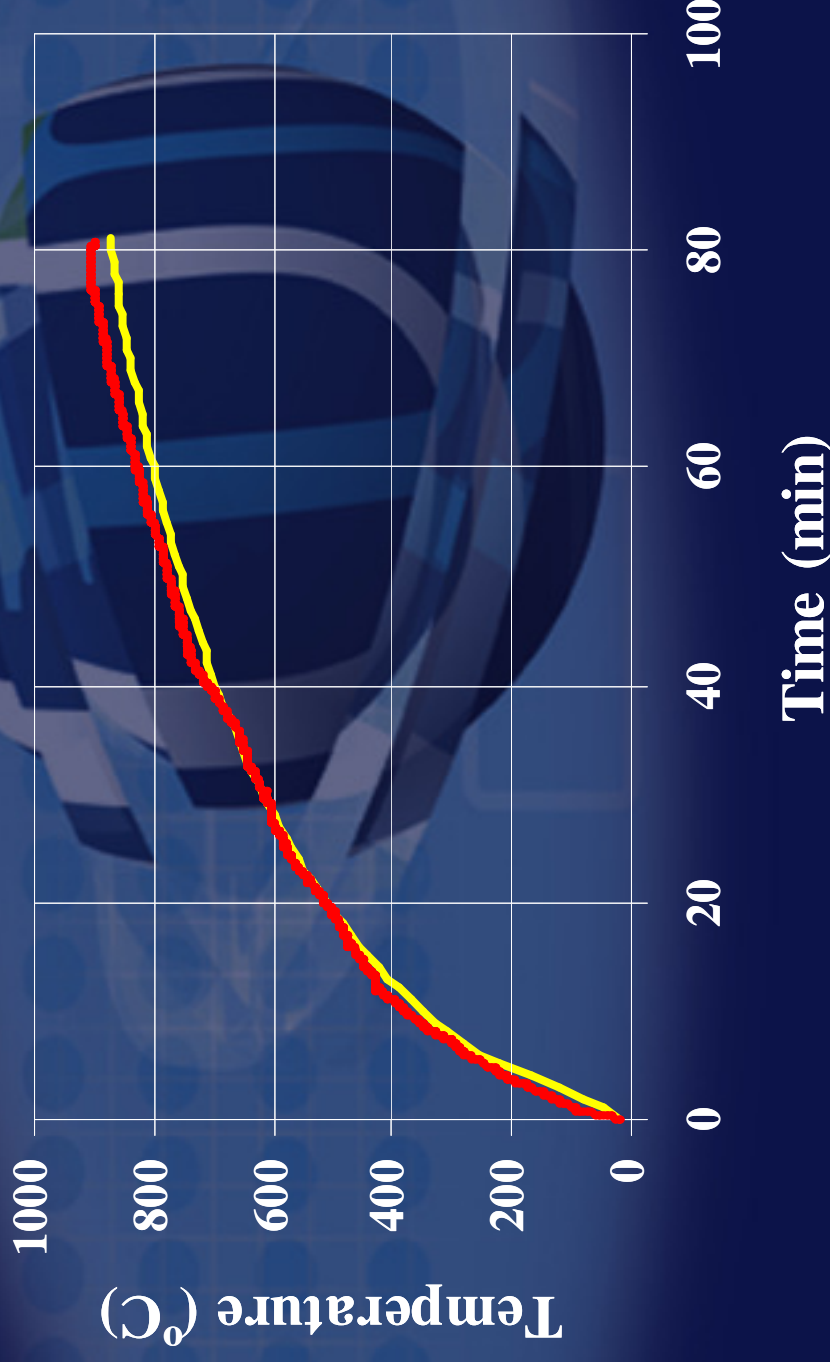
- ❖ Model of one half of the beam
- ❖ Typical mesh shown



