Numerical generation and contact analysis of rough surfaces in concrete

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1 Introduction

In concrete, ***mixed-mode*** loading leads to development of inter-facial stresses (τ, σ) between crack lips. This leads to increase in shear-carrying capacity of a concrete structure [1, 2].

Our aim is to understand the role topography (***roughness, aggregate distribution***) of cracks in concrete play in determining the inter-facial shear stress.

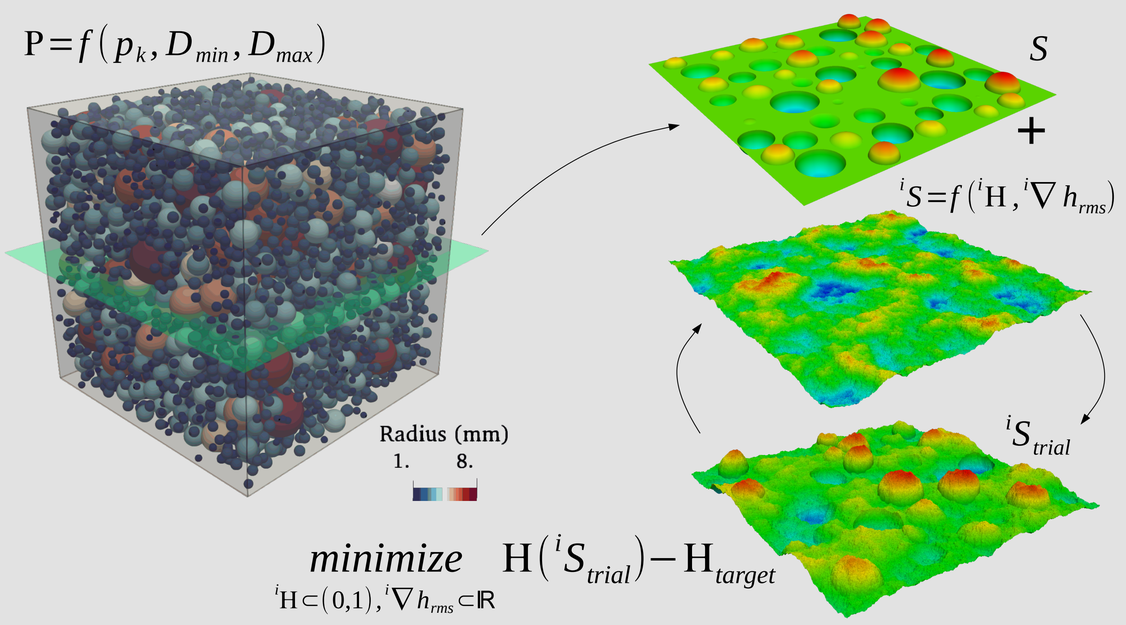
The interfacial shear stress between two contacting surfaces can be represented with a probability density integral depending on:

- Number of contact clusters, $\boldsymbol{N}$
- Contact force per cluster, $\boldsymbol{f}$
- *y*-component of Normal vector per cluster, $\boldsymbol{n_y}$

$$E[\tau] = \frac{1}{A_0} \iiint_{N f n_y} \rho(\boldsymbol{N}).\rho(\boldsymbol{f}|N).\rho(\boldsymbol{n_y}|N).\boldsymbol{f}.\boldsymbol{n_y}.\boldsymbol{N}.\partial N \partial f \partial n_y$$

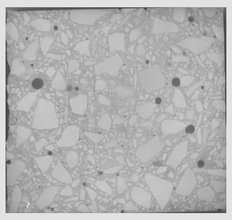
2 Method overview

Artificial concrete rough surfaces are fabricated to control the parameters : aggregate size distribution and roughness (*Hurst exponent*, **H**).

