

Fragment Patterns behind Concrete Structures caused by KE Projectiles

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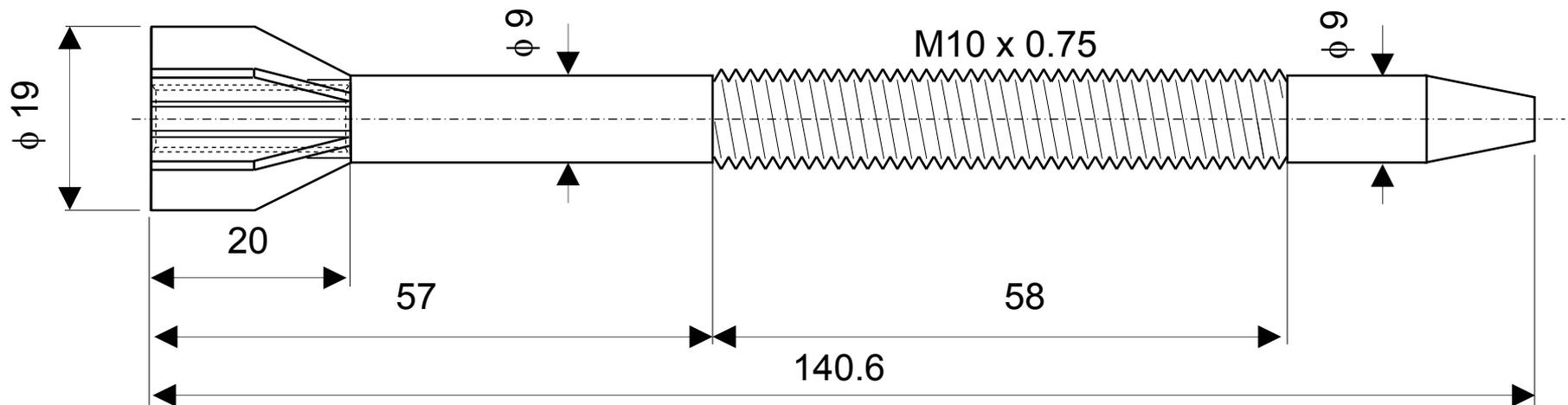
- **Interest of Swiss Army: to know more about ...
effectiveness of ammunition against urban targets (concrete, brick wall)**
- **especially medium caliber ammunition (APDSFS and FAPDS)**
- **Computer Model (PANZKI3) for vulnerability assessments**
- **Modul of ammunition effectiveness against urban targets:
Effects of concrete fragments are not yet taken into consideration**
- **Aim of present study**
 - **learn more about risk for people exposed to concrete fragments**
 - **describe the dynamics of concrete fragments in a realistic model**
 - **Focus on perforation of concrete walls by KE projectile (APFSDS)**

Model projectile

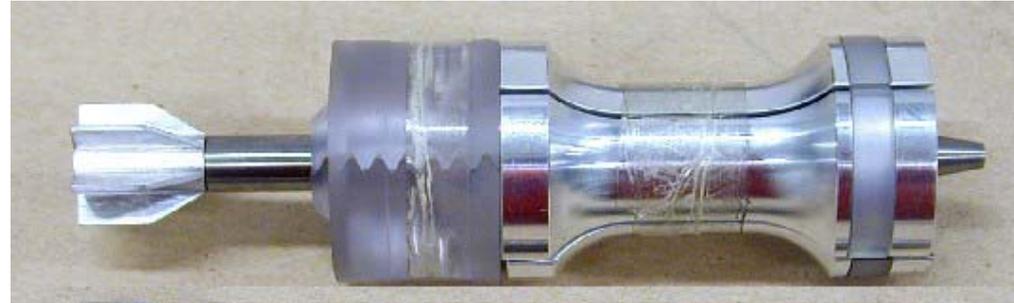
mass 152 g

Rod material: Tungsten-alloy Y 925

Fin material: Aluminum



Laboratory gun



Acceleration of model projectile

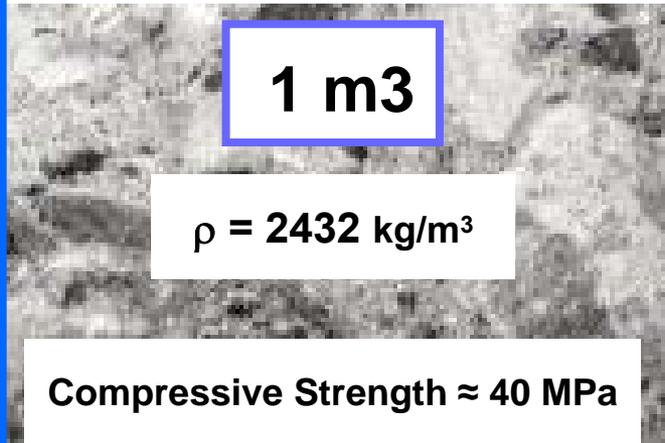
smooth barrel powder gun

Caliber **38 mm**

Specifications of concrete



**391 kg, 20 V%
Bebbles Ø 4 – 8 mm**



1 m³

$\rho = 2432 \text{ kg/m}^3$

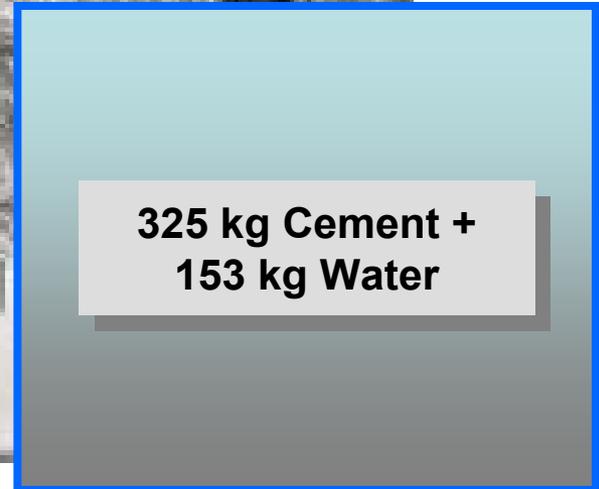
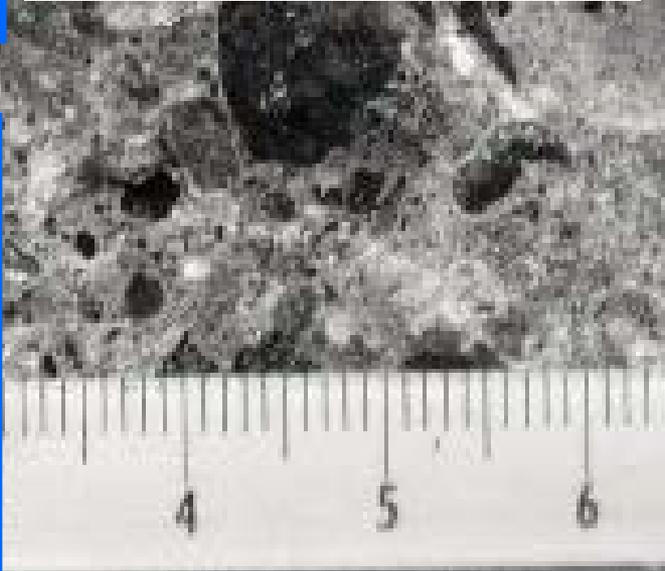
Compressive Strength $\approx 40 \text{ MPa}$



