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The wet tensile test for clay-bonded sands reviewed

Report 1570

by P. J. Rickards

Synopsis—The wet tensile test is described, and the significance of results obtained with clay-bonded sands reviewed. The test has been widely used to study the activation of calcium bentonites by base exchange with sodium carbonate, and to assess the scabbing tendency of clay-bonded sands. The wet tensile test can reveal changes in the characteristics of clay-bonded sand mixtures which are not shown by other test procedures.

Introduction—When a greensand mould is filled with molten metal a dried surface layer is formed, the moisture driven away from the mould-metal interface condensing some way behind the surface.¹ The zone in which condensation occurs may have a water content considerably higher than the remainder of the mould. The low strength of this zone, referred to as the wet zone, is partly responsible for mould

dilation which occurs when castings are made in greensand moulds. Work by Pettersson² and Levelink³ indicated that the wet condensation zone was also an important factor responsible for mould-surface expansion and spalling defects. Both workers attributed the occurrence of these defects to a lack of cohesion between the dried surface layer and the underlying wet layer.

Because of the importance of the wet condensation zone and its association with casting surface defects, Patterson & Boenisch⁴ developed a test to measure the cohesive strength between the dried surface layer and the wet zone. In this test one surface of a cylindrical greensand test specimen was heated, causing the formation of a wet zone several millimetres behind the heated surface. After a predetermined heating time, a tensile stress was applied to the specimen in such a way as to cause it to fracture through the weakened wet zone. The tensile strength at fracture was called the wet tensile strength. Subsequently a testing machine was developed for laboratory use by George Fischer Ltd, and this is marketed in Britain by Ridsdale & Co. Ltd.

The purpose of the present paper is to describe the wet tensile test and to review some of the applications. The use of the test for determining clay quality and for the control of clay-bonded sand properties has been assessed.

The wet tensile tester and test procedure

The George Fischer wet tensile tester is shown in Fig. 1. A greensand specimen is prepared in a special tube having a pull-off ring, using the usual standard 3-ram method with sufficient sand to give a 50mm-high specimen. The sand specimen contained in the tube is loaded onto the testing instrument and the test is then carried out automatically. A thermostatically controlled electric heating plate operating at about 300 °C is brought into contact with the surface of the specimen for a predetermined time of between 15 and 25 seconds. A piston-operated fork then engages the ring on the top of the specimen tube, and a tensile stress is applied to the specimen. The specimen ruptures through the wet sub-surface layer and the maximum stress is recorded on a pressure-gauge. It is advisable to perform each test immediately after ramming the specimen, so that no water is lost from the surface layers. At least three measurements should be made on any given sand and the results averaged. The testing apparatus is supplied complete with specimen tube, rammer base, pull-off ring and control equipment.

