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Hail impact testing: quantitative determination of differences between IEC and VKF procedures through impulse recording

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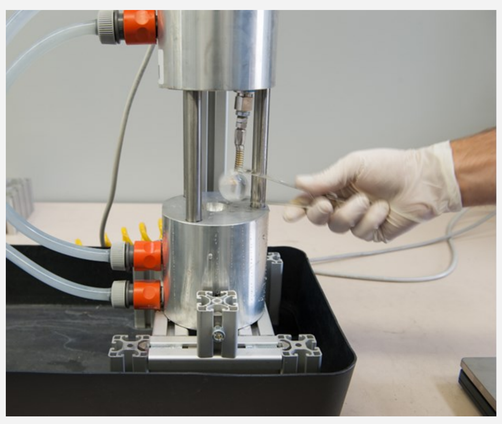
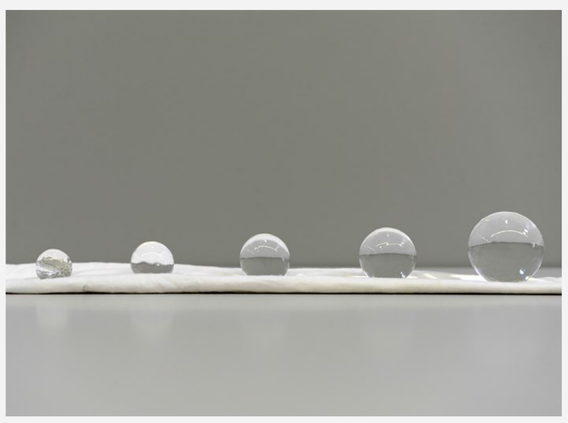
ABSTRACT

The rapid changing in solar module technology, with increasing dimensions of silicon wafers (from M2, 156.75mm, in 2018 to M12, 210mm today), increased options for inter-cell contacting technologies (multi bus-bar, shingled, tiling ribbon, smartwire), reduced thickness of glasses (from 3.2 mm to 2.85 mm and less), reduced section of aluminium frames, is generating questions on the reliability of the new mass products that are entering the market. Among the critical points for insuring long lifetimes to the photovoltaic modules on the Swiss Alps, is the resistance to hail stones with larger diameters.

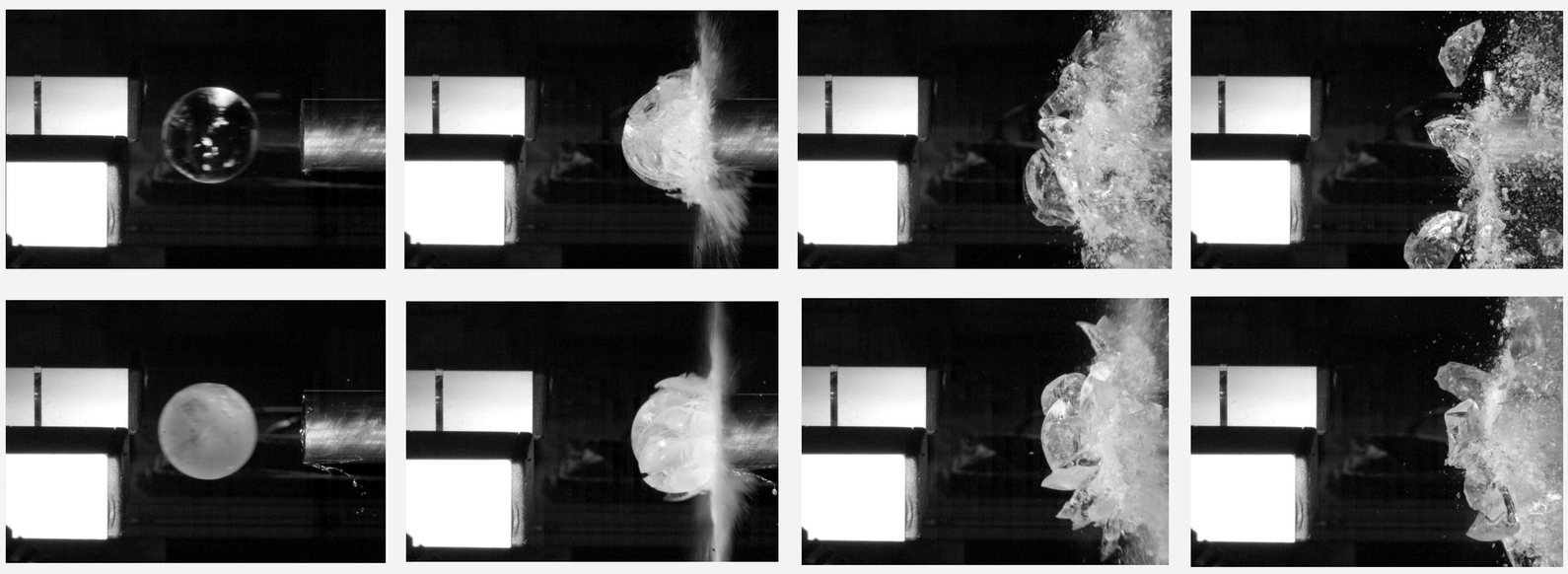
As a background, in 2012, several improvements in hail testing were accomplished in the frame of a research work funded by the “Vereinigung Kantonaler Gebäudeversicherungen” (VKG). In that occasion, after a round robin activity organized between four laboratories in Switzerland and Austria, the test setup at SUPSI was improved from 25-35 mm up to maximum 60 mm ice ball diameter. At 10 years distance, SUPSI PVLab has characterised indoor the impact of normalised hailstones on solar modules in cooperation with the colleagues of SUPSI Dynamat, in order to properly determine the maximum impact force of different hail projectiles, ranging from 25 to 70 mm diameters, with different recipes for the preparation of the ice, following the Swiss norm (VKF prüfbestimmung n.25) and international norms (IEC 61215-2).

