Stuck in the middle with glue: Lap shear testing of ochre and beeswax in Middle Stone Age compound adhesives

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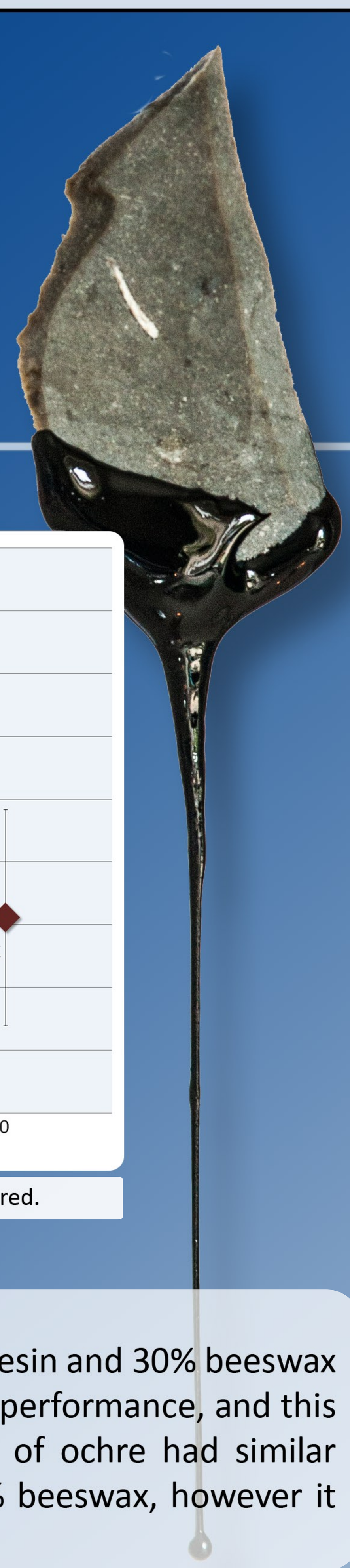

Introduction:

Compound adhesives can be seen as evidence of advanced cognition and fully modern behaviour outside the realm of symbolism [1, 2]. However, it is unclear how efficient different adhesive recipes are, to what extend specific ingredients influence the performance, and how difficult it is to combine ingredients to maximum effect. In this study, we conducted laboratory based lap shear tests to better understand the effects of specific ingredients and ingredient ratios. The adhesive mixtures were all pine resin based, as currently the only chemically identified African Middle Stone Age (MSA) adhesive is a conifer resin [3], and contained different portions of ochre as a loading agent and beeswax as a plasticiser (Table 1).

Table 1. Recipes and results of single lap shear tests including one standard deviation.

Main Ingredient	Primary Additive	Secondary Additive	Fbreak (Mpa)	S	Fmax (N)	S	DL at Fmax (mm)	S
50% Pine resin	50% Beeswax	None	1.85	0.55	598	176.0	1.4	0.2
50% Pine resin	50% Beeswax	+ 10% Ochre	0.65	0.06	411	48.8	1.2	0.3
50% Pine resin	50% Beeswax	+ 20% Ochre	0.78	0.21	503	137.1	1.3	0.2
50% Pine resin	50% Beeswax	+ 30% Ochre	0.71	0.05	461	29.4	1.1	0.1
60% Pine resin	40% Beeswax	None	1.90	0.64	685	137.7	1.4	0.2
60% Pine resin	40% Beeswax	+ 10% Ochre	1.06	0.30	615	45.5	1.4	0.1
60% Pine resin	40% Beeswax	+ 20% Ochre	1.09	0.06	703	40.7	1.5	0.2
60% Pine resin	40% Beeswax	+ 30% Ochre	1.70	0.53	780	64.8	1.5	0.1
70% Pine resin	30% Beeswax	None	2.62	0.45	853	153.2	1.5	0.3
70% Pine resin	30% Beeswax	+ 10% Ochre	3.36	0.34	1093	94.5	1.9	0.1
70% Pine resin	30% Beeswax	+ 20% Ochre	3.47	0.66	1127	216.2	1.6	0.3
70% Pine resin	30% Beeswax	+ 30% Ochre	2.99	0.68	964	219.3	1.5	0.3
80% Pine resin	20% Beeswax	None	1.58	0.53	512	172.4	1.6	0.4
80% Pine resin	20% Beeswax	+ 10% Ochre	1.61	0.25	522	83.2	1.6	0.5
80% Pine resin	20% Beeswax	+ 20% Ochre	3.00	0.88	976	279.1	1.8	0.3
80% Pine resin	20% Beeswax	+ 30% Ochre	3.16	0.70	1021	224.1	1.8	0.2

Methods:

Tests were performed in the Delft Aerospace Structures and Materials Laboratory at the Delft University of Technology, using a Zwick-Roell 1455 tensile bench. The adhesives were used to glue standardised pieces of birch plywood together and these were then tested using the ASTM D 1002 standard for apparent shear strength of single lap joint assemblies. Lap shears are used to test adhesives because of their resemblance to many practical joints; in our archaeological application they resemble cleft hafting, one of the most common and versatile hafting methods [4] (Fig 1). Specimens are mounted vertically between two clamps, which are then moved apart from one another at a constant speed and increasing force until the bond fails. The data are recorded automatically: strain in millimetres (mm), force in Newtons (N), and force at break in N/mm^2 (Mpa). Five specimens were tested for each adhesive recipe.