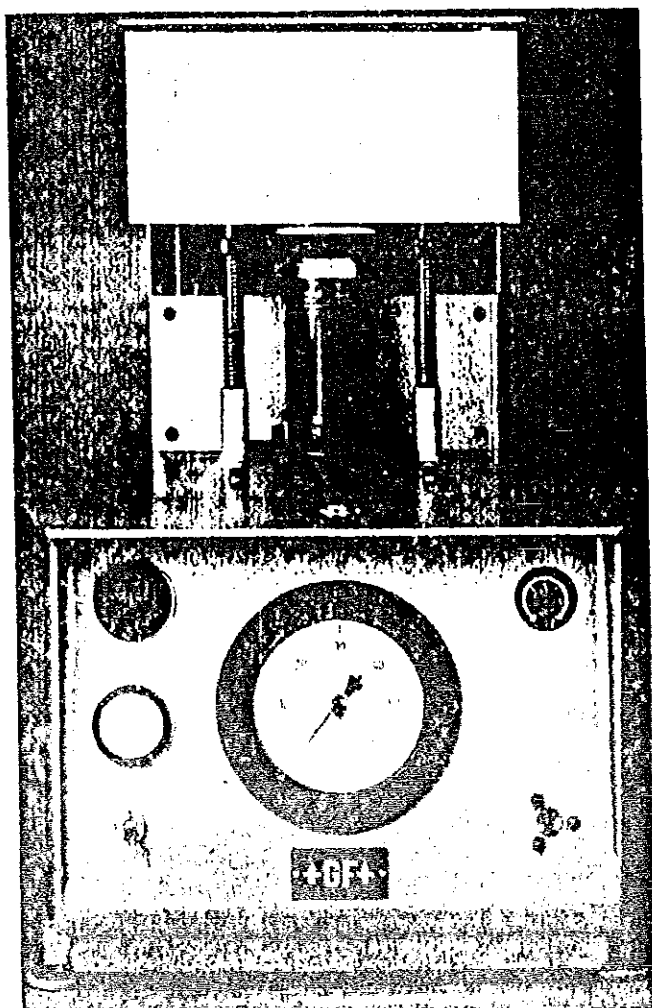


Fig. 1 The George Fischer Wet Tensile Tester.

Discussion

It has become clear from the results presented in this paper and from other tests carried out at BCIRA that recycled foundry greensands have a much lower wet-tensile strength than greensand mixtures made with new sand. Since much of the experimental work reported in this paper has been carried out with new-sand mixes, foundries should not expect to obtain the high values quoted in some of the Figures when testing recycled sands. Typical values for recycled foundry greensands fall in the range 6–20 gf/cm², whereas values above 30 gf/cm² are commonplace with new-sand mixes having high clay contents, as shown in Fig. 3. The lower values obtained for recycled sands are thought to be due to the build-up of burnt clay and fines which possibly decrease the amount of water available for the clay bond.

All the applications referred to suggest that the wet tensile test provides a very useful means of assessing the condition of the clay in a greensand. The test has practical use in evaluating different clays and for monitoring changes in clay activation. It seems to be generally agreed that there is a good correlation between the wet tensile strength of greensands and the occurrence of expansion defects such as scabs and rat-tails in castings.

A feature of the wet tensile test is that it reveals changes in greensand quality which may not be detected by other test methods, for example the green compression strength and shatter index value may show only small variations with changes in the clay activation. The wet tensile test has also been shown to be invaluable in assessing the extent to which a greensand will tolerate contamination by chemically bonded core-residue materials, where green compression strengths may again be only little affected.

The wet tensile test is likely to have increasing application now that clay blends are coming into wider use in foundries. It has obvious applications for clay producers and suppliers for quality-control purposes. Since the wet tensile test can reveal changes in the condition of a sand which is not revealed by routine physical tests, it should be of special benefit to those foundries needing particularly close control of their greensand system. For these foundries the wet tensile test has the further advantages that it can be carried out rapidly, and the results can be related directly to casting quality.

Conclusions

- 1 Measurement of the wet tensile strength of a greensand, which varies with the amount and type of clay used, the water content of the mixture and the milling time employed, reveals changes in properties which may not be detected by other test procedures.
- 2 Applications of the wet tensile test include:
 - monitoring changes in the activation level of calcium bentonite clays, for example by treatment with sodium carbonate;
 - determining the effects of chemically bonded core-residue materials incorporated in greensand, where other tests may show no change in properties;
 - assessing whether a greensand is likely to lead to expansion defects such as scabs and rat-tails. ■

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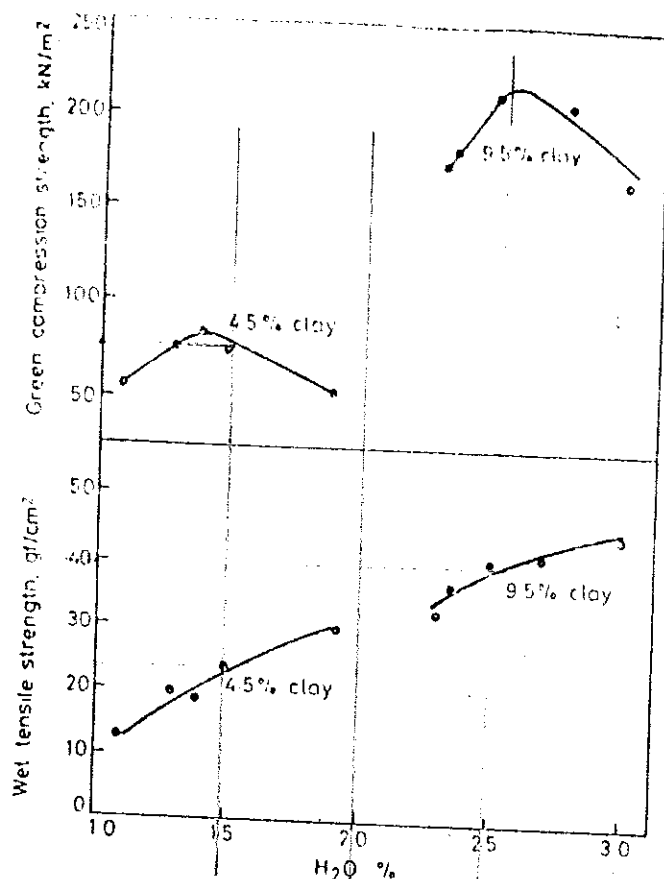


