

REDISIGNING THE REBREAKABLE BOARD

by
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1.0 Introduction

The audience applauds as the black belt candidate finishes his ten-board breaking routine, required of all black belt candidates at the University of California Martial Arts Program at UC Berkeley. Almost always, the administrators of the taekwondo black belt promotional exam reserve the board and brick breaking section for the end of this display of the martial artist's skill, which last for over an hour. The test also includes demonstrations of endurance, countless variety of kicks and combinations of kicks, quick self-defense routines, about ten pre-arranged sets of taekwondo moves, and free sparring, full contact taekwondo fighting restricted by a few rules of the Olympic sport. Still, the breaking section remains as the grand finale.

1.1 Demonstration of Ability

Martial artists value both physical strength and mental concentration. In an external style such as taekwondo, attacks involve strikes with quick impact. So taekwondoists use mostly kicks and punches, as opposed to the grabbing, twisting, throwing, pushing, and locking techniques of other arts. Board breaking shows that a martial artist can strike with good accuracy, speed, and force. Thus taekwondoists take great pride in their board breaking demonstrations.

1.2 Problems with Breaking Real Boards

Board breaks may impress an audience as a display of a human being overpowering great forces of nature manifested in a significantly sized piece of a real tree, a plant whose body can form strong buildings and weapons. However, that chunk of natural power costs up to two US dollars per 12-inch by 12-inch by $\frac{3}{4}$ -inch board, which will, in time, add up to a big sum of money. Besides, the use of real boards contributes its small part towards deforestation. Of course, board breaking martial artists probably are not the lumber industry's biggest consumer, but one can imagine the martial artist's guilt over sending out such a politically incorrect message by wasting a perfectly good piece of wood. Also breaking wood can leave all sorts of splinter and debris, which could eventually cause some discomfort to martial artists' bare feet if not properly disposed. But since the visual and audio effects of a wooden board cracking in half, throughout the whole thickness of its center, impresses the audience so well, wooden boards probably will always survive as the mainstay of board breaking demonstrations. Still perhaps for unobserved practice, martial artists should consider the advantages of artificial breaking boards. And manufacturers should consider further researching this idea.

This paper will discuss what engineers have already achieved in this field and what an engineer must consider in an attempt to design a rebreakable board.

2.0 Available Alternatives

Currently, martial artists have at least two unique commercially available options.

Figure 1. Macho's Version of the Rebreakable Board¹

2.1 Macho's "Ultimate" Martial Arts Board

Macho, a popular brand of martial arts training equipment, sells three rebreakable boards manufactured by The "Ultimate" Martial Arts Board (The UMAB), a Southern California business.² Each of their products consists of a nominally 10-inch by 12-inch nylon contraption (actually a little smaller, 9 $\frac{3}{4}$ inches by 11 $\frac{3}{4}$ inches). The entire setup breaks down into two pieces of about six-inches by ten-inches. The breakable edge of each piece has a series of pegs sticking out, which connect into complementary slots between the pegs of the other piece. The pegs at each end of the series are only $\frac{1}{2}$ inch long, while the remaining pegs have a $\frac{7}{8}$ -inch length. Upon impact, the hollow pegs elastically deform, reduce in diameter, and squeeze out of $\frac{1}{4}$ -inch by 1-inch holes in the slots on the back of the board. The manufacturers provide rubber grips on the back for easier holding and a board stand for storing the board in a proud display.

The UMAB produces three boards of different strengths: "easy," "average," and "strong." The consumer can visually differentiate the three strengths by looking at the color of the rubber grips: Black refers to a "Strong Board," green to a "Average Board," and tan to an "Easy Board." On the "Strong Board," the $\frac{3}{8}$ -inch-diameter pegs are spaced a $\frac{1}{2}$ inch apart. Though, the only available specimen for close inspection was a "Strong Board," the manufacturers probably vary the rated strength of the boards by adjusting the number of pegs. They suggest that the user can decrease the board's strength by misaligning the pegs, decreasing the actual number of pegs the martial artist must squeeze out. According to Macho, the "Easy Board" has less strength than one

¹ From the Macho Internet Page at <http://www.macho.com>

² The "Ultimate" Martial Arts Board, 125 N. Glover St., Chula Vista, CA 91910, Telephone: (619) 476-8660

normal board, the “Average Board” has the strength of one and one-half boards, and the “Strong Board” has the strength of two and one-half boards. During experimentation, the “Strong Board” required a considerably more powerful strike to break than the “Easy Board.” Taekwondoists joked about the ease with which the “Easy Board” broke. The Macho Rebreakable Boards retail from \$29.99 to \$34.95, but usually within the lower end of that spectrum.

