







# GEOPOLYMER BASED BRAKE PADS

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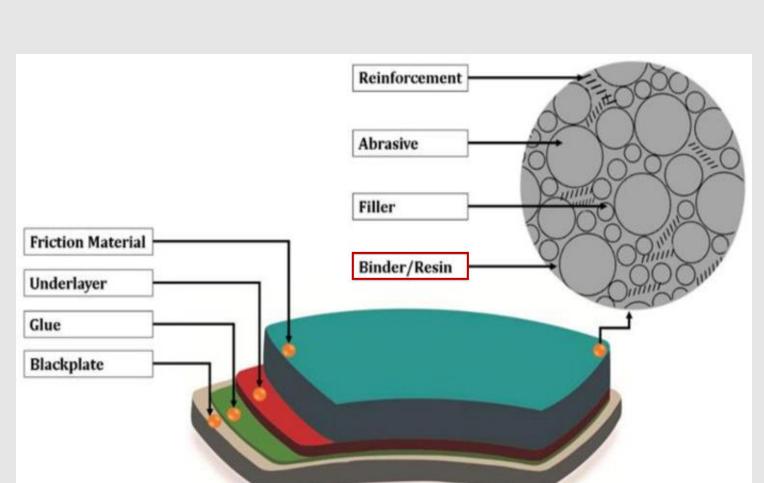
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#### INTRODUCTION

## Brake pads and binder's carbon footprint

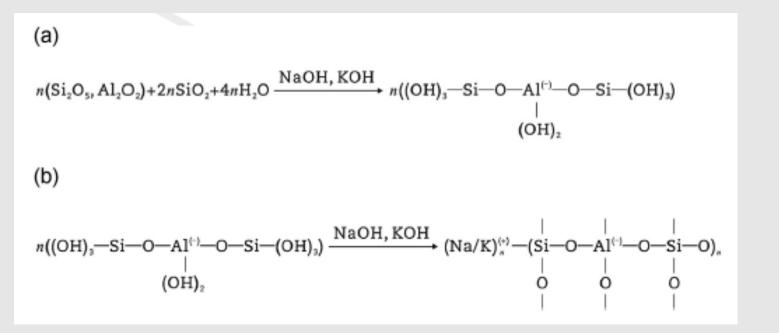


The development of products with reduced carbon footprint is of major interest in the automotive industry, especially for brake pads. They are composed by a complex mixture of materials that can be grouped into four categories: reinforcing fibres, binders, fillers, and friction additives.

The most common binder is the phenolic resin (PR), a polymer formed by a condensation reaction between phenol and formaldehyde. Challenges related to the environmental impact of petroleum-based resources have led to a growing interest in the development of new inorganic binders, whose production involves a smaller carbon footprint.

Geopolymers (GPs) are eco-friendly materials and RAICAM is studying the replacement of phenolic resin (PR) with GPs as a binder in brake pads.

The selected geopolymer was obtained in laboratory through the reaction of metakaolin with an alkaline silicate solution

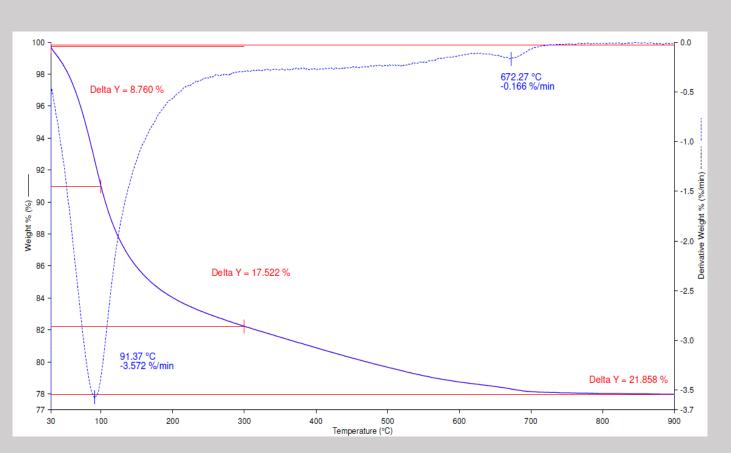


# METHODS AND **CHARACTERISATION**

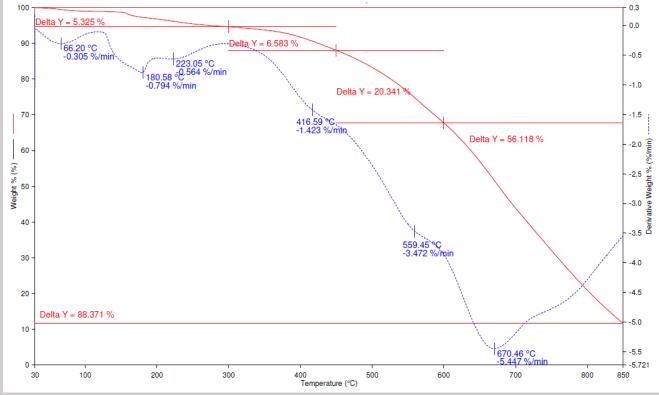
### Comparison PR vs GP: thermal resistance and performance in Brake Pads

The selected geopolymer was fully characterised (i.e. by SEM-EDS, DSC, TGA) and then compared to the behaviour of PR

TGA on GP shows a total weight loss of 22%, probably ascribed to water loss (free and structural).



TGA on PR shows a degradation start around 300°C and leads to a significant total weight loss (i.e. 88%).



To verify the applicability of GP as a binder, P1 and P2 prototypes were prepared with the same formulation, but adding GP to the first prototype and PR to the second one. P1 appears weaker in terms of hardness and shear strength, but TG analysis shows a major degradation till 600°C for P2 due to the binder thermal instability.

600°C→ %

Prototype 1	GP	PAD	600°C-	<b>→</b> %	Hardness (HRS): 60/100
Weight loss%	21.85	13.29	3.52	26.50	Shear: 50.09 Kg/cm <sup>2</sup>
Prototype 2	PR	PAD	600°C-	<b>→</b> %	Hardness (HRS): 83/100
Weight loss%	88.37	10.8	5.05	46.80	Shear: 73.57 Kg/cm <sup>2</sup>

