

The Role of Wet-Tensile Strength of Foundry Sands in the Surface Finish of Aluminium Sand Casting

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ONE of the most striking features of industrial development during the past decade has been the rapid growth in the use of aluminium and its alloys in the form of castings. To obtain sound casting has always been a problem for the foundry engineer, as the qualities required of a moulding sand are in some measure contradictory and a compromise must be made. Thus permeability is favoured by a low clay content and coarse particle size, whereas a smooth finish calls for a fine sand with a higher clay content. Similarly, green strength is improved by the addition of clay up to a certain point but permeability is reduced. Further permeability and green strength depend largely on the moisture content. These conventional green properties do not allow conclusions of sand properties on casting conditions^{1, 2}, because all these are tested at room temperature, where temperature and material distributions are uniform inside the moulding sand. To overcome the above difficulties a new concept of Wet-Tensile Strength has been developed recently in the Foundry Institute of Rheinsch-Westfalischen Technischen Hochschule Aachen (West Germany). It shows a very good correlation with the scabbing tendency of moulding materials and has been found to be of practical importance in order to control the quality of aluminium castings in the foundry.

Characteristics of Wet-Tensile Strength of moulding sand

Under casting conditions, the heating of the moulding surface by the liquid metal causes a temperature gradient in the sand and leads to vaporisation of the water in the strongly heated surface layers. The arising vapour passes through the porous moulding material and condenses in a cooler zone of the sand mould. The condensation zone lies parallel to the mould surface and moves inwardly with increasing heating time. Such a behaviour of the foundry sand just after casting showing the variation in the properties is shown in schematical Fig. 1.

The tensile strength measured in this sand layer is only a fractional part of the green tensile strength and is called Wet-Tensile Strength³. This is determined under sets of conditions, different from those for the green tensile strength.

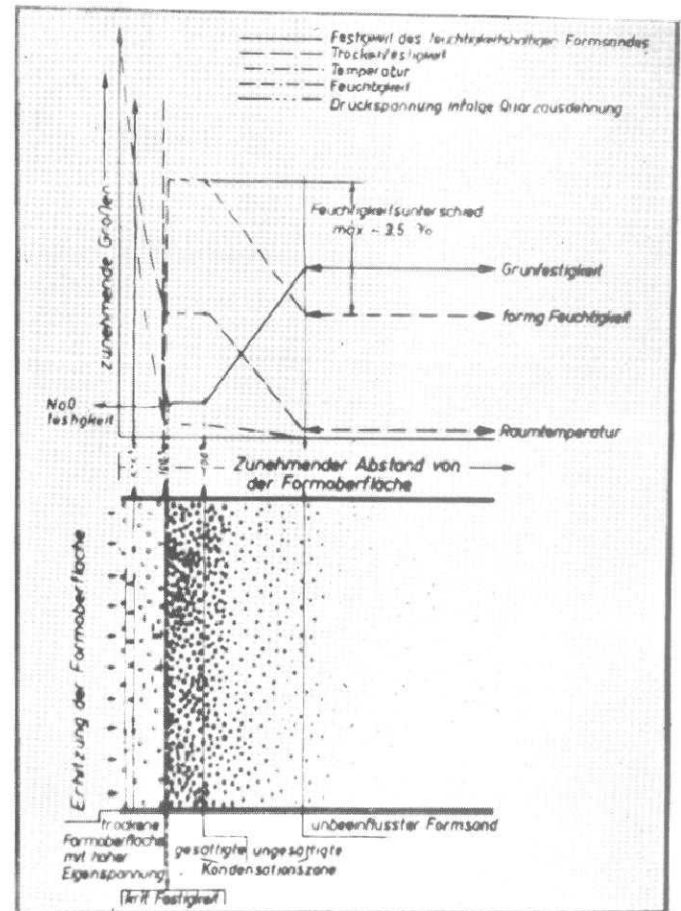


Fig. 1.³

Variation in the properties of a sand mould by the effect of heat. (Schem. representation)⁷.