Figure 3. A Photo of the “BREAK-UP Board”³

2.2 The “BREAK-UP” Board

System Analysis Corporation of Massachusetts sells their “BREAK-UP” rebreakable board at a retail price of \$34.95, a higher price for a bigger product.⁴ The two pieces of the “BREAK-UP” slide together to form a 11-¼-inch square piece of high density polyethylene, held together by the configuration in Figure 4, which remains consistent in shape along the whole length of the joint. The two halves disjoin upon a solid, direct impact to the center of the board. The edges elastically deform, slip, and pop apart. With its size and weight, the completely solid “BREAK-UP” board much more resembles a real wooden board than the previous product with its hollow design.

Figure 4. The Cross-Section of the Joint Edge of the “BREAK-UP” Board

(The circular areas of 7/8-inch diameter slip out of their slots as the slots elastically deform upon impact.)

³ From the Asian World of Martial Arts Internet Page at <http://www.awma.com>

⁴ System Analysis Corporation, Liberty Rd., Boxboro, MA 01719

2.3 Problems with Current Designs

Though undoubtedly brilliant inventions, these current designs still have their imperfections. The Macho board lacks reality in its size, shape, and weight. Surveyed martial artists prefer the “BREAK-UP” board. But the “BREAK-UP” lacks the useful rubber grips, which the Macho board provides, and can more easily slip out of the board holder’s hands, especially since “BREAK-UP” has a slippery surface. The polyethylene material also present the problem of plastic deformation. The well-used specimen showed evidence of great permanent, plastic deformation as the joint no longer held the two halves as tightly together as it originally did. As the “BREAK-UP” has a solid construction, like a real board, it has at least the weight of a real board if not more. The sharp corners of the board can injury someone during the break. Fortunately, the lighter Macho board has taken the extra precaution of having rounded corners. Both designs limit the kinds of breaks the martial artist can perform. They do not allow him or her to perform multiple-board breaks as a second board behind the first one will not allow the joint to pop open. Though an ideal break splits the board in the middle, sometimes a real board can break along the grain in a different location. Both of these artificial boards only break in the middle. Thus these rebreakable boards provide a little difficulty when used for speed breaks, where the holder supports only one edge of the board while the striker may need to sacrifice accuracy for speed. These problems leave engineers with more work to do.

3.0 Further Exploration

The first step for the engineer involves analyzing the mechanics of the board break.

3.1 Dr. Dennis Lieu's Research on Taekwondo Kicks

In his article "A Parametric Study of the Thoracic Injury Potential of Basic Taekwondo Kicks," Dr. Dennis Lieu of the Department of Mechanical Engineering at the University of California at Berkeley analyzes taekwondo kicks for the sake of improving safety gear used for the sport.⁵ From his research, he writes: "The average foot velocity at impact was 16 m/s for the swing kick and 9 m/s for the thrust kick. The applied constant force was 0.9 kN and 2 kN for the swing and thrust kicks, respectively..." In this article, "swing kick" refers to a roundhouse kick, and "thrust kick" refers to a sidekick. Dr. Lieu's research gives most of the external dynamics needed to design the artificial board if the engineer assumes the martial artist using the board will use similar strikes.

3.2 Mechanics of the Break

Now the engineer must continue and further analyze the external as well as the internal dynamics of the break. The martial artist knows from experience that the board will always break easier in the direction of the grain, and materials engineers, through tests, have shown that wood always has this difference between the strength along the grain and the strength across the grain.⁶ The strike that breaks the board cannot be so easily represented as a constant force resting on the surface of the board, making the board bend more and more until it breaks. Instead, the force contacts the board very

⁵ Chuang, T.Y., Lieu, D.K., "A Parametric Study of the Thoracic Injury Potential of Basic Taekwondo Kicks," *Journal of Biomechanical Engineering: Transactions of the ASME*, Vol. 113, pp. 346-351, August 1992.

