Final Report, Proposal number 99200431:

Feasibility Study: Concrete Roughness Measuring Device

Introduction

This is the final report of the feasibility study, to demonstrate the potential for building an image based concrete roughness measuring device, for the purpose of evaluating the roughness of sand-blasted concrete surfaces prior to applying fiber reinforced polymers.

Work Completed

Preparation of 6 concrete surfaces for the measurements.

Eight concrete pads (2' by 1" by 4") were caste and allowed to cure for 45 days. The surfaces of five of these were roughed to various degrees by sandblasting. These five plus one control sample were cut in two to create matching surfaces (Figure 1).

Evaluation of the three techniques (shadow profilometry, laser striping, texture mapping)

These three techniques for measuring roughness were tested on the six supplied samples, under laboratory conditions.

The shadow profilometry technique could not be applied to this problem because of the color contrast between the aggregate and the cement paste.

The laser striping method proved to be the most useful. In this method, a high resolution CCD camera was mounted vertically over the sample and a 670 nm 10 mW stripe laser was mounted at a 45 degree angle (Figure 2). A 670 bandpass filter was placed over the camera lens to admit only the laser light (Figure 3). Figure 4 shows the profiles generated by the laser stripe for the 6 different surfaces at a 200 mm scale. Figure 5 shows the profile of the roughest surface at a scale of 200, 100, 50, and 25 mm. Figures 6-9 show the average results of 10 tests each on the different surfaces (0-5) different scales of observations, (20, 10, 5, and 2.5 cm), and for parameters (RMS → root mean square amplitude, Z2→ root mean square of the first derivative, i-angle → micro average inclination angle, and R_p → roughness profile index.

The texture mapping method was applied to the six surfaces (Figure. 10). The initial results of these analyses reveal that this method may not be as sensitive to roughness as the laser striping method (Figure 11).

Identification of potential limiting factors (measurement size ranges, color limitations, spatial variability concerns, etc).

Limiting factors found were:

1) Color of the aggregate negated the shadow profilometry method.
2) Size range of the profile (scale of observation) resulted in different numerical measurements, but trends proved consistent within that range, suggesting that any of the size ranges tested could be used.
3) Spatial variability dictated that about 10 samples (stripes) were required to characterize an average roughness.

Evaluation of optimal light angles, conditions, sampling requirements etc.

Optimal required conditions:

1) Camera at 90 degrees to the surface (no image restoration required).
2) Laser stripe at 45 degrees to the surface.
3) Sample size of 10 cm picked for convenience.
4) Ten samples stripes are required for a single characterization

Building and assembling of necessary code structures.

The necessary code structures for analysis were developed and incorporated on a temporary basis into an existing platform.

Developing a first draft for specification of prototype measuring device.

A rough sketch of the prototype measuring device is pictured in Figure 17.

Other preliminary specifications are:

1) 10 cm wide imaging plane
2) High resolution (tiny) board CCD camera with c-mount 7.5 mm lens, mounted vertically with standoff distance of about 15 cm.
3) 20 mw 678 nm striping laser with 11 stripes, mounted at 45 degrees with standoff distance of about 10 cm.
4) 678 nm bandpass filter.
5) Moderately light tight enclosure, with handle for overhead use
6) 4 corner standoffs for uniform fit to surface being measured.
7) Wires for a) video, b) video power, and d) laser power to a laptop computer and battery packs.
8) Windows based laptop computer with PCMCIA frame grabber.

