ISSN 1605 – 427X

www.sustech.edu

Effect of Some Treatments on the compatibility of some lignocellulosic materials with Portland cement

Tagelsir E. Mohamed[i], Abdelazim Yassin Abdelgadir[2],
M. M. Megahed[3] and Ramadan Nasser[3]

1. College of Forestry and Range Science Sudan University of Science and Technology
2. Faculty of Forestry University of Khartoum
3. Department of Forestry and Wood Technology, University of Alexandria-Egypt

ABSTRACT: This study investigated the effect of some treatments on the compatibility of three lignocellulosic materials with cement. The lignocellulosic materials used were sunt (*Acacia nilotica*) sawdust, bagasse and cotton stalks collected from Es-Suki Sawmill, EL Gunied Sugar Factory and the fields of EL Kamlin governarate, respectively. The treatments were control, addition of 3% $CaCl_2$, hot water extraction, hot water extraction 3%$CaCl_2$, 1%NaOH extraction, and 1%NaOH extraction+3%$CaCl_2$. Two Dewar flasks and a digital thermocouple were used. Hydration characteristics (maximum hydration temperature, time to reach maximum temperature and rise in temperature above ambient) of the lignocellulosic materials with cement were determined for each lignocellulosic material. The most suitable treatment common to all materials was the 1%NaOH extraction +3%$CaCl_2$. The average maximum hydration temperatures attained by this treatment were 63.87 °C for bagasse, 67.87 °C for cotton stalks and 67.9 °C for sunt sawdust. Bagasse was the least responsive material to the treatments used followed by cotton stalks and then sunt sawdust. Extraction with sodium hydroxide (1% solution) was found to be the most effective treatment for the three lignocellulosic materials under investigation.

KEYWORDS: *compatibility, wood, lignocellulosic materials, cement, hydration*.

INTRODUCTION

Cement bonded boards have gained increasing interest in building industry[1]. Extensive studies on expansion of raw material base have demonstrated the possibility of using lignocellulosic materials such as wood, some agricultural residues and industrial residues with cement(1-3). The ability of wood to combine with Portland cement is termed compatibility. Previous studies indicated that some wood materials are not compatible with cement due to adverse effects of certain wood extractives on cement setting (4-6). Hydration characteristics of wood-cement mixtures have been commonly used to assess the compatibility of potential lignocellulosic materials with cement(6–9). The compatibility of wood with cement can be enhanced by the extraction of the inhibitory substances found in wood or by the addition of chemical additives (10-12). Hot water and weak alkali extractions are among the common treatments used to extract the inhibitory substances found in wood. Calcium chloride is one of the widely used accelerators of cement setting. They are relatively cheap and easy to use. The objective of this study was to investigate the effect of some selected treatments on compatibility of sunt wood, bagasse and cotton stalks with ordinary Portland cement.

MATERIALS and METHODS

Preparation of the lignocellulosic raw materials

Three lignocellulosic materials were used in this study; bagasse, cotton stalks and sunt (*Acacia nilotica*) sawdust. Bagasse was processed by a hammer-mill, cotton stalks were processed first in a chipper then hammer-milled. Each of the three lignocellulosic materials was screened using laboratory sieves to remove the oversize, fines and other impurities. The smaller particles which passed a sieve hole-size of 0.8 mm (20 mesh) and retained on a sieve hole-size of 0.4 mm (40 mesh) were used for hydration studies.

Treatments

The elimination of cement hardening inhibition has been tried either by partial removal of soluble extractives (extraction with hot water for 6 hours or soaking in 1% NaOH solution for 24 hours) or prevention of their action by the addition of $CaCl_2$ as an accelerator.

The following treatments were used:

Treatment 1 (TRT 1) = control (untreated material)

Treatment 2 (TRT 2) = addition of 3% $CaCl_2$ (based on cement weight)