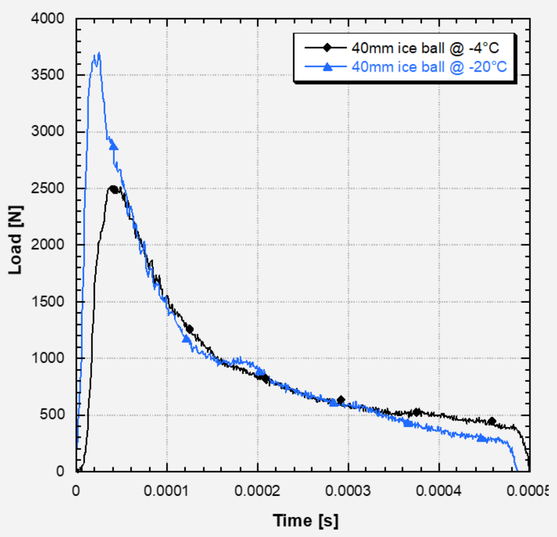
Testing execution





- Preparation of hail stones was accomplished through use of ultra pure ice bars and direct melting of ice cubes with metal moulds.
- Projectiles have been stored at different temperatures (1 hour at -4°C for IEC 61215-2 and 48 hours at –20°C for VKF Pr.25) in order to compare the requirements of Swiss standard and IEC standard.
- A calibrated aluminium bar was used as an output bar for wave recording of the impulse generated by the impact of ice balls.
- By means of a strain-gauge station, it is possible to record the strain signals and, as a consequence, the load signal vs time.
  Two high-speed cameras were used to record the impact of the ice ball on the target.





Results

- Testing with larger hailstones with good repeatability is possible, verified according to normative up to 70mm, preliminary testing up to 100mm.
- Standards do not define how to prepare ice balls: there are important differences based upon the method of preparation and the storage temperature and
- lower temperatures for longer times result in much higher maximum force (40 to 77 % higher)
- In the experiment, glass-backsheet modules with tempered glass performed better than glass-glass modules with the same thickness but with thermally reinforced glass.

Temperature (LAB)	Mass (LAB)	Diameter (LAB)	Velocity (LAB)	Energy (LAB)	Impulse	Max impact force	Trasmitted Energy		Ave. Max impact force	
[°C]	[g]	[mm]	[m/s]	[J]	[N*s]	[N]	[J]	[%]	[N]	
-4	7.8	25.1	22.8	2.0	0.1	1017.8	1.1	54.8		
	7.9	25.1	21.6	1.8	0.1	786.3	1.2	63.2	864.2	
	7.9	25.3	21.8	1.9	0.1	788.4	0.9	49.0		
-20	8.0	25.2	23.4	2.2	0.1	1649.2	1.3	58.5		
	7.9	25.4	23.2	2.1	0.1	1396.2	1.1	53.4	1525.8	Increase 77 %
	7.9	25.3	23.3	2.1	0.1	1532.1	1.1	49.3		
-4	29.7	39.4	27.5	11.2	0.4	2516.5	3.4	30.2		
	29.7	39.4	28.0	11.6	0.5	2659.6	4.9	41.8	2588.1	
-20	29.9	39.5	28.2	11.9	0.6	3397.8	5.3	45.0		
	29.9	39.5	27.2	11.1	0.5	3699.8	3.9	35.4	3624.6	Increase 40%
	29.6	39.5	28.1	11.7	0.4	3776.3	3.1	26.7		
-4	159.6	69.1	36.1	104.0	1.6	9610.1	7.7	7.4		
	159.9	69.0	37.1	110.0	1.7	10361.6	9.2	8.3	10083.2	
	159.5	69.0	36.8	108.0	1.8	10277.9	9.7	9.0		
-20	160.0	69.1	38.4	118.0	2.0	13844.1	11.9	10.1		
	159.9	69.1	38.6	119.1	1.7	14904.2	9.1	7.6	14509.3	Increase 44 %
	160.1	69.1	38.4	118.0	1.9	14779.6	11.5	9.7		