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(b) ϕ'=10°
(c) ϕ'=15°
(d) ϕ'=20°

Fig. 12. Relationship between critical tunnel spacing *S/D* and *H/D* (ϕ'=5°, 10°, 15°, 20°, smooth interface).

(a) ϕ'=5°
(b) ϕ'=10°
(c) ϕ'=15°
(d) ϕ'=20°

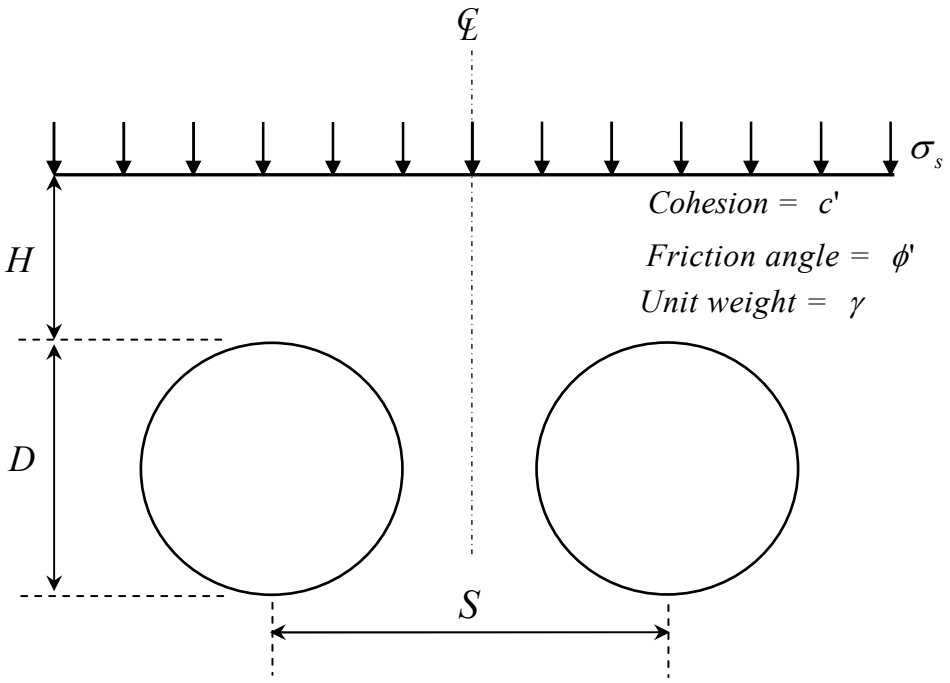


Fig. 1. Plane-strain dual circular tunnels in cohesive-frictional soil.