PAD

#### **DYNO TEST**

## AK Master and Krauss dyno-tests and the possible application of GP in Brake Pads industry

Prototype 1

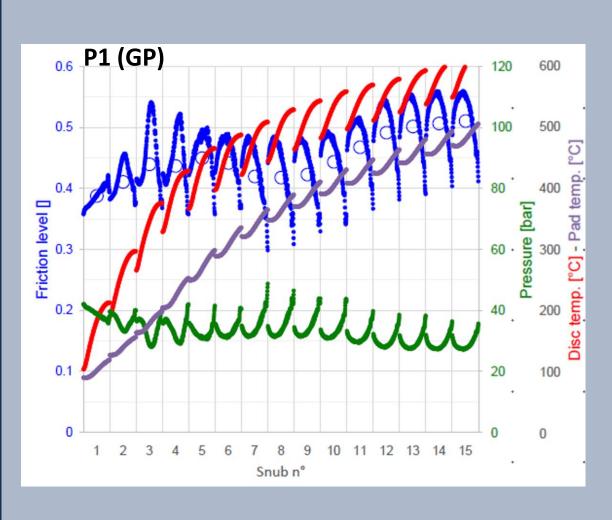
GP

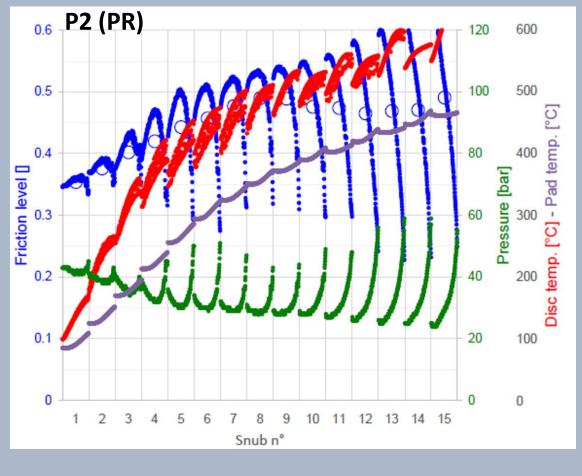
Performance was evaluated on a bench dynamometer by AK Master test (involving brakes at different pressures, speeds and temperatures) and by a Block Wear test (temperature steps at 100, 300 and 500°C).

#### **AK Master**

The standard AKM test involves a section named «Fade» in which the interface between BPs and rotor reaches a temperature above 500°C.

P1 shows a more stable friction level than P2 with respect to the temperature increase. The friction variation during a single brake (i.e. in-stop variation) is significantly larger for P2 than P1, because of the thermal instability of PR.

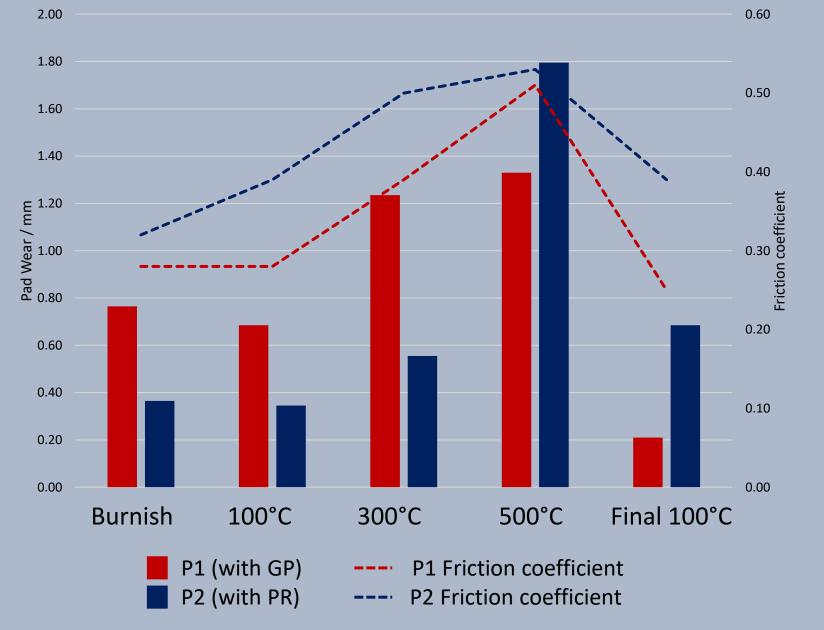




## **Block Wear Test**

The Block Wear Test is applied to investigate the friction and wear behaviour of brake pads at different levels of temperature. After 100 brakes as assessment (i.e. burnish), 200 brakes were carried out at each step (i.e. 100°C, 300°C, 500°C and again 100°C).

P1 shows in general a higher pad wear till 300°C, due to the binder weaker structure. Instead, the pad wear does not change at 500°C thanks to the thermal stability of GP.



Due to the thermal degradation of PR above 300°C, the wear significantly increases for P2 at 500°C. Furthermore, P2 results weaker after the section at 500°C, which is the reason for the higher wear in the final section.

P1 shows an opposite trend because, after the high T step, the structure seems stronger (i.e. lower pad wear).

#### TAKE HOME MESSAGES

The geopolymer based formulation shows a more stable friction level compared to the phenolic based one, especially at high temperature. This result derives from the better thermal stability of the GP, less sensitive to temperature, but GP has a weaker structure than the phenolic resin.

The present study highlights the potential use of GP as a binder in BPs; the replacement of phenolic resin with a geopolymer could lead to a significant reduction in terms of carbon footprint. Further studies are necessary to improve the structural stability of GP for a convenient application in brake pads fabrication.