Treatment 3 (TRT 3) = Hot water (HW) extraction

Treatment 4 (TRT 4) = HW + 3% $CaCl_2$

Treatment 5 (TRT 5) = extraction with 1% NaOH

Treatment 6 (TRT 6) = extraction with 1% NaOH + addition of 3% $CaCl_2$

Procedure of Hydration Test

Preliminary hydration characterization was carried out for each of the three lignocellulosic materials to test its compatibility with ordinary Portland cement. An amount of 200 grams of ordinary Portland cement (produced by Al Amria Company, Egypt) and 15 grams of oven dry lignocellulosic material from each species were dry mixed in a small plastic bag with or without the addition of calcium chloride for the treated and untreated materials. The mixture was then kneaded with 90.5 ml of water for approximately 2 minutes. The plastic bag was wrapped with aluminum foil and then put in a Dewar flask. One of the probes of a type K Thermocouple (Digi-Sense Digital Thermometer) was placed inside the kneaded mixture of cement and wood and the other connected to the thermocouple. The plastic bag was then covered with fiber glass and the cap of the Dewar flask closed tightly. The exthothermic temperature was then recorded at suitable intervals. Finally the maximum temperature (T_{max}) of the hydration reaction and the time to reach that maximum (t_{max}) were recorded.

Statistical Analysis

Analysis of variance (ANOVA) and Duncan's Multiple Range Test were conducted to study the significance of the difference between treatments using Statistical Analysis System. [13].

Results and Discussion

Maximum hydration temperature

The three materials used in this study when mixed with cement, without any treatment, appreciably decreased the temperature rise when compared to neat cement (Figure.1). In accordance to the classification of Sandermann, and Kohler [6], the material is suitable for cement mixing if the (T_{max}) is greater than 60°C. and hence they are all considered incompatible.

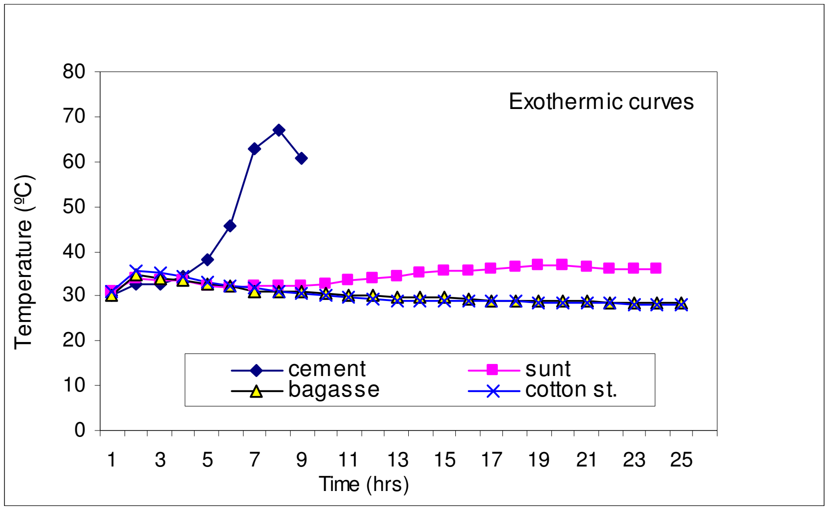

Figure 1. Exothermic curves of the untreated lignocellulosic materials–cement mixtures as compared to neat cement.

Figures 2 - 4 show the effects of different treatments on hydration characteristics of sunt, cotton stalks and bagasse, respectively.

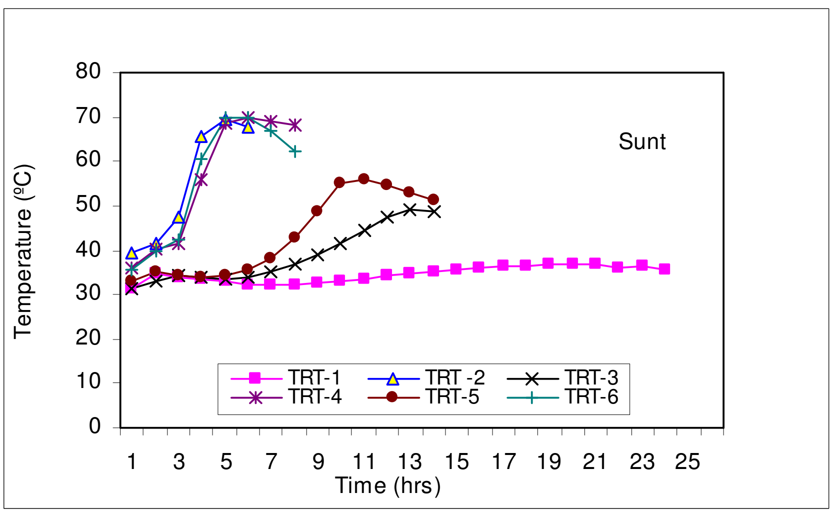

Figure 2. Exothermic curves of Sunt wood–cement mixtures under different treatments. TRT-1 = Untreated wood, TRT-2=TRT-1+3%$CaCl_2$. TRT-3 = Hot water, TRT-4=TRT -3+3%$CaCl_2$, TRT -5=1%NaOH and TRT-6=TRT -5+3%$CaCl_2$.

