DESIGNING DN RUNNER PLANKS FOR STIFFNESS

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Introduction: The runner plank of a DN is really a very simple structural element. It is, after all, merely a beam supported at the ends by the runners and the windward shroud and loaded at the center by the hull. Stiffness is the plank characteristic most closely associated with performance. To date, information on plank stiffness has been largely anecdotal: "When I stand on my plank, it bends down an inch and a half, and I go like smoke (or molasses, or whatever)". It appears that nobody has systematically developed plank stiffness data, or, if they have, they haven't made the information public.

Object: The charts and tables of this report are intended to provide a guide for building DN runner planks that will have the desired pre-selected stiffnesses, or spring rates*.

How Stiff Should a DN Plank Be? - Optimum plank stiffness is probably in the 90 to 110 lb/in. range for a wide range of DN skippers (Paul O'Neil says 90 to 100 in the March, 1990 IDNIYRA Newsletter). Heavyweight skippers need stiffer planks than lightweights. Stiff aluminum and wood masts may work best with plank stiffness tending toward 90 lb/in. Flexible wood masts may need planks tending toward the upper 110 lb/in. stiffness since mast bending depowers the rig and less plank flexibility is needed. Hopefully, optimum plank stiffnesses will be more firmly established in the next year or so.

Designing Three-Piece Planks - Figures 1 and 2 show the spring rates for three-piece planks of rectangular cross section and ash or birch faces. Cores of redwood and Sitka spruce are covered specifically, but other lightweight woods with similar properties can be used.

The solid curves of Figures 1 and 2 are based on the deflection formula given in the Appendix. The dashed face-thickness curves were added for the user's convenience. Figures 1 and 2 are based on the structural properties for clear, defect-free wood. I'm sure that we all take pains to select the best boards we can find for our planks. In that case, these charts provide estimates of plank stiffness that will generally be quite accurate. Sometimes, however, an individual board may vary significantly from typical in its properties and will give a plank with more or less stiffness than predicted.

Plank Made of One Wood Throughout - Table I gives the spring rates for planks with all plies of the same wood. The number of plies makes no difference. You will find that the spring rates for these planks correspond to the values found along the left and right vertical axes of the charts of Figures 1 and 2; that is, they are for "all-core" or "all-face" planks respectively.

Planks with Streamlined Cross Sections - Streamlined planks typically are made with all plies of the same wood, and that is assumed in this discussion. The streamlined cross section is at the whim of the builder and may be any of a variety of shapes. An elliptical cross section is probably a good one and will be assumed here. Further, let us assume, to begin, that the plank is streamlined uniformly over its entire length. In that case, the overall thickness

*In this report, the terms stiffness and spring rate are equivalent and will be used interchangeably.

of the elliptical plank must be 19 percent greater than that of a rectangular plank to give the same stiffness. Usually, the top surface of the plank is not streamlined under the hull, so the 19 percent might be reduced a little.

Measuring Spring Rates - A simple, and reasonably accurate, way to determine plank stiffness is to stand on the plank at midlength and measure how much it deflects. The spring rate, SR, is your weight divided by the measured deflection. Your weight and the deflection should be measured as accurately as possible, of course. Put wax paper under the ends of the plank to prevent restraint in the lengthwise direction. If the plank has chocks, set the outer faces on wood blocks covered with wax paper.

More refined load-deflection tests can be made using a series of weights and a dial gage. Paul Goodwin's September, 1990 Newsletter article, "Measuring Mast Stiffness", gives detailed instructions on making such tests and analyzing the results. A word of caution: a flexible plank with chocks will give a load-deflection plot that is slightly non-linear because the span increases as successive weights are added. Interpreting such plots introduces problems that are perhaps best avoided by using the less elegant stand-on-it-and-measure-it method discussed in the previous paragraph.

How Much Crown is Proper? - Generally, the lower the plank stiffness, the greater the crown should be to prevent the plank from hitting the ice during heavy wind conditions. Not enough data are presently available to properly relate optimum plank stiffness and crown, but it appears that crowns in the 2 to 3½ in. range work well. The interplay between crown and spring rate is being studied and will be covered in a future report.