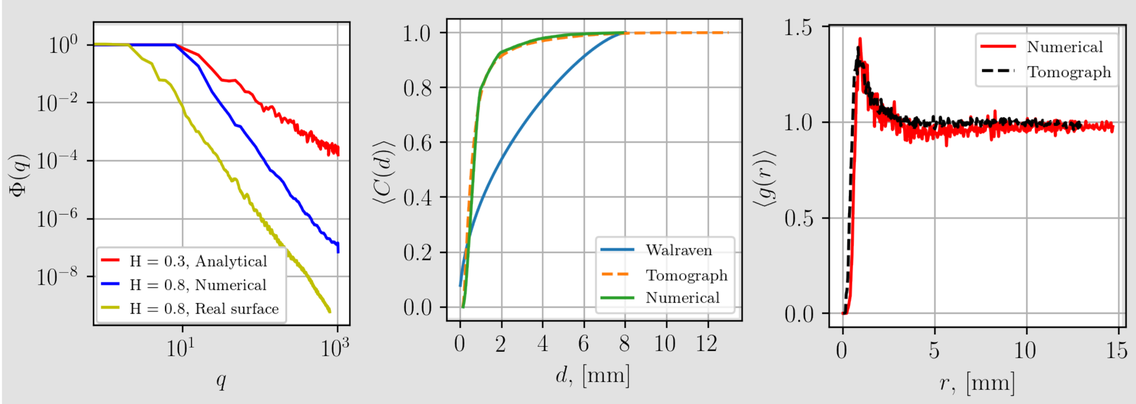


Artificially generated concrete rough surfaces are validated against surfaces from real concrete sample on 3 criteria:

- Hurst exponent, $\mathrm{H}({}^iS_{trial}) = 0.8$ matches with real surface
- Distribution of aggregate sizes $\langle C(d) \rangle$ on surface S matches that of real concrete surface scanned using Tomograph
- Average density of aggregates in all direction, $\langle g(r) \rangle$

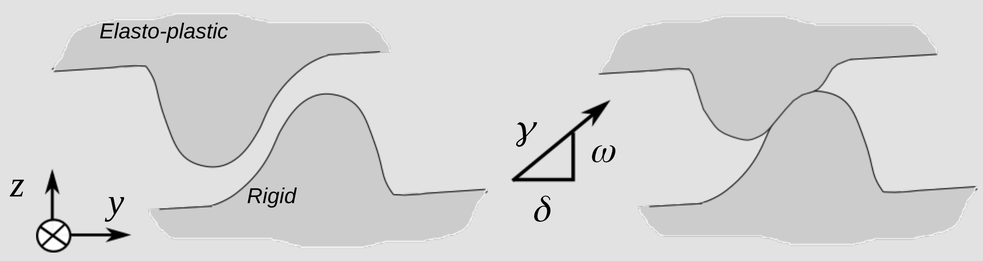


Tomograph scan of concrete



We employ *Boundary-Element Method* [2] to numerically solve for contact between artificially generated surfaces considering *elasto-plastic* interactions.

The two conforming surfaces are loaded under mixed-mode loading.

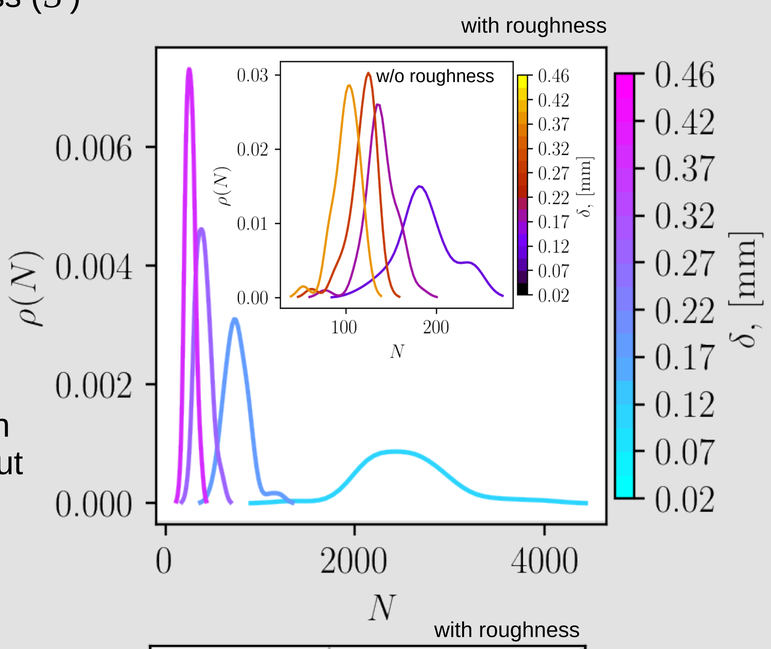


3 Results and discussion

Probability densities for surface with roughness (${}^iS_{trial}$) and surface without roughness (S)