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Testing of Wet-Tensile Strength

Fig. 2 shows the apparatus used for determining the Wet-Tensile Strength values. By heating the top surface of a standard test specimen similar to usual practice a temperature gradient is produced. Thus, at a distance of some millimetres from the top surface an over-moistured sand layer of strongly reduced strength results. By applying a tensional stress the specimen is torn in the weak condensation zone. The quotient of tearing tension to the sectional area of the specimen (19, 6 sq cm) is called the Wet-Tensile Strength. The testing usually takes 45 seconds.

The influence of various factors on Wet-Tensile Strength^{4, 6, 7}

1. *Water content*: With the increase in water content till about three times the temper-water Wet-Tensile Strength increases. The increase is caused by ionic binding forces.

2. *Clay content*: Increasing clay content results in an increase of Wet-Tensile Strength values.

3. *Preparation of sand mixture*: With increasing hardness of preparation according to Patterson and Boenisch⁵, the Wet-Tensile Strength follows the same tendency.

4. *Shape and size of silica sand grains*: With the constant clay content the Wet-Tensile Strength increases with increasing grain size and with the decreasing degree of angularity of the sand grains.

5. *Activation with sodium carbonate and other salts*: By the addition of sodium carbonate in calcium bentonite, the adsorbed Ca^{++} ions are replaced by the Na^+ ions. This method is being used in many foundries for a long time, in order to improve the properties of the moulding sand. The Wet-Tensile Strength value of a moulding sand containing Ca-base bentonite increases with the increasing amount of sodium carbonate, and after attaining a maximum value, with the further addition of the salt the value is decreased.

The values of the Wet-Tensile Strength of Mainburg bentonite as obtained after activation with different milli-equivalents of various carbonates have been shown in Fig. 3. In one of the recent investigations⁷ it has been found that both the anions and single valency cations have a strong influence on the Wet-Tensile Strength.

Degree of activation

The degree of activation for under-activated samples is as follows:

$$N_x = \frac{N_A}{N_{\max}} \cdot 100(\%) \quad \dots \quad (1)$$

and for the over-activated samples, it is represented by:

$$N_x = \frac{N_{\max} + (N_{\max} - N_B)}{N_{\max}} \cdot 100(\%) \quad \dots \quad (2)$$

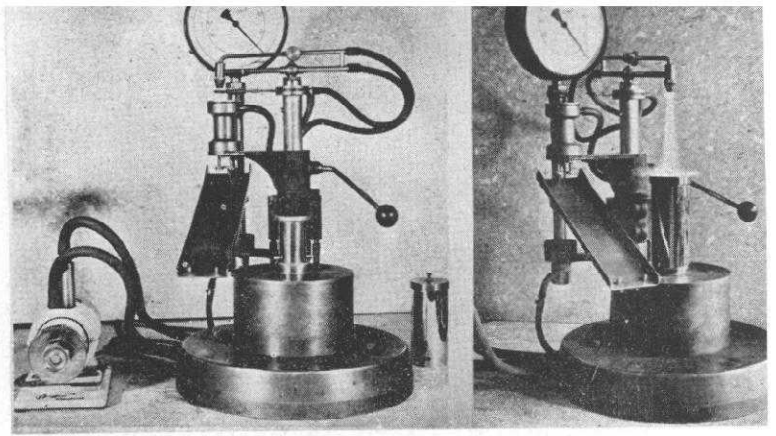


Fig. 2.^s

Testinz apparat for measuring Wet-Tensile Strength.

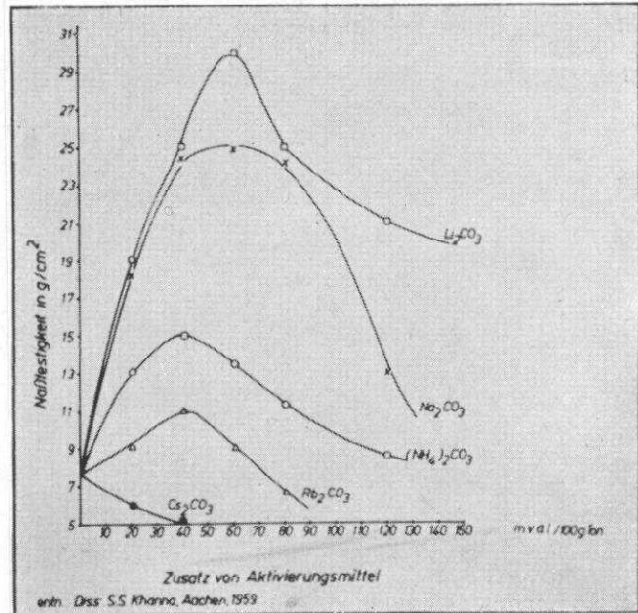


Fig. 3.7

Wet-Tensile Strength curves of the moulding sand by activating with carbonates of one valency cations. (5% Ca-bentonite from Mainburg, 85% montmorillonite).