**586 kg, 30 V%
Bebbles Ø 8 – 16 mm**

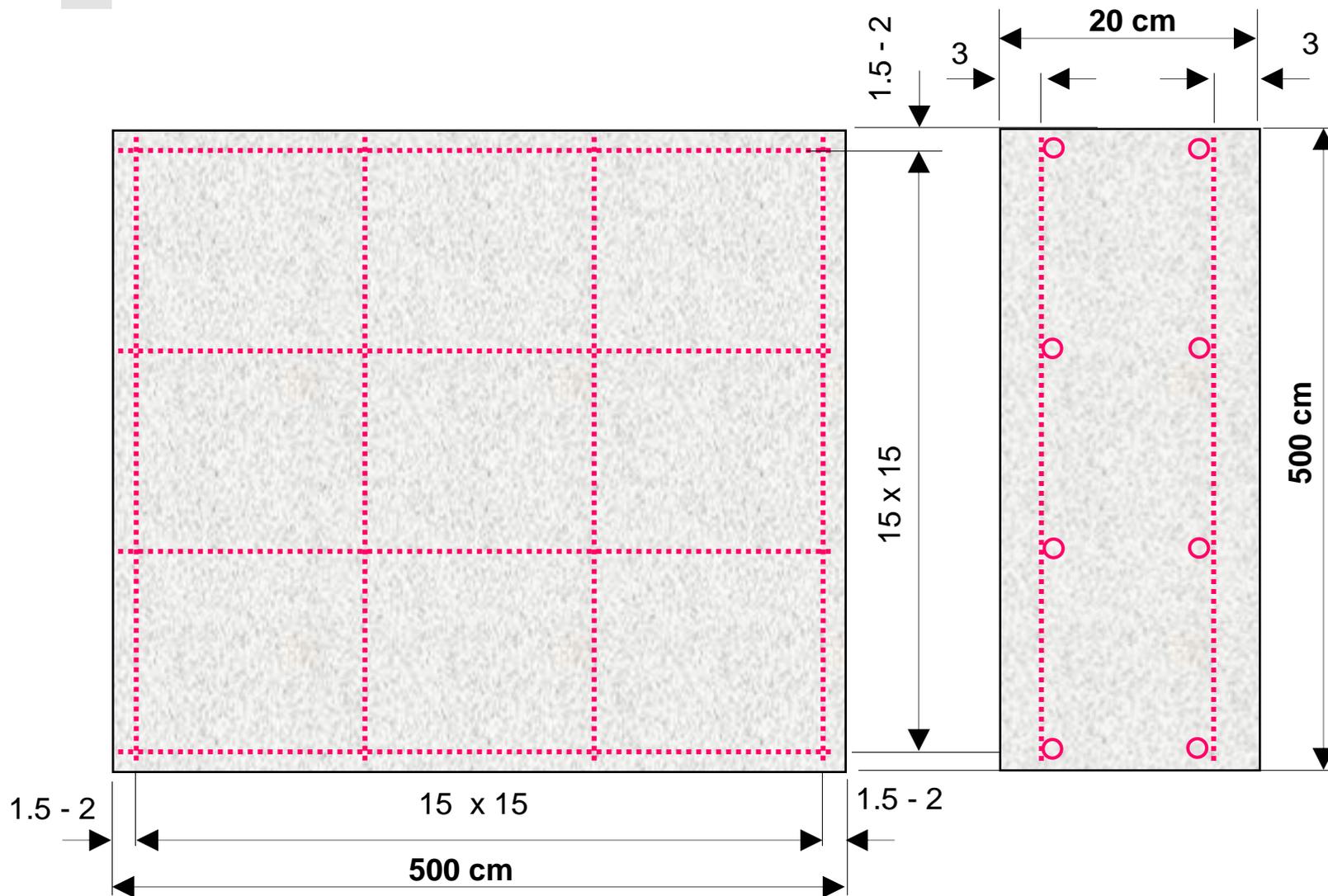


977 kg, 50 V% Sand

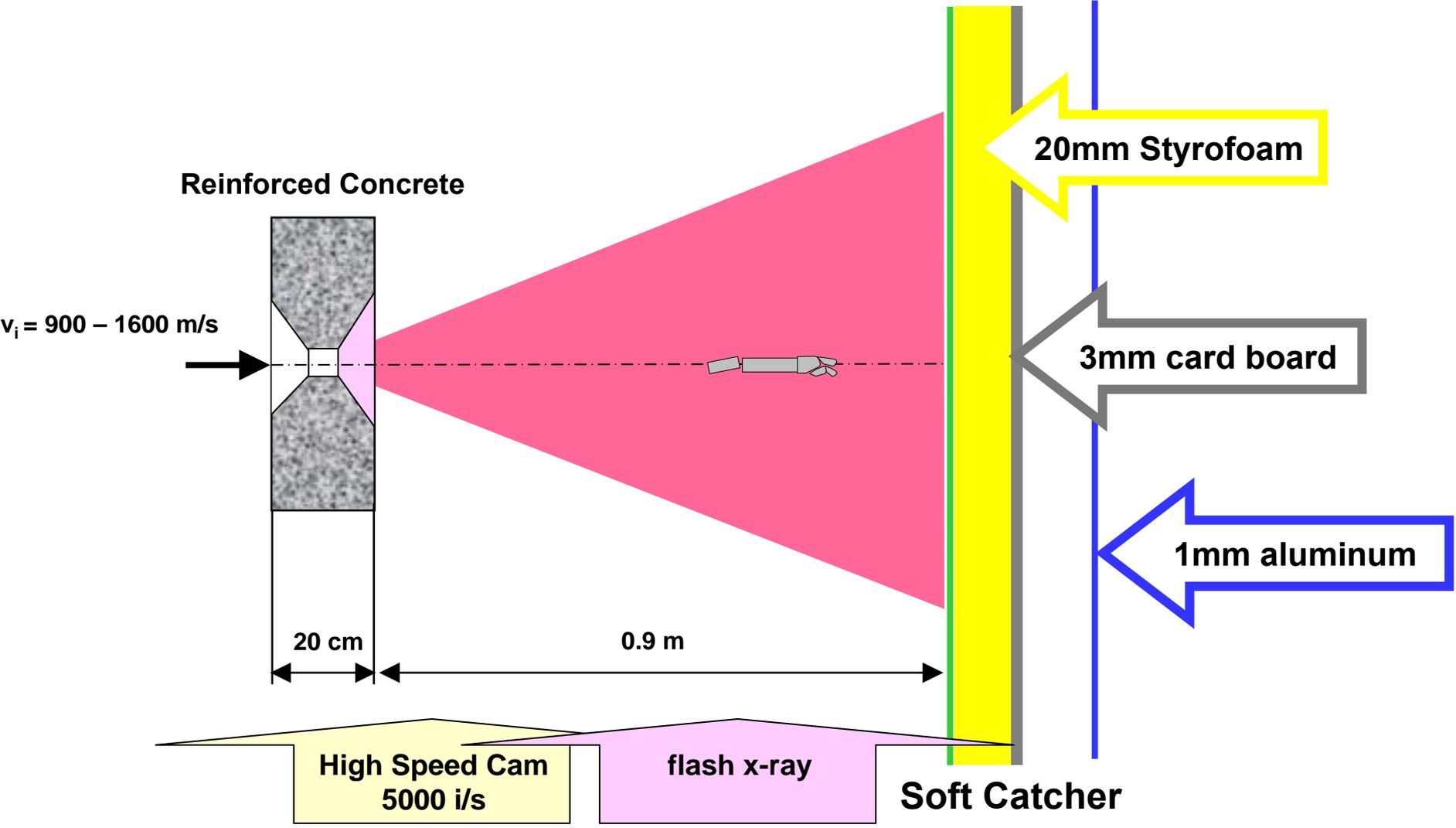


**325 kg Cement +
153 kg Water**

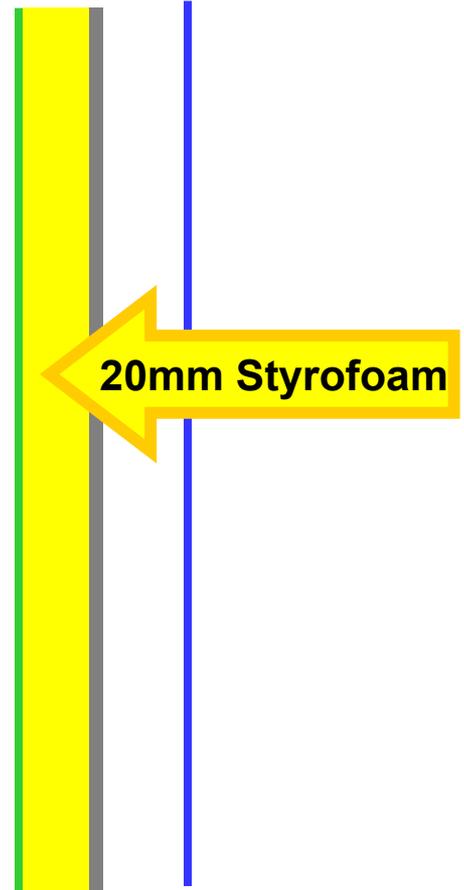
Concrete wall (dim)