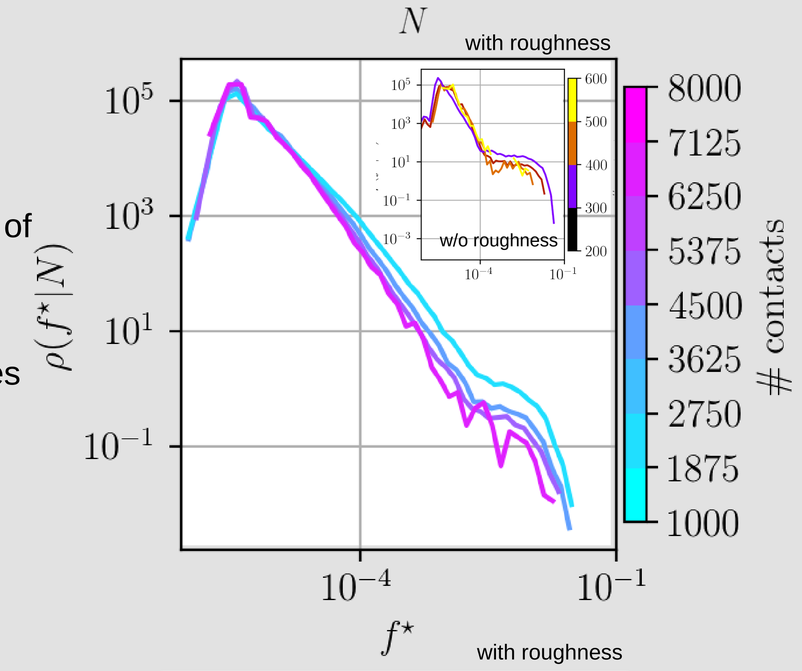
$\rho(\boldsymbol{N})$

- Number of contact clusters decreases with increasing δ
- Follows Gaussian distribution
- Large number of contact clusters with roughness when compared with surface without roughness



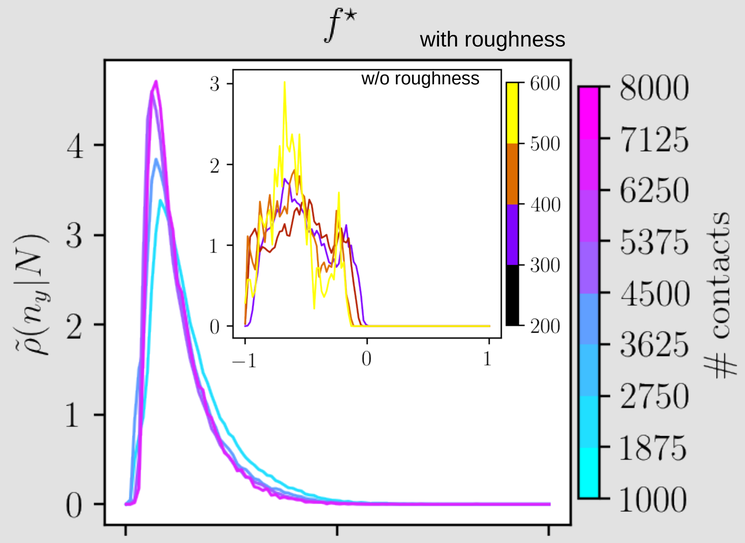
$\rho(\boldsymbol{f}|N)$

- Follows a power-law
- Slope depends on number of contacts and therefore on δ
- Probability density saturates for higher forces (more evident for surface without roughness), effect of aggregates



$\rho(\boldsymbol{n_y}|N)$

- Max probability density shifts from value of -1 to 0 as increases δ
- A value of -1 indicates that $E[\tau]$ will have large value, hence more resistance
- Thus, as δ increases $E[\tau]$ will decrease



4 Conclusion

- Artificial surfaces generated satisfy necessary characteristics and thus gives a better representation of a real rough surface in concrete
- Various probability densities follow a well-defined distributions when roughness is considered
- Thus, analytical expressions can be deduced as $f(\delta, \gamma)$ for analytical computation of $E[\tau]$

5 References

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