The Korean Journal of Ceramics, **4** [4] 368 - 371 (1998)

Abrasion Resistant Paver Production Utilising Modern Brickmaking Technology: Possibilities and Difficulties

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(Received September 23, 1998)

The work aims to evaluate the necessary physical properties of Abrasion Resistant Pavers designed for high volume pedestrian and road vehicle traffic and their influence on the selection of raw materials and ceramic processes. The pavers' specifications such as high strength and ware resistance demand a careful clay preparation, slow drying, slow firing and a balanced chemical and mineralogical composition. Therefore, developing Abrasion Resistant Pavers in existing modern brickmaking plants, which are designed primarily for making bricks and pavers for domestic applications, has become a challenge for manufacturers and ceramic professionals. The significance of quality control and research and development in the production of these high class pavers is also emphasised in this work through the investigation of a paver that exhibits shrinkage cracking.

Key words : Pavers, Abrasion resistance, Manufacturing, Shrinkage cracks, Thermal expansion data

I. Introduction

The growing demand for clay pavers (paving bricks) is increasingly encouraging brick manufacturers to produce pavers in their existing brick plants.

The similarity of the raw materials used in making both domestic pavers and bricks and the physical properties of these products is no doubt the main factor leading to such decisions.

However, the commercial applications of pavers such as shopping malls, railway platforms, and roads for heavy vehicles require a specific paver with high mechanical strength (Breaking Load and Compression Strength) and high Abrasion Resistance,[1] whereas, domestic applications do not require these properties.

The superior properties and higher unit price of the commercial pavers would justify the increased production costs and/or decreased output.

The aim of this report is to try to unfold potential problems in the production of abrasion resistant pavers in a modern brickmaking plant, and to discuss the optimisation of process parameters in order to maintain the required paver properties.

II. Suggested Criteria

1. Raw Materials

Success in developing a new product mainly depends on understanding the relationship between the characteristics of raw materials and the end properties of the product. Therefore, in the selection process of raw materials, chemical, thermal and dilatometric analyses are crucial to determine the types and the possible behaviours of clays.

Illitic clays/shales due to their moderate flux content would be more suitable for the purpose of developing abrasion resistant pavers.

A further reduction of particle size may be necessary during clay preparation, if shale is used. The use of a double shaft mixer can also be beneficial to improve the uniformity of the mixture.

2. Shaping & Drying

Stiff extrusion would be the preferred method of controlling shrinkage. Soft extrusion may result in an unnecessarily long drying time.

The drying process in tunnel dryers is generally satisfactory for stiff extruded shaley mixtures. Soft extruded clay pavers may be dried safely in a chamber dryer or a continuous dryer designed for drying this type of paver.

Some important parameters (Water Content during extrusion, Linear Drying shrinkage and Transverse Breaking Load) of green pavers can be used to determine the shaping ability and the drying sensitivity of mixtures.[2]

3. Firing

Fast drying and fast firing systems have increasingly gained importance in the Heavy Clay Industry. Today, fast firing appears to be the accepted way of tile manufacturing and has potential in the field of brick production.

Contrary to this recent development, Abrasion Resistant pavers require slow drying and slow firing due to the characteristic and/or the preparation of materials used in their production, which is crucial for making the pav-

Table 1. The Properties of Abrasion Resistant Paver

Nominal Dimensions: 230 mm × 114 mm × 65 mm
Hardness:
Impact Abrasion Index: 2.7
(Australian/New Zealand Standard AS/NZS 4456.9-1997)
Characteristic Abraded Volume: 3.2 cm^3
(Paver Note-1, July-1993, Clay Brick and Paver Institute)
Compressive Strength:
Characteristic Unconfined Compressive Strength: 35.0 Mpa.
(Australian/New Zealand Standard AS/NZS 4456.4-1997)
Characteristic Compressive Strength: 62.6 Mpa
(Paver Note-1, July-1993, Clay Brick and Paver Institute)
Water Absorption:
Cold Water Absorption (24 h immersion): 4.6%
(Australian/New Zealand Standard AS/NZS 4456.14-1997)

er harder and durable.

Furthermore, a longer period of soaking at the top firing temperature is necessary to increase the consistency in the paver properties.