Fig. 2 Effect of water content on the green compression strength and wet tensile strength—sodium-treated calcium bentonite clay (after Rickards¹³).

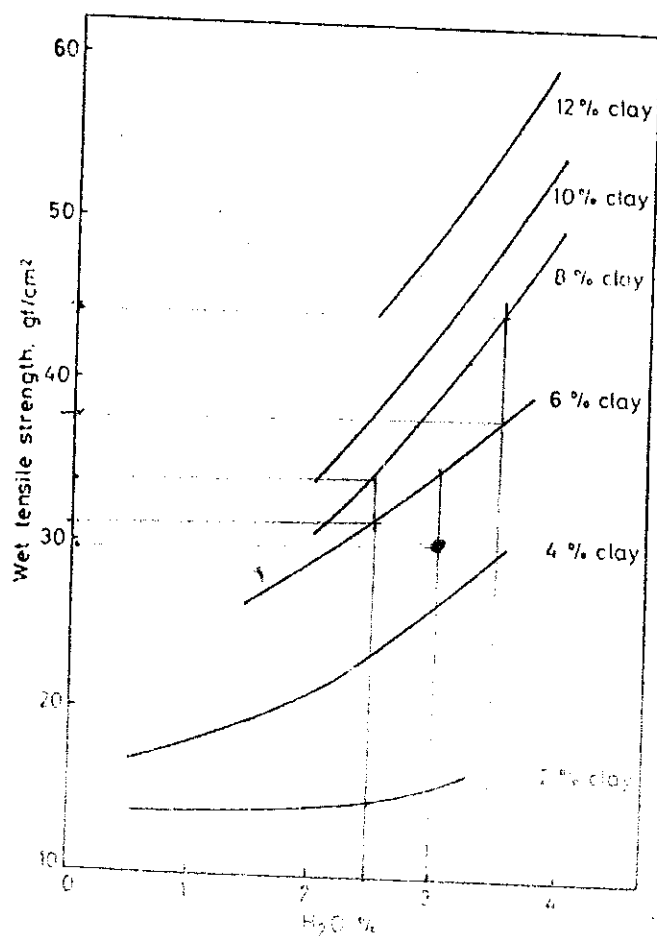


Fig. 3 Effect of clay content on wet tensile strength—Wyoming bentonite (after Patterson & Boenisch⁵).

Factors affecting wet tensile strength

Sand composition and preparation—It is well known that the green compression strength of a clay-bonded sand increases to a maximum value at a critical water level and then decreases as the water content is raised further. The maximum strength occurs at fairly low water levels, and in the normal working range green strengths fall as water additions are made to a bonded sand. Wet tensile-strength values also increase to a maximum value as water is added to a clay-bonded sand, but the maximum value occurs at a higher water level.⁵ Thus, in practice, the wet tensile strength usually increases with increasing water content. These effects are illustrated in Fig. 2, which shows how the green compression strength and wet tensile strength of two greensands varied with increasing water content. The results in Fig. 3, taken from the work of Patterson & Boenisch, show that wet tensile strength increases as greater amount of clay are used in a greensand mixture. Coaldust addition have been reported to have only a small effect on wet tensile strength, increasing the water requirement for the maximum value⁶ to be obtained.

