Guide to Processing CFF® V110-1 Fibrillated Fiber For Friction Materials Production

1 INTRODUCTION

CFF® V110-1 fibrillated fiber is a high surface area acrylic pulp engineered specifically as a processing aid to improve green strength, particle retention and dust suppression in friction products. Mixing procedure is key to fiber opening/preform quality, and because of its high level of fibrillation and fiber length, some modification of mixing procedure may be desirable for CFF V110-1 fibrillated fiber relative to other pulps. Internal testing by Sterling Fibers, as well as extensive customer evaluations over a ten year production history, demonstrate that CFF V110-1 behaves in a manner very similar to aramid and is an economic alternative to aramid pulps.

Sterling Fibers, Inc. has carried out an evaluation of mix quality and preform properties using CFF V110-1 fibrillated fiber as a processing aid in a non-asbestos organic brake formulation. The study included mixing protocol, equipment options and the effect of loading level for CFF V110-1 fibrillated fiber versus aramid.

This study focused on a single formulation using Littleford and Eirich mixers. It is recognized that optimum processing conditions and loading level are highly dependent on the specific formulation, as well as on available production equipment, and as such must be established empirically for each formulation. However, the present study will provide friction material engineers with an understanding of how CFF fibrillated fiber responds to changes in processing conditions and serve as a useful starting point for process engineering studies.

Sterling is committed to a high level of technical support for engineered fiber products. We look forward to an opportunity to provide technical assistance in the effective use of CFF fibrillated fiber for your specific needs.

Sterling Fibers, Inc.
5005 Sterling Way
Pace, FL 32571
Tel: (850) 995-5311
Fax: (850) 994-2579
Email: jhagerott@sterlingfibers.com

2 SUMMARY

The following report contains the details of internal testing performed by Sterling to evaluate the dry mix performance of CFF fibrillated fiber in non-asbestos organic (NAO) friction materials. This work forms the basis for the following mixing guidelines, and should be read and thoroughly understood before these suggestions are applied.

2.1 LITTLEFORD MIXING

1. Use Becker type (heat dissipation) plows at standard (160 rpm) speed and with about 3/8" wall clearance.
2. The alternating two star, two bar chopper configuration is more effective than a tulip chopper in opening CFF V110-1 fibrillated fiber. Depending on the specific formulation, it may be desirable to reduce the length of bars down to the diameter of the stars.
3. Where a formulation contains fibers which have a tendency to cause balling, e.g. fiberglass, it is recommended that CFF V110-1 fibrillated fiber be premixed with powders prior to the addition and post mixing of these fibers.
4. Premix time should be sufficient to disperse and open CFF V110-1 fibrillated fiber. Depending on equipment conditions this may be slightly longer than for aramid pulp.
5. Post mix time, at least for mixes with low strand integrity fiberglass should be kept to a minimum. Mix bulk density and preform properties decrease with additional post mix time. Excessive post mix time can cause fiber balling.
6. At equivalent weight percent loading, mix bulk density is somewhat higher with CFF V110-1 fiber than with aramid, but preform break strength and stiffness values are about equal.

2.2 EIRICH MIXING

1. Mix and preform quality can be equivalent to Littleford mixes.
2. Low bowl speed is preferred to minimize balling.
3. Use beveled beater bars at high tip speed to improve fiber opening.
4. Fiber preopening in Eirich mixers appears to improve mix quality.

3 RESULTS AND DISCUSSION - LITTLEFORD MIXER

3.1 APPROACH

Using a model formulation shown in Figure 1 containing components typical of commercial non-asbestos organic (NAO) products, a series of batches was made and evaluated to establish a basic mixing protocol. This NAO formulation was selected because, as shown in Figure 2, it represents a mix which is difficult to preform without the use of a binder fiber.

Using the established mixing protocol, several batches were made using a Littleford Model FM-130 mixer, with the specifications shown in Figure 3, to evaluate the effect of plow and chopper configuration on mix quality and preform properties. Work with the Littleford mixer at Sterling's Stamford, CT Research Laboratories (now part of the Technical Fibers Development Center in Pace, FL) was augmented by a series of trials at the Littleford Company laboratory in Florence, KY. Mixes were also made to evaluate preform properties for a range of CFF V110-1 and aramid pulp loading levels. These were interrupted at various times for visual observation, bulk density measurements, and preform evaluation. Figures 4 and 5 provide details of bulk density and preform preparation/testing procedures.

Figure 1: Model NAO Formula

	wt%	vol%	Weight (g) added to batch
Phenolic Resin	17	27	3400
Fiberglass (1/8")	10	9	2000
Ebonite Dust	12	20	2400
Seacoal	7	9	1400
Barytes	35	16	7000
Vermiculite	16	15	3200
Abrasive	1	0.6	200
Fibrillated Fiber	0 - 4.8*	0 - 6.5	0, 200, 400, 600, 800*

* Other components of mix reduced 20% to avoid overfilling mixer. The standard mix used 2 wt% of fibrillated fiber.

Figure 2: Typical appearance of non asbestos performs with and without pulp added as a processing aid.