DISCUSSION ON ANALYTICAL RESULTS

- ❖ Temperature progression at TC1

— Experimental — Theoretical

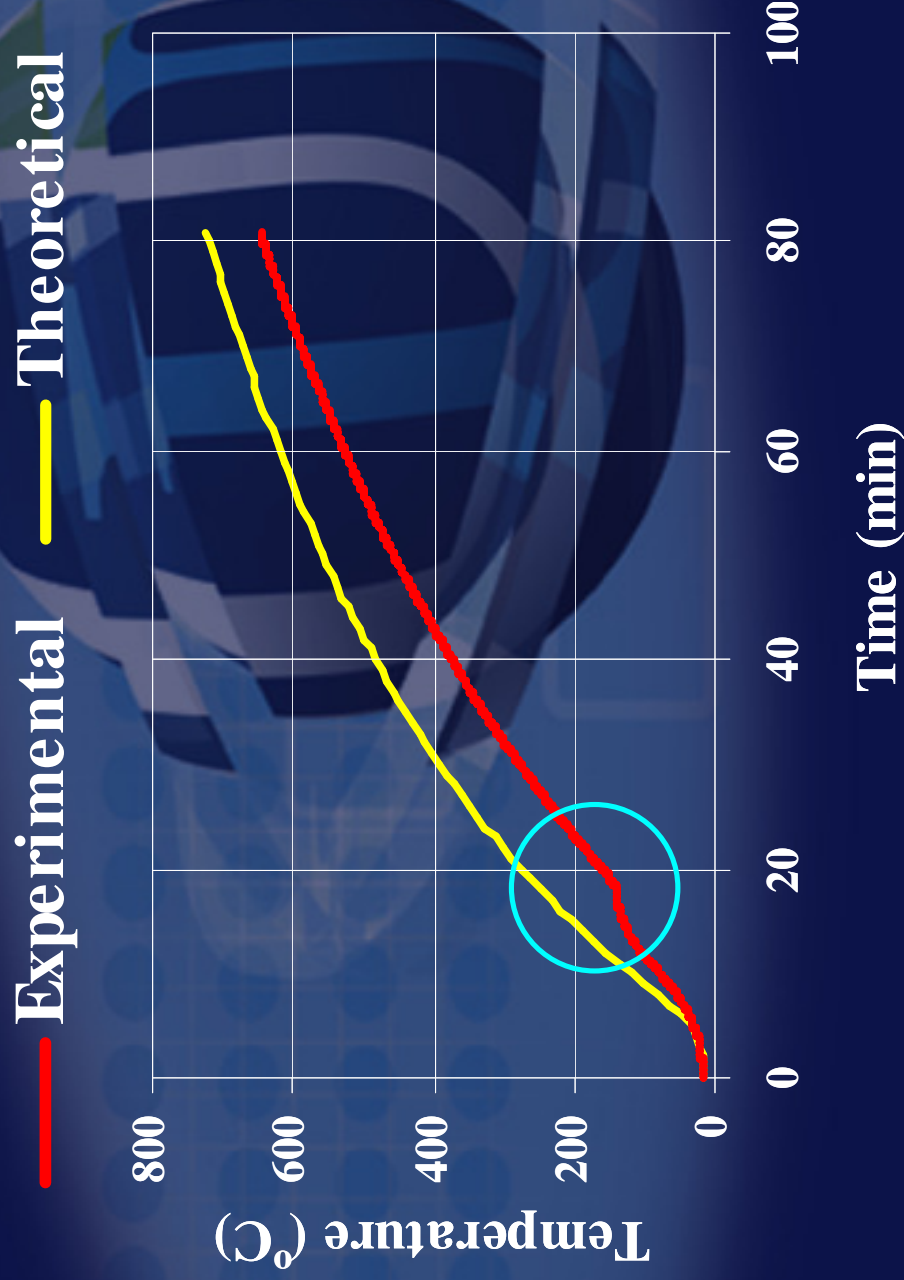


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DISCUSSION ON ANALYTICAL RESULTS

