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EFFECT OF PUGGING ON PARTICLE SIZE AND PLASTICITY OF A QUEENSTON SHALE FROM BURLINGTON, ONTARIO

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SYNOPSIS

Diamond Clay Products Limited, brick manufacturers at Burlington, Ontario, are considering the installation of additional pugmilling machinery to counteract the adverse effect of coarser grinding on the plasticity of their raw material, a hard Queenston shale. The effect of pugging time on the plasticity and particle size distribution of the shale was investigated, using the mixer of the Brabender Plastograph to simulate a pugmill.

During the initial stages of mixing, in which the action appears similar to that in a commercial pugmill, there is a substantial decrease in particle size, concluded to be principally due to attrition. A second stage of mixing commences after about 15 minutes in the Plastograph, marked by an increase in consistency. At this point, it is assumed that the water has been sufficiently dispersed so that the material begins to flow plastically under the blades. In consequence, there is little further disintegration of the particles: the relatively small amount of particle size reduction is probably as much a product

of slaking action as of attrition. This stage of pugging is probably attained in commercial practice only in the augers of the extruder. Therefore, there should be considerable scope for improved plasticity through additional pugging.

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INTRODUCTION

At the request of Mr. R.R. Shaw, Manager of Engineering, Diamond Clay Products Limited, Burlington, Ontario, a study was made of the effect of extended pugging on the plasticity and particle size distribution of the local Queenston shale. It is well known(1) that the deposit at the plant is relatively hard and must be finely ground to develop enough plasticity for satisfactory extrusion. Under adverse weather conditions, the existing grinding plant was unable to meet production requirements in normal hours of operation. Resort to coarser grinding to maintain output had an adverse effect on plasticity, which possibly could be overcome by increased pugging.

Samples of plant-ground shale were provided in two sizes: minus 14 mesh (Sample No. 2829) and minus 12 mesh (Sample No. 2830).

PROCEDURE AND RESULTS

The samples were thoroughly oven-dried at 100°C(212°F). All aliquots for testing were obtained using riffle-type sample splitters, to ensure representative particle size distribution. Particle size analyses were performed by standard wet-screening methods(2) modified somewhat to minimize slaking during washing and to thus ensure reproducible results, i.e. preliminary dispersion was largely dispensed with and washing times were closely controlled. Duplicate tests showed results to be reproducible within 3 to 4 per cent for each screen size, with deviations largely compensatory from one screen size to the next. Normal plastograms were obtained using procedures normal to this laboratory: sample weight, 200 grams; rate of water addition, 0.5 per cent per minute; instrument setting, low sensitivity and low speed.

Normal plastograms of the two samples are shown in Figure 1. The finer sample (No. 2829) shows a slightly higher peak, but both show maximum consistencies between 650 and 700 metre-grams of torque, which is considered to be minimal for satisfactory extrusion of brick. Contrary to expectations, the coarser sample (No. 2830) peaked at a slightly higher water content even though the surface area to be wetted should have been lower. On the basis of the plastograms, it was elected to conduct pugging tests using 15 per cent moisture.

The effect of pugging time on particle size distribution was studied in the mixer of the Plastograph. A 200-gram sample was placed in the mixing chamber and the instrument was turned on. Thirty millilitres of water (15% of dry weight) was added during the first 1 to 1·5 minutes of operation. The mixing chamber was then covered to prevent evaporation, and the instrument was allowed to run continuously for a predetermined interval. The particle size distribution of this pugged material was determined by wet screen analysis. Figures 2 and 3 compare the particle size distribution of the samples, after

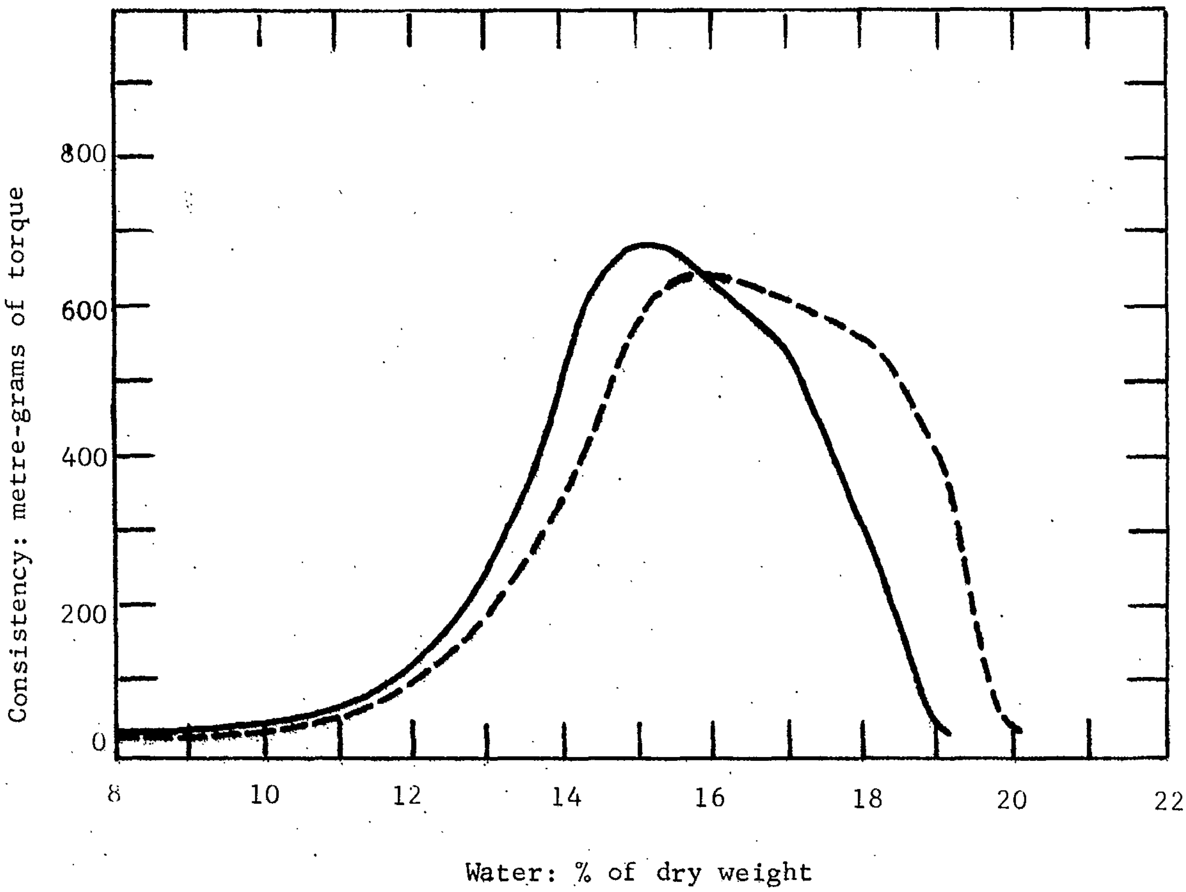

Figure 1. Plastograms of shale samples from Diamond Clay Products Ltd.