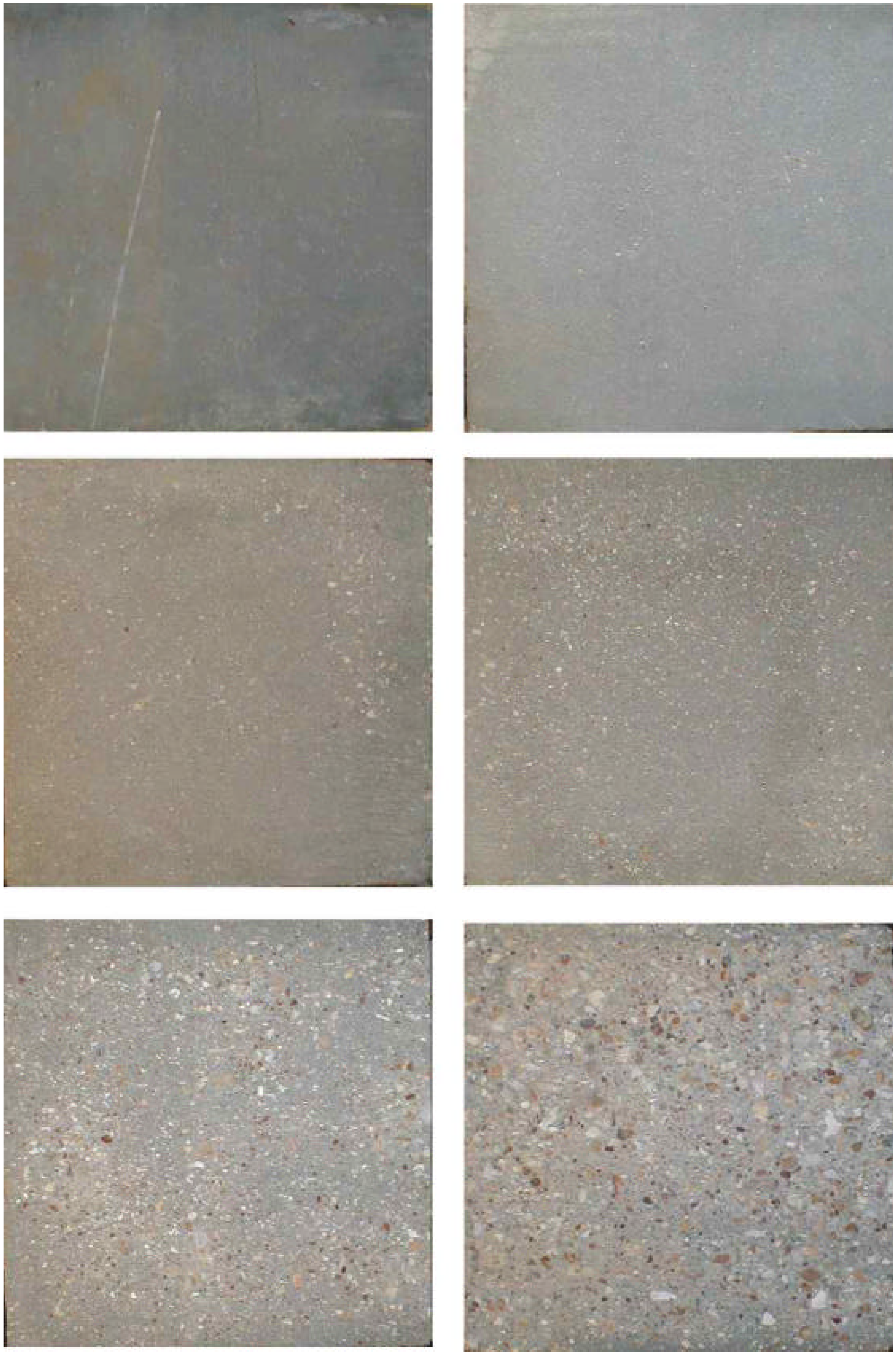

Figure 1. Initial test samples, 0,1,2,3,4,5, in order of roughness.

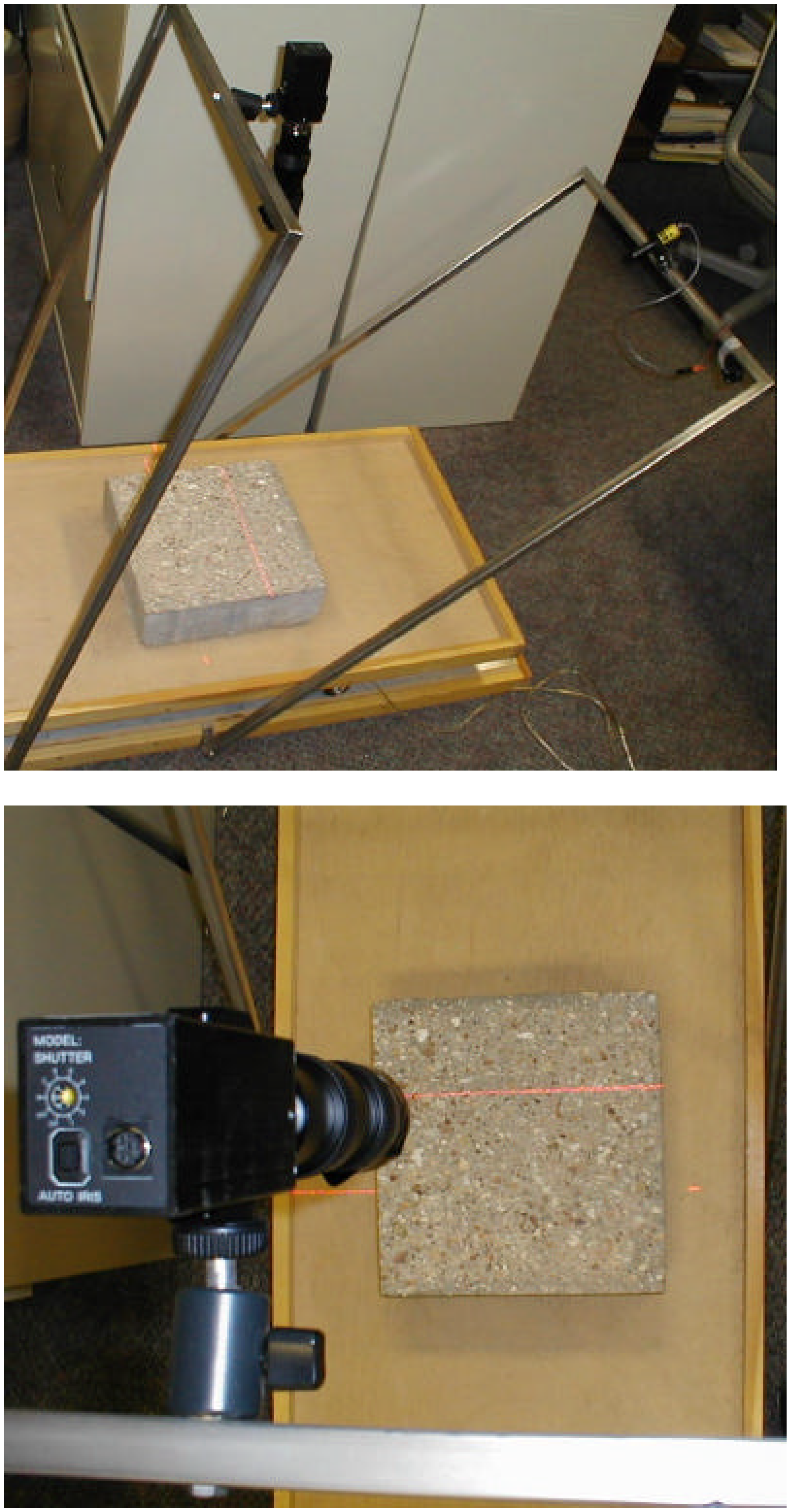

Figure 2. Laboratory measuring device.