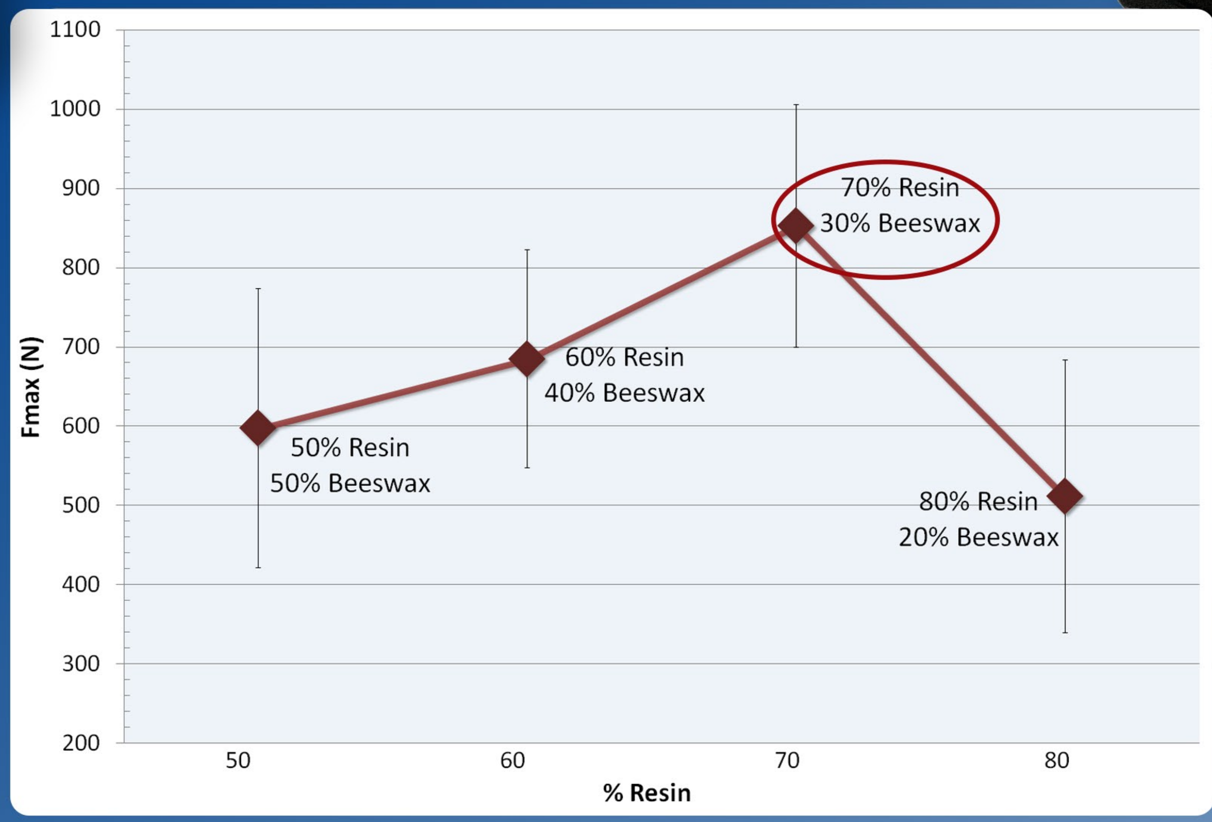

Fig 2. Maximum force of resin/beeswax adhesives with the optimum circled in red.

Results:

Tests conducted on resin/beeswax recipes showed that 70% pine resin and 30% beeswax is the strongest (Fig 2). Adding ochre to this recipe further improved performance, and this mixture with an additional 20% ochre was stronger still. Addition of ochre had similar positive performance effects on adhesives containing less than 30% beeswax, however it was detrimental to those with more beeswax (Fig 3).

