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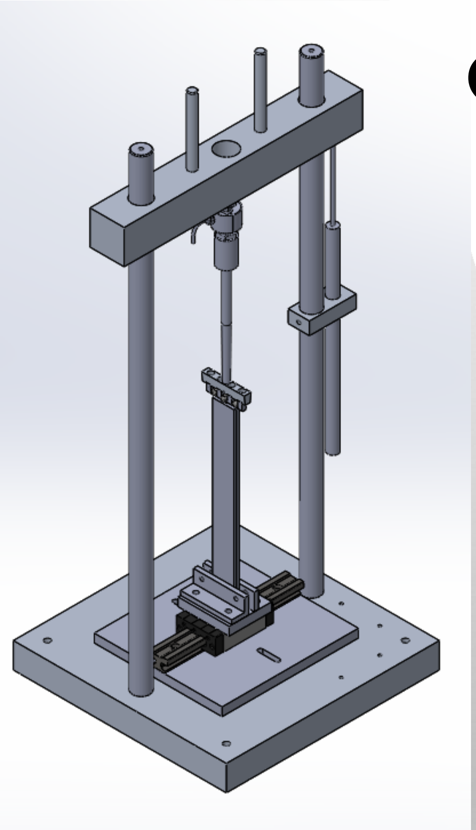
ANALYSIS AND ADVANCED MATERIALS FOR STRUCTURAL DESIGN



A METHODOLOGY FOR THE EXPERIMENTAL CHARACTERIZATION OF ENERGY RELEASE RATE-CONTROLLED CREEP CRACK GROWTH UNDER MODE I LOADING

Edwin Meulman

Advisors:
Dr. Jordi Renart Canalias **Dr. Laura Carreras Blasco**
Dr. Javier Zurbitu Gonzalez

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Girona – Spain

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I – Introduction

I – Adhesively Bonded Joints

Adhesively bonded joints

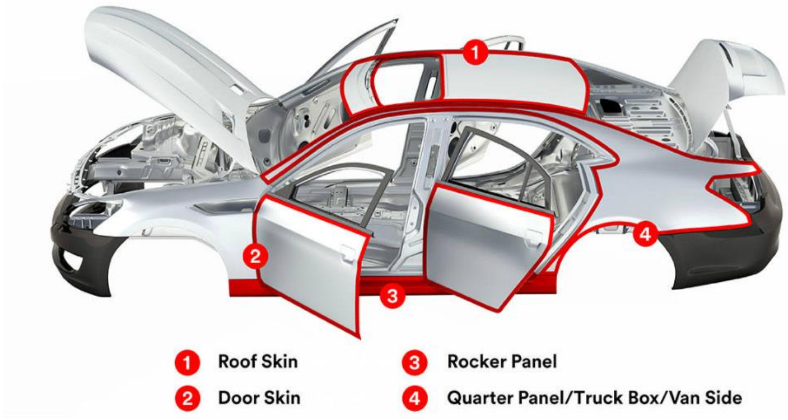
Advantages:

- Potential **lighter** structures
- Easier to bond **dissimilar** materials
- Less **stress concentrations**

Disadvantages:

- Adhesive **mechanical properties characterization**
- Long term adhesive properties **uncertainty**
- Lack of test methods for **durability testing** of adhesives

Use of bonded joints in aeronautic and automotive industries



Sources: 10.13140/RG.2.2.20580.83848, 3M

I - Bonded Joints Durability

Durability testing of bonded joints

Why:

Temperature, humidity and **time** affect the mechanical properties of an adhesively bonded joint

