WAS NOAH'S ARK STABLE?

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The article deals with the question, "Would Noah's Ark survive the cataclysmic forces of a world-wide flood?" The procedure followed is that which is followed by naval architects in modern ship design. Initially the weight and contents of the ark are evaluated. Then, by way of calculations, the ability of the ark to remain upright in high winds (up to three times hurricane force) is investigated. The results of these calculations are evaluated on the basis of modern practice, including the U.S. Coast Guard Regulations. The conclusion drawn from the investigation is that the ark was extremely stable, well able to withstand the forces hurled against it in the flood.

In consideration of the Biblical story of Noah's Ark and the Flood, the question is often raised concerning the ability of such a box to withstand the cataclysmic forces which would occur in a world-wide flood. The ark had not only to withstand 40 days and nights of rain, but also the wind and wave action, if the Biblical account is accurate. It is proposed to examine the ark by means of naval architectural investigation of its stability, to determine if it indeed had the ability to survive these forces.

In an article in *Creation Research Society Quarterly*, Henry M. Morris[1] went someway in dealing with this issue. He made a good attempt based on his assumptions. However, he only considered what would be called the statical stability of the ark, that is the stability of a vessel in still water, with the exciting forces removed. This is only half of the necessary investigation to determine the stability of a vessel at sea.

One needs to consider also the magnitude of upsetting forces, the wind and waves, that could be survived, in order to demonstrate that it would be stable under adverse weather conditions. There are four features of stability that warrant consideration:[2]

1. The angle of steady heel** under the influence of the force acting to overturn the ship.
2. The range of positive stability.
3. The residual dynamic stability.
4. The relative magnitudes of the maximum moment*** to right the ship and the moment to overturn it.

These four areas will be investigated later in this paper.

Construction of the Ark

This is the description of the ark in Genesis 6:14-16:

> Make for yourself an ark of gopher wood; you shall make the ark with rooms, and you shall cover it inside and out with pitch. And this is how you shall make it: the length of the ark three hundred cubits, its breadth fifty cubits, and its height thirty cubits. You shall make a window for the ark and finish it to a cubit from the top; and set the door of the ark in the side of it; you shall make it with lower, second and third decks.

The ark was evidently a box-type structure rather than the curved ship-shapes of classical or modern times. "The word ark signifies a box (Hebrew, *tebah*; Greek, *kibotos*)[3]". This rectangular construction would have been the simplest; they wouldn't have to bend timbers and planks to suit the curvature. The curvature in a ship's hull is primarily so that under propulsion it may gain additional speed. The ark was unpowered! It had no need for speed or efficient use of its propulsive force. Another advantage of the box-shape is a gain of about 30% in the amount of inside space.

What is a cubit? "The actual length of the cubit varies from 18 inches to 25 inches. There were long cubits and short cubits and royal cubits and Egyptian cubits and Talmudic cubits"[4] For present purposes I will assume the cubit equal to 18 inches. The final stability calculations would be basically independent of the choice because the stability will be determined by the proportions. The resulting dimensions in feet are shown in Figure 1.

The relationships of these figures compare favorably with those of modern shipping, as Giannone has shown.[5]

How deep did the ark float? In order to determine the stability it is necessary to establish the draft of the ark. The draft is the height that the water comes to along the side of the ship, measured from the bottom of the ship. Morris assumes that the draft was 15 cubits, the same as the depth of the water over the land.[6] But if one works by estimating weights, which is the normal procedure, a much different answer is obtained. It is standard procedure in ship design, whenever estimates or assumptions are involved, to choose that which would result in the least stable condition. The less the draft, the more difficult to maintain a stable condition.

For example, oil tankers have a very deep draft and are the most stable ships built today; on the other hand, containerships have very small drafts and are often in borderline stability. A lesser draft not only decreases the ability of the ship to right itself, it also increases the surface area available to the wind force, yielding a larger capsizing moment. Therefore one should follow the estimate of the smaller draft to be on the safe side. Nowthe weight of the ship and its cargo will be determined.

Weight and Load of the Ark

Filby used a reasonable method for estimating the weight of the ark. Since no one today knows what gopher wood is, he took the weight of cypress as a

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**Heel is the action of tipping over sideways, away from an upright condition.