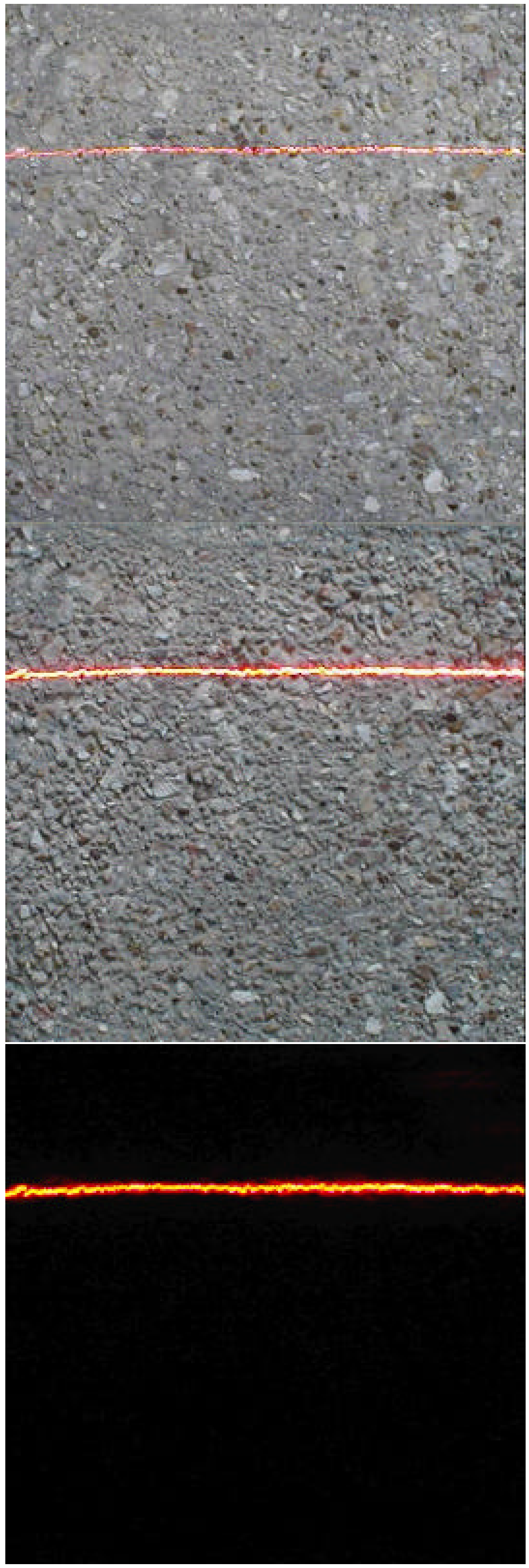

Figure 3. Shadow profile, normal light conditions, dark room, conditions, and through a bandpass filter.