⁶ Bewer, Michael B., Schniewind, A. P., *Encyclopedia of Material Science and Engineering*, Pergamon Press Ltd., Oxford, England, 1986.

instantaneously and quickly snaps the board in two. Engineers describe this type of fracture as brittle fracture, as opposed to ductile fracture, in which a material stretches a good deal before yielding. So to summarize the break, the engineer can say that the board experiences brittle fracture along the grain of the wood due to dynamic impact loading.

Figure 5. A simple free Body Diagram of the Situation

(The force will be distributed over the striking surface's area, which varies with the type of strike.

3.3 Materials Involved

After determining exactly which stresses affect the wood board and cause it to fail, the engineer should now determine how different materials will handle those stresses.

3.3.1 Material Properties of Wood

Martial artists at the University of California's Martial Arts Program use #3 Knotty Pine for their board breaks.⁷ Engineering publications mention nothing about "#3 Knotty Pine," but Western White Pine probably has similar characteristics. According to *Marks' Standard Handbook of Mechanical Engineering*, a "2 x 2" piece of Western

⁷ Often UCMAP martial artists purchase their boards from Ashby Lumber Company located at 824 Ashby Ave. in Berkeley, California. This store refers to the wood as #3 Knotty Pine but conveniently call a twelve-inch by twelve-inch by $\frac{3}{4}$ -inch board, of this wood, a "karate board."

White Pine fails by impact bending when a 50-lb hammer is dropped on it from a height of 23 inches, an interesting fact which may help an engineer solve this dynamic impact problem.⁸ In static bending, the wood has a modulus of elasticity of 1,360 ksi.⁹ The strengths of woods greatly depend on the temperature and moisture content of the wood. As the engineers do not consider the 12-inch by 12-inch by $\frac{3}{4}$ -inch pine board useful for most construction, documentation regarding its property is scarce. An engineer designing a rebreakable board will need to conduct extensive laboratory research to obtain the necessary numbers.

3.3.2 Properties of the Artificial Materials

Though the actual wood board fails by fracture, the rebreakable board should resist fracture and plastic deformation. The only failure should be the macro-structural failure of the joint mechanism. Thus the artificial material needs to withstand the impact of the martial artist's strikes. It also needs to provide a means for the two halves to disjoin through elastic deformation. And of course, the material must not cost too much. Nylon has these properties and a notably low coefficient of friction which allows for the Macho board's pegs to slide out really well. The material of the "BREAK-UP" board has its advantages as manufacturers can purchase polyethylene at a very low cost. By the completely solid construction of the "BREAK-UP" board, one can see that the material could not cost too much. However, the polyethylene cannot withstand harder hits and permanently deforms upon a sufficiently potent strike, an undesired quality. The nylon Macho board boasts survival of 5,000 break stress-test. If the board begins to fracture or plastically deform in testing, then the engineer should modify it.

⁸ Baumeister, Theodore et al, *Marks' Standard Handbook for Mechanical Engineers*, McGraw-Hill, Inc., New York City, NY, 1978.

⁹ Baumeister, p.6-124.

The nylon material of the Macho board will not plastically deform as easily, but a board utilizing the form of the “BREAK-UP” might not function properly if it were constructed from nylon. This version of the board might not elastically bend enough to allow the circular areas to pop out of their slots. But as the shape and weight of the “BREAK-UP” board better resembles a real board, perhaps a board should be constructed with the size specifications of the “BREAK-UP,” with its solid build, using the joint mechanism of the Macho Board.

4.0 Conclusion

The existing rebreakable boards work upon the principle of two pieces elastically bending upon impact and popping apart. The two designs discussed do their jobs fairly well but not perfectly. Designing a new rebreakable board involves much research, and the resources are not always easily found. Perhaps with more laboratory testing, engineers can design a better rebreakable board. Engineers pondering the predicament and the future of avoiding wood for board breaks should not limit themselves to the idea of multiple usage. Perhaps the future will reveal a solution in a cheap, recyclable material which has the same brittle fracture-related properties of wood. Until a revolutionary idea arises, martial artists will need to settle for wooden boards and the presently commercially available rebreakable boards. In any case, the Asian martial arts have always respected old traditions, including the spectacular display of the martial artist’s dominance over one of nature’s best construction materials, real wood.

References

1. Macho Internet Page at <http://www.macho.com>
2. Asian World of Martial Arts Internet Page at <http://www.awma.com>
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5. Baumeister, Theodore et al, *Marks' Standard Handbook for Mechanical Engineers*, McGraw-Hill, Inc., New York City, NY, 1978.