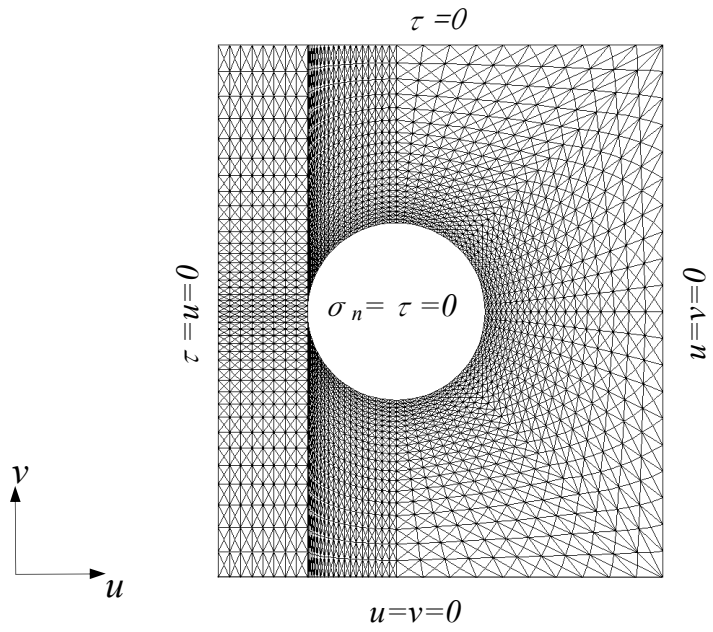
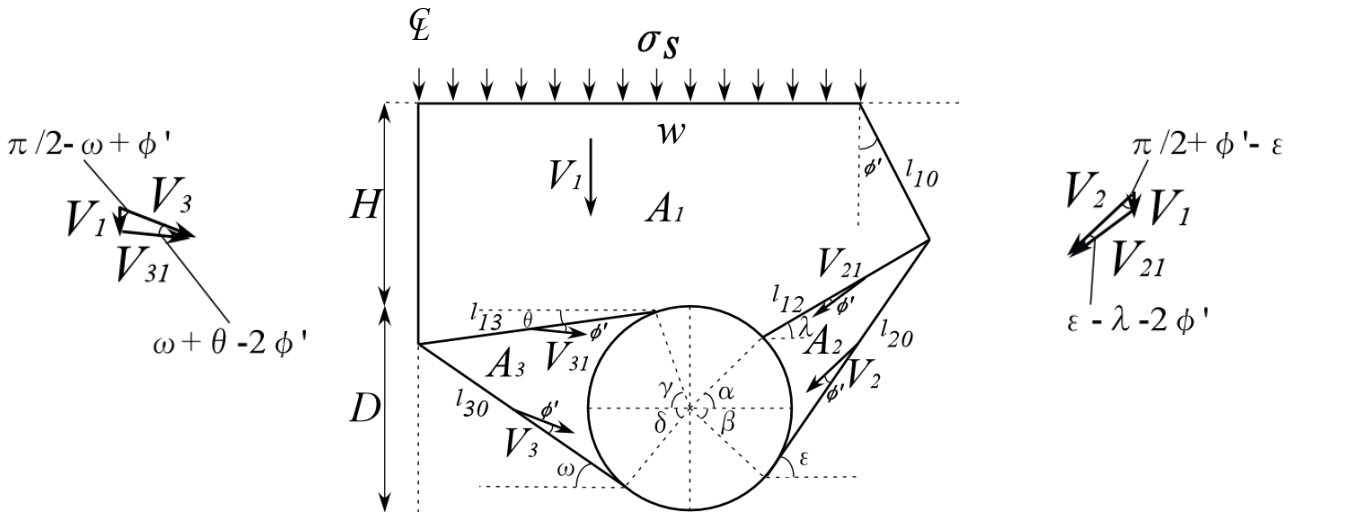
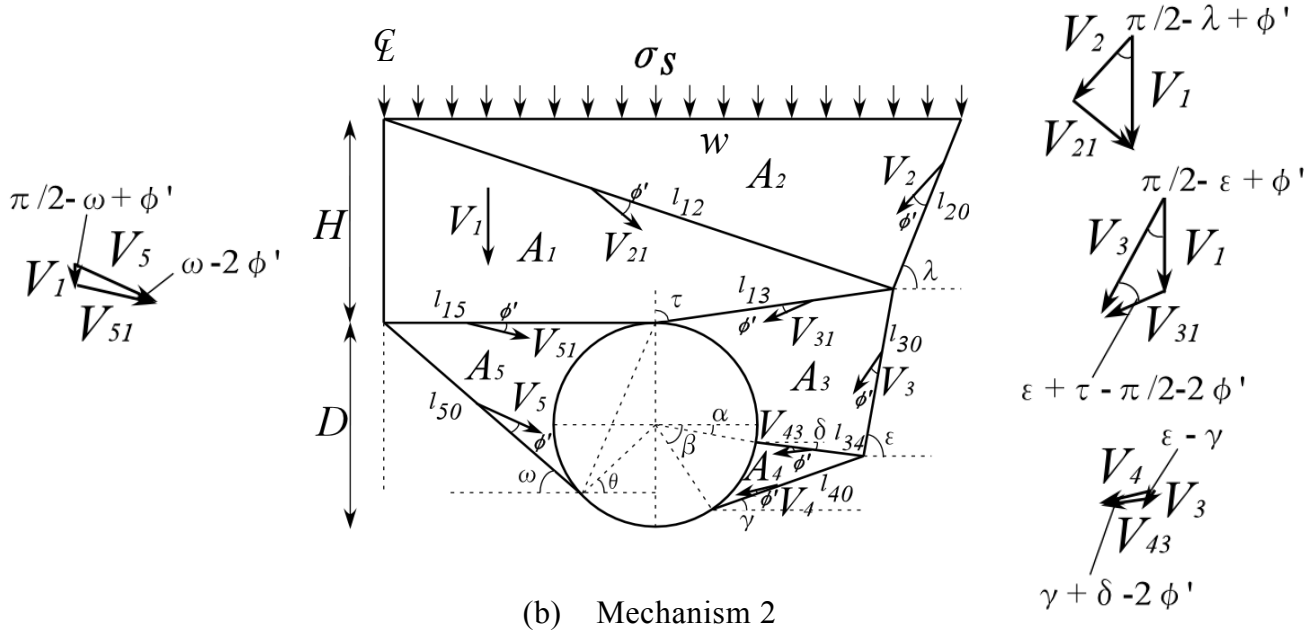