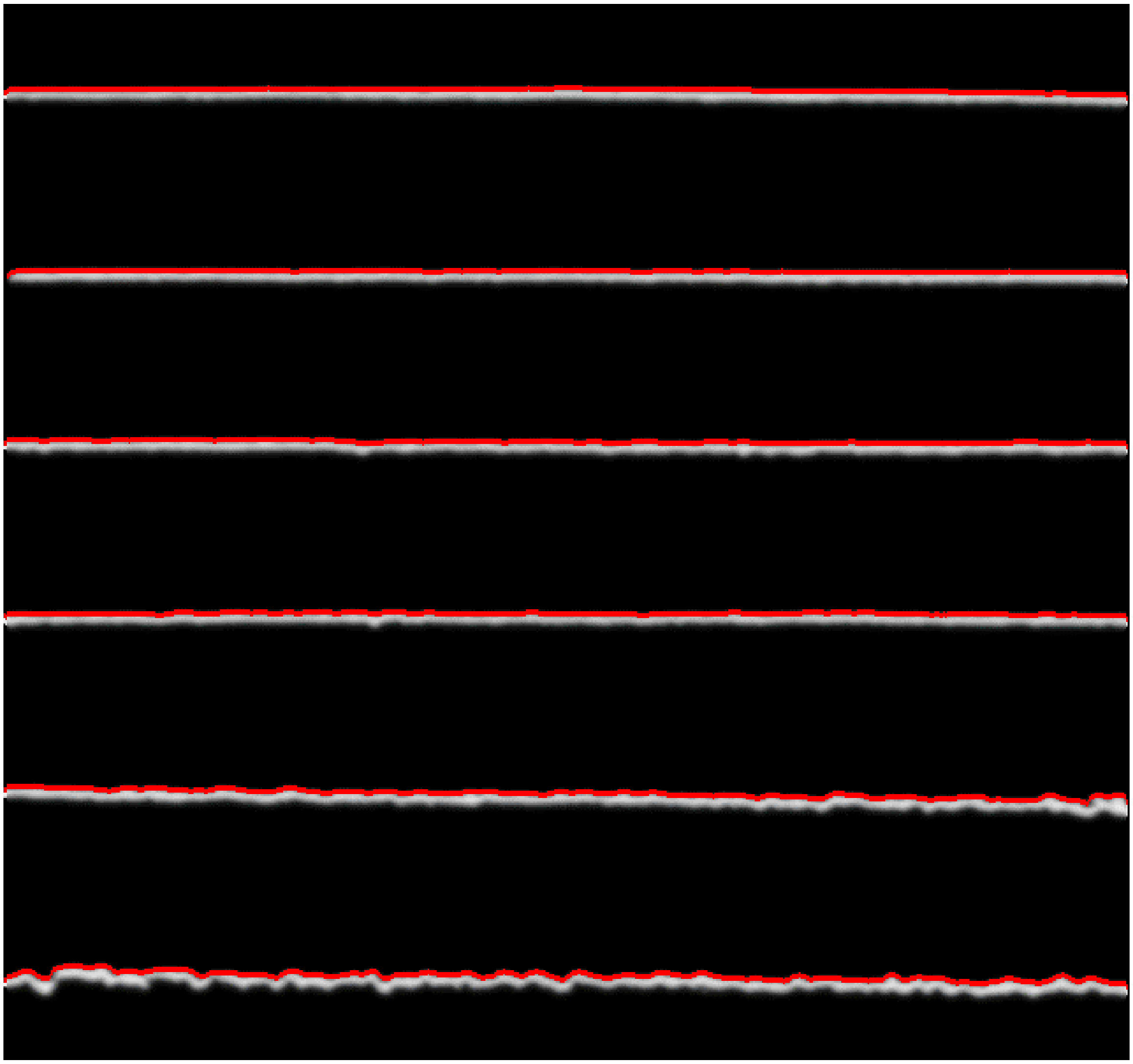

Figure 4. Six different concrete profiles at 200 mm scale

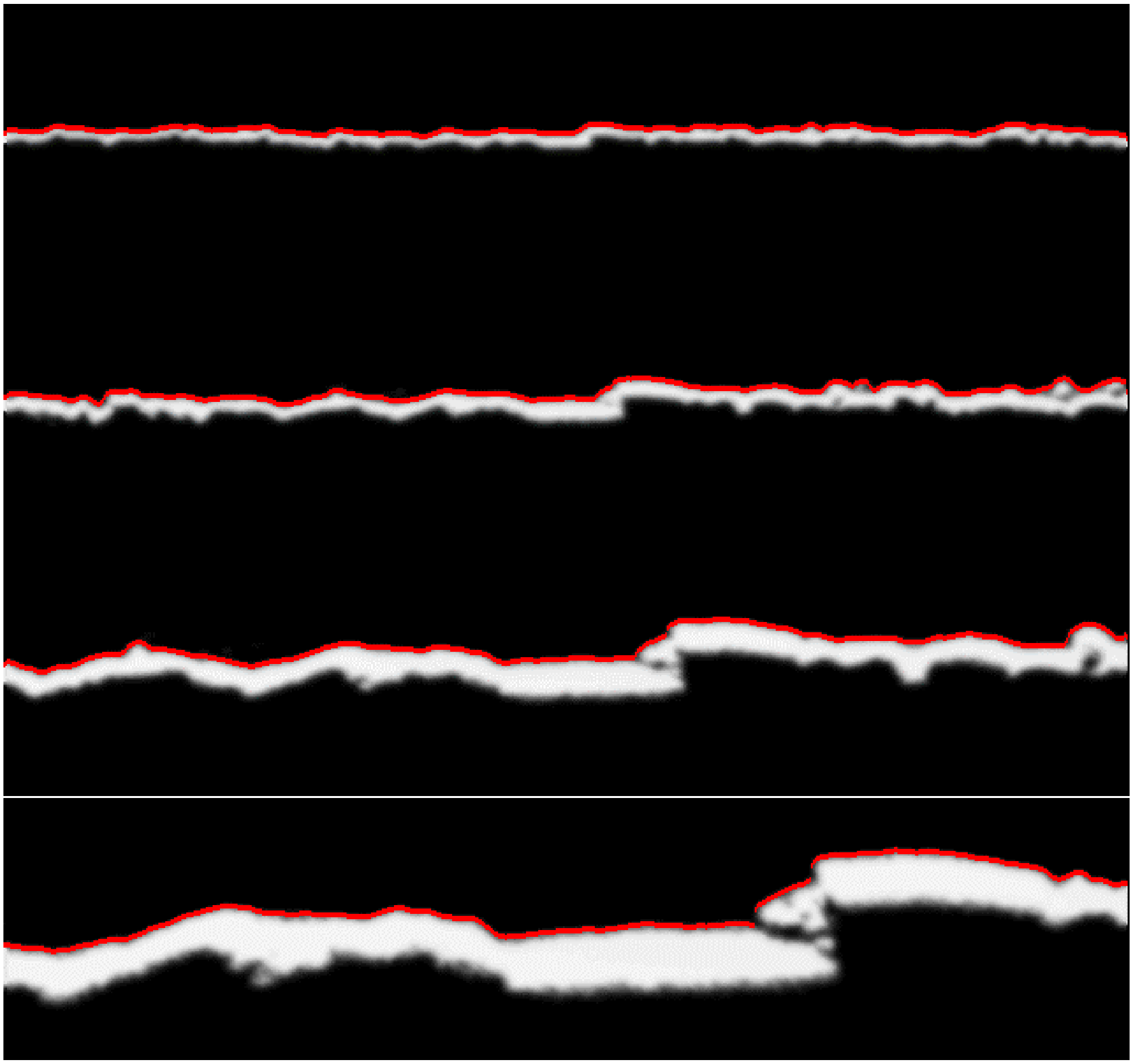

Figure 5. The profile of the roughest surface at scales of 200 mm, 100 mm, 50 mm, and 25 mm.

