Thermax® N990 in Bromobutyl Inner Liner Compounds

Tire inner liners are responsible for maintaining proper tire inflation which results in reduced rolling resistance and improved fuel efficiency. The elastomers of choice for tire inner liner applications are halobutyl rubbers which have low permeability relative to their glass transition temperatures. This means that low permeability can be achieved alongside low temperature flexibility. Some other properties that are important for the application are flex-fatigue resistance and heat aging properties. In this study, Thermax® N990 replaced furnace black N660 in a bromobutyl (BIIR) model tire inner liner formulation.

The benefits of Thermax® N990 confirmed in the study were:

- **12% to 22% reduction in mixing power consumption** and **improvement in dispersion**
- Significant decrease in compound viscosity
- Slight increase in tack which is an important property for the tire building process
- Improvement in fatigue resistance as measured by extension cycles to failure
- **8% to 15% reduction in compound permeability**
- Improvement in adhesion to ply skim
- Decreased hysteresis at low strains above room temperature for both uncured and cured compounds
- **Significant compound cost reduction** due to higher total filler loadings

The BIIR inner liner formulations can be found in Table 1. To maintain constant hardness the N660 was replaced at a 2.0:1.0 N990:N660 ratio. Testing was completed at 20%, 40% and 60% replacement of N660. Dispersion, Mooney viscosity, RPA, green strength, subjective tack, MDR, Shore A hardness, tensile, heat aging, fatigue life, oxygen permeability, adhesion, and DMA tests were run on all compounds. The compounding and testing were completed at Smithers in Akron, Ohio. Testing results can be found in the figures on the following pages.

Table 1. Test formulations

Ingredient	Control	A	B	C
X_Butyl® BB 2030	100	100	100	100
N660	60	48	36	24
Thermax® N990	**0**	**24**	**48**	**72**
Stearic acid	1	1	1	1
SP1068 resin	4	4	4	4
Paraffinic oil	7	7	7	7
MBTS	1.3	1.3	1.3	1.3
Zinc oxide	3	3	3	3
Sulfur	0.5	0.5	0.5	0.5
Total	**176.8**	**188.8**	**200.8**	**212.8**

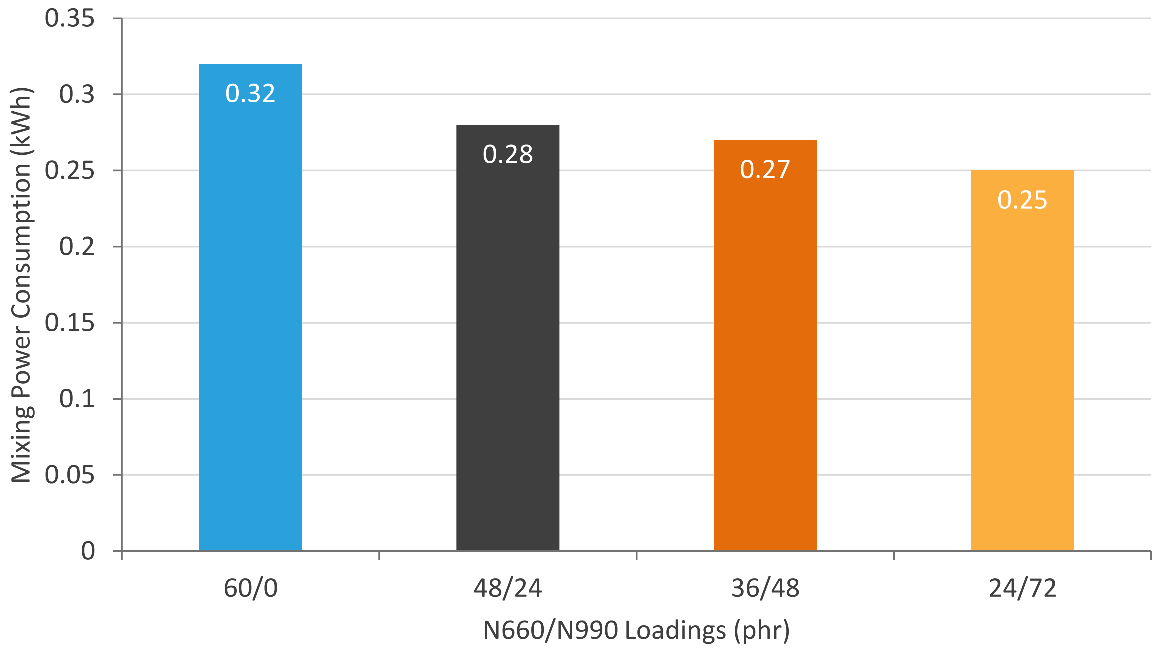

Figure 1. Mixing power consumption of the compounds. Mixing power decreased as N990 replaced N660.