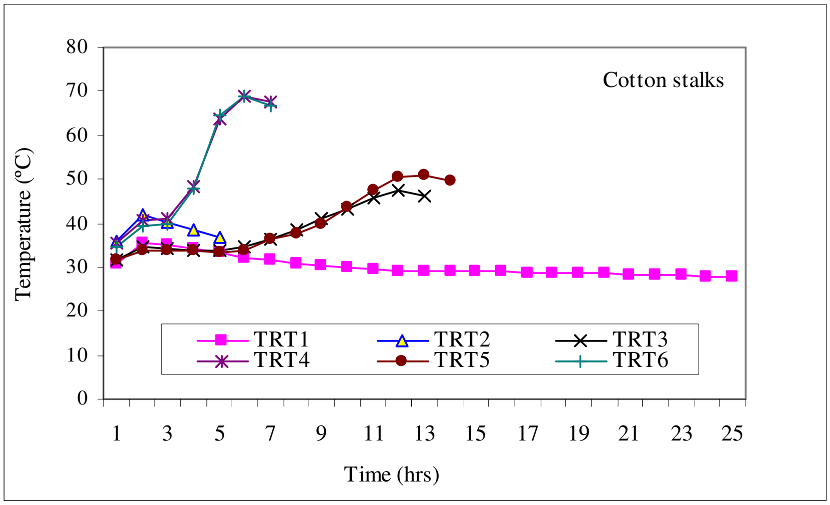

Figure 3. Exothermic curves of cotton stalks-cement mixture under different treatments. TRT-1=Untreated wood. TRT-2 =TRT-1+3%$CaCl_2$, TRT-3=Hot water, TRT-4=T RT-3+3% $CaCl_2$, TRT-5=1%NaOH and TRT-6=TRT-5+3%$CaCl_2$.

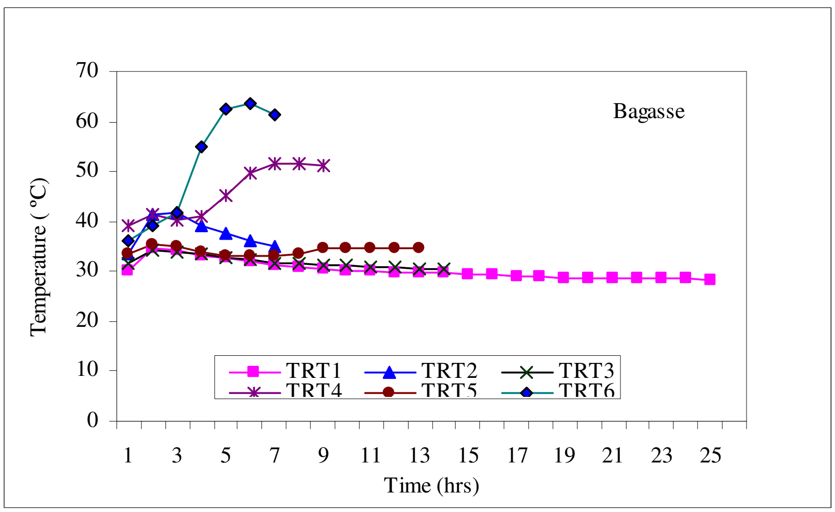

Figure 4. Exothermic curves of bagasse-cement mixtures under different treatments. TRT-1=Untreated wood. TRT-2 =TRT-1+3%$CaCl_2$. TRT-3=Hot water, TRT-4=T RT-3+3% $CaCl_2$.TRT-5=1%NaOH and TRT-6=TRT-5+3%$CaCl_2$.

Treating the three lignocellulosic materials with hot water slightly increased the maximum hydration temperature for both sunt and cotton stalk-cement mixtures 48.5 and 47.3 %, respecttively. The three lignocellulosic materials can still be considered incompatible since the maximum hydration temperature is below (60 ºC).