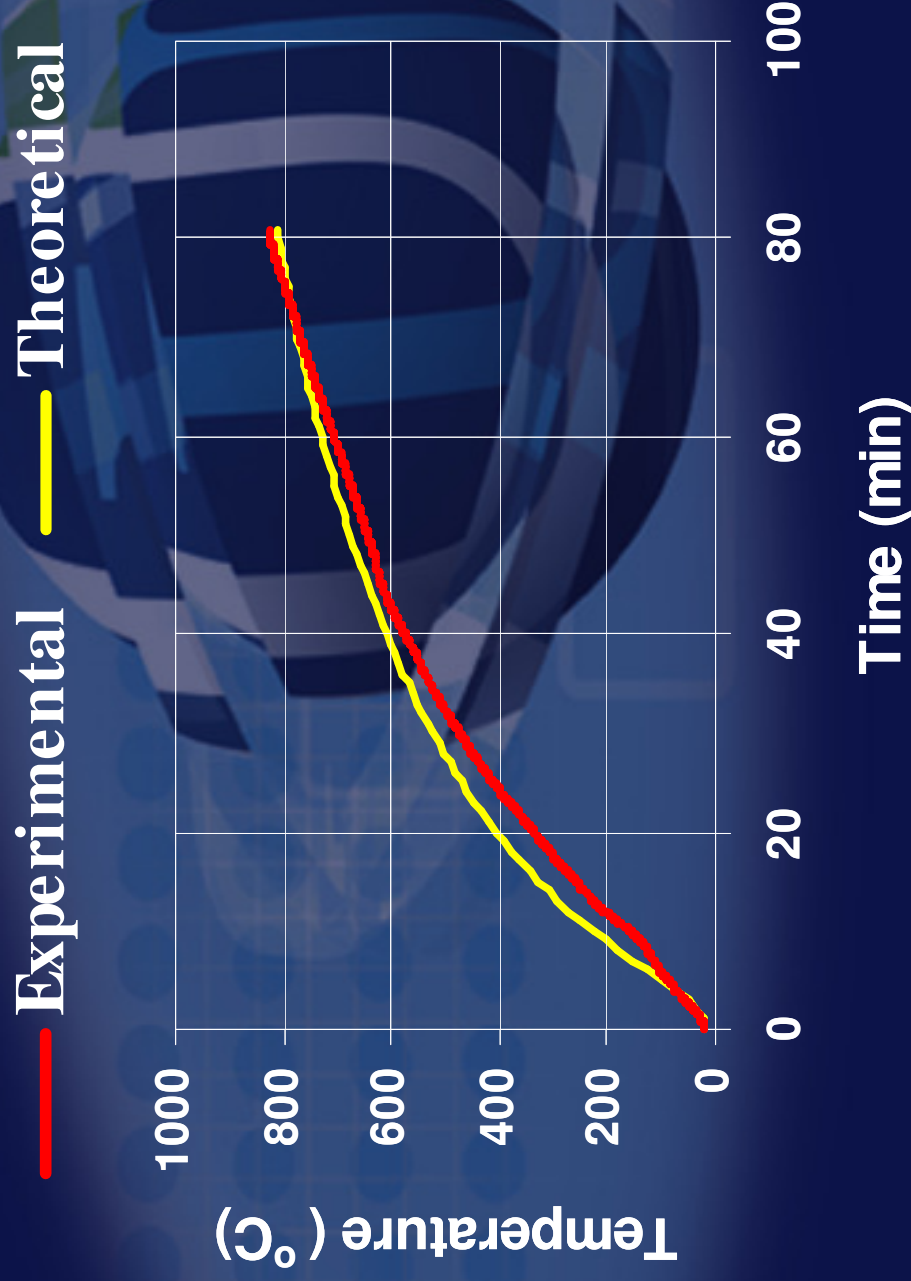
- ❖ Temperature progression at TC5



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DISCUSSION ON ANALYTICAL RESULTS

- ❖ Temperature progression at TC3

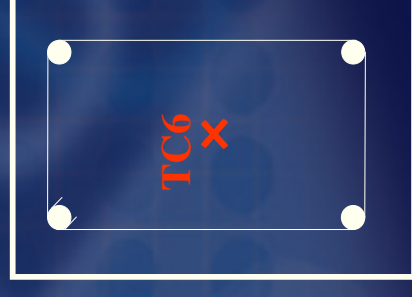
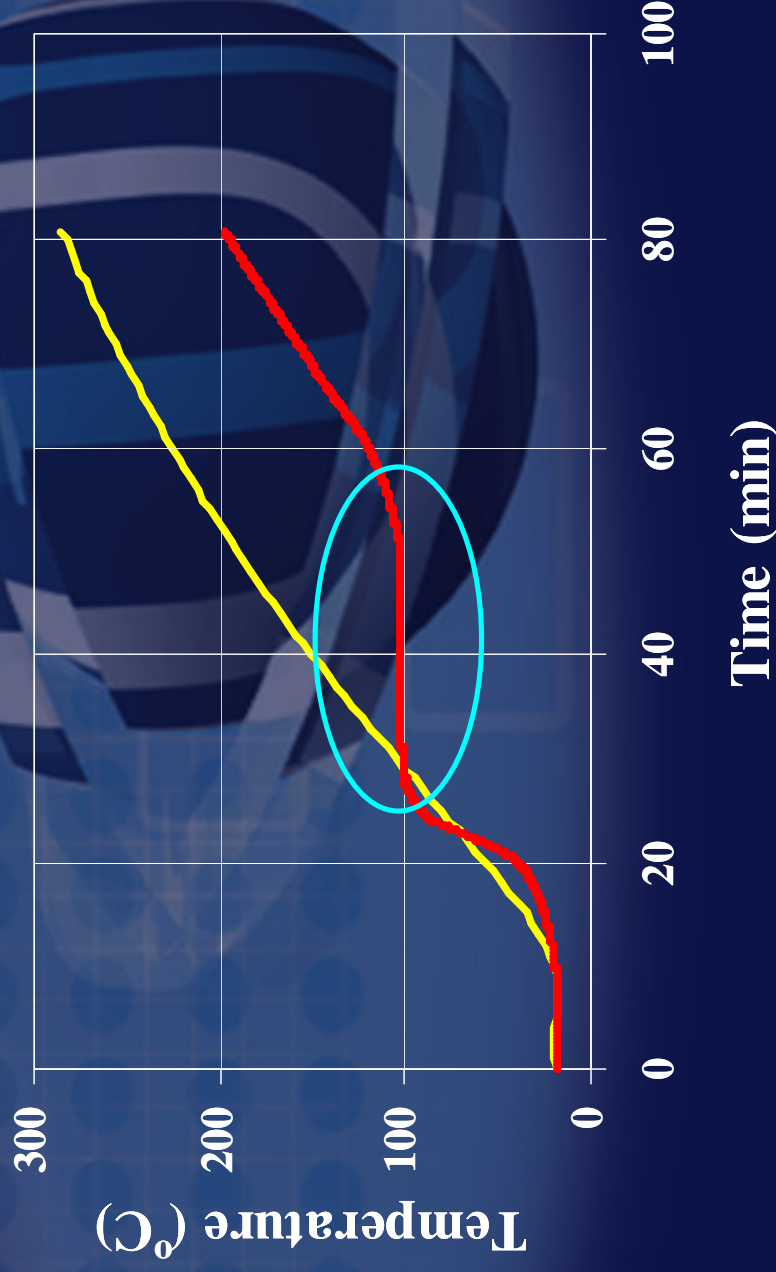


