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NUMERICAL CHARACTERIZATION OF TILES SELECTION FOR HUMAN APPLICATION.

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ABSTRACT- Slips and trips are often causes of accidents and in some situations the potential for serious injury is much greater. The use of ceramic tiles for both domestic applications (living rooms, toilets, bathrooms, walls and surrounding) and public (hotels, restaurants and hospitals) deserve much attention. Foot slips on floors are said to be probably due to insufficient friction between the sole and the floor. To control slipping and tripping events especially on ceramic tiles, proper selections of such tiles based on surface roughness (friction coefficient) would be adequate. This study therefore, elaborates the selection of tiles of different degrees of roughness (friction coefficient) that are commonly used for various domestic applications. Fractal analysis was employed to quantitatively characterize the surface roughness of tiles `relative to their uses.

Keyword: Tiles, Friction, Surface Roughness, Fractal analysis.

1.0 INTRODUCTION

Evidence of the first ceramic tiles used in dwellings and structures since 8 thousand years ago, did not have the required durability. The precursors of modern tiles were roughly shaped and not nearly as strong as tiles are today. The clay material was dug from river banks, roughly formed into blocks and baked dry in the sun. The first tiles were crude, but even these early civilizations decorated them by adding pigments for color and carved low-relief designs into the surfaces. Early man's evolution of building materials, starting with sun baked bricks to create a structure and evolved to create interior surfaces to decorate their living spaces with this material that was durable, beautiful and user friendly (Duparré, et al., 2002).

Slipperiness is a phenomenon that describes the causes of sliding which may result into a various degree of accidents (Chang, and Matz, 2010). The nature of slipping and the perception of slipperiness are very subjective and also dependent on the interaction of a large number of variables (i.e. surface roughness/friction) that individually may perceive. However, the type of contamination present on the floor, the speed of travel (whether ascending or descending), whether the feet are bare or shod (the heel and sole material), and so on, all affect slipperiness (Li et al., 2004). All of these result into accidents which may cause serious damage to the body. Thus, there is a need for adequate selection of tiles for various domestic applications ranging from living room to toilet, kitchen, bathroom, surroundings and walls. The objectives of this study are to investigate the surface roughness/friction coefficient of different tiles that is available in the market using fractal analysis, to predict their applications for domestic's uses based on fractal dimension and sphericity (Blackledge, and Dubovitskiy, (2011).

This study is important in that floor coverings such as ceramic tiles offer surfaces in a range of finishes that include textured finishes, abrasive inclusions and various surface relief profiles (Poon et al., 1995). Each is specifically designed to maximize frictional properties under specific conditions. The two biggest factors influencing the choice of slip-resistant tile for each application are the likely wetness of the floor and the type of foot traffic using the floor (i.e. barefoot or shod) (Creath and Wyant, 2010). Applications involving wet floors will require tiles with a surface finish that will improve performance and also improve overall slip resistance or friction.

In this study, 36 ceramic tiles of same geometries but of different surface roughness were obtained from major distributor in Oshogbo, Osun State, Nigeria. The surface roughness and sphericity of each of the tiles selected was analyzed using fractal analysis and the images were obtained using HP digital camera so as to predict the types of tiles that can be used for various human applications.

2.0 MATERIALS AND METHODS

2.1 Image Acquisition

Images of tiles were obtained with the use of HP Digital Camera, which took most of the snapshots used for the analysis.

The resolutions of these images were taken into recognition before simulations were done using genetic algorithm. For the purpose of this study, 36 ceramic tiles of same geometries but of different surface roughness were obtained from major distributor in Oshogbo, Osun State, Nigeria, out of which 1/3 of the selected tiles were shown in Figure 2.1 based on the same factor.

Preliminary study conducted revealed the ceramic tiles selected were commonly used for domestic applications such as floor, living rooms, bathroom, offices and the surroundings in South-west Nigeria. Further investigations also prove that tiles had resulted in various forms of accidents at home resulting in serious injuries. Numerical characterization of surface roughness of ceramic tiles is expected to reduce such domestic accident based on its suitability for specific application (Zmeskal, et al 2001).