Addition of 3% calcium chloride as accel -erator for the three materials when treated with hot water increased the hydration temperature from 48.5 to 70 ºC or by 44.5 % for sunt saw dust, from 47.3 to 67.3 ºC or by 42.35 % for cotton stalks particles and from 34.8 to 52.3 ºC or by 50.3% for bagasse particles. Sunt wood and cotton stalk particles can then be classified as compatible after extraction with hot water and addition of calcium chloride. Bagasse is still unsuitable for cement mixtures.

When the three lignocellulosic materials were treated with 1% NaOH without additive, similar results to those obtained with hot water treatment without additive were also observed.

When 3 % calcium chloride was added to the weak alkali treated materials, the maximum hydration temperature of the three lignocellulosic materials under investigation exceeded 60 °C and hence rendered suitable for cement mixing. The rise in maximum hydration temperature due to the addition of calcium chloride to the 1% NaOH treated materials increased from 55.3 to 67.9 °C or by 22.71 % for sunt wood, from 50.9 to 67.9 °C or by 33.4% for cotton stalks and from 34.8 to 63.7 °C or by 83.53% for bagasse particles. The temperature rose for a short time at the beginning of the reaction and then dropped a bit rose again and reached a maximum. The temperature rise depicts the general pattern of hydration reactions of neat cement and wood cement- water mixtures. The chemical additive did not appear to have neutralized the detrimental effect of high inhibitory species on exothermic reactions of cement. This statement is in agreement with Moslemi and co- workers[6] but in contradiction with earlier conclu-sions made by Biblis and Lo[14]. An other possible explanation is that the additive is believed to speed up the rate of hydration of plain cement without reacting with the wood substance [7].

The analysis of variance for the differ-ent treatments with regard to the maximum hydration temperature (T_{max}) variable showed highly significant differences (p = 0.0001). For the mean separation test and Duncan's grouping. (Figure 5).

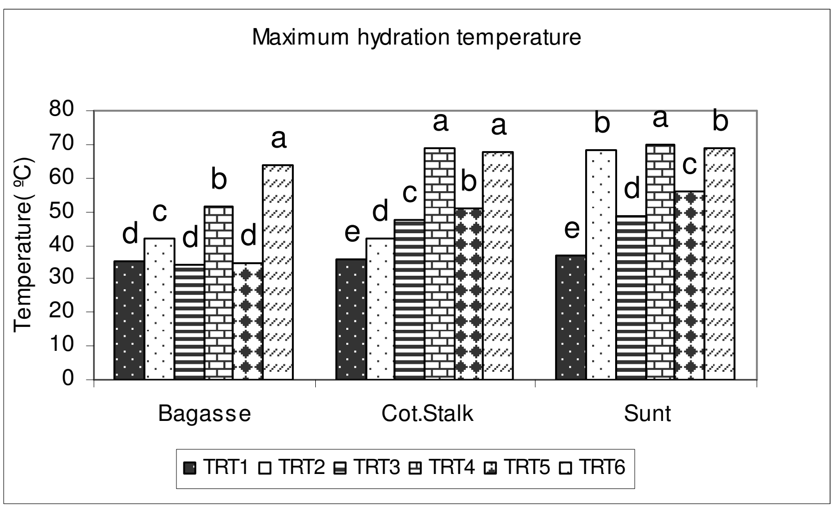

Figure 5. Maximum hydration temperature attained by different treatments of the three lignocellulosic materials. *Bars with similar letters in each species are not significantly different according to Duncan's test.

Time to reach maximum hydration temperature:

The results presented in Figure 6 show the time to reach maximum hydration temperature. The assessment of these results indicated that the addition of 3 % $CaCl_2$ reduced the reaction of hyd-ration time of the untreated sunt sawdust from 20 hours to 4.1 hours. Similar reduction in hydration time to reach maximum temperature was also recorded for the two other treatments.

The time to reach maximum tempe-rature for hot water treated sunt sawdust was reduced from 11.58 hours to 3.84 hours when the 3 % $CaCl_2$ was added. For the weak alkali (1% NaOH) treated sunt sawdust a reduction in time to reach maximum temperature from 10.0 hours to 4.4 hours was recorded when the 3 % $CaCl_2$ was added.

The analysis of variance for the dependent variable (t_{max}) for sunt sawdust is highly significant for all the treatments used (P = 0.0001). The analysis of variance and the Duncan′s grouping are shown in Figure 6.

