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BOOGIE BOARD FLEXIBILITY

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ABSTRACT

The flexibility of a closed cell polyethylene boogie board provides a man-machine interaction that differs qualitatively from the relatively rigid surfboard. Under the action of gravity and buoyancy forces, the closed cell polyethylene boogie board exhibits very large deflections that effect the shape of its bottom control surface. This paper demonstrates how hand placement provides an additional degree of freedom for the surfer.

INTRODUCTION

Wave-riding was traditionally undertaken with stiff buoyant surfboards or paipo boards which are manipulated as rigid bodies to harness the surf. Surfboards are narrow boards that vary from six to twelve feet in length and usually have one or two fins near their trailing edge (Ref. 1). They have a somewhat rounded leading edge and are lengthwise concave upward. This longitudinal profile is called "rocker" (Ref. 2). The ski-nose shape at the leading edge aids in water entry and prevents the nose from submerging. Tail rocker, when used, permits easier turning; nose rocker is greater than tail rocker. Surfboards are ridden in the prone, kneeling or standing position.

Paipo boards are flat wooden boards no more than 55 inches long (Ref. 3). Current paipo boards are carved out of half-inch thick marine plywood and are then painted with fiberglass. Most riders lie on their bellies, while some ride on their knees.

On July 7, 1971, Tom Morey revolutionized the field of surfing with a flexible, nearly flat polyethylene foam body board which became known as a boogie board (Ref. 4). The board is usually ridden by grasping the side edges and supporting the torso in different orientations. Because of the board's flexibility, the control surface, the bottom of the board, can be radically altered by changing the board's loading profile. It will be shown experimentally and analytically that the nose rocker (leading edge deflection) can assume upward, zero, or downward attitudes.

GENERAL DEFLECTION ANALYSIS

The flexibility of a boogie board may be explored by treating it as a linearly elastic straight prismatic beam. The deflection of such beams may be determined by various classic methods described by Gere and Timoshenko (Ref. 5).

The two-point loading scenario illustrated in Fig. 1 shows the surfer's torso loading the tail of a boogie board while the hands load a section interior to the span. A free-body

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Figure 1 - Two-Point Loading / Torso and Hands

diagram of a partially submerged boogie board of length L is shown in Fig. 2 where P represents the load applied by the surfer's hands at a station located a distance k in back of the leading edge. The load Q reflects the force imposed on the board by the surfer's torso. The total downward gravity load $P+Q$ is equal to the total upward buoyancy force WL.

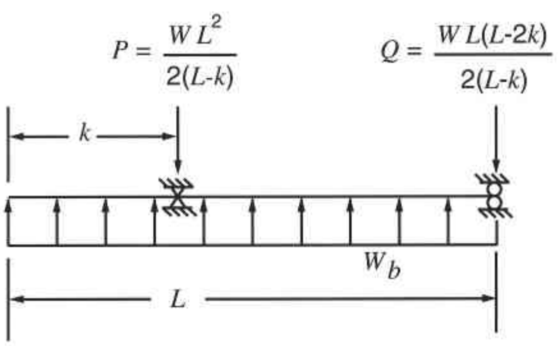

Fig. 2a - Free - Body Diagram

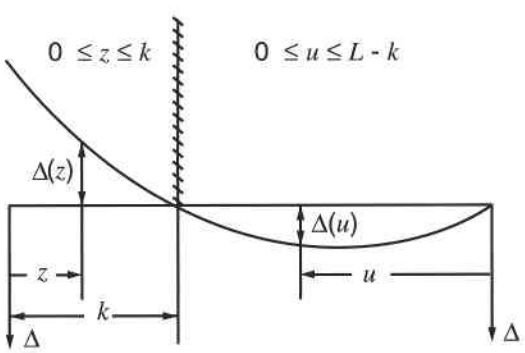

Fig. 2b - Definition of Terms

Figure 2 - Two-Point Loading / Submerged Boogie Board

Using the terms defined in Fig. 2b, Eqs. 1 describe the deflected shape of the left and right portions of the boogie board:

$0 \le z \le k$:

$$\Delta(z) = \frac{W_b L^4}{24EI}\left\{\left(\frac{k}{L}\right)\left[1-3\left(\frac{k}{L}\right)-\left(\frac{k}{L}\right)^2\right] - \left(\frac{z}{L}\right)\left[1-3\left(\frac{k}{L}\right)-\left(\frac{k}{L}\right)^2-\left(\frac{k}{L}\right)^3\right]-\left(\frac{z}{L}\right)^4\right\} \quad \text{Eq.1a}$$

$0 \le u \le (L-k)$:

$$\Delta(u) = \frac{W_b L^4}{24EI}\left\{\left[3\left(\frac{k}{L}\right)-\left(\frac{k}{L}\right)^2-\left(\frac{k}{L}\right)^3-1\right]\left(\frac{u}{L}\right) + 2\left[\frac{1-2\left(\frac{k}{L}\right)}{1-\left(\frac{k}{L}\right)}\right]\left(\frac{u}{L}\right)^3-\left(\frac{u}{L}\right)^4\right\} \quad \text{Eq.1b}$$

where E is the modulus of elasticity of the closed cell foam, W_b is a uniformly distributed buoyant force, and I is the centroidal moment of inertia of the board's cross-section. Equations 1 are plotted in Fig. 3 for $(k/L)=0.25$, 0.30278, and 0.5. The leading edge of the boogie board is deflected upward for $(k/L)=0.5$ and downward for $(k/L)=0.25$. A zero tip deflection occurs when $(k/L)=0.30278$. To see this, set $\Delta(z)=0$ at $z=0$ in Eq. 1a; thus,

$$1-3\left(\frac{k}{L}\right)-\left(\frac{k}{L}\right)^2=0 \quad \text{Eq.2a}$$

or

$$(k/L)=\frac{-3+\sqrt{13}}{2}=0.302776 \quad \text{Eq.2b}$$

In contrast to a surfboard, the nose rocker of a boogie board can be altered by locating the surfer's hands at various distances from the nose.

One of the most popular scenarios in body board surfing has the surfer's chest in contact with the rear of the platform as depicted in Fig. 4 taken from Peninsula Surf (Ref. 6). This condition may be modeled as a partially submerged cantilever subjected to uniformly distributed gravity loads W_g in balance with the buoyancy forces W_b as illustrated in the free-body diagram shown in Fig. 5. For this loading the deflection of the boogie board is given by Eqs. 3:

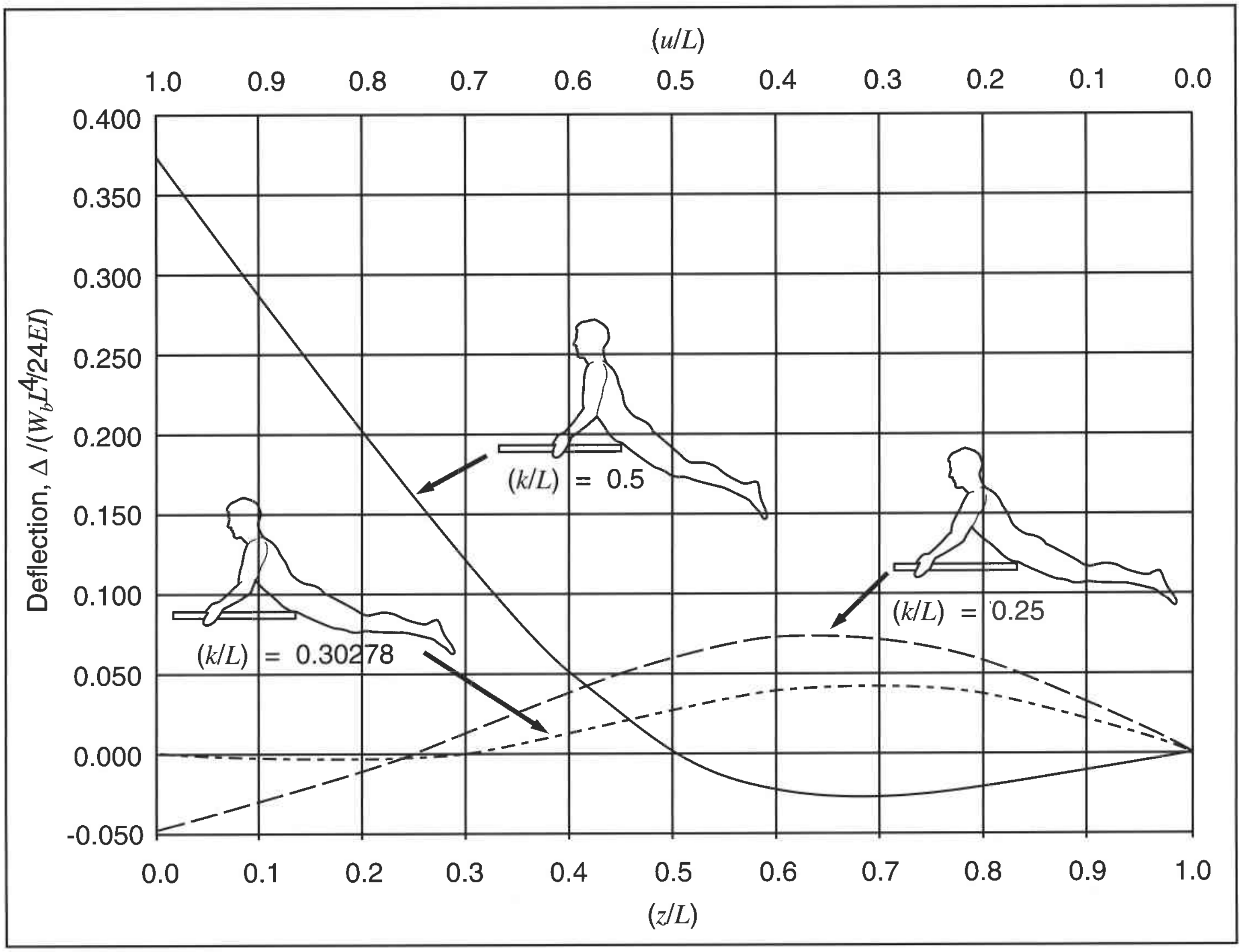

Figure 3 - Deflected Shapes of Boogie Boards Under Two-Point Loading

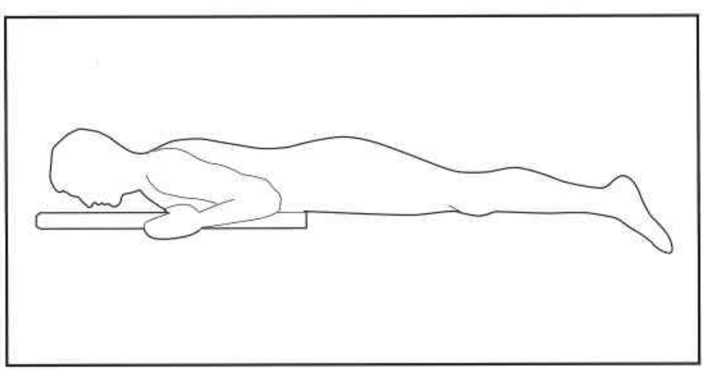

Figure 4 - Chest Riding Scenario

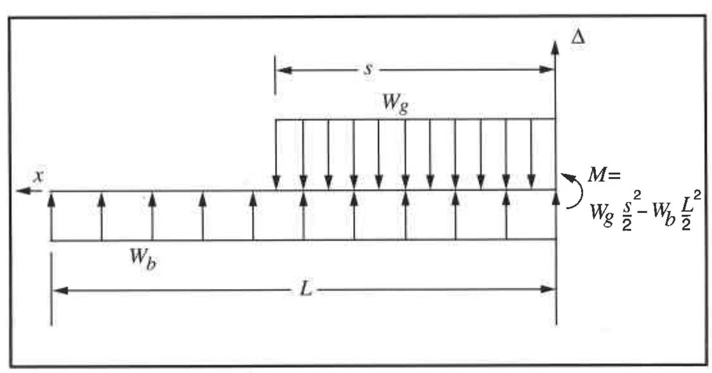

Figure 5 - Free Body Diagram

$0 \le x \le s$:

$$\Delta(x) = \frac{W_b L^4}{24EI}\left(\frac{x}{L}\right)^2 \left\{6\left[1-\left(\frac{s}{L}\right)\right]+\left(\frac{x}{L}\right)^2\left[1-\frac{1}{(s/L)}\right]\right\} \quad \text{Eq.3a}$$

$s \le x \le L$:

$$\Delta(x) = \frac{W_b L^4}{24EI}\left\{\left(\frac{x}{L}\right)^2\left[6-4\left(\frac{x}{L}\right)+\left(\frac{x}{L}\right)^2\right] -\left(\frac{s}{L}\right)^2\left[4\left(\frac{x}{L}\right)-\left(\frac{s}{L}\right)\right]\right\} \quad \text{Eq. 3b}$$

where $W_g s = W_b L$.

