Marble Dust Incorporate in Standard Local Ceramic Body as Enhancement in Sanitary Ware Products

R. Anwar, H. R. Kamarun, V. V. Vermol and O. H. Hassan

Department of Ceramics,
Faculty of Art and Design,
Universiti Teknologi MARA
40450 Shah Alam, Selangor Darul Ehsan, Malaysia

***Abstract*—The ceramic body strength enhancement in sanitary ware becomes a crucial situation in order to achieve new design development. This design development is directly related to the investigation of present manufacturing process that involved forms, materials and techniques. The material use in this work is typical ceramic body namely porcelain. Porcelain is composed from china clay, feldspar and quartz. In sanitary ware, the challenge is to design forms within the limitations of the porcelain body which are the strength after casting and firing. In this work we modified the present porcelain body using a waste marble that obtained from the marble quarry. The obtained marble waste was grinded into dust and mixed into porcelain body slips. Standard slip casting characteristic was determined. Later the drying and firing characteristics were also determined, specifically the strength. The strength enhancement was observed as well as other properties enhancement. Thus the intricate design can be developed.**

Author Keywords: *Sanitary Ware; Ceramic; Marble; Slip Casting*

I. INTRODUCTION

Slip casting signify as important research field in the sanitary ware product design. Developed from three basic components; clay, flux and filler. The British Standard for vitreous china sanitary ware specifies (BS3402:1969) that samples of fired body must have a mean water absorption of not greater than 0.5% and individual samples must not be greater than 0.75% [1-5]. In this paper, comparative strengths were studied between unmodified and modified vitreous china which is porcelain. To perform the strength analysis, the investigations begin from the mixture of the slips, mould and casting time. The form of a particular moulded shape is determined by the minimum wall thickness of the cast which is time dependant called casting rate [6-9]. Nowadays, industries of all kinds are looking for alternative and less expensive raw materials and to optimize their processes in order to reduce the amount of waste they produce and the corresponding environmental impact. The ceramic industry, particularly the sector devoted to the fabrication of building products, has been the target for the incorporation of other industries rejects, particularly where the inertness of hazardous waste is concerned. Recent studies demonstrated the possibility of incorporating wasted marble into clay-based ceramic products [10]. The results have shown that this type of reject has a good potential to be used as a sintering additive of the ceramic material [7]. Meanwhile, a case study explained that most of the marble manufacture wasted more than 20% of the marble during the production process. Wasted marble then sent to the unknown supplier for disposal with un-specified method. The large amount of marble and granite rejects produced during the industrial process are becoming a serious problem for industrial and environmentalists. In this work, the possibility to use the marble waste to strengthen the sanitary ware body, will be a good idea as part of the problem solving. The objectives of this investigation are to study the possibility on incorporating a waste marble into sanitary ware casting slip, without to degrade their properties. In order to develop new slip body formulation and search for an alternative method that can improve strength the porcelain body.

II. METHODS

A typical slip casting techniques used in sanitary ware is applied in this work. The slip which is sanitary porcelain is added with wasted marble which is obtained directly from the ornamental stone cutting industry. The wasted marbles are carefully selected and categorized according to sizes and colours. In this work, small marbles in form of powders are crushed and sieved to turn out into finer particle (1-10 µm). The colour of the wasted marbles is creamy white and suited the colour of porcelain sanitary slip. The wasted marbles then were added to the porcelain slip in series of 0, 10, 20, 30 and 40 wt % of dried porcelain body (before the mixture of water). The slips now termed as modified slips and casted using the plaster mould into solid rectangular test bar with dimension of (10 x 50 x 100) mm^3. All casted test bars were dried at room temperature overnight. The dried test bars fired in electrical kiln at 800 °C for 2 hours. The fired test bars were measured to determine the shrinkage from dried body to the fired body. Water absorptions and the apparent densities of the test bars were determined by Archimedes methods where both measurements required the test bars being immersed in the water. The mechanical strength or the flexural strength of the fired test bar was determined via 3 points bending test. The stress applied on the bar is described in Modulus of Rupture (MOR). The formula is given in equation 1 below;

$$\sigma = \frac{3FL}{2bd^2} \tag{1}$$

Where σ (N/mm^2) is the stress required to rupture the bars, F is the load (N) at the fracture point, L (mm) is the length of the support span, b (mm) is width and d (mm) is thickness. The MOR was measured in two conditions. The conditions are non-immersed and immersed in water. Both results are compared simultaneously.

III. RESULTS AND DISCUSSION

A. Shrinkage, Water Absorptions and Porosity of Modified Slips

Table 1 gives the average shrinkage analysis for same length, casting time and firing temperature. All test bars was measured in green and fired condition where the shrinkages were in between one and two percent respectively. The firing temperature was set at 800 °C. Setting temperature was defined which suit with quartz inversion where clay will turn into ceramics. At this stage, it is observed that the wasted marbles did not affect the shrinkage of the modified bodies even after the firing process. However the water absorptions of the modified fired bodies decreases from about 20 % to about 6 % absorption. This results shows that a clear indication of marbles role in reducing the water absorptions effect. The possible explanation of these effects is due to the formation of partial glaze layer that happened when the wasted marbles fused during the firing process.

TABLE 1. SHRINKAGE, WATER ABSORPTION AND POROSITY

Test bars	Marble dust (wt %)	Shrinkage (%)		Water Absorption (%)	Porosity (%)
		Dried	Fired		
1	0	0.988	1.975	20.36	37
2	10	0.979	1.980	12.94	35
3	20	0.976	1.950	11.31	34
4	30	0.985	1.964	7.72	31
5	40	0.995	1.997	6.29	28

The porosity of the modified fired bodies also did not vary much as expected. Fig. 2 below shows that there is no significant effects of marble contents to the ceramics body.

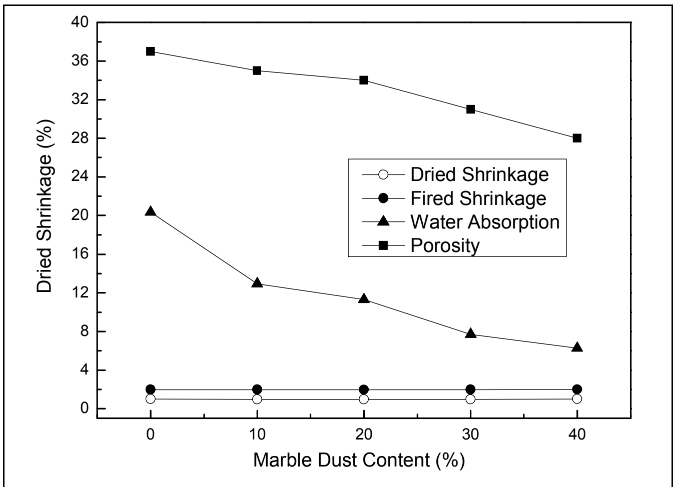

Fig. 1: The relationship of shrinkage, water absorption and porosity of fired test bars.

The firing (800 °C) did not affected the shrinkages which showed in between 2% only. Table 3 explained that the improvement of body strength was increased from 6% to 67%. The casting process still practiced as same method as practiced by manufacturer. Adding marble into slip did not affect any physical practiced. However, it changes the slip viscosity whilst the problem can solved with additional water based on percentage reduced. 45 minutes of casting time was also controlled in a same point with the practiced as well and yet, it does not show any changed practiced need.

B. Modulus of Rupture (MOR)

Table 2 gives the summary result of data evaluation for the MOR test which investigated on the test bar. Fig. 2 proved that the strength increasing with sequenced with additional percentage marble add to the slip. Nevertheless started from 30% additional marble, the bar's line growth hugely to show the strength increased a lot. It also shows that the marble was started to work effectively as strength component to the sanitary ware body. The strength sequence again for 40% but yet increased highly for the strength results.

TABLE 2. MOROF FIRED BODY

Marble dust (wt %)	MOR (N/mm^2)		Differences in strength (%)
	Non-Immersed	Immersed	
0	33.44	13.89	-58
10	35.78	16.22	-55
20	39.15	19.86	-49
30	47.90	32.76	-33
40	51.81	36.40	-35

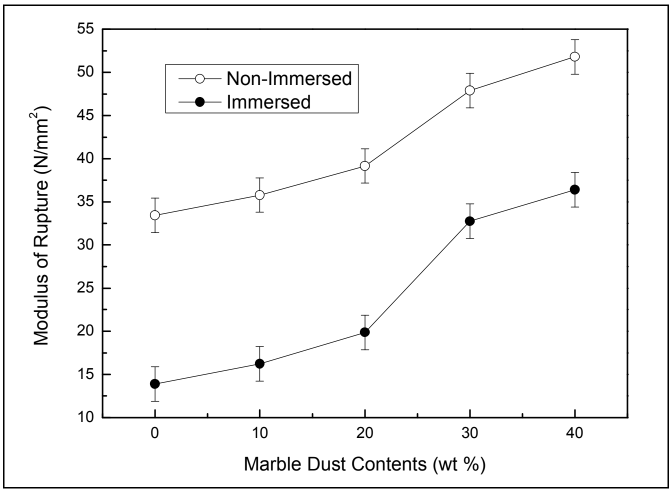

Fig. 2: Modulus of rupture of the fired bodies.