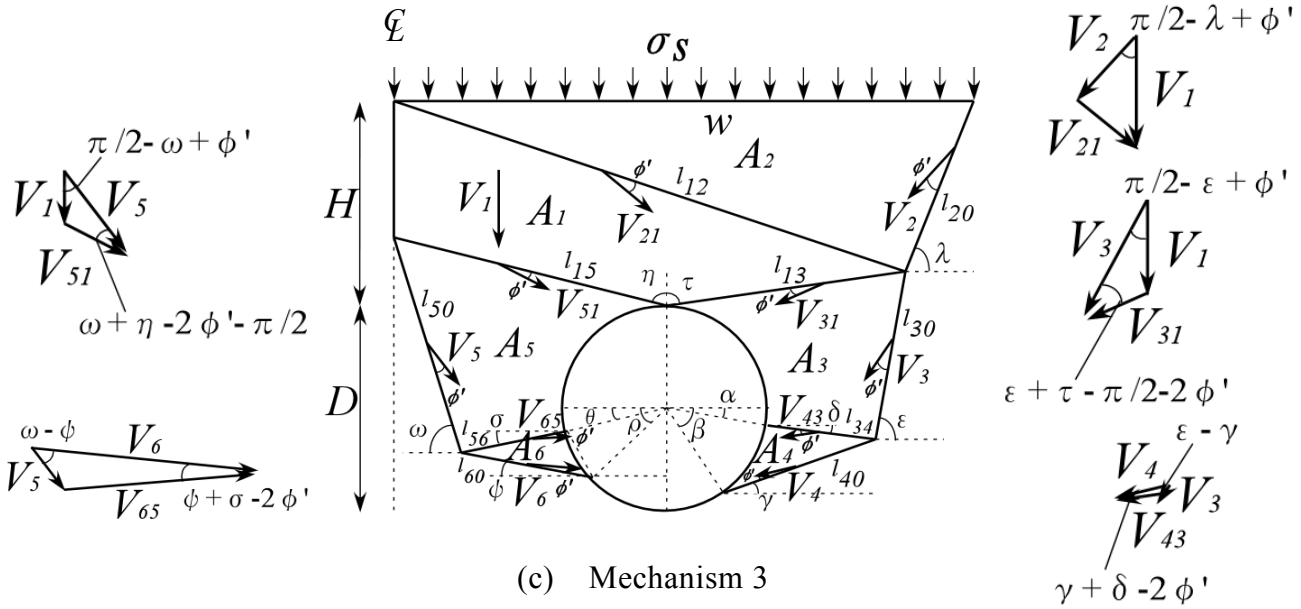
Fig. 2. Finite element mesh for *H/D*=1 and *S/D*=2 showing boundary conditions for numerical limit analysis.



(a) Mechanism 1

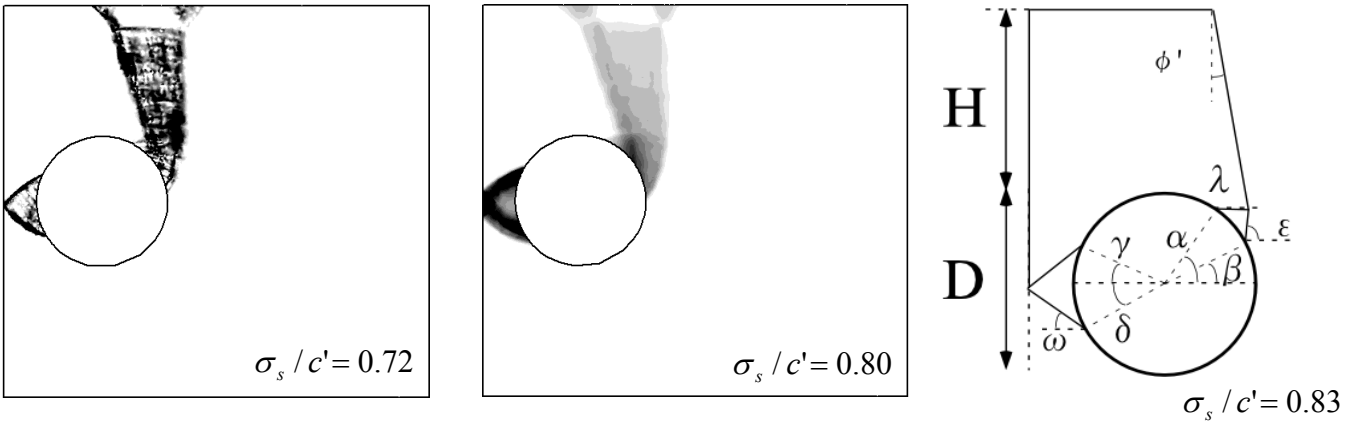


(b) Mechanism 2



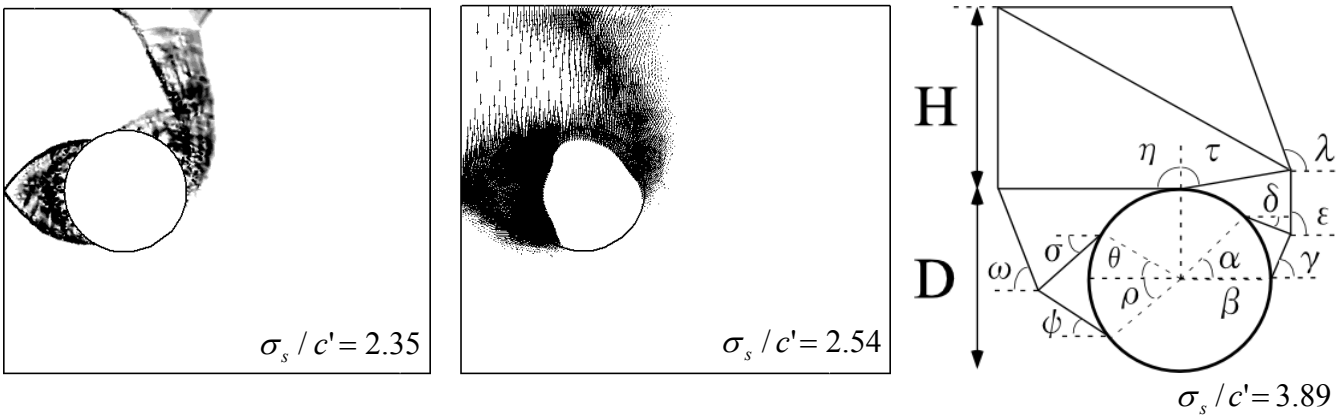
(c) Mechanism 3

Fig. 3. Upper-bound rigid-block mechanisms for dual circular tunnels.



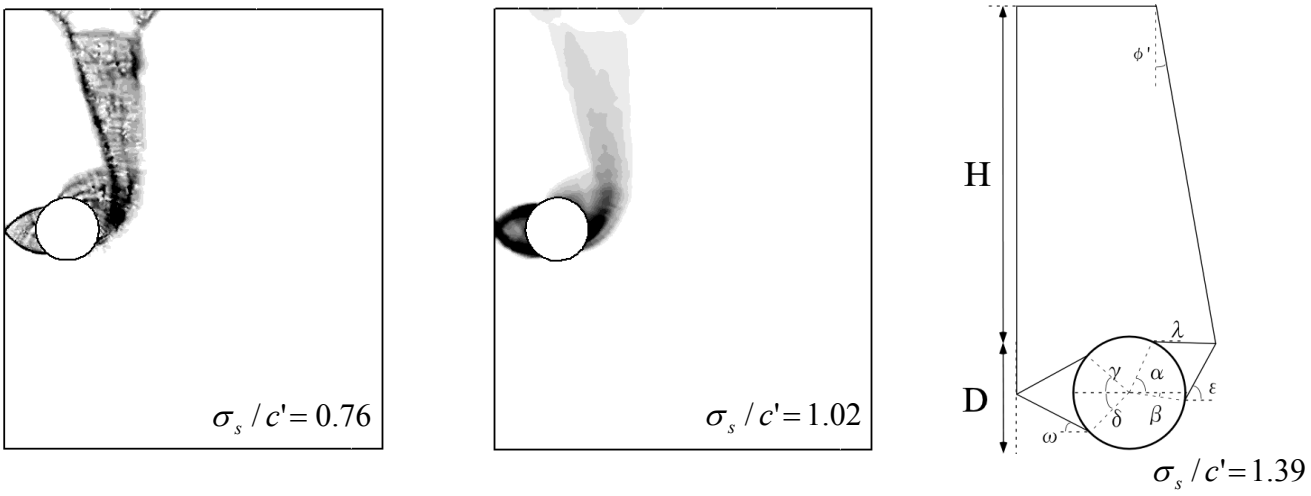
(a) Plastic multiplier field (b) Power dissipation (c) Rigid-block mechanism

Fig. 4. Comparison of rigid-block mechanism with finite element limit analysis (H/D=1, ϕ'=10°, $\gamma D/c'$=1, S/D=1.5, smooth interface).



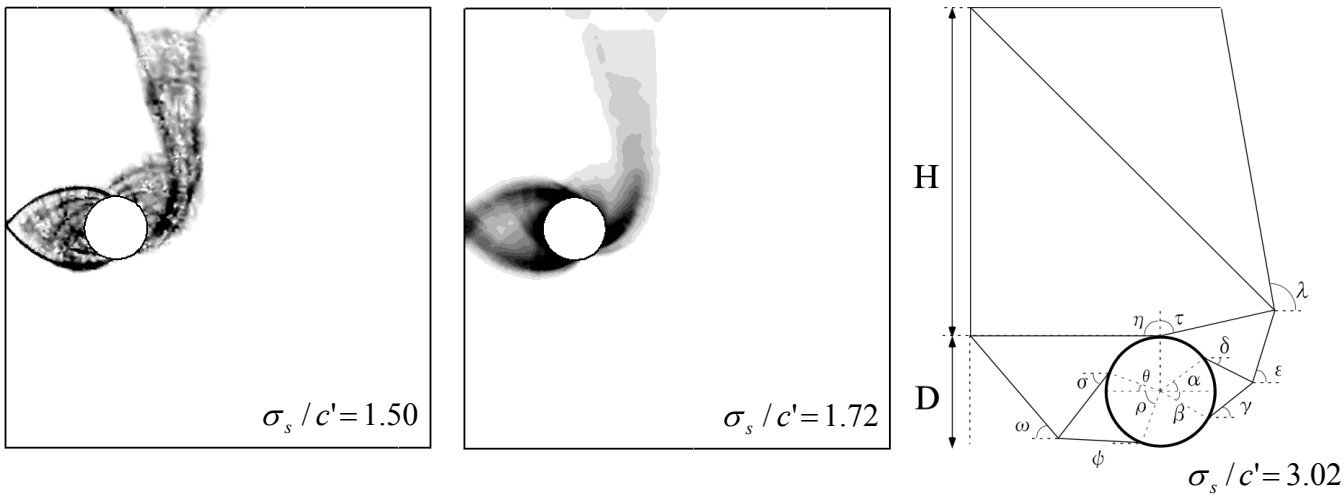
(a) Plastic multiplier field (b) Velocity plot (c) Rigid-block mechanism

Fig. 5. Comparison of rigid-block mechanism with finite element limit analysis (H/D=1, ϕ'=20°, $\gamma D/c'$=1, S/D=2.0, smooth interface).



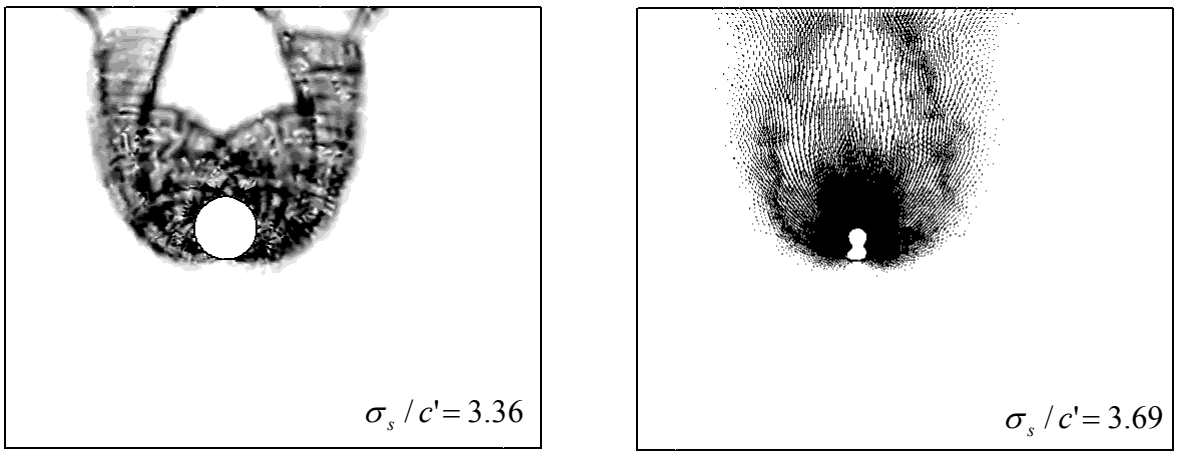
(a) Plastic multiplier field (b) Power dissipation (c) Rigid-block mechanism

Fig. 6. Comparison of rigid-block mechanism with finite element limit analysis (H/D=3, ϕ'=10°, $\gamma D/c'$=1, S/D=2.0, smooth interface).



(a) Plastic multiplier field (b) Power dissipation (c) Rigid-block mechanism

Fig. 7. Comparison of rigid-block mechanism with finite element limit analysis (H/D=3, ϕ'=10°, $\gamma D/c'$=1, S/D=3.5, smooth interface).



(a) Plastic multiplier field (b) Velocity plot

Fig. 8. Numerical results from finite element limit analysis (H/D=3, ϕ'=10°, $\gamma D/c'$=1, S/D=7.0, smooth interface).