Using Eq. 3b, it can be established that the nose of the boogie board can never deflect downward. $\Delta(L)$ becomes

$$\Delta(L) = \frac{W_b L^4}{24EI}\left\{3-\left(\frac{s}{L}\right)^2\left[4-\left(\frac{s}{L}\right)\right]\right\} \ge 0 \quad \text{Eq. 4}$$

since $0 \le (s/L) \le 1$. Further, the nose slope will never face downward. The derivative of $\Delta(x)$ at $x = L$ is given by

$$\left.\frac{d\Delta(x)}{d(x/L)}\right|_{\left(\frac{x}{L}\right)=1} = \frac{W_b L^4}{6EI}\left[1-\left(\frac{s}{L}\right)^2\right] \ge 0 \quad \text{Eq. 5}$$

Equations 3 are plotted in Fig. 6 for various values of (s/L) Observe that the "ski nose" configuration becomes less prominent as the surfer's chest is moved forward on the platform.

BOOGIE BOARD DEFLECTION TESTS

Figure 7 describes the geometry and physical properties of a typical boogie board. This board, which was almost perfectly flat, was submerged in a transparent water tank and held in position by two transverse wood 2x4's located at the tail and at a variable interior station. The resulting

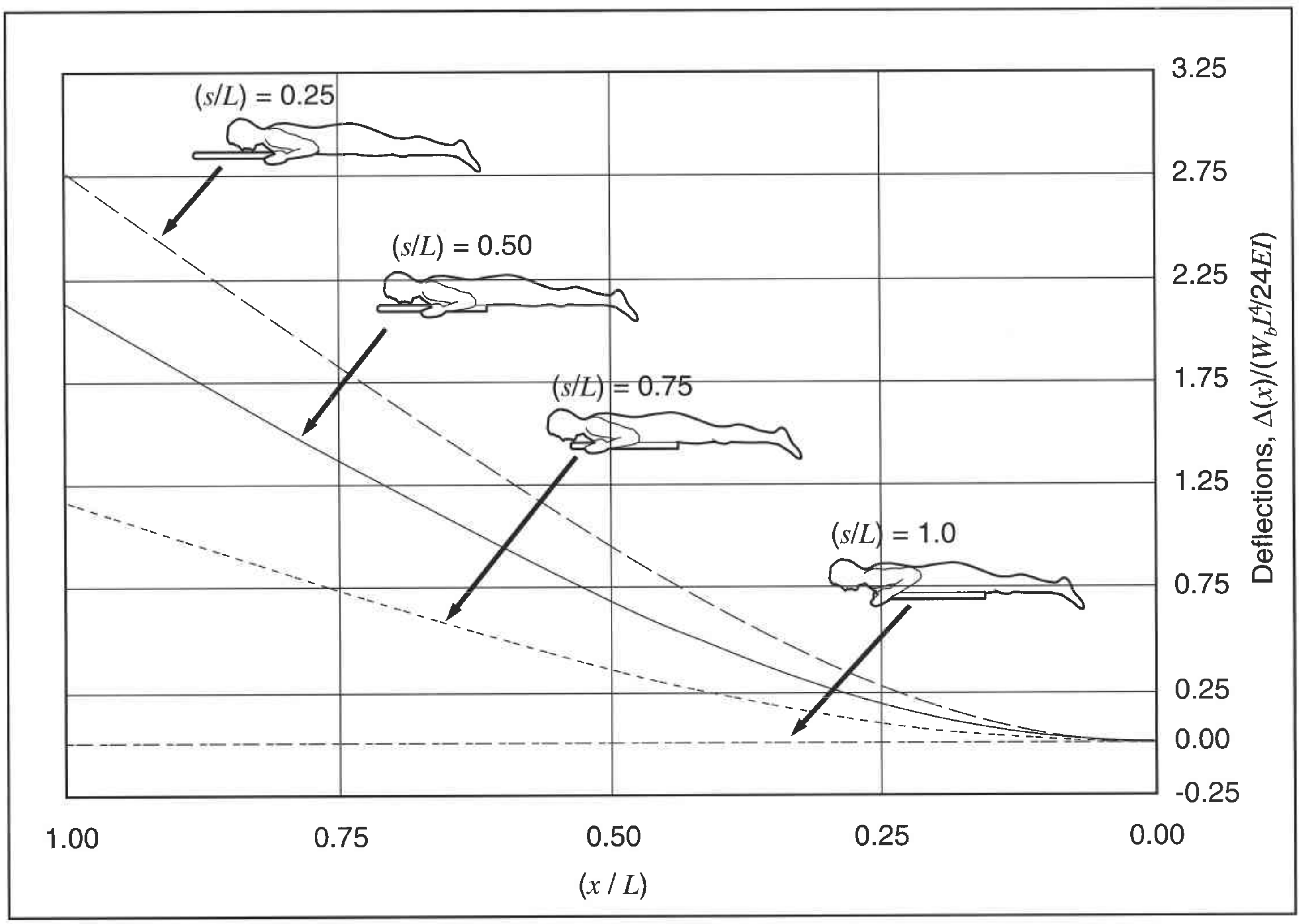

Figure 6 - Deflected Shapes of Prismatic Boogie Boards - Chest Contact Riding Scenarios

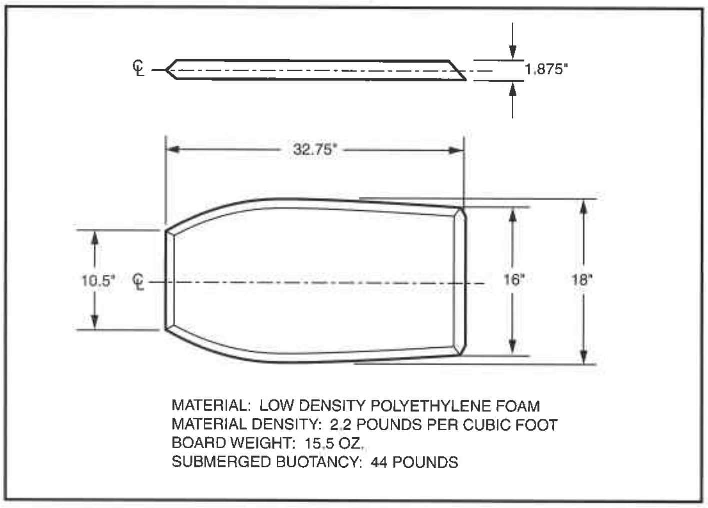

Figure 7 - Boogie Board Test Specimen

deflections of the boogie board, which are displayed in Figs. 8, were photographed through the tank wall for various values of (k/L) where k is measured from the nose of the platform. Even though the test specimen is not prismatic, the deflected shapes are quite similar to those predicted analytically. Note that the nose deflection was found to vanish when $(k/L)=0.32$; the analytical prediction was $(k/L)=0.303$.

DISCUSSION

1. The man-machine interaction associated with surfing is expressed eloquently by Mark Dowd (Ref. 2), "Surfing is a partnership with the pulse of the ocean; it is an interfusion of the surfer and the power of the water."

2. To use surfboards to harness the power of the waves, rigid body manipulation of the stiff platform is the only human interaction available to the surfer. On the other hand, the flexibility of the boogie board provides the surfer with an additional degree of freedom to control the surfing platform. It allows the profile of the control surface, the bottom of the board, to be altered.

3. How the surfer is located on the boogie board produces changes in the shape of the bottom surface. Equations 1 show that the dimensionless parameter (k/L) effects the character of the bottom profile when the surfer adopts the two-point riding scenario. Indeed, the nose rocker can be urged to provide zero, negative, or positive rocker.

