Derivation of the cross-sectional area of the virtual channel

Cross-section of the virtual channel can be divided into a trapezoid and two segments, one on each side. The width of the channel at the top \( w_t \) changes with bulging and can be expressed as a function of the sidewall radius of curvature \( R_S \) and the bottom contact angle \( \theta_S \). This is illustrated in Fig. A1.

![Cross-section of the virtual channel.](image)

**Fig. A1:** Cross-section of the virtual channel.

The total cross-sectional area \( A \) is given then by

\[
A = A_T + 2A_S
\]  
(A1)

where \( A_T \) is the trapezoid area and \( A_S \) is the segment area.

The area of a trapezoid is defined as

\[
A_T = h(w_t + w)/2
\]  
(A2)

The width at the top is defined as

\[
w_t = w - 2c
\]  
(A3)

where \( c = R_S \sin \theta_S \). Substituting A3 into A2 and simplifying leads to the trapezoid area

\[
A_T = h(w - R_S \sin \theta_S)
\]  
(A4)

The area of a circular segment is defined as

\[
A_S = \frac{R_S^2}{2} \left(\frac{\theta_S \pi}{180} - \sin \theta_S\right)
\]  
(A5)

Substituting A4 and A5 into A1 yields the cross-sectional area of a virtual channel as:

\[
A = h(w - R_S \sin \theta_S) + \frac{R_S^2}{2} \left(\frac{\theta_S \pi}{180} - \sin \theta_S\right)
\]
\[
= hw - R_S \sin \theta_S (h + R_S) + \frac{\theta_S \pi R_S^2}{180}
\]  
(A6)