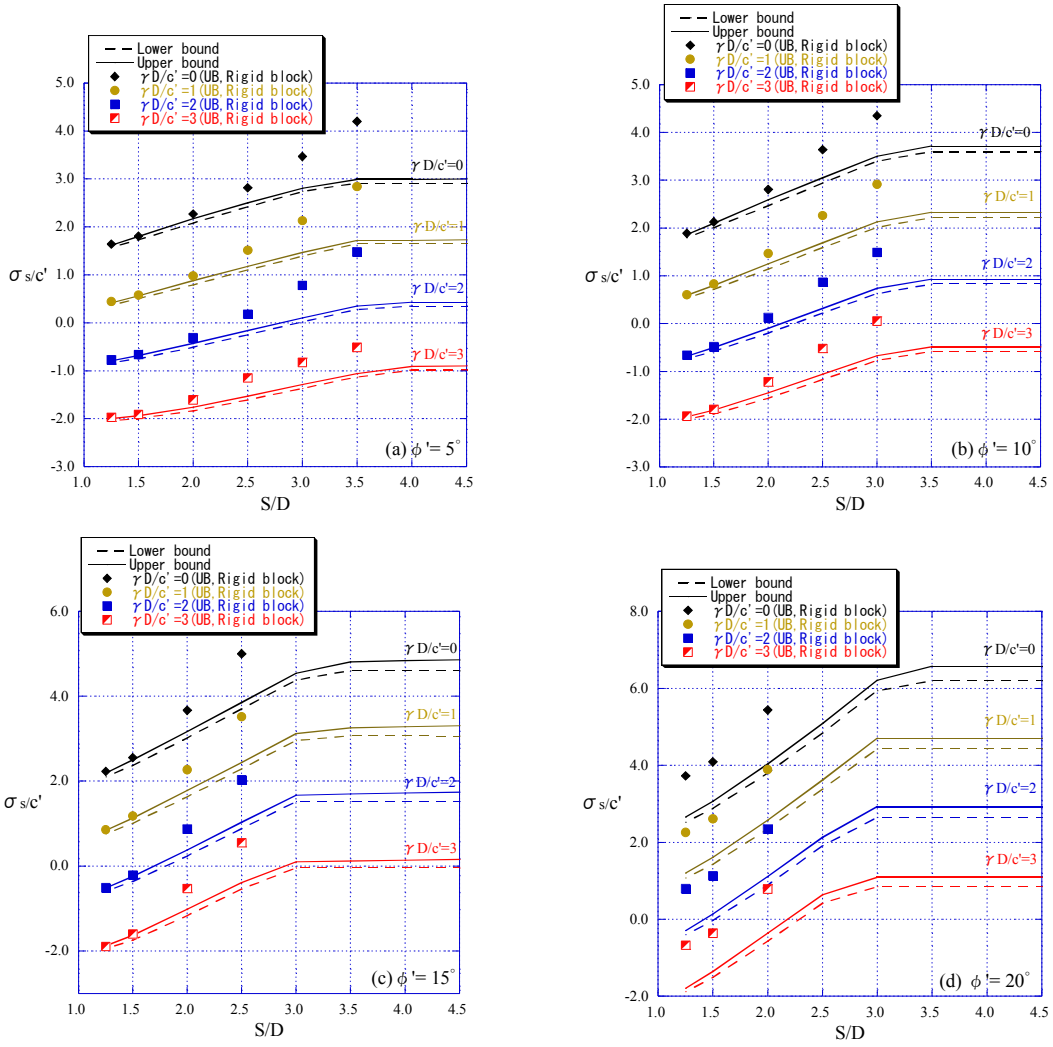


Fig. 9. Stability bounds for dual circular tunnels at *H/D*=1 (ϕ'=5°, 10°, 15°, 20°, smooth interface).

