

**NOVEL RADIOGRAPHIC TECHNIQUE TO ANALYZE
THE POROSITY AND WATER ABSORPTION OF
BRICKS**

Maddumage Anura Kumara Jayatilaka



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
(10/8306)
www.lib.mrt.ac.lk

Degree of Master of Science

Department of Materials Science and Engineering

University of Moratuwa

Sri Lanka

June 2014

**NOVEL RADIOGRAPHIC TECHNIQUE TO ANALYZE
THE POROSITY AND WATER ABSORPTION OF
BRICKS**

Maddumage Anura Kumara Jayatilaka



(10/8306)
University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Dissertation submitted in partial fulfillment of the requirements
for the Degree of Master of Science in Materials Science

Department of Materials Science and Engineering

University of Moratuwa
Sri Lanka

June 2014

DECLARATION PAGE OF THE CANDIDATE & SUPERVISOR

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date:

Name: M.A.K. Jayatilaka

The above candidate has carried out research for the Master's dissertation under my supervision



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Signature of the supervisor:

Date:

Name of the supervisor: Mr. V Sivahar

ACKNOWLEDGEMENTS

I would like to thank project supervisor Mr. V. Sivahar, Senior Lecturer, Department of Materials Science and Engineering, University of Moratuwa for his constant encouragement and guidance in the research work. Thanks are also due to the Dr. Shantha Amarasinghe, Senior Lecturer, Department of Materials Science and Engineering, University of Moratuwa for his kind and moral support.

This research was carried out with the equipment and laboratory support of the Atomic Energy Authority. I express my sincere thanks for the co-operation for this research to staff of Atomic Energy Authority.

I acknowledge the contribution by Mr. Thilawala, Mr. Seneviratne, Mr. Chaminda Jayathunga Arachchi and Mr. M.N.M Faizer to various supports.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

ABSTRACT

Properties of clay brick includes strength, water absorption, durability, expansion, efflorescence and pitting due to lime. Generally these properties are measured using destructive testing methods and as a result sampling errors are inevitable in addition to other considerations such as additional cost for discarding the tested component. Therefore to optimize the costing considerations as well as to reduce the sampling errors an NDT technique such as Radiographic Testing was used to evaluate the properties like water absorption etc.

Initially a theoretical model was developed to obtain a relationship between X-ray intensity and the absorbed water volume. From that model it was deduced that the natural log of the intensity changes and the absorbed water volume shows a linear relationship. First to find the appropriate tube voltage and the exposure time, a preliminary experiment was carried out as the first stage and from the results of that, the exposure time and the tube voltages were used for the subsequent second stage to determine whether the experimental findings were in line with the theoretical model

For the experimental purpose three sets of samples obtained from different locations were used with five clay bricks in each set. The samples were immersed in water for specified time intervals and the radiographic tests were performed on them. Natural log intensity (index) vs water volume relationship was studied and found to be linear which confirms the theoretical model developed. As per the findings of the research it could be concluded that the Radiographic testing method could be applied to find porosity and water absorption of clay bricks. Radiographic intensity of dry bricks remains constant for a given set. Therefore radiographs can be used to find origin of bricks and hence to sort out bricks of archeological importance.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

TABLE OF CONTENTS

| | |
|--|-----|
| Declaration page of the candidate & supervisor | i |
| Acknowledgements | ii |
| Abstract | iii |
| TABLE OF CONTENTS | iv |
| List of Figures | vi |
| List of Tables | vii |
| List of abbreviations | vii |
| 1 introduction | 1 |
| 2. review of the literature | 3 |
| 3. Theoretical background | 6 |
| 3.1 Radiographic Film properties | 6 |
| 3.2 Radiation Attenuation | 6 |
| 3.3 Film Digitization and Grey value | 8 |
| 3.3 Theoretical Model | 9 |
| 4. Experimental procedure | 13 |
| 4.2 Materials and Equipment | 14 |
| 4.3 First Stage - Preliminary Experiments | 14 |
| 4.3 Second Stage - Experiments | 15 |
| 4.3.1 Sample collection and preparation | 15 |
| 4.3.2 Film loading | 16 |
| 4.3.3 Exposure arrangement | 16 |
| 4.3.4 Obtaining radiographic images of the sample | 17 |
| 5. Results and discussion | 19 |
| 5.1 First Stage - Preliminary Experiments | 19 |
| 5.2 Second Stage - Relationship between Theoretical model and Experimental Results | 21 |

| | |
|--|----|
| 5.2.1 Sample Set 1 -Normalized Intensity Index Vs Water Volume | 21 |
| 5.2.2 Sample Set 2 - Normalized Intensity Index Vs Water Volume | 26 |
| 5.2.2 Sample Set 3 -Normalized Intensity Index Vs Water Volume | 29 |
| 5.3 Factors causing Deviation in the results | 33 |
| 5.3.1 Radiographic Film Factors | 33 |
| 5.3.2 Equipment Arrangement | 33 |
| 5.4 Relationship between Normalized intensity at dry condition and Sample sets | 36 |
| 5.5 Relationship between Normalized intensity index at dry condition and Void volume | 37 |
| 5.6 Absorbed Water Volume | 37 |
| 6. Conclusions and suggestions | 39 |
| Reference List | 40 |
| Appendix 1 | 43 |