4. The magnitude of the gravity loading on a boogie board is ultimately limited by the fully submerged buoyancy. The sample board used in the testing program produced a maximum buoyant force of 44 lbs. A surfer may elect to place less weight on the board. Equations 1 and 3 indicate that the magnitude of the deflections are proportional to the (partial) buoyant forces W_b. The full

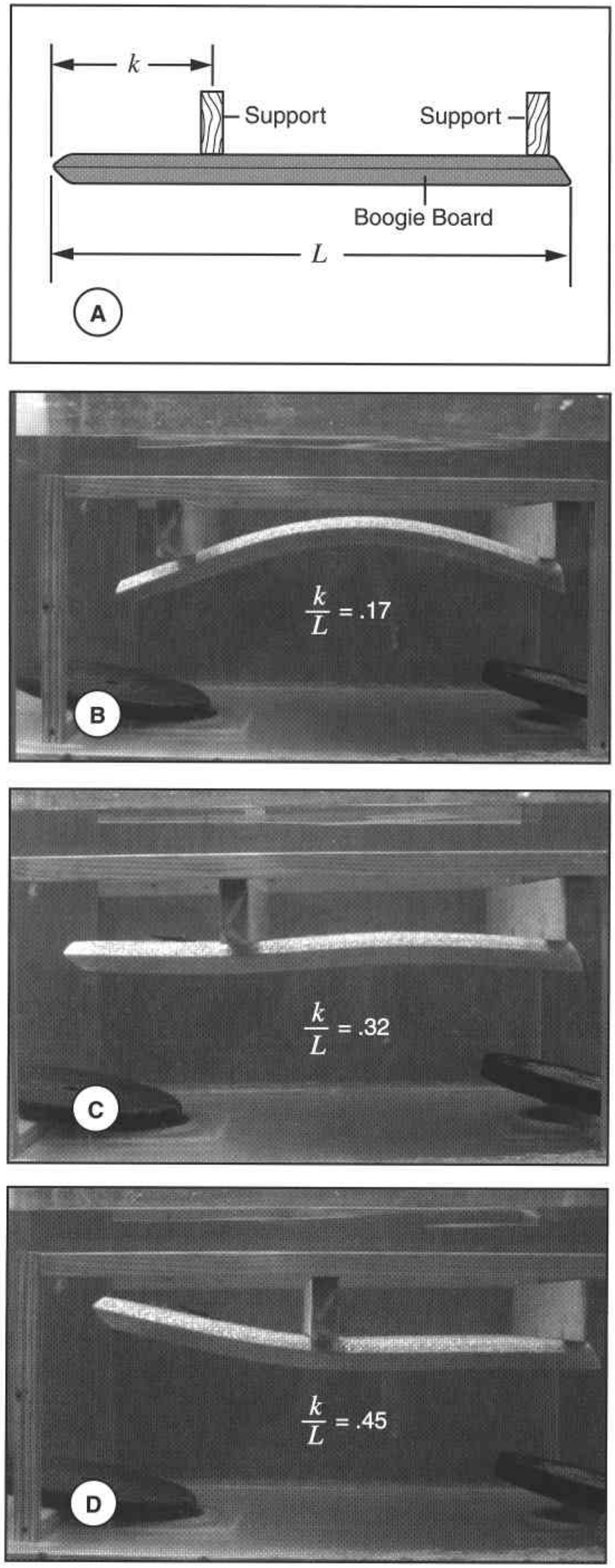

Figure 8 - Submerged Boogie Board Test Set-up

buoyant forces were developed in the testing program which completely submerged the boogie board. The deflections shown in Fig. 8 are quite large in the extreme scenario.

5. For the chest contact riding scenario, the shape of the deflection profile can vary from a perfectly flat deflection curve to a very large ski nose shape which depends on the dimensionless parameter (s/L) in Eq. 3.

6. Conventional beam deflection theory adequately describes the relationship between the shape and magnitude of the boogie board control surface and the various riding programs.

7. Using two-point loading during shallow diving applications, where head contact with the ocean floor is a hazard, a surfer has two forms of protection. The first positions his head behind the leading edge of the boogie board. The second provides a positive nose rocker, which redirects his motion away from the ocean floor. Both of these defense mechanisms are activated simultaneously when the surfer grips the board at a location greater than one third of the length of the board back from its leading edge.

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