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DISCUSSION ON ANALYTICAL RESULTS

- ❖ Temperature progression at TC6

— Experimental — Theoretical



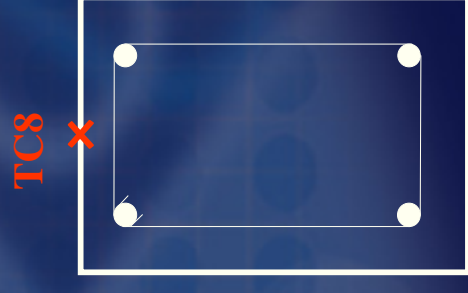
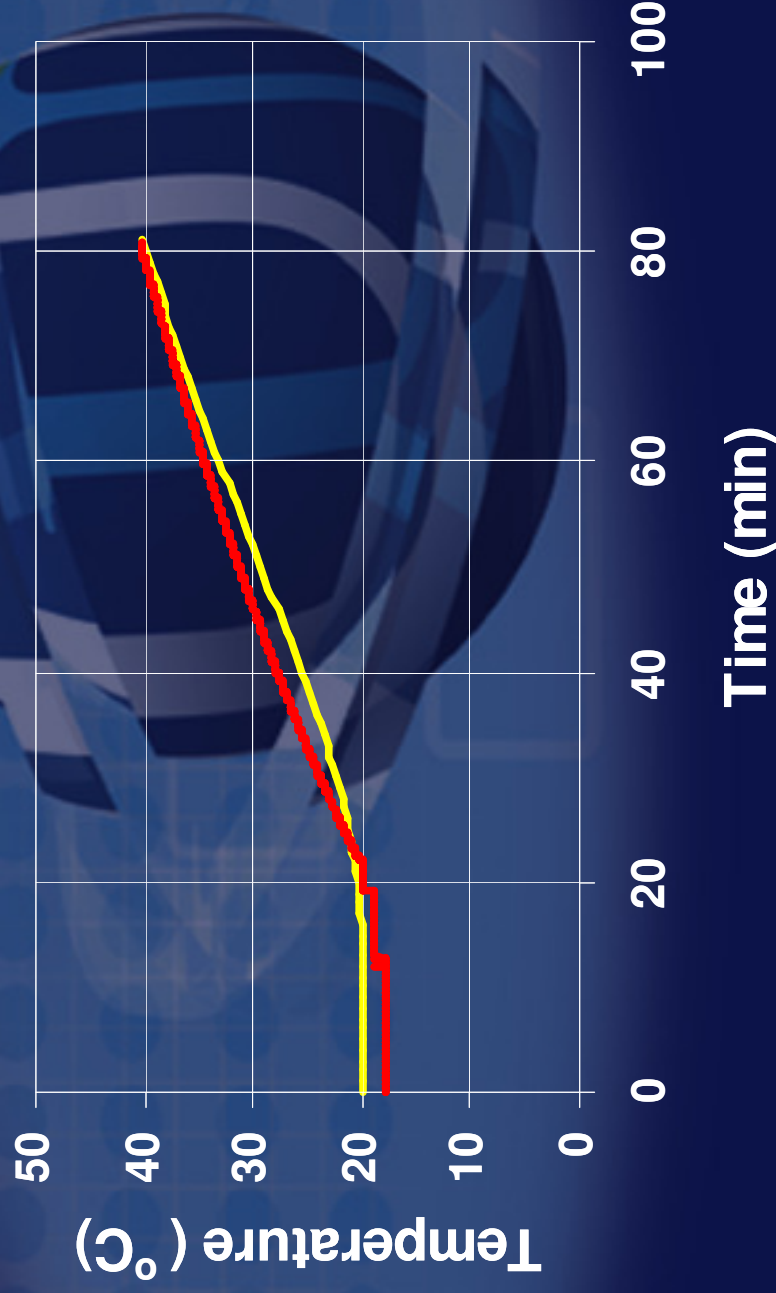
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DISCUSSION ON ANALYTICAL RESULTS