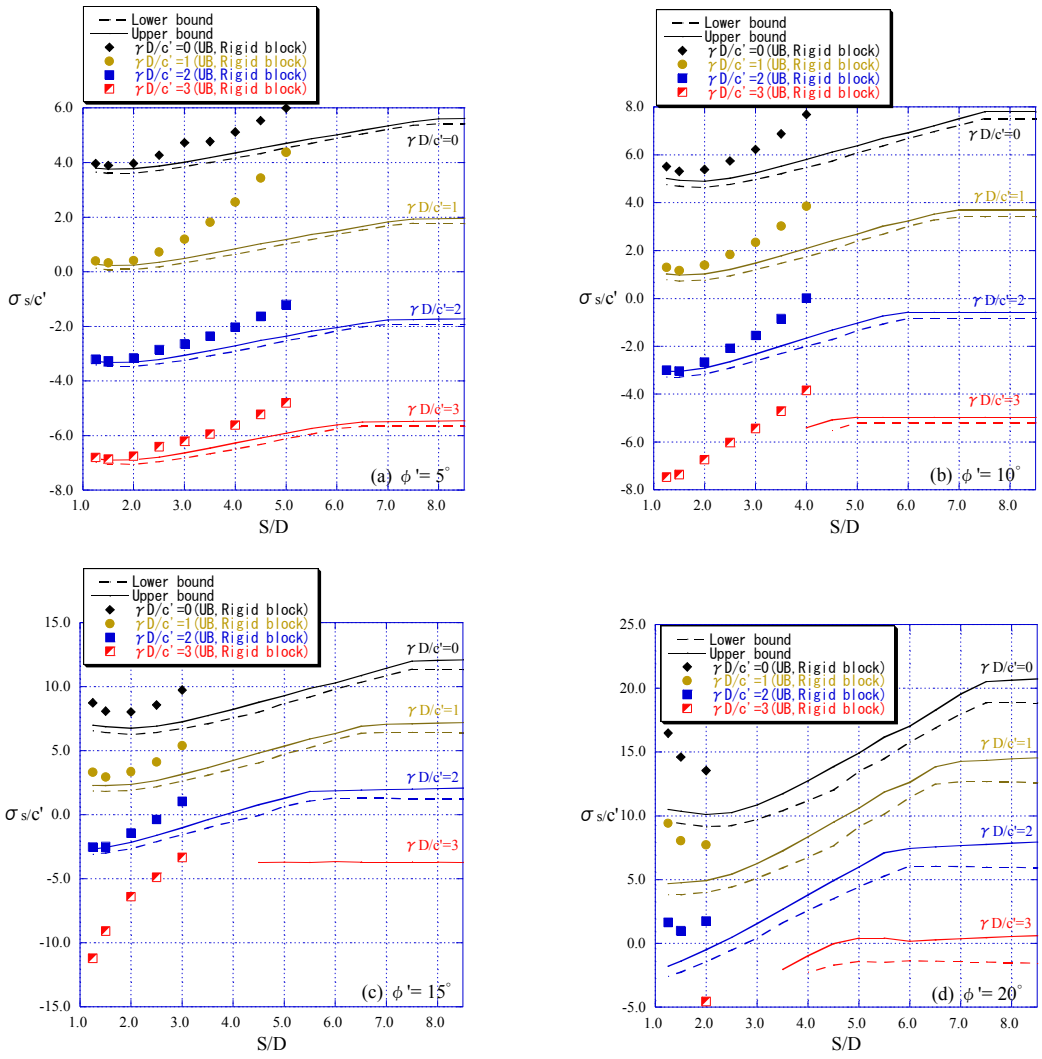


Fig. 10. Stability bounds for dual circular tunnels at *H/D*=3 (ϕ'=5°, 10°, 15°, 20°, smooth interface).