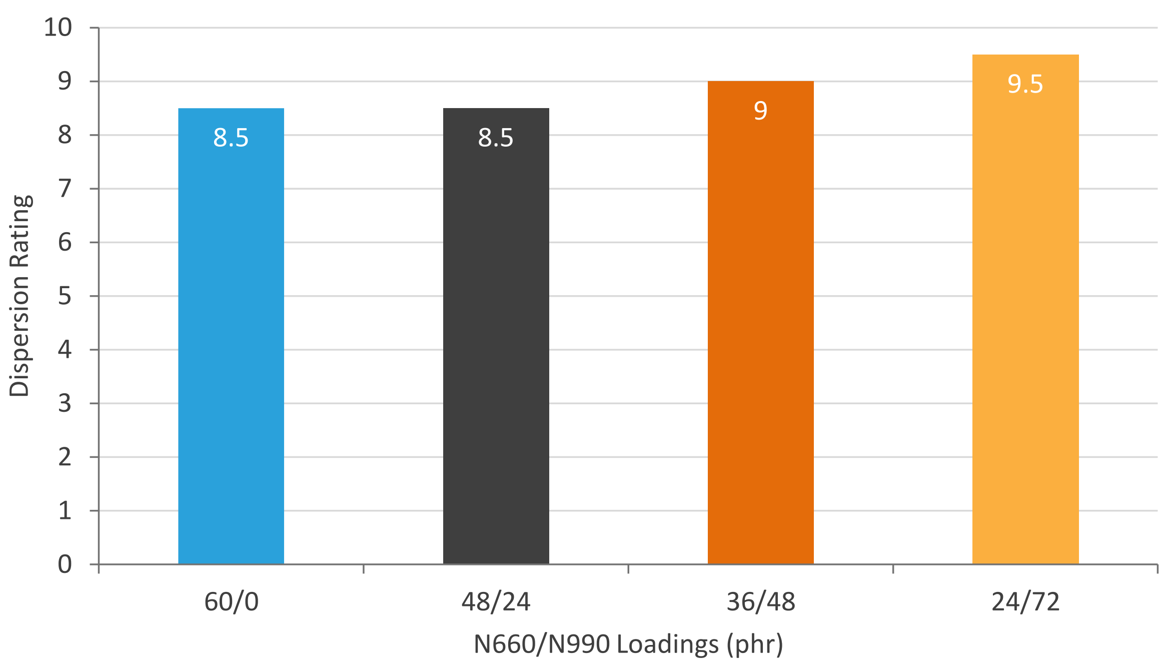

Figure 2. Dispersion rating of the compounds using the Phillips optical dispersion method. Dispersion improved as N990 replaced N660.

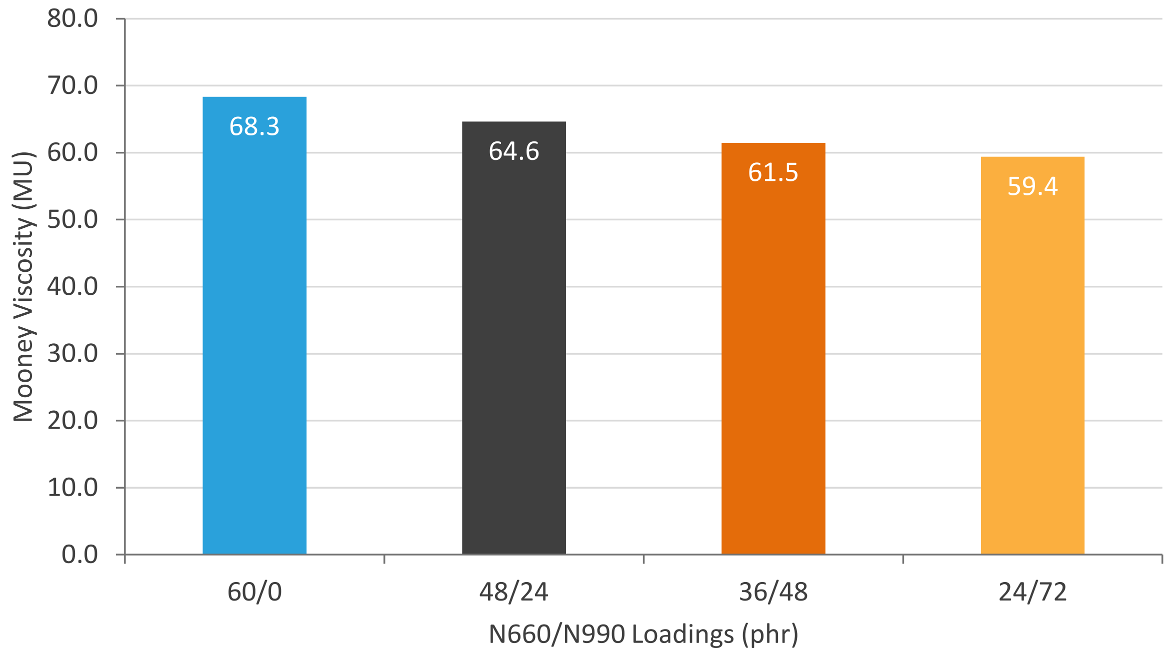

Figure 3. Mooney viscosity of the compounds measured at 125°C. Viscosity decreased as N990 replaced N660.

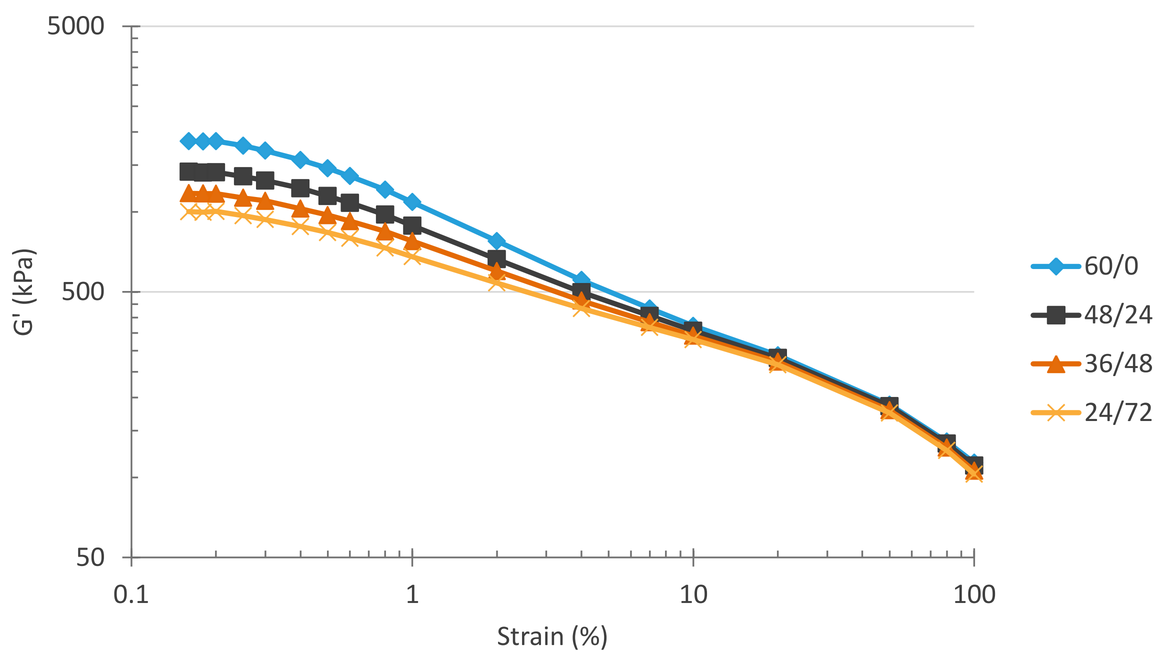

Figure 4. Payne effect, G' storage modulus versus strain, of the compounds measured at 70°C and 1 Hz. G' decreased as N990 replaced N660.