Sample No. 2829 (minus 14 mesh) ————————

Sample No. 2830 (minus 12 mesh) — — — — — — — —

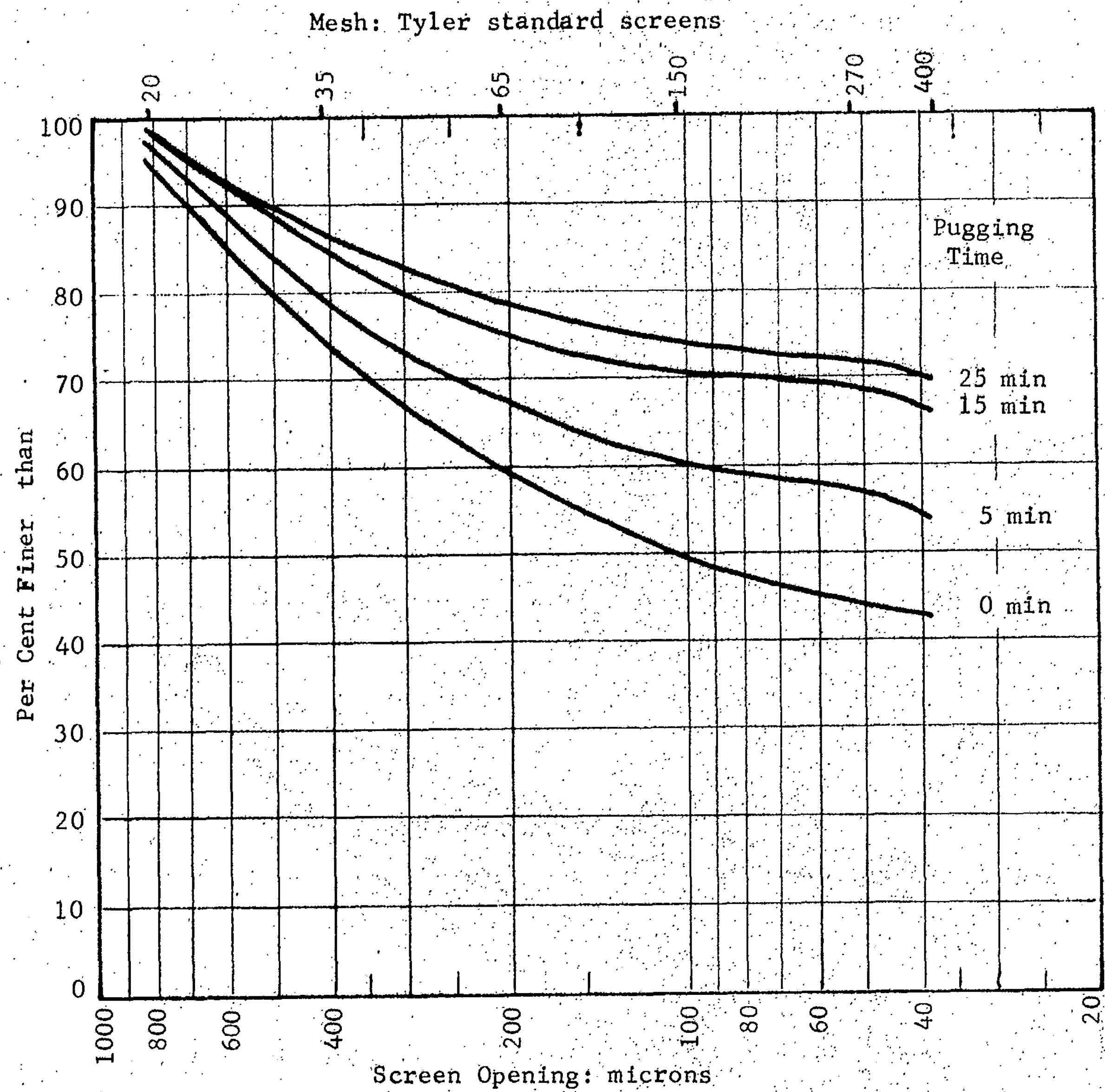

Figure 2. Effect of pugging time on particle size distribution (wet-screen) of Sample No. 2829, minus 14-mesh shale from Diamond Clay Products Limited, Ontario.