Recent tests at BCIRA have shown that the wet tensile strength increases as the clay bond is developed by more intensive milling. An example of the effect of milling-time on green compression strength, shatter-index value and wet tensile strength is shown in Fig. 4.⁷

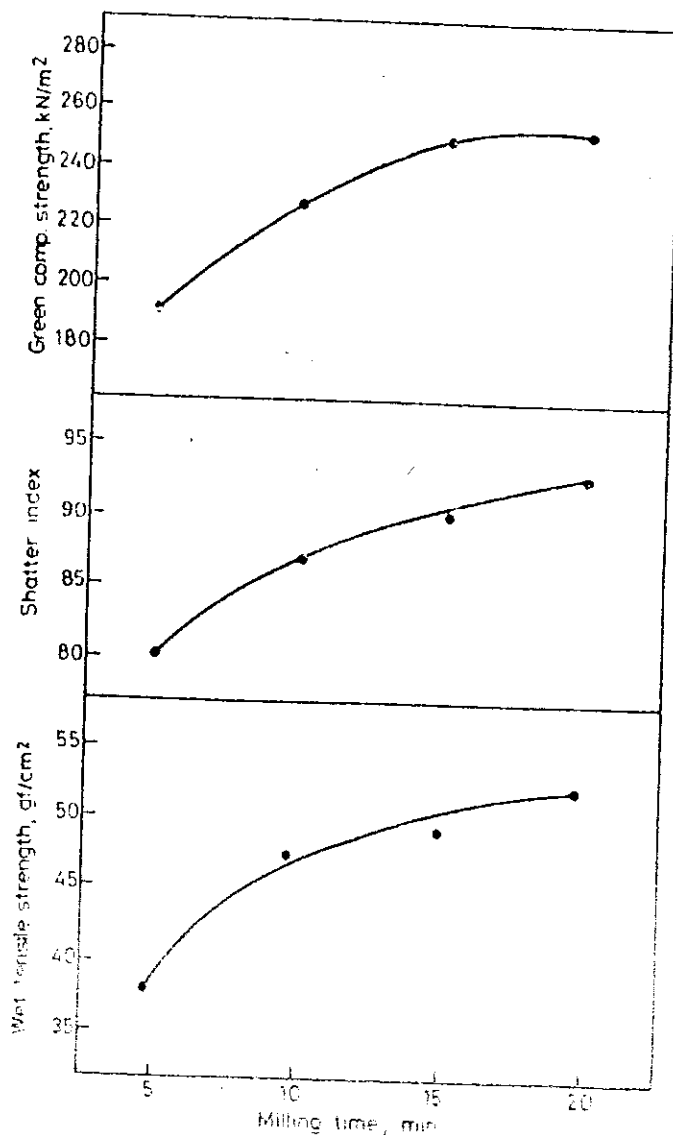


Fig. 4 Strength development with increasing milling-time for greensand bonded with a sodium-treated calcium bentonite clay (after Busby⁷).

Clay activation treatment—It is well established that clays from different sources give widely different wet tensile-strength values.⁸⁻¹¹ For example, reported values for sodium bentonites are 33–36 gf/cm², whereas naturally occurring calcium bentonites may only give values of 12 gf/cm². If a base-exchange treatment is carried out with sodium carbonate, these calcium bentonites may produce wet tensile strengths of up to about 40 gf/cm². These values relate to greensand mixtures made with new silica sand containing 6 per cent clay.

Patterson and Boenisch^{8,9} used the wet tensile test to examine the degree of activation of calcium bentonite clays by base-exchange treatment. Fig. 5 shows how the wet tensile

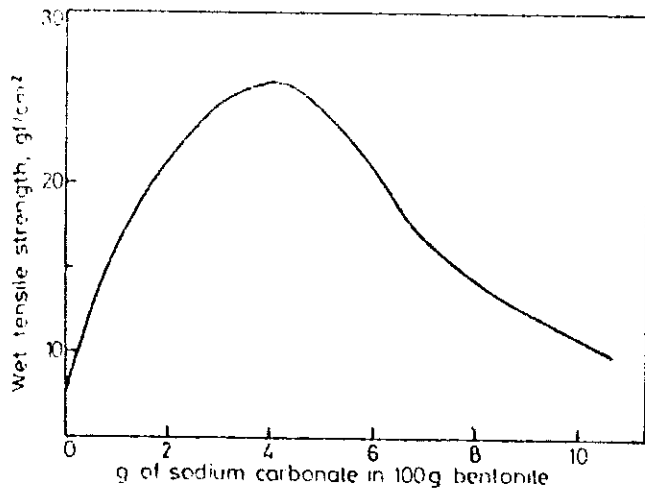


Fig. 5 Effect of activation of calcium bentonite clay with sodium carbonate (after Patterson, Boenisch & Khanna⁸).