III. Experimental

1. Abrasion Resistant Paver affected by shrinkage cracking

Shrinkage cracking may occur where sudden volume changes take place during the process. Shrinkage cracks are so distinctive that they are easily recognisable. The paver subjected to the cracking would rupture and will eventually break in half.

The properties of the fired paver product which was investigated are given at Table: 1.

2. Method of the investigation of shrinkage cracks

Testing of the samples of unfired pavers for the thermal expansion/contraction, according to Australian Standard AS 1774.11, would be a valuable means of ascertaining whether the paver material is sensitive to temperature changes. The thermal expansion test can also be carried out on the individual clays used in the mixture, to find out which raw materials are responsible for the cracking.

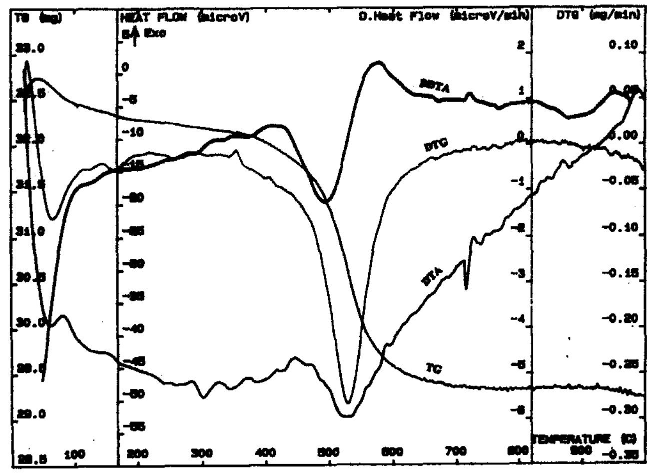

Fig. 1. DTA and TG analyses of the green paver.

3. Material tests

The typical chemical analyses and rational analyses (calculated analysis of the accompanying minerals by using chemical analysis)[3] of raw materials used in the paver mixture are shown at Table 2.

Differential thermal analysis (DTA) and thermogravimetric (TG) analysis of the unfired paver can be seen in (Fig. 1).

The test samples were cut from the extruded pieces in the length of approximately 50 mm with a maximum cross-sectional width of 15 mm, before the thermal expansion tests were carried out on the samples of each raw material and the unfired paver by utilizing the thermal expansion test apparatus made to the design of the British Ceramic Resarch Association.

IV. Results of the Investigation and Discussion

The results of linear thermal expansion/contraction test were evaluated to ascertain the behaviour of the each

Table 2. Typical Chemical and Rational Analyses of the Raw Materials

Typical chemical analysis of the raw materials

Raw Materials	SiO_2 (%)	Al_2O_3 (%)	TiO_2 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	I/L (%)
BS	55.5	22.3	1.2	7.0	0.3	0.6	0.2	0.9	11.8
NH	56.1	24.0	1.3	6.2	<0.1	0.3	0.1	1.2	10.5
RD	60.7	21.9	1.2	5.9	<0.1	0.5	0.2	0.9	8.5
TB	57.8	20.3	1.1	7.5	0.2	0.7	0.1	0.9	10.7

Rational analyses of the raw materials

Raw Materials	Kaolinite (%)	Micas (%)	Quartz (%)
BS	47.4	9.3	29.3
NH	50.0	11.0	27.9
RD	46.4	9.3	34.9
TB	43.1	8.5	33.9

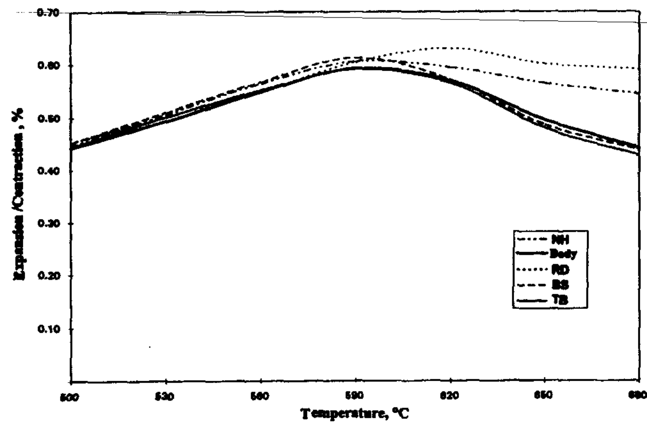

Fig. 2. Thermal expansion/contraction of the unfired clays and paver mixture.

clay and the paver mixture.

A rapid contraction, which occurred immediately after the silica expansion in the preheating zone, appeared to be the main cause of the cracking.

"This contraction around 600°C may be quite severe for a very high clay content body until the structure densifies." [4]

According to the results of the experiment, TB and BS clays exhibited the most rapid contraction between 600 and 650°C during preheating (Fig. 2).

Another test indicated that a paver mixture with a higher proportion of coarse fraction (between 1.18 mm and 3.35 mm) decreased the rate of shrinkage, as shown in (Fig. 3).

In this case, different alternatives may be considered in order to solve the problem.

1. To use coarser material

This may affect the paver strength and resistance to abrasion, adversely. Therefore, this option would not be recommended.

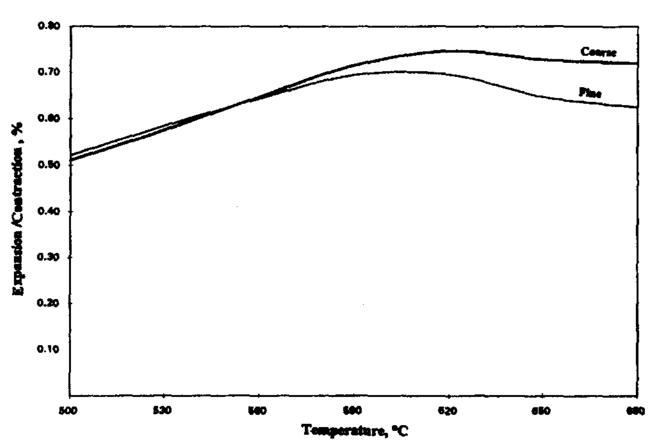

Fig. 3. Thermal expansion/contraction of a green paver (Coarse & fine preparation).

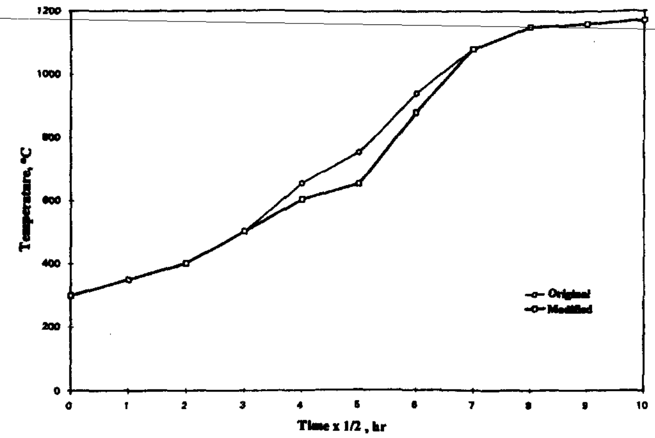

Fig. 4. Firing curve of the abrasion resistant paver.

2. To reduce the production rate

If, the car push rate in the tunnel kiln is already optimum for the drying and the cooling processes, no alteration would be suggested. To slow down the kiln would increase the cost of the production per unit as well.

3. To improve the mixture by using the result of the investigation

Body reformulation seems the most radical of all. But, this alternative can not possibly be chosen, if, there is a time restriction.

4. To redesign the firing curve according to the thermal expansion data

In our circumstances, the best solution was achieved by modifying the firing rate within the critical temperature range (Fig. 4). After the modification, the cracks were eliminated thoroughly.

When further adjustment of the firing rate in that zone can not be achieved, it will be necessary to reformulate the paver mixture.

V. Summary

Making Abrasion Resistant Pavers for commercial use is a challenge in which all aspects of product development and manufacturing must be considered. The significant process parameters must be predetermined.

Ultimate success lies in efficient and effective cooperation between R&D and the Manufacturing & Marketing departments of a company.

Acknowledgments

The author would like to thank R. Barr of Claypave for the thermal expansion tests, S. Zsembery of BMR Laboratory for the paver tests and P. Steven of QUT for the Dilatometric Analysis. The author gratefully acknowledges the genuine support of this work by Dr. A. Anderson, the manager director of Claypave.

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