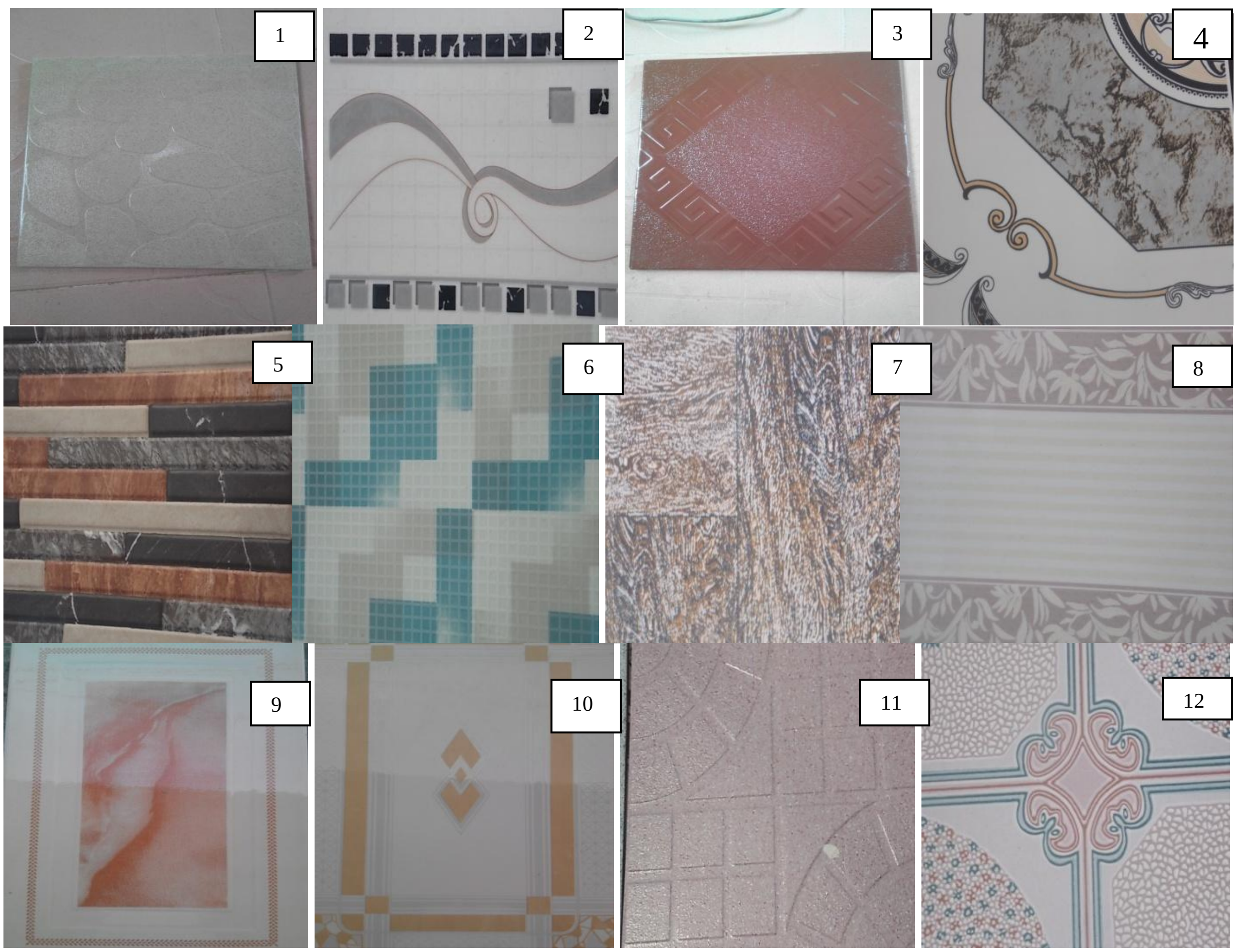

Figure 2.1: Images of Tiles obtained from major distributor in Oshogbo, Osun State, Nigeria.