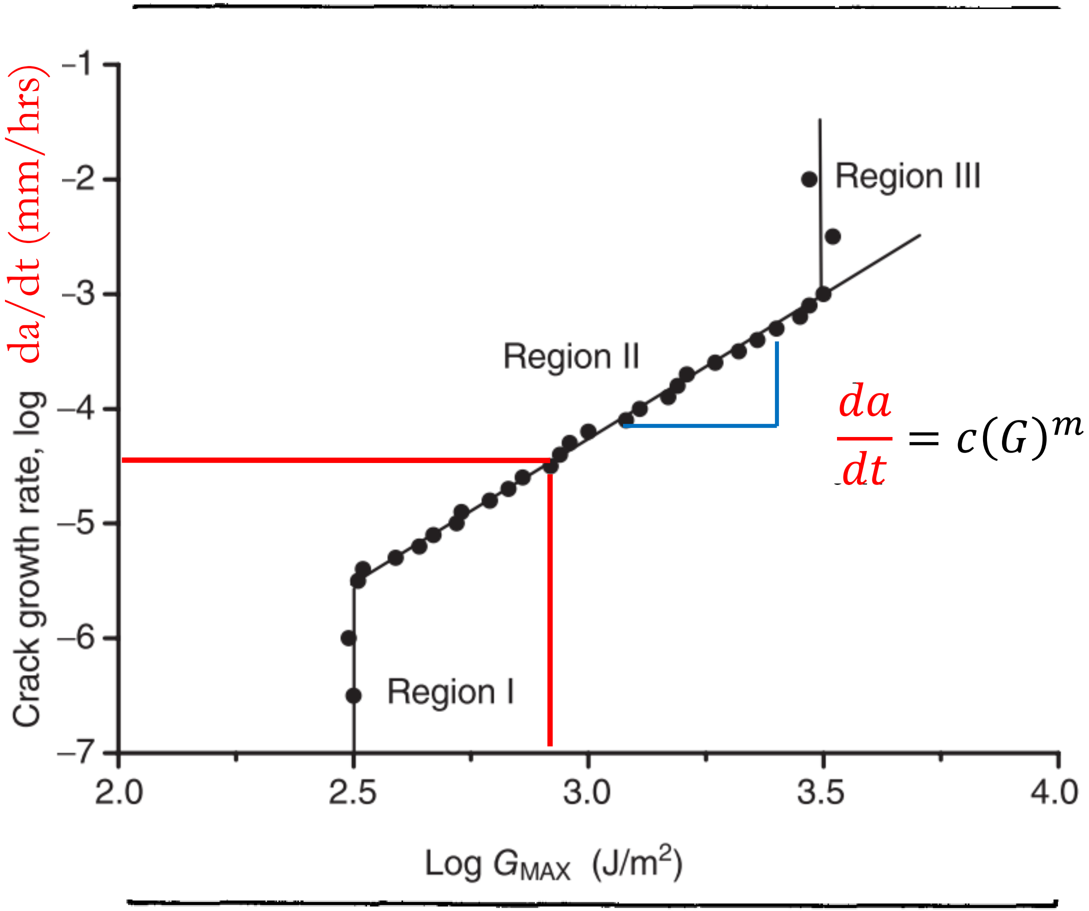
What:

Be able to **predict crack growth rates** in an adhesively bonded joint at **subcritical loads**

How:

Applying a constant subcritical load that provides a **constant energy release rate (*G*)** at the crack tip and measure the **crack growth over time**

Fatigue testing - Paris law



$$\frac{da}{dt} = c(G)^m$$

Sources: Cognard et. al., Use of the wedge test to estimate the lifetime of an adhesive joint in an aggressive environment (1986), Broughton et. al., Adhesives in Marine Engineering (2012)

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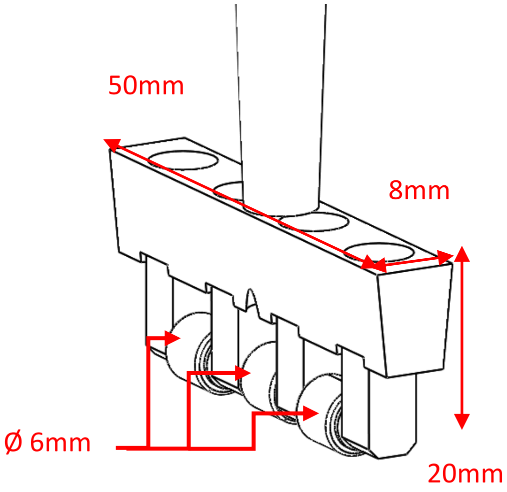
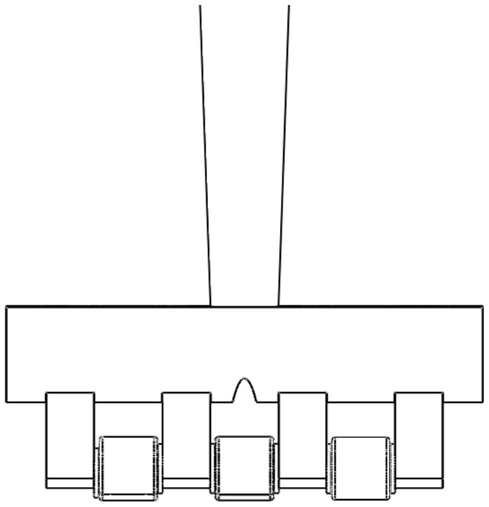
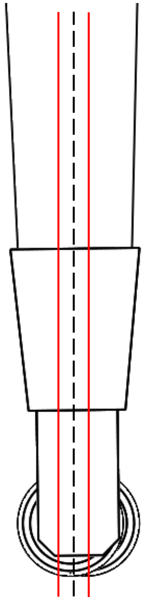
II – Energy release rate-controlled creep crack growth test