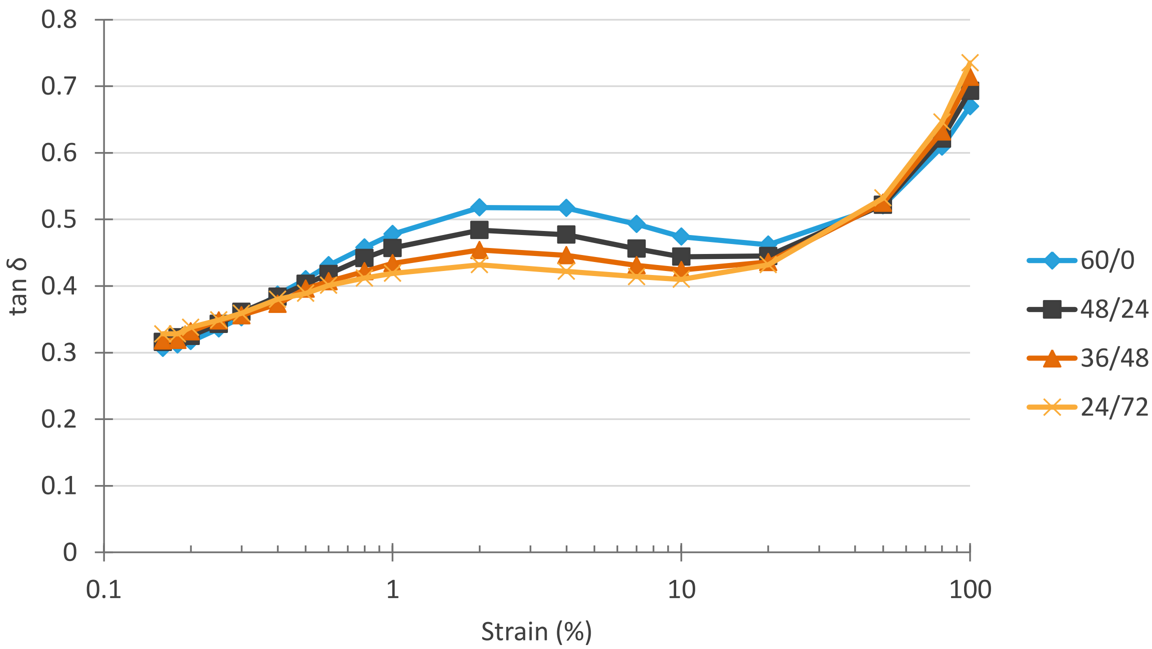

Figure 5. Tan δ versus strain of the compounds measured at 70°C and 1 Hz. Between 0.5% and 20% strain, tan δ decreased as N990 replaced N660. Above 50% strain, tan δ increased as N990 replaced N660.

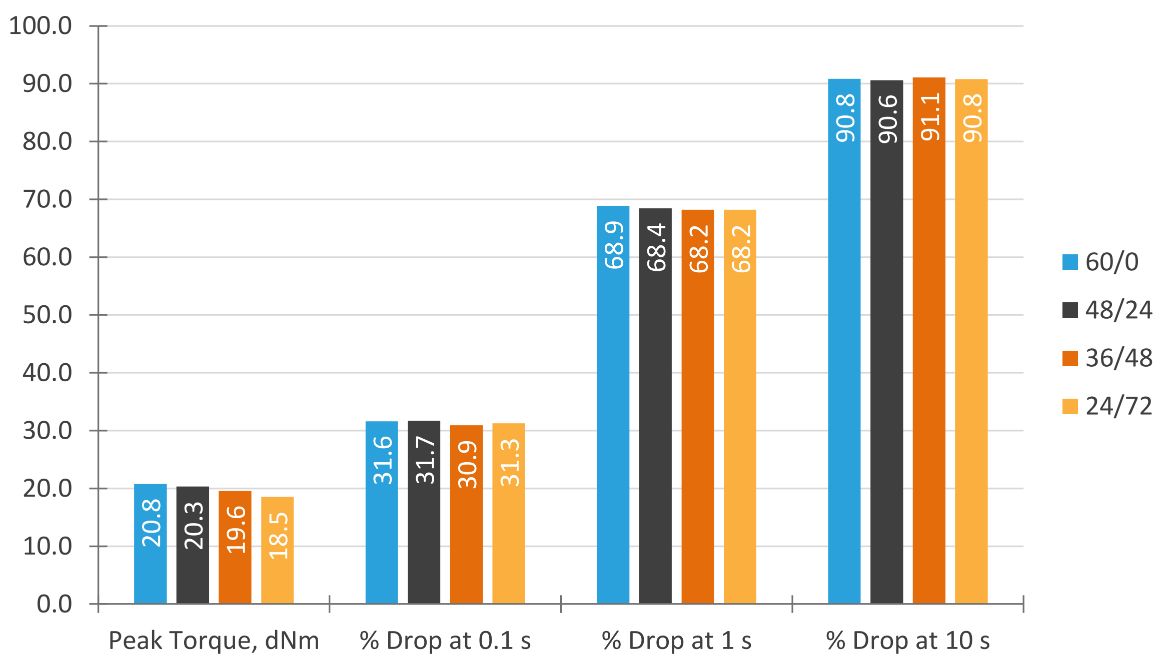

Figure 6. Stress relaxation data of the compounds measured at 100°C and 70% strain. Peak torque decreased as N990 replaced N660. Relaxation behavior was similar between the compounds.