strength of a synthetic greensand mix increased to a maximum value as sodium carbonate was added to a clay which was susceptible to activation. The maximum wet tensile-strength value corresponded to the fully activated condition. Van Eeghem¹⁰ showed that a natural clay-bonded sand behaved similarly, and his results are illustrated in Fig. 6. The results in Figs. 5 & 6 show that very low wet tensile strengths can be obtained if the clay is either under-activated or over-activated. Recent tests at BCIRA have

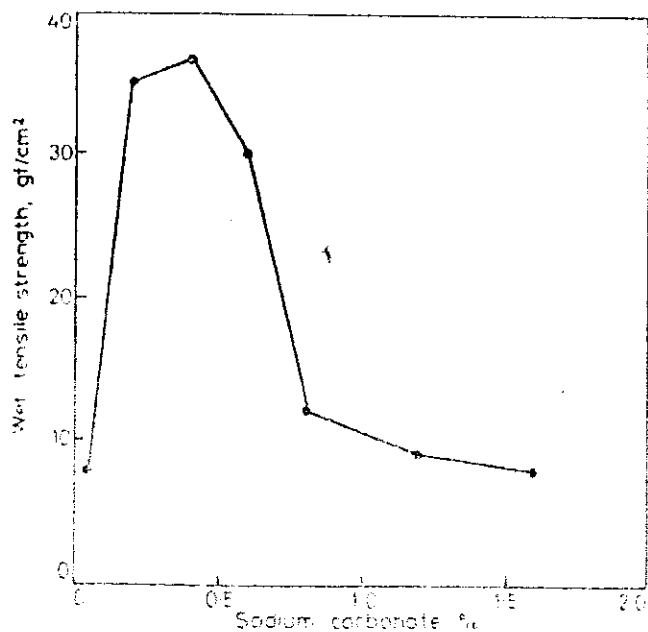


Fig. 6 Effect of addition of sodium carbonate on the wet tensile strength of a natural clay-bonded sand (after Van Eeghem¹⁰).

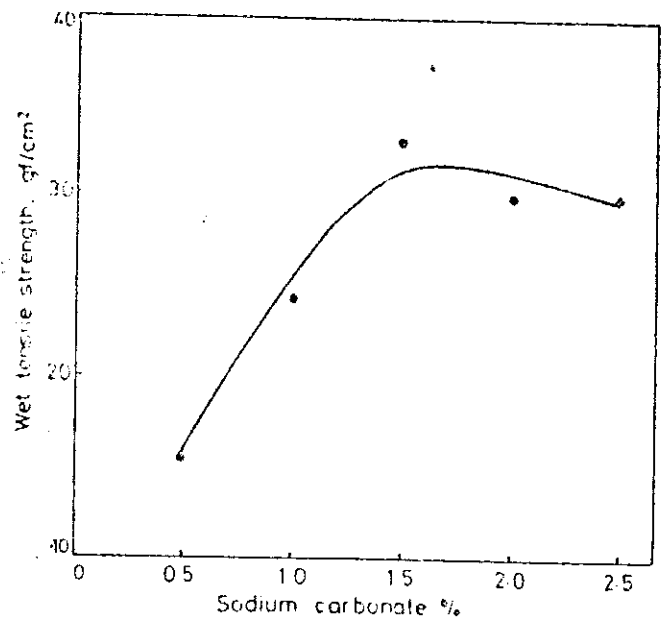


Fig. 7 Effect of clay activation with sodium carbonate on wet tensile strength.

confirmed the usefulness of the wet tensile test in monitoring clay activation by sodium carbonate, and these results are shown in Fig. 7.