where N_A = Wet-Tensile Strength of an under-activated sample at the beginning of the activation.

N_{\max} = The maximum value to be found by activation curve,

N_B = Wet-Tensile Strength value of an over-activated sample at the beginning of the activation.

Degree of quality

The degree of quality corresponds to the attainable specific max. Wet-Tensile Strength value for a particular clay:

$$\text{Degree of quality} = \frac{N_{\max} - K}{\% \text{ Bonding clay}} \text{ (g/cm}^2\text{.}\%) \quad \dots \quad (3)$$

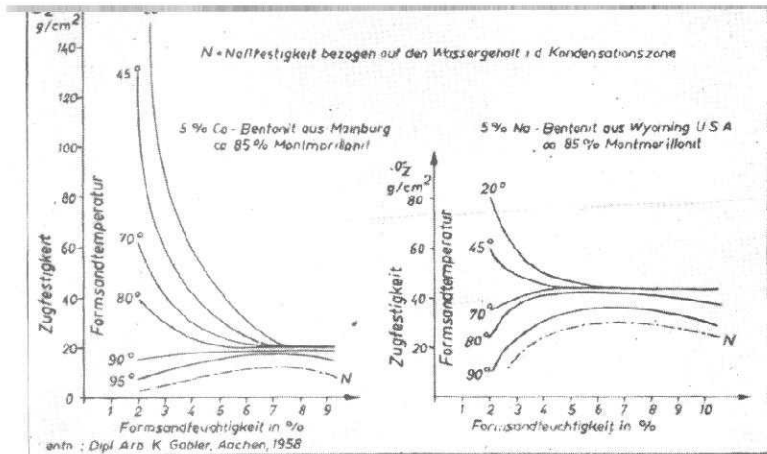


Fig. 4.4

Effect in Tensile Strength of the moulding sands with the change in moulding sand temperature.

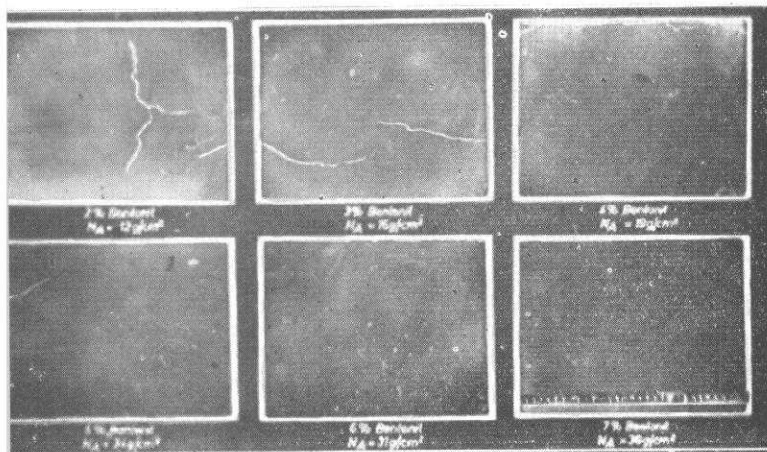
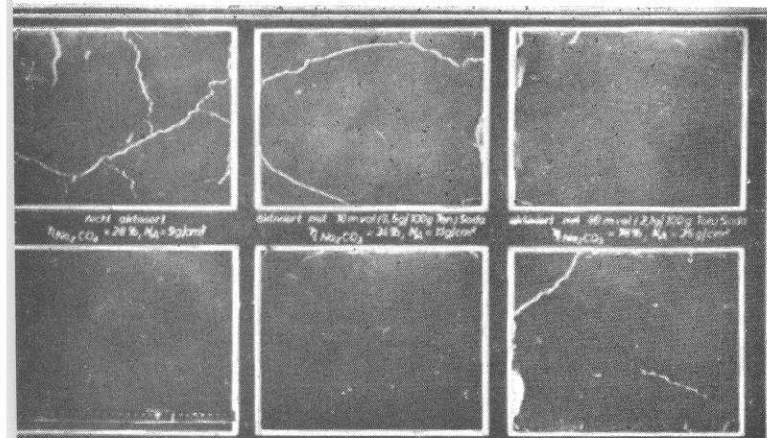


Fig. 5.