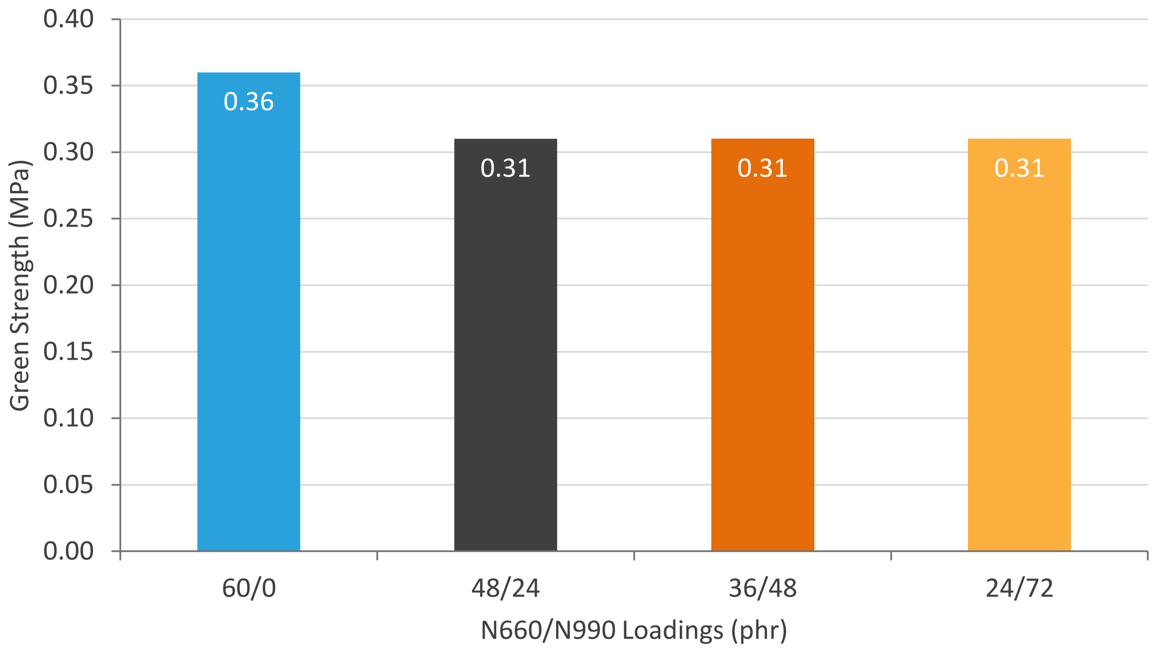

Figure 7. Green strength of the compounds. Green strength was slightly lower for the compounds with N990.

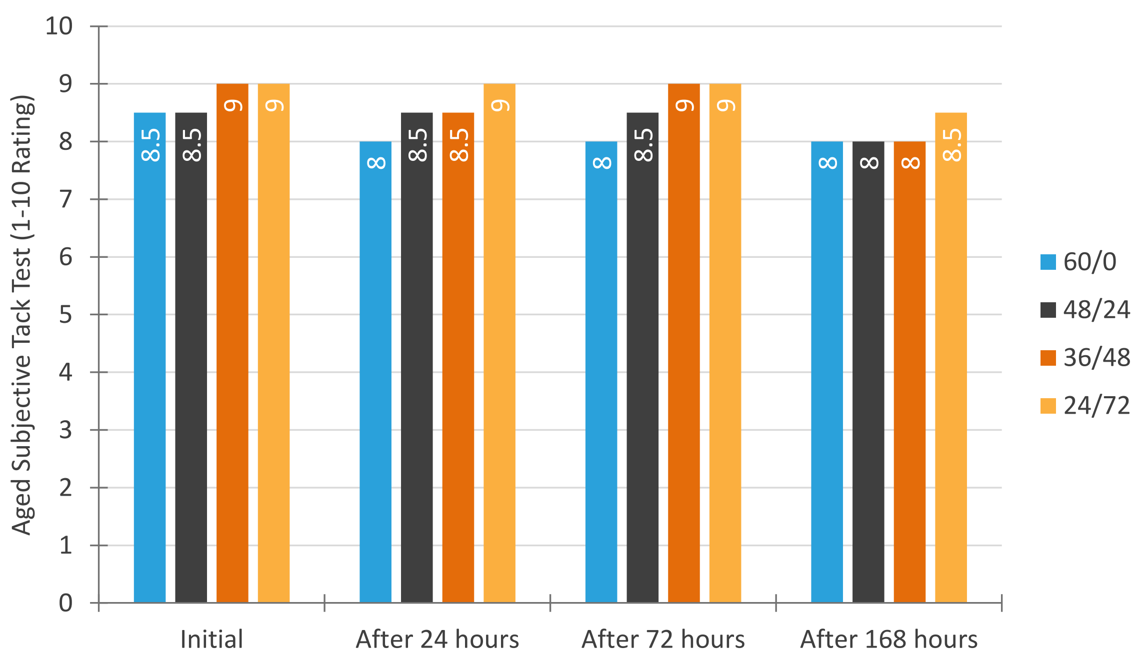

Figure 8. Subjective tack of the compounds. Tack increased slightly as N990 replaced N660. There was a slight decrease in tack with aging.

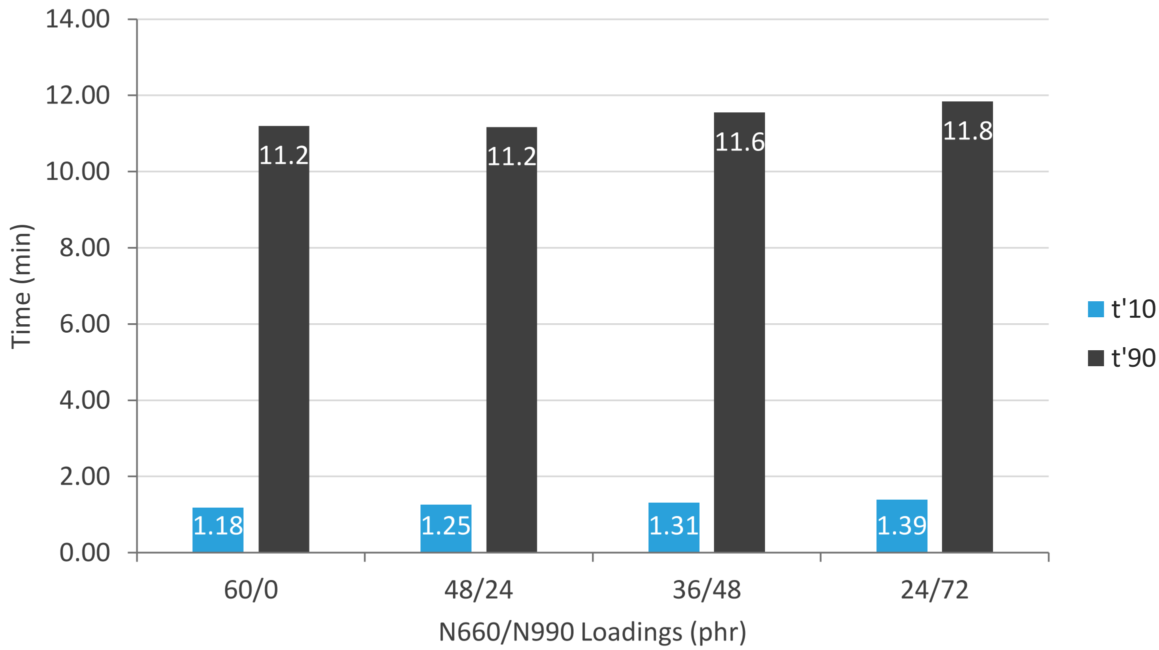

Figure 9. Scorch time, t'10, and cure time, t'90, of the compounds. Times tended to increase slightly as N990 replaced N660.