❖ Temperature progression at TC8

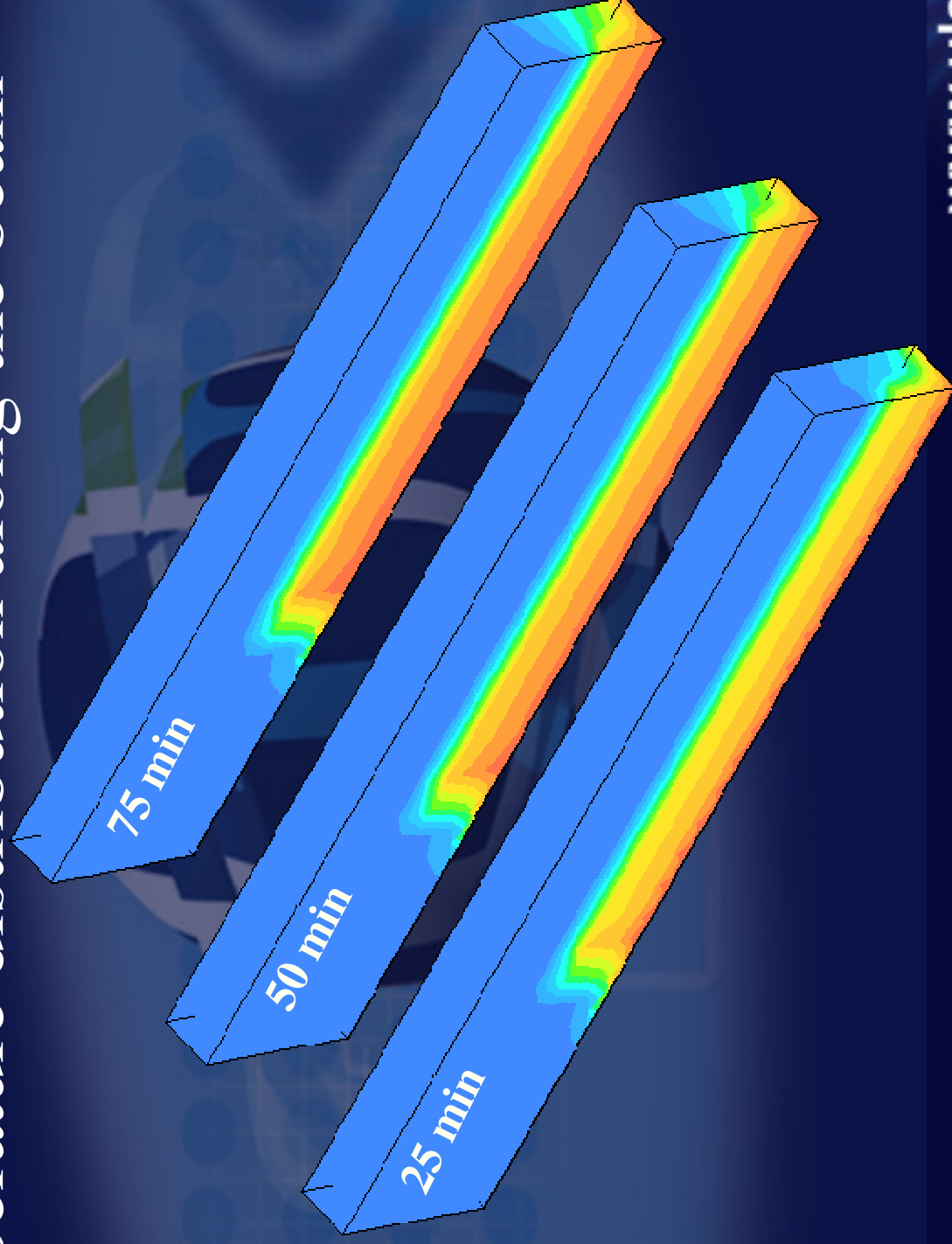
— Experimental — Theoretical



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DISCUSSION ON ANALYTICAL RESULTS