***Moment is the tendancy or measure of tendancy to produce rotation especially about a point or axis. Opening a door creates a moment on the hinge.

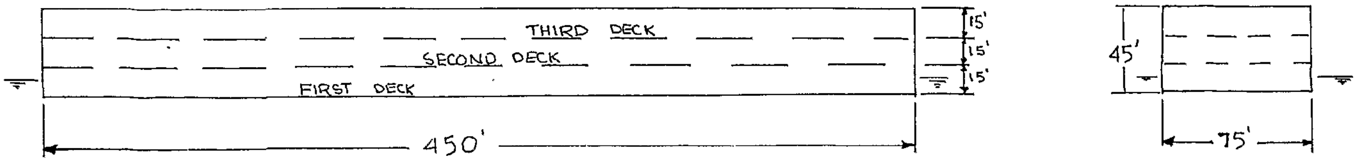

Figure 1. This shows the ark, in side and end views. The dimensions assumed in the text are indicated.

reasonable approximation, obtaining a rough approximation of the structure.

> Taking the ark as being made of cypress wood, with planks one foot thick, allowing two extra decks or floors and reasonable longitudinal and cross walls we can calculate that it would require something like 280,000 cubic feet of timber, which at about 530 oz. per cubic foot gives a deadweight of about 4140 tons.[7]

Having verified the figure of 4140 long tons (1 long ton = 2240 pounds) by independent calculation, the weight of the animals and provisions must be estimated.

Filby estimated 100 long tons of living cargo, which includes two of each kind, the extra clean animals and the humans.[8] Now taking a list of mammalian types from *Larouse Encyclopedia of Animal Life*,[9] in which basically all types of mammals are represented, and adding the maximum weight of each type, one gets 26.4 long tons; and when this is multiplied by two of each, yields 52.8 long tons. The eight humans would add about another long ton to make it 53.8 long tons. This leaves the birds, reptiles and additional clean animals.

All of the large animals are previously included; and the weight of additional animals would not bring the total over 100 long tons; especially since the use of the maximum weights for each species would give a high estimate because the ark would likely have to be carrying younger animals with their full reproductive life ahead of them so as to repopulate the earth. Therefore this estimate of 100 long tons leaves a reasonable margin to take into account any animals that might have been forgotten. The figure of 100 long tons, then is reasonably accurate for the present purpose.

Filby estimated that on the average each animal would consume 20 times its weight in food and 20 times its weight in water.[10] This seems low if it is considered that they would probably have to rely on the ark for provisions for a while after being released, to allow sufficient time for reproduction of other food sources. Therefore I will assume 30 times their weight for food and 30 times their weight for water. This results, initially, in 6000 long tons of provisions. Therefore the total initial weight was 4140 + 100 + 6000 long tons, or 10,240 long tons. This gives an initial draft of 10.6 feet.

Remembering that the lighter draft will have less stability, then one should estimate the lightest draft before grounding. One might consider that about half of the provisions would be consumed, and the wastes cast overboard, before the ship grounded. This gives a weight of 7240 long tons and a draft of 7.5 feet, much less than Morris's 22.5 feet (15 cubits). Assuming that most of the provisions are on the first (lower) deck, and that most of the animals are on the second and third decks, as the lower deck would probably have poor ventilation, the center of weight above the bottom of the ark is approximately 18.5 feet.

Investigation of Stability

Thus the ark had in the least stable condition, a weight (W) of 7240 long tons, a draft of 7.5 feet, and a center of weight of 18.5 feet above bottom. The length (L) 450 feet, beam (b) 75 feet, and height 45 feet.

How far can the ark be allowed to tip and still be considered stable? Morris wrote, "Thus for any angle up to 90° the ark would right itself." This is true, but there are other facets which need to be considered in investigating the stability of the ark. If the ark rolled that far, the animals be tossed all over the place (just try to imagine standing on a 90° slope, let alone tipping first 90° to one side then 90° to the other—they'd be piled in a heap and so seasick they couldn't eat!) There is also the more serious problem that if the ark tipped as much as 60° it would be flooded because the window (1 cubit from the top) would be under water. If air could go through it for ventilation, water certainly could!

