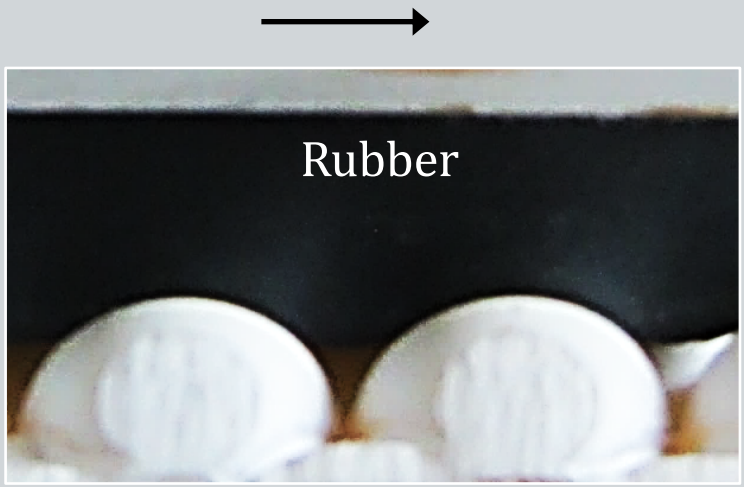
# Modélisation du frottement

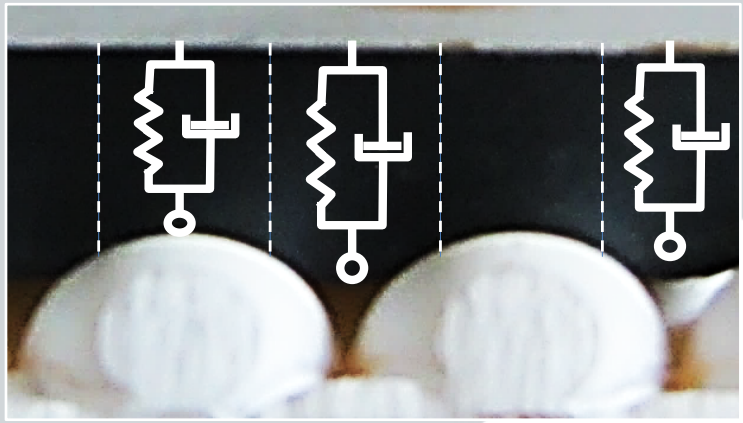
- **Approches possibles**





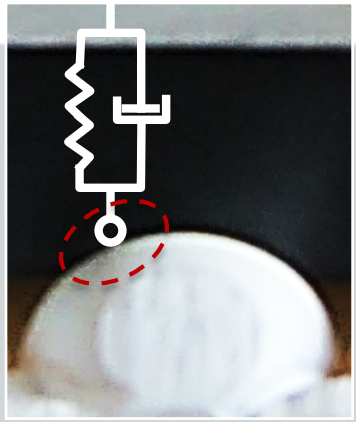
*Modèle mono-aspérité*

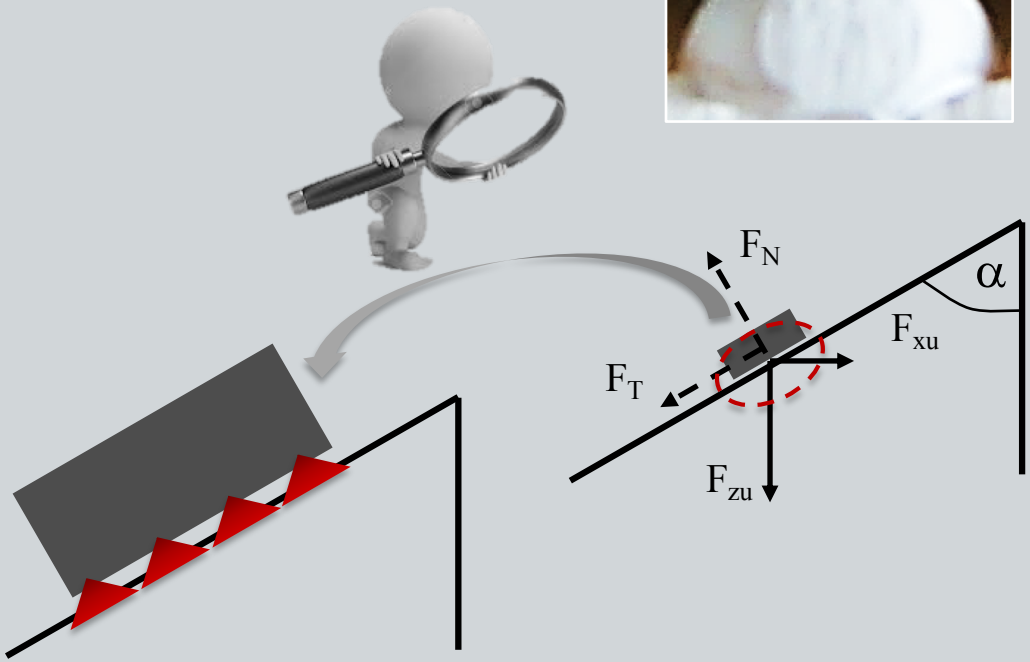
*Modèle multi-aspérités*



# Modélisation du frottement

- **Approche multi-échelles**



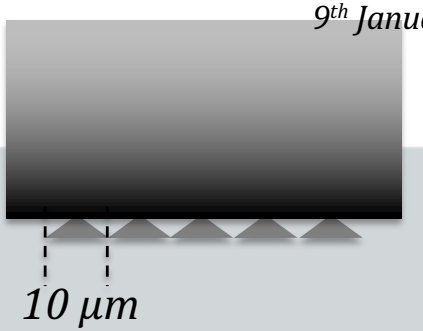



$$\mu_0 = \frac{F_T}{F_N}$$

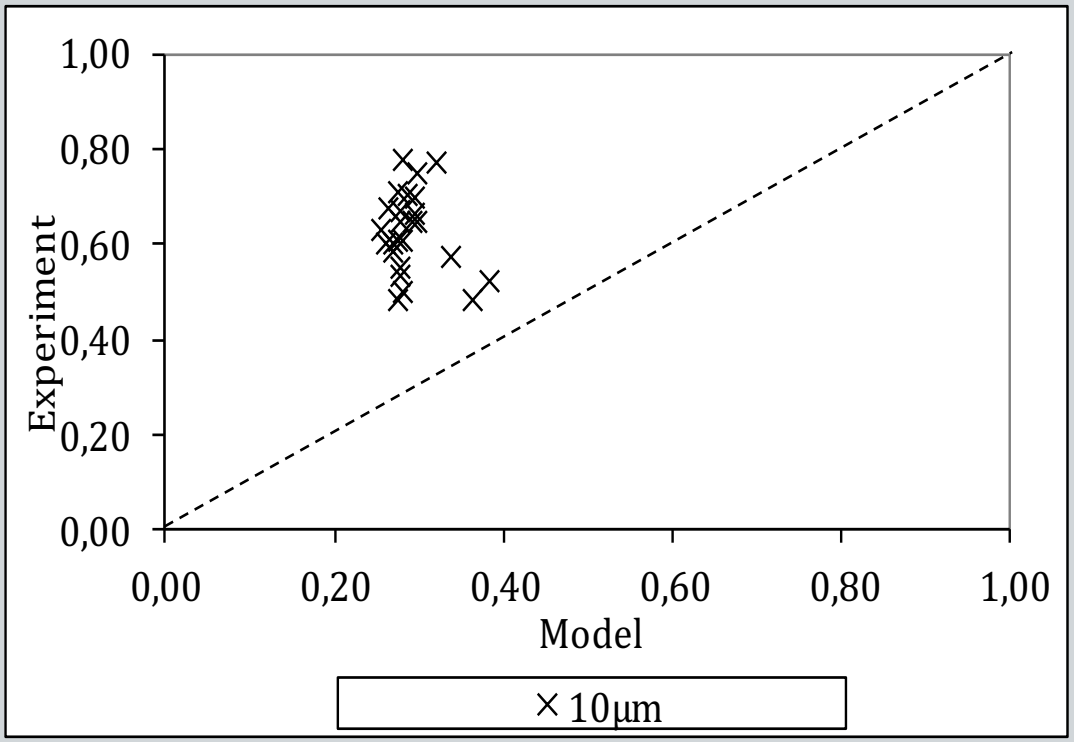
$$\frac{F_{xu}}{F_{zu}} = \frac{cos\alpha + \mu_0 sin\alpha}{sin\alpha - \mu_0 cos\alpha}$$

*$\mu_0$ est calculé en utilisant le modèle mono-aspérité à différentes échelles de texture*