Relation between wet tensile strength and the occurrence of expansion defects such as rat-tails and scabs—Patterson, Boenisch & Khanna⁹ used clays which had been activated to different extents with sodium carbonate to show that there was a direct correlation between the wet tensile strength of a moulding-sand and the occurrence of rat-tail defects in castings. Patterson & Boenisch^{8,9,11} recognized, however, that the wet tensile strength was not

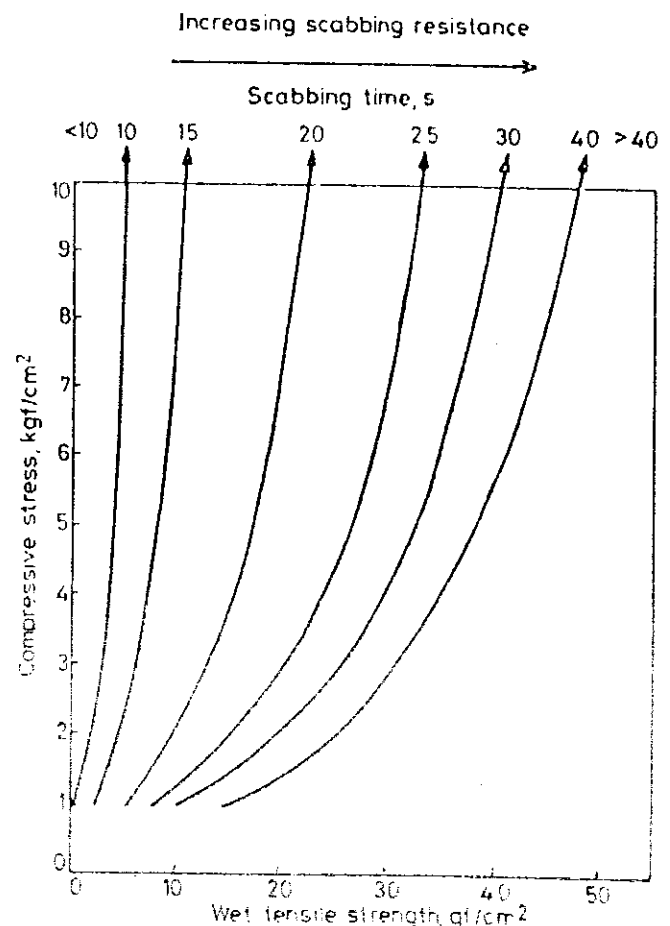


Fig. 8 Scabbing diagram (after Boenisch & Patterson¹¹).

the only factor governing the extent to which expansion defects occurred. They concluded that the mould-cavity surface is subjected to compressive forces due to the expansion of the heated sand, and that these forces contribute to the formation of expansion defects. It was suggested that the tendency to form scabbing defects could best be related to the ratio of the compressive force to wet tensile strength. Using results from 170 greensand mixtures, Patterson & Boenisch¹¹ developed a Scabbing Diagram which showed the relation between the compressive force, wet tensile strength and scabbing tendency. The compressive force was determined by measurement of the force exerted as a rammed disc of sand deformed when its concave face was heated. The sand disc was held firmly at its circumference. The tendency to deform was counterbalanced by a force applied to the unheated face, and this force was recorded and plotted against heating-time. Scabbing tendency was measured by the use of a mould in which the cavity surface of the cope was continuously examined as metal was poured into the mould. The mould cavity was half-filled, the time required for a spalled shell of sand to develop on the cope surface was measured, and this time was used in the scabbing diagram as shown in Fig. 8. It is claimed that the diagram can be used to predict the scabbing tendency of any sand mixture from measurements of the wet tensile strength and compressive force determined on test specimens. The diagram has been used to illustrate the effect of greensand-mould variables such as bentonite type and quality, moisture content, and greensand additives, on scabbing tendency.¹¹

In tests using 25 different bentonites Van Eeghem¹⁰ has confirmed that the wet tensile test gives an excellent guide to scabbing tendency. He concluded that greensands having wet tensile strengths below 10 gf/cm² consistently gave scabbing, while with sands having wet tensile strengths above 15 gf/cm² scabbing was rare.