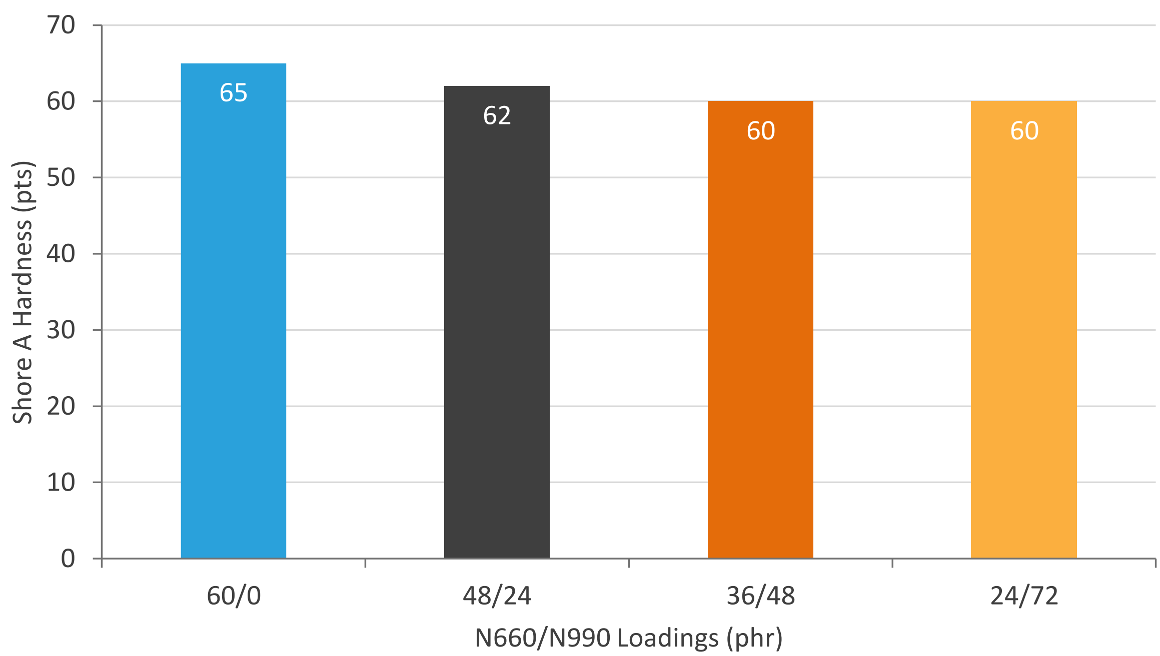

Figure 10. Shore A hardness of the compounds. Hardness tended to decrease as N990 replaced N660; however, all compounds were within 5 hardness points.

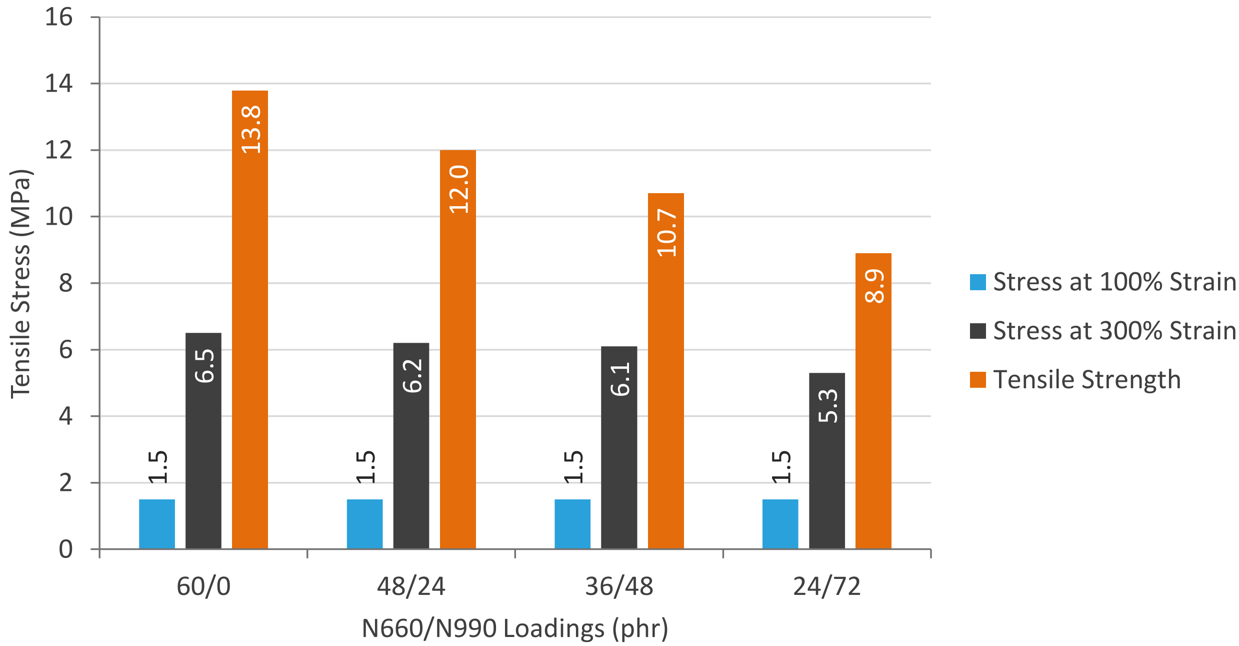

Figure 11. Tensile stress of the compounds. No significant differences in stress at 100% strain were observed. Stress at 300% strain and tensile strength tended to decrease as N990 replaced N660.