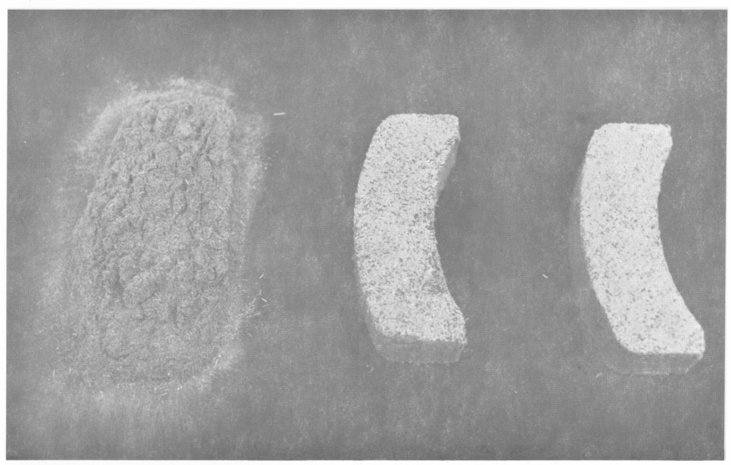

Figure 3: Littleford Mixer Specifications

1. Model FM-130, 10 hp and 160 rpm standard main shaft drive.
   Chopper 10 hp and 3600 rpm.
2. Fill level 40 - 45% after 1 minute premix with standard (2 wt% CFF V110-1) batch.
3. Same model mixer and batch size used at Sterling and at Littleford.
4. Mix temperature ranged from 72 to 110°F with most readings at 85 to 100°F.
   No external heating or cooling.
5. The mixer at Littleford was equipped with recording temperature and power meters. The recording power meter for the chopper was particularly useful in that it reflected differences in chopper configuration.

Figure 4: Bulk Density Measurement

Mix density can be a useful tool in establishing or monitoring NAO mix cycles, but results are highly dependent on technique. The following procedure is recommended:

1. Build a rigid box with 6" inside edges (1/8 cu. ft. volume), preferably out of acrylic sheet to observe mix uniformity.
2. Using a small cup or ladle scoop mix from mixer and sprinkle into box, filling it as uniformly as possible.
3. Scrape off excess mix with a straight edge, being careful not to pack the mix.
4. Weigh the filled box immediately and subtract the box weight. Calculate and record the bulk density in lbs/ft^3.

Figure 5: Preform Preparation and Testing

1. Spread 150g of mix evenly in a Friction Materials Standards Institute (FMSI) 728A disc pad preform mold. Press at 2500psi, holding maximum pressure for five seconds. Remove preform from mold and record any soft edges, breakage or non-uniformity. Measure preform height immediately after molding. Prepare at least five preforms for each mix sample.
2. Allow preforms to stabilize at ambient temperature for 18 - 24 hours before testing. Measure preform thickness again.
3. Perform a 3-point flexural strength test on preforms using an Instron (or equivalent) universal testing machine at a crosshead speed of 0.1 in/min. The 3-point bend fixture should be set to a 4" span. If a chart recorder is used, a full scale load of 5 lbs and chart speed of 2 in/min are suggested.
4. Record the breaking load (lbs) and the preform stiffness (lbs/in). Preform stiffness is calculated from the initial (linear) portion of the load-deflection curve.
5. Calculate and record the average and confidence interval for breaking load and stiffness. The confidence interval is calculated as:

$$\overline{X} \pm \frac{t\,s}{\sqrt{n}}$$

where: $\overline{X}$ =sample average
t = Student's t statistic (= 2.1 for 5 measurements and a 90% confidence level)
s = sample standard deviation
n = number of measurements

3.2 MIXING PROTOCOL

3.2.1 No Processing Aid

Figure 6 summarizes the bulk density versus mix time for a baseline batch with no fibrous processing aid. Relative to subsequent batches, the initial bulk density values are high but decrease rapidly after fiberglass is added. All samples fell apart at preforming.

3.2.2 All Components Added at Start of Mix

The simplest mixing procedure is to add all components at the beginning and mix to a predetermined end point. Figure 7 summarizes the bulk density and preform properties for a batch using this procedure. Relative to a subsequently "optimized" mixing procedure discussed below, the single addition procedure gave a rapid drop in bulk density, poor preform quality and early onset of fiberglass balling. This procedure is not recommended, at least for mixes containing fiberglass with low to medium strand integrity.

3.2.3 Pre/Post Mix

For dry mix NAO formulations containing fibers which ball up on excessive mixing, it is common industry practice to premix powders and the fibrous processing aid, then add fibers and complete mixing. Figure 8 summarizes the results for eight batches made using the premix/post mix procedure with variations in pre/post mix time.

For this formulation and mixer configuration, a 3-4 minute premix was required to stabilize bulk density and preform properties with no apparent improvement or deterioration of mix quality beyond the point of stabilization. There was a clear deterioration of preform quality, accompanied by a rapid loss of bulk density and onset of balling during the post mix cycle. The rate of deterioration will depend on the specific formulation, mixing equipment, batch size and glass strand integrity, but as a general recommendation, post mix time should be minimized.

3.3 EQUIPMENT OPTIONS

The basic mixer configuration used Becker* type plows on the main shaft running at 160 rpm. The chopper consisted of two flat stars separated by two 8" bars running at 3600 rpm. The bars extended 1" past the outer diameter of the stars. From this base, it was of interest to evaluate chances in plow type and speed, as well as chopper configuration.