2.2.1 Mathematical Model of Surface Roughness

2.2.2 Fractal Analysis Approach for Determining the Roughness of Tiles Selected

Fractal geometry is the geometry associated with naturally occurring objects that have repeating patterns at different scales. It was firstly developed by Mandelbrot (1982). Fractal analysis is widely used to quantify the self-similarity and complexity of natural structures or objects such as the perimeters of clouds, coastlines and various other geometries (Hangai and Kitahara, 2008).

In medicine, it has been used to distinguish cancer tissues from normal tissues (Zmeskal *et al.,* 2001; Parvu *et al.,* 2012). In this work, the mathematical basis for measuring objects with the power law modified was adopted. The basic equation is as follows:

$$P = P_E\, \delta^{D-1} \qquad \text{(for } 1 < D < 2 \text{ and } \delta_m < \delta < \delta_M) \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(1.1)$$

Where; P is the true perimeter, P_E is the measured perimeter, δ is the yardstick, D is the fractal dimension, δ_m and δ_M are the upper and lower limits respectively for any shape.

From this expression, it can be deduced that the true perimeter is actually a function of the yardstick for measurement. The smaller the yardstick used, the more accurate the measurement. The fractal dimension, *D*, therefore describes the complexity of the contour of an object. It can be more practically called its roughness (Huang and Lu, 2002).

When δ < δm, the measurement is not sensitive to the yardstick chosen, therefore giving a smaller value of the slope, while when $\delta > \delta_M$, the size of the yardstick exceeds that of the individual feature being measured so that the measurement loses meaning because the object falls below the resolution limit of the yardstick used for measurement (Lu and Hellawell, 1999).

Sphericity, *β*, another dimensionless number, is used together with the fractal dimension, *D*; to describe the shape of the tiles formed (Huang and Lu, 2002). It can be expressed as;

$$\beta = 4\pi A_T / P^2 \qquad \text{(for } 0 < \beta < 1 \text{ and } 1 < D < 2) \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(1.2)$$

Substituting equation (1.1) in eqn. (1.2) gives

$$\beta = \left(4\pi A_T / P_E^2\right) \delta^{2(1-D)} \qquad \text{(for } 0 < \beta < 1 \text{ and } 1 < D < 2) \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(1.3)$$

where A_T is the total area of a tile.

when $\beta = 1$ and $D = 1$, a perfect rectangular shape is formed by the tile in the microstructure.

as β decreases, the shapes become more elongated showing a departure from perfect sphere.

The locations of $1 < D < 2$ represent less regular shapes.

To calculate the perimeter P of the tiles, the Slit Island Method (SIM) introduced by Mandelbrot (1982) was used. It is expressed as:

$$\log_e P = 0.5D \log_e A_T$$

$$\log_e P = 0.5D \log_e A_T^{D/2} \qquad \ldots\ ..\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots(1.4)$$

$$P = A_T^{D/2}$$

2.3 The Computer Program

Using the equations, (1.1 – 1.4), an interactive MATLAB program was developed to numerically characterized the roughness "*D*"and sphericity "*β*" of the tiles selected. To develop the program the box counting method was used with a counter incorporated into the program and the small boxes or pixels occupied by tile outlines are counted. In all four pixels (2x2pixels, 4x4pixels, 8x8pixels and 16x16pixels) and four grid sizes (200x200, 100x100, 50x50 and 25x25) were selected. The selections were made for better resolution and to obtain accurate results. A flow chart in Figure 2.2 below shows the various stages and the subroutines in the computer program.

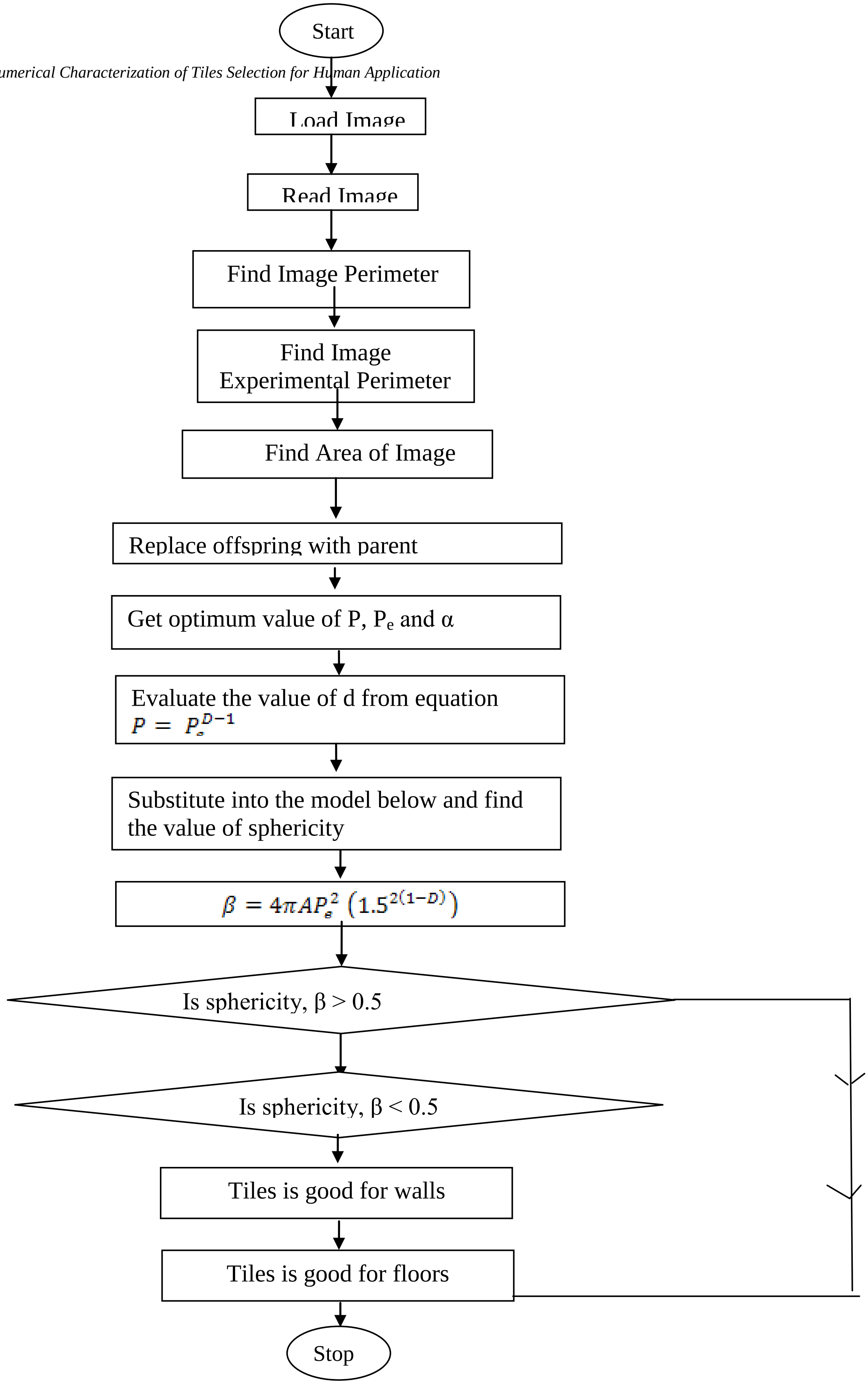

Figure 2.2 Flow-chart showing the genetic algorithm sequence

3.0 RESULTS AND DISCUSSION

3.1 Tiles Simulation Results

After different simulations were performed on the images, the optimum values of the fractal dimensions for each images were got, and the corresponding sphericity values were obtained. The simulation results for tiles that were generated are shown in the Table 3.1 below while figure 3.1 shows the graph of fractal dimension against sphericity for the tiles selected.

However, for the purpose of this study, 36 different images of tiles were simulated. It was observed that as the fractal dimension increases, the sphericity increases thus increasing the roughness of the tiles making it suitable for usage in toilet and bathroom holdings which prevent accidents at home.

Moreover, a measured static coefficient of friction of 0.5 has been adopted as a safety standard in the USA (Li, et al., 2004). In this study, the value of sphericity lies in the range of $0 < \beta < 1$. This implies that any tile with sphericity value greater than 1.0 has a more rougher surface and should be used for applications such as living room, toilet and bathroom where contamination can take place. In addition, tiles with surface roughness of $0.5 < \beta < 1$, can be chosen for other applications where there could be no contamination.

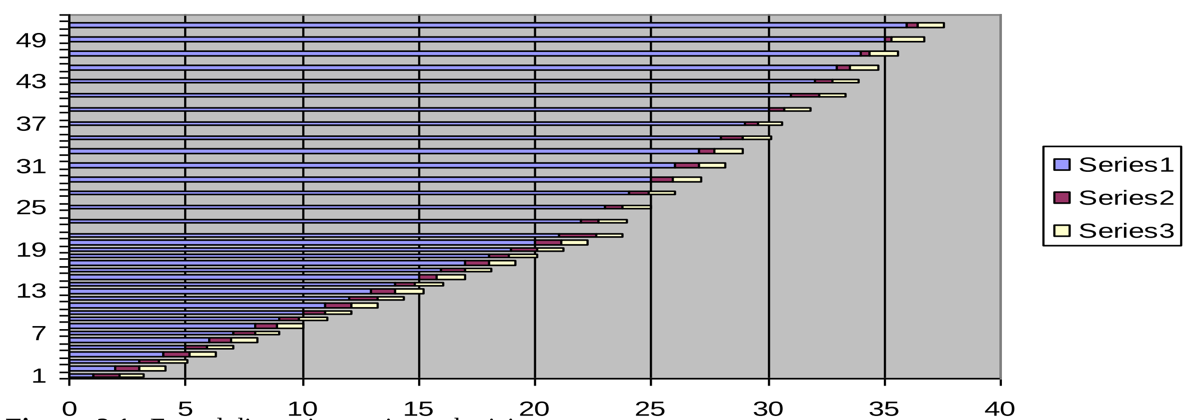

Figure: 3.1 . Fractal dimension against sphericity.

Table 3.1: Analysis of tiles based on fractal dimension and sphericity

Number of Tiles	Sphericity	Fractal Dimension	Number of Tiles	Sphericity	Fractal Dimension
1	1.1547	1.0807	19	1.0914	1.1378
2	1.0353	1.1279	20	1.1547	1.0807
3	0.8737	1.1797	21	1.6477	1.0859
4	1.1641	1.1265	22	0.7419	1.1948
5	0.9172	1.1499	23	0.7881	1.1856
6	0.9314	1.1700	24	0.8382	1.1763
7	0.9773	1.0121	25	0.9519	1.1571
8	0.9260	1.0866	26	1.0056	1.1700
9	0.8967	1.1414	27	0.7357	1.1984
10	1.0078	1.1241	28	0.9648	1.1744
11	1.1378	1.1061	29	0.5716	1.0793
12	1.2139	11.1508	30	0.7221	1.1381
13	0.9724	1.2528	31	1.1641	1.1265
14	0.8049	1.2837	32	0.7825	1.0838
15	0.7357	1.2984	33	0.5553	1.2265
16	0.9552	1.1955	34	0.3449	1.2863
17	1.0036	1.1955	35	0.3272	1.4213
18	0.8836	1.2077	36	0.4063	1.1534