Casted test plates of Al/Si alloy in sands with temper water content and containing different parts of bentonite. (Natural bentonite from Wyoming, casting temp. 740°C).

Fig. 6.

Casted test plates of Al/Si alloy, in sands with temper water content and having different degree of activation. (In each case 6% Ca-bentonite from Mainzurg, sodium carbonate activation, casting temp. 680°C).



K=Equivalent to correcting factor accounting for the hardness of sand preparation⁵).

Effect of temperature on the strength of the moulding sand with the change in water content

The strength of the moulding sand containing the same amount of water content is considerably reduced up to the boiling temperature⁴. Fig. 4 shows the change in tensile strength of two moulding sands with the valuation of the water content and the temperature. This temperature has a great significance in actual practice. By reaching up to a temperature of more than 90°C the surface bond has practically no effect on the strength of the moulding sand and it is only due to the hydration of the adsorbed cations⁹. With the increasing hydration of the cation the maximum value of Wet-Tensile Strength also increases⁷. For example Lithium ion possesses higher hydration capacity than the Caesium ion (Fig. 3). The adsorbed cations at this temperature are responsible for the variation in the Wet-Tensile Strength of the moulding sand.

Correlation between Wet-Tensile Strength and scabbing tendency

Green moulding sands can lead to faulty castings which are caused by the expansion of the silica sand grains. When molten metal is poured in a mould a thin heated surface-layer of the mould cavity is subjected to high compressive stresses. In case the Wet-Tensile Strength is low, there will be a separation of this dried layer of sand along the condensation zone and the formation of scabs, rat-tails, buckles, etc. will result. The separation of this dried layer of sand has been shown by H. Petterson¹ and H. G. Levelink². In Fig. 1 the position where the separation of the sand layer takes place is represented in the area of the critical strength. Just behind this dried sand layer there exists a condensation zone where the temperature of about 100°C is prevailing.⁸

Basically there are two possibilities of reducing these expansion defects. Firstly, the stresses in the dried sand layer can be reduced, as is already done in practice by the addition of coal dust, pitch, etc. to the moulding sand. The other possibility which should primarily be used is to increase the Wet-Tensile Strength of the sand so that the separation of the dried layer is inhibited.

The scabbing tendency can be inferred from the total length of rat-tails found on the bottom of the test piece cast in the shape of a plate.

Experimental procedure

The synthetic sand mixtures were prepared by mixing 3,000 gms of Quarzsand from Nivelstein, Germany, average grain size 0.2-0.3 mm, with different percentages of various clays. The base sand was first milled dry with bentonite for 2 minutes, after which the sand mixture was tempered to the requisite moisture content and milling continued for further 15 minutes.

The sand mixtures were activated stepwise with different salts of analytical quality by successively adding 20, 40, 60, 80, 100 and 150 meq/100 gms of dry clay. Milling was continued for a period of 5 minutes. After testing, the sand mixture was again transferred to the muller in order to maintain the constant amount of sand during the sand preparation. Water content during testing was corresponding to that of temper water.

The moulds were formed on a moulding machine with the constant vibration time of 35 seconds. The drag was filled with the test mixture, while the cope was filled with the normal moulding sand. The size of the plate was 320 mm × 270 mm × 15 mm. The sensitivity of the testing process was increased by using very fine ingates, resulting in a very slow pouring speed. The test plates were of Al/Si alloy (90% Al and 10% Si.). The pouring time was 14 ± 1 seconds, and temperature of casting varied from 680°C to 740°C. This test was repeated with various sand mixtures as described below. All the values given are averages of three tests in each case.