3.3.1 "V" Versus Becker Type Plows

Due to the constraint of mixer design, the difference in plow design had to be evaluated with shortened bars. Extension of the bars beyond the outer diameter of the stars was eliminated by cutting 1" from the ends. Figure 9 summarizes the results for "V" versus Becker plows. While there was little difference between these two plow designs, the rate of fiber opening during premix and rate of deterioration of preform quality during post mix slowed relative to the base line using Becker plows and two 8" bars. It is of interest that Littleford engineering personnel recommend the Becker plow configuration over the "V" configuration to avoid dead spots in production mixes.

3.3.2 Plow Speed

Plow speed was reduced by 50% to 80 rpm using the standard formula with Becker plows and a two star / two long bar chopper. The reduced plow speed resulted in poor mix uniformity during premix and into the post mix. If for some reason it is necessary to reduce plow speed, check mix uniformity carefully. Reduction of plow/wall clearance can improve mix uniformity, but introduces a potential for wedging.

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* The term "Becker" plows is used interchangeably with "heat dissipation" plows. The difference between these plows is not significant for dry mix compounds running at or close to ambient temperature.

3.3.3 Chopper Configuration

Short vs. Long Bars: Figure 10 summarizes results for a series of batches using long (8") and short (6") bars. Bulk density showed no difference during premix, but dropped more slowly during post mix with short bars. Lack of sensitivity during premix points out that bulk density may not be a sufficient criterion of mix quality. Preform strength and stiffness were lower with short bars during premix, but fell off slowly during post mix. The visual onset of balling was slower with short bars. It appears that long bars are particularly effective in opening glass strands, which in turn, initiates balling and loss of preform strength.

Tulip: Figure 11summarizes bulk density and preform strength results for a batch made with Becker plows and a type D tulip chopper. It is clear that preform quality is significantly lower with the tulip chopper. While a tulip may reduce fiber degradation in certain formulations, it is not as effective as stars and bars in opening CFF V110-1 fibrillated fiber.

Other configurations: Batches were made using one star / one bar, and two flat stars / two bent stars (no bars). Neither of these configurations showed sufficient improvements to warrant further evaluation.

4 RESULTS AND DISCUSSION - EIRICH MIXER

4.1 EQUIPMENT OPTIONS

Mixing studies were also run at Eirich Machines Ltd., in Maple, Ontario using a Model RV02 laboratory mixer and the standard NAO formulation. Based on the recommendations of Eirich engineering personnel, all trials were run with a batch size at 50% of the mixer volume, 13 rpm bowl speed and beveled beater bars. The variables investigated included:

- Beater bar speed
- Effect of pre-fluffing CFF V110-1 fibrillated fiber alone before adding powders

4.2 MIX QUALITY RELATIVE TO LITTLEFORD

Table I summarizes the bulk density, break load and stiffness values for various mixing conditions using the Eirich RV02 mixer. Reported values are after ten minutes premix of CFF V110-1 fibrillated fiber with powders and one minute after glass fiber addition. For reference, a Littleford batch was made and parts tested using the same lot of each raw material.

Table I: Bulk density (lb/ft^3) of Eirich Mixer Trials

		CFF Fibrillated Fiber Preopening	
Beater bar tip speed	**Preform Property**	**No Preopening**	**Preopened 30 sec**
22 m/s	Strength (lb)	1.5	1.9
	Stiffness (lb/in)	10.9	16.5
32 m/s	Strength (lb)	---	2.3
	Stiffness (lb/in)	---	20.0

NOTE: A Littleford mix from the same raw materials had a strength of 2.4 lb and a stiffness of 24.3 lb/in.

Based on this data, it is concluded that mix and preform quality obtained with the Eirich mixer can be equivalent to that obtained with Littleford mixers. Increased beater bar tip speed and fiber pre-opening appear to improve mix quality and preform strength.