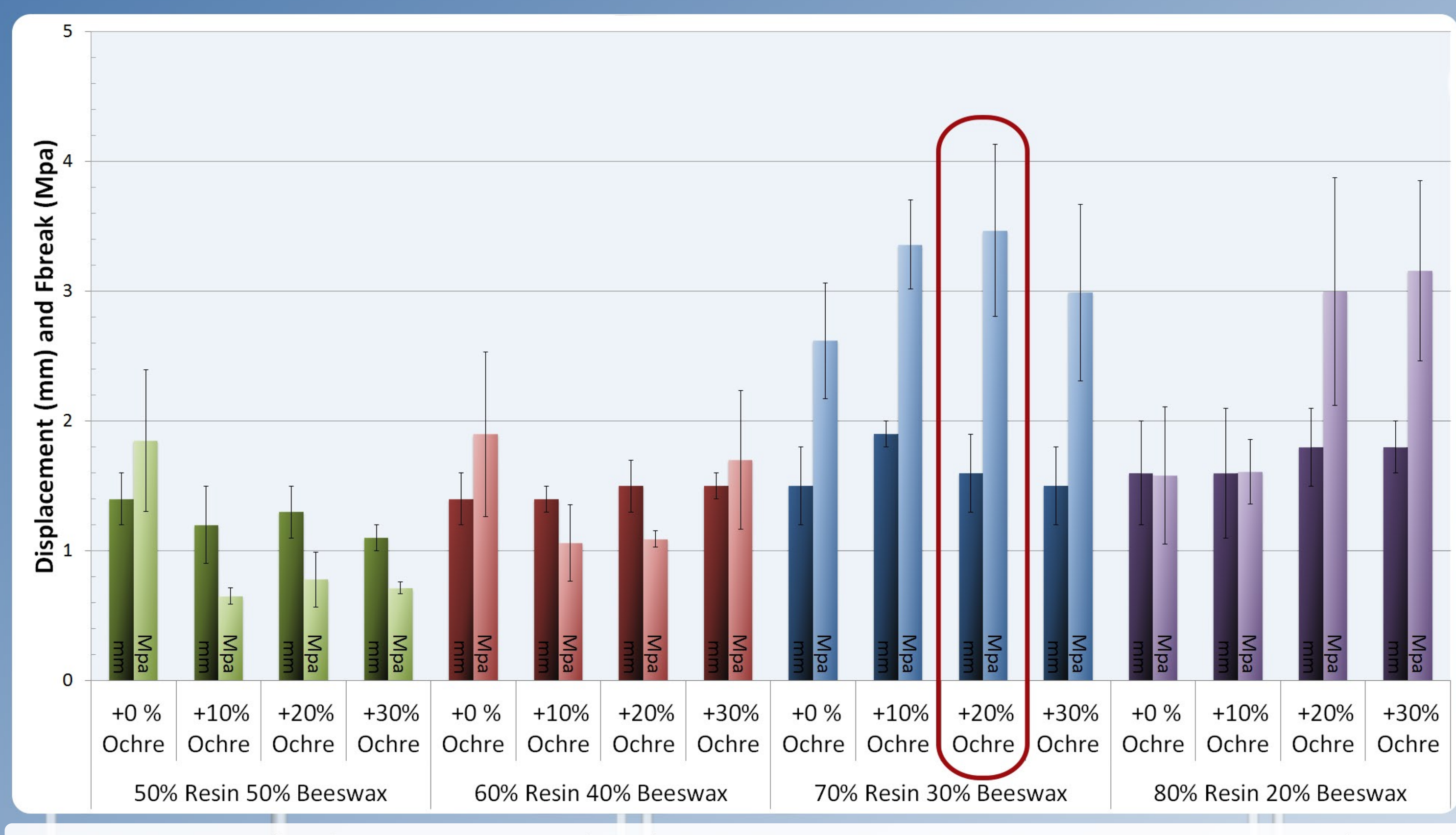

Fig 3. Displacement (mm) and force at break (Mpa) of all adhesives tested. The best performing adhesive (circled in red) is considerably stronger than all recipes containing 40 and 50% beeswax, and those without ochre.