Examples of Planks Designed for Stiffness

1. Desired: An ash-faced, redwood-cored plank with a spring rate of 100 lb/in. Figure 1a shows that a plank with 1/8 in. ash faces and 1-1/4 in. faces would provide a spring rate of 99 lb/in. However, 1/8-in. faces would probably have several shortcomings, so go back to Figure 1a for other candidates. A plank with 5/16-in. faces and an overall thickness of 1-7/32-in. (by interpolation) should provide a spring rate of about 102. Use this design.

2. Desired: A birch-faced, Sitka spruce-cored plank with a spring rate of 105 lb/in. Figure 2b shows that a plank with 1/4-in. birch faces and an overall thickness of 1-3/16-in. would give the desired stiffness. If 5/16-in. unidirectional birch plywood faces were chosen, Figure 2b indicates that the plank should be a little less than 1-3/16-in. in thickness.

3. Desired: A high-crown plank of solid shagbark hickory with a spring rate of 95 lb/in. Table I shows that a hickory plank of the minimum allowed 1-1/8-in. gives a spring rate of 100 lb/in. Rounded edges and a little streamlining would allow the plank to be tuned to the desired 95 lb/in.

4. Desired: A streamlined all-ash plank with a spring rate of 100 lb/in. Table I shows that a rectangular ash plank of 1-3/16 in. thickness has a spring rate of 97 lb/in. For the same stiffness, an elliptical-section ash plank would have to be 19 percent thicker, or 1.41 in thick ($1.1875 \times 1.19 = 1.41$). The non-streamlined top center portion of the plank would probably raise the stiffness to the desired 100 lb/in.

Some Random Comments on Runner Planks

1. A good IDNIYRA project would be to measure spring rates of Gold Fleet boats (non-compulsory participation) at the 1992 North Americans.

2. Laminating does not make wood stiffer (contrary, for instance, to the statement on page 77 of "Think Ice"). For thin glue lines, laminated and non-laminated boards of equal dimensions have the same stiffness.

3. Longitudinal profile (parabolic, gull-wing, etc) and crown have no effect on the bending behavior of a plank. They do have effects on splaying of the runners, ice clearance, etc.

4. It is not obvious that tapering the thickness of planks from end to end is beneficial overall. Tapering reduces plank weight a little, but increases splaying of runner blades over that of a uniform-thickness plank with the same spring rate.

5. If possible, build your planks 7-1/2 in. wide. You can then adjust stiffness downward by up to 13 percent merely by trimming the width down toward the minimum allowed 6-1/2 in.

6. You can always increase the stiffness (and weight) of your plank by adding fiberglass, but remember that carbon fibers are not allowed.

7. Three-piece planks with lightweight cores are susceptible to crushing at the ends if chock caps are used. Wood dowels bonded vertically into the plank ends, or some similar scheme, will prevent crushing.

8. Flying ice chips will erode or ablate the leading edges of low-density cores. Fiberglass or a facing of harder wood on the leading edge will help.

TABLE I

STIFFNESS OF DN PLANKS WITH ALL PLIES OF SAME WOOD
Spring Rates, lb per in., for 7-in. wide planks

Type of Wood	Overall Thickness of Plank, in. 1-1/8	1-3/16	1-1/4	1-5/16	1-3/8
Shagbark Hickory	100	118	138	159	183
Yellow Birch	94	110	128	148	171
White Ash	82	97	113	131	150
Sitka Spruce*	73	86	100	116	133
Redwood*	62	73	85	99	114

*All-spruce and all-redwood planks have relatively low strength and shock resistance; they are not recommended. They are listed for comparative purposes only.