Figure 6: Standard Mix, No Fibrous Processing Aid

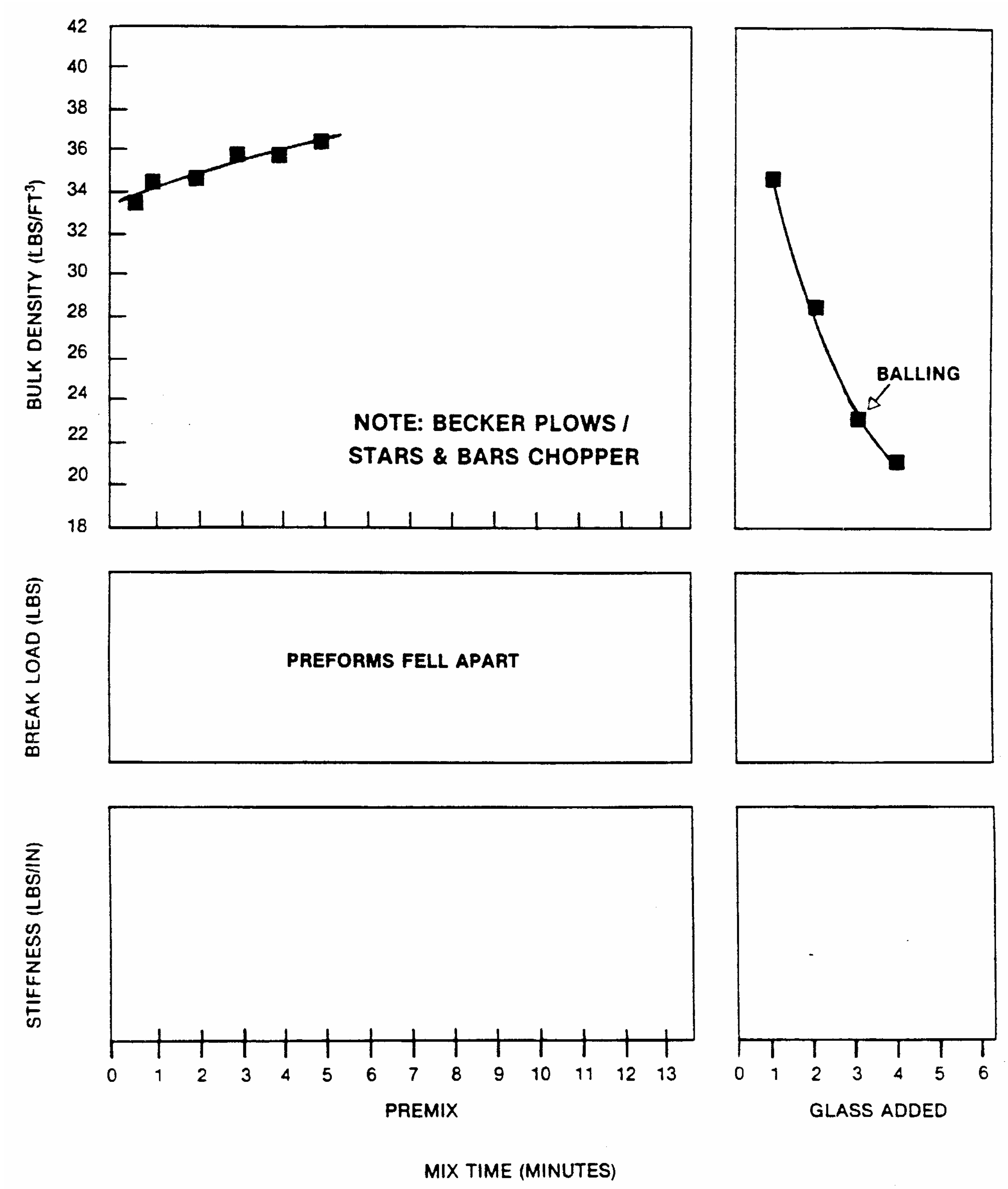


Figure 7: Effect