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Physics of Breaking

Martial Artists are always trying to develop techniques that can maximize the amount of damage with the smallest amount of effort and time. They rely heavily on the understanding of body mechanics (Physics) to help them in their endeavors. The concept of breaking put martial artists' abilities to the test. The secret lies in a few simple techniques – generating maximum acceleration, force, and mass, and focusing them to the smallest surface area possible.

The ability to apply the techniques needed for breaking comes from proper training and knowledge. A martial artist begins their training by learning the correct body orientation for an effective punch. Of course, there are many different theories on stance and form; however, most styles of Martial Arts can agree on the basic fundamental aspects of a strike. The first step is the positioning of the body. For an effective punch, the martial artist must utilize the concept of center of mass. Center of mass is the point where the body's mass is concentrated. This point is located about the hip in the human body. This ensures that the striker does not favor one side or the other, maintains stability, and focuses the body's entire mass towards the target. Form dictates that the legs are slightly bent and tilting inward with feet planted on the ground. The force upon impact depends on the mass of the body in motion. Physicist Isaac Newton stated this with his Second Law, the amount of force an object can produce is equal to its mass times

its acceleration (Force = mass x acceleration). By adding bodily momentum, the benefit of maximum mass is achieved without actually adding excess weight that increases the sluggishness of a strike, inertia – the apparent resistance of an object to change.

Once the body is properly oriented, the martial artist must prepare for delivery of the strike. The concept to keep in mind is that the strike must reach maximum acceleration in order to break the concrete slab. Accelerating the fist towards the target in a straight line is the fastest path between two points, thereby reducing the distance. Using the muscles in the legs, the hips, and the upper body (back, shoulder, forearm, wrist, and fist) not only increases the mass but also increases the velocity in a very short amount of time. Just before hitting the target, the body uses the rotational motion of the hips to cause the entire body to turn, the shoulder to extend, and the arm to gain distance accelerating through the target. Tensing all the muscles in the striking arm at the last second ensures that the punch lands solidly instead of deflecting. When breaking, martial artists will tell you to focus your strike a few inches past the target; thus, insuring that no velocity will be lost during the strike.

To ensure that the concrete slab is what ends up breaking, the martial artist will also focus the point of impact to the smallest surface area possible. There are many different types of strikes that a martial artist can choose from. The most common strikes being a hammer fist, shuto (karate chop), ridge hand, and reverse punch. Each of these strikes utilizes a small area of the hand (no greater than 1” x 1”) to maximize the amount of energy per unit surface area that transfers to the slab. Since pressure = force/area, an increased force over a small area is most effective.

To summarize these Martial Art concepts in Physics terms: an increase in mass times an increase in acceleration (Δ velocity/time) equals a massive force. An alternative way of thinking about a strike (mass in motion) is in terms of kinetic energy: the ability to do work by being in motion. In this case, the kinetic energy is a destructive force. The equation for the kinetic energy of a strike is

$$\text{Kinetic Energy} = \tfrac{1}{2}(MV^2)$$

Whenever a force affects the motion of a body, in this case, a concrete slab, the slab undergoes a displacement while the force acts on it. It makes sense if the force required to stop the fist is larger than the strength of the slab, the slab will break. This coincides with Newton's 3rd Law. After the strike makes contact with the target, the target moves from the force of the strike in the same direction.

What does all this really mean? Is it possible to generate enough force with the fist to break a concrete slab? Let us find out!

The Experiment

Clyde Surrett, a certified black belt with the United States Karate Federation, will attempt the actual breaking of a 2" concrete slab using a palm heel strike. The palm heel is formed by bending the wrist and fingers to expose the palm of the hand. The striking surface is the lower palm area (mostly the fleshy part toward the outside of the palm). The strike is excellent for protecting the fingers, knuckles and wrist from injury. Notice the relatively small surface area used in this strike.

To figure out how much mass Clyde can put into the strike I used the following figures on body part mass as a percentage of overall body mass for various parts of the human body by professor of kinesiology Vladimir Zatsiorsky. (Forbes).

Body Part	% of Total Mass (Male)	% of Total Mass (Female)
Head	6.9%	6.7%
Trunk	43.5%	42.6%
Upper Arm	2.7%	2.6%
Forearm	1.7%	1.4%
Hand	0.6%	0.6%
Thigh	14.2%	14.8%
Calf	4.3%	4.8%
Foot	1.4%	1.3%

Clyde is a male weighing approximately 122kg. Using mass from a combination of his fist, upper arm, forearm, and half his trunk would use approximately 27% of his total body mass or 33 kg of body mass to strike.

Below is a graph of the velocity needed by the hand and forearm to break through a board or concrete based on the maximum deflection (McGonagill).

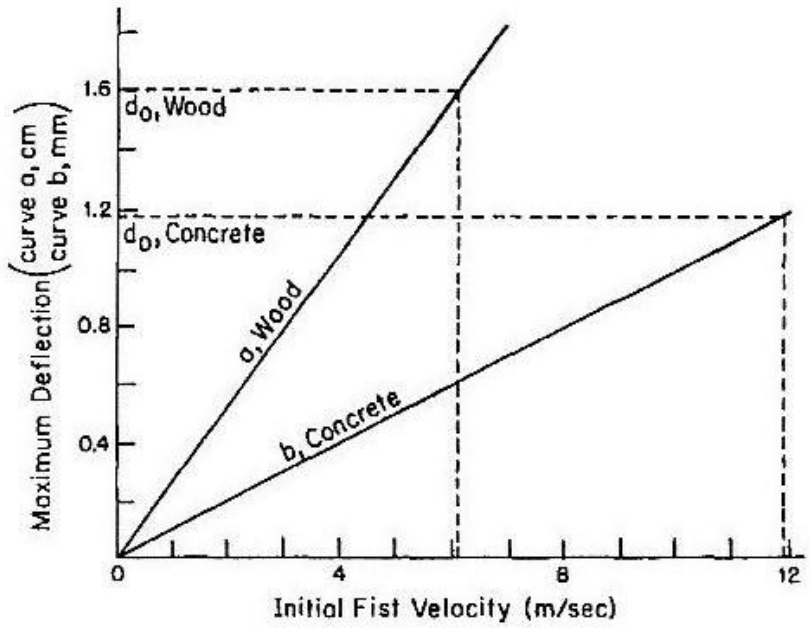

Fig. 9. Maximum deflection of block versus incident fist velocity, predicted by the dynamic model: (a) wood block; (b) concrete block.

The above chart suggests that it will take a fist velocity of at least 12m/s to break concrete. Fortunately, the average black belt can strike at 14m/s. The trick is to make sure that the slab is hit at the peak of this velocity (approx. 80% extension of the arm).

In his article *Breaking Boards*, Curtis Rist, reports that it takes approximately 1,900N to break a 1 ½ "concrete slab. In order to break a 2" concrete slab, a force of approximately 2,500 N is needed. Using our figures (mass = 33kg, velocity = 14m/s) the Kinetic Energy produced will equal 6468 J. KE = ½ (33kg x 14^2m/s), this equals 6468 J or the ability to exert a force of 6468 N over a distance of 1m. The distance between the fist and the slab is approximately 24in (.6m); therefore, the force exerted would equal out to 3881 N. With these calculations, it seems that Clyde will indeed be able to break the slab. Even with these reassuring numbers, Clyde has some reservations about breaking the concrete slab. Let us put Physics to the test and see.

Once again, Physics holds true! “I could feel the block hit me back for just a fraction of a second, [Newton’s 3rd Law] then I didn’t feel anything…the block just broke” (C. Surrett, personal communication, April 17, 2009).

References

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