There was also a door in the side, probably on the third deck. It is not known whether it was sealed water tight or not, so an angle of heel to keep the water below the bottom of the door will be used as the worst condition. This would mean that the angle of heel to be sure that the ark did not flood must have been less than 38° (the angle to the bottom of the door). (See Figure 2 with a comment.) This is called the angle of downflooding. In the United States Coast Guard "Rules for Passenger Vessels" there is a requirement for stability in heavy weather conditions. Before the construction of a ship is

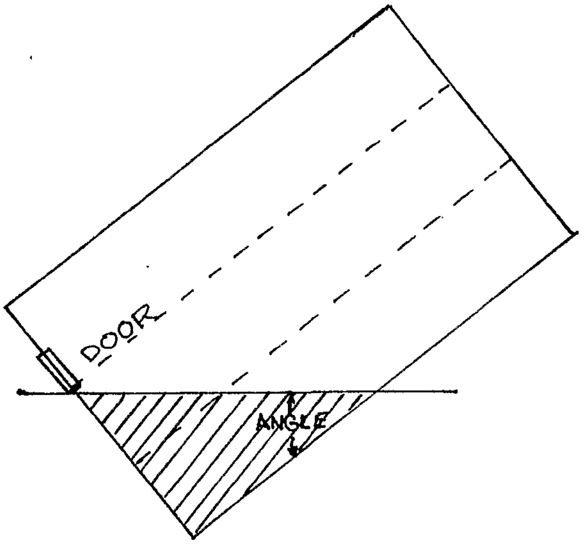

Figure 2. This shows the maximum extent to which the ark could have tipped without danger of water entering. The bottom of the door, up to which the water may come, is taken to be 30 feet above the bottom of the ark. The part under water, the triangle shown shaded, is equal in area to the part under water when the ark is level, i.e. a rectangle 75 by 7.5 feet. Thus the angle can be calculated.

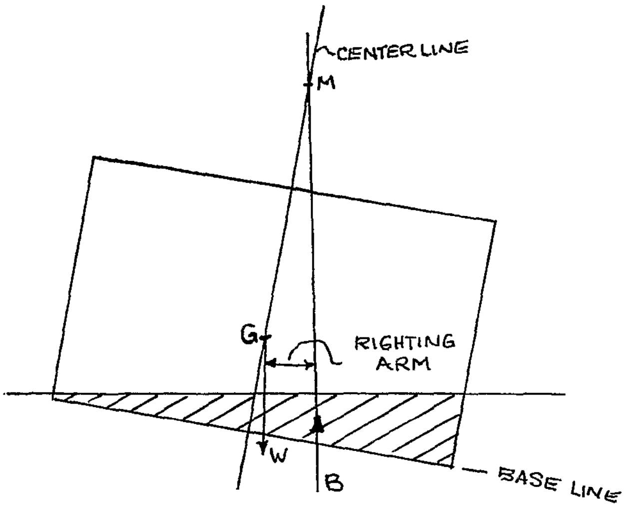

Figure 3. This shows the couple, or moment, tending to right the ark if it was tipped. The line GM is parallel to the sides of the ark, and passes through its center of gravity. The line BM is vertical, and passes through the center of gravity of the displaced water, i.e. through the center of gravity, or centroid, of the area under water, which is shown shaded.

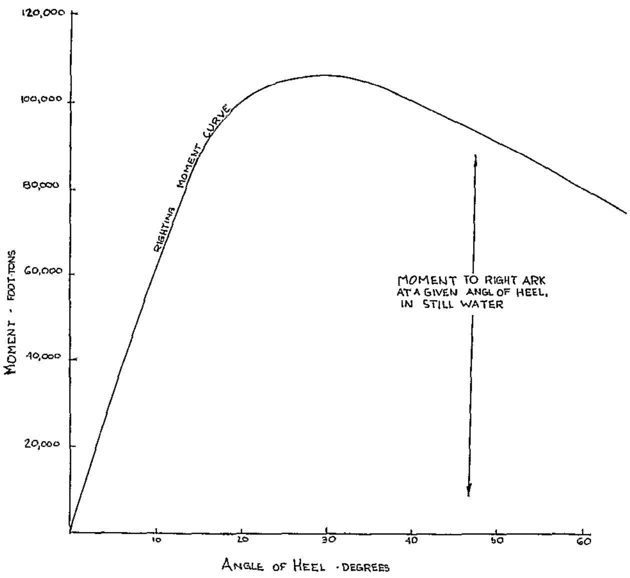

Figure 4. This shows the righting moment, a measure of the tendency to return to an upright position, vs. the angle of heel, through which the ark was tipped.