of Glass Addition

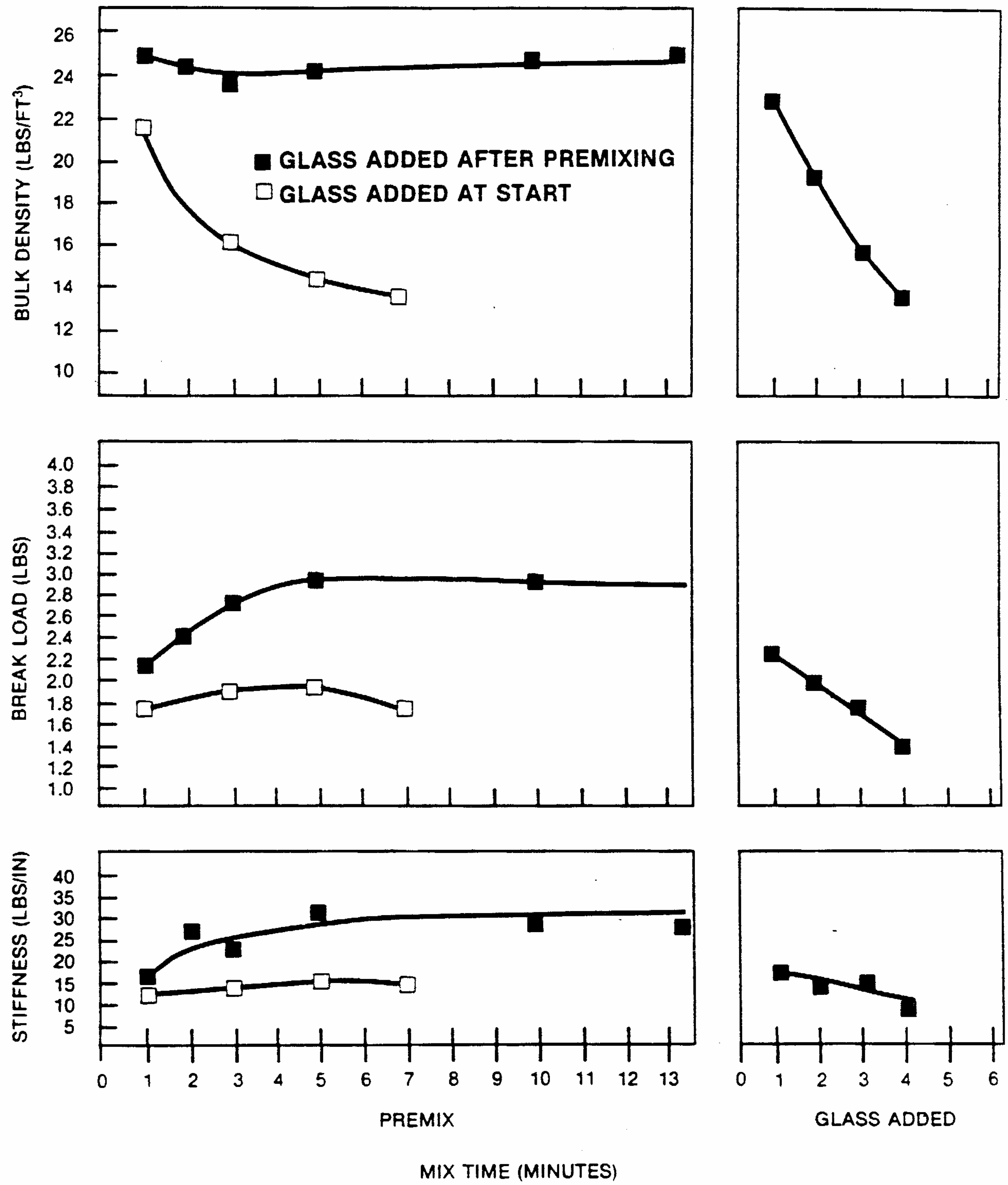


Figure 8: Premix / Postmix Trials