Table 2 also shows the strength comparison before and after the test immersed in water. While the body strength proved, the water absorption reduced, the MOR test also reduced. It means, the strength reduced but the reduced strength became less according to the additional marble. However, the experiment was executed on the bisque test bar with low density to get best water absorption. This procedure objective is to provide a strength body result more effectively. The water absorption automatically proved that the body strength still increased and it does not make sense for the body component as well. However, Fig. 2 shows some differences on the strength. With the 30% of the additional marble, it reduced less than the other groups. At this time, the marble played ruled more effectively than the other groups.

Improvement body strength results by using a marble dust as a body component for sanitary ware slip. These practice was not exaggerated any process for the production. In additional, it can improve until 420% of the production yield. And all achievement depending on the strength increased. With the MOR test, body strength can growth until 52 N/mm^2. For production notes, the casting thickness can be reduced until 67%. And as technical measured, 10mm of thickness automatically can be reduced to 3.31mm.

IV. CONCLUSION

Marble dust can be applied as a component and agent to improve the strength in sanitary ware body. The particle size for marble dust and particle size of sanitary ware should have similar size. The concept of waste to wealth research was to prove that the studies of marble have no limitation as long it’s a calcium base component. More percentage of marble dust added will give more improvement of body strength awarded. Slip fluidity was not affected although slip viscosity changed. However it’s only a minor problem and can be solved just by adjusting the amount of water. Increasing the percentage of marble dust into the conventional ceramic sanitary ware body, not only can improve the body strength but also can provide a lot of improvement for the design development as well. It is hope that this finding will yield the production.

ACKNOWLEDGMENT

Authors would like to acknowledge the Universiti Teknologi MARA (UiTM) for the financial support under the Excellent Fund Scheme. Authors also like to thanks Zamri Abdul Wahab from Ceramic Laboratory of Ceramic Department, Faculty of Art and Design, UiTM for his kind technical assistance.

REFERENCES

[1] Daniel Rhodes, (1972). Clay and Glazes for the Potter. Alfred. New York.

[2] F. H. Norton (1974). Elements of Ceramics. Addison-Wesley Publishing Company. Reading, Massachusetts-Menlo Park, California, London, Don Mills, Ontario.

[3] J.S. Reed, (1995). Principles of Ceramic Processing. (2nd ed.). Wiley, Canada.

[4] Lefteri, Chris. (2003).Ceramic (Materials for Inspirational Design). Rotovision. Switzerland.

[5] P. William Lee. (1961) Ceramics. United State of America.

[6] Paul Rado. (1969). An Introduction To The Technology Of Pottery. Pergamon Press. Ltd. London.

[7] Sasha Wardell. (1994). Slipcasting. A&C Black Limited. London.

[8] W. E. Worrall. (1975) Clay and Ceramic Raw Materials. Great Britain.

[9] A.M. Segadães, M.A. Carvalho and W. Acchar. Using Marble And Granite Rejects To Enhance The Processing Of Clay Products. Department of Physics, Federal University of Rio Grande do Norte. Volume 30. Issue 1, August 2005.

[10] Aylin akar-Deliormanlı and Zeliha Yayla. (2004). Effect Of Calcium Hydroxide On Slip Casting Behaviour. Chemistry Department, Dokuz Eylul University, Buca, Izmir, Turkey. Volume 24, Issues 3-4. February 2004.

[11] D. S. Adcock, I. C. McDowall, The Mechanism of Filter Pressing and Slip Casting, Journal of the American Ceramic Society. Volume 40, Issue 10, pages 355–360, October 1957

[12] F. Saboya Jr., G.C. Xavier and J. Alexandre. The Use Of The Powder Marble By-Product To Enhance The Properties Of Brick Ceramic (n.d). CCT Campos, Rio de Janeiro, Brazil. Volume 21, Issue10. October 2007.

[13] W. Acchar, F.A. Vieira and D. Hotza. (2005). Effect Of Marble And Granite Sludge In Clay Materials. Department of Civil Engineering, Federal University of Santa Catarina. Volume 419, Issues 1-2, 15 March 2006

[14] Wilson Acchar, Francisco A. Vieira and Ana M. Segadães. (2006). Using Ornamental Stone Cutting Rejects As Raw Materials For Red Clay Ceramic Products: Properties And Microstructure Development. Department of Ceramics and Glass Engineering, University of Aveiro. Volumes 435-436, 5 November 2006.

[15] Y. Zhang and J. Binner. (2002). Enhanced casting rate by dynamic heating during slip casting. J. Eur. Ceram. Soc. 22 pp. 135–142.

Periodicals

[16] C. Guler and E. Balci. (1998). Effect of some salts on the viscosity of slip casting. Appl. Clay Sci. **13** pp. 213–218.

[17] Freire AS, Mota JF. (1997). Potentiality of utilization of marble and granite waste. Quality Rocks Magazine, 123, Brazil.

[18] New England Bussiness Journal (2008). Omya seeks OK on plan to handle marble waste. Times Argus Online.