approved, it must be demonstrated that in a 60 knot wind the ship has adequate stability to limit the angle of heel to one half of the angle of downflooding or to 14 °, whichever is less.[12] In this case I will use 14 °, as it is less than 19 °, which is half of 38 °.

Righting Moment Curve Established

The next step is to establish the righting moment curve. This shows the amount of a moment, in foot-tons, there is to right the ship at a given angle. (See Figure 3) This is determined by heeling the ship to five or six different angles, calculating the righting arm at each angle, multiplying the righting arm by the weight (W), and plotting the results.

The righting arm is the perpendicular distance between the line of action of the weight of the ship (W) and the line of action of the buoyant force (B) as shown in Figure 3. The line of action of the weight is vertical through the center of weight, 18.5 feet above the baseline on the centerline of the ship. The line of action of the buoyant force is vertical through the center of the corss-section of submerged area, which is the center of gravity or the displaced water (shaded).

If the intersection of the line of action of the buoyancy and the centerline of the ship, point M, is above the center of weight, point G, then the righting arm is positive, resulting in a moment to right the ship. If point M is below point G then the righting arm is negative and will act to overturn the vessel.

The distance along the centerline from point G to Point M is called the metacentric height and is used as a measure of static stability. This is basically what Morris presented in his paper. However: "Stability is often, erroneously, evaluated on the basis of metacentric height alone, without the benefit of a complete righting arm curve."[13] But the notion of the metacentric height as a measure of stability is useful and is discussed later in this paper. The value of the righting arm is multiplied by the weight (W), yielding the righting moment. These values are then plotted on a graph, angle of heel versus moment. (See Figure 4)

Overturn Forces Considered

What about the forces that might overturn the ark? Well, because the ark has a very high freeboard (distance from the waterline to the bottom of the door) and a relatively low center of gravity, the primary capsizing force will be the wind. After the rain, "But God remembered Noah and all the beasts and all the cattle that were with him in the ark; and God caused a wind to pass over the earth and the waters subsided." (Genesis 8-1) This wind must have been more than just a mild breeze if it caused the waters to recede. The wave force will be small in comparison.

> "When a ship is exposed to a beam wind (a wind coming perpendicular to the length), the wind pressure acts on the portion of the ship above the waterline and the resistance of the water on the ship's lateral motion exerts a force on the opposite side below the waterline."[14] (See Figure 5)

The moment to overturn is equal to the force of the wind pressure times the arm (half the distance from the center of area exposed to the wind to the center of the underwater area) plus the force of the water pressure times the same arm. The water pressure is the result of the wind trying to push the ship sideways and is approximately equal to the wind pressure. Therefore the moment to overturn is reduced to the force of the wind pressure times the distance between the centers of areas.

The moment to overturn at 0 ° heel is therefore equal to the wind pressure at a given velocity times the area exposed to the wind times the vertical distance between the centers of the wind and water areas. The wind pressure is about 10 lbs/ft^2 at about 110 knots wind velocity.[15] The wind pressure varies with the square of the velocity, therefore for a 210 knot wind (three times

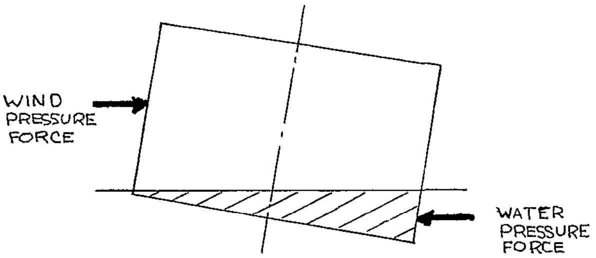

Figure 5. The wind pressure force and the water pressure force are equal and opposite. But, since they act at different levels, they form a couple, which tends to turn the ark clockwise in this instance. The magnitude of this couple is called the moment to (i.e. tending to) overturn the ark.

hurricane force) the pressure would be 110 lbs/ft^2.