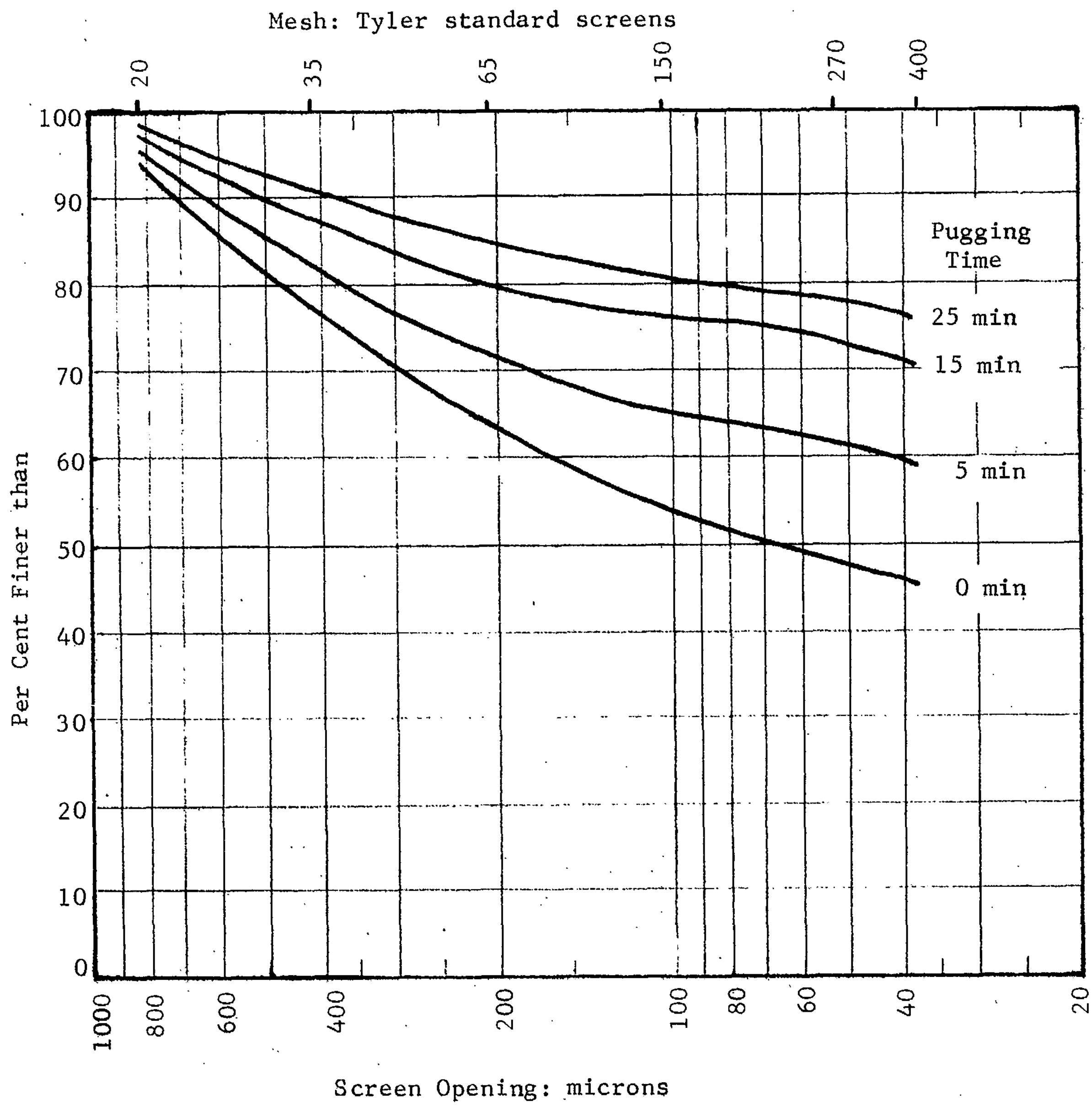

Figure 3. Effect of pugging time on particle size distribution (wet-screen) of Sample No. 2830, minus 12-mesh shale from Diamond Clay Products Limited, Ontario.

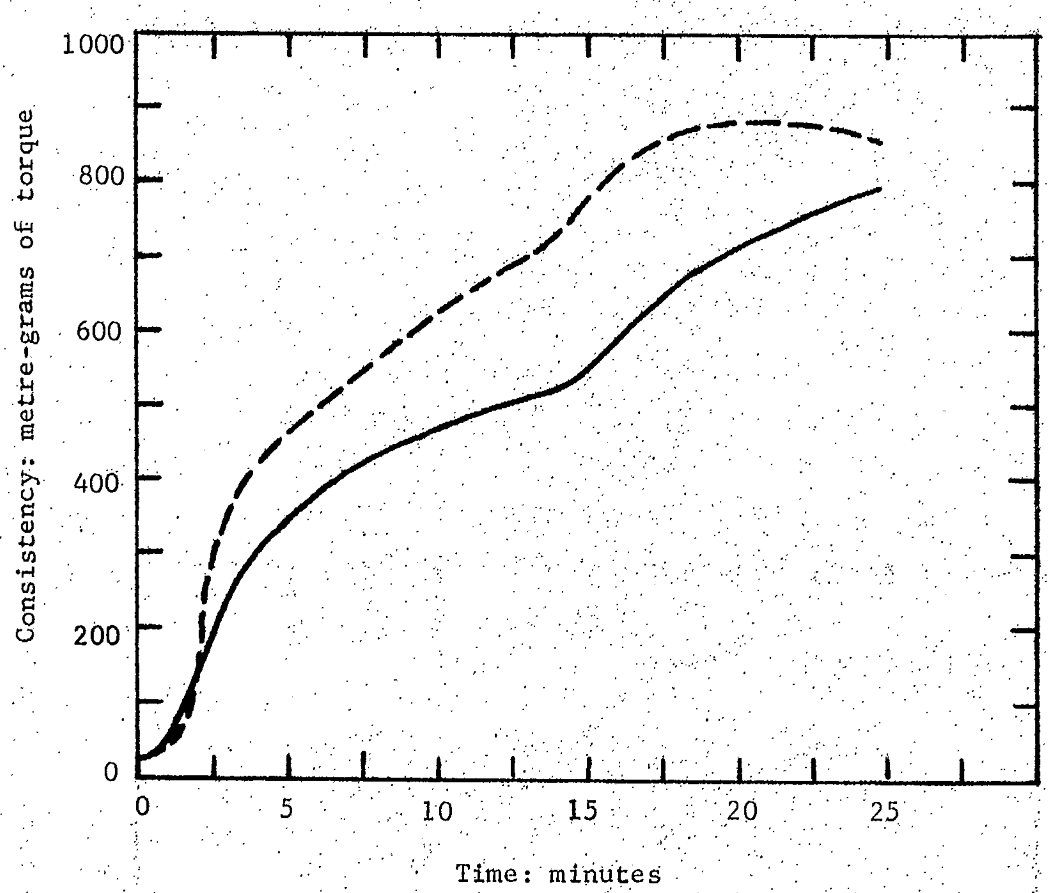

Figure 4. Effect of pugging time on consistency of shale samples from Diamond Clay Products Limited, Ontario. Moisture content: 15 per cent of dry weight.

Sample No. 2829 (minus 14 mesh) ————————

Sample No. 2830 (minus 12 mesh) — — — — — — —

pugging for 5, 15 and 25 minutes, with those of the samples as received.

Figure 4 shows the plastograms obtained for the two samples during the 25-minute runs.

DISCUSSION AND CONCLUSIONS

No data is available to enable correlation between the pugging efficiency of the Plastograph mixer and that of a full-size pug-extruder. Because the blades of the instrument pass each other closely and because material is drawn between them owing to the differential speeds of the shafts, a substantial amount of attrition might be expected, but the pressures on the particles are unlikely to approach those in a large commercial machine. It is doubtful that the laboratory results can be directly translated, in minutes, to practice.

The particle size distribution curves of Figures 2 and 3 clearly show that, in the early stages of pugging, there is a substantial reduction in particle size of both samples. Observations of the behaviour of the material in the instrument indicate that this phase corresponds to mixing in a commercial pugmill. After mixing for about 15 minutes there is a marked decrease in the rate of grinding or attrition. At this point the plastograms of Figure 4 show a marked increase in consistency, probably coincident with the achievement of thorough mixing (uniform wetting of essentially all particles). Beyond this point, the material moves under and between the blades in smooth plastic flow and the rate of attrition is sharply reduced. Such particle size reduction as takes place is probably largely due to slaking. This condition is probably achieved only rarely in commercial pugmills, owing to the limited pugging time. In most cases, such thorough distribution of water is probably attained only under pressure in the sealing augers or extrusion augers of the machine. Therefore, considerable scope should exist for increased particle size reduction through additional pugging machinery or more effective use of the present equipment. (Dwell time in the pugmill can usually be extended by judicious arrangement of the blades so that the material is alternately thrown forward and then back upon itself). Vacuum pugging would probably not be as effective for the purpose because the water would be distributed more rapidly into the voids and the plastic state would be attained sooner, with a resultant decrease in rate of attrition.

There is an apparent anomally in the particle size distributions of the two samples as received. The difference in the size of openings between the 12-mesh and 14-mesh screens is reflected in the coarseness of the products only in the fractions of particle size greater than about 20 to 35 mesh. Below this particle size, the product ground through the coarser screen contains the most fines. This explains why it required more water of plasticity, as previously noted. It is probable that this reflects changing hardness of the shale during the 2-week interval between samplings. Hardness of the shale is reported to increase with depth in the pit. Sample No. 2830 is the more friable of the two: it contains more fines initially and seems to disintegrate more during pugging. (Although the latter tendency is indicated by the curves of Figures 2 and 3, the differences are of the same order as the observed experimental error and therefore cannot be considered significant). Because the samples were not selected with respect to their point of origin in the pit, it is improbable that the extremes of softness or hardness are represented. However, even with the least friable raw material, a substantial reduction in particle size should be anticipated with increased pugging time. After 15 minutes in the plastograph, both samples showed an increase of about 25 per cent in the minus 400-mesh fraction. Both samples ultimately attained a consistency level of 800 metre-grams of torque or more, well above the minimum limit for satisfactory extrusion of brick.

REFERENCES

1. "Some Aspects of the Plastic and Related Properties of Queenston Shales", by K.E. Bell, J. Can. Ceram. Soc., Vol. 31, 1962.

2. "Wet Sieve Analysis of Ceramic Whiteware Clays", ASTM Designation: C325-56.

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