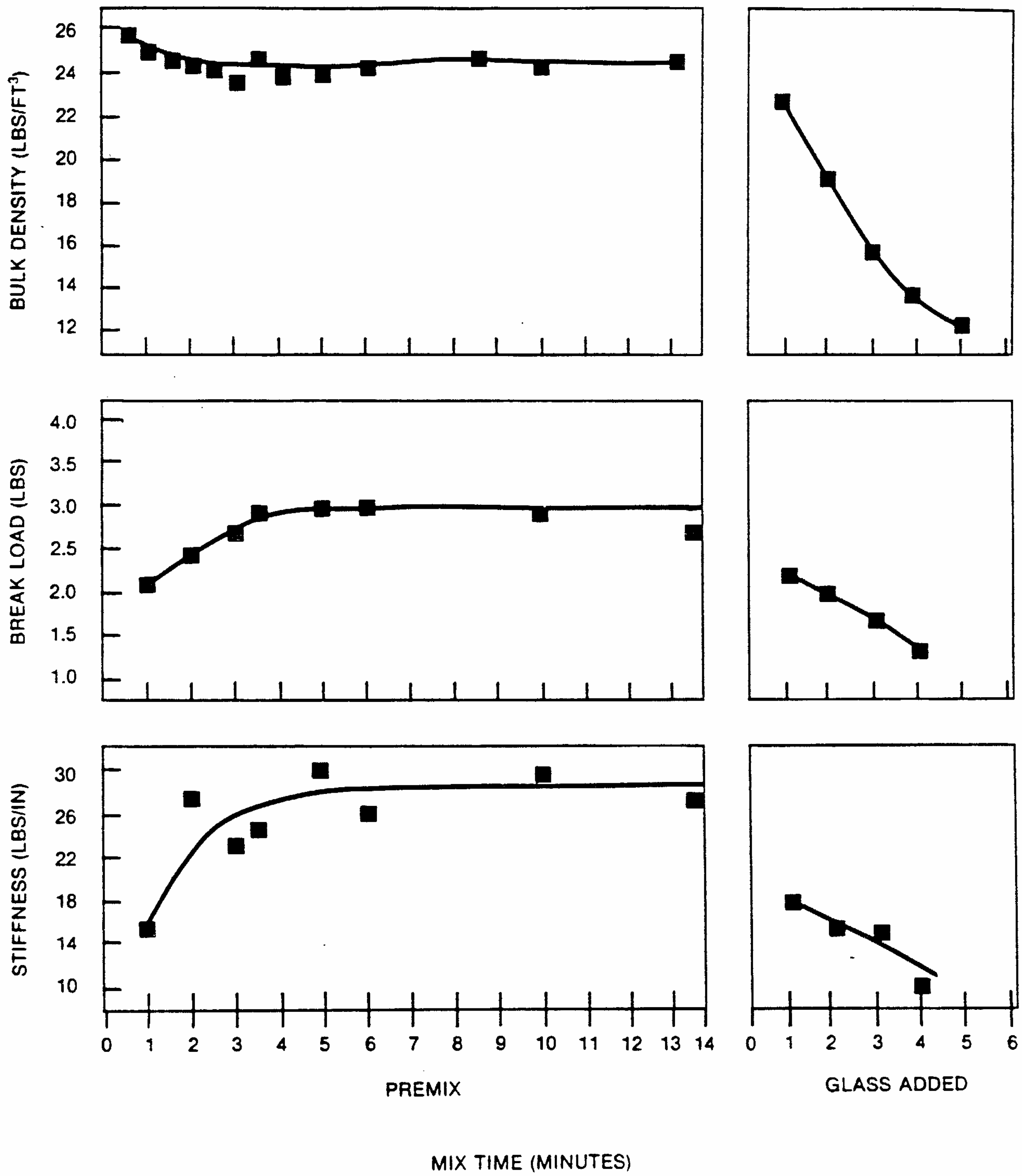


Figure 9: "V" Versus Becker-type Plows

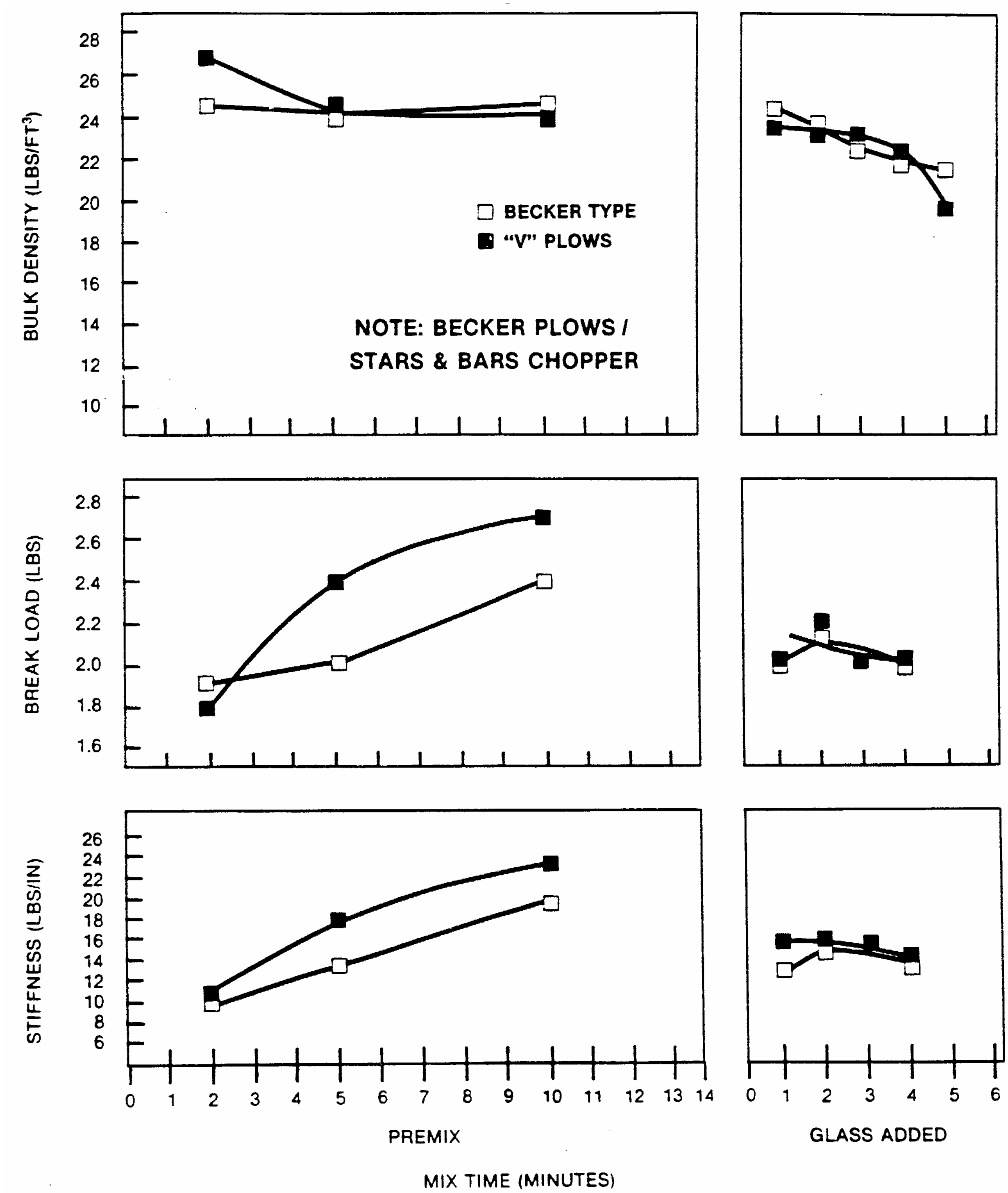