- ❖ Temperature distribution along the beam

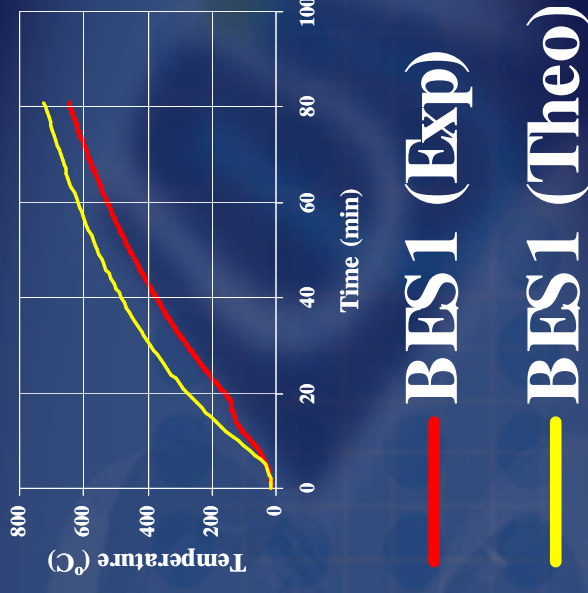
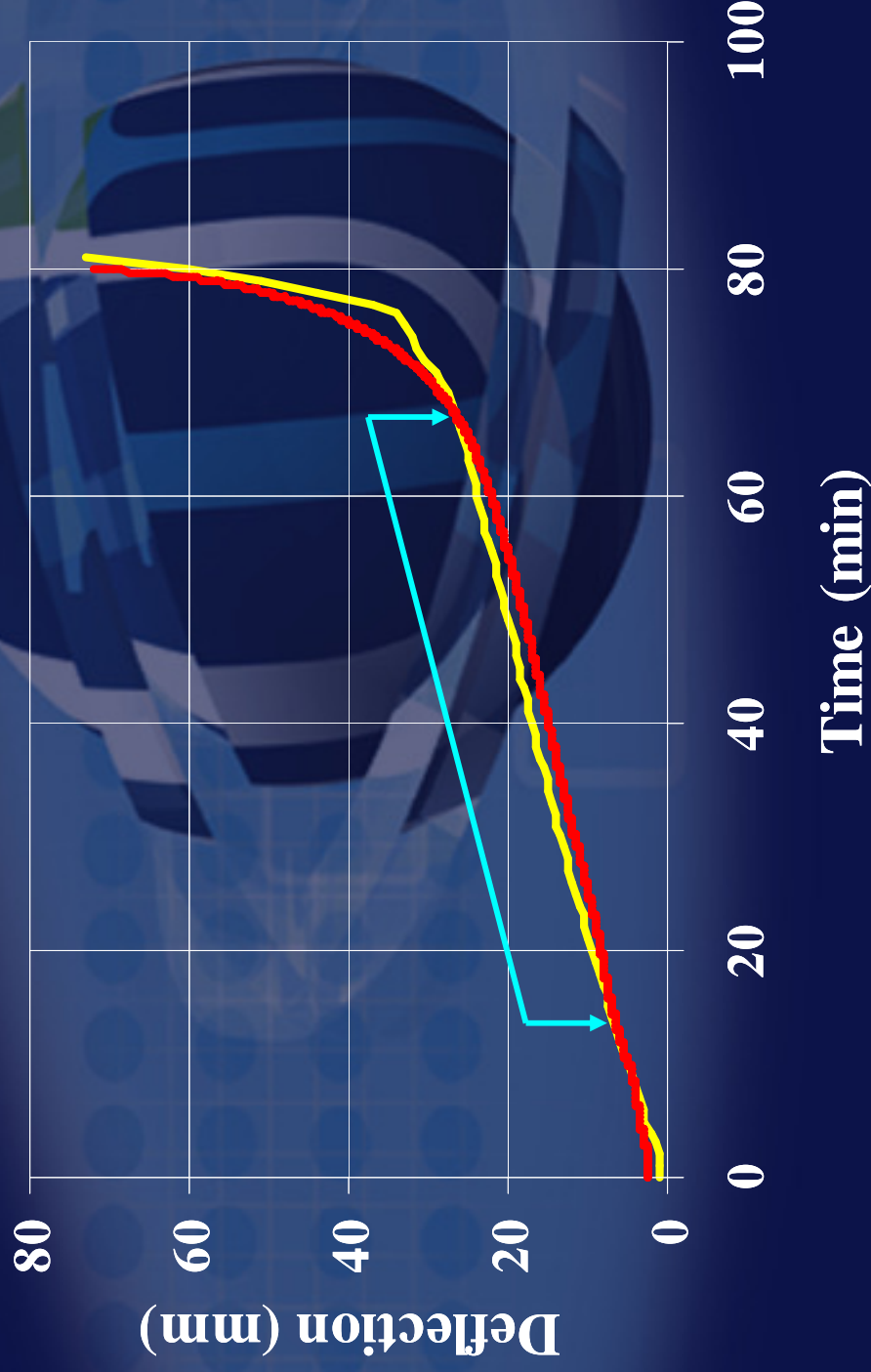


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DISCUSSION ON ANALYTICAL RESULTS