Experimental results of the test aluminium/silicon plates

Figs. 5, 6, 7 and 9 show the surfaces of the cast test plates of Al/Si alloy. The Wet-Tensile Strength of the clay bonded moulding sand in each of the experimental series was varied by changing the influencing factors as stated before.

(a) *Effect of clay content*: With the increase in the clay content the Wet-Tensile Strength is increased and the scabbing tendency is decreased according to Figs. 5 and 8. The same type of silica sand and Wyoming bentonite was always used. From 6% bentonite the Wet-Tensile Strength was found to be 31 gms/cm², and the casting plate was free from the expansional defects.

(b) *Effect of degree of activation*: As a consequence of sodium carbonate activation the scabbing tendency is decreased up to the maximum Wet-Tensile Strength value, and increases sharply again in the region of over-activation, where there is a decrease in Wet-Tensile Strength (Fig. 6). In the bottom of every picture the value of Wet-Tensile Strength and the degree of activation is mentioned, and the bentonite content remains unchanged.

(c) *Effect of the quality of the bonding clays*: Fig. 7 shows the effect of the quality of optimum activated bonding clays on Wet-Tensile Strength and scabbing tendency. In each case the attainable maximum Wet-Tensile Strength is dependent on the specific clay surface,⁶ which decides the quality. By using the same clay content in all cases, the poor clays therefore cause the higher scabbing tendency and low Wet-Tensile Strength. According to the quality of the bonding clays all values in between two extremes are possible.

Graphical representation of Figs. 5, 6 and 7: Effect of clay content, degree of activation and the quality

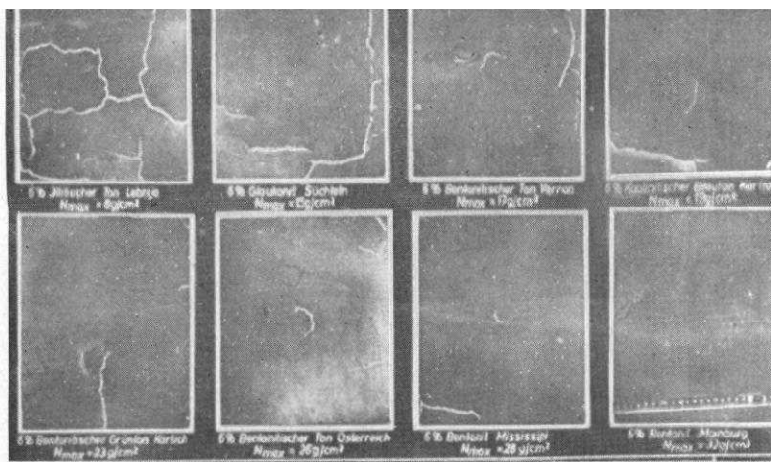


Fig. 7.

Casted test plates of Al/Si alloy, in sands with temper water content, containing different quality of bonding clays. (In each case 6% bonding clay, with sodium carbonate, maximum activated, casting temp. 720°C.)

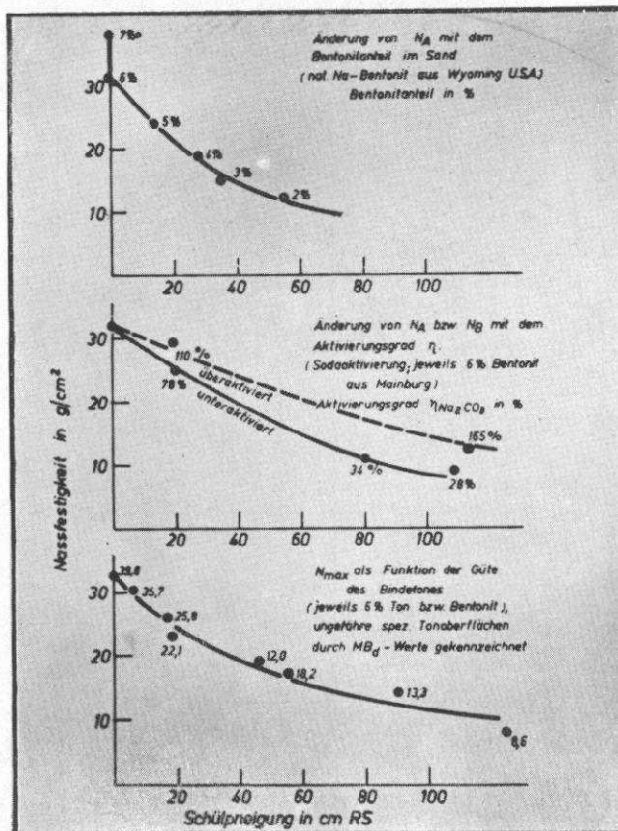


Fig. 8.