# Modélisation du frottement



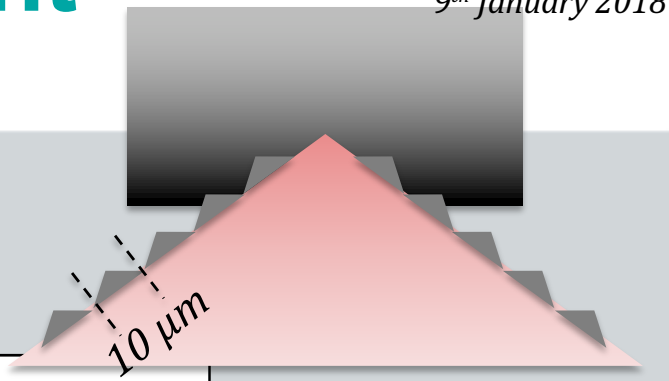

- **Approche multi-échelles**

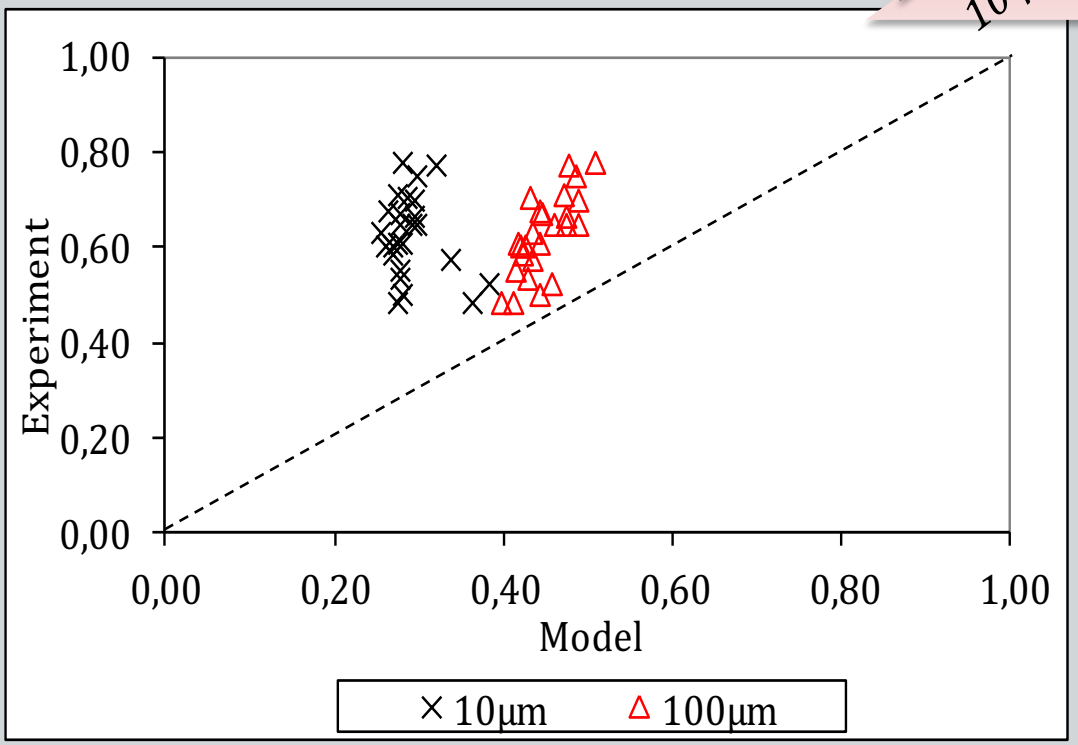



*(Do, ERLPC CR35, 2004)*

# Modélisation du frottement

- **Approche multi-échelles**

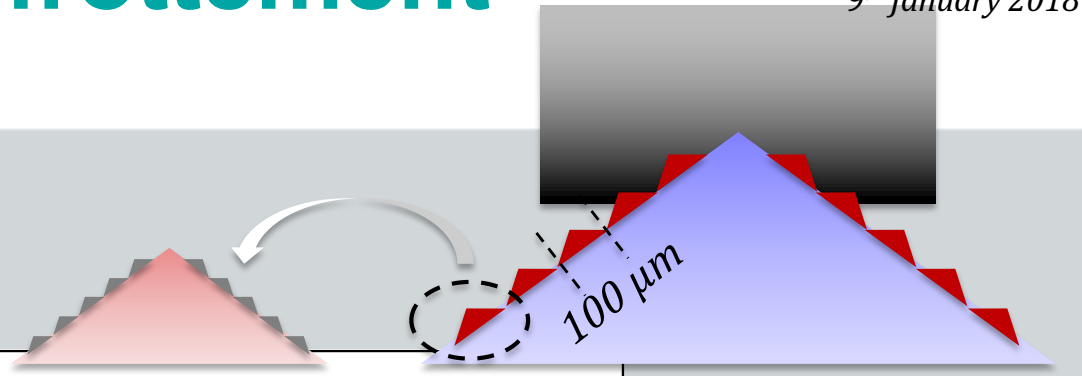


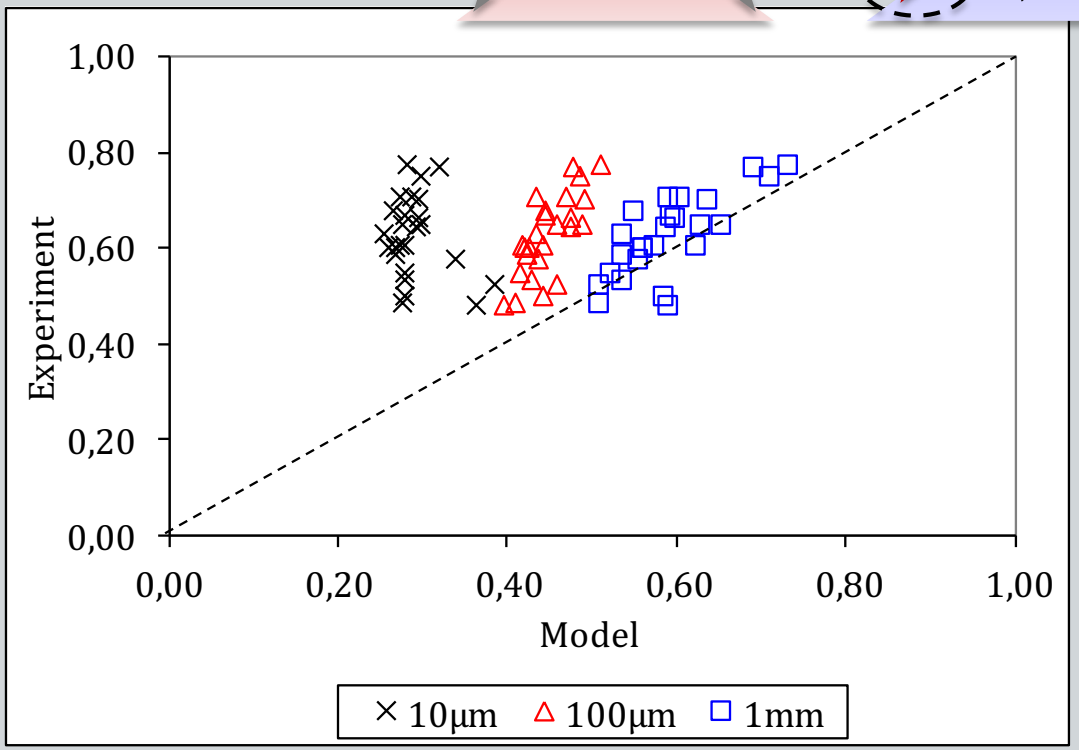




*(Do, ERLPC CR35, 2004)*

# Modélisation du frottement

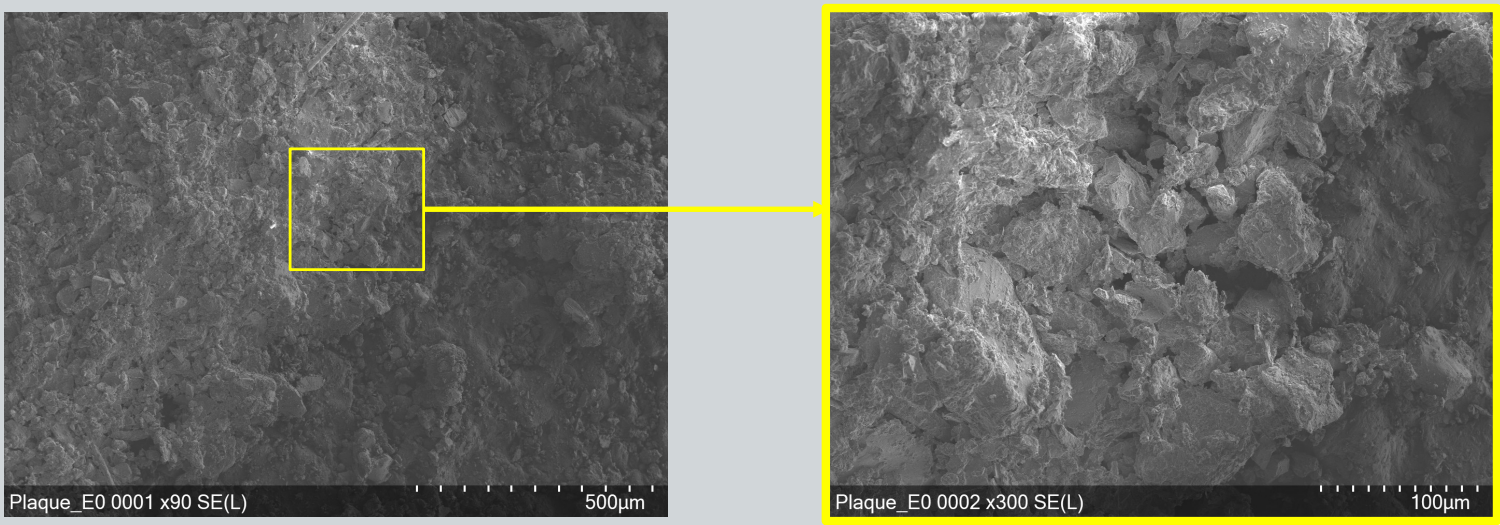
- **Approche multi-échelles**