II - Design of a roller wedge

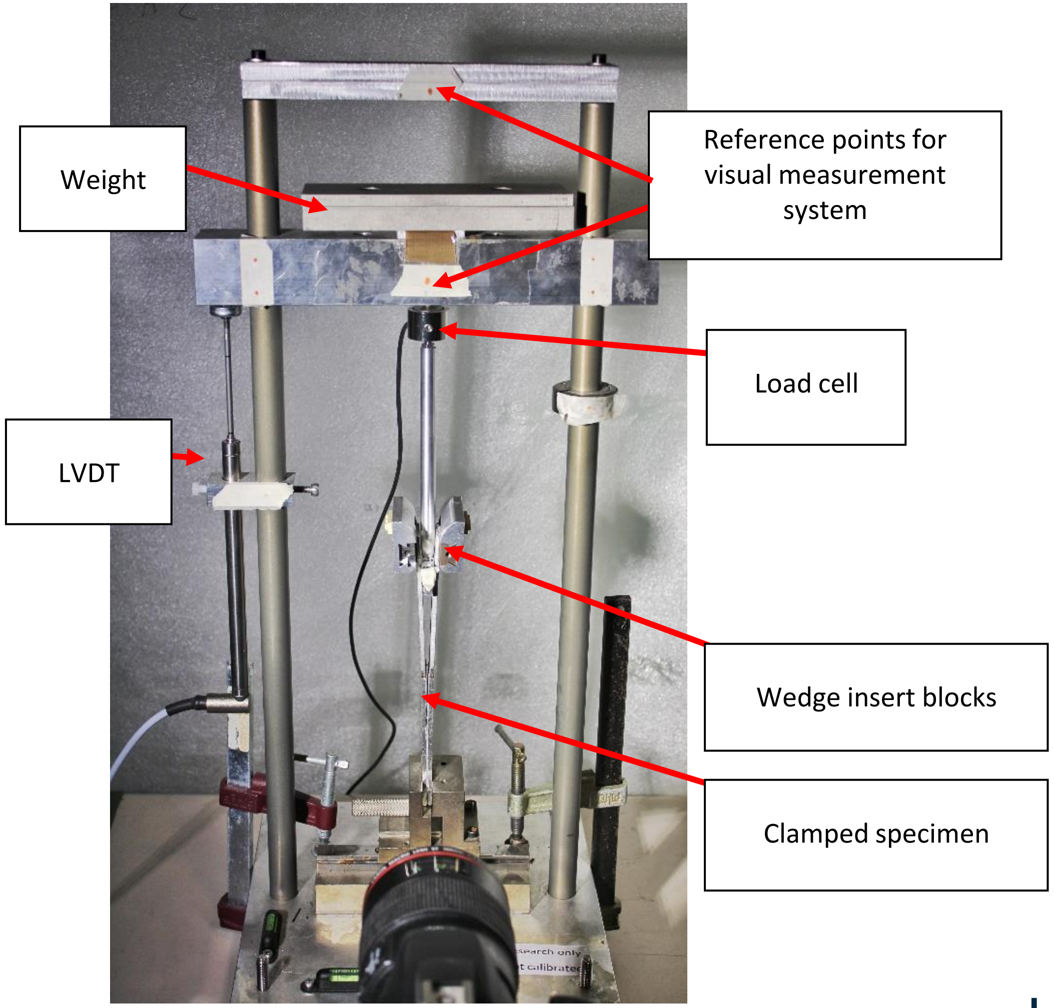






Offset from center line = 0.5mm

Roller Wedge Driven test (RWD)