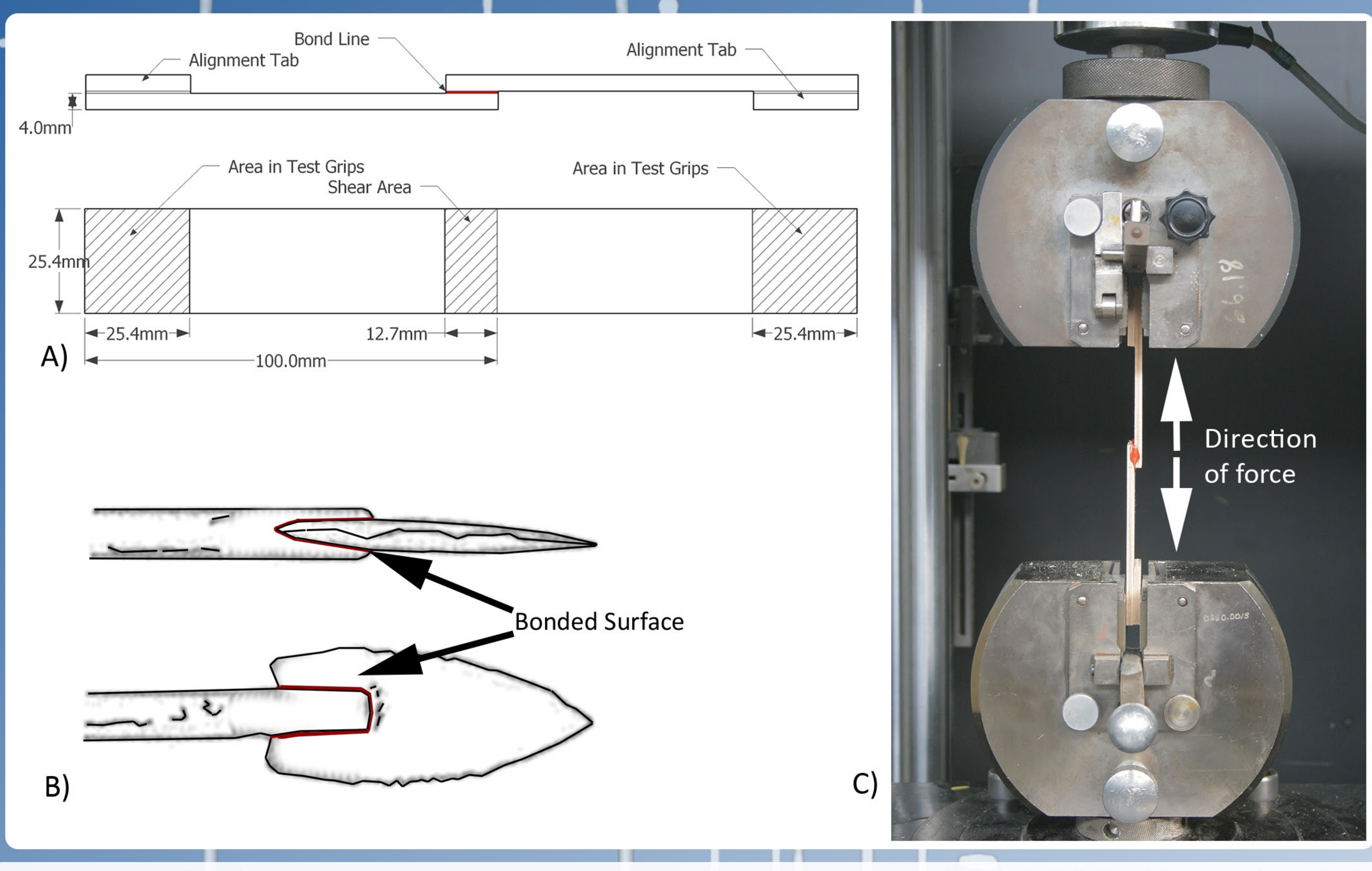

Fig 1. A) Wood lap shear specimen dimensions illustrating bond line and shear area. B) Cleft haft (After [4] pg. 183) in which most of the force applied during use occurs in the shear plane along the bonded surface. C) Lap shear test specimen in grips with arrows showing the direction of clamp movement.

Discussion and Conclusion:

Not only are there significant changes in performance due to relatively small changes in ingredient ratios, the further addition of ochre only benefits those adhesives with 30% or less beeswax. The first step in the process must therefore be correct in order for the second ingredient to work effectively. Variation among individual recipes also suggests high levels of skill were necessary to consistently create and apply the adhesive. If overheated, allowed to cool too much before application, or not mixed thoroughly enough, the same adhesive will perform very poorly.

The complex relationship between different ingredients and the specific ratios required for optimal adhesive performance further supports the idea proposed by Wadley [1] that MSA complex adhesive use would require high levels of cognitive ability and working memory capacity. Further research is required to determine how distinguishable adhesive performance is during practical applications. However, modern standardised tests have proven to be a fast and accurate method of prehistoric adhesive testing.

References:

[1] Wadley, L., 2010. Compound-adhesive manufacture as a behavioral proxy for complex cognition in the Middle Stone Age. Curr. Anthropol. 51 (Suppl. 1), S111-S119.

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[3] Charrié-Duhaut, A., Porraz, G., Cartwright, C.R., Igreja, M., Connan, J., Poggenpoel, C., Texier, P.-T., 2013. First molecular identification of a hafting adhesive in the Late Howiesons Poort at Diepkloof Rock Shelter (Western Cape, South Africa). J. Archaeol. Sci. 40, 3506-3518.

[4] Barham, L., 2013. From hand to handle: The first industrial revolution. Oxford: Oxford University Press.

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Top photographs: flint flakes with pine resin, beeswax, and ochre (left); pure pine resin (middle); and pine tar (right).

Figure: Drawing of Zwick Z330E with hydraulic grips