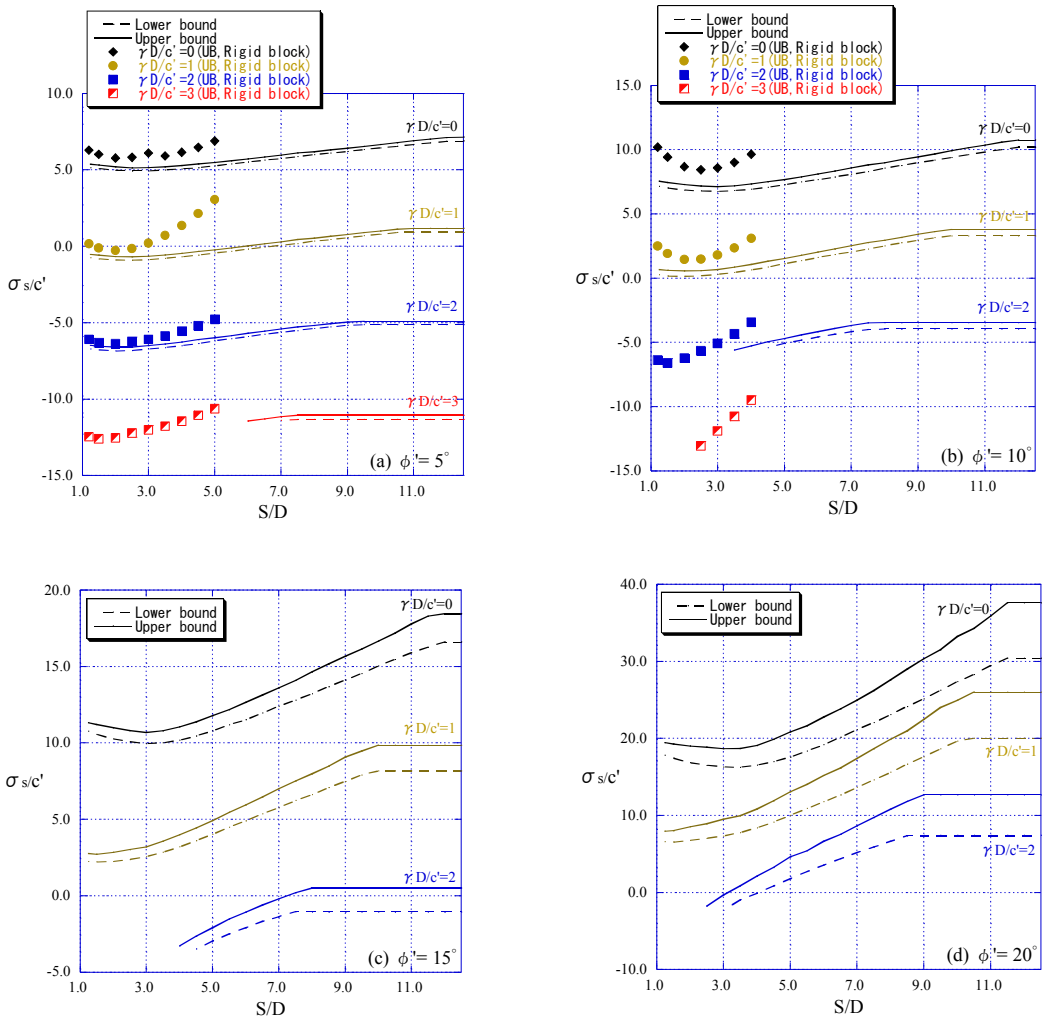


Fig. 11. Stability bounds for dual circular tunnels at *H/D*=5 (ϕ'=5°, 10°, 15°, 20°, smooth interface).

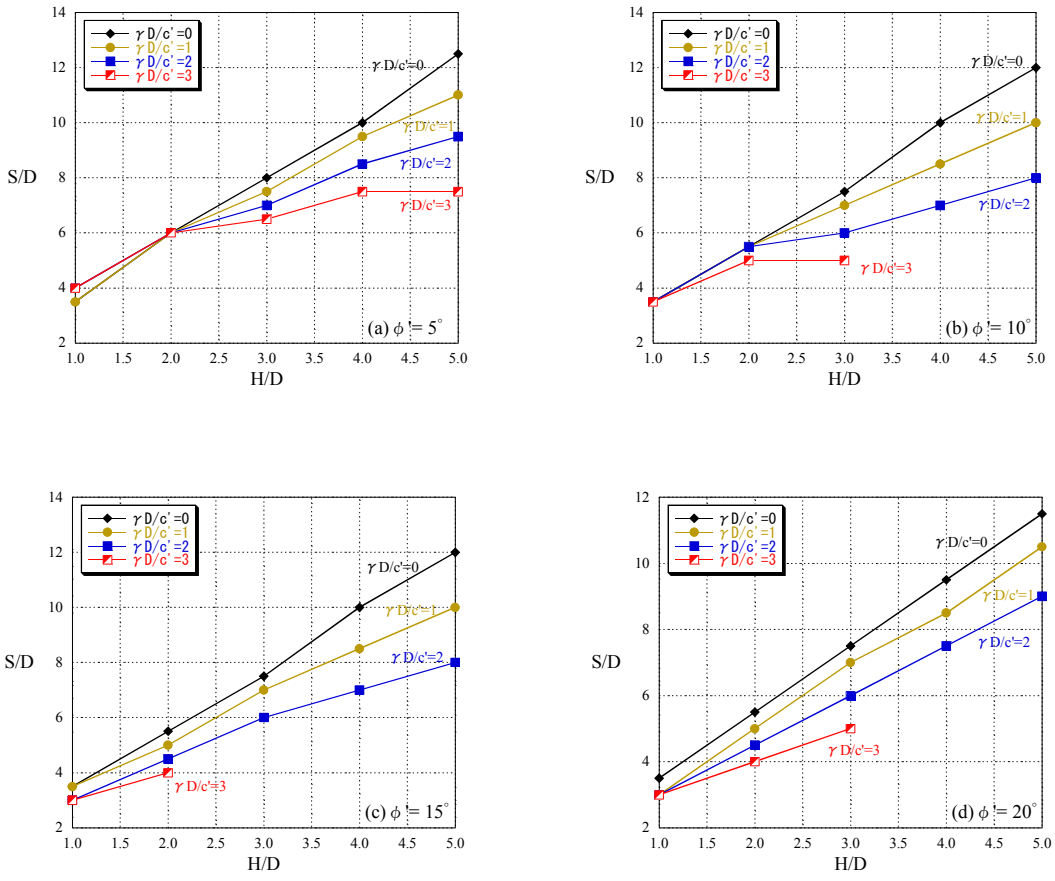


Fig. 12. Relationship between critical tunnel spacing *S/D* and *H/D* (ϕ'=5°, 10°, 15°, 20°, smooth interface).