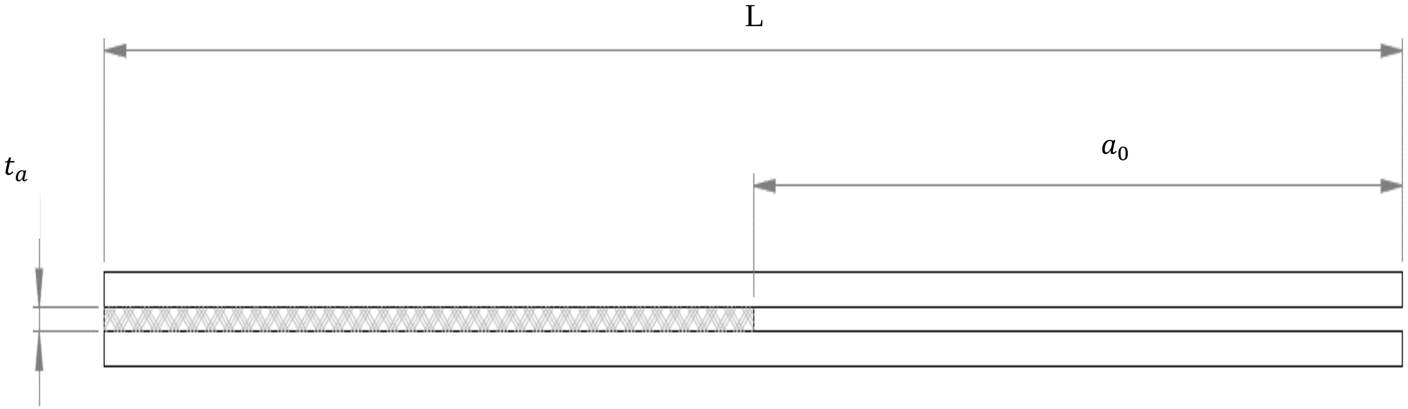


II - Methodology

DCB-like specimens

Adherends: Alu 7075-T6

Adhesive: Araldite 2021-1 (methacrylate-based, rigid)



L x W x H = 200 x 25 x 3 mm

t_a = 0.4 – 0.7 mm

a_0 = 100 mm

Pre-crack = 10-15 mm

Tested specimens

Specimen	Weight applied (N)	Measurement method
RWD-C_01	31	Visual+LVDT
RWD-C_02	48	Visual+LVDT
RWD-C_03	57	Visual
RWD-C_04	70	Visual+LVDT
RWD-C_05	80	Visual

Specimens 3 and 5 chronologically tested first, at that time no proper LVDT available

II - Results

Work in progress of publication but not published yet at moment of presenting

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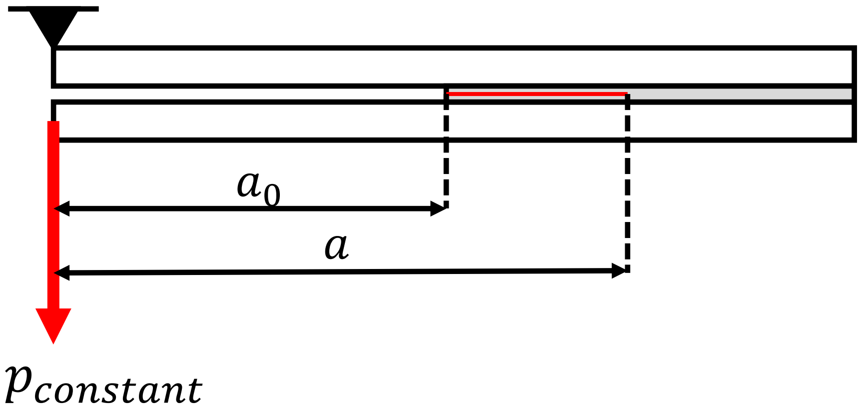
III – Tapered-DCD constant load test

III - Methodology

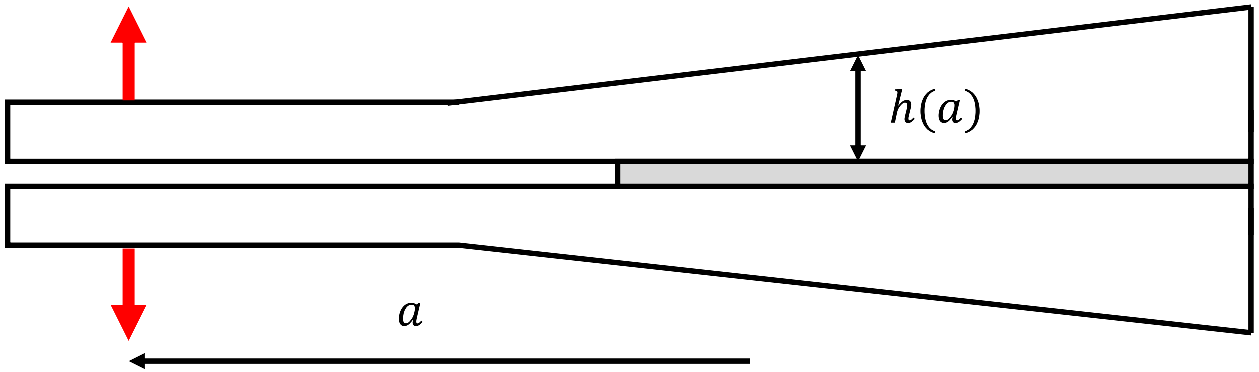
Why a Tapered-DCB and not a DCB?