Figure 10: Long vs. Short Bars

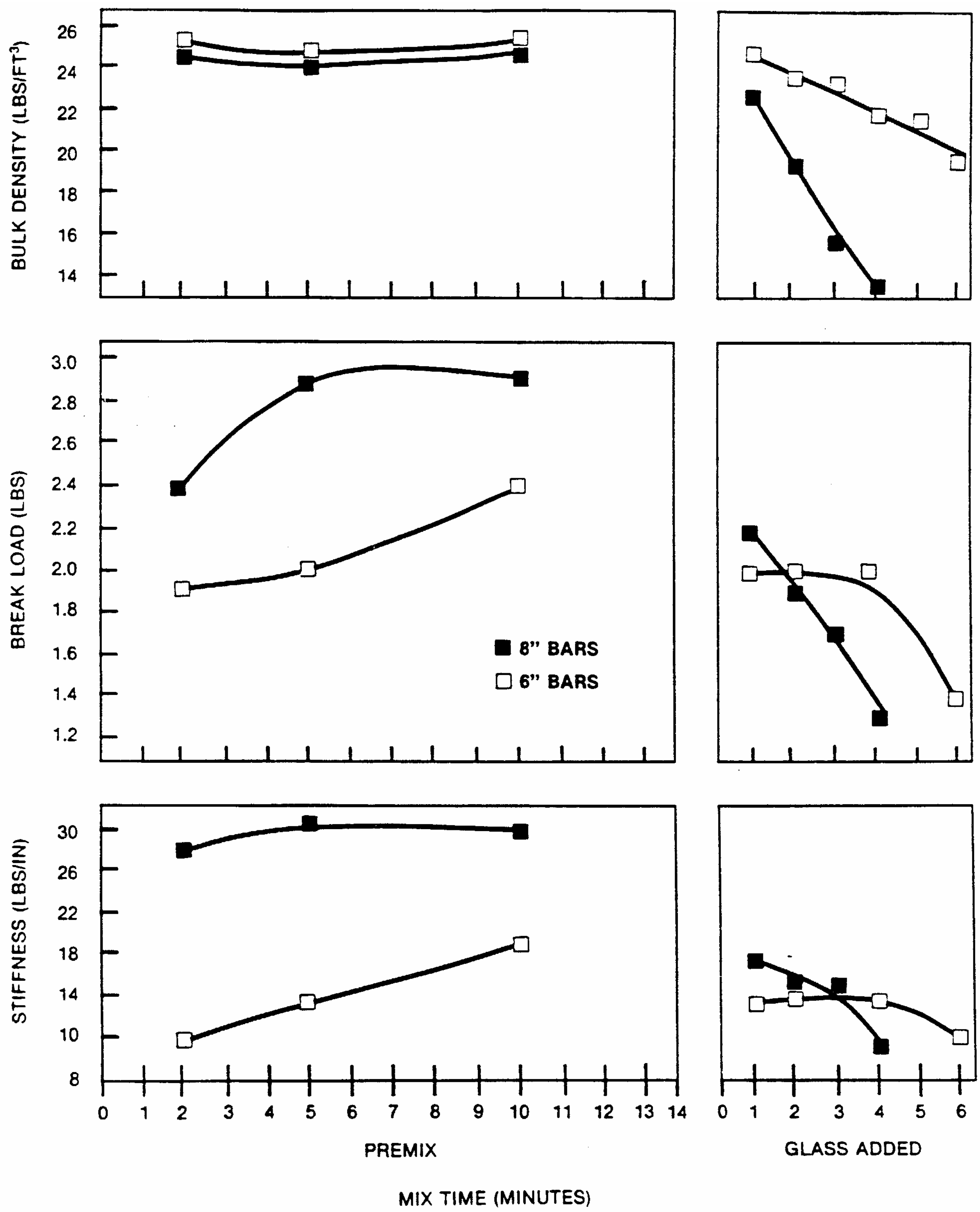
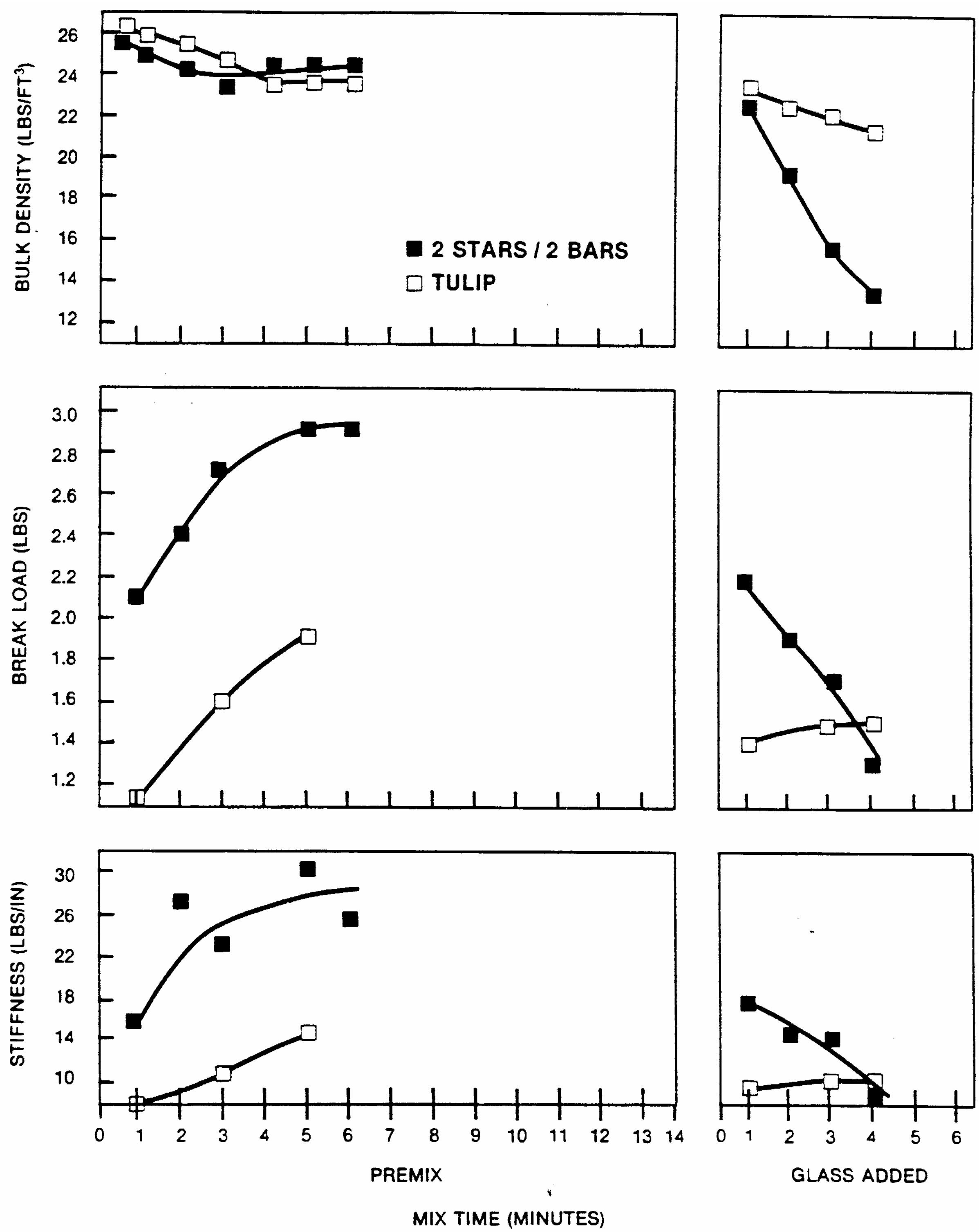