At 60 knots the resulting moment is 1700 foot-tons.
At 110 knots the resulting moment is 5090 foot-tons.
At 210 knots the resulting moment is 18650 foot-tons.

The curve of the moment to overturn is determined by multiplying the moment at 0 ° by the cosine^2 at each of the angles and plotting the results on top of the Righting Moment Curve. This results in Figure 6.

Four Features of Stability

These curves show that the ark was extremely stable, even in 210 knot winds, three times hurricane force. In examining the four features of stability mentioned earlier I will use the curve for 210 knot winds and the righting moment curve in Figure 6.

1. The first stability consideration is the *angle of steady heel under the influence of the force acting to overturn the ship*. This is determined by the intersection of the righting moment and the overturning moment curves, Point A. Its value for the ark is about 3 °. This is very good, better than most modern ships, which average about 5 °. This means that when the ark is tipped by a gust the righting moment will act to return the ark to within 3 ° of vertical. Due to the steepness of the righting moment curve at this point, the ark would rarely tip much beyond this point. This means the occupants had a reasonably comfortable ride.

2. The second stability consideration is the *range of positive stability*. This demonstrates how far the ark could roll without capsizing. It is to the point where the righting arm curve would re-cross the overturning moment curve. It can be seen from Figure 6 that it would be well past 60 °. Again this is much better than modern shipping, where it is not at all uncommon for the range to be less than 30 °.

3. The third stability consideration is the *residual dynamic stability*. This represents the work required in addition to the effects of the overturning moment under consideration to capsize the ship. To demonstrate sufficient dynamic stability for the ark, one needs to determine the area between the righting moment and overturning moment curves from point A to the angle of limitation, 14 ° (the shaded area in Figure 6). This must be larger than 22,370 degree-foot-tons, based on Table 4 in *Principles of Naval Architecture.*[16] The area in Figure 6 is equal to 365,000 degree-foot-tons, more than 16 times that required.

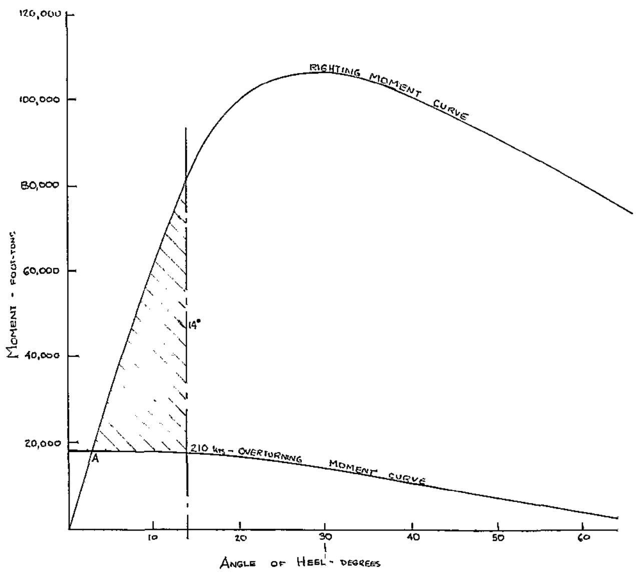

Figure 6. The ark would heel at the angle at which the overturning and righting moment curves intersect, here about 3 ° under the conditions assumed. The shaded area is a measure of extra stability, so to speak, and, as is shown, is most generous.

4. The fourth stability consideration is the *relative magnitude of the maximum moment to right the ship and the moment to overturn it.* "The excess of maximum righting arm over the heeling arm, in addition to providing a margin for the upsetting forces of wind and wave, is essential as an allowance for inaccuracies in calculating the heeling and righting arms."[17]

This takes into account any minor variations in the assumptions, such as weight, draft or center of weight. It is basically a factor of safety. The maximum righting moment is 106,000 foot-tons. The maximum overturning moment is 18,650 foot-tons. The margin is more than four and one half times the maximum overturning moment!