- ❖ Comparison of beam deflection

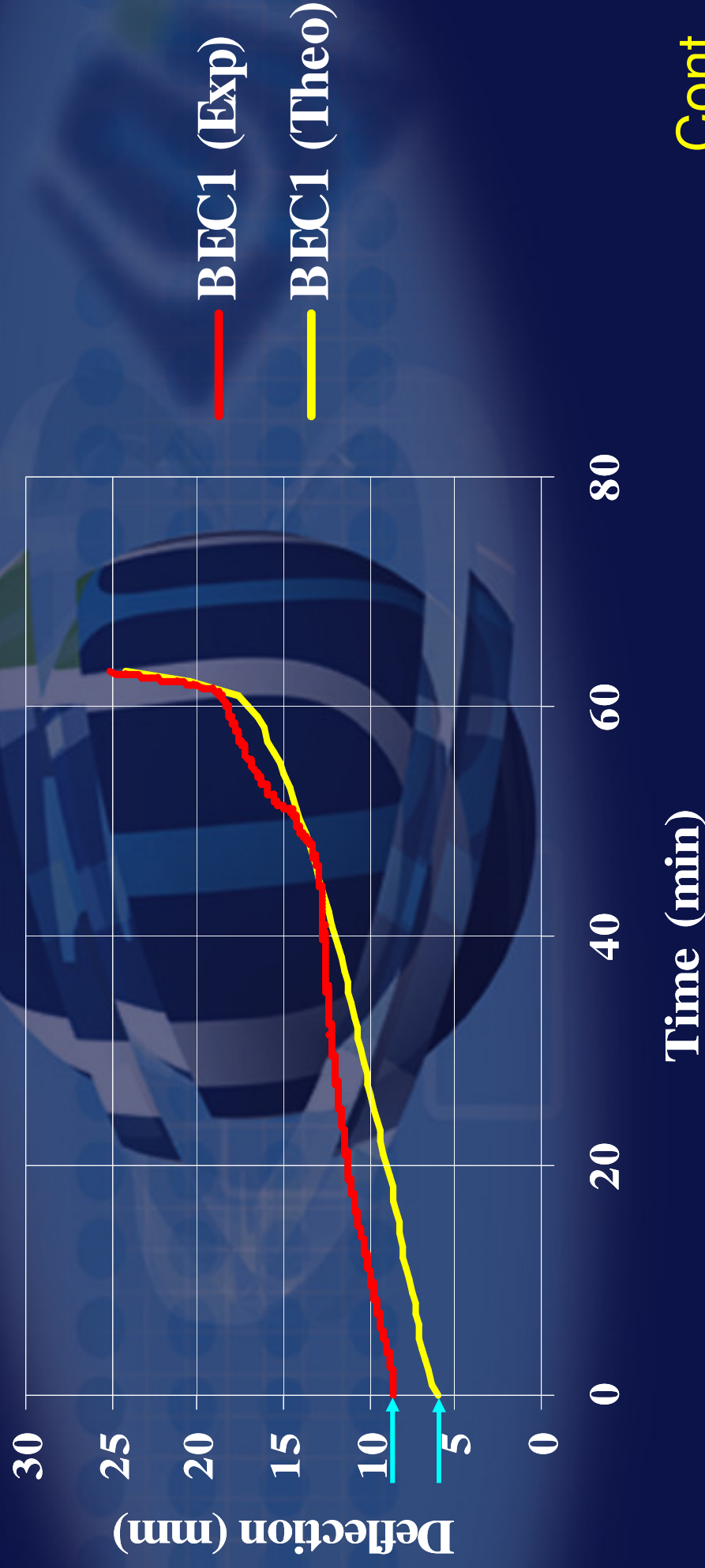


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DISCUSSION ON ANALYTICAL RESULTS

❖ Comparison of beam deflection

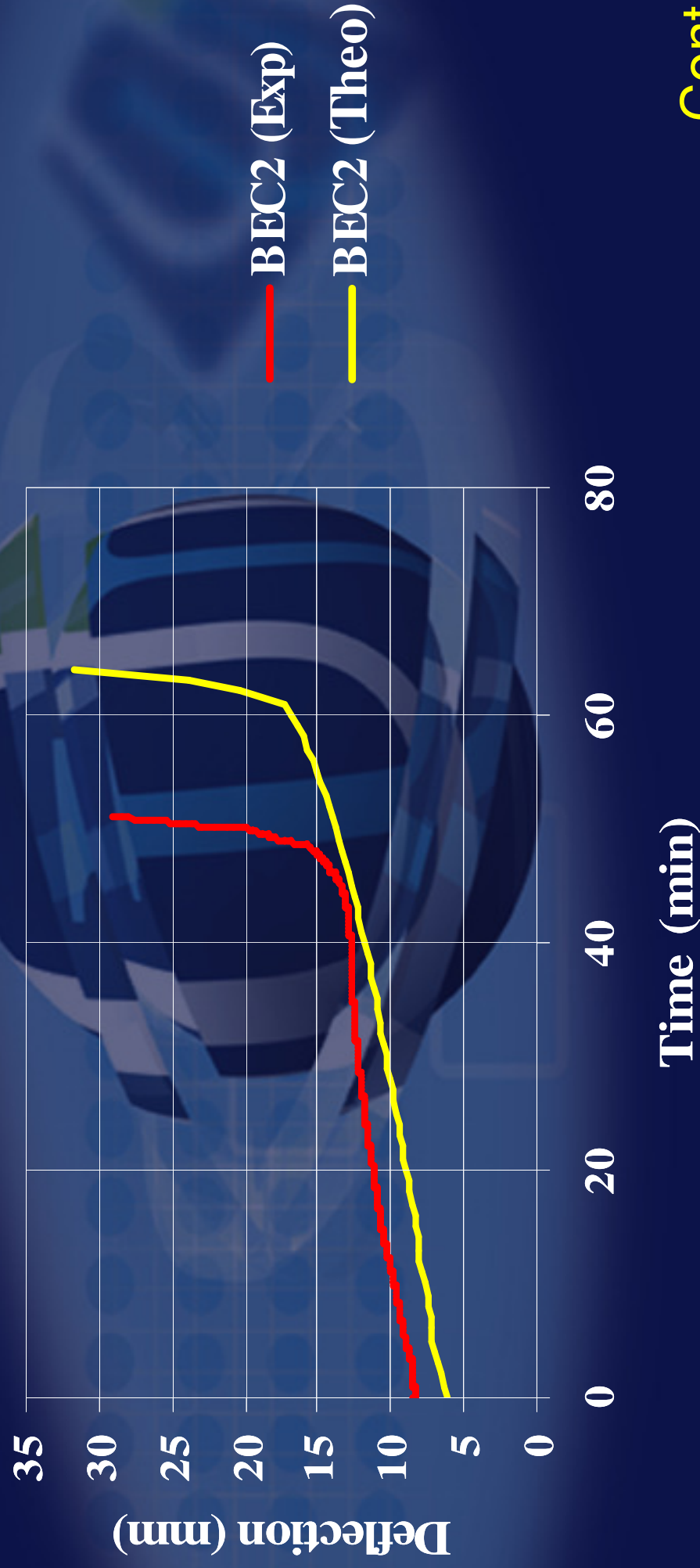


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DISCUSSION ON ANALYTICAL RESULTS