Effect of Wet-Tensile Strength on the scabbing tendency of the clay bonded, tempered water moulding sands. (Al/Si alloy, casting temperature 680–740°C)

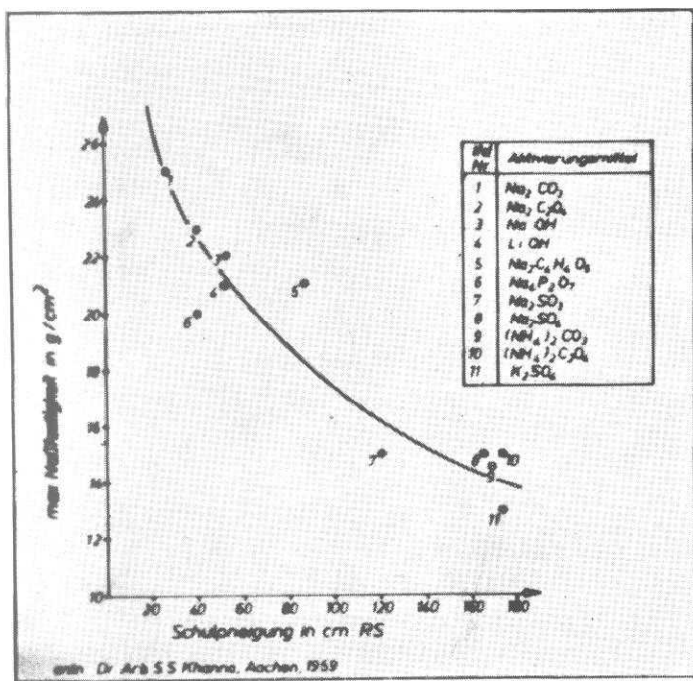


Fig. 9.7

Effect of maximum Wet-Tensile Strength on the scabbing tendency of the clay bonded, tempered water moulding sands, maximum activated with different salts.

(In each case 5% bentonite from Mainburg, 80-85% montmorillonite, Al/Si alloy, casting temperature 710 C).

of the clay on Wet-Tensile Strength and the scabbing tendency are graphically represented in Fig. 8. According to the central graphical representation (Fig. 8) the sands of equal Wet-Tensile Strength have in under-activated condition a lower scabbing tendency than in the over-activated region.

(d) *Influence of different activating salts* : The scabbing tendency is also clearly decided by the Wet-Tensile Strength, when this is varied alone by the different effects of various activating salts. Always equal mixtures of moulding sands were optimum activated, with several activating salts. The required amount of salts was determined by drawing activation curves beforehand. The salts used for the activation are given in the table of Fig. 9.

Conclusions

A close correlation has been observed between Wet-Tensile Strength values and sand expansion defects, for example scabs, rat-tails and buckles. With the increase of Wet-Tensile Strength by the following influencing factors :

- Clay content,
- Degree of activation,
- Quality of clay,
- Activating salt,

the scabbing tendency is found to be decreased on Al/Si alloy test plates.

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DISCUSSIONS

Mr. K. S. Ganapathi, Aluminium Manufacturing Co. (P) Ltd., Calcutta : I would like to compliment the authors for their interesting paper. The Wet-Tensile Strength of Indian bentonite is poor compared to that of European bentonites. Since these are to be used in any case, I would suggest the work should be taken up both at the National Metallurgical Laboratory and Banaras Hindu University to improve the quality of Indian bentonites by activating agents, etc. so that the indigenous bentonites can be brought to maximum use.
Dr. Ing. S. S. Khanna (Author) : Investigations on Indian bentonites are in progress in the Department of Metallurgy, Banaras Hindu University and it is hoped that the results of investigation will be presented shortly.