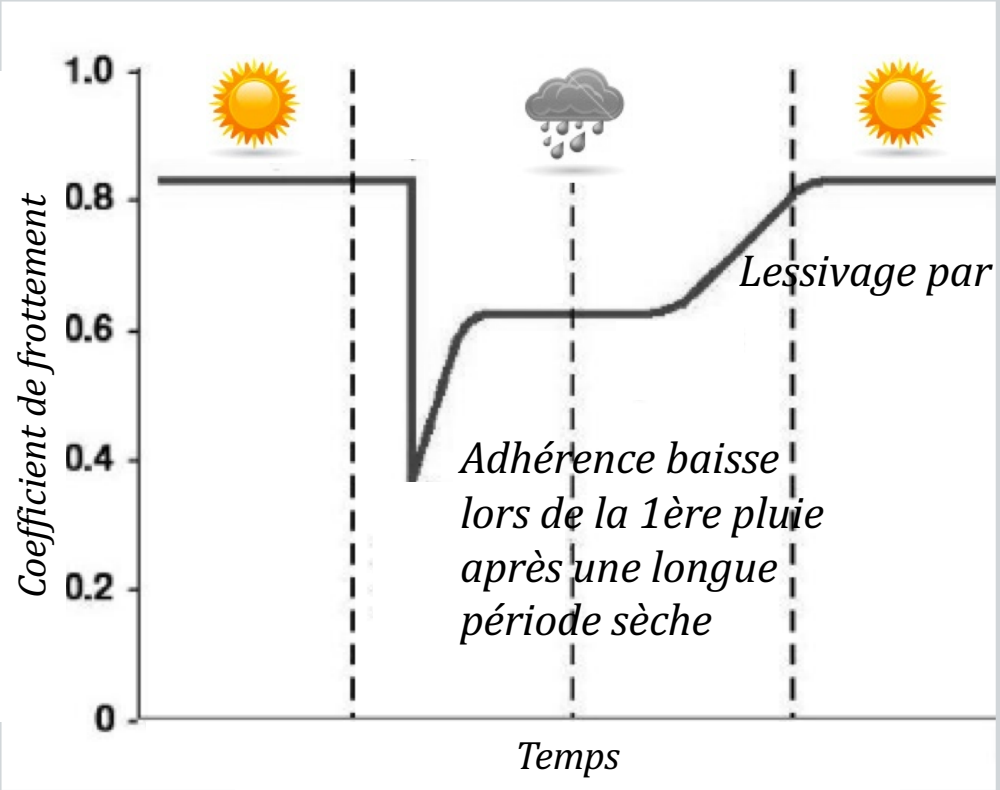

*(Do, ERLPC CR35, 2004)*

# La contamination par des particules



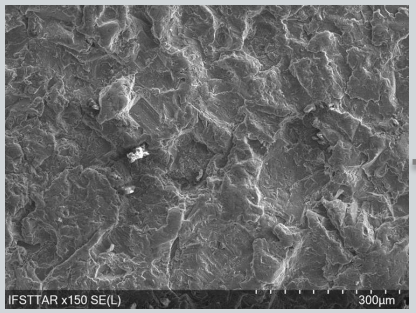
# Contamination particulaire

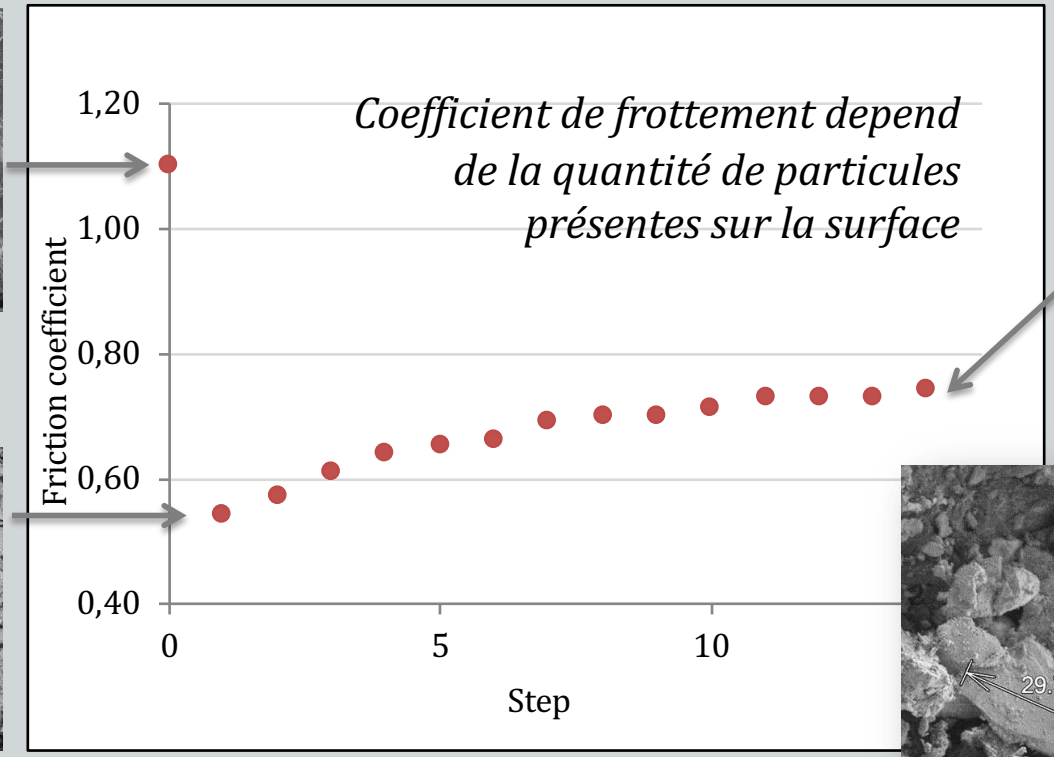
- **Evolution de l'adhérence**

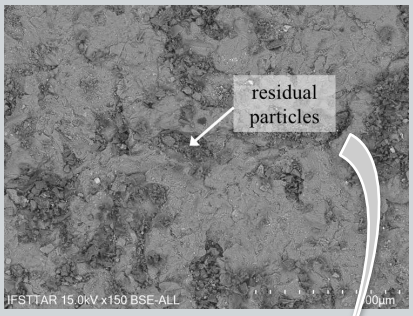


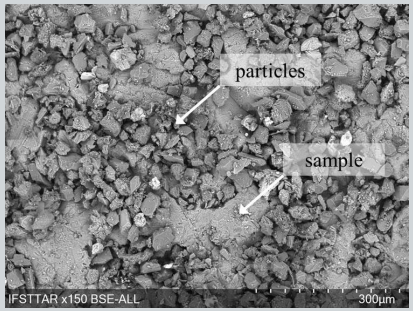
# Contamination particulaire

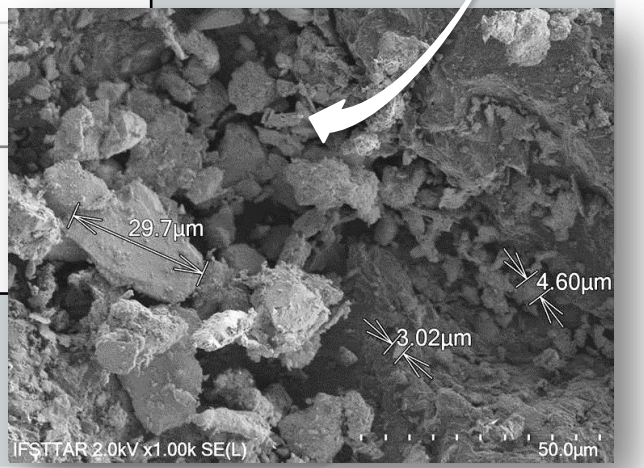
- **Effet des particules sèches**