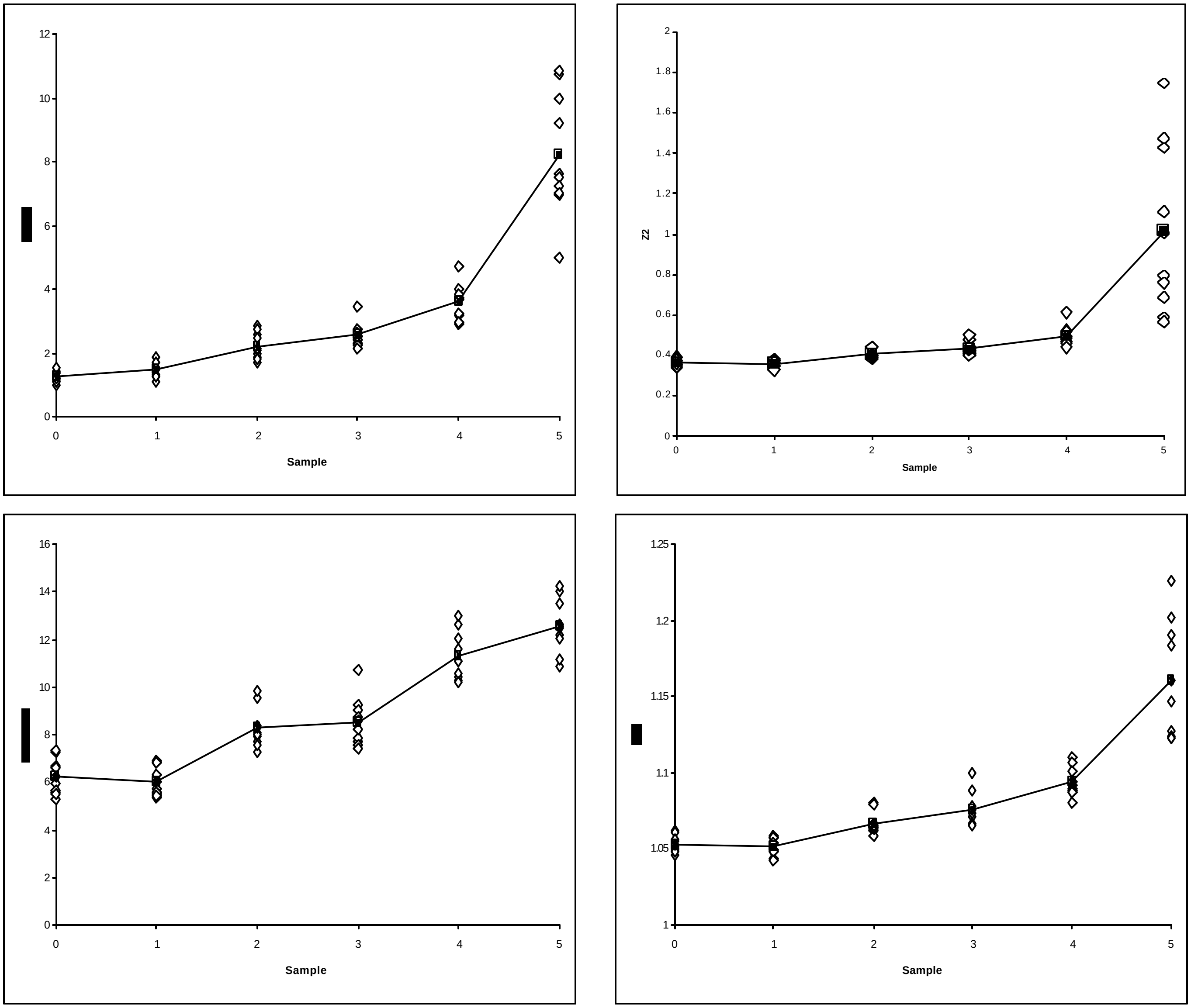

Figure 6. Laser profilometery, 25 mm samples

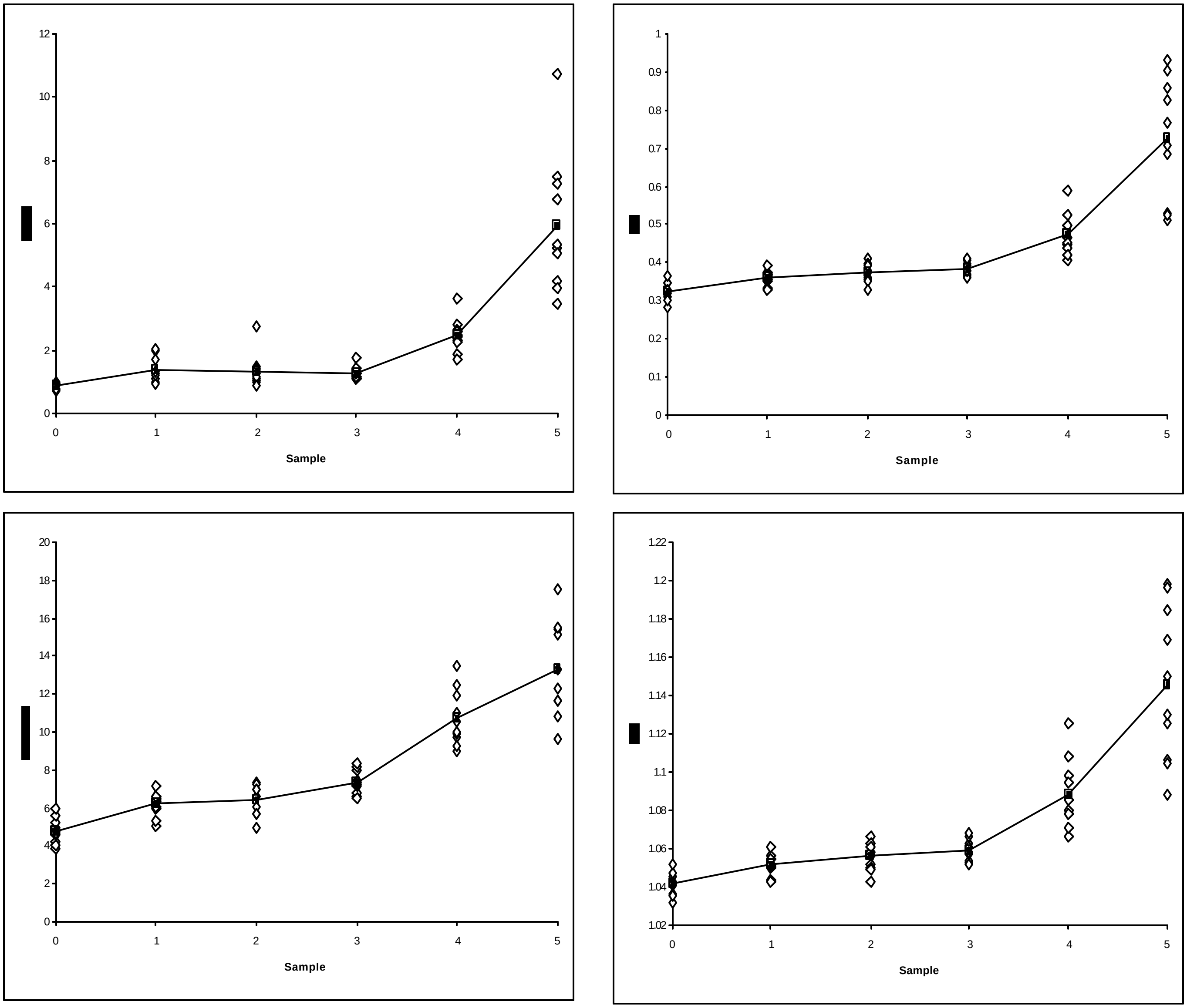