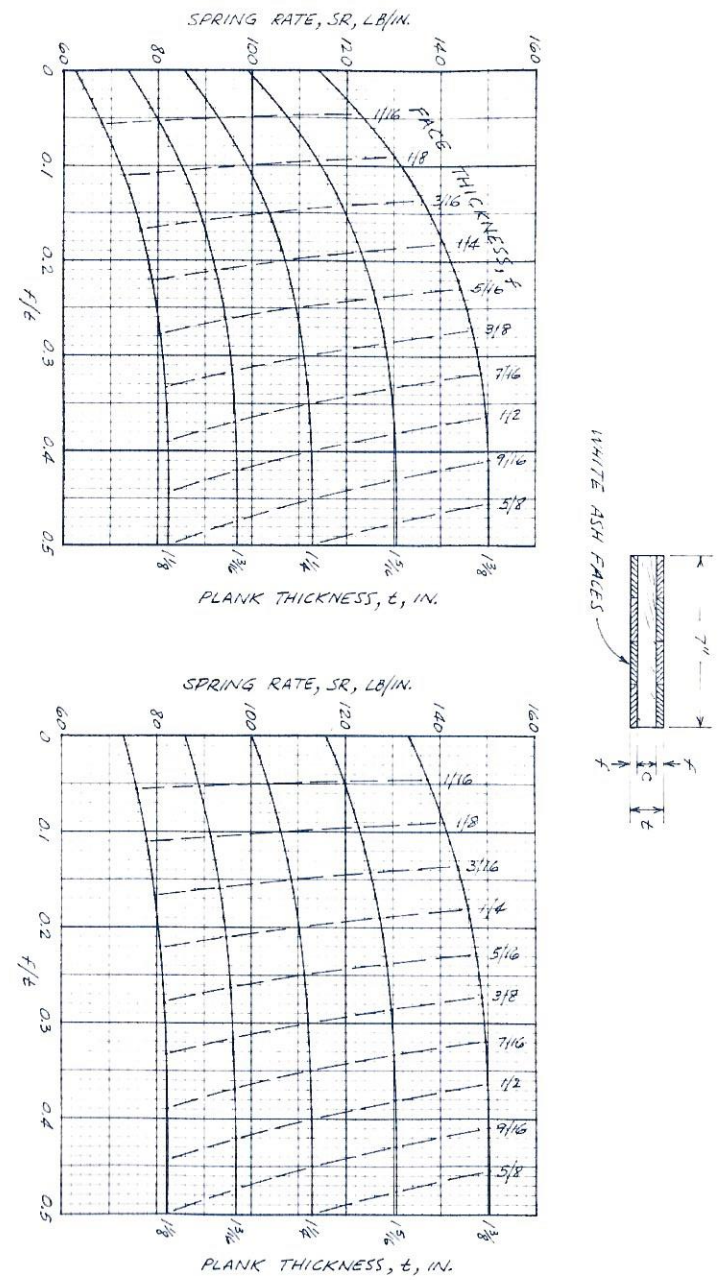


FIGURE 1 - STIFFNESS OF DN RUNNER PLANKS WITH WHITE ASH FACES

FIGURE 1a - PLANKS WITH REDWOOD CORES

FIGURE 1b - PLANKS WITH SITKA SPRUCE CORES

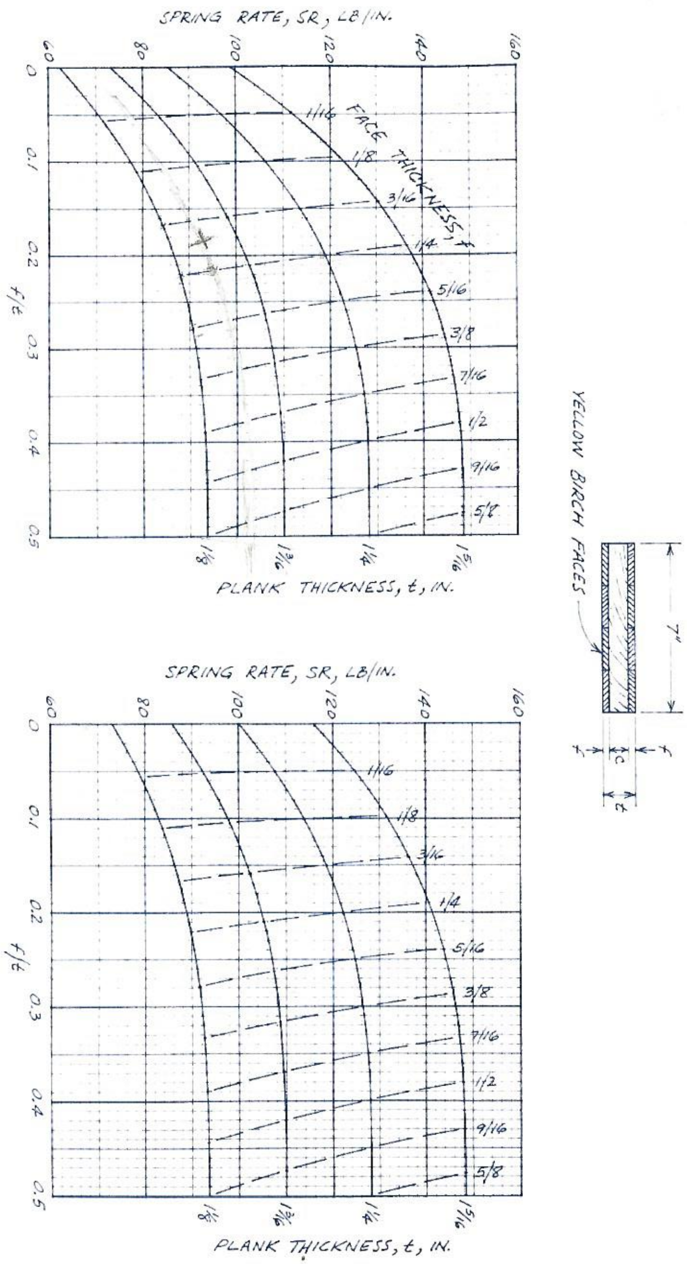


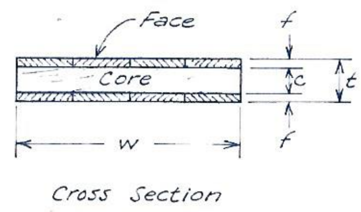
FIGURE 2a - PLANKS WITH REDWOOD CORES

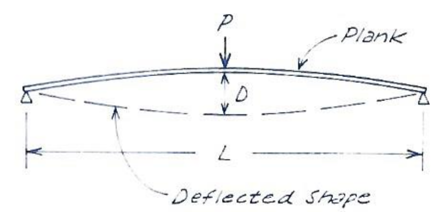
FIGURE 2b - PLANKS WITH SITKA SPRUCE CORES

FIGURE 2 - STIFFNESS OF DN RUNNER PLANKS WITH YELLOW BIRCH FACES

APPENDIX

STIFFNESS ANALYSIS OF THREE-PIECE PLANKS





The stiffness, or spring rate, of a three-piece runner plank can be calculated with this formula:

$$SR = \frac{P}{D} = \frac{4E_f w t^3}{L^3}\left[1-\left(\frac{c}{t}\right)^3\left(1-\frac{E_c}{E_f}\right)\right] \times 10^6$$

For a DN plank, letting $w = 7$ in. and $L = 95$ in.,

$$SR = 32.7 E_f t^3\left[1-\left(\frac{c}{t}\right)^3\left(1-\frac{E_c}{E_f}\right)\right]$$

Where
- c = thickness of core, in.
- D = deflection of plank at midlength, in.
- E_c = modulus of elasticity of core, psi × 10^{-6}
- E_f = modulus of elasticity of faces, psi × 10^{-6}
- f = thickness of faces, in.
- L = length of plank between support points, in.
- P = load at center of plank, lb
- SR = spring rate, lb/in.
- t = overall thickness of plank, in.
- w = width of plank, in.

Modulus of elasticity values used in this report were taken from "Wood Handbook", Handbook No. 72, Forest Products Laboratory, U.S. Dept. of Agriculture. They were:

White Ash,	$E = 1.77 \times 10^6$ psi
Yellow Birch,	$E = 2.01 \times 10^6$ psi
Shagbark Hickory,	$E = 2.16 \times 10^6$ psi
Redwood,	$E = 1.34 \times 10^6$ psi
Sitka Spruce,	$E = 1.57 \times 10^6$ psi

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