Effect of recycling greensands—Wet tensile-strength values decrease when greensands are recycled, owing to the build-up of burnt clay and fines within the system.^{10,12} Van Eeghem¹⁰ showed that if clays are heated prior to use in a mixture the wet tensile strength is reduced. He also showed how the wet tensile test could be used to monitor the performance of foundry sands as they were recycled. The results in Table 1 show how the wet tensile strength decreased when a particular clay was used in one foundry for a few months. The reduced wet tensile strength led to a deterioration in casting surface-finish and severe scabbing occurred. The addition of 3 per cent of new clay to the

recycled sand restored the wet tensile strength to the original value as is shown by the results in Table 1, and eliminated the scabbing problem. Hubay & Tothe¹² have more recently shown that the wet tensile strength of a recycled sand can be regenerated by the use of sieves to remove the fines and by raising of the moisture content. A greater improvement in wet tensile strength was obtained when fresh bentonite was added to the recycled sand.

Influence of chemically bonded core residues in greensand—Recent tests at BCIRA^{13,14} have indicated that the inclusion of residual chemically bonded core sands in a greensand mixture can cause some deterioration in properties, particularly if the resin binder is not fully burnt out.

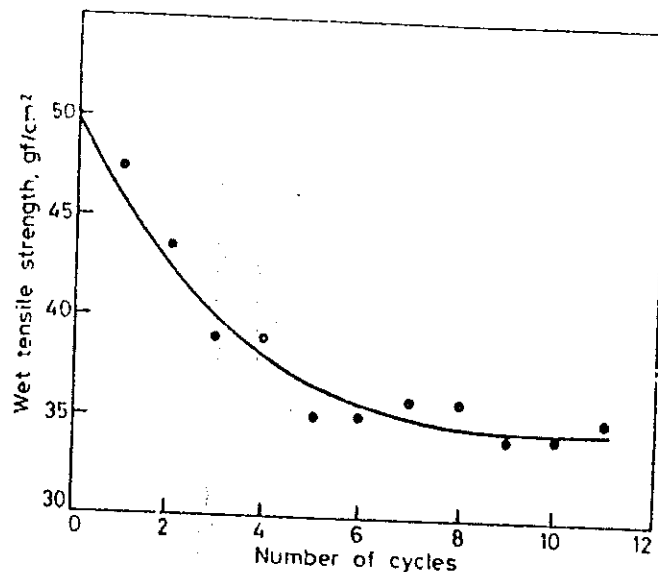


Fig. 9 Effect of recycling a greensand containing phenolic urethane core residues (after Rickards¹³).

The wet tensile strength showed the most pronounced change when coresand was added. Table 2 shows how the inclusion of residues from phenolic urethane, acid-catalysed resin, SO₂-cured resin, or shell cores affected the wet tensile strength of the greensand mixtures. In the recycling of greensands containing core material the most pronounced decrease in properties was again shown by the wet tensile test. Fig. 9 illustrates the effect of recycling a greensand containing residue from phenolic urethane cores.

Table 1 Wet tensile strength of foundry sand (after Van Eeghem¹⁰).

Property	Initial standard mixture	Foundry sand after a few months	Foundry sand + 1% bentonite	Foundry sand + 2% bentonite	Foundry sand + 3% bentonite
H ₂ O%	3.4	4.2	—	—	—
Green compression strength, kN/m ² (lbf/in ²)	61 (8.7)	125 (17.8)	137 (19.5)	136 (19.3)	155 (22.0)
Wet tensile strength, gf/cm ²	19	7	9	13	17

Table 2 Effect of chemically bonded core residues on the wet tensile strength of greensand mixtures bonded with 5% sodium-treated calcium bentonite.

Core residue material	Wet tensile strength, gf/cm ²			
	No residue	Burnt-out residue	Partially burnt residue	Unburnt residue
Phenolic urethane (50% addition level)	40	41	43	36
Acid-catalysed resin—1.0% resin (50% addition level)	44	42	41	35
Acid-catalysed resin—2% resin (50% addition level)	42	39	35	23
SO ₂ -cured resin (50% addition level)	42	43	—	31
Shell (25% addition level)	44	39	39	37