Electronic Supplementary Material (ESI) for Soft Matter.

Supplementary Information of "Suction Effects of Craters Underwater"

Shutao Qiao[a], Liu Wang[a], Kyoungho Ha[b], Nanshu Lu*[a, b, c, d]

[a]*Center for Mechanics of Solids, Structures and Materials, Department of Aerospace Engineering and Engineering Mechanics, the University of Texas at Austin, Austin TX 78712, US.*

[b]*Department of Mechanical Engineering, the University of Texas at Austin, Austin TX 78712, US.*

[c]*Department of Biomedical Engineering, the University of Texas at Austin, Austin TX 78712, US.*

[d]*Texas Materials Institute, the University of Texas at Austin, Austin TX 78712, US.*

* Corresponding author: nanshulu@utexas.edu, 512-471-4208, 210 E. 24th St, Austin, TX 78712

S1. Raw finite element simulation results

This section contains tables of raw finite element simulation results that are referred in the main text. Table S1 shows the nominal suction force $\hat{F}$ of unreinforced spherical-cap-shaped (SCS) craters as a function of the crater aspect ratio α and the dimensionless stiffness parameter β. All specimens in Table S1 were preloaded with the nominal strain $\Theta = \Theta_m$. Based on the data in Table S1, a contour plot of $\hat{F}$ was made and presented in Fig. 6b in the main text. Table S2 corresponds to Fig. 8b in the main text. It lists all the simulation results of the nominal suction force $\hat{F}$ of a reinforced hemi-spherical crater with shear modulus $\mu = p_0$ (i.e. $\alpha = \beta = 1$) as a function of the reinforcement parameters α' and β'. The background color has the same meaning used in Fig. 8b: the green color represents craters that exhibit instabilities upon both loading and unloading, the red color indicates craters that exhibit instabilities upon unloading only, and the blue color corresponds to stable craters. "NA" denotes a finite element job that diverges before full unloading. In Table S3, the nominal suction force $\hat{F}$ of unreinforced hemi-spheroidal craters with different α and β were collected. Data in Table S3 produces the contour plot Fig. S1b, which will be discussed later.

Table S1. Finite element simulation results of unreinforced SCS craters at $\Theta = \Theta_m$

$\hat{F}$		β							
		0.2	0.5	1	2	4	6	8	10
	0.049783	0	0	0	0	0.310271	0.609197	0.609197	1
	0.09999	0	0	0	0	0.610301	0.829661	0.901584	1
	0.176327	0	0	0	0.527908	0.872468	0.942231	0.963738	0.994089
	0.249328	0	0	0.110721	0.760677	0.933554	0.96735	0.978581	0.9938
	0.267949	0	0	0.229163	0.791353	0.948403	0.977824	0.98262	0.993228
	0.315299	0	0	0.457389	0.860282	0.959966	0.978792	0.983527	0.99774
	0.36397	0	0	0.587125	0.900493	0.975772	0.984062	0.99217	0.993411
	0.414214	0	0	0.688574	0.91581	0.965588	0.985403	0.991935	0.991935
α	0.466308	0	0.079166	0.757595	0.925787	0.966642	0.974824	0.980546	0.99061
	0.520567	0	0.256136	0.808409	0.934979	0.96422	0.975524	0.980349	0.99041
	0.57735	0	0.401606	0.827734	0.914991	0.956574	0.9675	0.980214	0.990826
	0.63707	0	0.571608	0.851765	0.9085	0.9653	0.9632	0.9789	0.981755
	0.700208	0	0.60989	0.857284	0.902963	0.945565	0.957316	0.978494	0.9787
	0.767327	0	0.683776	0.845801	0.8913	0.9386	0.9501	0.9646	0.975716
	0.8391	0	0.724998	0.80161	0.861889	0.932589	0.949021	0.959904	0.963877
	0.900404	0	0.726778	0.762221	0.839201	0.910794	0.9391	0.955602	0.9587
	1	0	0.65419	0.690264	0.818424	0.903924	0.939446	0.956766	0.967559

Table S2. Finite element simulation results of reinforced hemi-spherical craters at $\Theta = \Theta_m$