Experimental set-up

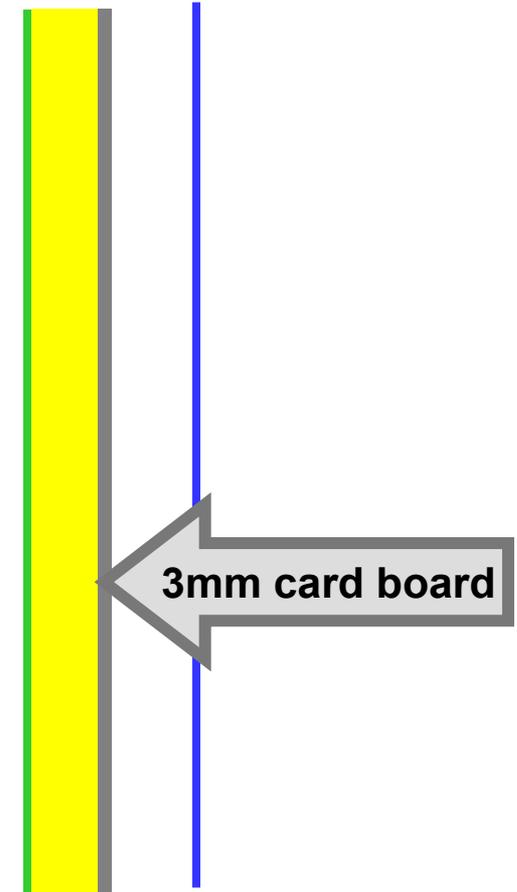
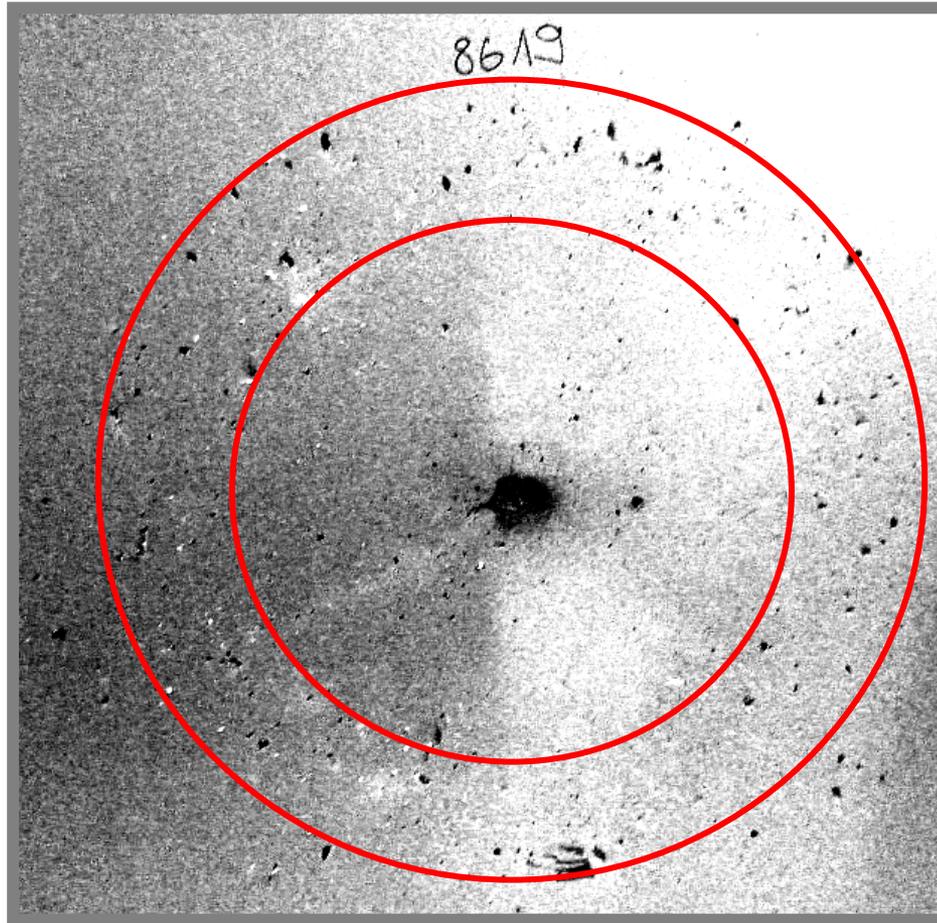


Soft catcher (1)



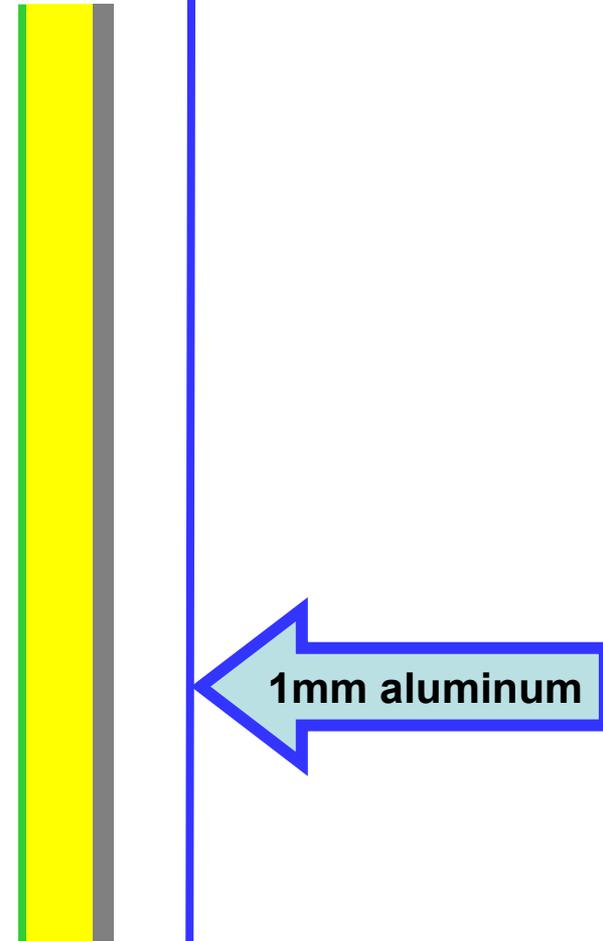
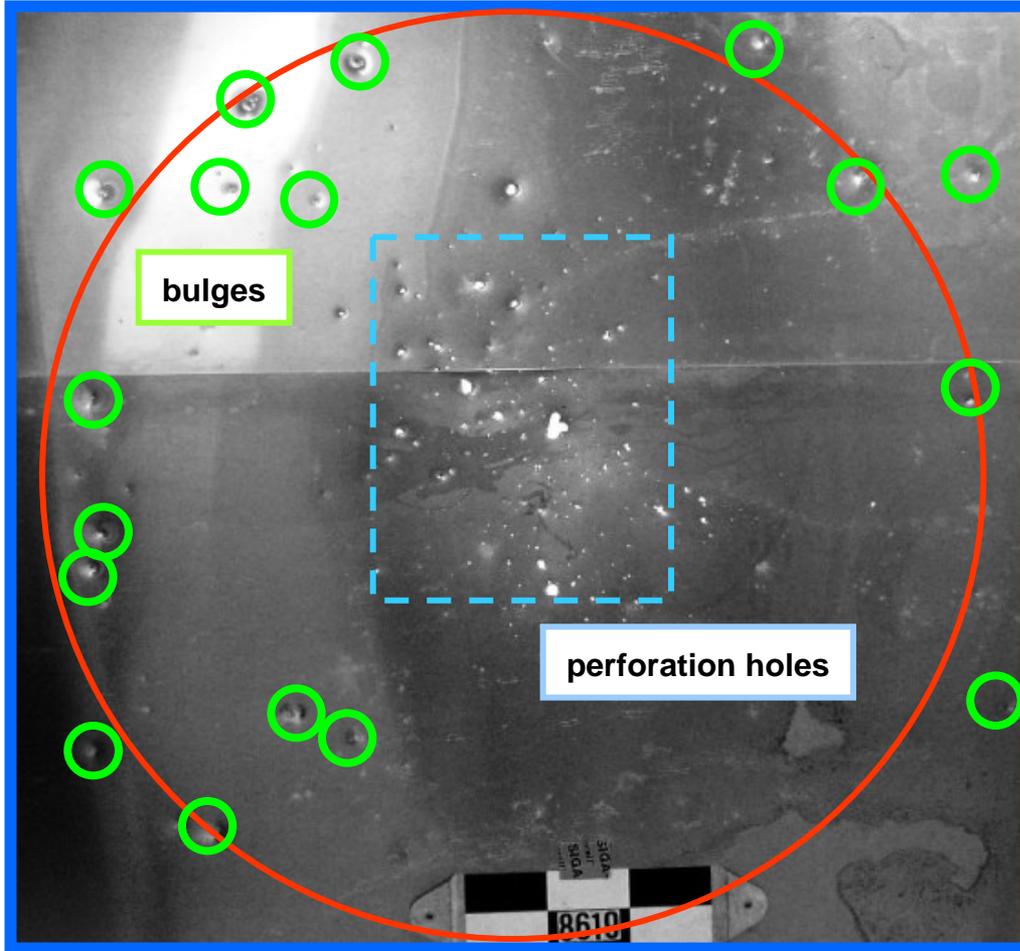
- Small pebbles and concrete lumps were stopped
- Mass of stopped fragments is only 5 % of the total crater mass