Figure 11: Tulip vs. 2 Star / 2 Bar Chopper



5 *RELATIVE PERFORMANCE OF CFF V110-1 FIBRILLATED FIBER AS A PROCESSING AID*

The function of a fibrous processing aid in a dry mix NAO formulation is to improve preform quality, prevent mix segregation and reduce dust. However, because the cost of pulp fiber is higher than the composite mix cost, it is important that the compounder use only as much as required by his specific formulation and processing conditions.

Figures 12, 13 and 14 summarize the effect of loading level through five weight percent for CFF V110-1 fibrillated fiber and aramid pulp for NAO mixes made in the Littleford mixer. In all cases, the bulk density with aramid and with CFF V110-1 fibrillated fiber have the same curve shape. The breaking strength and stiffness are about the same.

Similar comparisons have been made with mixes made in the Eirich mixer. As shown below in Table II, preform quality with CFF V110-1 fibrillated fiber is equivalent to aramid pulp.

Table II: Comparative Results - Eirich Mixer

Preform Property	**CFF V110-1**	**Aramid**
Strength (lb)	2.3	2.2
Stiffness (lb/in)	20.0	20.3

Figure 12: Bulk Density vs. Loading

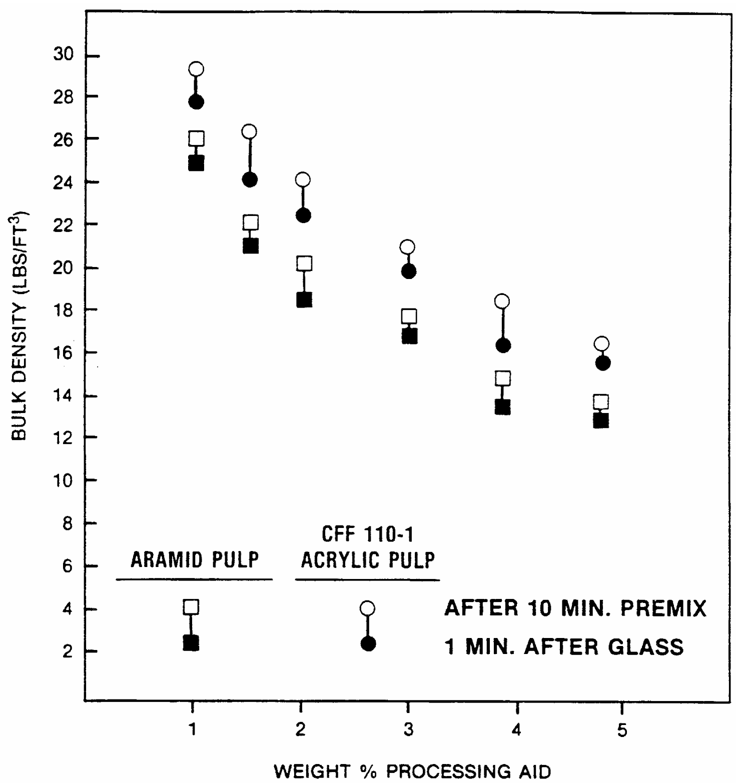


Figure 13: Breaking Strength vs. Fiber Loading

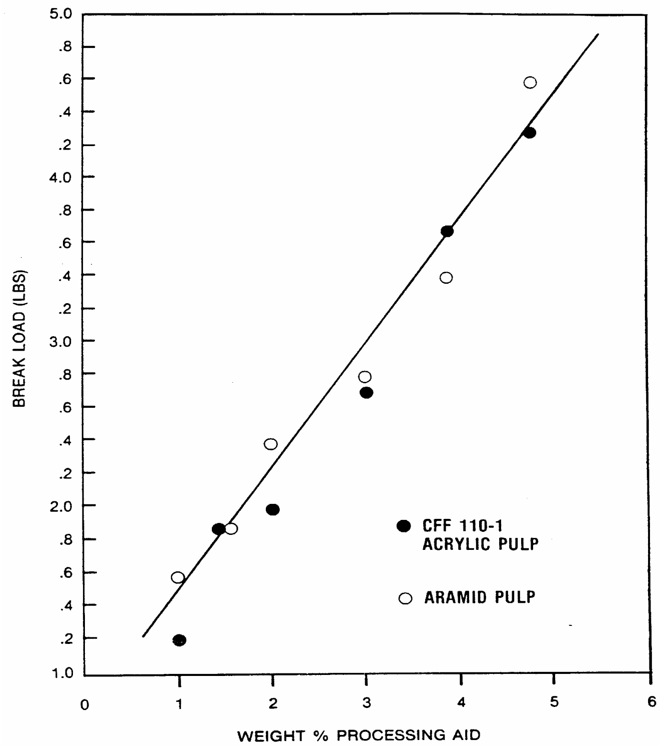


Figure 14: Stiffness vs. Fiber Loading