As seen by the above considerations, Noah's Ark was extremely stable, more stable, in fact, than modern shipping. This is primarily because in modern shipping the extra margin of stability is sacrificed for attaining higher speed and more maneuverability.

As a secondary check on the stability the metacentric height can be evaluated and compared to the United States Coast Guard "Rules for Passenger Vessels". The metacentric height is the distance from point G to point M in Figure 3, as earlier explained. The available metacentric height (GM) is determined by taking the moment of inertia of the waterplane (L x b^3/12) divided by, the length times the beam times the draft, adding the center of bouyancy (one half of the draft, 3.75 feet) and subtracting the center of weight (18.5 feet). For the ark this yields GM equal to 47.75 feet. The Coast Guard[18] requires:

$$GM = \frac{PAh}{\Delta \tan 14^\circ}$$

P = .005 + (length/14,200)^2
A = area acted on by wind
h = the distance from the center of wind area to the center of water area
Δ = the weight, W (7240 long tons)

This results in a required GM of 1.27 feet. In ship design it is normal to require an additional 1.0 foot margin, yielding 2.27 feet required. The available GM, 47.75 feet is much greater than 2.27 feet. This verifies the earlier calculations. The ark is *extremely* stable.

Conclusion

Noah's Ark was extremely stable. When God told Noah how to build it, he did a very good job. He made the ark so stable that it would be fully safe whatever cataclysmic forces of the flood were hurled against it!

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[8] *Ibid.*

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[14] *Ibid.*, p. 57

[15] Comstock, John P. 1944. Introduction to naval architecture. Simmons-Boardman Publishing Co., New York, p. 94.

[16] Reference 2, p. 149.

[17] *Ibid*, p. 98.

[18] Reference 11, p. 72.

DELTA FORMATION, HISTORY AND ARITHMETIC

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In reading *The Genesis Record* by Henry M. Morris I was struck by the statement that Ur of the Chaldees was originally a seaport before delta deposits filled the sea and left Ur high and dry in the desert.[1] I recalled an article in a *Creation Research Society Quarterly*[2] containing the point that the earth under deltas does not subside by the tremendous amounts which would be necessary to accomodate present rates of formation to allow them to fit in with the geological ages postualted since their beginning.

Accepting the age of Ur in the Encyclopedia Britannica as 3500 BC, (a Creationist might make it younger) and the present position of almost 200 miles from the Persian Gulf, one finds a delta formation rate of about 35 miles for every 1000 years. This is true whether or not there has been a subsidence of the sea bottom as the delta advanced for the simple reason that 5500 years ago the Persian Gulf was at Ur, and now it is almost 200 miles away.

It is probable that formerly the Tigris and Euphrates rivers deposited delta materials more rapidly than at present, as the materials would have been deposited in the shallower waters near the normal shore, the rivers would have had more available top soil to wash away, etc. This means that the dates obtained by simple arithmetic in projecting this action back into time would probably be too long rather than too short. Even so extending the gulf on back in its present direction, 80,000 years ago one finds that it extended inland about to Paris! If this seems a bit absurd, one may go a step farther. Assuming the same rate of formation for the delta of the Mississippi would suggest that 120,000 years ago the Gulf of Mexico extended clear up to the North Pole.

If these calculations are not true, because in prehistoric times the sea bottom really did subside enough to slow delta formation significantly, why is there no evidence of such a slow rate in historical times? It must certainly have been a marvelous breach of uniformitarian principles. Ur gives investigators a check which cannot be passed off as being irrelevant because of dealing with only a few score years, as modern delta studies might be. Whether or not sea bottoms are subsiding under deltas so that their formation is much slower than would otherwise be the case, Ur is now almost 200 miles from the Gulf!

In addition if one assumes that at one time the Persian Gulf actually extended all the way back up the Euphrates Valley so that the mountains of Syria were the extreme limit, or even that it cut all the way through to the Mediterranean Sea, (which certainly is stretching everything to the maximum possible), the delta building process would still have had to start less than 40,000 years ago. In (alleged) geological time, 40,000 years is nothing. Thus evidence of this kind from deltas is evidence for a recent creation.

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