Soft catcher (2)



Perforations were registered, mainly caused by pebbles (in the ring)

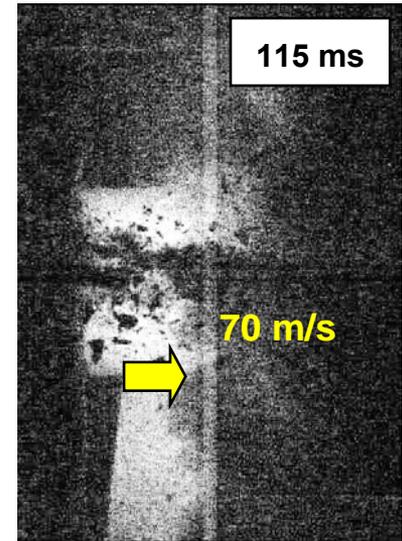
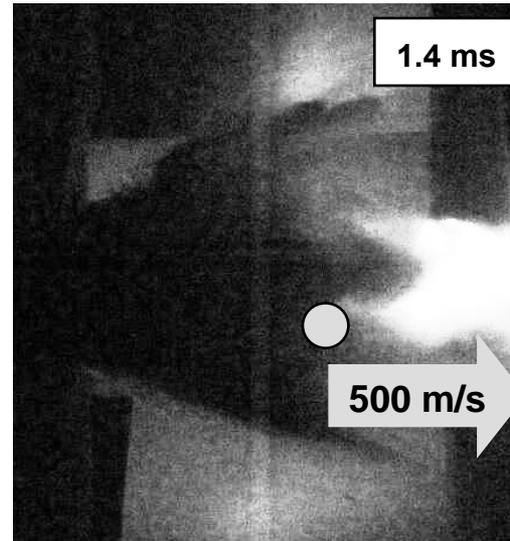
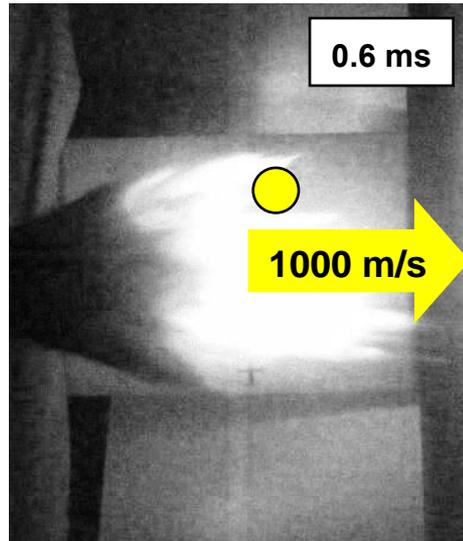
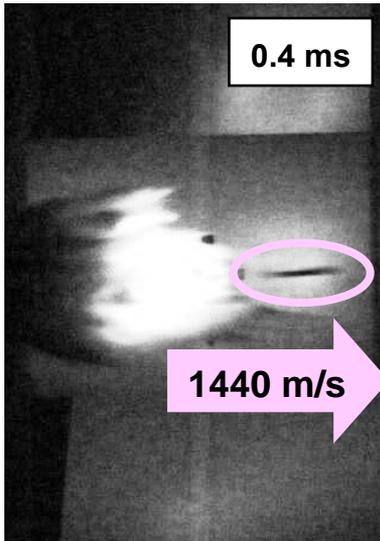
Soft catcher (3)



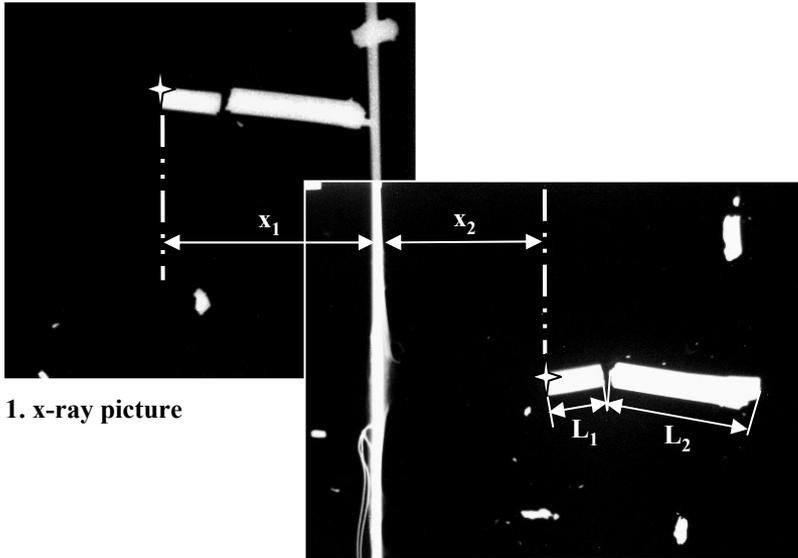
- No perforations of concrete fragments could be observed
- only perforations of projectile fragments

High speed recordings

Impact velocity of model projectile: $v_i = 1600$ m/s



x-ray pictures



1. x-ray picture

2. x-ray picture

Residual velocity of projectile

$$v_r = \frac{x_1 + x_2}{\Delta t}$$

Residual length of projectile

$$L_r = L_1 + L_2$$

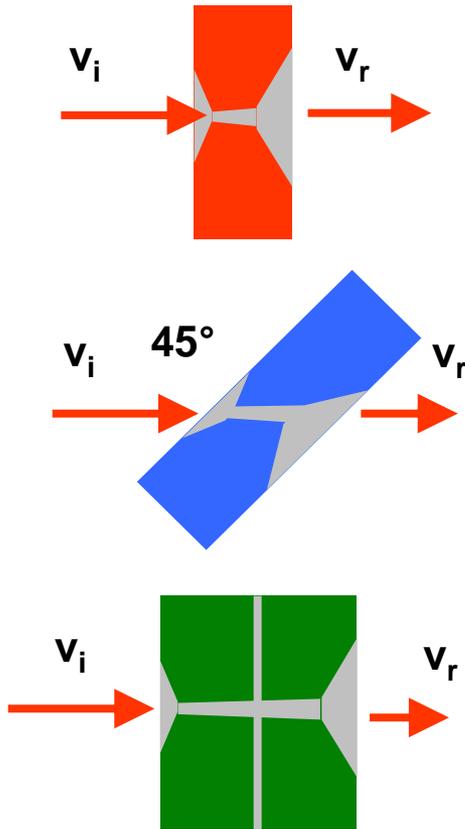
Empirical Formulas

“Perforation of Concrete Targets by an eroding Tungsten-alloy Rod“
by Lampert and Jeanquartier