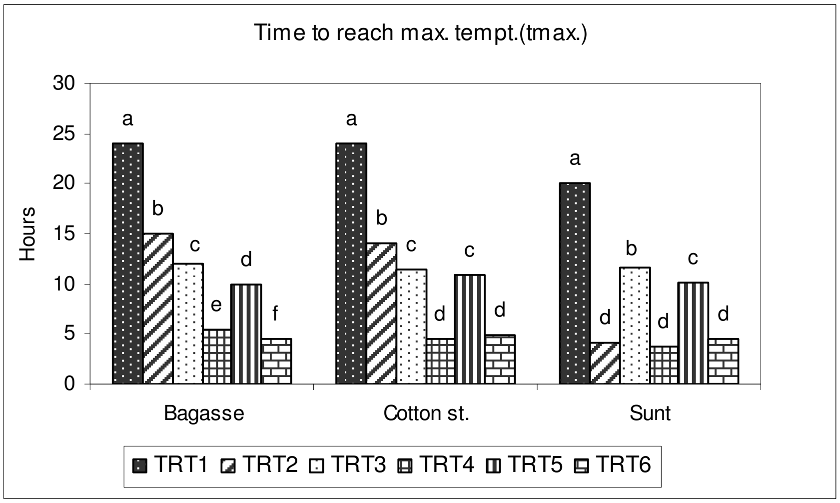

Figure 6. Mean values of time to reach maximum hydration temperature (t_{max}) as an effect of treatments on the three lignocellulosic materials. * Bars with similar letters for each species are not significantly different according to Duncan′s test. TRT-1 = Untreated wood, TRT-2 = TRT-1+ 3 % $CaCl_2$. TRT-3 = Hot water, TRT-4 = TRT-3 + 3 % $CaCl_2$, TRT-5 = 1 % NaOH and TRT-6 = TRT-5 + 3 % $CaCl_2$.

The effect of $CaCl_2$ as an accelerator on the time to reach maximum temperature for both cotton stalks and bagasse was also significant for the different treatments (P = 0.0001) .

Rise in temperature above the ambient (ΔT)

The effect of different treatments on the rise in temperature above the ambient followed a similar pattern as the maximum hydration temperature. The lowest values were observed with the untreated materials and with the other two treatments when the 3 % $CaCl_2$ was not added. The highest values in general were associated with hot water and 1 % NaOH when the calcium chloride is used as an accelerator. A remarkable rise in temperature above ambient is recorded with the untreated sunt sawdust when the additive is used. The analysis of variance for the rise of temperature above ambient (ΔT) for the three lignocellulosic materials showed highly significant differences among the treatments used (p = 0.0001). It was clear from Figure 7 that the addition of $CaCl_2$ appreciably affected the temperature rise above the ambient for all the lignocellulosic materials. For the Duncan′s grouping (Figure 7).

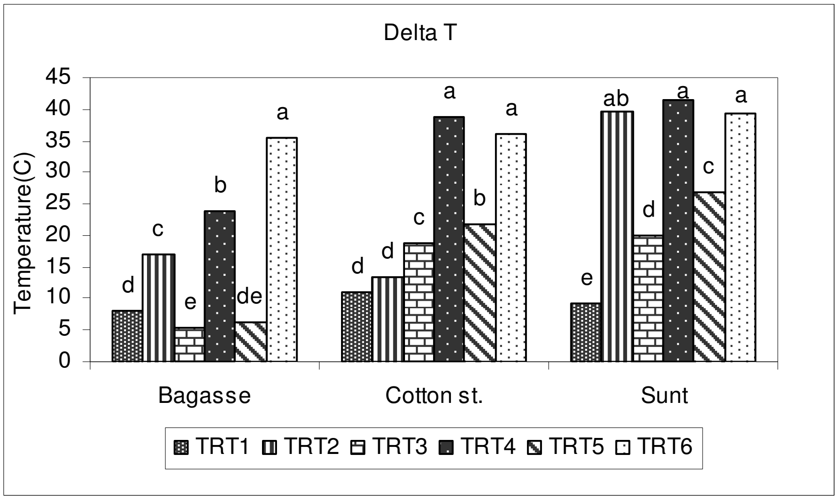

Figure 7. Mean values of rise in temperature above the ambient (ΔT) as an effect of treatments for the three lignocellulosic materials used.
* Bars with the same letters in each species are not significantly different according to Duncan's test. TRT1 = Untreated wood. TRT2 = TRT1+ 3 % $CaCl_2$. TRT3 = Hot water. TRT-4 = TRT-3 + 3 % $CaCl_2$.TRT-5 = 1 % NaOH. TRT-6 = TRT-5 + 3 % $CaCl_2$.