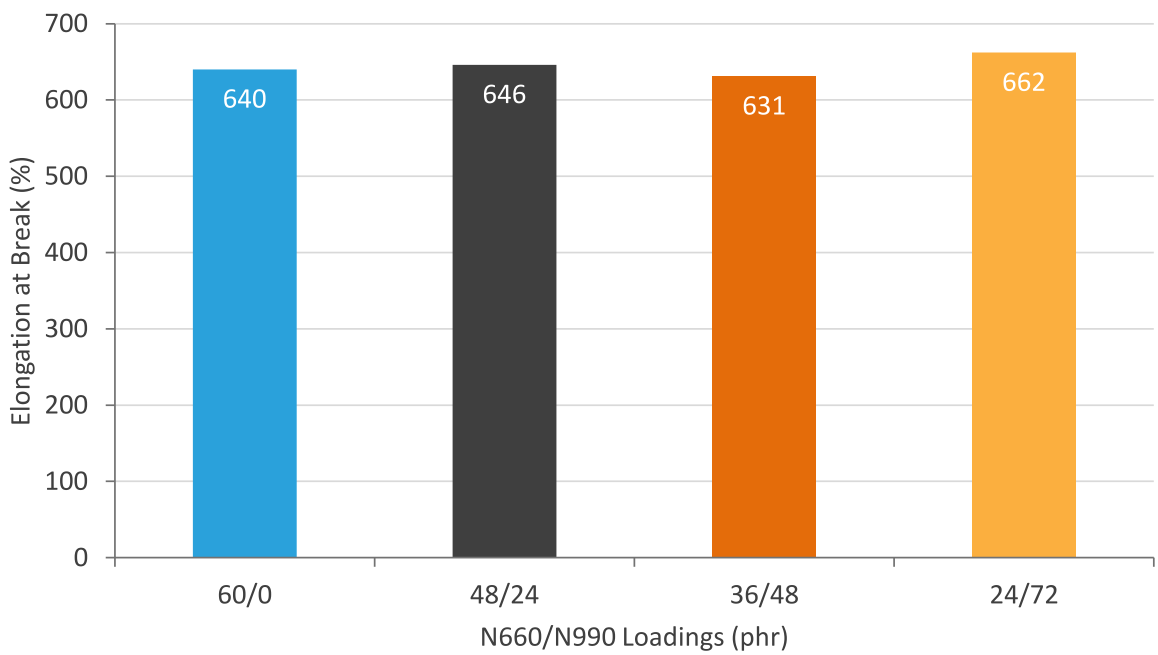

Figure 12. Elongation at break of the compounds. There were no significant differences observed.

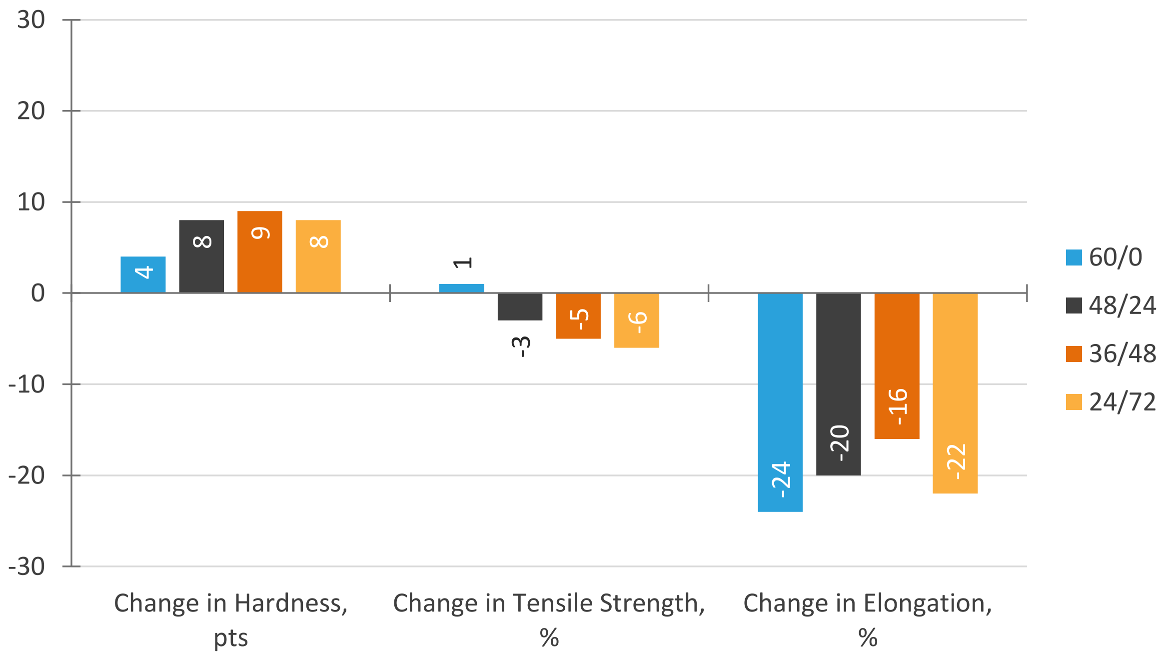

Figure 13. Changes in physical properties after heat aging 72 hours at 100°C. Compounds had similar responses to heat aging.