Figure 7. Laser profilometery, 50 mm samples

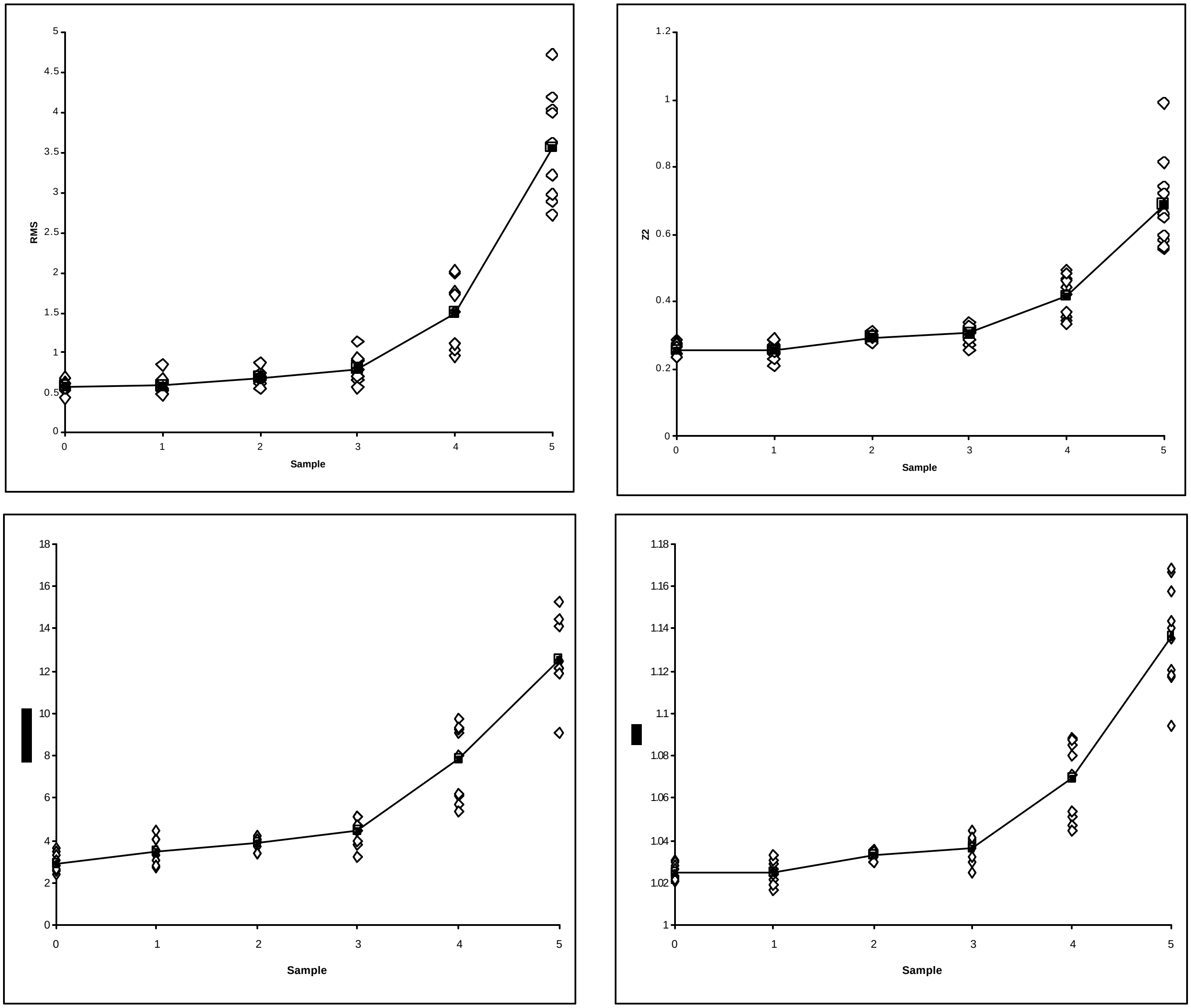

Figure 8. Laser profilometery, 100 mm samples

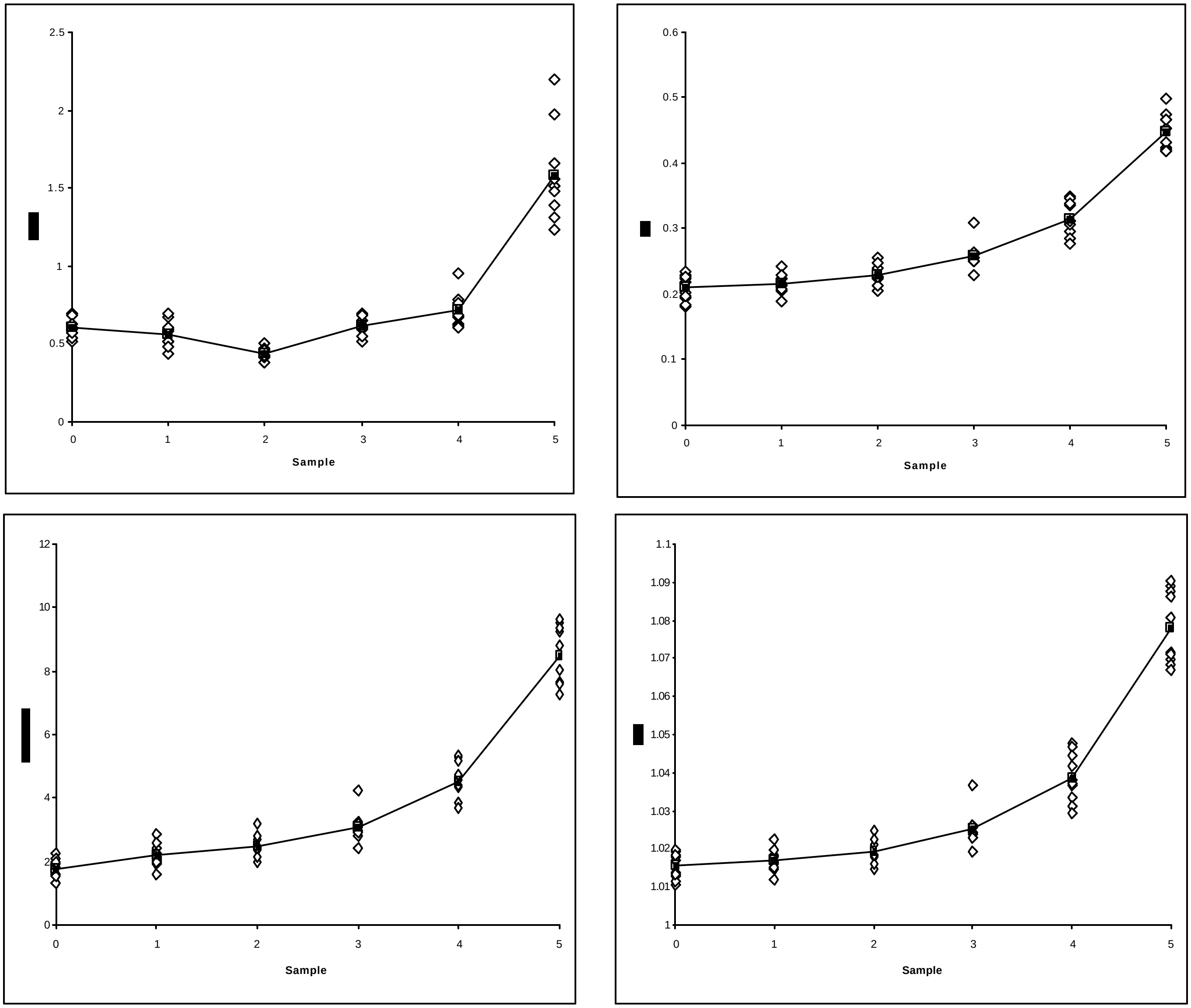

Figure 9. Laser profilometery, 200 mm samples

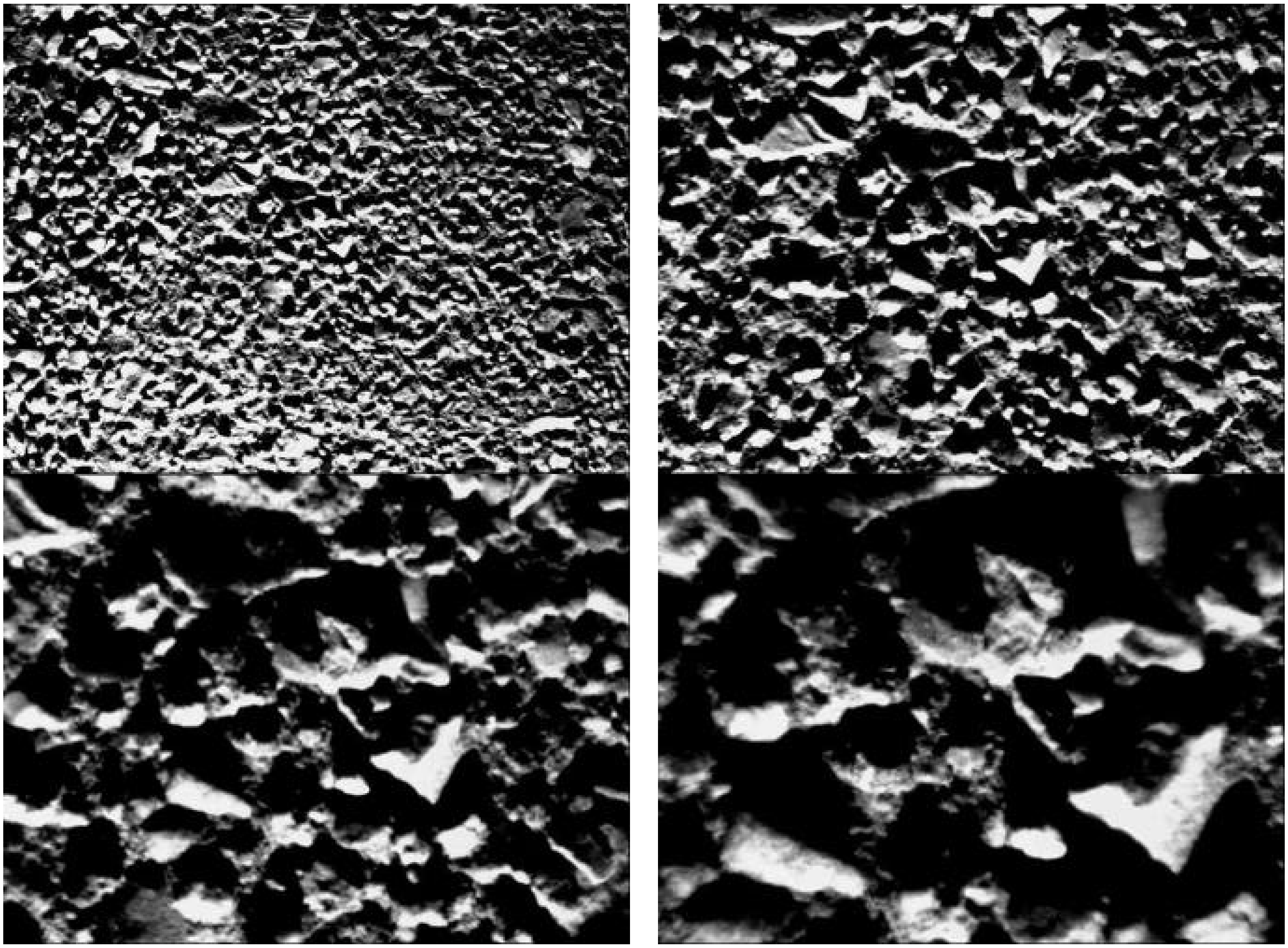

Figure 10. Texture mapping images, at 200 mm, 1000 mm, 50 mm, 25 mm.

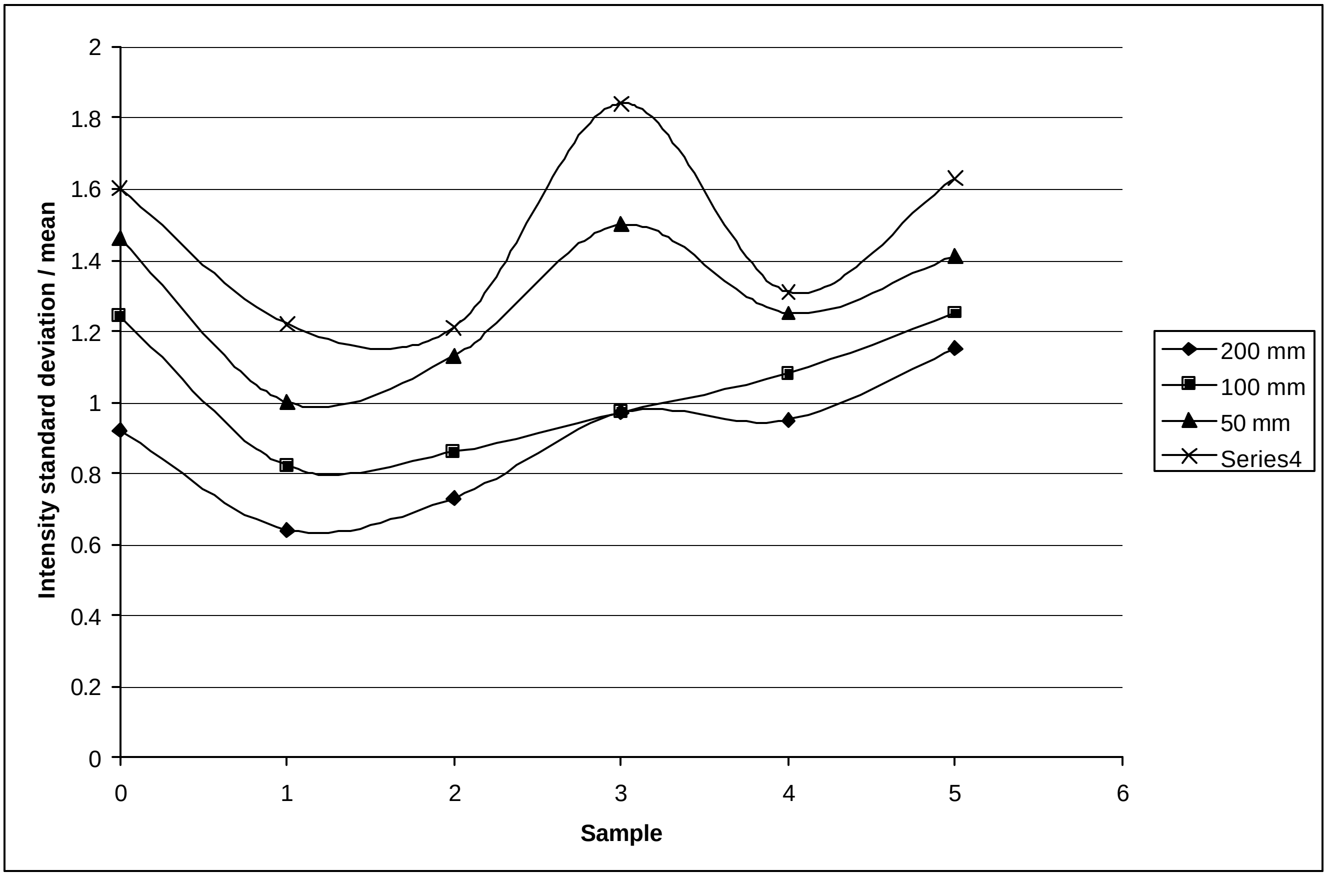

Figure 11. Results of texture mapping, standard deviation /mean by sample.