- To have a **demonstrator** to check if the **energy release rate (G)** is the controlling parameter
- To obtain a **constant crack growth rate** by applying a **constant load**
- Appling a **constant load** to a DCB specimen will result in an **increasing energy release rate** at the crack tip when the crack length is increasing during the test
- Therefore, the **crack growth rate increases** during the test until G_{Ic} is reached, followed by failure of the specimen



III - Methodology

Defining the geometry of the TDCB specimen



$$Compliance:\ C = \frac{\delta}{P}$$

$$ECM:\ G_{IC} = \frac{P^2}{2B} \cdot \frac{dC}{da}$$

$$\frac{dC}{da} = \frac{8}{E_s B}\left(\frac{3a^2}{h^3} + \frac{1}{h}\right)$$

$$\frac{3a^2}{h^3} + \frac{1}{h} = constant$$

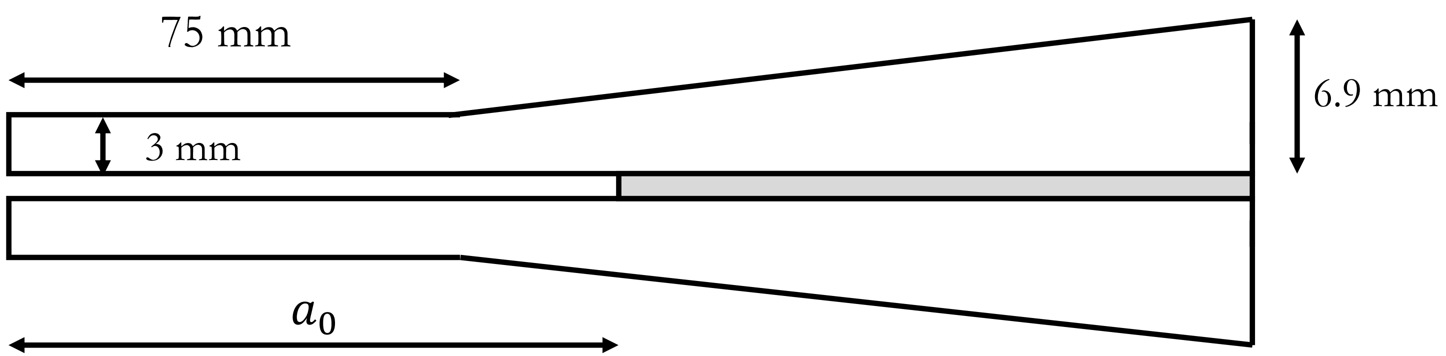
Sources: ISO 25217 Adhesives – determination of the mode 1 adhesive fracture energy of structural joints using double cantilever beam and tapered double cantilever beam specimens, B.R.K. Blackman et al. Engineering Fracture Mechanics 70 (2003) 233-248

III - Methodology

Tapered-DCB specimens

Adherends: Alu 7075-T6

Adhesive: Araldite 2021-1 (methacrylate-based, rigid)



L x W = 200 x 25 mm

t_a= 0.6 – 0.9 mm

a_0= 100 mm

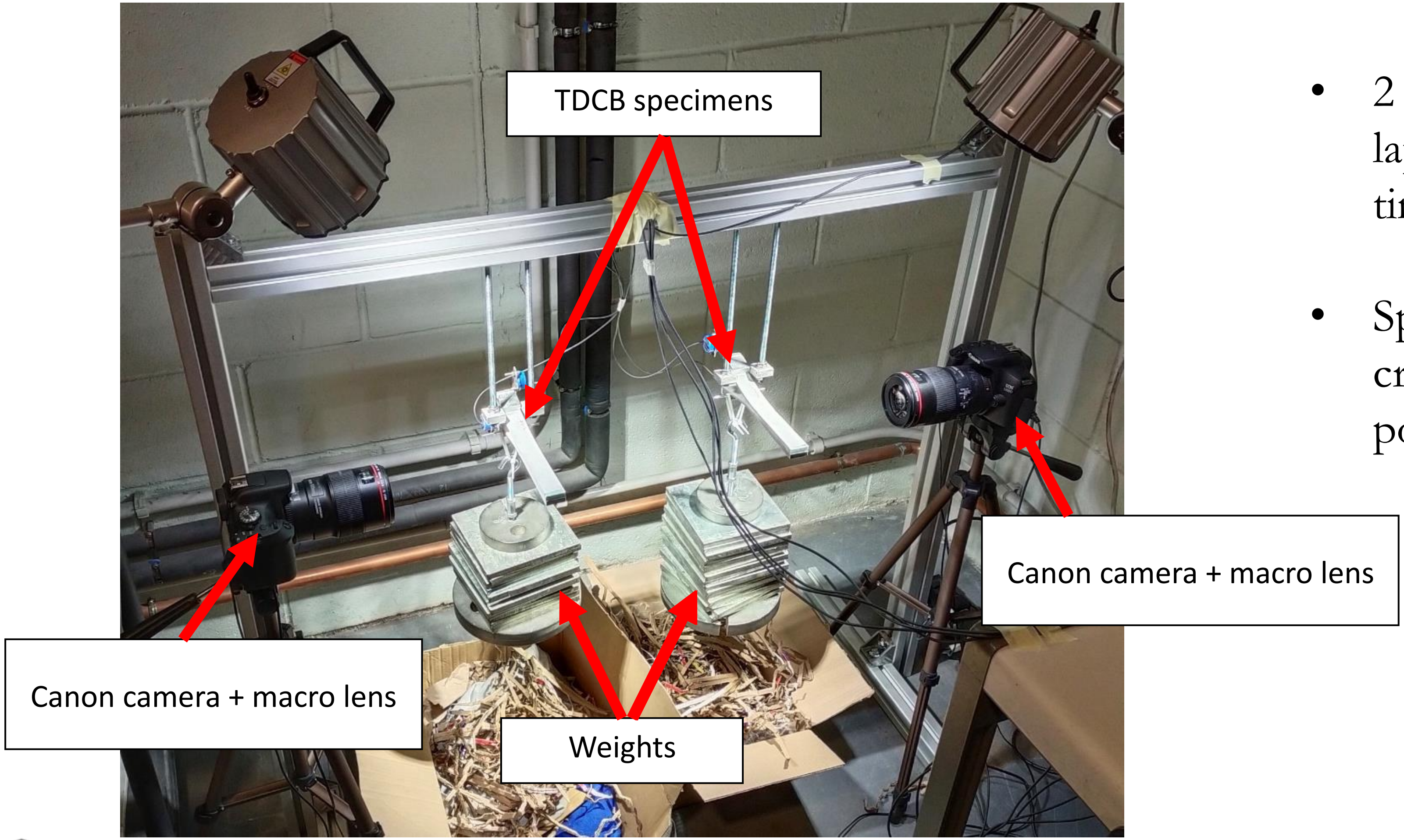
Pre-crack = 10-15 mm

Tested specimens

Specimen	Weight applied (N)	Test method
TDCB_01	-	Quasi-Static
TDCB_02	-	Quasi-Static
TDCB_03	-	Quasi-Static
TDCB_04	203	Constant load
TDCB_05	222	Constant load
TDCB_06	242	Constant load
TDCB_07	274	Constant load

III - Methodology

Constant load TDCB test setup



- 2 Canon cameras are connected to a laptop to take automatic photos with time intervals
- Specimens are marked on the side so crack length can be measured during post-processing of the photos

III - Results

Work in progress of publication but not published yet at moment of presenting

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IV – Conclusions

IV - Conclusions

- The RWD test method can apply a constant energy release rate to the crack tip of a DCB-like specimen.
- With the RWD test method it is possible to obtain creep crack growth rate curves.
- The TDCB constant load test has produced similar results as the RWD test method, for these two specific types of specimens the energy release rate, G, seems to be the controlling parameter for creep crack growth.

Thank you for your attention!

http://amade.udg.edu – testlab.amade@udg.edu
edwin.meulman@udg.edu

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