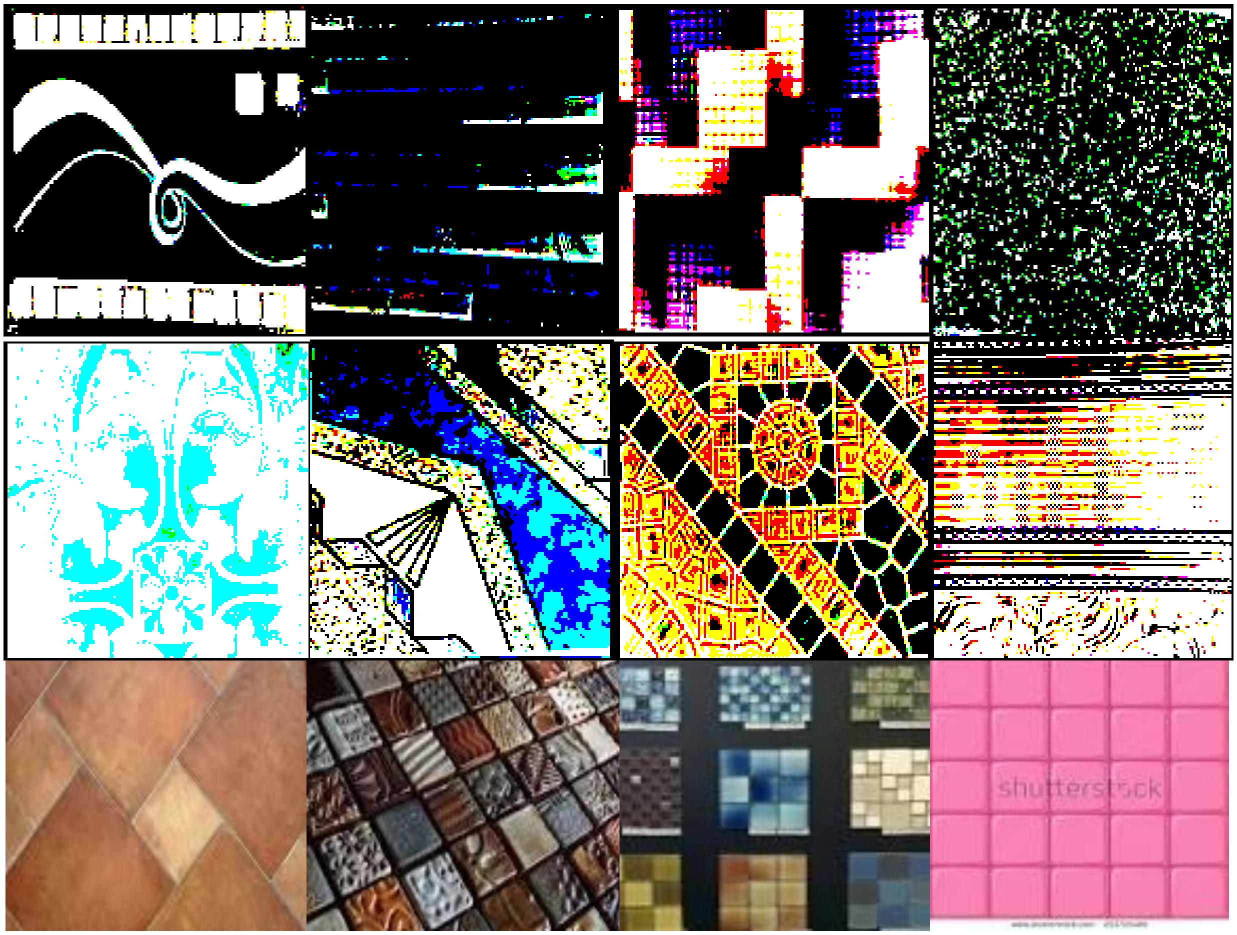

Figure 3.2: Transformed smooth surface images

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

Most people give little thought to the flooring on which they work and walk each day unless they slip, trip or fall. A strategy focusing on the selection of ceramic tiles can go a long way towards reducing safety problems. Using the right floor tiles for right environment is critical in preventing slips and falls. Thus, it is highly recommended that ceramic tiles with bright reflective surface finish should not be used for flooring as they can pose a slip hazard because of their poor abrasive resistance.

The fractal analysis of tiles was carried out and it was observed that as sphericity increases, fractal dimension also increases. For tiles with high sphericity such as 1.0 were found to be more rough, thereby making them suitable for living rooms, toilets and bathroom fittings, which are expected to reduce home accidents, while tiles with sphericity less than 1.0 could be used for building walls.

4.2 RECOMMENDATIONS

- Tiles with low sphericity should be replaced to avoid an unexpected accident.
- Relationship between the tiles and the foot, slippers or shoes can be established so as to improve on the human uses of tiles.
- Tiles to be used in hotels, restaurants, toilets should have a high value of sphericity to increase the surface roughness.
- Shoes with wooden sole should not be worn on smooth surface tiles.

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