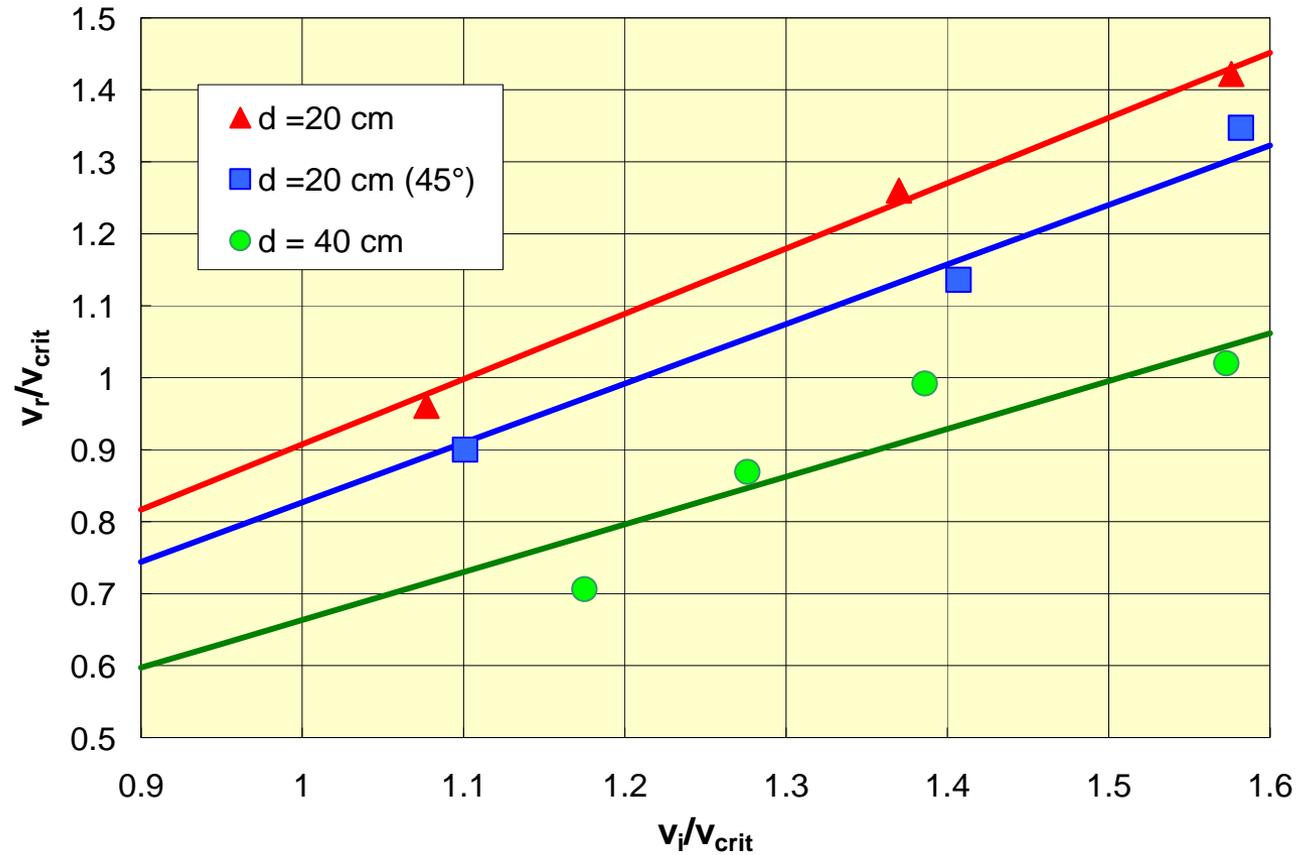
$$v_r = \left(1 - k_1 \cdot d^{k_2}\right) \cdot v_i$$

$$L_r = L_0 \cdot \left(1 - k_3 \cdot d \cdot \exp\left\{-\left(\frac{1 + \frac{k_4}{d}}{\frac{v_i}{v_{crit}}}\right)^{d \cdot k_5}\right\}\right)$$

Residual velocity of projectile

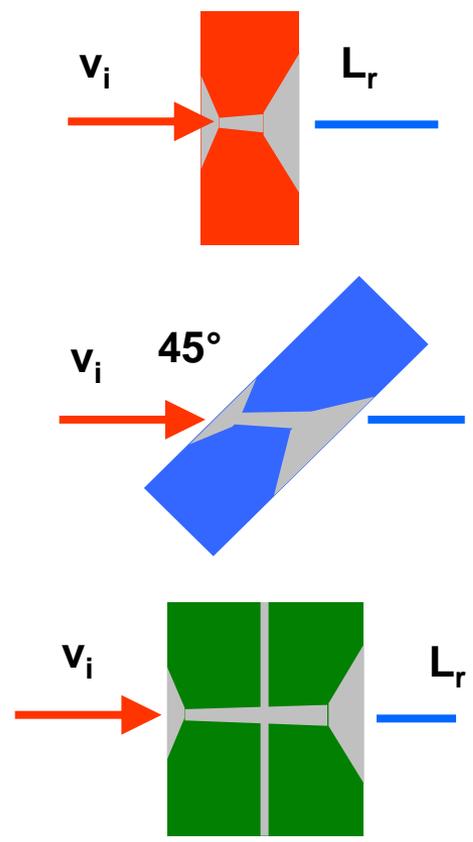


Normalized residual velocity versus normalized impact velocity

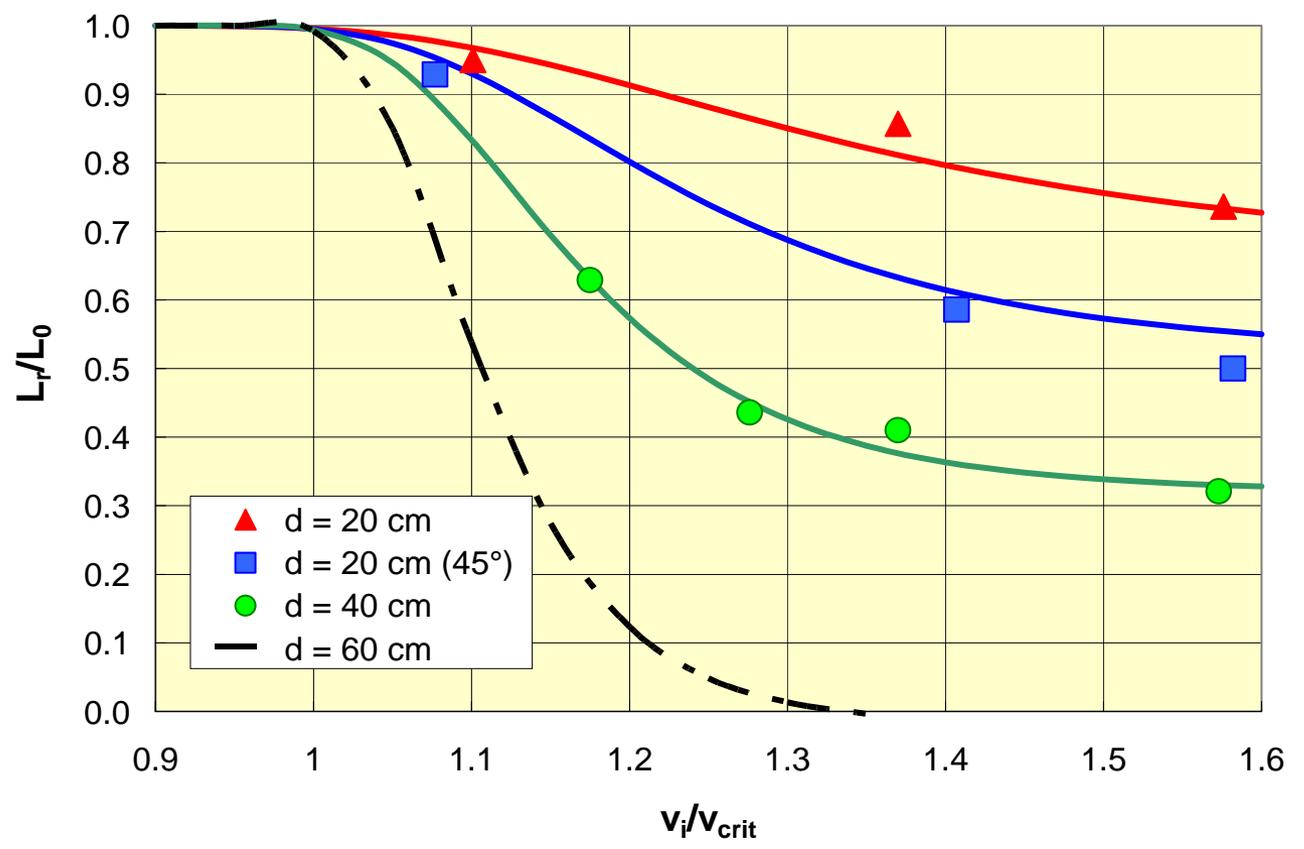


$v_{crit} = 1000$ m/s (determined by experiments)

Residual length of projectile

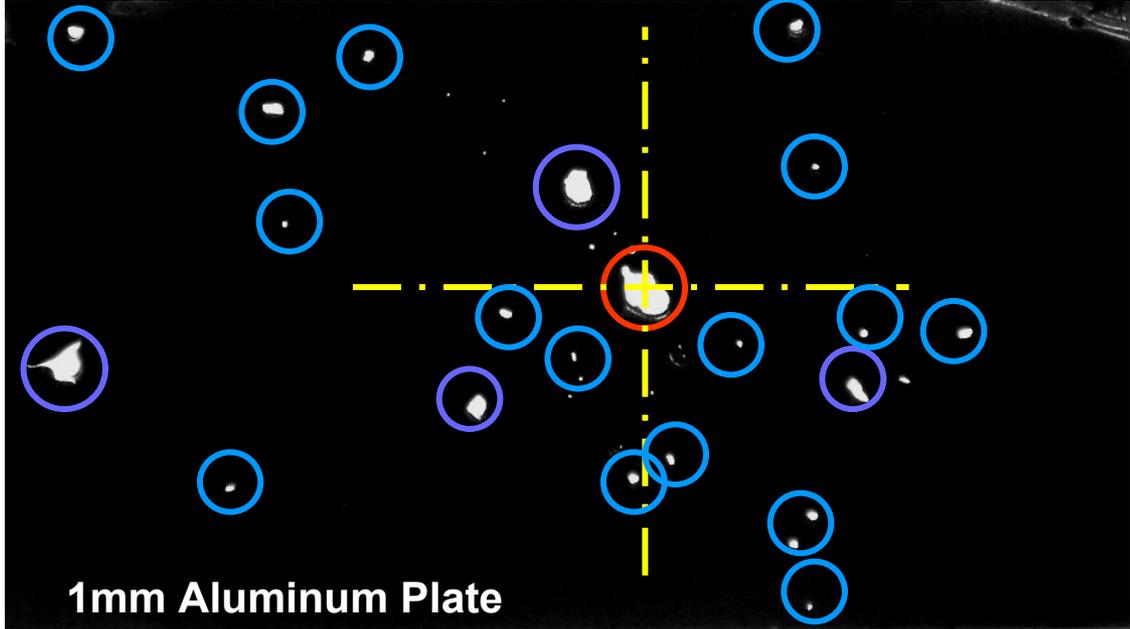
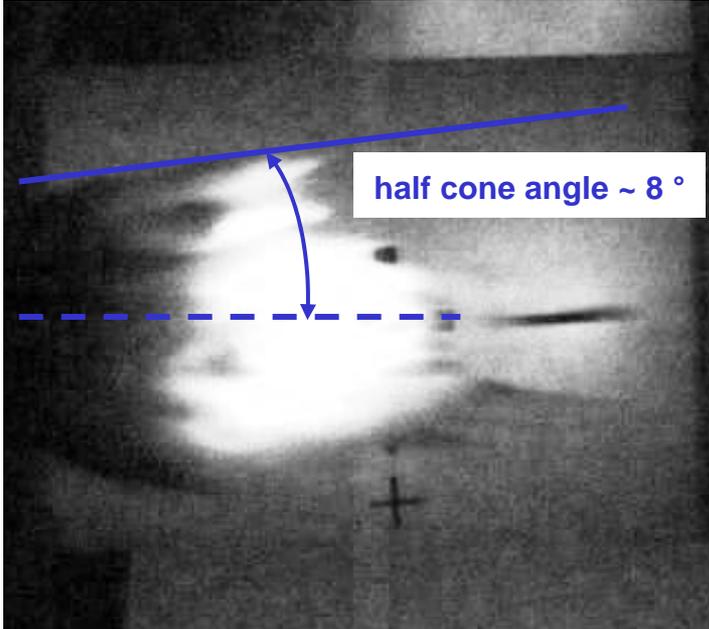


Normalized residual length versus normalized impact velocity



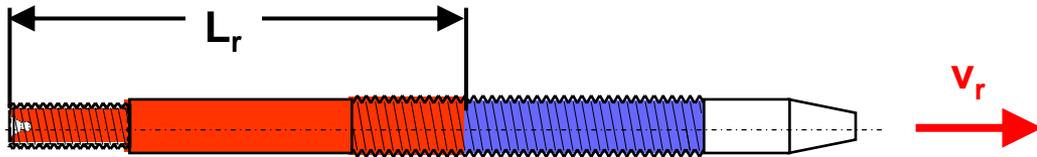
$v_{crit} = 1000 \text{ m/s}$ (determined by experiments)

Fragments of projectile



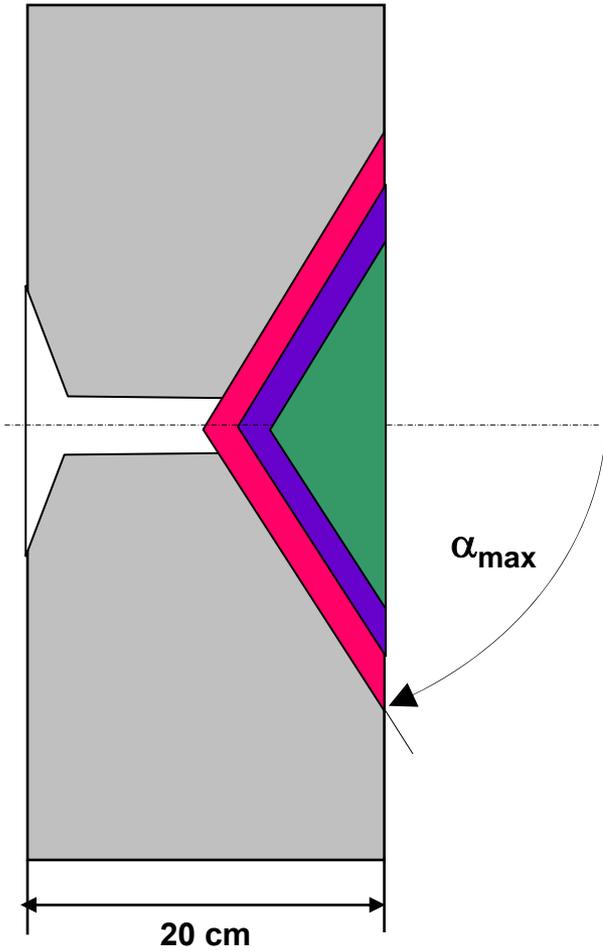
Residual Projectile

Projectile Fragments

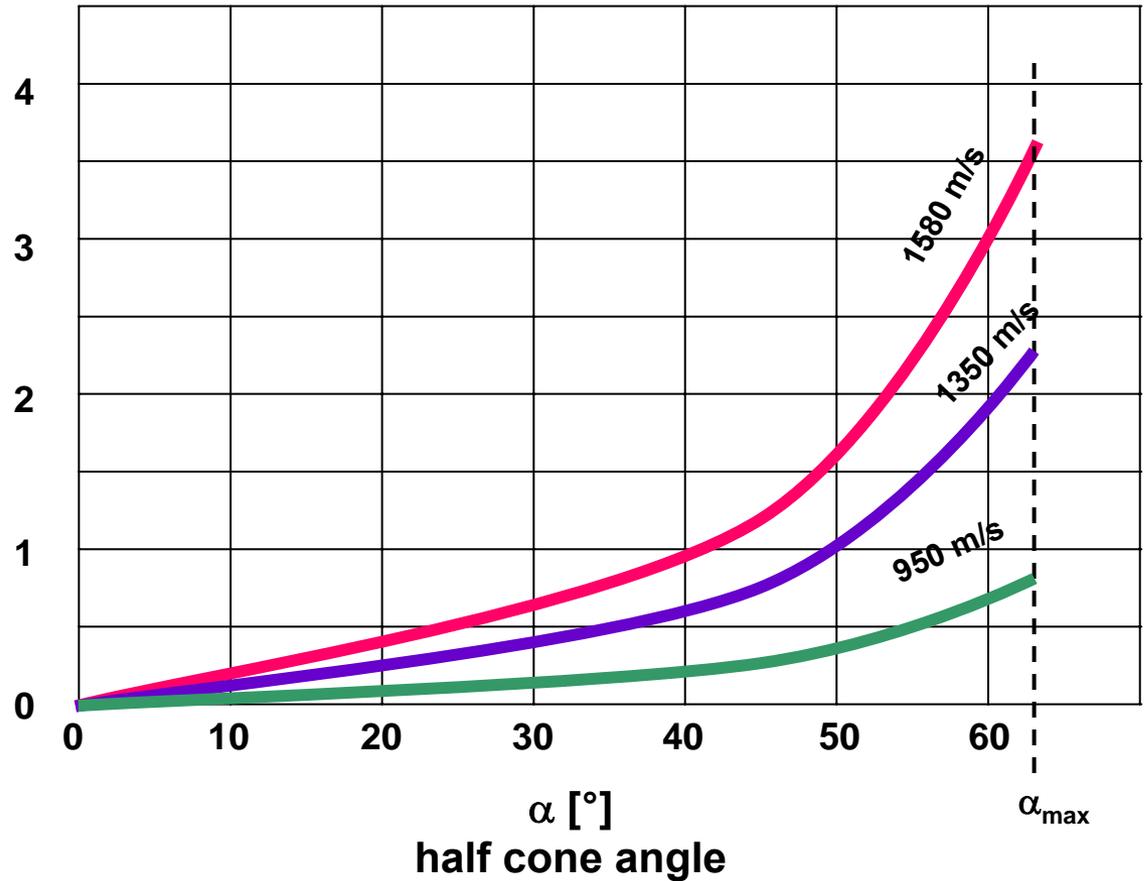




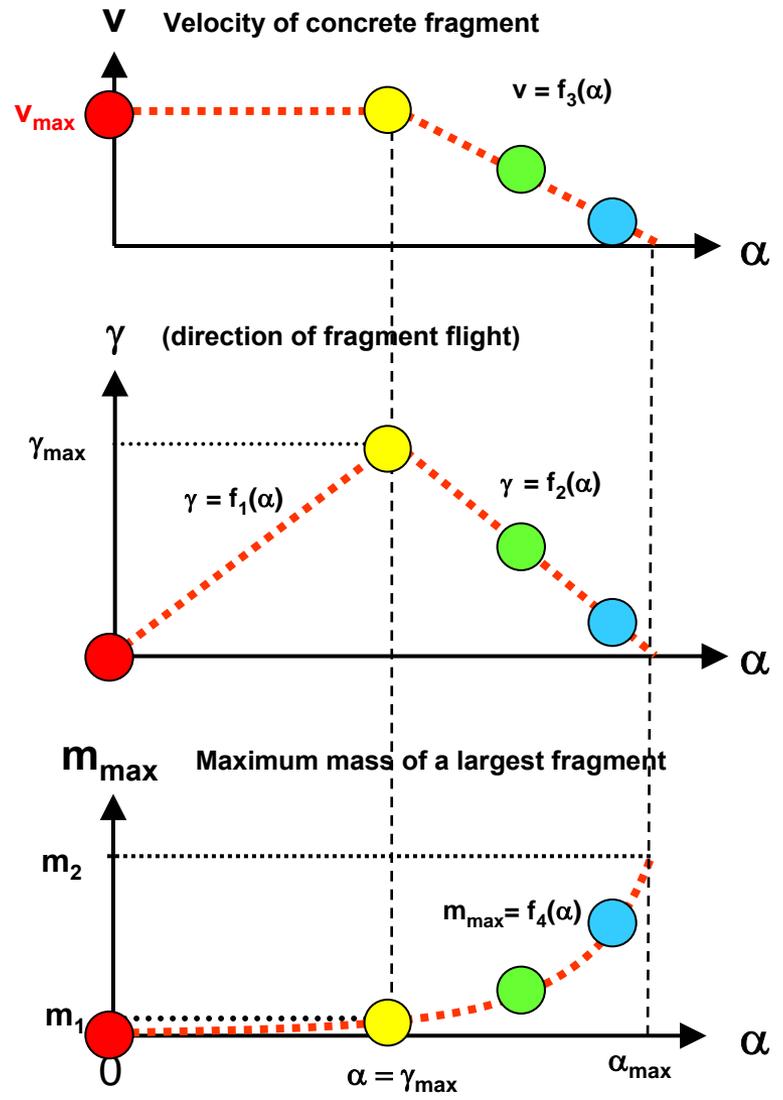
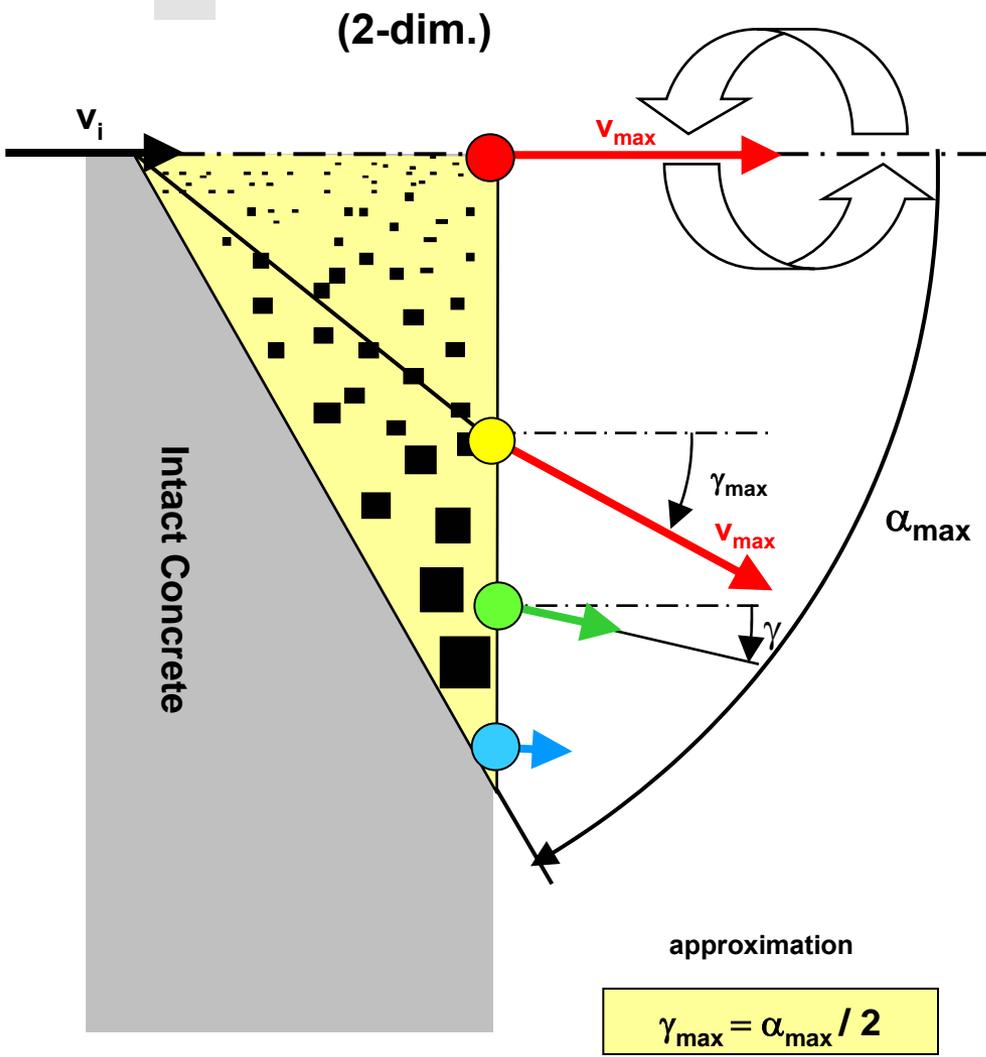
Excavation crater