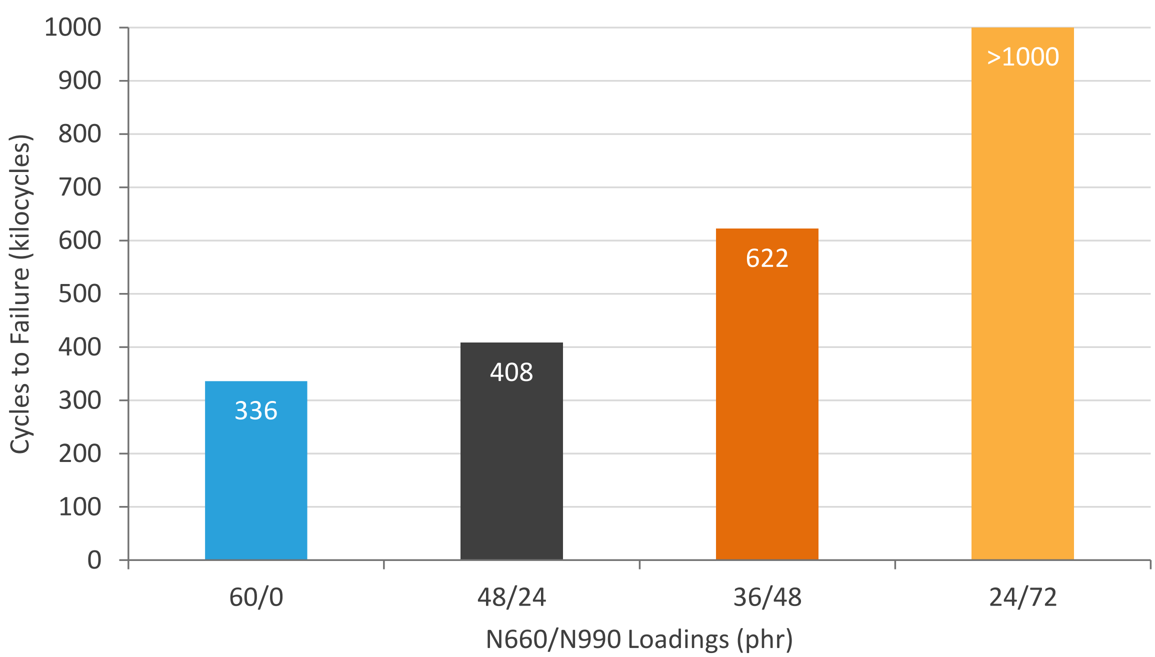

Figure 14. Extension cycling fatigue to failure of the compounds measured according to ASTM D4482. The number of cycles to failure increased as N990 replaced N660.

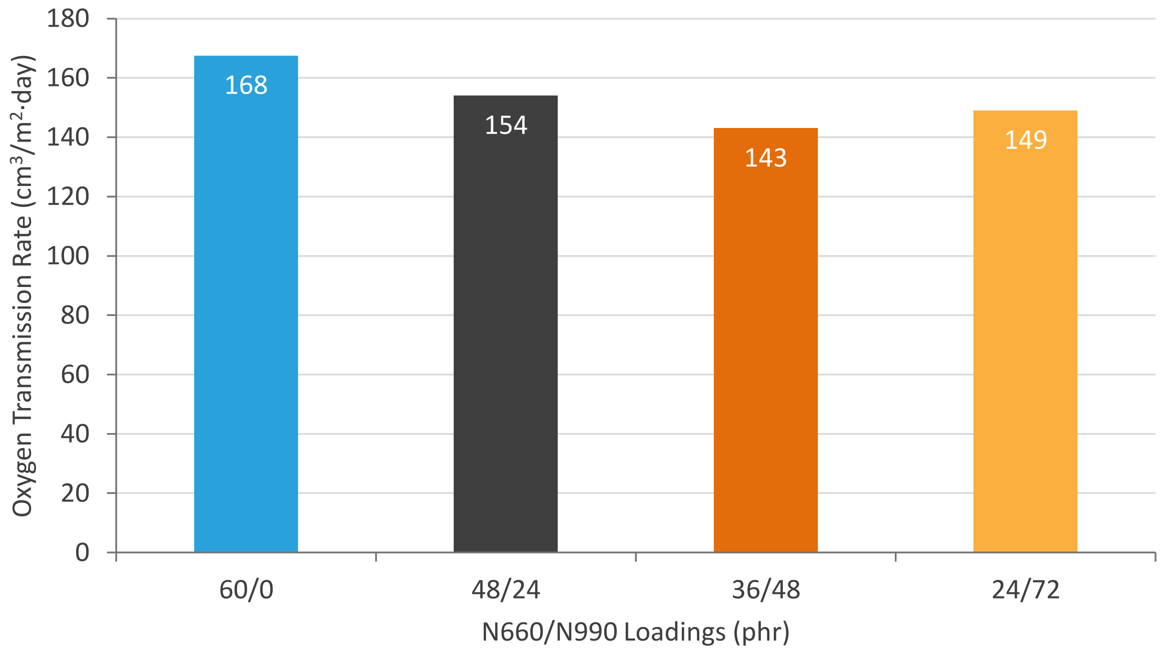

Figure 15. Average oxygen transmission rate of the compounds measured at 40°C, 50% relative humidity, and 760 mmHg. Permeability was 8% to 15% lower for the compounds with N990.

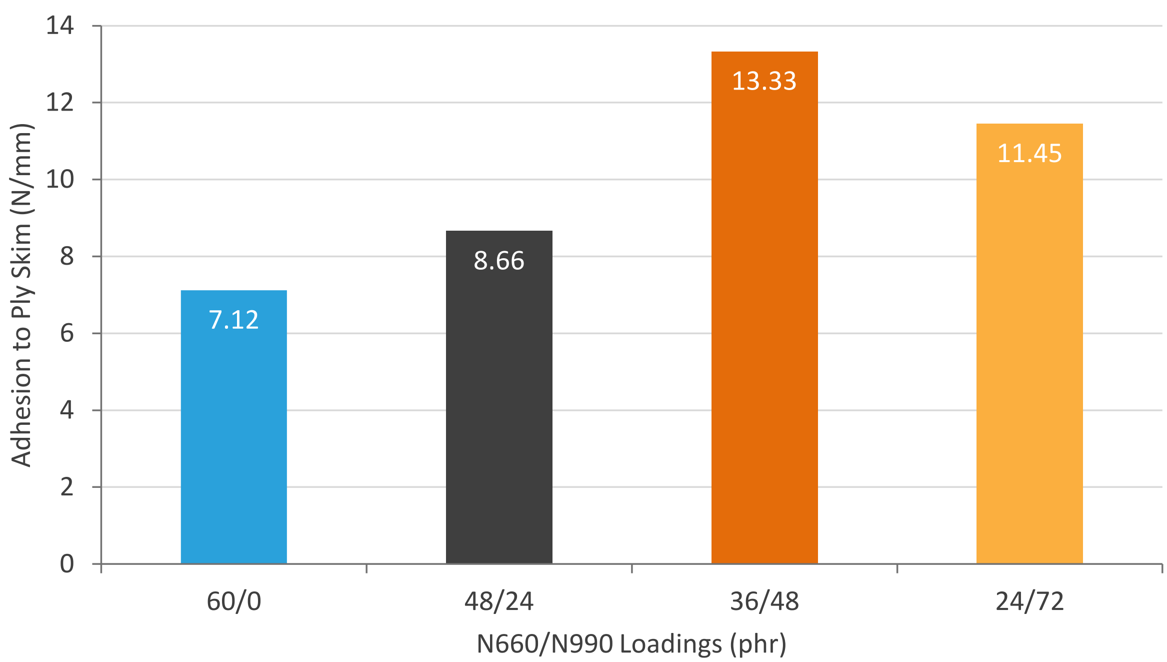

Figure 16. Adhesion to ply skim for the compounds. Adhesion improved when N990 replaced N660.