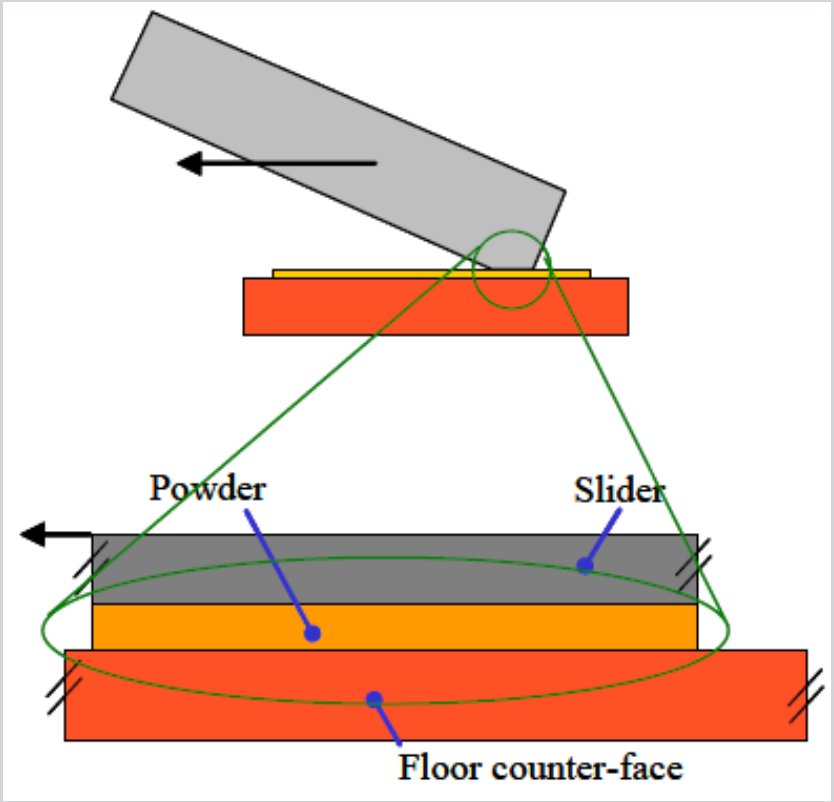



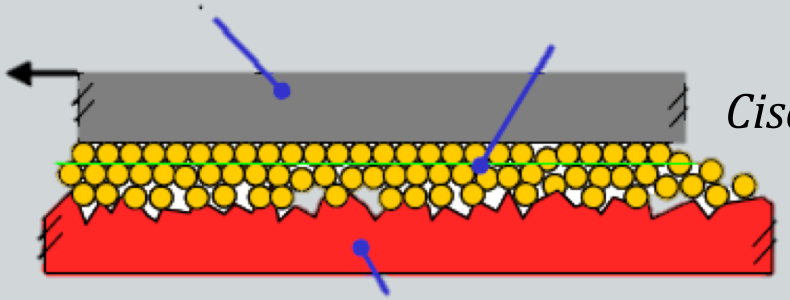




*(Hichri et al, J. Wear 376-377, 2017)*

# Quelques notions de base

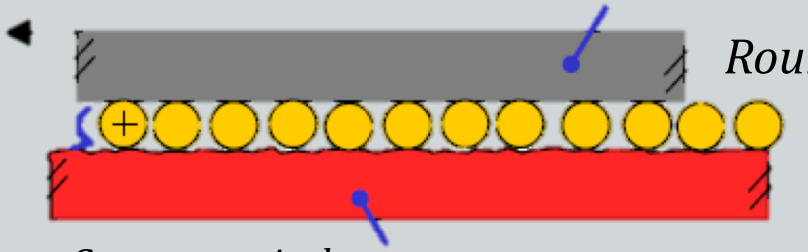
- **Lubrification sèche**



*Cisaillement*

*Particules fines (une partie est piégée par la texture de la surface)*



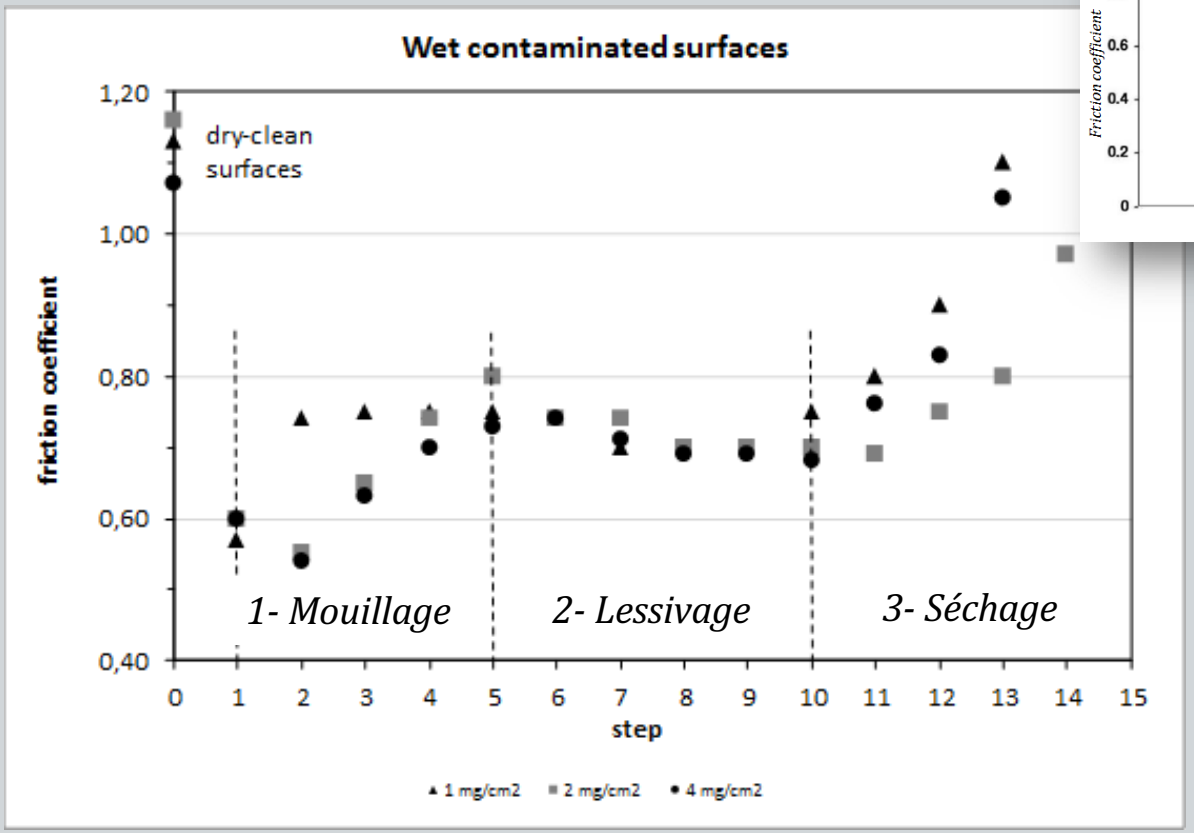
*Roulement*

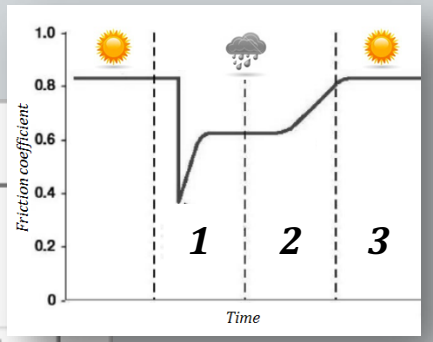
*Grosses particules*

*(Mills et al, J. Tribology International 42, 2009)*

# Contamination particulaire

- **Evolution du frottement par des particules "mouillées"**



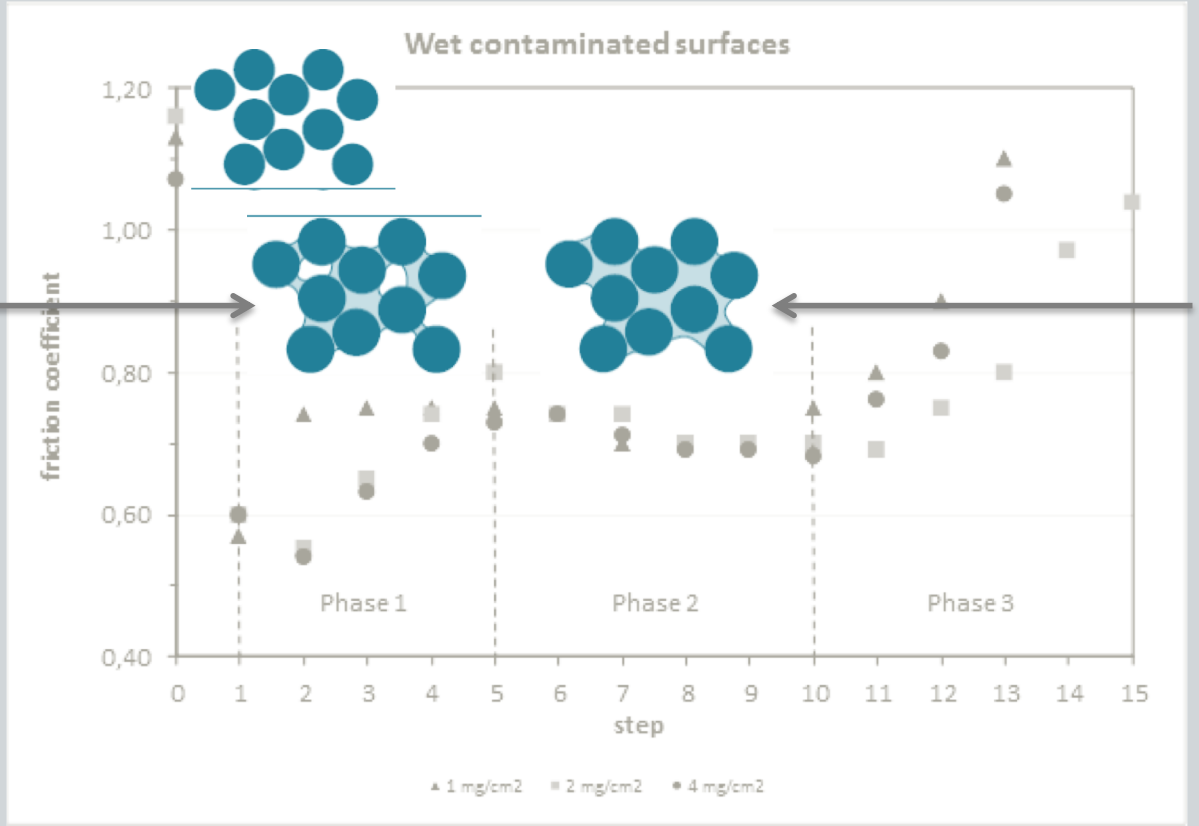




*(Hichri et al, J. Engineering Tribology 231(9), 2017)*

# Contamination particulaire

- **Mécanismes à l'origine de l'evolution du frottement**

*"Ponts capillaires" entre les particules (tension superficielle) créent de la cohésion*



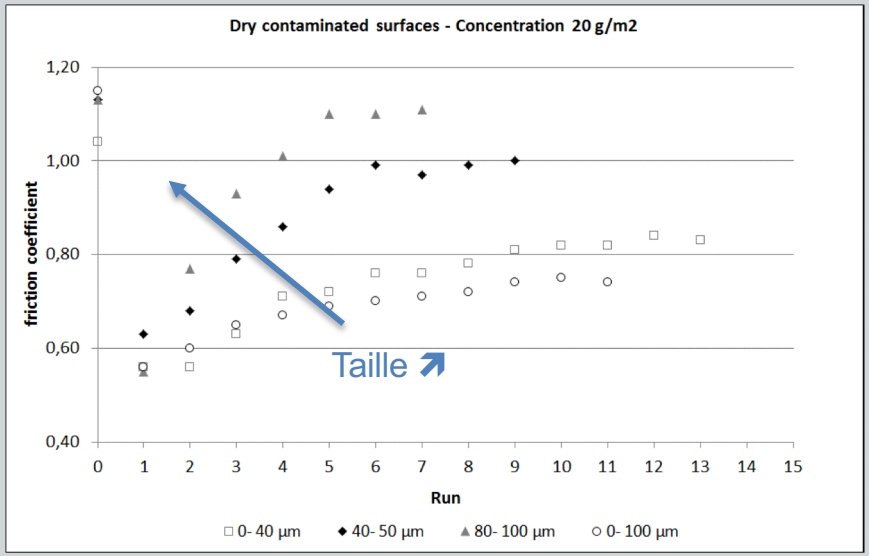

*Toutes les pores sont pleines d'eau → Plus aucune cohesion des particules*

*(Hichri et al, J. Engineering Tribology 231(9), 2017)*

# Contamination particulaire

- **Travaux en cours**

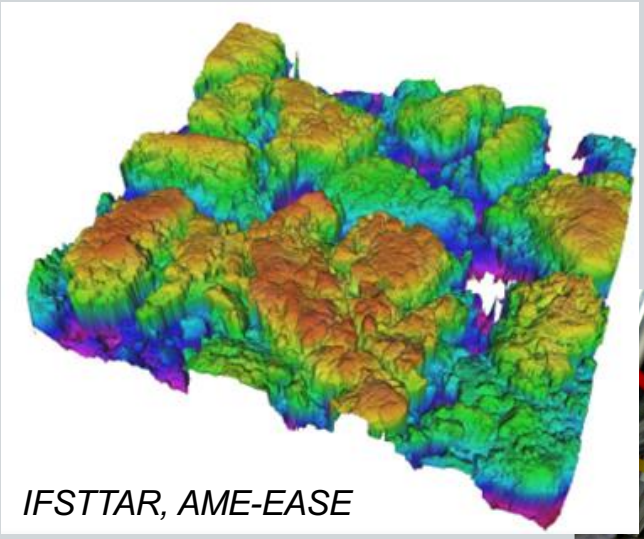
  – Evaluation expérimentale de:
    - la taille des particules
    - la concentration




*(Hichri et al, Wear, 2017)*

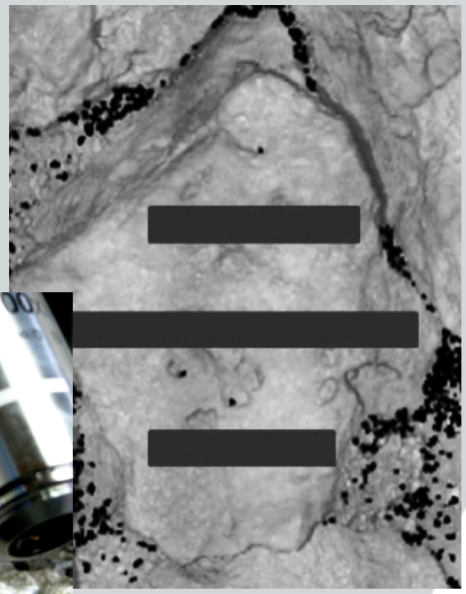
  – Modélisation théorique:
    - Masquage de la texture
    - Piégeage dans les interstices
    - Comportement rhéologique de la couche de particules…

# Le polissage des chaussées



IFSTTAR, AME-EASE

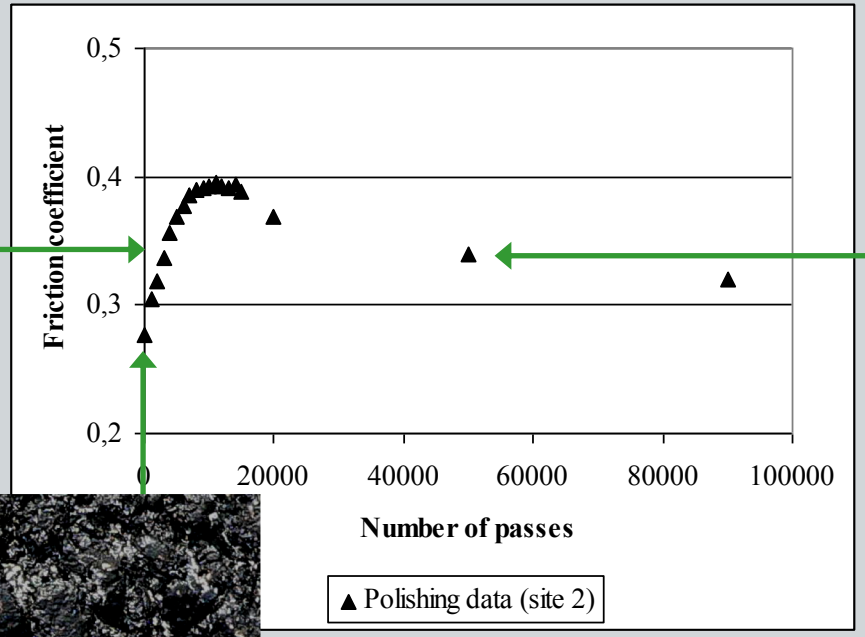
IFSTTAR, AME - EASE

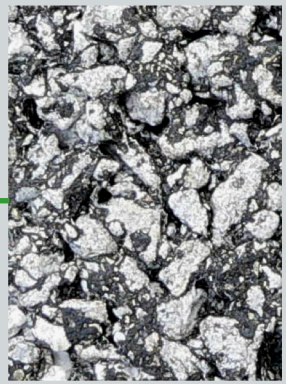


# Polissage des enrobés

- **Evolution du frottement et de la surface**

*Décapage du bitume*



*Granulats*

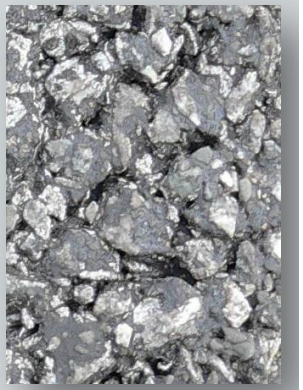
*Enrobé neuf*

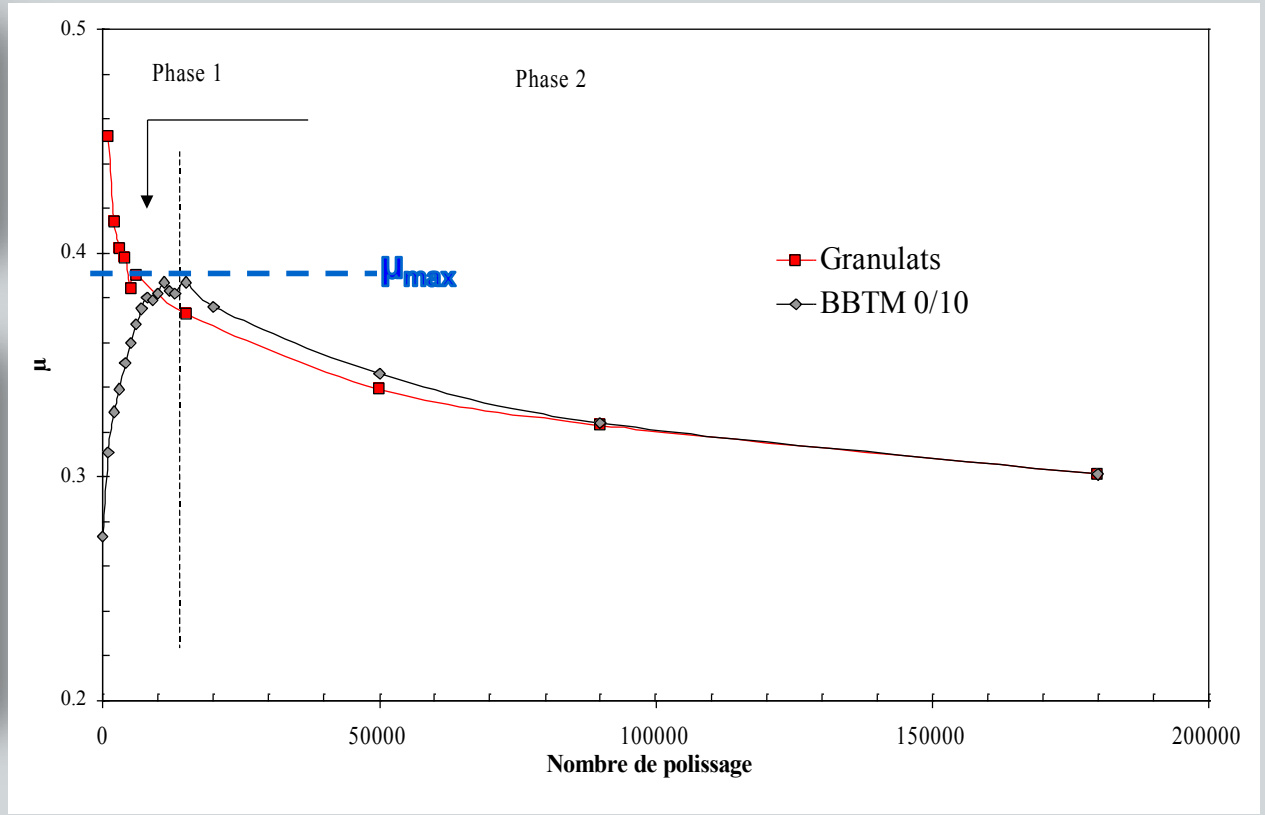
*Enrobé bitumineux*
*Essais Wehner/Schulze*

*(Do et al, J. Wear 263, 2007)*

# Polissage des enrobés

- **Rôle des granulats**

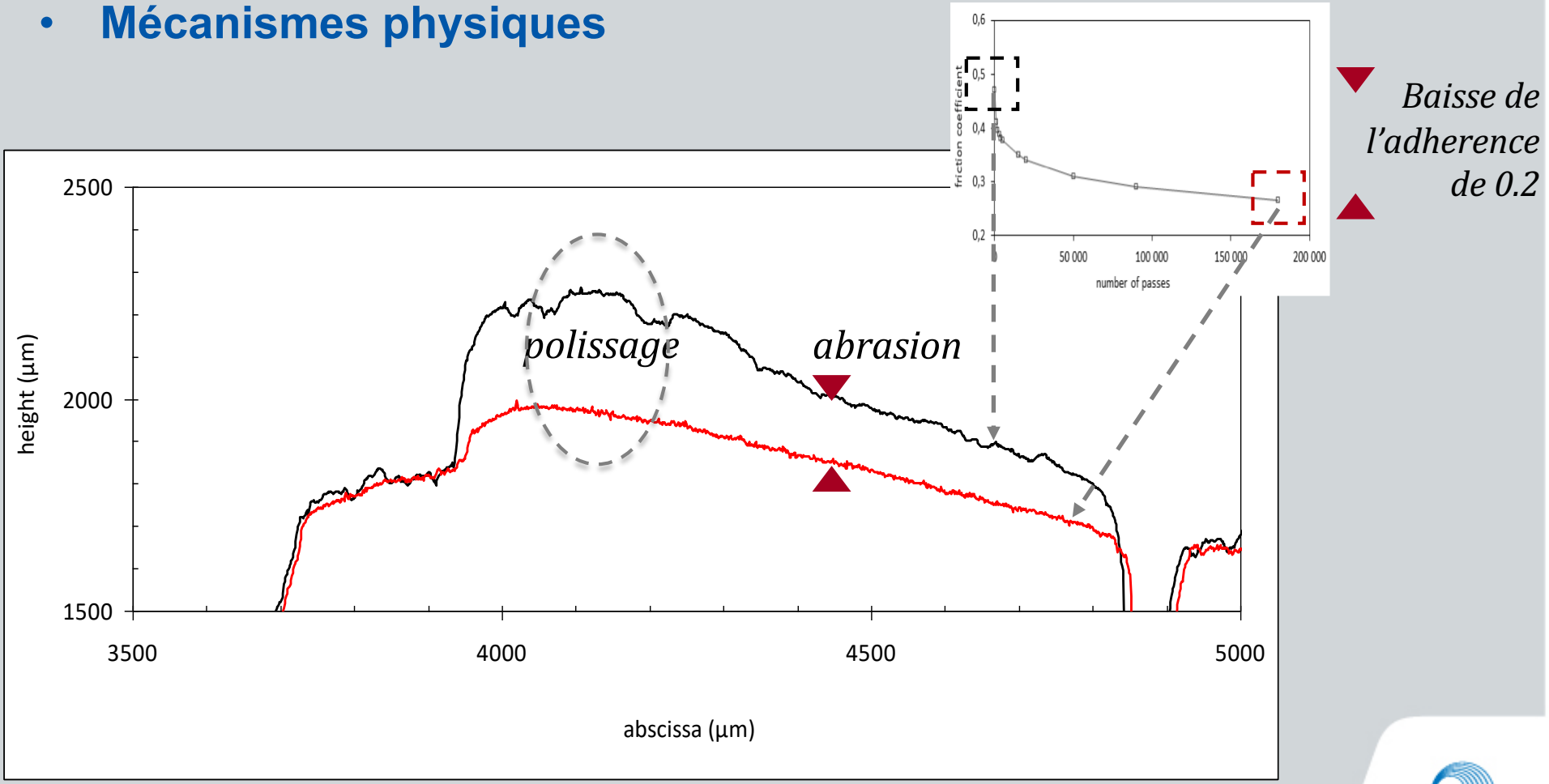





*(Tang, PhD thesis, 2007)*

# Polissage des enrobés

- **Mécanismes physiques**




*(Nataadmadja et al, J. Wear 332-333, 2015)*

# Conclusion

# Conclusion

- **Théorie de la lubrification a permis de mieux comprendre les mécanismes de frottement et d'usure**
- **Effet des différents paramètres sur le frottement et l'usure mieux connu**
- **Modélisation physique**
  - Frottement avec eau
  - Frottement avec des particules

# Merci pour votre attention

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