Cumulative Mass (cone) [kg]



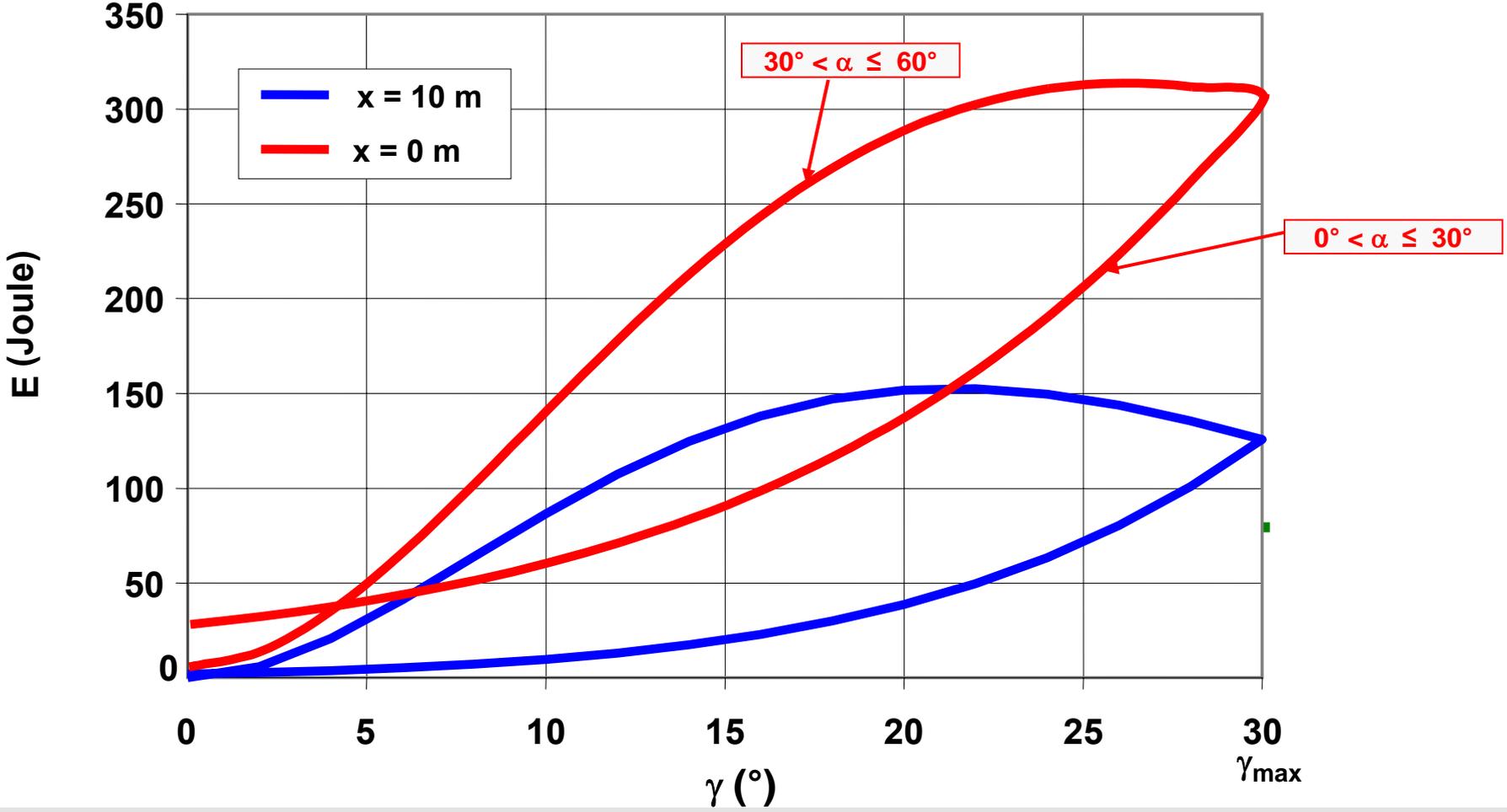
Concrete fragment model



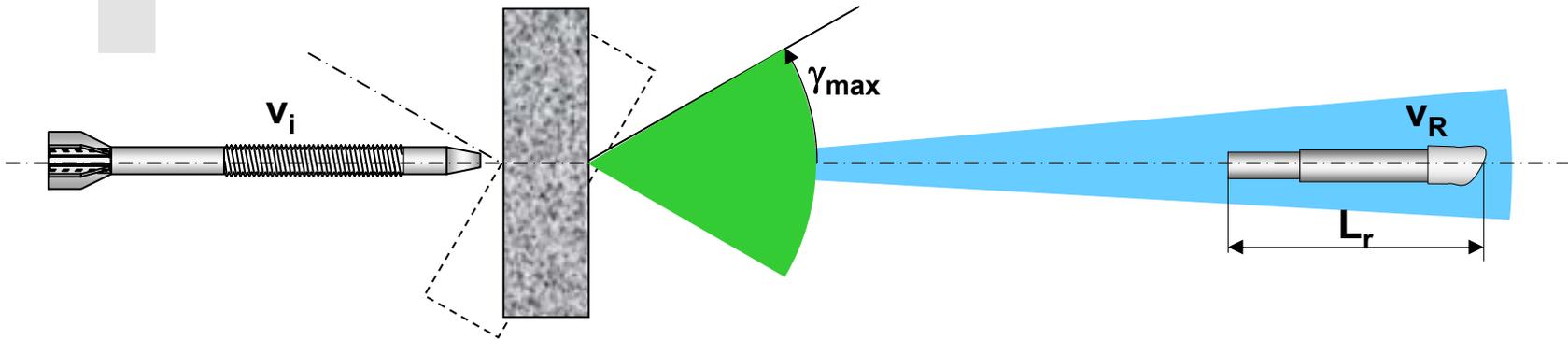
Example

Impact velocity: $v_i = 1350$ m/s
 → $v_r = 1230$ m/s
 → $L_r = 0.83 \cdot L_0$
 → $v_{max} = 1/3 \cdot v_r = 410$ m/s

Maximum possible Energy of a single fragment depending on angle γ



Summary



Residual Projectile with enormous perforation potential

and the remaining fragments of projectile (half cone angle $\sim 8^\circ$) represent the major threat

**The fastest concrete fragments are small and the biggest fragments are very slow (half cone angle $\sim 30^\circ$)
From energetic point of view the concrete fragment cloud does not represent a dramatic threat for people
But low-energy concrete fragments (unfractured pebbles) are dangerous for an unprotected person
and also dust can affect eyes and respiratory organs**

Thank you