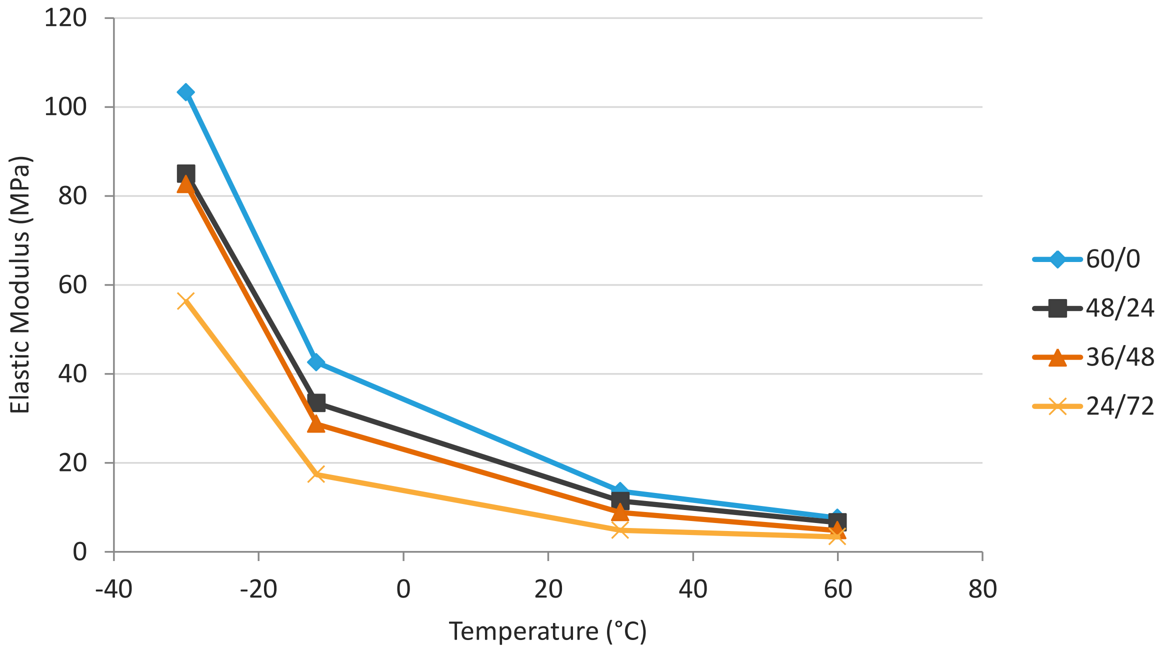

Figure 17. Cured elastic modulus versus temperature of the compounds measured at 1 Hz and 0.25% strain. Elastic modulus decreased as N990 replaced N660.

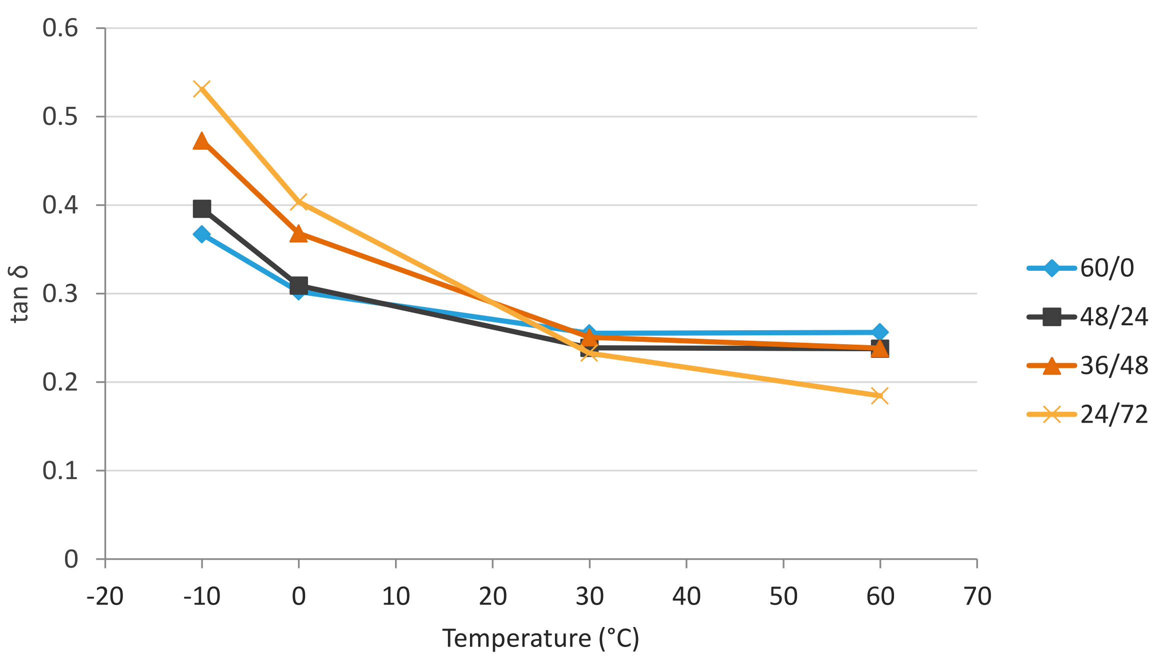

Figure 18. Cured tan δ versus temperature of the compounds measured at 1 Hz and 0.25% strain. At low temperatures, tan δ increased as N990 replaced N660. At 60°C, tan δ decreased as N990 replaced N660.