❖ Comparison of beam deflection

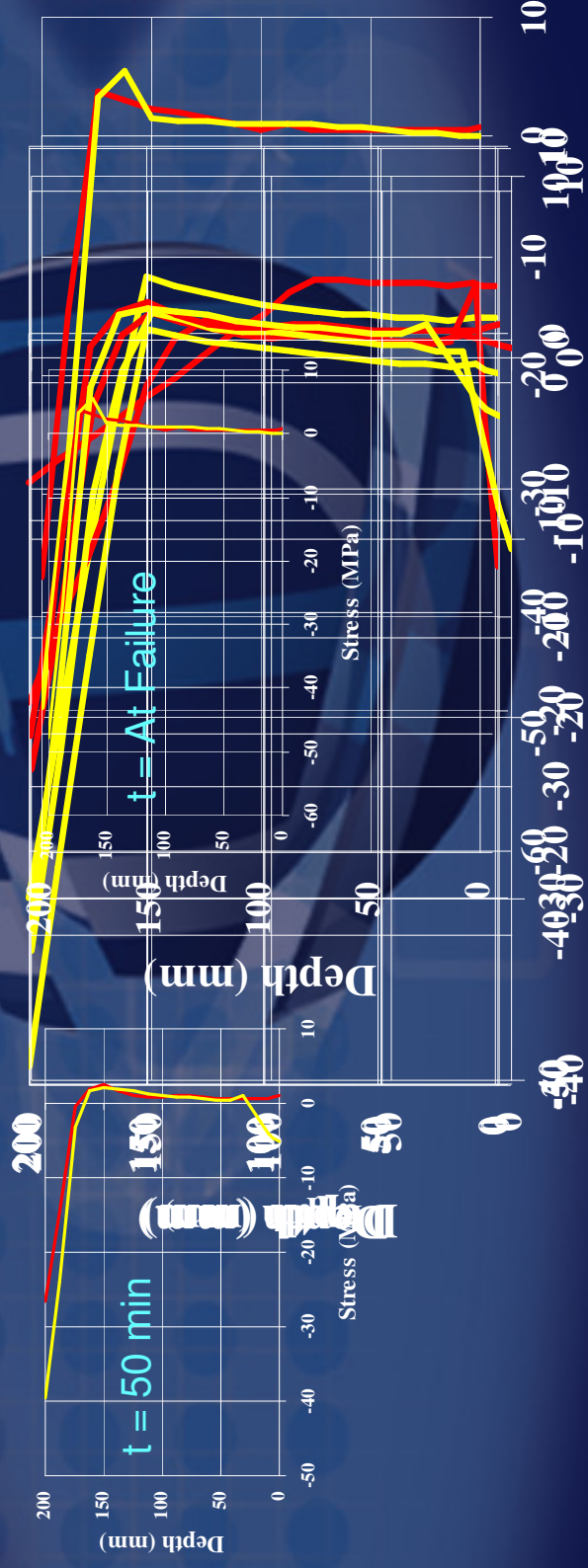
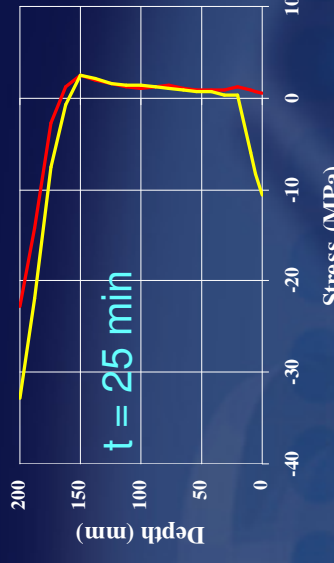
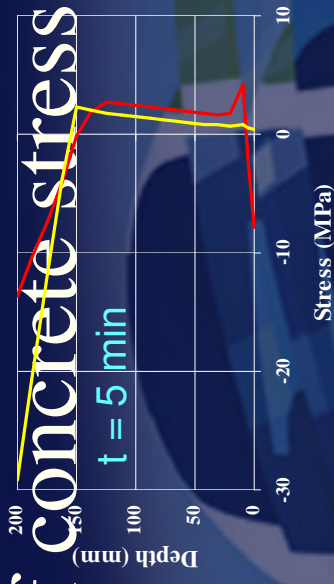


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DISCUSSION ON ANALYTICAL RESULTS

Comparison of concrete stress



BES1

BEC1

t = At Failure

Stress (MPa)



CONCLUSIONS

- ❖ Comparable temperature predictions with the recorded data
- ❖ Satisfactory simulation of behaviour
- ❖ Good predictions of non-linear deflection
- ❖ Close agreement for CFRP RC beams with the proposed constitutive model



**THANK YOU FOR YOUR
ATTENTION !**