$\hat{F}$		β'										
		1	2	3	4	5	6	8	10	20	40	80
α'	0.01	0.692958	0.701492	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.015	0.692958	0.702884	0.764178	NA	NA	NA	NA	NA	0.917544	NA	1.072737
	0.02	0.692958	0.705822	0.779385	NA	NA	NA	NA	NA	NA	1.09307	NA
	0.025	0.692958	0.721489	0.786343	NA	NA	NA	NA	NA	1.024023	1.092736	NA
	0.03	0.692958	0.712848	0.736633	0.849924	0.883666	0.906161	NA	NA	NA	NA	NA
	0.035	0.692958	0.718483	0.74342	0.855849	0.899487	NA	0.961659	0.992165	1.047798	1.034452	NA
	0.04	0.692958	0.729041	0.759017	0.848359	0.904894	0.93715	0.976462	1.005026	1.052553	1.052553	NA
	0.045	0.692958	0.722019	0.747672	0.768905	0.792344	0.928099	0.972324	1.027	0.976927	0.976927	NA
	0.05	0.692958	0.732289	NA	0.787044	0.816408	0.866547	0.939709	0.965676	0.987199	0.938918	0.966761
	0.055	0.692958	0.725032	0.752817	0.775869	0.793717	0.808901	0.835963	0.873838	0.902897	0.942404	0.971305
	0.06	0.692958	0.729936	0.758829	0.783418	0.801732	0.817024	0.843453	0.861821	0.909597	0.94905	0.974459
	0.07	0.692958	0.733964	0.76681	0.79023	0.808863	0.824041	0.849896	0.867629	0.91827	0.95439	0.977979
	0.08	0.692958	0.735181	0.769283	0.793681	0.812758	0.829739	0.853691	0.871482	0.921053	0.955888	0.978036
	0.09	0.692958	0.741726	0.775823	0.803271	0.822711	0.838415	0.862253	0.882305	0.928982	0.964424	0.984929
	0.1	0.692958	0.750244	0.787071	0.81406	0.833553	0.850783	0.875987	0.894053	0.935604	0.966902	0.986128

Table S3. Finite element simulation results of hemi-spheroidal craters at $\Theta = \Theta_m$

$\hat{F}$		β													
		0.1	0.2	0.5	0.75	1	2	3	4	5	6	7	8	9	10
α	0.05	0	0	0	0	0	0	0	0	0	0	0.998221	1.00044	1.00046	1.00048
	0.1	0	0	0	0	0	0	0	1.00016	1.00088	0.999966	0.99889	0.99859	0.998395	0.984243
	0.15	0	0	0	0	0	0	1.00076	0.998293	0.995687	0.994494	0.994645	0.994912	0.995397	0.988369
	0.2	0	0	0	0	0	0.992795	0.995715	0.989758	0.988372	0.989014	0.989876	0.990879	0.991902	0.992504
	0.25	0	0	0	0	0	0.995473	0.984542	0.982515	0.984114	0.985966	0.987986	0.98915	0.990957	0.991867
	0.3	0	0	0	0	0.438962	0.984711	0.974122	0.974171	0.978028	0.981231	0.984133	0.98592	0.988219	0.989494
	0.35	0	0	0	0	0.908604	0.967335	0.961114	0.966533	0.972366	0.975974	0.979676	0.982842	0.984802	0.986444
	0.4	0	0	0	0.556324	0.953365	0.946933	0.950746	0.959501	0.966317	0.971782	0.976245	0.979174	0.981562	0.984322
	0.45	0	0	0	0.842755	0.960888	0.929603	0.941862	0.953605	0.962018	0.967674	0.972896	0.97633	0.979977	0.982255
	0.5	0	0	0	0.899637	0.949467	0.915365	0.934915	0.948405	0.958394	0.966047	0.970984	0.976018	0.979124	0.981675
	0.55	0	0	0.224251	0.921537	0.928363	0.901343	0.92533	0.941595	0.953267	0.960702	0.967723	0.97207	0.975557	0.978408
	0.6	0	0	0.574303	0.914403	0.899265	0.889021	0.918586	0.936739	0.949407	0.957642	0.96497	0.96975	0.973567	0.976685
	0.65	0	0	0.726073	0.898018	0.86054	0.878106	0.911171	0.931433	0.945352	0.954359	0.962324	0.967516	0.972924	0.976282
	0.7	0	0	0.774089	0.869442	0.818763	0.867966	0.905291	0.927567	0.9428	0.954033	0.961219	0.966773	0.972754	0.976338
	0.75	0	0	0.803562	0.827854	0.786113	0.857902	0.899034	0.923094	0.937893	0.949755	0.957472	0.963419	0.969599	0.973431
	0.8	0	0	0.80051	0.779013	0.7613	0.848247	0.892921	0.918705	0.934482	0.947085	0.955266	0.963122	0.968106	0.972159
	0.85	0	0	0.786716	0.722447	0.743072	0.839745	0.887773	0.915216	0.933618	0.945266	0.955643	0.962241	0.967477	0.971733
	0.9	0	0	0.748796	0.685597	0.724747	0.833695	0.882989	0.911989	0.931403	0.943614	0.954578	0.961482	0.966956	0.971403
	0.95	0	0	0.707101	0.658813	0.708784	0.82518	0.877227	0.907616	0.927874	0.940656	0.952028	0.959244	0.964962	0.969603
	1	0	0	0.653268	0.637126	0.69272	0.818424	0.872442	0.903924	0.923054	0.939446	0.949243	0.956766	0.962724	0.967559