CONCLUSION

Within the limitation of the study, the following conclusions were drawn:

- The three lignocellulosic materials; bagasse, cotton stalks and sunt sawdust are incompatible with ordinary Portland cement
- The best treatment which proved effective for enhancing the compatibility of the three lignocellulosic materials was the extraction with 1% NaOH and addition of 3 % $CaCl_2$ as accelerator.
- Hot water treatment with 3 % $CaCl_2$ is equally suitable for both sunt - sawdust and cotton stalks particles.
- Addition of 3 % $CaCl_2$ to the untreated sunt sawdust also proved to be a suitable treatment.
- Bagasse is the least responsive among the lignocellulosic materials to the treatments used, followed by cotton stalks, then sunt sawdust.

REFERENCES

1. Eusebio, D. A. (2003). Cement bonded boards: Today's alternative. *Proceedings of the Technical Forum in Celebration of the 21 Philippine council for Industry and Energy Research and Development Anniversary.* Dept. of Science and Tech., Edsa Shangri-La, EDSA, Pasing City, Philippines, March 17, 2003.9 pp.
2. Fernandez, E. C. and V. P. Taja-on. (2000). The use and processing of rice straw in the manufacture of cement-bonded fiberboard. Wood-cement composites in the Asia region. *In*: *Proc. of a workshop held at Rydges Hotel*, Canberra, Australia.. pp. 49-54.
3. Evans, P. D. (2000). Summary: An introduction to wood - cement composites. Wood cement composites in the Asian region. In :Proc. of a *workshop held at Rydges Hotel*, Canberra, Australia. pp.7-10.
4. Kumar, S. (1980). Development of wood–wool boards from indigenous materials. PL-480 *Project. Final Research Report.* Forest Research Institute and College, Dehra Dun, India.96, pp .
5. Sandermann, W. H., J. Preusser, and W. Schweers. 1960. Studies on mineral-bonded wood materials.

Holzforschung materials; the effect of wood extractives on the setting of cement- bonded wood, Berlin, **14**: 70-77 (C.F. Forest Abstracts. 1961, **22**: 2568).

6. Sandermann, W., and R. Kohler (1964). Studies on mineral bonded wood materials VI.A short test of the aptitude of woods for cement bonded materials. *Holzforschung, Berlin*, **18** (1/2): 53-59. (C.F. *Forest Abstracts.1965*, **26**:1502).
7. Moslemi, A. A., J. F.Garacia, and A. D. Hofstrand (1983). Effect of various treatments and additives on wood Portland cement–water systems. *Wood and Fiber Science*.**15**:165-176.
8. Hachmi, M., A. A. Moslemi., and A. G. Camphell (1990). A new technique to classify compatibility of wood with cement, *Wood Science and Technology* **24**: 345-354
9. Kavvouras, P. K. (1987). Suitability of *Quercus conferta* wood for the manufacture of cement bonded flake boards. *Holzforschung*.41: 159-163.
10. Abdalla, Ashraf. M. A. (1998). *Effect of Pretreatment, Particle Size, Pressure and Cement –Wood ratio on Properties of Cement Bonded Products From Acacia nilotica (sunt wood).* M.Sc. Thesis, University of Khartoum.
11. Abdelgadir, A. Y. and M. F. Ibrahim. (2002). A note on compatibility of five-home grown species with Portland cement. *University of Khartoum*, *Journal of Agricultural Science* **10**: 150-155.
12. Abdelgadir, A. Y. and M. F. Ibrahim. (2003). Effect of pretreatment and Cement / Wood Ratio on the compatibility of wood with Portland cement. *Sudan Silva* **9**: 77-85.
13. SAS Institute Inc. (1990). *SAS /STAT Guide for personal computers Version 6 Edition*. SAS Institute Inc., Cary, N.C.
14. Biblis, E. J., and C. F. Lo. (1968). Sugars and other wood extractives: Effect on the setting of southern pine-cement mixtures. *Forest Products Journal* **15**: 28-34.