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF FIGURES

| | |
|--|----|
| Figure 1:1 Industrial radiography of an object and a radiograph | 2 |
| Figure 3:1 The effect of wave length of primary radiation (tube voltage) on contrast | 6 |
| Figure 3:2 Intensity Variation with depth | 7 |
| Figure 3:3 Effect of the number of pixels on the image resolution [23] | 9 |
| Figure 3:4 Effect of the grey value resolution [23] | 9 |
| Figure 3:5 Exposure arrangements | 11 |
| Figure 4:1 Flow Chart for experimental procedure | 13 |
| Figure 4:2 Sample sets | 15 |
| Figure 4:3 Brick dimensions and a sample brick | 15 |
| Figure 4:4 Experiment setup | 16 |
| Figure 4:5 Radiographs of brick and aluminum plate | 18 |
| Figure 5:1 Normalized intensity Vs Water volumes – Pre Test Brick 1 | 19 |
| Figure 5:2 Normalized Intensity Index Vs Water Volume – Set 1 Brick 1 | 22 |
| Figure 5:3 Normalized Intensity Index Vs Water Volume – Set 1 Brick 2 | 23 |
| Figure 5:4 Normalized Intensity Index Vs Water Volume – Set 1 Brick 3 | 24 |
| Figure 5:5 Normalized Intensity Index Vs Water Volume – Set 1 Brick 4 | 24 |
| Figure 5:6 Normalized Intensity Index Vs Water Volume – Set 1 Brick 5 | 25 |
| Figure 5:7 Normalized Intensity Index Vs Water Volume – Set 2 Brick 1 | 26 |
| Figure 5:8 Normalized Intensity Index Vs Water Volume – Set 2 Brick 2 | 27 |
| Figure 5:9 Normalized Intensity Index Vs Water Volume – Set 2 Brick 3 | 27 |
| Figure 5:10 Normalized Intensity Index Vs Water Volume – Set 2 Brick 4 | 28 |
| Figure 5:11 Normalized Intensity Index Vs Water Volume – Set 2 Brick 5 | 28 |
| Figure 5:12 Normalized Intensity Index Vs Water Volume – Set 3 Brick 1 | 29 |
| Figure 5:13 Normalized Intensity Index Vs Water Volume – Set 3 Brick 2 | 30 |
| Figure 5:14 Normalized Intensity Index Vs Water Volume – Set 3 Brick 3 | 30 |
| Figure 5:15 Normalized Intensity Index Vs Water Volume – Set 3 Brick 4 | 31 |
| Figure 5:16 Normalized Intensity Index Vs Water Volume – Set 3 Brick 5 | 31 |
| Figure 5:17 Grey value profile axis of a radiograph | 33 |
| Figure 5:18 (a) Radiograph (b) X direction grey value profile | 34 |
| Figure 5:19 (a) Radiograph (b) Y direction grey value profile | 35 |
| Figure 5:20 Normalized intensity of dry brick Vs Sample No | 36 |
| Figure 5:21 – Characteristic graph to find unknown water volume | 38 |

LIST OF TABLES

| | |
|---|----|
| Table 5:1 R ² values for preliminary test samples | 20 |
| Table 5:2 R ² values, gradient and intercept for Set 1 samples | 25 |
| Table 5:3 R ² values, gradient and intercept for Set 2 samples | 29 |
| Table 5:4 R ² values, gradient and intercept for Set 3 samples | 32 |



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF ABBREVIATIONS

| | |
|-----|-----------------------------|
| NDT | Non Destructive Testing |
| NDE | Non Destructive Examination |
| XRF | X-ray fluorescence |

| | |
|---|--|
| XRD | X-ray diffraction |
| RT | Radiographic testing |
| I_0 | Initial intensity |
| I | Intensity after attenuation |
| μ | Linear attenuation coefficient |
| d | Material thickness |
| τ | Attenuation coefficient due to photoelectric effect |
| σ_s | Attenuation coefficient due to scattering |
| π | Attenuation coefficient due to pair production |
| w_a, w_w and w_s | weight fraction of air, water and solid material respectively |
| $(\mu/\rho)_a, (\mu/\rho)_w$ and $(\mu/\rho)_s$ | mass absorption coefficients of air, water and solid material respectively |
| ρ_{ave} | Bulk density |
| V_a, V_w and V_s | Volume of air, water and brick material respectively |
| V_T | Total volume |
| V | Void volume, |
| I_{Al}, I_B | Attenuated intensities received by the film by aluminum plate and brick respectively |
| μ_{Al}, μ_B | Linear attenuation coefficient of aluminum plate and brick respectively |
| T_{Al}, T_B | Thickness of aluminum plate and brick respectively |
| <i>Grey B</i> | Mean grey value of bricks |
| <i>Grey Al</i> | Mean grey value of aluminum plate |

$$\ln \frac{Grey\ B}{Grey\ A1}$$

Normalized intensity index



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk